

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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## VOLUME- II

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### SECTION II SUB-SECTION 01 Turbines, Governors and Main Inlet Valve

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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## TABLE OF CONTENTS

<b>1</b>	<b>TURBINES, GOVERNORS AND MAIN INLET VALVE.....</b>	<b>4</b>
1.1	SCOPE .....	4
1.2	HYDRAULIC SYSTEM.....	5
1.2.2	<i>Design Requirements .....</i>	<i>9</i>
1.2.3	<i>Problem of Silt &amp;Provisions to mitigate it:.....</i>	<i>11</i>
1.2.4	<i>Guarantees for Turbine Output, Efficiency &amp; Penalties for Shortfall.....</i>	<i>11</i>
1.2.5	<i>Other Operational Requirements .....</i>	<i>14</i>
1.2.6	<i>Turbine Model Test.....</i>	<i>17</i>
1.3	GENERAL TECHNICAL REQUIREMENTS.....	20
1.3.1	<i>Design &amp; Workmanship.....</i>	<i>20</i>
1.3.2	<i>Rigidity and Strength of Various Components.....</i>	<i>20</i>
1.3.3	<i>Interchangeability .....</i>	<i>21</i>
1.3.4	<i>Sectionalizing of Components.....</i>	<i>21</i>
1.3.5	<i>Matching &amp; Jointing of Sections / Components .....</i>	<i>22</i>
1.3.6	<i>Manufacture &amp; Materials of Components .....</i>	<i>22</i>
1.3.7	<i>Provision of Abrasion Resistant Hard Coating on Critical Components: .....</i>	<i>25</i>
1.3.8	<i>Turbine Embedment / Foundation Fixtures.....</i>	<i>26</i>
1.3.9	<i>Handling of Components.....</i>	<i>26</i>
1.3.10	<i>General Physical Layout &amp; Arrangement.....</i>	<i>29</i>
1.3.11	<i>Miscellaneous Items .....</i>	<i>29</i>
1.4	CONSTRUCTION FEATURES.....	30
1.4.1	<i>Runner .....</i>	<i>30</i>
1.4.2	<i>Shaft, Coupling and Alignment.....</i>	<i>33</i>
1.4.3	<i>Turbine Guide Bearing .....</i>	<i>34</i>
1.4.4	<i>Main Shaft Gland (Sealing Box).....</i>	<i>36</i>
1.4.5	<i>Spiral Case.....</i>	<i>36</i>
1.4.6	<i>Stay-Ring.....</i>	<i>37</i>
1.4.7	<i>Bottom Ring .....</i>	<i>39</i>
1.4.8	<i>Discharge Ring.....</i>	<i>39</i>
1.4.9	<i>Draft Tube.....</i>	<i>39</i>
1.4.10	<i>Head Cover .....</i>	<i>41</i>
1.4.11	<i>Turbine Pit Liner.....</i>	<i>42</i>
1.4.12	<i>Guide Apparatus.....</i>	<i>42</i>
1.4.13	<i>Guide Vane Servomotors.....</i>	<i>43</i>
1.4.14	<i>Centralised Grease Lubrication System (if required).....</i>	<i>44</i>
1.4.15	<i>Turbine Flow Meter.....</i>	<i>44</i>
1.4.16	<i>Piezometers Gauges .....</i>	<i>45</i>
1.4.17	<i>Resistance temperature detectors (RTD's) and Dial Type Thermometers (DTT's) .....</i>	<i>45</i>
1.4.18	<i>Oil Level Gauges and Relays.....</i>	<i>46</i>
1.4.19	<i>Vibration Monitoring System.....</i>	<i>46</i>
1.4.20	<i>Over Speed Device.....</i>	<i>46</i>
1.4.21	<i>Spares:.....</i>	<i>47</i>
1.5	TURBINE GOVERNORS .....	49

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

1.5.1	Type.....	49
1.5.2	Control Requirements.....	49
1.5.3	Governor Operating Parameters.....	50
1.5.4	Constructional Features and Other Provisions.....	51
1.5.5	Spares:.....	54
1.6	TURBINE MAIN INLET VALVES .....	56
1.6.1	Description and Operation Requirements .....	56
1.6.2	Basic data/ other data for Spherical Valves Design and Installation.....	57
1.6.3	Provision to Withstand Silt Abrasion .....	58
1.6.4	Construction Details.....	60
1.6.5	List of Mandatory Spares for MIV: .....	64
1.7	PRESSURE OIL SYSTEM FOR GOVERNORS AND TURBINE INLET VALVES.....	65
1.7.1	General .....	65
1.8	CONTROLS AND INSTRUMENTATION FOR TURBINES, GOVERNORS, INLET VALVES AND AUXILIARIES....	69
1.9	HYDRAULIC QUANTITIES MEASUREMENT SYSTEM.....	69
1.10	DEVICES AND INSTRUMENTS FOR TESTS DURING ERECTION AND COMMISSIONING .....	70
1.11	TESTING DEVICES AND INSTRUMENTS FOR FIELD ACCEPTANCE TEST .....	70
1.12	MANUFACTURE, INSPECTION, SHOP ASSEMBLY, MEASUREMENTS AND TESTING .....	70
1.12.1	Material Tests .....	70
1.12.2	Pressure Tests.....	71
1.12.3	Testing of Parts Exposed to Gas Pressure .....	71
1.12.4	Testing of Parts Exposed to Liquid Without Over Pressure.....	71
1.12.5	Tests on Steel Plates.....	72
1.13	INSPECTION AND TESTING AT SITE .....	73
1.14	INDEX AND FIELD ACCEPTANCE (EFFICIENCY) TESTS.....	75

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

## 1 TURBINES, GOVERNORS AND MAIN INLET VALVE

### 1.1 Scope

The scope of contract includes supplies for Turbines, Governors, Main Inlet Valve along with all auxiliaries and accessories as well as complete mounting ready to operate.

This section of the specifications covers the design, material selection, manufacture, assembly, intermediate storage, tests at works, packing and forwarding for shipment, delivery at site (final destination), receipt and storage at site, services for performing on-site assembly, erection, testing and commissioning in a complete shape of 3 nos. Vertical Shaft, Francis Turbines, Governors, Main Inlet Valve along with all auxiliaries and accessories including water and air piping, cabling, valves and fittings, instrumentation, controls and safety devices, and recommended spares for five (5) year trouble free operation of the plant, special tools etc. as described and detailed in the specification and as considered necessary by the Tenderer.

The scope of supply shall include all parts, accessories, spares etc. which are essential for assembly, erection, construction, trial operation, trial run, test run, commissioning and testing of the complete unit even though these are not individually or specifically stated or enumerated. Corresponding components of all the Turbines and associated equipment and spares shall be of the same material, dimensions and finish and shall be inter-changeable.

This section of the specification covers the design, engineering, manufacture, testing at works, despatch and delivery of

- a) Three (3) numbers of vertical Francis turbines with rated output 81.20 MW (capable of generating minimum 80 MW at generating terminals) at rated net head condition and shall have 10 % continuous overloading capacity, 300 rpm, for driving generators described in section 2 (Vol.2, Part II) of the specifications
- b) Three (3) numbers of digital electro- hydraulic governors
- c) Three (3) numbers 2750 mm (tentative) nominal diameter main inlet valves, of Spherical type to suit above turbines. If the bidder wishes to select MIV of higher size, the necessary provisions for matching with the penstock shall be in the bidder's scope.
- d) Six (6) numbers pressure oil system for Governor and MIV i.e. 3 sets/ number of pressure oil system for Turbine Governor and MIV each.
- e) Model testing of turbines
- f) Field Acceptance Testing of Turbines
- g) Spare parts, Special Tools, Consumables & Testing Devices.

The scope shall include following services also-



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- a) Overseas Transportation covering freight & insurance from port of shipment to the port of entry in India (in case of goods of foreign origin)
- b) Inland Transportation in India for delivery at site
- c) Storage and preservation at site till installation & commissioning
- d) Complete assembly, testing, erection & commissioning at site.
- e) All other works incidental to and connected with the above services from delivery up to handing over the equipment after successful commissioning.

The Tenderer must inspect and check all relevant details of the site and is expected to introduce all necessary steps in time. All parts are to be delivered directly on site. All workshop-manufactured parts should be coated and be treated as per anti-rust coating requirements. Equipment shall be equipped with transport lugs for ease of mounting and handling. All lugs shall be retained to allow for future removal/installation of Turbines and auxiliaries.

The Tenderer is expected to co-operate fully with other parties and civil contractor, involved in commissioning and other works on site. He shall supply all information for civil structure design and all details for structural design of the power station as per prudent practice and relevant IS codes. Any dissent shall not entitle for any additional claim.

The relevant codes have to be respected as well as ranked as given below:

- Technical Specifications including all relevant supplements/amendments
- Applicable Indian Standards, and with priority all relevant International Standards.

## 1.2 Hydraulic System

- 1.2.1.1 The details of the hydraulic system of the generating units and basic data for design of turbines are given in Table-1 below:

**TABLE-I**  
**HYDRAULIC SYSTEM AND DATA FOR TURBINE DESIGN**

1.	Barrage	
(i)	Length of Barrage	86.0 m
(ii)	HFL	1400.0 M
(iii)	FRL	1400.0 m
(iv)	Average river Bedlevel	1386.0 m
(v)	Maximum Height of Barrage above River bed ;eve;	16.0 m
(vi)	Bridge Deck Level	1402.0 m

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

(vii)	Design Flood (SPF)	3200 m <sup>2</sup> / sec
<b>2.</b>	<b>POWER INTAKE</b>	
(i)	Length	31.0 m
(ii)	FRL	1400.0 M
(iii)	MDDL	1398.0 M
(iv)	Invert Level	El 1387 m
(v)	Deck Level	El 1402.00 m
(vi)	Size of Trash rack	6 number each of 4 m width 15 m height
(vii)	Size of Intake Gates	2 numbers each of 9.0 m width x 6.5 m height
(viii)	Type of Gates	Vertical lift gates
<b>3.</b>	<b>HEAD RACE TUNNEL</b>	
(i)	Length	3550 m
(ii)	Shape (Excavated )	Modified inclined legs horse shoe
(iii)	Shape (Finished)	Circular
(iv)	Diameter	6.5 m
(v)	Design discharge	130.25 m <sup>3</sup> /s
(vi)	Head Pond Level	EL 1400 .0 m
<b>4.</b>	<b>SURGE SHAFT</b>	
(i)	Type	Restricted Orifice
(ii)	Diameter (m)	13.5
(iii)	Orifice Diameter (m)	3.2
(iv)	Vertical height(m)	78.5
<b>5.</b>	<b>VALVE HOUSE</b>	
(i)	Type	Underground
(ii)	Length	20.25 m
(iii)	Width	11.0 m
(iv)	Height	17.25
(v)	Number of Valves	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

(vi)	Diameter	5.75 m
<b>6.</b>	<b>PRESSURE SHAFT</b>	
(i)	Number	1
(ii)	Type	Underground Steel lined
(iii)	Internal Diameter	5.75 m
(iv)	Horizontal length at EL 1345.0 m	112.92 m
(v)	Length of upper bend	31.42 m
(vi)	Vertical Length	117.74 m
(vii)	Length of lower bend	30.08 m
(viii)	Inclined length from EL 1190.80 m to EL 1182.07 m	83.83
(ix)	Thickness (mm)	Varies 16 mm to 46 mm
(x)	Grade of Steel	Sumiten 610 Grade F
<b>7.</b>	<b>UNIT PRESSURE SHAFT</b>	
(i)	Number	3
(ii)	Diameter(m)	2.75
(iii)	Length (m)	Average 25 m each
(iv)	Thickness (mm)	Varies 24 mm to 50 mm, bifurcator 58 mm
(v)	Grade of steel	Sumiten 610 Grade F
<b>8.</b>	<b>POWER HOUSE</b>	
(i)	Type	Surface
(ii)	Head (m)	
	c) Gross Head (m)	211.0 m
	d) Net Head (m)	201.8 m
(ii)	Turbine(s)	
	a) Turbine C/L Elevation	El 1184.8 m
	b) Min Tail Water Level	El 1189.00 m
<b>9.</b>	<b>TAILRACE</b>	
(i)	Type and shape	Open air tail race basin
(ii)	Normal Tail Water level	El 1189.0m

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

(iii)	Number of draft-tube gates	3
(iv)	Size of draft Tube gates	7.0m (w)x 3.95 m(H)
(v)	Sill Level of Draft Tube Gates	EL 1177.50 m

#### 1.2.1.2 Main Technical Parameters of Turbine

The turbines shall be vertical shaft Francis type coupled directly to the Generator of matching rating. The basic data for design of turbines are given in Table –II below.

**TABLE-II**

**TURBINE BASIC DATA**

- |    |   |   |
|----|---|---|
| a) | Minimum Net Head  | 199.80 m  |
| b) | Rated Net Head  | 201.8 m   |
| c) | Design Net Head   | 201.8 m   |
| d) | Maximum Net Head  | 201.8 m   |
| e) | Rated Output at rated net head of 201.8 m   | 81200 kw  |
| f) | Maximum Continuous Output at rated head of 201.8 m  | not less than <b>89320 kw</b>   |
|    | The maximum power output of turbine at rated net head shall be sufficient to give 10% COL at generator terminals. |   |
|    | Maximum power rating of Generator shall be as given in the specifications.  |   |
| g) | Capability to give minimum output at any head without any adverse effect  | <b>50%</b> of rated output or lower.  |
| h) | Continuous overload Capacity  | At all heads rising proportionally with heads to 10% at rated net head.                     |
| i) | Continuous out put at design head at best efficiency point  | To be furnished by the bidder. Corresponding efficiency & gate opening also to be furnished |
| j) | Maximum continuous output at design head  | To be furnished by the bidder Corresponding efficiency & gate opening also to be furnished  |
| k) | Maximum Speed Rise on maximum load rejection by all units simultaneously  | <b>45%</b>  |
| l) | Maximum penstock Pressure Rise on maximum load rejection by all units simultaneously                              | <b>35%</b>  |

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

- |    |  |   |
|----|--|---|
| m) | Rated speed  | <b>300 rpm</b><br>(to be coordinated with generator manufacturer) |
| n) | Turbine setting (Centre Line of Distributor)       | El. 1184.8 masl   |
| o) | Seismic Forces withstand capability of the turbine | 0.24 g (Horizontal)<br>0.16g (Vertical)                           |
| p) | Direction of rotation                              | clockwise when viewed from top                                    |

The Turbine shall be capable of generating the rated capacity kW at the Generator terminals at rated head with guide vane opening of about 85% such that the over load capacity 10% is satisfied.

The turbines shall be capable of delivering 81.20 MW plus 10% continuous overload at the rated net head of 201.80 m. In addition, the tenderer shall guarantee the maximum output which will be available at the minimum net head of 199.80 m without exceeding normal stresses. Maximum unit stresses in rotating parts of the turbine shall not exceed provisions as per relevant Clause. The operational net head range will be 201.80 m to 199.80 m and the turbine shall be designed to operate safely continuously under the range of net heads specified. The rated head of the plant shall be 201.80 m.

### 1.2.2 Design Requirements

The turbines shall be designed to give satisfactory, quiet and smooth operation, free from excessive noise, vibrations, pressure pulsations, power swings, hunting etc. in the required range of operation of heads and outputs including over load output.

The inertia constant of the generating unit at the maximum output shall not be less than 4.0 kW–sec per kVA. The fly wheel effect (GD<sup>2</sup>) of the generating unit shall be worked out accordingly by the Bidder in coordination with generator manufacturer.

The Contractors shall compute the maximum momentary pressure, and speed rise using the parameters of the plant, and the operating conditions and furnish the design computations of pressure rise and speed rise worked out in their bids.

The maximum momentary pressure at turbine inlet, considering the effect of water hammer due to water mass inertia, under worst conditions of load acceptances and rejection and governor closing and opening times, shall be indicated by the bidder. However, the pressure rise shall not be more than 35% of static head acting on the scroll case with the reservoir at maximum water level of 1400 m.

The maximum momentary speed rise after load rejection, under the most adverse combination of load and head, shall be indicated by the tenderer. The speed rise should not be more than 45% of the synchronous speed.

The flywheel effect of the turbine in conjunction with the generator shall be adequate to fulfil the requirement of specified speed rise & pressure rise criteria.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The turbine shall be so designed and constructed as to enable assembly of components at works and at the same time to permit easy transportation. The weights and sizes of the components/packages shall be within the permissible transport limits.

At least the information listed hereunder shall be given by the Tenderer. The Tenderer may support advantages in his design or of special technical features of his offer by additional documents / descriptions.

1. Compute pressure rise at turbine inlet under the most unfavourable conditions (load acceptance and rejection). Conditions considered as well as governor acting times to be clearly indicated in the computations.
2. Compute turbine speed rise under conditions as above and for following load rejection parameters.
  - From maximum output at maximum head to zero
  - from 100 % rated output to zero
  - from 80 % rated output to zero
  - from 60 % rated output to zero
  - from 40 % rated output to zero
3. Expected flow characteristics during closing and opening of wicket gates as function of time.
4. Expected performance curves for the net heads of 199.80 m and 201.80 m. The curves shall also show the overload output at maximum possible wicket gates opening extending beyond the guarantee points.
5. Curves showing the critical sigma values.
6. Velocity Diagrams giving values of velocities and angles at runner inlet and outlet & absolute.
7. Provide dimensional drawing (cross section) of turbine and associated equipment showing main dimensions.
8. Applicable method and type of vibration monitoring system.
9. Provide information on model or field performance tests performed on a turbine which is hydraulically similar (within reasonable range) to the proposed turbine. Indicate at least the following:
  - Name of the projects & its year of commissioning
  - place of model or field tests
  - year of model or field tests
  - designed rated turbine output
  - rated net head
  - rated speed

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

### 1.2.3 **Problem of Silt & Provisions to mitigate it:**

The suppliers shall note that the water going to the turbines shall contain harmful, hard and coarse silt particularly during peak flow in the river. The chapter related to Sedimentation study and the related appendices are attached as Annexure- I-A.

The report on petrography of suspended silt sediments collected from Yarjep River for Heo HEP, carried out in 2024 is attached as Annexure-I-B.

The Suppliers shall critically examine the Silt Data and the Chemical Analysis of water and if required, take the same into account in designing the turbines, Spherical Valves and other auxiliary equipments susceptible to abrasive effects of silt, making all such specific provisions and measures which will help to resist silt abrasion and easy and quick maintenance/replacement of worn out components. Subject to the conclusive studies as done by the bidders these provisions shall cover but not limited to

- a. Use of special abrasion resistant materials for silt susceptible components
- b. Use of feasible hard abrasive resistant facings, coatings etc on susceptible components.
- c. Easy and quick replacement and maintenance of affected components.

Suppliers shall furnish the details of the specific provisions proposed and offered by them, in their offers along with past cases and experience of the same along with the offer.

### 1.2.4 **Guarantees for Turbine Output, Efficiency & Penalties for Shortfall**

The Contractors shall provide turbines having the specified ratings and highest feasible efficiencies in the permissible range of operation. The turbine tenderer on tendering stage shall supply supporting documents for the prescribed guarantees by means of displaying results from earlier model tests of the model turbine which conforms as much as possible to the one now offered. The output and the efficiencies shall be guaranteed under penalty as given below.

Efficiencies below 94.5% for Turbine, 98.5% for Generator and 93.08% Overall TG, at rated conditions shall not be accepted. No weightage shall be given during evaluation for efficiencies better than above.

The turbine OUTPUT and EFFICIENCY shall be guaranteed by the Contractor. The following requirements and rules for the guarantees apply:

- a) Rated output at rated net head of 201.8 m.
- b) Maximum continuous output at design net head of 201.8 m
- c) Turbine efficiencies at following net heads in the specified working head range:  
201.8 m & 199.80 m.
- d) Weighted turbine efficiency

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The model and the prototype weighted turbine efficiency shall be guaranteed. The weighted average efficiency of the Turbine at rated net head for 110 %, 100 %, 75 % and 50 % rated output shall also be guaranteed as per the formula

$$E_{VT} = K1 * E_{110\%} + K2 * E_{100\%} + K3 * E_{75\%} + K4 * E_{50\%}$$

Where  $E_{VT}$  is the weighted average efficiency of the Turbines,

$E_{110\%}$ ,  $E_{100\%}$ ,  $E_{75\%}$  and  $E_{50\%}$  are the guaranteed efficiency of the Turbine at the respective percentage of the operation with reference to the rated head and

$$K1 = 0.20, K2 = 0.40, K3 = 0.15, K4 = 0.25$$

The prototype weighted average efficiency will be calculated from the model efficiency stepped-up to prototype efficiency according to IEC 60193, using the same grid of weights as above.

e) Efficiency guarantee and penalties

If the weighted average efficiency on field testing is less than the guaranteed weighted average efficiency the Contract Price for payment purposes, be decreased at the rate of Rs 1094000 for each one hundredth of one percent shortfall in efficiency for each unit.

Same amount of penalty shall be payable for each of the other Turbine for shortfall of weighted average Turbine efficiency, i.e. the total amount of Penalty shall be equal to "Penalty against shortfall in weighted average efficiency of Turbine for one unit" multiplied by "total number of units, i.e. three (3) nos".

Adjustments will, however, not be made until after the Contractor has been given an opportunity to correct the defects in performance. Modifications in design, if necessary, shall be made within a reasonable time not exceeding 3(three) months so that the guaranteed performance can be obtained and the manufacturing shall commence only after satisfactory results are obtained in the model test. In the event of extra time taken by the manufacturer for rectification of design deficiencies, the delivery schedule as agreed earlier shall be adhered to by the contractor. In case of failure to obtain satisfactory results to ensure guaranteed performance, the purchaser reserves the right to cancel the contract or to accept the same subject to levy of penalty as specified above.

The model weighted average efficiency is the weighted average efficiency calculated from the model test results.

If the model weighted average efficiency falls below the guaranteed figure by more than 1.5 percentage point, then the turbine may be subjected to rejection.

f) Capacity and efficiency tests

The capacity and efficiency test at different heads and gate opening on the prototype turbine shall be conducted within one year after commissioning to



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

verify that the power output and efficiency guarantees of the prototype have been fulfilled.

The turbine efficiency and capacity tests shall be conducted in accordance with the provisions of IEC Publication 600 41, International Code for Field Acceptance Tests of Hydraulic Turbines,.Any deviation from the IEC-60041shall be clearly stated in the offer. Efficiency shall be measured by the thermodynamic method or any other applicable method to be decided by the purchaser. Supplier shall furnish details of test method, agency which will conduct the test, provisions to be made for the field testing, calibration of instruments for the purpose of the test and all other relevant details in the offer . Supplier shall be under obligation to accept these tests for purposes of liquidated damages.

The Contractor shall make any subsequent adjustments in the turbine working parts as may prove necessary to secure optimum turbine performance.

The employer reserves the right to appoint an independent agency for repeating these tests at his own costs. The contractor shall be under obligation to accept these tests for purposes of liquidated damages

g) Capacity guarantee and penalties

The maximum continuous output at rated net head of 201.8 m shall not be less than – 89320– kW. In case of shortfall in the tested values during field test, a penalty of Rs-109400 for each hundredth of one percent (1%) shortfall in test value of output vis-à-vis guaranteed value.

For fractional values of the shortfall the penalty amounts will be computed on pro-rata basis.

The turbines not fulfilling the guarantees will be subjected to penalty by multiplying the penalties for one (1) turbine by the no. of turbines and the total amount of penalty shall be the sum of these two.

h) Limits on Functional guarantee:

- i. Efficiencies below 94.5% for Turbine, 98.5% for Generator and 93.08% for Overall TG, at rated conditions shall not be accepted. No weightage shall be given during evaluation for efficiencies better than above.
- ii. The Guaranteed Weighted Average Efficiency of the Turbine and Generator as per formula given in the Bid Specifications shall not be less than 93.5% and 98% respectively. The formula for WAE is as given in d) above.

i) Limitations on Liabilities;

Subject to para 1.2.4-h) above, the Contractors's aggregate liability to pay liquidated damages for failure to attain the functional guarantees shall not exceed twenty five percent (25%) of the Contract price.

1.2.4.1 Cavitation guarantee

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The Supplier shall guarantee the guide vanes, runner, discharge ring and other hydraulic passage of the turbine against excessive pitting caused by cavitation for the first 8000 hours of operation, or not over two calendar years after provisional acceptance of the turbine, whichever is the earlier. If the guarantee expires before 8000Hrs of operation the weight loss shall be on pro-rata basis.

The cavitation guarantee shall be as per IEC Publication 60 609.

Excessive cavitation pitting is defined as the removal of metal from the turbine runner, discharge ring, draft tube cone and guide vanes because of removal of material in excess of the weight defined by the following formula:

$W = 0.1 \times D_3^2$  per 1000 Hours of operation during the guarantee period defined above.

Where:

W= total permissible weight of metal in kilograms removed during the period of operation.

D3 = discharge diameter of the turbine runner in meters

The loss of material shall be measured by the direct measurement according to IEC-Code 60 609. Erosion or damage caused by solid particles in the water and corrosion caused by aggressive chemical substances in water are not intended to be covered by the pitting guarantee. If excessive cavitation pitting occurs, the Contractor shall repair the resulting damage during the turbine guarantee period. All areas where the depth of pitting exceeds 1 mm shall be restored to their original contours by welding with stainless steel and grinding to a smooth surface equal in finish to the adjacent undamaged areas. The Turbine after such modifications, repairs and replacements shall be subject to same cavitation guarantees as per the original equipment. In case of local cavitation damage caused or aggravated by any contour errors, the Contractor shall make the modifications necessary in the turbine parts to prevent its reoccurrence. For field cavitation repairs the Corporation will make the turbine available at a mutually convenient time and will provide proper access to the work. The Corporation will also provide free of charge the use of station power and compressed air. All other items of equipment and materials required for the repairs shall be furnished by the Contractor.

There will be an inspection of the runners during guarantee period to establish whether the cavitation guarantee has been met or not.

- 1.2.4.2 Limit on Erosion By Silt: With the silt of the given characteristics & quantity suspended in the waters going to the turbines, the abrasion resistance of the under water parts including runner of the turbine shall be such that interval between erosion maintenance shall not be less than 12000 hrs of operation.

## 1.2.5 Other Operational Requirements

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

#### 1.2.5.1 Smooth, Stable & Quiet Operation and Noise Limit

Turbine design shall be such as would ensure smooth and quiet operation with low vibrations, pressure pulsations, power fluctuations and noise etc. The vibration amplitude at the shaft shall not exceed the recommended values specified in ISO-7919 (part 1), ISO-3945, ISO-20816-5 and VDI-2056 or as per latest revision of applicable standards.

The vibrations and pulsations of prototype turbine shall be measured at site as per the IEC No.60994 "Guide for field measurement of vibrations and pulsation in the hydraulic machines". The Contractor shall guarantee that the detrimental pulsations (both for pressure and power) do not occur at any load from 40% of full load to permissible maximum load at any net head from minimum to maximum.

The peak to peak pressure pulsations at any of the taps to be provided below the runner shall not exceed 3% of the rated net head.

The peak to peak power pulsations shall not exceed 1% of the rated power ignoring any isolated sharp peaks.

If air injection equipment is required for reducing the vibrations, pressure and power pulsations and to have smooth running of the machines, it shall be the responsibility of the Contractor to provide the same.

The maximum noise level when operating near the rated output shall not be higher than 90 dB at 1.0 Metre distance.

For transient conditions (start, rejection or surge), maximum noise level of 95 dB shall not exceed and the same shall be guaranteed and proved at site by actual measurement. Design provision made for achieving these guarantees shall be elaborated during design stage.

#### 1.2.5.2 Critical and Plant Sigma

Values of critical sigma as determined from cavitation model tests as per IEC 60193 shall be given by the Tenderer in the form of curves for different heads of operation. Plant sigma curves as recommended by the Tenderer shall also be plotted on it clearly to show the safety margin available. The Tenderer shall determine and indicate the limiting levels for installation of the equipment in his offer.

The Hill curves shall contain the requisite information of Head, Flow, Power, Efficiency, Guide Vane Opening, TWL upper limits, Expected Cavitation Limits, continuous operating range etc.

#### 1.2.5.3 Limits on Speed Rise, Pressure Rise and Runaway Speed

The maximum momentary speed rise of the generating units shall be limited to 45% of rated speed on sudden load rejection by the generating units under any permissible conditions of operation including overload and shall be guaranteed.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The maximum momentary pressure rise at the turbine inlet shall be limited to 35% of the maximum static head on the generating unit.

The Contractor shall also compute the speed rise and pressure rise taking into account the actual turbine characteristics and shall demonstrate that the governing system offered is stable. The turbine supplier shall co-ordinate with the generator designer for providing the required flywheel effect for the generating unit so as not to exceed the specified speed rise.

The maximum runaway speed shall be indicated and guaranteed. The turbine shall be designed to withstand safely the maximum runaway speed without damage to any parts for a period of 15 (Fifteen) minutes for every such occurrences excluding costing down period up to standstill.

#### 1.2.5.4 Design Stress Limits

The turbine shall be designed to withstand forces arising under the worst conditions of operation taking also into account superimposed seismic forces. The Heo HEP Project falls in seismic zone five (5). For final design, the following values of Design Basic Earthquake (DBE) shall be taken into account:

- horizontal DBE: 0.24 g
- vertical DBE : 0.16 g

Under the most severe conditions of loading expected in normal operation, stresses in the materials shall not exceed the values listed below:

##### Direct or combined steady stresses:

- (1) For materials used in the construction of the equipment, the maximum stress due to maximum normal rated load operating conditions shall not exceed one-third of the minimum yield point or one-fifth of the minimum ultimate strength of the material, which ever is lower. The minimum factor of safety under the worst conditions shall not be less than 1.5 on yield point (Y.P.) or 3 (three) on ultimate tensile strength (UTS).
- (2) Parts subject to water pressure shall be designed to the applicable provisions of the ASME Code and welding shall be as specified herein and in accordance with ASME Boiler and Pressure Vessel code Section 8, Division 2.
- (3) Stresses in standard products:  
Standard products are not subject to the above conditions i.e. will be custom designed. Such products are for example:  
Oil pumps  
Air compressors etc  
Loads on Foundations

The Contractor shall determine maximum forces emanating from normal and/or emergency operation of the equipment, acting upon equipment foundations or upon

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

adjacent structures. The Contractor shall guarantee that those forces will not be exceeded.

#### 1.2.5.5 Operating Temperature Limits

The guide bearing metal temperature of the turbine shall not exceed 70°C.

#### 1.2.5.6 Cooling Water Failure Duration Withstand Capacity:

The Turbine Guide Bearing shall be designed and guaranteed to withstand operation for a period of at least 15(Fifteen) minutes for the condition of cooling water supply getting cut off for any reason without suffering or incurring any damage after which period the turbine shall be signalled to stop and shall come down to standstill condition.

### 1.2.6 Turbine Model Test

#### 1.2.6.1 General

Before the contractor takes up the manufacture of the prototype turbine, homologous scale model of the prototype turbine shall be carried out to demonstrate that the prototype turbine will meet the guaranteed performance in respect of efficiency, output, smooth operation, pressure pulsations, and other guarantees as stipulated in the specifications.

#### 1.2.6.2 Model Details, Drawings and Homology

Before taking up the manufacture of the model turbine, the Contractor shall submit to the purchaser in a sequential manner, within 90 days after award of contract, drawings and description covering details of the proposed model, testing equipment to be used, instrumentation, testing procedure, method of interpretation as well as method of computation of test results for the approval of the Employer. The Corporation will convey his approval or comments within 45 days after receipt of the information/data/drawings.

The turbine model shall be homologous to the prototype in all respects. The water passage of the model turbine shall be homologous with those of prototype right from the scroll case inlet to the draft tube exit point. The draft tube cone shall be made transparent to permit observation of the vortex flow pattern and cavitation phenomenon and to take photographs of the same.

The model scale, minimum size and homology/ similarity to the prototype turbine shall be in conformity with the IEC code 60193. The model size shall not be less than 300 mm, and the test head shall not be less than 40 m.

#### 1.2.6.3 Conducting of Model Test, Test Code, Submission of Report

The test shall be conducted in accordance with the IEC publications 60193. The test shall be completed and comprehensive test reports submitted for approval of the Corporation within ten (10) months after the award of contract.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The detailed programme of carrying out the comprehensive model test shall be intimated to the Purchaser 8(Eight) weeks in advance of the start of the test for the Employer/consultant to depute their representatives for observation of the comprehensive tests.

#### 1.2.6.4 Tests on Turbine Model

The test shall include

- a) Turbine performance (efficiency) tests.
- b) Cavitation tests with photo documentation.
- c) Runaway speed test.
- d) Pressure pulsation (fluctuation) tests for the draft tube frequency at half, full and over load.
- e) Hydraulic thrust.
- f) Wicket gate torque.
- g) Air admission test for the full sigma range.
- h) To determine best location of the Winter Kennedy taps and to determine the exponent co-efficient for the flow calculation on prototype.

The model test shall simulate all possible normal operating conditions of the prototype for the entire range of reservoir and tail water levels, wicket gate openings, overload etc.

#### 1.2.6.5 Step-up Formulae

The prototype efficiencies shall be calculated and derived from the model efficiencies as per the latest edition of IEC-60193 Code.

#### 1.2.6.6 Presentation of Model Test Report

After the completion of the model test, the Contractor shall submit to the Employer, 6 copies of complete report, which shall include but shall not necessarily be limited to the following.

- a) Introduction, dates of test, by whom conducted
- b) Description of test equipment and test procedures
- c) Drawings showing plan and cross section of the model turbine as well as the prototype turbine giving all principle dimensions and profile
- d) Detailed drawings showing the complete set up of the test
- e) Records of calibration of all test instruments and equipment
- f) Record of all actual measurements made during the test viz. manometer readings, torque, speed, etc. which are used in the calculation of Head (H), Discharge (D), Speed (N), Power Output (P) etc.
- g) Comprehensive & complete sample calculation for each computation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- h) Model hill curves & universal characteristics
- i) Model efficiency curves
- j) Curves showing sigma vs efficiency and sigma vs unit power and unit discharge for specified head with envelope curves drawn
- k) Curves showing relationship between wicket gate angle and also wicket gate opening in mm vs servomotor stroke related to maximum opening of guide vane and clear opening between two adjacent wicket gates
- l) Prototype performance curves, hill charts and performance in tabular form for various operating conditions
- m) Photographs and sketches of the cavitation phenomenon and vortex phenomenon with corresponding operating conditions
- n) Pressure pulsation curves for various conditions of operation including air admission test
- o) Establishment of hydraulic similarity of the model turbine to the prototype
- p) Statements as to inaccuracy of each class of measurement and inaccuracy on combined measurement shall be indicated
- q) A table showing the comparison of the test results with the guaranteed data, followed by technical conclusions.

#### 1.2.6.7 Witness of Model Turbine Test by Employer's/ Consultants Representatives & Model Acceptance:

Along with the submission of the comprehensive model test report on the basis of test, the turbine contractor shall include a detailed programme (with at least 4 weeks advance notice) for actual demonstration of the correctness of the model test in the presence of Purchaser's representatives by repeating the tests at important points of operation as selected/ required by the Purchaser.

The Corporation will depute 4(Four) engineers drawn from his own organization who will visit the accredited laboratories as per requirement of IEC 60193 and will witness tests. They will also carry out model dimensional checks and other relevant verifications. If the tests are in order, formal approval will be granted by the Employer.

Should the model fail to meet the guarantees and requirements, it shall be optional for the Corporation to conditionally accept the model and direct the contractor to modify the model until it complies with the requirements. All expenses involved for the modifications and subsequent model tests shall be borne by the contractor.

The Corporation reserves the right to get the model turbine tested in an independent laboratory.

#### 1.2.6.8 Charges for Model Test



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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The Contractor shall quote for the model test and shall separately indicate the charges for conducting the model tests including submission of model test report in the schedule of prices.

The prices shall be inclusive of the arrangements etc., for witness of these tests by Contractor's representatives and as well as their consultant.

The contractor shall bear all expenses covering international travel, local transport, boarding & lodging for the 4 engineers for 5 (five) working days + international travel transit, daily allowance of US\$ 200 shall be payable to each engineer.

### **1.3 General Technical Requirements**

#### **1.3.1 Design & Workmanship**

The vertical Francis turbines shall be of the plate steel spiral type. The turbine designer shall take into account the site specific factors such as the quality of water and characteristics of silt present in water. Contractors shall offer turbines to suit the technical requirements as specified herein. The turbines shall be manufactured with the best workmanship and the state-of-the-art technology.

#### **1.3.2 Rigidity and Strength of Various Components**

1.3.2.1 Various components shall be strong and rigid to withstand forces acting upon them under any conditions of operation with safety and without undue deformations.

1.3.2.2 The stay vanes, top cover, bottom ring, discharge ring, draft tube cone & liner, turbine pit-liner etc. shall be amply robust and substantially ribbed.

1.3.2.3 When detached from generator shaft and seated on the ledge on the discharge ring, the runner shall be capable of bearing the shaft weight.

1.3.2.4 The maximum static pressure acting on the turbine (inlet, scroll casing, guide vanes etc.) will be 215.2 m and the maximum coincidental dynamic pressure considering maximum transient pressure rise of 35% and surge effects etc. is estimated to be 290.52 m.

1.3.2.5 The spiral casing and other parts subjected to penstock pressure shall be designed for the max. pressure of 290.52 m to which it will be subjected under most severe conditions of operation.

1.3.2.6 The forces acting under maximum tail water condition load rejection shall be particularly taken care of in designing top cover. The head cover shall provide rigid support to the turbine guide bearing housing, turbine shaft seal housing, guide vane upper stems and guide operating ring.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- 1.3.2.7 The stayring shall be designed to withstand safely the loads and forces acting upon it.
- 1.3.2.8 The upper un-embedded portion of the draft tube cone and liner shall be especially strengthened with ribs and other means to avoid undesirable vibrations and limit the same within permissible limits.
- 1.3.2.9 The guide operating ring and its supporting structures shall be of adequate strength and stiffness to prevent deflection of the ring, guide bearing or the main shaft in the event of the guide operating ring getting subjected to the thrust of only one servomotor with the other servomotor blocked or without oil pressure. The gate operating mechanism (levers, links etc.) shall be of ample strength to withstand most severe operating conditions.
- 1.3.2.10 The maximum operating governor oil pressure shall not exceed hundred (100) kg per cm<sup>2</sup>. For piston accumulator 120 bar system will be applicable. The servomotors and oil piping between servomotors and the governor hydraulic actuator shall be designed and selected respectively to suit this working pressure.
- 1.3.2.11 All parts that would be embedded in concrete shall be designed assuming no contribution in load sharing by the surrounding concrete. Adequate corrosion and erosion allowance in the wall thickness of embedded parts shall be allowed in the design. This allowance shall be deemed to be not contributing to the strength of the embedded parts.
- 1.3.3 Interchangeability**
- All identical components of the turbines and the spares shall be interchangeable with one another. Thus at the time of initial site assembly it shall be possible to use the main embedded components of any turbine with similar components of any other turbine.
- 1.3.4 Sectionalizing of Components**
- Heavy and large structural components such as scroll casing, stay ring, bottom ring, top cover, draft tube cone & liner etc. may need to be split, into two or more segments/sections as necessitated by
- Inland Transport limits as specified.
  - Routine convenience of handling of components during initial site assembly, erection & installation and later for dismantling & removal or maintenance & replacement through stator bore.
  - Special provision for dismantling and removal downwards of runner and other under water components affected by silt erosion, for quick maintenance and replacement (necessitated by presence of silt in water)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

The number of segments /sections shall however be the barest minimum as warranted by the above constraints so that the work of initial assembly at site and later for dismantling for removal, replacement and reassembly for maintenance is the least.

Sectionalizing of smaller components such as Liners, Cheek Plates etc. may be provided where feasible for easy and quick replacement.

### **1.3.5 Matching & Jointing of Sections / Components**

#### **1.3.5.1 Matching**

The various segments/sections of scroll casing stay ring, and other components shall have properly machined matching faces to ensure proper matching, circularity and dimensional accuracy during site assembly.

The mating welding edges of the main components such as spiral casing and draft tube liner which shall be joined together at site by welding shall be prepared at the works.

The various segments/sections/quadrants of the components shall be temporarily assembled at works and match marked before despatch for ease of site assembly in presence of Purchaser's representative.

#### **1.3.5.2 Jointing**

The joints between the various sections and quadrants of the scroll casing and stay ring shall be of welded and bolted flanged type respectively. Alternatively shop welded Stay Ring is also acceptable. Stay ring in a single piece is preferable.

The various mating joints between the assembled stay ring, top cover, bottom ring, draft tube cone shall be bolted type with resilient sealings for water pressure tightness.

The joint between the stay ring and turbine pit liner shall be made by welding at site.

The Supplier shall consider shop welding of the joints between the respective sections of the scroll casing and stay ring.

### **1.3.6 Manufacture & Materials of Components**

#### **1.3.6.1 Main Components**

The manufacturing methods/processes and the suggested materials for various components are tabulated in Table 2.

The Contractor shall furnish details of the manufacturing process and the materials of construction of the various components as offered by them in tabulation in a similar pattern as Table-2. The manufacturing process and materials of the construction selected shall be the most appropriate and optimum in respect of the components and the conditions of their operation. Presence of silt shall be taken into account in

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

selection of materials of components susceptible to and affected by silt erosion. The Contractor shall furnish the measures and criteria adopted by them in this regard.

The workmanship with quality control shall be ensured in the manufacture of components. The castings and plate steel weld fabricated structure shall be duly machined as required. Surfaces shall be sound and free from hollows, cracks and projections.

All castings and welded structures shall be stress relieved prior to machining. Shop welds and field welds in scroll casing, stay ring and other components shall be 100% ultrasonic tested. Where ultrasonic indication can not clearly be interpreted, radiograph shall be taken.

Bolted joints between different sections of components and between different components shall be doweled for ensuring true and precise matching and alignment of the components.

#### 1.3.6.2 Fastening Elements-Materials

Fastening elements comprising of bolts, studs, screws, nuts and washers etc. other than these given in the Table-2 shall be made as per material standards given below:

- Bolts, Nuts, Studs and Screw - AISI 420 or DIN 1/4021.
- Washers - ASTM 434 Clause BC or ASTM 449.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

**TABLE 2**

**MATERIALS SPECIFICATIONS FOR MAJOR COMPONENTS**

COMPONENTS	MATERIAL	EQUIVALENT STANDARD
<b>A) Turbine</b>		
1. Runner	Cast stainless steel (13% Cr. 4% Ni)	ASTM A 743 GR/ CA 6 N or equivalent.
2. Runner Snorkel	-do-	-do-
3. Rotating & Fixed Labyrinth (Upper & Lower)	Cast stainless steel (13% Cr. 4% Ni) or better	-do-
4. Draft Tube Cone (Top)	Cast stainless steel (13% Cr. 4% Ni)	ASTM A 743 GR/ CA 6 N or equivalent.
5. Guide vane	Cast stainless steel (13% Cr. 4% Ni)	-do-
6. Guide Vane Stem Bush	Cast Phosphor Bronze	ASTM 400 or equivalent
7. Liners for Top Cover & Pivot Ring	Cast stainless steel (13% Cr. 4% Ni) or better	ASTM A 743 GR/ CA 6 N or equivalent.
8. Shaft	Forged carbon steel	ASTM 668 or equivalent
9. Stay ring	Welded Plate Steel Fabricated Structure or Casting, Stainless Steel Plate	ASTM A537 or equivalent
10. Spiral casing	Welded Plate Steel Fabricated Structure, Stainless Steel Plate	ASTM A537 or equivalent
11. Top cover / bottom ring	Welded Plate Steel Fabricated Structure, Stainless Steel Plate	ASTM A537 or equivalent
12. G.V. servomotor cylinder	Carbon steel plates Boiler steel	DIN 17100, St 37-2 St 52-3, ASTM A 283 Grade B ASTM A 287, Grade B IS 2002 Gr.2A
13. Discharge ring	Welded Plate Steel Fabricated Structure or Casting, Stainless Steel Plate	ASTM A537 or equivalent

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

COMPONENTS	MATERIAL	EQUIVALENT STANDARD
14. Draft tube Cone(Bottom)	- do -	- do -
15. Pit liner	- do -	- do -
16. Guide bearing	White metal	IS 25, Gr.84 (Lining)
17. Shaft Seal	Special Material Resistant to silt abrasion	-
18. Shaft Runner Fasteners	Stainless Steel	AISI420 or equivalent
19. Shaft Liner at Shaft Seal	Stainless Steel	ASTM 743 GR/CA-6NM or equivalent
<b>B) Main Inlet Valve</b>		
1. Sliding Service Seal	SST 13-4 or better	ASTM 743 GR/CA-6NM or equivalent
2. Stationary Service Seal	SST 13-4 or better	ASTM 743 GR/CA-6NM or equivalent
3. Maintenance Sliding Seal	SST 13-4 or better	ASTM 743 GR/CA-6NM or equivalent
4. Maintenance Stationary Seal	SST 13-4 or better	ASTM 743 GR/CA-6NM or equivalent
5. a. Valve Rotor b. Rotor Trunnion c. Valve Body	Cast Steel	ASTM A418 Grade 80-50
6. By Pass Valve Body	Cast Steel	ASTM A418 Grade 80-50
7. Bypass Valve Needle &Seat Surface	SST 13-4 or better	ASTM 743 GR/CA-6NM or equivalent

**Note :** Materials of other equivalent standard may be used. Any alternative material offered must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and material properties. However, the detailed comparison of Chemical composition and material properties must be submitted to the Purchaser for approval during detail engineering stage.

Materials of different standards such as ASTM, DIN EN, EN, IS can be offered if they are better or at least equivalent in terms of chemical composition, properties etc. A side by side comparison of both the materials shall be carried out during detailed engineering.

### 1.3.7 Provision of Abrasion Resistant Hard Coating on Critical Components:

The Supplier may propose to provide hard coatings /facings on the silt affected under water components for consideration of the purchaser if felt necessary.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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HVOF Coating is not envisaged at present. However, based on the silt data, the requirement of HVOF or other coating maybe discussed during detail engineering.

### **1.3.8 Turbine Embedment / Foundation Fixtures**

Components which shall be embedded in concrete viz. scroll casing, stayring, draft tube liner, turbine pit liner shall have ample number of integral pads, for resting/supporting on jacks fixed to concrete pedestal for erection and concreting and shall be covered in the scope of supply.

Ample number of jacks, adjustable tie rods, holding down-bolts, fastenings for holding down bolts and turn-buckles for the adjustment and setting various components in place for their erection and concreting shall be covered in the scope of supply. Also all internal temporary reinforcements shall be provided by the turbine manufacturer to allow embedding in concrete without any undue deformations of those components, assuming concrete lift height of 1 meter.

### **1.3.9 Handling of Components**

- 1.3.9.1 Structural components shall be provided with reinforcement braces and spiders where applicable to prevent deformation and strain during transportation and for handling during assembly/erection.
- 1.3.9.2 The sections, segments and components shall be provided with eye-bolts and lifting lugs of suitable size for handling.
- 1.3.9.3 The turbines shall be designed and constructed such that main parts viz. Runner, Shaft, Top Cover, and Wicket-gates operating ring can be removed through stator bore conveniently as a routine provision with minimal amount of dismantling and disturbance to other parts of turbine or generator.
- 1.3.9.4 It shall be further ensured that the removal of runner shall not require the guide vanes to be dismantled or displaced. Removal of guide vanes shall also be possible downward or partially upwards at the turbine pit level itself without need for dismantling the generator components.
- 1.3.9.5 In addition to the removal of turbine components through stator bore as mentioned above, turbine construction shall provide for removal of the following components from bottom without dismantling generator.
  - i) Runner,
  - ii) Bottom ring/pivot ring,
  - iii) Discharge Ring,
  - iv) Wicket gates,
  - v) Draft Tube Cone,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- vi) The facing plates,
- vii) Wearing rings,
- viii) Any other part subject to wear due to silt.

The items at ii), iii), v) and vi) shall be removable either in a single piece or in sections as feasible. The supplier shall, however, ensure that with this provision the size of gallery for removal of runner does not exceed from the provisions of layout drawings.

- 1.3.9.6 For quick removal and installation of runner and turbine components the following handling equipment shall be included in the offer:
- a) A special trolley running on wheels, and provided with movable servomotor operating platform and devices, for the removal of the runner and any other heavy parts from below, which can be handled by electric winch.
  - b) Electric winch for moving the special trolley carrying runner, draft tube cone etc. in the reach of PH crane & back.
  - c) Monorail and electric hoist on the turbine pit described under Turbine Pit Liner.
  - d) Rails, hooks, etc. required for dismantling and erection shall be supplied.
  - e) Any additional device for the quick removal and installation, from below, including devices for quick removal of bolts and screws.
- 1.3.9.7 Further the removal and replacement of worn out labyrinth wearing rings, cheek plates, shaft gland, guide bearing and such other components shall be fast and easy. Where possible the design shall provide for the removal and replacement of these components particularly the labyrinth wearing rings, cheek plates, shaft gland etc. from below.
- 1.3.9.8 The supplier shall furnish all pertinent details/drawings explaining the procedure for dismantling/handling the said components in the manner explained (upwards removal through stator bore, bottom removal and in situ replacement), during offer.
- 1.3.9.9 The supplier shall indicate during the design stage the expected times, in hours, required for replacement of the eroded turbine components on the following basis:  
Total time (in days considering three working shifts) including dewatering and filling operations needed to replace with spares, i.e. turbine runner, the guide vanes, the facing plates and wearing rings and any other movable parts subject to wear due to silt erosion or abrasion.
- 1.3.9.10 It is also intended to make use of the EOT crane for handling the runner and other components for dismantling from below. This will require the rod to be lowered through the bore of the generator shaft and the turbine shaft. The supplier shall make provisions for enabling use of EOT crane for the said purpose in addition to alternative 1.3.9.5.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

- 1.3.9.11 The design of the turbine shall permit an upwards vertical movement of the turbine rotating parts viz. runner and shaft by an amount sufficient for access for adjustment of the generator thrust bearing and for clearing the joint at the coupling of the turbine and generator shaft. Similarly, downwards vertical movement of the turbine rotating parts shall also be provided for resting on the ledge on discharge ring when detached from generator shaft.
- 1.3.9.12 Two inspection platforms, one to be installed in the draft tube through the inspection manhole and the other to be placed over the draft tube opening after the draft tube cone is removed for maintenance. The first one shall be made of aluminium for easy handling.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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### 1.3.10 General Physical Layout & Arrangement

Various levels of the power house are mentioned as follows:

- |   |                |
|---|----------------|
| – Elevation of Runner removal gallery         | EL1180.80 m    |
| – Elevation of MIV Floor                      | EL. 1180.80 m  |
| – Elevation of Turbine/ Generator floor       | EL. 1187.05 m  |
| – Elevation of Machine hall/service bay floor | EL. 1193.30 m  |
| – Elevation of Central line of the turbine    | EL. 1184.80 m. |

However, the tenderer is free to suggest minor alterations in the above proposed levels to suit the design and construction of the generating units being offered by him.

The load of the generator thrust bearing shall be transferred to the civil works structure through the generator upper bracket.

Easy access for repair and maintenance of removable/ renewable under water parts of turbine such as wearing rings, cheek plates, guide vanes sealing elements and turbine guide bearing and shaft seals shall be provided from the turbine pit without resorting to dismantling of turbine runner.

All equipment in the turbine pit shall be neatly arranged and shall be readily accessible for operation and maintenance.

Similarly, all accessories and associated auxiliary equipment such as governor pressure oil equipment shall be arranged in a neat and functional manner.

Suitable erection devices and tools shall be provided by the Contractor for enabling assembly of main components i.e. rotor, stator, MIV, runner, etc. on the assembly bay floor. The contractor shall furnish the maximum likely live load intensity on the assembly bay floor.

The draft tube of each unit at its exit shall be tunnel of modified horse shoe cross section discharging water into the river. To avoid construction difficulties for integrating the conventional draft tube opening with horse shoe tail race tunnel, the draft tube profile may be suitably modified so as to form the smooth transition with the tunnel.

### 1.3.11 Miscellaneous Items

Following miscellaneous items shall form part of the supplies of the turbines:

- a) Necessary walkways, ladders, handrails, chequered plates etc.
- b) Illumination and power service points inside the turbine pit, including wiring in suitable conduits, suitable for single phase, 240 V, 50 Hz, AC supply.
- c) Suitable fixtures, accessories, sockets, conduits shall be covered in the supplies. Switches shall be located at turbine pit entrance.
- d) Terminal blocks, wiring, conduits for control, instrumentation, metering inside turbine pit, outside generator barrel.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- e) First fill of governor and lubricating oil including 10% extra.
- f) Welding electrodes of suitable material and grade for site welding & assembly of sections of turbine components.
- g) All handling equipment such as hoists, hoist beams, slings, turn buckles, tie rods, jacks, trolley etc. for handling turbine components inside turbine pit.

## 1.4 Construction Features

### 1.4.1 Runner

#### 1.4.1.1 Manufacture

The runner shall be of cast stainless steel, in one piece and shall be designed to provide the best hydraulic profile so that it gives the maximum efficiency with minimum cavitation. The runners shall be homologous with the model runners. The runner shall be provided with renewable labyrinth wearing rings.

The runner shall be designed to safely withstand loading due to normal and abnormal operating conditions including effects of blade thickness reduction due to cavitation erosion, introduction of stress due to on site welding of damaged blades, increased pressures at transient conditions and discharge related to maximal guide vane opening. The runner shall be designed to withstand stresses due to resonant vibrations. The Contractor shall clearly present his calculation criteria with respect to maximal possible stresses in the runner, related to mechanical properties of the runner material.

The maximum peak to peak stress amplitude in the runner shall be less than 40 MPa at rated conditions. This shall be shown with reference to a finite element stress analysis of the proposed runner.

The coupling between shaft & runner shall be combination of friction and shearing type fastened by means of hydraulically prestressed coupling bolts & shearing pins.

When detached from generator shaft and seated on a ledge at discharge ring, the runner shall be capable of withstanding the shaft weight.

During turbine operation, leakage water from the upper runner labyrinth seal shall be drained through a relieving pipe from the upper turbine cover to the draft tube to minimise hydraulic thrust.

Sufficient vertical clearance between turbine rotating parts and the surrounding stationary parts shall be provided.

The finished runner shall be balanced statically in the manufacturer's shop according to ISO 1940, class G 6.3.

The Contractor shall state the guaranteed runner unbalance after final treatment. Unbalance shall be checked in the Contractor's shop.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

#### 1.4.1.2 Materials

The Turbine Runners shall be made of stainless steel of 13 % chromium, 4 % nickel (DIN 17.445, Werkstoff-Nr. 1.4113, G-X5 CrNi 13.4, ASTM A 743 CA 6 NM), with ultra low sulphur and nitrogen content. The minimum Charpy V-notch impact strength at -10°C shall be 30 J, to be fulfilled by each of 3 specimens.

Castings and forgings shall be furnished by a foundry respectively a forge shop having the necessary skill, experience, and capacity for this type and size of work. The runner manufacturing method as well as the name of the intended foundry or forge shop shall be listed on the Technical Data Sheets.

Welded runner must be welded using metallurgically matching electrodes. The Contractor may offer alternative austenitic welding material.

The runner shall be free from internal stresses and casting or forgings imperfections. All surfaces of the runner exposed to the flow of water shall be carefully machined and finished smooth to templates. There shall be no hollows, depressions, waviness, projections and/or other surface imperfections that might lead to local disturbance, erosions and/or cavitation. Other highly stressed areas of the runner shall be finished smooth to judge the quality of the casting or forging and evaluate possible material defects.

The Contractor shall guarantee that no cracks will appear on the runner.

#### 1.4.1.3 Fabrication

The finished runner metallurgic quality must conform to requirements of an recognized standard such as CCH 70.3. The Contractor shall control the runner during fabrication as required by the standard.

The runner shall be examined by means of magnetic flux, penetrants or ultrasound method or combination of all three methods. The control procedure must be in accordance with appropriate ASTM standard.

Acceptable standards are:

Magnetic flux control equivalent	CCH 70.3, (MT 70.3) or
Penetrant control equivalent	CCH 70.3, (PT 70.3) or
Ultrasonic control equivalent	CCH 70.3, (UT 70.3) or

The conformity of the blade shape to the design drawings shall be verified by use of templates or other shop control devices. Templates for guidance in restoring blade and bucket shapes to original contour shall be supplied with the runners. The geometrical deviations may not exceed tolerances set out in IEC Publication 60193-1.

The Contractor shall make templates for profile geometry control, to be used for checking of the prototype homologous geometry with accepted model geometry. The

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

Contractor shall prove to the Corporation the templates have been made in accordance with the model geometry which gave guaranteed characteristics. The number of templates and their design shall be approved by the Employer. All prototype profile geometry deviations shall be within guaranteed tolerances for the runner.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

#### 1.4.1.4 Surface Finish

The surface of the runners shall conform to indicative specimens of the Quality Sheets according to CCH 70-3.

Runner inspection and quality control shall also be according to CCH 70-3. Acceptance criteria shall be in accordance with these specifications and shall be subject to approval by Employer.

The Contractor may offer better surface roughness and profile waviness if deemed to be necessary for guarantees to be fulfilled. In case the Contractor offers surface roughness and profile waviness other than required, the fabricated model and prototype runner surface roughness must meet given guarantees.

#### 1.4.1.5 Other Requirements

A series of templates for prototype control, based on accepted model runner geometry shall be surrendered to the Employer. The templates will be used for profile control after profile repair due to cavitation erosion.

The runner shall have a bolted flange connection for attaching to the existing shaft. Wherever the design of the new runner is modified in such a way that the existing coupling bolts cannot be utilised, new coupling bolts and nuts shall be included in the supply.

The labyrinth ring of the upper cover shall be oriented by a rabbit fit while the labyrinth ring of the lower cover shall be laterally adjustable to allow centering with the turbine runner, after finishing the turbine/generator shaft alignment. The rotating ring shall be suitably fixed so as to ensure easy replacement. The material of the rings shall be 13-Cr-Ni or better stainless steel. To minimise silt erosion on the stationary labyrinth mounted on top cover relative to that of rotating labyrinth rings mounted on runner, the surface hardness of the fixed ring may be selected higher than that of moving rings. The method & sequence of renewing these rings shall be furnished along with the offer.

Supply of special tools for tightening the coupling bolts, and/or special erection devices shall also be included in the scope of supply.

### 1.4.2 Shaft, Coupling and Alignment

- 1.4.2.1 The turbine shaft shall be of forged steel properly heat-treated. The shaft shall be hollow bored and of ample size to transmit torque and run at maximum run-away speed without detrimental vibration or distortion. The central bore shall be of sufficient diameter along the entire length of the shaft to permit visual inspection. The turbine shaft shall have integrally forged coupling flanges for bolting to the runner and to the generator shaft and shall conform to the American standard for shaft coupling (ANS-B.49.1-1967 / IEEE 810 latest standard or any other equivalent standards.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- 1.4.2.2 For calculating critical speed and determining the shaft diameter of turbine and generator, factors such as characteristics of mechanical parts, forces due to turbine during starting, stopping and running etc. shall be taken into consideration.
- 1.4.2.3 The contractor shall furnish to the purchaser the calculations of critical speed and shaft diameter for perusal and record.
- 1.4.2.4 The shaft shall be accurately machined all over and polished where it passes through the guide bearing. Maximum shaft run out on cylindrical surfaces shall not exceed the tolerances recommended in the NEMA standards for vertical hydraulic turbine generator shaft run out tolerances.
- 1.4.2.5 The turbine shaft shall have removable and renewable sleeve where it passes through the gland in the head cover. The sleeve shall be of stainless steel and shall be resistant to abrasion and corrosion. The sleeve shall be split and adequately fastened to the shaft.
- 1.4.2.6 A removable finger shall be fitted to the shaft immediately above the shaft seal to prevent leakage water travelling up the shaft to the main guide bearing.
- 1.4.2.7 The contractor shall furnish to the Purchaser the design calculation of turbine and generator shaft coupling. The coupling base should be machined to final dimensions and drilling of the bolt holes are to be done three (3) mm undersize. The contractor shall arrange final reaming of coupling bolt holes and shall also supply the coupling bolts and nuts, as well as suitable cover for the coupling bolts.
- 1.4.2.8 Before shipment of turbine and generator shafts, these shall have final reaming, corrections required for matching both shafts, match marking etc. The final coupling and alignment of both shafts are to be made in works before despatch or at site.. For above works, no expenses shall be borne by the purchaser for transporting turbine shaft from the works of turbine to the work of generator where checking of the matchings of both shafts shall be made.
- 1.4.2.9 The contractor is responsible for the alignment and coupling of turbine and generator shafts and the unit as a whole at site. Any defects on this account shall be made good by the contractor at his own cost.

### **1.4.3 Turbine Guide Bearing**

- 1.4.3.1 The turbine guide bearing shall be of the oil self lubricating type with babbitt lined bearing pads. It shall be located on the inner head cover as close to the runner as possible but above the turbine shaft gland. It shall permit vertical movement of the shaft to facilitate adjustment and dismantling of the generator thrust bearing and clearing the male and female portions of the shaft coupling. It shall be designed to withstand safely and without damage natural retardation from maximum over-speed without application of generator brakes.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- 1.4.3.2 Access to bearing shall be such as to enable inspection of bearing without dismantling other turbine parts. The bearing housing and shell shall be split to two or more sections to facilitate dismantling and shall be dowelled securely. The bearing shall be lined with suitable high grade antifriction material such as babbit. The lining shall be bonded securely to the shell, and shall be suitably bored and grooved to cause lubricating oil to circulate over the bearing face without the aid of a circulating pump.
- 1.4.3.3 A suitable heat exchanger shall be provided through which cold water from the unit cooling water system can be circulated for cooling of the lubricating oil. The contractor shall supply all the pipe and fittings including valves. A flow indicator with alarm contacts to indicate low/no flow and a throttling valve shall be provided downstream of the heat exchanger. The cooling water shall be discharged into the tailrace. The cooling tubes shall be of Cupro Nickel or any other better material.
- 1.4.3.4 The bearing oil sump shall be provided with an oil level indicator with switches for high and low oil level alarm. The metal and oil temperature detectors, vapour pressure thermometers (dial type indicators with adjustable alarm and trip contacts), RTDs and connections for oil filling and drain as well as purification by means of a purifier shall be provided. RTDs, thermometers and pressure gauges at the inlet and outlet of cooling water pipes of the bearing shall be provided.
- 1.4.3.5 The bearings shall be adequately insulated where considered necessary, to prevent any harmful circulating current from passing through the bearings surfaces. The insulation shall be arranged to break the possible path of such currents in not less than two places in series, so that positive test for ground currents readily can be made. Continuous monitoring of shaft current shall be made and contacts shall be provided to arrange automatic shutdown of the unit in case of excessive shaft current.
- 1.4.3.6 The design shall be such that no water shall enter the lubricating system and there shall be negligible loss of oil by leakage or overflow from any part of the oil system under any condition of normal operation. A water detector device with alarm contacts shall be provided at the lowest point of the oil sump.
- 1.4.3.7 The turbine guide bearing shall be designed for the following conditions:
- That the normal working metal pad temperature shall not exceed 70°C for turbine operating at all loads up to permitted overloads.
  - Continuous operation at any speed from 90% to 110% of rated speed.
  - Capability of operating safely at maximum allowed load for a period of 15(fifteen) minutes without cooling water supply
  - Safely withstand turbine going to run away speed due to any fault for a period of 15(fifteen) minutes with cooling water supply intact and subsequent closing down period without any damage to the guide bearing.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- e. Withstand safely and without damage the natural retardation from maximum over speed without application of generator brakes
- f. Withstand operation at low speed (4-5% of rated speed) for a period of at least 30(Thirty) minutes.

1.4.3.8 non-cooling The first fill of oil plus ten percent in excess shall be supplied by the contractor in returnable drums. The tenderer shall furnish details such as quantity and pressure water required, quantity of oil, specification of oil etc. in the tender.

#### **1.4.4 Main Shaft Gland (Sealing Box)**

1.4.4.1 The turbine shaft gland shall be of non touching labyrinth or any other suitable type located below the main guide bearing in the inner head cover. It shall work towards a rotating stainless steel sleeve mounted on the turbine shaft. No harm shall occur to the seals even if they touch during the initial period of operation.

1.4.4.2 Suitable wear indicator for local read out shall be provided.

1.4.4.3 The seal shall be easily accessible for inspection and adjustments/replacements of the sealing rings. The tenderer shall indicate the quantity, pressure and purity of seal water required.

#### **1.4.5 Spiral Case**

1.4.5.1 The spiral casing shall be of full spiral type of welded high tensile plate steel construction and shall be made and supplied in minimum number of sections with a view to keep welding at site to the minimum feasible and within the limitation of transport and handling etc. Welded joints may be provided between the various quadrant sections of the scroll casing. The spiral case shall be designed for maximum operating pressure including water hammer. The scope shall also include the bulk heads, test ring, the high pressure generation pump etc. required for hydrostatic testing at site.

1.4.5.2 Sufficient quantity of electrodes required for site welding of spiral casing for all the units shall be included in the scope of supply.

1.4.5.3 The embedding of spiral casing in concrete is proposed to be carried out with the spiral casing under a hydraulic pressure to be decided during detail engineering.

1.4.5.4 The casing and the joints with the stay ring will be completely field welded by the contractor. All such joints shall be butt welds only. In case of welding joints suitable machined marking faces shall be provided between the different sections to ensure proper matching circularity and other dimensional accuracy during assembly and erection at site. In case of bolted flanged joints, seal welding shall be provided at the joint periphery for tightness.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

- 1.4.5.5 The spiral case, stay ring welds shall be 100 percent Ultrasonic tested.
- 1.4.5.6 A suitable flanged drain connection, complete with pipe down to a suitable point in the draft tube, with cast steel gate valve etc. shall be provided at the bottom casing inlet. A grill which will follow the original surface of the water passages shall be provided for the drain opening in the spiral casing.
- 1.4.5.7 A manhole of suitable diameter shall be provided in the spiral case. A small test cock below the manhole level shall be provided to ensure its emptiness before opening the manhole. Suitable number of piezo-meter connections shall be provided to indicate water pressure according to the Winter Kennedy method and for connection to the discharge measuring equipment.
- 1.4.5.8 The spiral casing shall be provided with dismantling joint for connection to spherical type inlet valve and thrust collar to transfer hydraulic forces into the concrete.
- 1.4.5.9 The following flanged connection shall be located in the expansion joint.
- Four outlets for pressure measurement
  - One flange outlet for drainage of spiral casing to dewatering sump through draft tube.
  - One flange outlet for air bleeding valve
  - One flange outlet for efficiency test by thermodynamic method.
- 1.4.5.10 Ample number of machined pads for application of jacks and adjustable tie rods shall be provided for field alignment of the assembled spiral case and stay ring, and for anchoring or holding-down purposes during concreting. Sufficient number of turn-buckles and jacks required for holding the scroll case during concreting shall be supplied.
- The contractor shall furnish all spiders or bracing required to prevent distortion of the spiral case sections during transportation and erection.
- 1.4.6 Stay-Ring**
- 1.4.6.1 The stay-ring shall be of cast steel or fabricated from welded steel plate and suitably stress relieved prior to machining. It shall be segmented radially as required for shipment, properly flanged to secure bolting in the field and shall be prepared for field welding to the spiral case. Flanges shall be provided for bolted connections between the stay ring and the head cover, and between the stay ring and the discharge ring. Alternatively the discharge ring may be welded to the stay ring prior to stress relieving and machining. A flange to receive the pit-liner shall be provided. The stay ring shall be designed to support the weight of the superimposed structures and parts, with spiral case empty, and to withstand safely the upward thrust due to maximum head, including maximum pressure rise. For fabricated stay ring designs, the stay vanes shall protrude through the upper and lower shroud plates and shall

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

be shop-welded with full penetration welds. Fabrication of the stay ring in the field will not be allowed.

- 1.4.6.2 Each section of the stay ring shall be provided with eyebolts and/or lugs for attaching slings for handling. A sufficient number of machined pads for the application of jacks and fastenings for holding down bolts and a corresponding number of jacks and holding down bolts, shall be furnished for levelling the spiral casing and stay ring during erection and for holding & supporting it in proper position, while the concrete surrounding the spiral case and stay ring, is being placed. Grout holes of suitable diameter shall be provided in the lower flange of the stay ring to facilitate placing of concrete under that section. Suitable provision shall be made for closing these grout holes after the concrete is placed.
- 1.4.6.3 Two (2) drain pipes shall be provided by the contractor through the stay vanes, for connection to purchaser's embedded drain piping, in order to drain the stay ring collection area (outside the head cover) to the sump. The pipes shall be so located that the strength of the stay vane is not impaired. Removable and readily accessible strainers shall be provided on the top of these pipes.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

#### **1.4.7 Bottom Ring**

- 1.4.7.1 The bottom ring shall be made of cast steel of good weldability or welded plate steel, suitably sectionalized if necessary, to facilitate shipment and handling. If the bottom ring is made of welded plate steel, all welds shall be stress-relieved. It shall be dowelled and bolted to the discharge ring.
- 1.4.7.2 Bronze-bushed bearings shall be provided for the lower stem of each wicket gate, located in the bottom ring. Stainless steel overlay shall be provided at the wicket gate openings and on the entire surface between the wicket gate and the discharge ring. Renewable stationary labyrinth sealing wearing rings of stainless steel for the runner shall be provided.
- 1.4.7.3 Provisions shall be made in the bottom ring for the wicket gate seals.

#### **1.4.8 Discharge Ring**

- 1.4.8.1 The discharge ring shall be cast steel or welded plate steel construction or combination of the two, heavily ribbed to maintain its circularity, properly stress relieved and suitably sectionalized for shipping. A renewable stainless steel or stainless steel-clad throat liner shall be mounted at the inside of the discharge ring to form the water passage directly below the runner. It shall be machined at its upper end for connection to the stay ring or alternatively may be welded to the stay ring prior to machining. It shall be machined at its lower end for connection to the draft tube liner and on its top face to receive the bottom ring.
- 1.4.8.2 Suitable adjustable jacks, turnbuckles and foundation bolts shall be furnished to position and level the discharge ring during erection.
- 1.4.8.3 The discharge ring shall be designed to support the weight of the runner and turbine shaft when the turbine is disengaged from the generator shaft.
- 1.4.8.4 Taped grout holes of suitable diameter shall be provided in the top face of the discharge ring to facilitate placing of concrete underneath.

#### **1.4.9 Draft Tube**

- 1.4.9.1 The draft tube shall be elbow type and the profile shall be designed to gain maximum recovery of velocity head and thus provide high turbine efficiency. The design shall be such as would prevent causation of undue pressure pulsation and surges. The draft tube shall consist of the following:
- a) The cone shall be of fabricated steel structure with adequate stiffening ribs and strong upper flange. A hinged rectangular manhole cover and suitable off-takes for the connection of pressure and vacuum gauge shall be provided. An inspection plug is to be provided below the manhole door, to ensure before

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

opening it, that water is below the level of manhole. Provision shall be made for a platform to be positioned under the runner to facilitate inspection of the inside of the water way and also to enable possible repairs to be made. This platform shall be so designed as to be easily erected and the dimensions of the parts shall be such that they can be introduced through the access door to the draft tube. The upper part of the cone shall be connected to the discharge ring by flanged connection.

- b) The cone portion of the draft tube shall not be embedded in concrete to allow its dismantling for removal of runner and other components downwards for maintenance and replacement Adequate head room and space shall be provided around draft tube for the purpose of handling of components.
- c) The liner shall be of fabricated or welded steel plate structure with adequate stiffening ribs and erection brackets, holding down bolts, anchor rods, turn buckles etc. for anchoring the liner securely into the concrete and for levelling it in place. The liner shall be designed for stiffness against vibration and deflection due to hydraulic loads.

1.4.9.2 If necessary, the liner shall be divided into suitable segments keeping in view the transport and weight handling limitations. In such a case the draft tube liner shall be assembled and match marked in the manufacturer's shop before shipment for convenience of proper assembly and alignment at site. Specifications and quantities of the welding electrodes required and the welding sequences of the draft tube liner shall be indicated by the contractor. Adequate number of holes for free passage of air and grout, whilst the liner is being concreted in, shall be provided.

Piezometer taps shall be provided for connection to pressure and vacuum gauges.

1.4.9.3 A drain box for dewatering of the draft tube shall be provided. One end of the drain box shall be connected to the lowest point on the draft tube and the other end shall be connected to a common header located in dewatering gallery. Gratings shall be provided between draft tube and the drain box. The dewatering header connecting the entire unit shall open into the dewatering sump. A MIV floor operated control valve shall be provided in the drain box before it is connected to the dewatering gallery. The spindle of the control valve shall rise upto the turbine floor. The pipe sleeve to house the spindle in the mass concrete shall also be supplied. Provision shall be made of an adequate sealing arrangement so that draft tube water does not rise through the sleeve. Penstock and spiral casing shall also be dewatered under gravity through the draft tube. Necessary pipes, pipe fittings and control valves etc. for this purpose shall be supplied by the contractor.

1.4.9.4 It is essential that the turbine operation be stable at all gate openings and that no pulsations should originate in the draft tube to cause objectionable power swings or pipe line breathing. Aeration piping consisting of a manifold with four inlet connections equally spaced around the draft tube liner shall be provide at a suitable

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

elevation for automatic admission of air into the draft tube. In case compressed air is required for this purpose, suitably provision shall be made in the compressed air system to be furnished by the contractor.

- 1.4.9.5 It is to be ensured by the contractor that the frequency and amplitude of draft tube surges anticipated on the basis of model test, is not close to the natural frequency of the generating unit to avoid resonant conditions and objectionable power swings.

#### **1.4.10 Head Cover**

- 1.4.10.1 The head cover shall be of cast steel or welded plate construction or a combination of the two properly stressed relieved, and segmented radially as required to facilitate shipping and assembly. Provision shall be made to facilitate lifting of the complete head cover assembly with the power station crane.
- 1.4.10.2 The head cover shall be substantially ribbed and designed to withstand all forces acting upon it with safety and without undue de-formation, specifically those caused by the maximum tail water level and of those resulting from load rejection. The head cover shall also be designed to give rigid support to the main guide bearing, main shaft and maintenance seals, wicket gates, and wicket gate operation mechanism. When designing the head cover the contractor shall assure direct accessibility to the main shaft seal and to the wicket gate stem packing boxes. Pipes or passage ways shall be provided in the head cover to drain the leakage water from the wicket gate stem seals into the stay ring collection area.
- 1.4.10.3 Two bronze bushed bearings and packing box with a proven type of packing and bronze gland ring shall be provided in the outer head cover for the upper stem of each wicket gate. Stainless steel overlay shall be provided at the wicket gate openings. Provisions shall be made in the outer head cover for the wicket gate seals.
- 1.4.10.4 The gravity drainage would be effected through minimum two stay-vanes. As a standby arrangement for drainage of the top-cover, ejector type pump, and centrifugal pump with automatic pick-up shall also be provided. The top cover shall have an integral bearing surface for the regulating ring, guide bearing support flanges, packing box or shaft gland support flange and tapped holes with flanges for checking runner seal clearances. In case of rise in level of water in turbine head cover the ejector shall operate automatically so as to drain the head cover. Necessary float switches, wiring and controls shall be provided. Tappings from the ejector should be preferably from down stream side.
- 1.4.10.5 The top cover shall be fitted with renewable upper and lower stainless steel liners (bushes) for guide vanes, secured to it by countersunk screws and shall have stationary labyrinth sealing/wearing rings of stainless steel.
- 1.4.10.6 Air should be admitted either through the shaft bore with a vacuum break down valve connected at the end of the turbine shaft or if the air is admitted through the turbine

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

top cover, the inlet pipe should be taken up to a level above the maximum tail water level and the contractor shall provide the necessary air piping from the head cover and extend it to the interior downstream. The air inlet openings, automatic air inlet valves and air piping etc. shall have sufficient flow area for admission of air to the turbine water passage to relieve excess vacuum created by certain operating conditions.

#### **1.4.11 Turbine Pit Liner**

- 1.4.11.1 A pit liner for each turbine pit shall be provided. The pit liner shall be made in suitable sections of welded steel plate construction and shall be site welded together and to the stay ring. The pit liners shall be used as a form for concrete work of the concrete barrel. Therefore, the outside surfaces shall be sufficiently reinforced with the ribs to prevent deformation and shall be provided with anchor bars at appropriate locations to ensure satisfactory contact with surrounding concrete. Adequate reinforcement shall be fitted to protect the liner from deformation or strain during transportation and placement for concrete.
- 1.4.11.2 Fabricated steel recesses shall be provided in the pit liner properly ribbed and braced and machined to receive and support the gate servomotors and to transmit the servomotors thrust loads into the concrete. An opening for the entrance stair-way shall be provided in each pit liner. The pit liner shall be complete with necessary platforms, floor plates, walkways and ladders. Monorail and girders for handling equipment inside the turbine pit shall be provided. For illuminating the turbine pit and the entrance stair case, service power sockets shall be installed at the proper places in the pit. All devices and accessories for illumination shall be furnished by the contractor. The lighting fixtures shall be suitable for operation on 240 volt., single phase, 50 cycles supply. The lighting fixtures shall be water proof. Switches for lighting fixtures shall be provided at the entrance of the stair case.
- 1.4.11.3 All wiring for meters, relays and other instruments inside the pit liner shall be gathered at the terminal blocks provided in the pit liner. The contractor shall furnish necessary wirings, conduits and also ducts for passing through the concrete barrel.

#### **1.4.12 Guide Apparatus**

- 1.4.12.1 The number of guide vanes selected shall be well matched to ensure turbine operation without objectionable vibration. The guide vanes shall be shaped to permit smooth flow of water through the turbine and shall be so proportioned as to maintain closing tendency under any normal operating conditions of the turbine.
- 1.4.12.2 The turbine wicket gates and stems shall be of die forged 13-4 Cr-Ni stainless steel/ stainless steel casting. Each gate shall be machined smooth and ground to an accurate form and finish.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- 1.4.12.3 Each wicket gate shall be provided with three greaseless self lubricating bush type guide bearings one located in the bottom ring and the other two provided in the head cover straddling the stem packing box . Each stems shall be provided with a thrust bearing of bronze to carry the weight of the gate and withstand hydrostatic uplift. Convenient means shall be provided for adjusting and maintaining the vertical clearances of the wicket gates.
- 1.4.12.4 The upper gate stems shall be amply designed to withstand, without torsional effects, the hydro-dynamic forces after shear pin breakage.
- 1.4.12.5 The gate operating mechanism shall be of ample strength to withstand the most severe operating conditions. All working points with relative motion shall be bronze bushed and provided for grease lubrication. Alternatively stainless steel bushed bearing instead of bronze-bushed with self-lubricated bearings is also allowed. Means shall be provided for adjusting the position of any individual gate independently.
- 1.4.12.6 Each gate shall be individually connected to the gate operating ring through a set of lever and links.
- 1.4.12.7 Suitable shear pin shall be provided between each wicket gate stem and gate operating ring which shall be strong enough to withstand the maximum normal operating forces but will break or yield due to forces in opening or closing direction and will protect the rest of the mechanism from damage when one or more of the wicket gates become jammed. A shear pin failure check circuit shall be provided which shall be electrically continuous if all pins are sound and open. If any one pin is sheared it shall furnish annunciation in the unit control board. A shear pin break test shall be performed in the shop.
- 1.4.12.8 Solid stops and suitably designed friction device shall be provided for each wicket gate to limit the angle and rate of movement of gate stem levers while opening and closing on shear pin failure. The loose gate and its linkage after shear pin failure shall not interfere with the operation of other gates or turbine parts or cause progressive failure of adjacent shear pins.
- 1.4.12.9 All the components of the guide apparatus shall be readily accessible for inspection, adjustment and repair. The gate operating ring shall be made of cast steel or welded plate steel. The guide operating ring and its supporting structure shall be of adequate strength and stiffness to prevent deflection of this ring, guide bearing or the main shaft if the gate operating ring is subjected to the thrust of only one servomotor with the other servomotor blocked or without oil pressure.
- 1.4.12.10 Seals shall be provided above and below wicket gates to effectively reduce leakage of water or air. Segmented seals of proven design shall be used.

#### **1.4.13 Guide Vane Servomotors**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- 1.4.13.1 The guide vanes shall be operated by two numbers of double-acting oil pressure operated, fabricated or cast steel servomotors having adequate capacity to operate the turbine gates to full opening or closing stroke with minimum oil pressure.
- 1.4.13.2 The servomotors shall be provided with suitable adjustable bypass connections for cushioning to achieve retardation in the rate of closure during the portion of gate travel from slightly below speed-no-load position to the fully closed position to prevent excessive pressure changes in the water passages.
- 1.4.13.3 Manual locking devices to hold the guide vanes in the closed or open position against maximum oil pressure shall be provided. Switches for interlocking circuits and lamp indication of the locking device position shall be provided on local panel and on unit control board.
- 1.4.13.4 Provision for connecting the restoring cable from the actuator on the piston rod of servomotor shall be provided. A scale calibrated in tenths of gate position shall be rigidly attached to servomotor position by means of a pointer.
- 1.4.13.5 Effective sealing to prevent oil leakage shall be necessary.

#### **1.4.14 Centralised Grease Lubrication System (if required)**

Each turbine shall be provided with an automatic centralised grease lubrication system comprising of lubricant reservoir, two motor operated grease pumps complete with motor starters, switches, oil pipes, fittings etc and the initial fill of the grease for the complete lubrication of the rubbing surfaces turbines with provision also for manual operation of the grease pump.

The system shall be designed to supply measured quantities of operating grease to all the bearing surfaces of levers, links, operating ring, rods, wicket gate stem (if applicable), inlet valve and other points of the turbine required to be lubricated by grease as often needed.

#### **1.4.15 Turbine Flow Meter**

- 1.4.15.1 Each turbine shall be provided with a flow metering equipment for local indication and recording. The flow meter shall be designed to operate utilising the pressure differential obtained from Winter Kennedy tapplings to be provided in the top shroud of the stay ring and the spiral case or at any convenient locations. The flow-meter shall indicate the instantaneous flow (in cubic meters per second) through the turbine on a uniformly graduated direct reading indicator and shall record the flow on an uniformly graduated synchronous motor drive paper chart. The equipment shall be capable of measuring over the entire range of turbine operation from 10% to 110% of maximum turbine discharge. A transducer shall be provided for remote indication in the control room of power station.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

1.4.15.2 The flow-meter shall be suitable for mounting on wall/unit control Board and shall be complete with required vent valve, shut off valves, pressure pulsation damper, supports, all piping from the Winter Kennedy tapping to the flow meter and all other accessories that may be required such as mercury for manometer, chart paper, ink etc. for one year and special tools for initial calibration.

1.4.15.3 The flow meter shall be calibrated during the field testing of the turbine. Output shall be indicated in the SCADA.

#### **1.4.16 Piezometers Gauges**

1.4.16.1 Four piezometer tapings equally spaced around the turbine inlet pipe, four piezometer tapings at the draft tube exit section, two in the pier and two in the walls shall be provided for measurement of net head in accordance with IEC Field test code. In addition, Piezometer tapings at two diametrically opposite locations in the draft tube liner below the runner shall be provided.

1.4.16.2 Connections shall be terminated in a manifold adjacent to the draft tube manhole. Vacuum/pressure gauge shall be connected to the manifold and mounted conveniently.

1.4.16.3 At least three piezometers shall be located under the head cover on a vertical plane. A pressure gauge mounted on the pit wall shall be provided for each tapping.

1.4.16.4 Winter-Kennedy tapings in the top shroud of the stay ring and spiral case shall be provided for flow measurement.

1.4.16.5 All piezometer tapings used for pressure measurement shall be made of stainless steel and shall conform IEC field test code. Stainless steel piping shall be used for connections. The portion of piping to be embedded in concrete shall be enclosed in a conduit to protect the pipe during placement of concrete.

1.4.16.6 Gauge shall be supplied complete with necessary piping, capillary tubing, valves, fittings, etc. The pressure gauges shall be calibrated to indicate the value in meters as well as in Kg/cm<sup>2</sup>.

#### **1.4.17 Resistance temperature detectors (RTD's) and Dial Type Thermometers (DTT's)**

1.4.17.1 The temperature detectors for turbine guide bearing and lubricating oil shall be of the resistance type. One RTD in each of alternative pads for indication and recording shall be provided, besides, 2 RTDs in the lubricating oil bath, 1 RTD shall be provided in the outlet cooling water from turbine bearing coolers.

1.4.17.2 In addition, five (5) dial type thermometers (DTT's) shall be provided in turbine bearing pads & oil. Dial type thermometers shall be of the mercury/vapour pressure

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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actuated type. The meters shall be of dial type with needle indicator (with maximum indicator) and mounted on the panel near generator barrel along with generator DTT's. A flexible pressure conduit tube, properly armoured, shall be provided between each temp. detector and the panel. Two sets of hermetically sealed, independent, normally open contacts for alarm and trip purpose shall be provided on the meter. The contacts for alarm and trip shall be easily adjustable to set the alarm and trip temperature, and shall have sufficient resistance to arcing, adequate operating current capacity, and shall be accurate in operation.

- 1.4.17.3 Resistance temperature detectors for the turbine bearing shall be used in combination with temperature recorder located on the unit control board and local panel at turbine floor. The temperature detectors shall conform to AIEE standard No. 551. RTDs shall be of dual/multioutput type suitable for temperature monitoring through temperature indicator/recorder and DAS. At least 20% RTDs shall be provided as spare.

#### **1.4.18 Oil Level Gauges and Relays**

- 1.4.18.1 Oil level gauges shall be of the float gauge type and shall be fitted with appropriate protective devices. They shall be so constructed that there is no oil leakage.
- 1.4.18.2 The gauges shall be fixed at locations convenient for inspection even during operation. Normally upper and lower level relays shall be accurate and reliable in operation.
- 1.4.18.3 They shall be installed in convenient positions to enable easy inspection and checking of operation, and shall be provided with suitable air release valves. The relays shall be provided with two sets of normally open contacts (one for alarm and one for operating condition of turbine start) on lower and upper oil level, respectively and with asset of normally open contacts at the extreme lower oil level to stop the turbine.

#### **1.4.19 Vibration Monitoring System**

One (1) no. of common vibration monitor shall be supplied for monitoring the vibration level of Generator as well as Turbine points at a single location. All the vibration sensors of Turbine & Generator points shall be connected to this common vibration monitor. The vibration detector monitoring system (displacement type) shall initiate alarm and trip contact and shutdown the unit in case of excessive vibration of the Turbine during operation.

#### **1.4.20 Over Speed Device**

The Contractor shall furnish a heavy duty over speed trip device with provisions for electrical and mechanical tripping, on the shaft of each Turbine. The mechanical tripping device will close the Spherical valve, in case of Turbine speed exceeding

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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preset limit. It shall be furnished complete with rotating and stationary trip mechanism, guards, connection to Spherical valve control, and necessary supports.

The device shall meet the following requirements."

The mechanism shall be completely mechanical or oil-hydraulic and not dependent on electrical equipment for its operation. However, two electrical independent ungrounded changeover contacts shall be provided for alarm and initiating governor shutdown.

The rotating mechanism shall be designed for mounting on the Turbine shaft below the coupling. It shall be of the fly ball weight design acting against a compression spring. The entire rotating mechanism, including cover guard, shall be statically balanced in the Contractor's shop. It shall be calibrated, visibly marked in percent rated speed and set to trip at approximately 5 percent above full load rejection overspeed. It shall have a reasonable adjustment range above and below this speed.

The stationary trip mechanism shall be arranged for convenient manual resetting and shall be provided with an interlocking device to close and prevent reopening the Spherical valve until the fault is cleared. The trip connection to the main inlet valve shall be by oil pressure, and the mechanism shall have sufficient capacity to positively operate the main inlet valve controls to close the main inlet valve.

#### 1.4.21 Spares:

General and recommended spares shall be supplied in accordance with relevant clauses of the Specification". Specified spares to be supplied under this section are as follows:

S.No.	Description	Qty.
1.	Runner complete with moving labyrinth seals, runner cone and fixing bolts	1 no.
2.	Coupling bolts runner to turbine shaft	2 set
3.	Coupling bolts turbine shaft to generator shaft	2 set
4.	Labyrinth seals Upper including fasteners · Fixed labyrinth seals Moving labyrinth seals	3 sets 3 sets
5.	Labyrinth seals Lower including fasteners · Fixed labyrinth seals · Moving labyrinth seals	3 sets 3 sets
6.	Liner/ facing plates for top cover including fasteners	3 sets
7.	Liner/ facing plates for bottom ring including fasteners	3 sets
8.	Complete set of guide vanes	3 sets
9.	Shaft seal segments	3 sets
10.	Shaft seal sleeve	3 sets
11.	Turbine guide bearing segments/ pads complete set	2 sets

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

12.	Guide apparatus	
i.	Bushes for top, middle and bottom stems of guide vanes	3 sets of each used type
ii.	Guide vane servomotors LH and RH	2 no. each
iii.	Shear pins	3 sets
iv.	Bushes for regulating mechanism	2 sets
v.	Key laid / key driven , if applicable or relevant part	3 sets of each used type
vi.	Servomotor Piston Rings	2 sets
13.	Turbine head cover water level detector	3 nos.
14.	Turbine head cover pump-motor sets	2 no.
15.	Grease Lubrication System (if applicable)	
i.	Feeders	1 set
ii.	Filters	1 set
iii.	Grease pump with motor including reservoir, dozer etc	1 no.
iv.	High pressure grease pipe	1 set
v.	Connectors, needle valve, NRVs etc.	1 set
16.	Air injection Valve	1 set
17.	Air injection Valve	
i.	Seat & Plunger	2 sets of each used type
ii.	Spring	2 sets of each used type
18.	DTT (Dial Type Temp. Thermometer) / thermometer of each type	2 set
19.	RTD ( Resistance Temperature Detector) of each type	2 set
20.	Water flow indicator of each type	2set
21.	Pressure gauge of each type	2 set
22.	Pressure switch / pressure transmitter of each type	2 set
23.	Oil level gauges of each type	2 set

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

24.	Valves of size 80 mm and above including penstock drain valve	2 no. of each type
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## 1.5 Turbine Governors

### 1.5.1 Type

- 1.5.1.1 Turbine governor shall be of latest design and shall comprise of a digital electronic, microprocessor based part for control and regulating function and a hydraulic part acting as a power-amplifying servo unit.
- 1.5.1.2 The electronic part shall house all the electronic devices and circuitry of the governor viz. microprocessor circuits, speed sensing transducer and circuits, amplifier circuits, feed back loop circuits, parameters speed drop circuit, stabilizing circuits and other control for adjustment of governor parameters.
- 1.5.1.3 The hydraulic part shall house complete hydraulic mechanical equipment comprising of pilot valves, auxiliary servomotor, main distributing valves, devices for, automatic shutdown, emergency shutdown and adjustment of governor closing and opening times.
- 1.5.1.4 The electronic governor shall be supplied by turbine supplier.

### 1.5.2 Control Requirements

- 1.5.2.1 The turbine governor shall perform following governing tasks for the regulation and control of the generating units.
- Speed/frequency control.
  - Power Control
- 1.5.2.2 The electronic governor shall have provision for local and remote automatic operation as well as local manual control through the hydraulic actuator. The governor shall be adaptable for use in an unattended station with automatic start-up/shut down, automatic synchronising, joint control and automatic load frequency control of units in all modes of operation.
- 1.5.2.3 The governor shall come into action automatically when the turbine start signal is given from the unit control board/control room. It shall then regulate the speed of the generating unit in operation.
- 1.5.2.4 It shall provide stable governing in all stages or conditions of operation of the generating unit viz. (a) speed-no-load, (b) Isolated operation, (c) Operation connected with power system grid, (d) black start of the unit.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- 1.5.2.5 The governor shall regulate the turbine generator unit to a uniform speed free from hunting or instability at all loads. It shall have provision for optimization of speed governing parameters, servomotor positioning parameters and turbine loading rate. Governor shall be fail safe on the failure of speed sensing element, loss of oil pressure or defect in the actuating system so that under any of these conditions, the machine shall be automatically shut down with alarm and indication.

### 1.5.3 Governor Operating Parameters

- 1.5.3.1 The speed governing of the generating unit shall be carried out by a combination of proportional, integral and differential actions and non-linear characteristics in order to provide best quality of control.
- 1.5.3.2 The governor shall have high Sensitivity, quick response to speed/load changes, least possible dead band times and wide adjusting ranges as given below in respect of the various parameters.

a)	Sensitivity	Not more than 0.01% of rated speed
b)	Speed level settings	Adjustable between – 5 Hz & (+) 5 Hz of normal 50 Hz (90 % to 110 %)
c)	Permanent speed droop	Adjustable between 0-10%
d)	Temporary speed droop	Adjustable between 0-100%
e)	Proportional action gain	Adjustable between 0.1-20
f)	Speed dead band at rated Speed	Shall not exceed 0.02 percent of the rated speed at any gate setting.  However the same shall be adjustable
g)	Governor dead band time	0.2 sec for step load change of 10 % of rated load or more
h)	Guide vane closing time	Adjustable up to 20 sec., having dual rate of closure
i)	Integral action time	0.1s-20s
j)	Derivative action time	0s-5s
k)	Guide Vane opening time	Adjustable upto 60 sec.

- 1.5.3.3 For the closing operation a dual rate of closure has been considered to be required to restrict transient speed rise of the turbine to within 45%. The governors shall therefore provide a dual rate of closure for the wicket gates faster in the first half of the closing period and slower in the second half. The governor closing and opening times as also the dual rates of closure shall be adjustable within the specified range.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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The maximum dynamic pressure at the turbine inlet level has been specified to be restricted to 290.52 m.

The wicket gate operating law shall be dual. The bidder may finalize the opening/closing time based on transient analysis keeping the pressure rise and speed rise within defined limits.

#### **1.5.4 Constructional Features and Other Provisions**

##### **1.5.4.1 General**

The microprocessor based regulator console shall have a local control panel on its front face with a keyboard display unit that shall permit digital display, modification/adjustment in the governor parameters etc. This control panel shall also have hand control of turbine signalling devices, a key switch for access to the maintenance program. The keyboard display unit shall enable reading or entering of the various governor parameters which shall be expressed in applicable units. The selector switches and potentiometers shall be provided through which the various governor parameters can be controlled and adjusted easily and fast. The selector switches and potentiometers shall be provided through which the various governor parameters can be controlled and adjusted easily and fast. The governor shall have means for monitoring of the turbine manually from the front face control panel.

The electronic governor shall have various devices, controls, indications for various required purposes and functions such as operating mode changeover, auto-manual operation mode etc.

##### **1.5.4.2 Location and Controls for Generating Units**

- i) The electronic governors specified above shall be mounted on UCB located in machine hall.
- ii) The hydraulic actuator units shall be located at the turbine floor level close to the turbine wicket gate servomotors.
- iii) Various controls for change over of governor operation from auto to manual and vice versa, from local to remote and vice versa, for switch over to emergency manual control will be arranged and provided on UCB. Emergency shutdown of unit shall be possible at all times from UCBs and control room.
- iv) The control devices pertaining to governors which will be required to be mounted on the UCB and in control room for operational control of the generating units will be installed on the front of the cubicle containing the electronic governor. These devices shall be:
  - a) Speed level setting control with set point indicator.
  - b) Speed indicator.
  - c) Combined gate limit setting control with set point indicator and gate position indicator.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- d) Any other essential device, if necessary, shall be part of the scope of supply.

#### 1.5.4.3 Provisions in Governors

- i) The electronic governor shall have provisions for setting/adjusting and indicating display of the set values of various governor characteristics/parameters with the help of the keyboard viz.
  - a) Permanent speed droop.
  - b) Temporary speed droop.
  - c) Temporary speed droop decay time constant.
  - d) Sensitivity.
  - e) Frequency dead band.
  - f) Speed regulating (PID-P structure)
  - g) Power regulation (PI structure)
  - h) Opening limitation.
  - i) Speed set point.
  - j) Output set point.
  - k) Monitoring and supervision of speed, power and position feedback signals.
  - l) AGC (Automatic Generation Control)
- ii) These shall also have other essential provisions and devices such as protective device for locking out on failure of the regulator, for transfer to emergency manual control.
- iii) The hydraulic actuator units shall have various devices, control, indications as given below:
  - a) Two remotely controlled shutdown devices for normal and emergency closure of wicket gates. For emergency closure two solenoid operated valves will be fed from two independent 220V DC sources.
  - b) Manual control devices acting directly on the actuator hydraulic system following opening and closing of wicket gates to any position. The actuator valve shall have provision for manual operation also.
  - c) Direct indications of gate limit and position of actuator units.
  - d) Speed indicator.
  - e) Other essential devices for smooth operation protection and safety of the units.

#### 1.5.4.4 Speed Sensing/Speed Switches



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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Speed sensing for governor operation shall be taken from magnetic pick-ups mounted near a toothed wheel which shall be mounted on the generator shaft.

#### 1.5.4.5 Wicket Gate Feed Back and other Devices

- i) The feed back between the actuator and regulator cubicles and wicket gate servomotors shall be of the electronic/electrical type. The cables for feed back shall be as short as possible and shall be properly protected against injury and damage and shall be supplied by the supplier.
- ii) The load feed back for the governor shall be provided by position sensing devices and from the CTs & PTs provided in the bus ducts separately.

#### 1.5.4.6 Software Programme Features

- i) The software for the microprocessor based speed governor shall be capable of quick programme running. In case of any power supply failure the programme and parameters shall remain indefinitely retained.
- ii) The governor shall have auto test programme for checking permanently for correct operation for the main governor components. The correct execution of the software shall also be permanently checked for which suitable “watchdog” monitoring circuit shall be provided.
- iii) The software shall prohibit the programming of the parameters beyond the allowed values.

#### 1.5.4.7 Other Provisions

The speed governor shall be provided with following provisions

- a) Facility of data communication i.e. exchanging information through serial communication link.
- b) Provision for data exchange with automatic systems of the power station for remote indication, logic information and remote control etc., if there are any data exchange that cannot be realised through the serial communication link.

#### 1.5.4.8 Maintenance / Replacement Provisions

The electronic governor of microprocessor based type shall have modular construction with suitable configuration to enable quick and easy maintenance/replacement in case of faults. The maintenance operation of the speed governor shall be feasible by use of an automatic internal checking programme and also step by step manual internal checking programme with the help of instruction manual. Adequate number of test points and electroluscent diodes on the front face of each card for an easy detailed analysis of each sub-assembly shall be provided.

#### 1.5.4.9 Fail Safe Provision

Electronic governor and hydraulic actuator shall be designed on the basis of fail safe principles. In case of failure of the main digital governor the system will switch over

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

automatically to the independent manual control. The digital governors will be supervising themselves by continuously checking their functions (watchdog). The digital governor shall be equipped with “grace mode” checking system. This system is based on the “sampling cycle” method, holding the programme sequent upto the next “sapling cycle” is activated.

#### 1.5.4.10 Governor Operating Time Adjustment

The adjustment for wicket gate closing and opening times shall be possible without dismantling the main distribution valves of the actuator.

#### 1.5.4.11 Joint Control of Units

Provision for the joint control of units in the station is as given elsewhere in the specifications. The governing equipment offered shall be compatible with, for achieving joint control.

#### 1.5.4.12 Working Oil Pressure

- i) The oil supply equipment for the governors comprising the oil pressure unit (accumulator) oil pumping units and sump complete with their piping valves etc. will be supplied as part of the turbine.
- ii) The normal working pressure for the governor oil shall be 100 kg/cm<sup>2</sup> (max). For piston accumulator 120 bar system will be applicable. The OPU shall have high pressure compressed air system or piston type accumulator with nitrogen bottles battery.
- iii) The governors shall, therefore, be suitable for the above governor oil pressure system offered.

#### 1.5.4.13 Control and Power Supply for Governor

- i) The DC Power/Control supply will be made available by the purchaser at 220V or 48 V DC and 415V AC, 50 Hz or 230 V AC, 50 Hz as required.
- ii) In case DC power voltage requirement are different than 220V DC, the supplier shall include DC/DC converters of requisite power and voltage in their scope of supply.
- iii) Similarly in case of AC, if power voltage requirement is different from the above, the supplier shall include the required step down equipment in their scope of supply.

### 1.5.5 Spares:

The Spare mentioned hereunder are meant for use by the Employer during operation and maintenance stage and shall not be used as erection spares required during installation.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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### General spares:

The Contractor shall supply the general spare as per relevant clause of Specification.

### Specified Spares:

The Contractor shall supply following specified spares.

S.No.	Description	Quantity
1.	Complete proportional valve assembly	2 nos. of each type
2.	Main distributing valve	2 nos. of each type
3.	Directional/Control valves (except solenoid operated)	2 nos. of each type
4.	Solenoid valve	3 nos. of each type
5.	Speed sensing device complete with pick ups, amplifiers, etc.	3 nos. of each type
6.	Transducer assembly complete of all type used in the system	2 nos. of each type
7.	Printed circuit card/module (except power supply unit)	2 nos. of each type
8.	Power supply unit	3 nos. of each type
9.	Pressure oil pump-motor set	2 nos.
10.	Jockey oil pump-motor set	1 no.
11.	Set of micro oil filter of each type used in the electro-hydraulic actuator	6 nos. of each type
12.	Set of oil/air filters of each type used in the oil sump tank	2 nos. of each type
13.	Un-loader valve complete assembly	2 nos. of each type
14.	Safety relief valve complete assembly	2 nos. of each type
15.	Oil leakage unit pump-motor set	1 no.
16.	Leakage unit oil level detector	1 no.
17.	Coils of solenoid used in the system	2 sets
18.	Indicating lamp bulbs/LED for each colour (Red, Yellow, blue, amber etc )	10 nos. of each type
19.	Sight glass gauges for pressure and sump tanks	1 set.
20.	Level switches, level transmitter and level indicator	2 nos. of each type
21.	Pressure switches and relays, limit switches	2 nos. of each type
22.	RTDs, Thermometers, pressure gauges used in the system	2 nos. of each type
23.	Ball and roller bearing used in the pumps and motors	2 nos. of each type used.
24.	Complete set of gaskets, O-rings, sealing rings and packing	2 nos. of each type
25.	Nitrogen cylinders	1 set
26.	Valves of each type (25mm and above)	2 nos. of each type

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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## **1.6 Turbine Main Inlet Valves**

### **1.6.1 Description and Operation Requirements**

1.6.1.1 Each turbine shall be provided with an inlet Spherical valve of 2750 mm nominal size. The maximum static head on the valves will be 215.2 m and with water hammer and upsurge in surge shaft, the maximum pressure shall be 290.52 m. The Spherical valve therefore shall be designed for operation against this pressure.

The Main Inlet Valve shall be of Spherical type. 2750 mm is the minimum nominal diameter of the MIV. If the bidder wishes to select MIV of higher size, the necessary provisions for matching with the penstock shall be in the bidder's scope. The valves shall conform to IS 7326.

The valve opening and closing time shall be adjustable to a closing time range of 50-60 sec. and opening time range of 50-120 sec.

1.6.1.2 The valve shall be suitable for joining with the scroll case inlet of the turbine. Marginal adjustment in the valve as to size and flange dimensions and drilling for bolting shall be the responsibility of the supplier. He shall coordinate this aspect with turbine supplier prior to manufacture. No extra charges shall be applicable for these adjustments.

1.6.1.3 The valve will be designed for automatic control with electric start and stop impulses from the supervision system, from the control room or from the UCB. In addition to automatic control complete and independent manual control system will also be supplied.

1.6.1.4 The MIVs shall be installed in the power house upstream of the turbine scroll casing inlet.

1.6.1.5 The inlet Spherical valve shall comprise of valve body and rotor, double acting servomotor(s) for opening and closing operation of the valve, control gear for operation, penstock inlet pipe, outlet pipe with compensator and dismantling joint, and other essential accessories and auxiliaries viz. by-pass valves, sealing valve, air valve, piping with valves, for water, air and oil, master switch, slide valves with electromagnets etc.

A dismantling joint shall be provided with Spherical valve on the down stream end to facilitate installation and dismantling of the valve and to permit replacement of the upstream and downstream seals and gaskets.

1.6.1.6 The Spherical type inlet valves shall be designed to close against full discharge in emergency and to open under balanced conditions.

1.6.1.7 The closing operation of the MIVs shall be with counterweight to ensure positive and reliable closure. The supplier may also indicate any other suitable closing system

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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for consideration of purchaser highlighting the merits over the above described system. Such proposal shall be discussed during design stage.

- 1.6.1.8 Valve shall have two stainless steel working seals; one at downstream (service seal) for use during normal closure operations and other at the upstream (maintenance seal) for use during maintenance of service seal. Both seals shall be water operated with oil operated solenoid valves. The seals shall be of material having high resistance to silt erosion. Suitable protection against abrasion shall be provided to ensure high reliability of sealing and long life. Leakage, if any, shall be stated and guaranteed. Permissible leakage shall be guided by IS:7326 (Part-1).
- 1.6.1.9 Lugs and Lifting Eyes shall be provided for convenience in handling the assembled valve.
- 1.6.1.10 Opening operation of the MIV shall be carried out by pressure oil operated servomotor(s). The pressure oil will be supplied from its independent pressure oil system or the governor oil pressure system. All piping from OPU to MIV shall be in the MIV supplies.  
Separate OPUs shall be provided for Turbine and MIV.
- 1.6.1.11 The oil supply system will be designed for a working pressure of 100 Kg per cm<sup>2</sup>. For piston accumulator 120 bar system will be applicable. The MIVs, servomotor(s) piping and valves shall suit this oil pressure.
- 1.6.1.12 The valves shall conform to IS: 7326 or any other internationally approved standard.
- 1.6.1.13 One emergency D.C. pump, for black start, complete with motor shall be supplied.

## 1.6.2 Basic data/ other data for Spherical Valves Design and Installation.

### Basic Data

The Spherical Valves shall be designed for the following tentative operational design data and system.

#### A) Valve Size and Other Data/ Requirements:

i)	Diameter /size of valve	2750 mm dia (clear bore)
ii)	Flow Velocity though the Valve for rated discharge.	7.3 m/s
iii)	Normal flow through valve equivalent to rated full load discharge of one unit at rated head at turbine (201.8m).	43.41 m <sup>3</sup> /s.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

v)	Maximum static head on valves when all the three generating units are stand still.	215.20 m
vi)	DESIGN PRESSURE	
	a) Maximum static pressure	21.52 Kg/cm <sup>2</sup>
	b) Design pressure	29.10 Kg/cm <sup>2</sup>
vii)	Maximum head at maximum upsurge	237.48 mWC
viii)	Pressure for leakage test	21.52 kg/cm <sup>2</sup>
ix)	Pressure for hydraulic test	43.65 kg/cm <sup>2</sup>
x)	Duration of Hydrostatic Test	30 Min.

### B) Operation of Spherical Valves

i)	Opening	In balanced conditions with practically equal pressure on both sides of disc as well as when the differential pressure across the valve is 50%.The opening time range shall be 60 to 120 secs. However, in case if different opening time is indicated by the bidder in his offer complete justification for the same may be furnished in the bid.
ii)	Closing	At no flow as well as against rated turbine flow under equal/ unbalanced pressure condition (Normal as well as emergency closing), the closing time under balanced conditions shall be adjustable between 60 to 120 sec. and is to be stated and guaranteed by the bidder. Closing time under emergency condition shall be stated by the Bidder. Full closer shall be achieved with the weights only independent of any assistance from the oil pressure system.

## 1.6.3 Provision to Withstand Silt Abrasion

### 1.6.3.1 General

- The valve shall be of design and construction and use materials as would resist silt erosion.
- The provisions in construction of the internal working parts of the valves shall ensure that silt loaded water does not ingress or impinge directly on the sealing

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	---

component/surfaces during flowing conditions. Means shall also be considered and provided so that water does not flow into the annular spaces/clearances/cavities between the rotor in open position and the valve body.

- iii) Specific provisions proposed and offered shall be clearly brought out in the offer with write-ups, drawings and sketches. Guaranteed minimum intervals between repairs, replacement and time taken for the same, both for the worn out working or service seals and maintenance seals shall be given separately.
- iv) A broad list of materials of construction and manufacturing method of the components is given in Table 2. The supplier shall also furnish a detailed list of actual materials of construction and abrasion resistant hard coating and facings on susceptible and vulnerable components before manufacturing starts.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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#### 1.6.3.2 Hard coating on working parts

The Supplier may propose to provide hard coatings /facings on the silt affected under water components for consideration of the purchaser if felt necessary.

HVOF Coating is not envisaged at present. However, based on the silt data, the requirement of HVOF or other coating maybe discussed during detail engineering.

#### 1.6.3.3 Maintenance and Replacement of Worn out Working Parts

- i) The valve design and construction shall be such that when worn out, the working seals shall be capable of being replaced without having to dismantle the main valves. The complete method and sequence of replacing the working seals shall be furnished by the supplier during design stage comprising explanatory write ups, sketches, drawings. It may be ensured that dewatering of the pressure shaft upstream of the maintenance seal shall not be essential for the replacement of the working seals.
- ii) Replacement of worn out maintenance seal on the upstream end of valve shall be possible without dismantling of the spherical valve, but after dewatering of the upstream pressure shaft.

### 1.6.4 Construction Details

#### 1.6.4.1 Valve Body

- i) The valve body shall be made of high strength steel plates equivalent. The valve body shall be suitably split for assembly and transport and shall have integral support feet. Bidder has the liberty to offer the MIV in a single piece, without vertical split joint, if transport limits allow the same.
- ii) Valve body shall have following provisions:
  - a) Piping connections for drainage at bottom.
  - b) Bearing bushes of bronze or Ni-Pb gun-metal, for rotor trunnions, grease lubricated type. Bidder has the liberty to offer MIV bearing bush of self-lubricating material with bronze backing and without grease lubrication.
  - c) Glands and packings for trunnions. It shall be possible to replace the packings under water pressure in the valve.

#### 1.6.4.2 Rotor, Trunnions & Bearing

- i) The valves rotor shall be made of high strength steel plates corresponding to ASTM-537 class-2 modified, or steel casting corresponding to A 148 Grade 80-50, or equivalent. Materials of different standards such as ASTM, DIN EN, EN, IS can be offered if they are better or at least equivalent in terms of chemical composition, properties etc. A side by side comparison of both the materials shall be carried out during detailed engineering. The 2 (two) trunnions of the rotor shall be integrally cast with the rotor, or made as forgings of carbon steel



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

machined all over and shall be fixed to the valve rotor either by welding or by fasteners.

- ii) The portions of the trunnions which rotate in the bearings shall be lined with stainless steel deposition and machined over.
- iii) The journal bearings shall be made of Bronze or better material. Every movement of the rotor body shall automatically inject new grease into the bearings and the used grease shall be forced out via ejection grooves/valves and collected. In case such a design is not possible then provision for admission of grease into the bearing shall be made complete with tubing valves, automatic valves etc. and grease will be arranged to be provided and supplied from the turbines grease supply systems.

Bidder has the liberty to offer MIV bearing bush of self-lubricating material with bronze backing and without grease lubrication. Comparative study of both options shall be carried out during detail engineering.

- iv) Cup sealing shall be provided to check water leakage into the bearings and grease from the bearings.

#### 1.6.4.3 Service and Maintenance Seals

- i) The sealing systems, one for normal service on downstream side of the MIV and the other on the upstream side for maintenance of the service seal shall be provided in the MIV.
- ii) The service seal system shall consist of the movable sealing ring of step-piston type design located in the valve body and the fixed seal ring fitted on to the valve rotor. The sealing rings shall be castings of 13-4 Cr-Ni stainless steel or better, of suitable grades and machined over. The maintenance sealing rings shall be identical to the service seal system as above.
- iii) When closed, the sealing systems shall provide a drip tight seal both on the downstream and upstream. The movable seals shall be pressed hydraulically against the fixed seals. Permissible leakage shall be guided by IS:7326 (Part-1).
- iv) The design of the movable sealing rings of the service and maintenance seal pairs shall be such as would remain tight against the fixed seal during closed conditions and shall not tend to flutter whatever be the hydraulic conditions in the penstock.

#### 1.6.4.4 Servomotors and Operating Gear

- i) Two hydraulic servomotors, one on each side of the valve shall be provided. Servomotor(s) shall be of cast steel or of fabricated design with steel piston and rods, upper and lower covers, cast iron-bronze piston rings, sealing glands, pipe connections, plugged holes for air and oil discharge from the cavities in the upper and lower servomotors.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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Any alternative material offered must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and material properties. However, the detailed comparison of Chemical composition and material properties must be submitted to the Purchaser for approval during detail engineering stage.

- ii) The servomotors shall have following provisions
  - a) A mechanical device manually operated to lock the valve both in open and closed position.
  - b) A suitable throttling device for adjusting the time of closing and opening.
  - c) Oil and water piping and valves complete with flanges, bolting material, gaskets, packings etc. required for interconnections between the various equipment. The piping and tubing shall be of steel suitable for maximum oil/water pressure and the various valves shall be of cast or forged steel with flanged ends.

#### 1.6.4.5 By-pass Valves and Air Valves

- i) Two hydraulically operated needle type by pass valve of suitable diameter not less than 250 mm by-pass valves for filling of the scroll casing etc. for balancing of pressure on two sides of the valves shall be provided. The valves shall be needle type, operated automatically by oil pressure from governor oil system to achieve equalization of pressure within reasonable time. A manually operated guard valve, sluice/gate or globe type, shall also be provided interposed between the Spherical valve and the by-pass valve. The by-pass valve connection shall have suitable dismantling joint.

Needle type by pass valves are preferred. However, other alternatives can be discussed during detail engineering.

- ii) The inlet and outlet connections to the bypass valves shall be respectively taken from the inlet pipe and outlet pipe of the Spherical valve. The needle and sealing rings shall be made of erosion and corrosion resistance stainless steel 13-4 Cr-Ni or better and shall provide leakage proof tight sealing when the by-pass valve is closed. Indication of the position of by-pass valve i.e. open and closed position shall be provided by limit switches.
- iii) For air venting of the spiral casing when being filled, suitable automatic air vent valve shall be provided and installed on the outlet pipe. Allowance for mal-operation/failure of this valve to operate shall be kept in view and suitable provisions made for rectifying the defect. The details of this valve with drawings, sketches and write-up giving operating pressure, vacuum etc. shall be furnished during design stage.

#### 1.6.4.6 Inlet Pipe

- i) The inlet pipe shall be fabricated high strength steel plates ASTM-537, class-2 modified steel. It shall have provision for bolted flanged and connection to the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

Spherical valve inlet and welding end for connection to the penstock of 2750 dia. The flare angle shall not exceed 7.50 and length of the inlet pipe provided shall be fixed accordingly with sufficient extra length as trim allowance for errors in installation. Welding of the inlet pipe to the penstock shall be the responsibility of the supplier.

- ii) The following connections shall be provided on the inlet pipe.
  - a) 2 (two) for the by-pass valves.
  - b) One for Spherical valve control.
  - c) One for emptying the penstock.

#### 1.6.4.7 Outlet Pipe with Compensator (Dismantling Pipe)

- i) Outlet pipe shall be of fabricated steel of high strength steel plates ASTM-537, class-2 modified. It shall comprise of pipes, compensating ring, packing and fasteners. One side shall be connected to the spherical valve and other end shall remain free over the scroll casing with packings for sealing.
- ii) It shall have ample rigidity to withstand the force resulting from the by-pass valve etc. The gap between outlet pipe and spiral casing which will give possibility of free movement of Spherical valve in axial direction shall be properly sealed with the help of compressor/dismantling pipe, packing rings and rubber cards.
- iii) Following flanged connection shall be provided on the pipe.
  - a) 1 (one) for air vent and breather valve connections.
  - b) 2 (two) for by-pass valve connections.
- iv) The size of the Spherical valve and compressor ring shall be same as that of scroll case inlet and the joint shall be coordinated with the turbine supplier. The approximate diameter of the scroll casing inlet works out to about 2750 mm.

Note- Any alternative material offered for Inlet Pipe and Outlet Pipe must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and properties. However, the detailed comparison of Chemical composition and material properties must be submitted to the Purchaser for approval during detail engineering stage.

#### 1.6.4.8 Control Gear

- i) The control gear of the Spherical valve and its bypass valves shall be suitable to provide for
  - a) Manual electrical operation from the local and remote panels.
  - b) Automatic control for opening and closing in sequence with the automatic start-stop operation of the generating unit.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- c) Emergency auto closure of the Spherical valve in case of turbine over-speed (failure of governor).
- d) For test and maintenance purpose, a control panel shall be provided and located close to the MIV. It shall be equipped with a local/remote selector switch, control switches and other elements required for operation of the valve.
- ii) All necessary limit switches, instruments, pressure gauges, level gauges, position indicators etc. shall be provided and mounted on the Spherical valves. These instruments shall conform to the international standards/codes.

#### 1.6.4.9 Safety Arrangements

- i) The Spherical valve will not open until the upstream and downstream pressures are balanced.
- ii) It will be possible to invert the opening and closing movement of the valve in any position by activating the corresponding control circuit.
- iii) It will not be possible to open the Spherical valve unless both the service seal and the maintenance seal are in open position.

#### 1.6.4.10 Piping, Valves and other Miscellaneous Items

- i) The Spherical valve shall be complete with all piping and valves which shall be of steel and cast/forged steel respectively and of adequate pressure class to suit maximum active coincident pressure. Drain valves with piping shall be provided at the lowest point of valve body.
- ii) All foundation bolts, sole plates, lifting brackets, pressure gauge, oil strainers/filters, jointing materials, springs shall be part of the supply. Foundation details for MIV and servomotors shall be furnished by the supplier.
- iii) Working, operating and inspection platform complete with supporting steel work, floor plates, grating, stairs etc. shall form part of supply of Spherical valves.
- iv) All tools, erection devices and special keys shall be included in the scope of supply.

#### 1.6.5 List of Mandatory Spares for MIV:

Sl.	Item	Unit	Quantity
1.	Main seal rings.	No.	1
2.	Servomotor piston rings.	Set	1
3.	Piston rings for hydraulic drive of by pass valve.	Set	1
4.	Pressure gauge of each type	No.	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications	
		Volume II Section-II	
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve	
5.	O-rings, cup sealings.	Set	1

## 1.7 Pressure Oil System for Governors and Turbine Inlet Valves

### 1.7.1 General

Each turbine shall be provided with a pressure oil system comprising of sump tank, the oil pumps and oil accumulator, all installed at the turbine floor for operation of turbine wicket gate servomotors through governors and separate pressure oil system for the opening of MIV and a leakage recovery tank (if required). All pipes, valves, fittings, instrumentation, switchgear and controls for manual and automatic operation of the system shall be included in the scope of supply.

#### (1) Design conditions

- A. Maximum oil pressure in the governing system will not exceed:
 

for oil/air accumulator	100 bar
for nitrogen filled bladder or piston accumulator	120 bar
- B. Oil velocity in pipes not to exceed 3 m/s at maximum oil flow
- C. Capacity of oil accumulator  
The system will be provided with an oil/air respectively oil/nitrogen type accumulator with a capacity to meet the following requirements:
  - a) The oil pumps are assumed to be disabled.
  - b) The oil in the accumulator tank has dropped to the level where the pumps should resume operation.
  - c) The amount of oil still available in the tank will be able to operate 3 full strokes (close-open-close) of the guide vane servomotor(s) and one opening stroke of MIV servomotors.

#### (2) Oil Accumulator

Replenishing air to the accumulator shall occur automatically in case of an air/oil accumulator.

In case of air/oil accumulator tank, the accumulator tank shall be fabricated from boiler plate quality steel. It shall include the following equipment:

- Inspection hole of adequate size.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- Drainage valve.
- Suitable flanges for connection with pressure system and compressed air system.
- Safety valve.
- Pressure switches.
- Pressure transducer for remote indication, 4-20 mA
- Level switches
- Pressure gauge
- Oil level indicator
- High pressure compressed air system for automatic control of pressure and oil volume under any operating conditions.

If the Contractor supplies an air/oil type accumulator, the following applies for the high pressure compressed air system.

One (1) complete compressed air stations shall be provided. The station shall include:

- Two air compressors (one in service and one in standby) with automatic and manual change over.
- One air pressure tank.
- The necessary piping, safety fittings and accessories such as safety valves, pressure gauges and control devices.

In case of nitrogen filled bladder type or piston type accumulator unitwise the following equipment shall be included:

- Drainage valve
- Suitable flanges for connection with pressure system
- Safety valve
- Pressure transducer for remote indication, 4-20 mA
- Pressure gauge
- Special equipment for control of nitrogen pressure and for filling

All electrical equipment shall be wired to a terminal box installed on the accumulator.

### (3) Oil Sump Tank

The oil sump tank shall be made of welded plates steel duly stiffened with steel sections. Its capacity shall be at least 10 % greater than the total oil quantity contained in the whole governor, guide vane servomotors and piping. All oil drainage, leakage and/or exhaust pipes, shall be conveyed to the oil sump tank.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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If water-cooling is required, the system shall be so designed that 45 degree oil temperature will not be exceeded under the operating conditions of one oil pump in operation for at least 15 minutes with no cooling water circulation and for five minutes no external oil circulation.

All necessary control devices and accessories shall be installed at the oil sump tank and be easily accessible for maintenance and setting.

The sump tank shall be equipped with an inspection hole of adequate size, visual level indicator, filtered air vent, connection for filling and draining and magnetic filters. Tapping points with check valve, shut-off valves and caps for temporary hose connections to the oil purification unit shall be provided.

The following instrumentation shall be included:

- Oil level switch for alarm purposes with "high", "low" and "too low" switch points.
- Temperature gauge.
- RTD for oil temperature

All electrical equipment shall be wired to a terminal box installed on the sump tank.

#### (4) Oil Pumps

For the pressure oil supply, two pumps (max. speed 1450/1500 rpm) shall be installed in the sump tank. The pumps shall be electric motor driven (One Pump of 415 V, 3 phase AC and another of 220 V DC).

Each pump shall be equipped with check valve, unloader valve, safety valve, pressure switch and all other accessories necessary for reliable operation.

The pumps shall operate intermittently to replenish the accumulator volume. The pumps control shall be provided for lead/lag control with manual switch-over and manual override. On receipt of a switch-on signal, the lead pump shall start. The standby pump shall start if the lead pump pressure does not rise or the lead pump fails.

Provisions shall be made to allow the complete disconnection of whichever pump from the system for maintenance without affecting the system operation.

#### (5) Filter and Cooler

As a general rule, a solution without cooler or with air/oil cooler is preferred.

If water cooling is required the oil-water heat exchanger shall be placed outside of the oil sump tank. The water circuit shall be combined with the cooling system for the bearings.

The heat-exchangers shall be designed to minimize sediment accumulation inside the tubes. The water cooling tubes, tube sheets and water boxes shall be made of corrosion resistant metal. Any kind of heat-exchanger shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 01 Turbine, Governors and Main Inlet Valve

dimensioned for a cooling capacity corresponding to 120 % of rated the cooling capacity.

Twin full-flow magnetic and mesh cartridge filters shall be provided and shall, by means of three-way valves, allow the cleaning or replacement of the mesh carriage from one filter side without interruption of the filtering procedure. A differential pressure indicator with alarm contacts shall be provided.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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#### 1.7.1.1 Individual Oil Pressure Unit for Governor & Main Inlet Valve

Tenderer shall offer a individual oil pressure unit to be used for the turbine governor and the MIV separately. Separate OPUs shall be provided for Turbine and MIV.

#### 1.7.1.2 Local Control Panel

A local control panel arranged (wall or floor mounted) in the vicinity of the turbine at elevation 1021.22 m shall allow basic operation of the turbine control system for maintenance purposes.

The control panel shall include at least the following components respectively it shall allow the following maintenance operations:

- One key operated selector switch, three positions, "Off", "Local-Maintenance" and "Remote", for the control system.
- Push buttons "On" and "Off" for starting and stopping of the oil pumps.
- Manual selector switch "No. 1" and "No. 2" for the oil pumps.
- Push buttons "Opening" and "Closing" of wicket gates.

#### 1.7.1.3 Leakage Oil Tank and Pump

An oil leakage tank, screw type pump and necessary piping and valves shall be provided and located at suitable location (valve floor el. 1014.62 m asl). The tank shall be provided with suitable gauge glass, level switches for automatic start/stop of the pumps. The pump motors shall be suitable for 415 V, 3 phase, 50 Hz AC supply. An alarm shall also be provided to indicate high oil level in the tank. A floor mounted panel incorporating all controls, etc. shall be provided.

### 1.8 Controls and Instrumentation for Turbines, Governors, Inlet Valves and Auxiliaries

Tenderers shall cover in their tenders all signalizers, sensors and instrumentations installed on the turbine, governor, inlet valve, or on turbine gauge panel. Provisions for suitable interface to SCADA shall be provided.

### 1.9 Hydraulic Quantities Measurement System

The system is intended to measure the following hydraulic parameters :

- Headrace and tail water levels.
- Net head on turbine.
- Turbine flow.

The above quantities shall be measured using the primary pneumo-hydraulic instruments (measurement of compressed air pressure in the pulse tube to be brought to the measuring section) or some other suitable devices. Reading of the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
---	--	--

primary instruments will be transmitted to the secondary instruments by means of 0-5 mA D.C. out put signal.

The headrace and tail water levels shall be measured by sensors to be installed in front of the water intake structure and behind the outlet portal of the tailrace channel. The data shall be displayed at the main control board.

Net head on each turbine shall be measured by means of a head differential measuring device. The output signal shall be displayed at the unit control board and be fed in to the speed governor which shall automatically set the distributor gate limit according to the available head.

#### **1.10 Devices and Instruments for Tests During Erection and Commissioning**

All devices and instruments required for testing of turbine components, sub-assemblies, governors, MIV, Spherical valves and auxiliary equipments during erection and commissioning shall be covered in the tender. This shall cover bulk head, test ring etc for pressure testing of scroll casing. A detailed list of items giving description, make, quantity shall be covered in the tender.

#### **1.11 Testing Devices and Instruments for Field Acceptance Test**

All instruments / devices for the set-up required for conducting field acceptance tests for demonstration of fulfilment of efficiency and output guarantees shall be listed in the offer and provided by the contractor.

#### **1.12 Manufacture, Inspection, Shop Assembly, Measurements and Testing**

##### **1.12.1 Material Tests**

The material tests include chemical analysis, mechanical tests and non-destructive tests shall be furnished.

##### **1.12.1.1 Chemical Analysis**

For all main components and components exposed to high stresses and / or conditions where the composition is of importance, chemical analysis of the material will be taken in accordance with normal practice to verify that the components conform to the required specifications.

##### **1.12.1.2 Mechanical Tests**

Mechanical tests shall be carried out on all main components according to normal practice and relevant standards to ascertain that material properties conform to the requirements and specifications. Such tests shall include the determination of the yield strength, ultimate strength, elongation / contraction and impact strength in aged / non-aged condition as required. Bend test of plates and sheets shall also be performed as required.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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#### 1.12.1.3 Non-Destructive Tests

Non-destructive tests include ultrasonic tests, X-ray tests, magnetic particle tests and dye-penetrant tests.

The section VIII of the ASME Boiler and Pressure Vessel Code will be applicable.

The test and visual examination shall be carried out on all principal castings and forgings which are subjected to, or affected by, high service stresses. Major defects, if any, shall be removed by suitable means and soundness of metal will be checked by means of magnetic particle or dye penetrant inspection.

Plates which are subjected to high service stress, impact, fatigue, or vibration stress, shall undergo visual inspection and ultrasonic testing prior to use for manufacture and welding.

Welds shall be 100% radiographically tested. Alternately, these shall be subjected to ultrasonic examination. Defects in welds disclosed by ultrasonic or radiographic testing or dye penetrant / magnetic particle testing will be completely removed by chiseling. After rewelding, the new weld shall be again subjected to the same examination.

#### 1.12.2 Pressure Tests

All parts subject to internal or external pressure or containing any liquid or gases temporarily or permanently during operation shall be tested prior to painting as per relevant standards. As far as possible these tests shall be done in the shop.

If any liquid, which may cause corrosion, is used for the test, all equipment and piping will be thoroughly cleaned immediately after the test.

Pipe systems will generally be pressure tested with water. Oil might be used when special precautions against damage are taken.

The test pressure will generally be 150% of the design pressure. The pipe systems will be cleaned thoroughly before tests.

Embedded systems shall be pressure tested before embedding.

#### 1.12.3 Testing of Parts Exposed to Gas Pressure

The parts subjected to gas pressure during operations, e.g. governor pressure tanks, pressure air tanks etc. will be inspected and tested according to the official regulations in respect of design, construction, fittings, etc. The pressure test is to be executed by applying the prescribed test pressure in accordance with the relevant standards.

#### 1.12.4 Testing of Parts Exposed to Liquid Without Over Pressure

The exposed parts subjected to small pressure, e.g. bearing housing, oil containers, etc. shall be tested for tightness with a suitable liquid of low viscosity.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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### 1.12.5 Tests on Steel Plates

Steel plates used for manufacturing shall be certified by the steel plate producer highlighting the following information.

- a) Charge No.
- b) Chemical analysis of melt
- c) Following tests along rolling direction
  - i) Yield strength, tensile strength & elongation at rupture.
  - ii) Three ISO, V-notch toughness tests at 0 deg.C. in the “thickness direction”.

The findings will conform to minimum requirements of the specifications for the material approved for the relevant structure.

Ultrasonic test will be made on all plates subject to lateral stresses.

Each plate will be stamped in the mill, showing

- a) Charge no.
- b) Plate number
- c) Quality designation

Sound quality control and inspection procedures shall be adopted during the shop manufacture and fabrication. All bought out items shall be of reputed manufacturer and conforming to standards and engineering practice. Employer’s and consultant’s representatives/ engineers will regularly and periodically verify that the manufacture is being carried out according to the laid out procedures and norms. The contractor shall provide free access and facilities for such inspections.

The turbine components /sub-assemblies shall be match-marked and dowelled to ensure correct assembly and alignment in the field. For other sub-assemblies suitable dowels shall be furnished for insertion after field assembly and drilling.

The components which operate under pressure of water, air, oil etc. (excepting those which cannot be pressure tested in shop) shall be subjected to hydrostatic pressure tests in shop using a tests pressure of 150% (one hundred and fifty percent) of the working pressure for a duration of 120 minutes.

All turbine components shall be given dimensional, functional and other checks applicable, in respect of the following :

- |                                      |  |
|--------------------------------------|--|
| a) Runner and shaft                  | Dimensional check, static balancing, homology of runner interchangeability |
| b) Guide vanes, regulating mechanism | Clearance, synchronous and free movement, geometry, openings etc.          |
| c) Servomotor                        | Stroke, free movement, pressure tests                                      |

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- |                               |   |
|-------------------------------|---|
| d) Guide bearing coolers      | Hydraulic pressure test                 |
| e) Governor oil pressure unit | Hydraulic pressure test, operation test |
| f) Electro-magnet valves      | Working operation test                  |

- |  |   |
|--|---|
| g) Important castings, forgings, plate steel fabricated structures | Material tests (mechanical and chemicals) composition |
| h) Draft tube assembly (homology) with model                       | Geometrical similarity                                |

All motors, accessories and auxiliary equipment forming part of turbine shall be tested in accordance with the requirement of the latest relevant standards. Each mechanical and electrical sub-assembly shall be tested for proper functioning and continuity of the electrical circuit.

The first governor shall be assembled in the shop and tested as per the IEC 60308 or other applicable code in the presence of Corporation or his authorised representatives. The tenderers shall furnish a list of shop tests and inspection items on governors in their bids, tests and checks to be carried out at site shall also be furnished in the bids.

The inlet valves shall be completely assembled and pressure tested in the shop a pressure equal to 150% of design pressure for 120 minutes to check the valves bodies strength. Leakage tightness of the repair seals shall be carried out at design pressure for 30 minutes. Servomotors and oil piping shall also be pressure tested at 1.5 times working oil pressure. Spherical valves shall be thoroughly inspected, assembled and dimensionally checked. Their operation shall be demonstrated comprehensively covering all main working parts, accessories, attachments.

A list of all items for inspection and testing, shall be furnished by the Contractors in the bid.

On auxiliary equipments viz. pumps, compressors etc., routine and type tests shall be carried out in the shop as per standards and test certificates shall be submitted to the Corporation for approval before despatch.

### 1.13 Inspection and Testing at Site

All welding on pressure carrying parts, such as scroll case, MIV inlet and outlet pipe etc., done at site shall be subjected to 100% radiographic examination. 100% Ultrasonic testing of weld joints of Spiral Case and Stay Ring shall also be accepted.

All essential tests at site shall be performed on the turbines, Governors, MIV's during the course of assembly, erection, precommissioning and commissioning. The contractor shall furnish a comprehensive and exhaustive list of all such tests for approval, which shall cover but not limited to the following:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- |   |   |
|---|---|
| a) Scroll case  | Hydraulic pressure test at 150 % of the maximum dynamic head including water hammer |
| b) Turbine components like pressure tanks, governor oil sump tanks, valves, piping system | Hydraulic pressure tests, leakage tests, operational tests etc.                     |
| c) Governors and auxiliaries  | Pressure and other relevant tests.  |

Precommissioning checks/inspection measurement as below shall be performed.

- |                                 |   |
|---------------------------------|---|
| a) Draft tube                   | Welding inspection                          |
| b) Scroll case                  | Welding inspection, hydraulic pressure test |
| c) Guiding bearing              | Clearances, operation, running              |
| d) Runner and turbine top cover | Clearances                                  |
| e) Guide vanes                  | Clearances, clear openings                  |
| f) Governor oil pumping system  | Performance test                            |
| g) Shaft                        | Alignment check and runout check            |

The contractor shall furnish a detailed procedure for commissioning of the turbines governors. MIVs, other associated equipment and shall submit the same to the Corporation not later than 12 (twelve) months prior to the scheduled date of the commissioning of the first unit. The contractor shall calibrate all instrument and equipment prior to commissioning. Commissioning tests shall be carried out by the contractor, as per IEC commissioning guide. The Contractor shall take full responsibility for operation and safety of the equipment during site testing and commissioning. All applicable commissioning tests listed in IEC commissioning guide (IEC publication no. 60545) shall be carried out according to the test procedures specified therein.

The pre-commissioning tests and checks shall cover but not be limited to the following.

Transient pressure rise and speed rise for various load throw offs (overload, 100, 80, 60 and 40 percent of the rated load), at various heads in the head range.

- a) Servomotor in operation.
- b) Bearing heat run test.
- c) Setting of main inlet valve opening and closing time.
- d) Setting of governor closing & opening times.
- e) Time-rpm deceleration curve, without excitation on the generator from rated speed to stand still.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 01 Turbine, Governors and Main Inlet Valve
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- f) Operation of by-pass valve, air vent and anti-vacuum valve on MIV.
- g) The machine shall be designed to withstand the runaway speed test for 15 minutes. Runway speed test is envisaged to be carried out on completely assembled turbine generators at site by the Contractor, at the discretion of the Employer. In case of failure, the Contractor shall rectify the damage and inherent defects and make such modifications as well make the turbines capable of withstanding the designed "Runway Speed". The Contractor shall demonstrate the same by conducting this test again.

#### **1.14 Index and Field Acceptance (Efficiency) Tests**

The index tests shall be conducted on one unit (unit on which test is to be conducted shall be decided later during detailed engineering) in order to verify and confirm that the shape of efficiency curve is in order and the guaranteed power output is achieved. The values from the efficiency tests shall be used to calibrate the turbine flow meter. The index tests shall be performed in accordance with the latest IEC code for field testing.

The Contractor shall carry out capacity and efficiency tests on the prototype turbine within the period stipulated in the contractual conditions.

The turbine efficiency and capacity tests shall be conducted in accordance with the provisions of IEC Publication 60041, International Code for Field Acceptance Tests of Hydraulic Turbines.

The Contractor shall make any subsequent adjustments in the turbine working parts as may prove necessary to secure optimum turbine performance.

The method of discharge measurement shall be proposed by the turbine tenderer in their tender in order of suitability, application and accuracy, in consonant with the water conductor system of the project.

Complete details of the test, required duration, list of equipment, etc. shall be furnished before conducting the test. In case the tests are to be got conducted by other agencies, the tenderer shall depute his supervisors for observation & witness of tests and for acceptance of the test results and liabilities.



Anyway, the works foreseen to be executed imply a limited risk both for the construction achievement and local population. Therefore, there are limited damages in case of occurrence of higher flood than the TR 25.

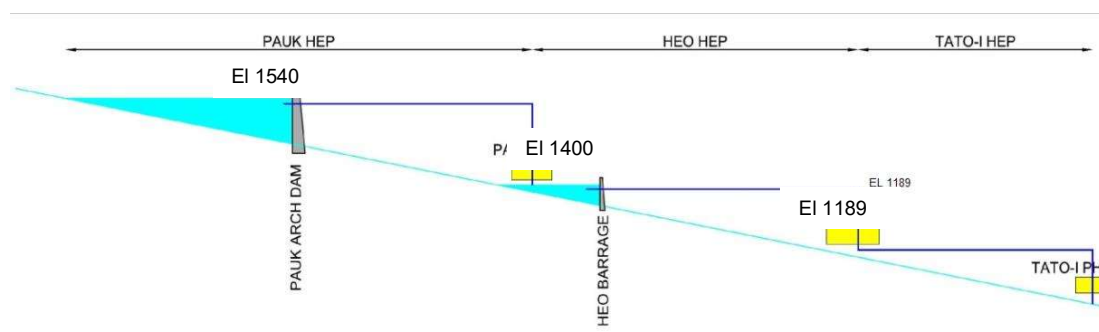
## Conclusion

The construction program has been designed so that the works at intake only occur during lean season, from November to March. The diversion flood of 1219 cumec for intake construction has hence been adopted as per CWC approval communicated in letter No.2/ARP/22/CEA/10-PAC/3743-45 dated 3<sup>rd</sup> September 2010.

## 8.8 SEDIMENTATION STUDY

### General

VELCAN Energy is developing Pauk (145 MW), Heo (240 MW) and Tato I (186 MW) Hydro Power Projects on Yarjep River, a tributary of Siyom River and Siang River in Arunachal Pradesh. The three projects are designed as a cascade type development with reservoir and tail water elevations as shown below.



DETAILS OF PAUK, HEO AND TATO-I HEPS				
Sr. No.	Description	PAUK HEP	HEO HEP	TATO-I HEP
1	Catchment Area	982 sq.km	1065 sq.km	1154 sq.km
2	FRL	1540 m	1400 m	1189 m
3	River level at Diversion	1445 m	1386 m	1188 m
4	Dam height	105m	16 m	From Heo tailrace
5	Gross capacity	11.5 Mcum	0.39 Mcum	nil
6	Live capacity	1.67 Mcum	0.15 Mcum	nil
7	T.W.L.	1401m	1189m	1025 m
8	Distance from origin of river	60.30 KM	63.60 KM	68.60 KM

Pauk HEP (145 MW) proposes to utilize available head between EI 1540 m and EI 1401 m and its headwork comprises of a 105m high arch dam (above foundation level) to provide a gross storage capacity of 11.5 mm<sup>3</sup> with live storage capacity of 1.67 mm<sup>3</sup>. The reservoir spreads over an area of about 34.1 Ha and occupies 2.37km length in Yarjep River and encroaches about

0.8km length in to Sae Chu nallah, a right bank tributary of Yarjep River with its confluence about 1.2 km upstream of dam location.

Heo HEP (240 MW) proposes to utilize available head between El 1400 m and El 1189 m and its headwork comprises of a 16 m high gated barrage having a gross storage capacity of 0.39mm<sup>3</sup> and live storage capacity of 0.15 mm<sup>3</sup>. The pondage area spreads over about 8.4 Ha and occupies about 1km length in Yarjep River.

Tato-1 HEP 186 MW proposes to utilize available head between El 1189 m and El 1025 m. The tailbasin of Heo HEP directly coupled with head race channel of Tato-1 HEP. In addition, a weir is proposed across Yarjep River to divert 2.63 m<sup>3</sup>/s of flow from intermediate catchment downstream of Heo Barrage for power generation at Tato-1 HEP.

Pauk, Heo and Tato-1 hydro power projects are designed as peaking run of the river type development with live storage of 1.67 Million m<sup>3</sup> being provided only at Pauk dam and a small balancing reservoir with live storage of 0.15 mm<sup>3</sup> at Heo barrage.

Yarjep River is a tributary of Siyom and Siyom in turn is a major tributary in Indian territory of Siang River and forms a part of the Brahmaputra basin. Yarjep River originates from mountainous ranges along Indo Tibet border at El ±4660 m and travels a length of about 80 km up to its confluence with Siyom River near Tato village.

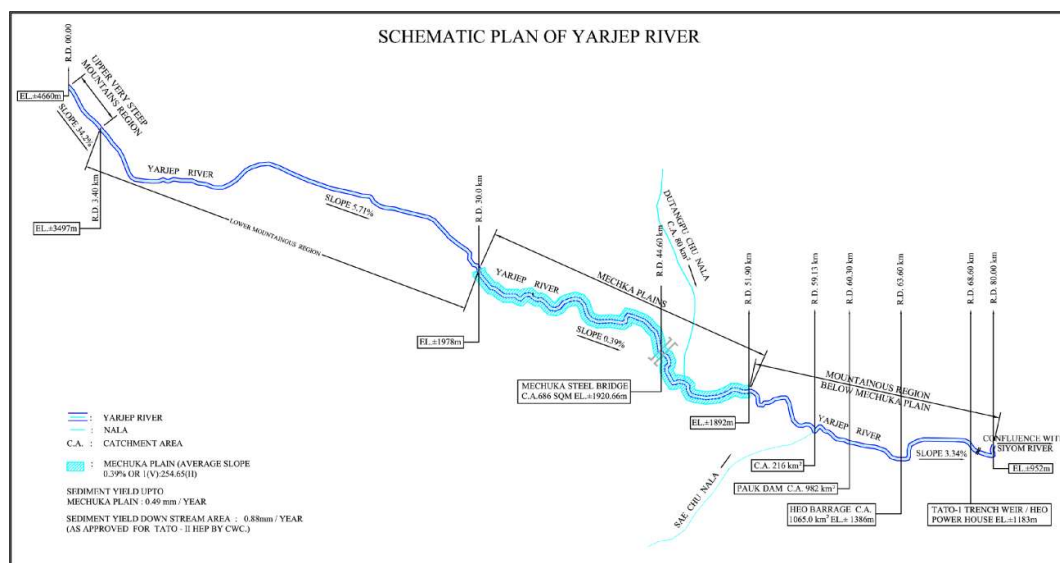
A schematic diagram showing plan of Yarjep River from its origin (El ± 4660 m), location of Pauk Dam site (El 1455 m), Heo barrage site (El 1386 m) and weir of Tato-1 HEP (El 1188 m), is presented in figure 8.25. The catchment area of Yarjep River at Pauk dam site is 982 km<sup>2</sup>, at Heo barrage site is 1065 km<sup>2</sup> and at weir site for Tato-1 HEP is 1154 km<sup>2</sup>. The total drainage area of Yarjep River up to its confluence with Siyom River is 1222 km<sup>2</sup>. The longitudinal section of Yarjep River from its origin to its confluence with Siyom River is illustrated in figure 8.26.

The Yarjep River from its origin to its confluence with Siyom River has been classified into four reaches based on river bed slope for the purpose of this sedimentation study. Details are indicated in table 8.35 below.

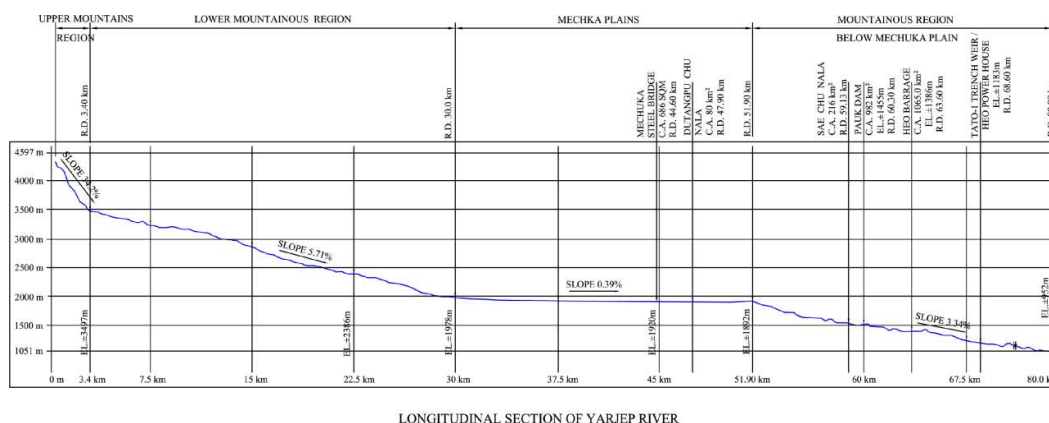
**Table 8.35: Classification of Yarjep River based on river slope**

S No	Description	Distance from origin	Elevation	River Bed Slope
1	Upper mountainous reach	0.00 km to 3.4 km	4660m to 3497m	34.2%
2	Lower mountainous reach	3.4 km to 30 km	3497m to 1978m	5.71%
3	Mechuka plains	30km to 51.9 km	1978m to 1892m	0.39%
4	Mountainous reach below Mechuka plain	51.9km to 80km	1892m to 952	3.34%

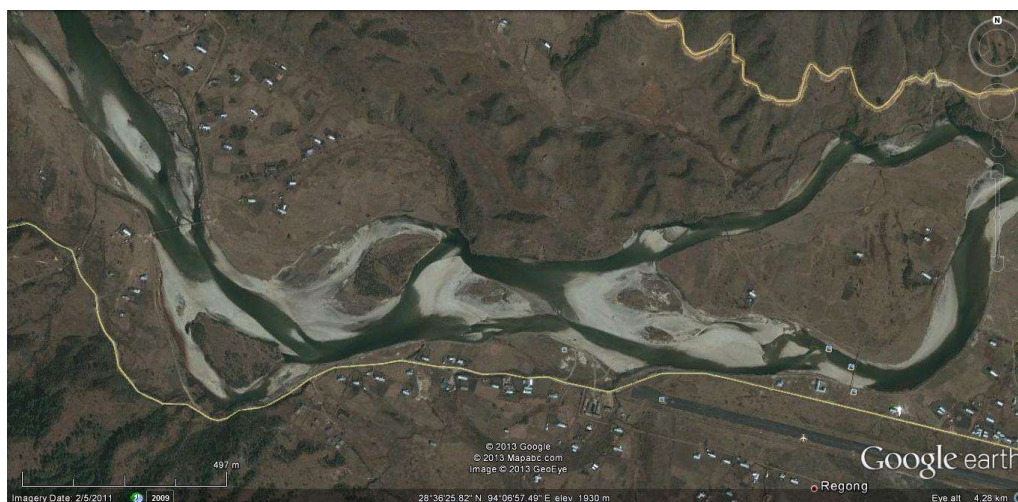
**Fig. 8.25 Schematic Plan of Yarjep River**



**Fig. 8.26 Yarjep River Longitudinal section**



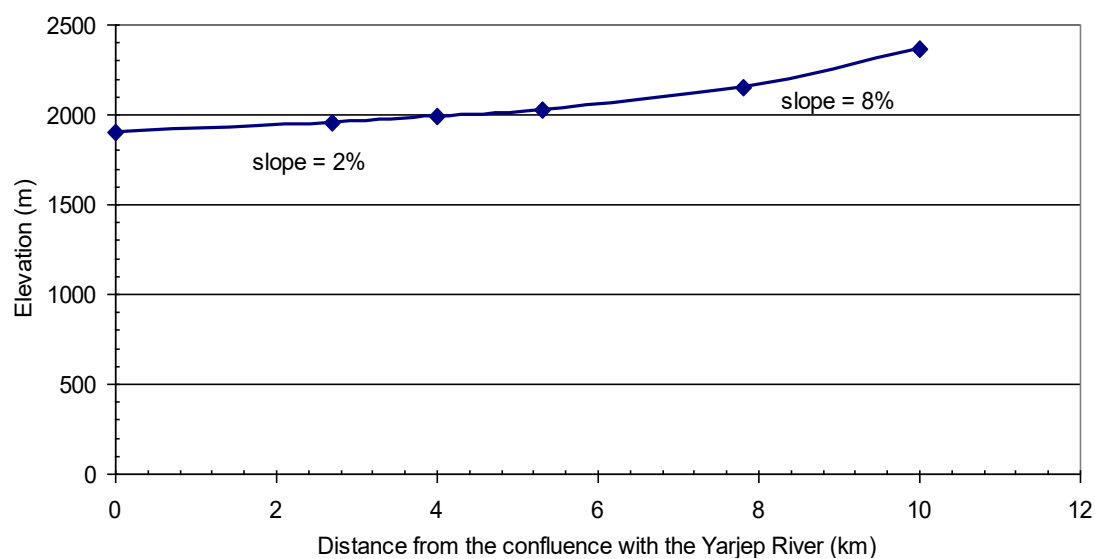
In its upper mountainous reach spread over a length of about 3.4 km, Yarjep River has a very steep average bed slope of 34.2%. Thereafter, the river follows a moderate bed slope of 5.7% for a length of 26.6 km up to RD 30 km. Yarjep River then flows in Mechuka plains for a distance of about 22 km (from RD 30km to RD 51.9km) with river slope of 0.39%. This reach is characterised by wide river section and shallow water depth thus giving the appearance of a large lake. The lower velocity of flowing water through Mechuka plains leads to settlement of sediments carried from upper mountainous river reach. A satellite image of meandering river course through Mechuka plains with sediment deposits is shown in figure 8.27. Within the Mechuka plain, Dutangphu Chu joins Yarjep River from the left bank at RD 47.9 km. The characteristics of this tributary are identical to those of Yarjep River within Mechuka plain reach. The catchment area of Yarjep River at the downstream end of Mechuka plain at RD 51.9 km including catchment area of Dutangphu Chhu is 766km<sup>2</sup>. Satellite image of Mechuka plain is shown in figure 8.27 along with photographs of Dutangphu Chu valley. Longitudinal section of Dutangphu Chu is also presented in figure 8.27a.



**Fig. 8.27 Yarjep River passing through Mechuka plains (above) and Dutangphu Chu upstream of confluence with Yarjep River (below).**



**Fig 8.27a: Longitudinal profile of Dutangphu Chu**



Downstream of Mechuka plain, Yarjep River flows with an average river bed slope of 3.34% for a length of 28.1 km up to its confluence with Siyom River. This reach of Yarjep River is also classified as mountainous reach for the purpose of this sedimentation study. All three projects being developed by Valcan Energy laying in this reach.

Pauk dam is located at RD 60.30 km, Heo barrage at RD 63.60 km and Tato-1 weir at RD 68.60 km along Yarjep River.

Daily discharge measurement and sedimentation data collection for design of above three projects is being done since 2009 at Mechuka steel bridge located at RD 44.6km within Mechuka plain. The catchment area of Yarjep River at Mechuka steel bridge location is about 686 km<sup>2</sup>. Rain gauges are installed at four locations within the catchment area of Yarjep River at Mechuka, Segong located about 9 km upstream of Mechuka bridge, Hanuman camp located about 20 km upstream of Mechuka Bridge and at Gapo located downstream of Mechuka. Daily rainfall data is available since 2008 at Gapo and Mechuka and since 2010 at Segong and Hanuman camp.

Pauk HEP propose construction of a 95m high arch dam at RD 60.3km and utilises flow from a catchment area of 982km<sup>2</sup>. Storage reservoir at Pauk dam has a gross capacity of 11.5 mm<sup>3</sup> and live capacity of 1.67 mm<sup>3</sup>. Sedimentation study at Pauk dam is carried out considering catchment area of 766 km<sup>2</sup> up to RD 51.90 km including Mechuka as plain area and the remaining catchment area of 216km<sup>2</sup> up to Pauk dam (between RD 51.9km to RD 60.3km) as mountainous region. The sedimentation studies have been carried out duly taking into consideration sediment in transportation and deposition behaviour.

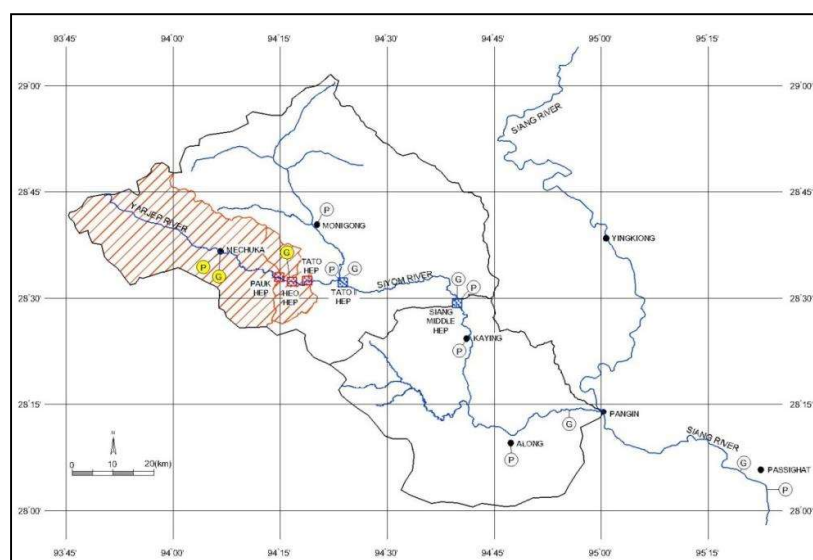
Heo barrage is proposed at RD 63.6km about 3.3 km downstream of Pauk dam and utilises flow from a total catchment area of 1065km<sup>2</sup>. Heo barrage receives flows from Pauk power house, surplus flows of Pauk dam and flow from intermediate catchment area of 83 km<sup>2</sup> downstream of Pauk dam up to Heo barrage. The gross storage at barrage is 0.39 mm<sup>3</sup> and live storage is 0.15 mm<sup>3</sup> providing benefit of a balancing reservoir for Heo HEP. Heo Hydro Electric Project does not have any storage over a month/year. Therefore as per IS:12182-1987 "Guidelines for determination of effects of sedimentation in planning and performance of reservoirs" as well as CBIP TR No.-19, Life of Reservoirs – 1980, design for this project does not require detail sediment study. However the impact of sediment from Pauk dam and 83km<sup>2</sup> intermediate catchment area is also studied and discussed in the following sections. Sedimentation study takes into consideration, periodic flushing of sediment from diversion barrage during monsoon period to avoid permanent deposition of sediments in pondage area of Heo barrage.

Tato-I receives 98% of flows directly from tailrace of Heo power house and additional 2% flow (2.7 cumec) is diverted from Yarjep River through weir constructed at RD 68.6km. The total catchment area of Yarjep River at weir site is 1154km<sup>2</sup> and the intermediate catchment downstream of Heo barrage is 89 km<sup>2</sup>. As 98% of flow from Heo power house will be used for power generation at Tato-1 HEP and only 2% additional flow is added from Yarjep River, the sedimentation study for Heo HEP is valid for Tato-1 HEP. Accordingly, no separate site specific sedimentation study is carried out for Tato-1 HEP.

Sedimentation study has been carried out based on the discharge and sediment data collected since 2009 to estimate the impact of sediment problems for the entire cascade (Pauk HEP, Heo HEP, Tato-I HEP). Sedimentation study is carried out in three steps – in first step, sediment load is estimated at downstream end of Mechuka plain, in second step at Pauk dam location taking in to consideration the impact of Pauk reservoir and in the last step at Heo barrage location.

### Sediment Data

No sediment flow data on Yarjep River is available prior to allotment of projects to Velcan Energy. However sediment data on Siyom / Siang River collected by Brahmaputra Board and NHPC, downstream of its confluence with Yarjep River is available at Raying site ( $CA = 3285 \text{ km}^2$ ) for the period 2000 to 2005 and at Pangin site ( $CA = 5110 \text{ Km}^2$ ) from 1978 to 2003. The location of above sites with reference to project location of Tato-I HEP is illustrated in Figure 8.28.



**Fig. 8.28 Location of sediment measurement site on Siyom / Siang River**

Sediment data collection has been started by Velcan Energy at Mechuka bridge site since 2009 and at Heo HEP barrage site in 2012. Presently about 4 years sediment data at Mechuka site is available. At Heo HEP barrage location (at Puring), water samples for estimation of suspended sediments have been collected during 2012. Sediment concentration, grain size analysis and petrography analysis on sediments has been carried out on the water samples collected at Mechuka and Puring and the results are discussed in subsequent sections. In addition, 7 samples from river bed-at Mechuka steel bridge (3 no), Pauk dam site, confluence of Sae Chhu and Yarjep and at Heo barrage (2 no) have been collected and analysed for grain size distribution.

The above sediment data has been analyzed to assess the quantity of sediment load expected at Pauk dam site as well as at Heo barrage site.

### Sediment data at Pangin and Raying Sites

Sediment concentration measurements carried out in Yarjep / Siyom River by Brahmaputra Board and NHPC are available for Pangin and Raying sites on Siyom River. The location of these two sites is illustrated in figure 8.28. Brief details of suspended sediment data are given below;

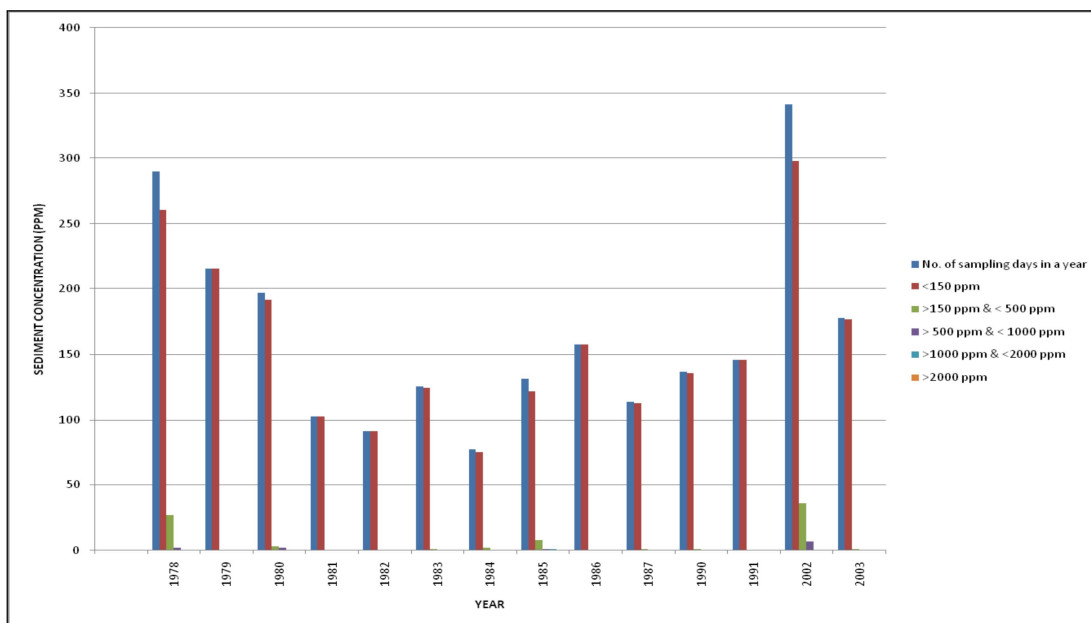
**Table: 8.36 Detail of sediment concentration at Pangin site (CA = 5110 km<sup>2</sup>)**

Year	No. of sampling days in a year	No. of days having sediment concentration				
		<150 ppm	>150 ppm & < 500 ppm	> 500 ppm & < 1000 ppm	>1000 ppm & <2000 ppm	>2000 ppm
1978	290	261	27	2	0	0
1979	216	216	0	0	0	0
1980	197	192	3	2	0	0
1981	103	103	0	0	0	0
1982	92	92	0	0	0	0
1983	126	125	1	0	0	0
1984	78	76	2	0	0	0
1985	132	122	8	1	1	0
1986	158	158	0	0	0	0
1987	114	113	1	0	0	0
1990	137	136	1	0	0	0
1991	146	146	0	0	0	0
2002	341	298	36	7	0	0
2003	178	177	1	0	0	0
Total	2308	2215	80	12	1	0
Percent (%)		96	3.5	0.46	0.04	0

**Table: 8.37 Sediment concentration at Raying site (CA = 3285 km<sup>2</sup>)**

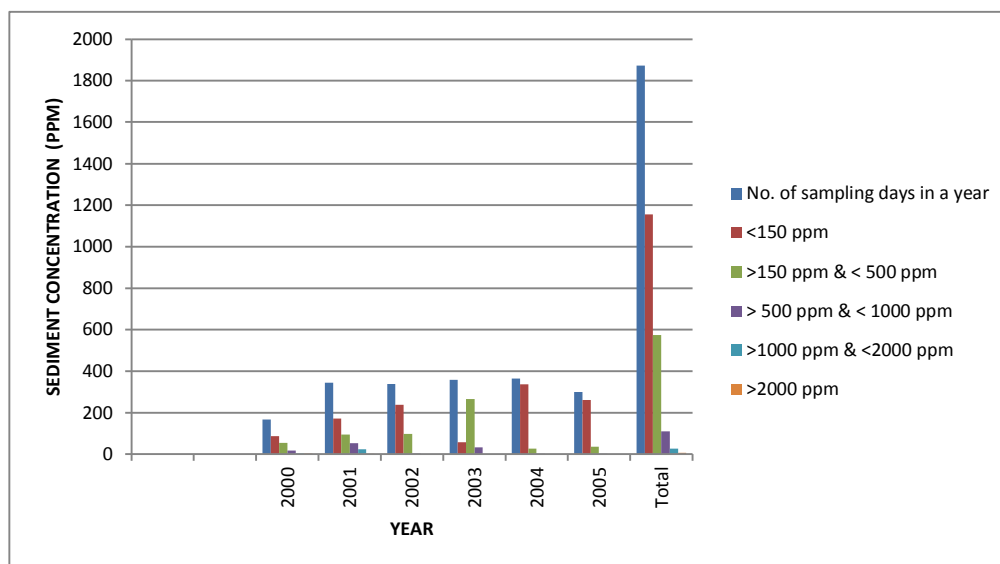
Year	No. of sampling days in a year	No. of days having sediment load				
		<150 ppm	>150 ppm & <500 ppm	>500 ppm & <1000 ppm	>1000 ppm & <2000 ppm	>2000 ppm
2000	167	87	54	18	4	4
2001	344	173	94	52	23	2
2002	339	238	97	4	0	0
2003	359	59	267	33	0	0
2004	365	338	26	1	0	0
2005	299	261	36	2	0	0
Total	1873	1156	574	110	27	6
Percent (%)		61.7	30.7	5.9	1.4	0.3





**Fig.8.29 Sediment concentration at Pangin site (CA : 5110 km<sup>2</sup>)**

Sediment measurement studies carried out by the Brahmaputra Board and NHPC on Siyom / Siang River for Pangion and Raying water samples indicates that event of sediment concentration more than 500 ppm is very rare.



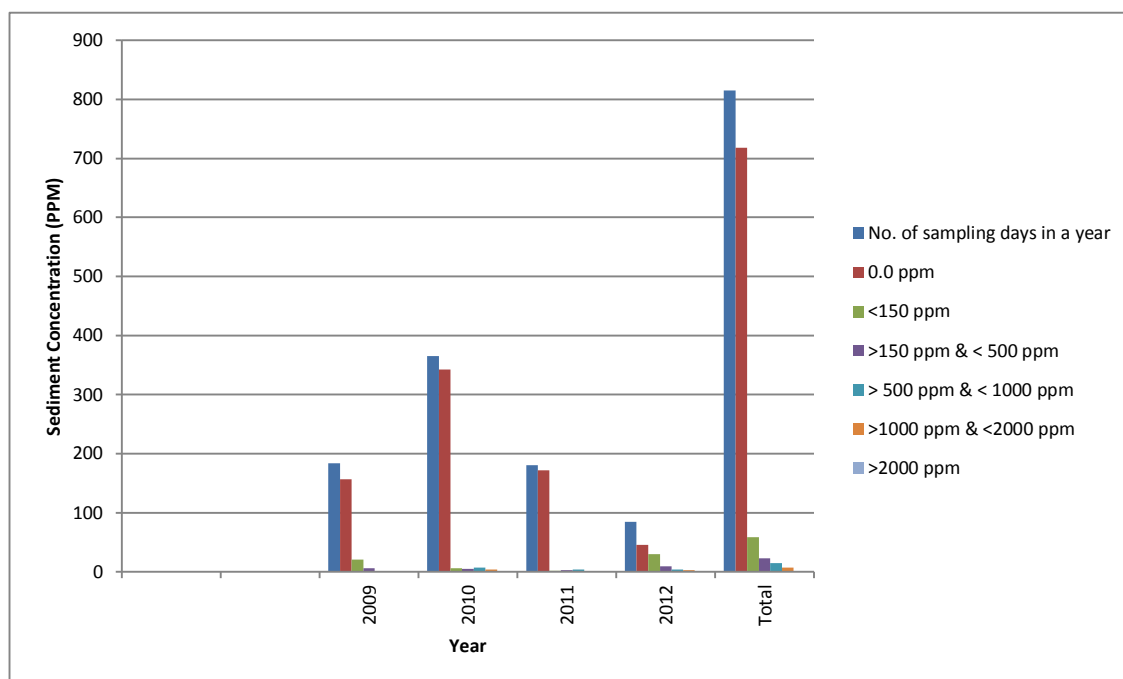
**Fig: 8.30 Sediment concentration at Raying site (CA = 3285 km<sup>2</sup>)**

#### Sediment data in Yarjep River at Mechuka Bridge

Daily sediment observations on the Yarjep River at Mechuka Steel Bridge (catchment area 686 km<sup>2</sup>) have been carried out during 2009 to 2012. The details of sediment concentration for this data are presented below in Table 8.38 and figure 8.31.

**Table: 8.38 Sediment Concentration in Yarjep River at Mechuka Bridge**

Year	No. of sampling days in a year	No. of days having sediment load					
		0.0 ppm	> 0.0 to 150 ppm	>150 ppm & < 500ppm	> 500 ppm & < 1000 ppm	> 1000ppm & < 2000ppm	>2000 ppm
2009	184	157	21	6	0	0	0
2010	365	343	6	5	7	4	0
2011	181	172	2	3	4	0	0
2012	180	134	30	8	5	3	0
Total	910	806	59	22	16	7	0
Percent (%)		88.5	6.5	2.4	1.8	0.8	0



**Fig: 8.31 Details of Sediment Concentration at Mechuka bridge (CA: 686 km<sup>2</sup>)**

#### 8.8.4.1 Grain size distribution for Suspended sediments at Mechuka Bridge

Grain size distribution has been performed on sediments obtained from water samples at Mechuka Bridge gauging site. This testing is carried out for 10 no water samples collected during 2010 and appended in **Appendix -E**. Details of grain size distribution on sample collected during year 2010 are tabulated below.

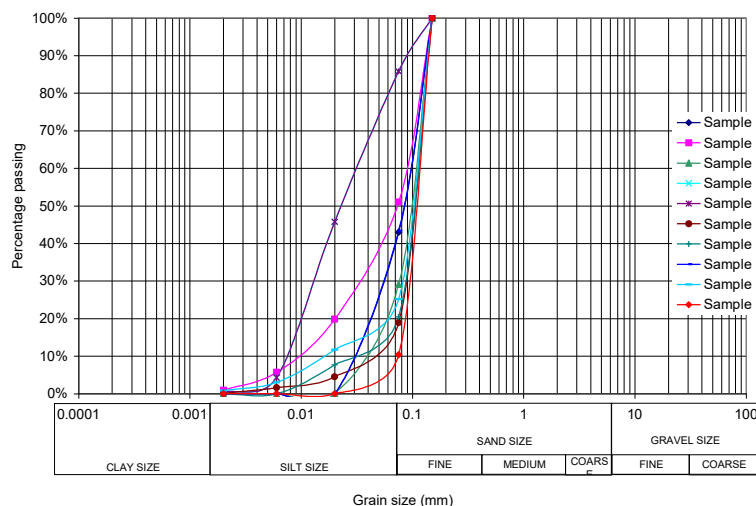
The result of grain size distribution on 10 samples for 2010 indicates that maximum size of suspended sediment at Mechuka Bridge is less than 0.15 mm or 150 microns. Grain size distribution for suspended sediments for samples collected during year 2010 is presented below in table 8.39 and figure 8.32.

About 46 number of samples containing suspended sediments were collected during 2012 and sediment concentration was obtained for each of these samples and results appended in **Appendix -E**. The sediments obtained from these 46 samples were mixed and grain size distribution was performed on this mixed sample. Details of grain size distribution on samples collected in 2012 are presented in table 8.40 and figure 8.33.

**Table 8.41: Sediment Concentration and Grain size distribution of Suspended sediments in water samples for year 2010**

Sample no	53	54	56	57	58	59	61	62	63	64
Date of Sample Collection	23/06/2010	24/06/2010	26/07/2010	30/07/2010	10/08/2010	11/08/2010	21/08/2010	22/08/2010	23/08/2010	24/08/2010
Sediment Concentration (ppm)	467	617	764	600	917	1600	659	433	1065	1957
GRAIN SIZE DISTRIBUTION										
IS Sieve (mm)	% of Sediments Passing (by weight)									
0.15	100	100	100	100	100	100	100	100	100	100
0.075	43	51	29.1	85.8	85.8	18.9	20.5	43.4	25.2	10.4
0.02		19.8		45.8	45.8	4.5	7.7		11.7	
0.006		5.67		4.34	4.34	1.61			3.0	
0.002		0.94		0.39	0.39	0.15			0.9	

**Fig. 8.32 - Grain size distribution of suspended sediments at Mechuka Bridge for year 2010**



Grain size distribution for suspended sediment observed at Mechuka steel bridge during year 2010 indicates that all suspended particles are smaller than 0.15 mm in size.

Petrographic analysis of suspended particles for the samples collected during year 2012 has been conducted by AIMIL and the results are enclosed in **Appendix E**.

Table: 8.40 Sediment Concentration and grain size distribution of Suspended sediments in water samples at Mechuka for year 2012

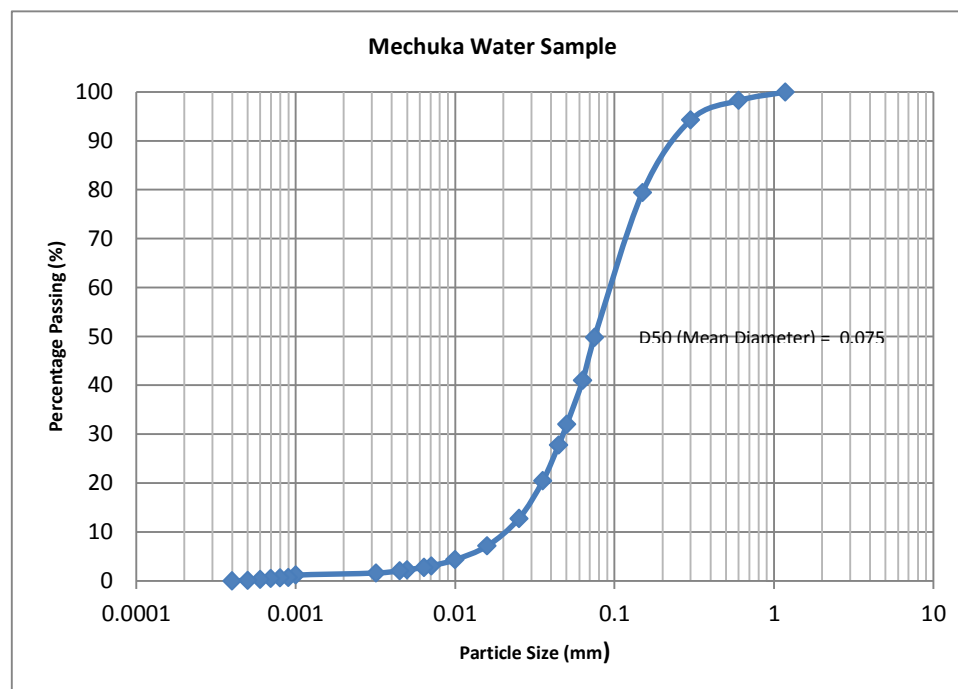
Sample no	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Date of Sample Collection	24-Jul-12	25-Jul-12	26-Jul-12	27-Jul-12	28-Jul-12	29-Jul-12	30-Jul-12	31-Jul-12	7-Aug-12	8-Aug-12	9-Aug-12	10-Aug-12	11-Aug-12	12-Aug-12	13-Aug-12	14-Aug-12	15-Aug-12	16-Aug-12	22-Aug-12	23-Aug-12	24-Aug-12	25-Aug-12	29-Aug-12
Sediment Concentration (ppm)	12	656	8	8	4	10	7	2	2	669	8	29	1269	407	9	9	1	3	167	1	131	1023	1
	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Date of Sample Collection	31-Aug-12	16-Sep-12	17-Sep-12	18-Sep-12	19-Sep-12	21-Sep-12	22-Sep-12	23-Sep-12	24-Sep-12	25-Sep-12	26-Sep-12	30-Sep-12	1-Oct-12	2-Oct-12	3-Oct-12	4-Oct-12	5-Oct-12	6-Oct-12	10-Oct-12	11-Oct-12	12-Oct-12	13-Oct-12	16-Oct-12
Sediment Concentration (ppm)	1449	217	863	228	154	310	104	18	550	171	16	8	16	10	12	12	62	8	16	470	756	15	20

GRAIN SIZE DISTRIBUTION

IS Sieve (mm)	% of Sediments Passing (by weight)
1.180	100
0.600	98.25
0.300	94.26
0.150	79.44
0.075	49.83
0.050	32.012
0.025	12.730
0.001	4.320
0.0004	0.000

Grain size distribution of 46 samples for 2012 indicates that maximum size of suspended sediment at Mechuka Bridge is less than 1.18 mm and 80% of sediments are smaller than 0.15 mm. Graphical representation of grain size distribution for suspended sediments for year 2012 is presented below. From this graph, it is interpreted that 88% of suspended sediments are finer than 0.2 mm.

**Figure 8.33 Grain size distribution of suspended sediments at Mechuka Bridge for year 2012**



#### Sediment data in Yarjep River at Heo Barrage Site

Daily water samples have been collected at Puring Bridge near Heo Barrage during year 2012. Details of test results are presented below.

**Table 8.41: Sediment Concentration at Puring near Heo Barrage (CA: 1065 km<sup>2</sup>)**

Year	No. of sampling days in a year	No. of days having sediment load					
		0.0 ppm	> 0.0 to 150ppm	>150 ppm & < 500 ppm	> 500 ppm & < 1000 ppm	>1000ppm & <2000ppm	>2000 ppm
2012	180	129	31	0	4	15	1
Percent (%)		71.6	17.2	0	2.2	8.4	0.6

About 51 no. water samples containing suspended sediments were collected from Heo Barrage location during 2012 and sediment concentration was obtained for each of these samples. The sediments obtained from these 51 samples were mixed and grain size distribution was performed on this mixed sample. Details of grain size distribution on samples collected in 2012 are tabulated below in table 8.42.

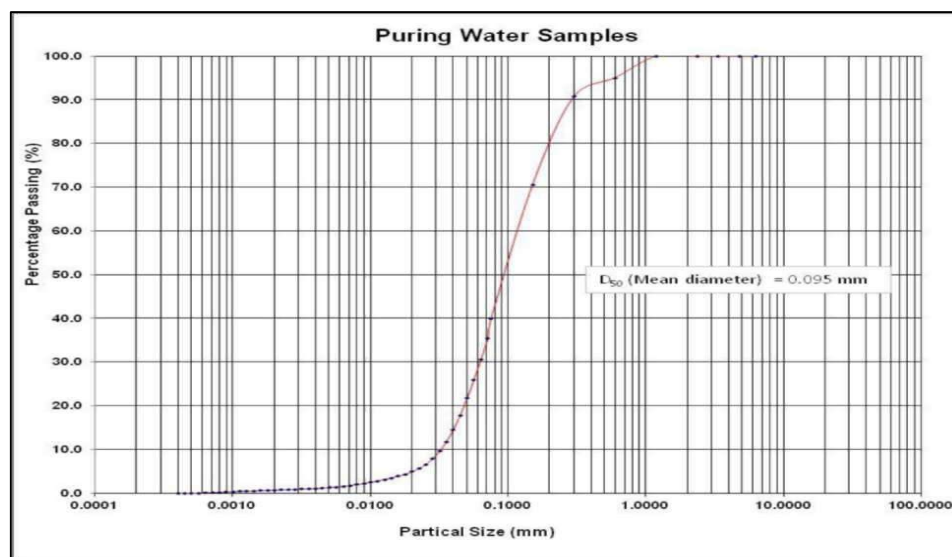
**Table 8.42: Grain Size Distribution**

IS Sieve (mm)	% of Sediments Passing (by weight)
1.180	100.00
0.600	95.10
0.300	90.79
0.150	70.61
0.075	40.05
0.050	21.75
0.025	6.66
0.001	2.56
0.0004	0.000

Grain size distribution of 51 samples for 2012 indicates that maximum size of suspended sediment at Heo Barrage is less than 1.18 mm and 70% of sediments are smaller than 0.15 mm. Graphical representation of grain size distribution for suspended sediments for year 2012 is presented below. From this graph, it is interpreted that 80% of suspended sediments at Heo Barrage are finer than 0.2 mm.

Petrographic analysis of suspended particles for the samples collected during year 2012 has been conducted by AIMIL and the results are enclosed in **Appendix E**.

**Fig: 8.34 Grain size distributions for suspended sediment at Heo HEP barrage site**



**Fig. 8.11 Particle Size Distribution**

### Sdiment Analysis for Samples collected from River Bed

A total of seven samples were collected from Yarjep River bed as per details given in Table 8.43. These seven samples were analysed for grain size.

**Table: 8.43 Table showing Location of Sample collection point for Bed Load Samples**

S No	Description	Location of sample collection point
1	Sample 1	Mechuka steel bridge Right bank
2	Sample 2	Mechuka steel bridge Right bank
3	Sample 3	Mechuka steel bridge Left bank
4	Sample 4	River bed Pauk dam
5	Sample 5	River bed of Sae Chu and Yarjep
6	Sample 6	Puring near Heo barrage beach Left bank
7	Sample 7	Puring near Heo barrage beach Left bank

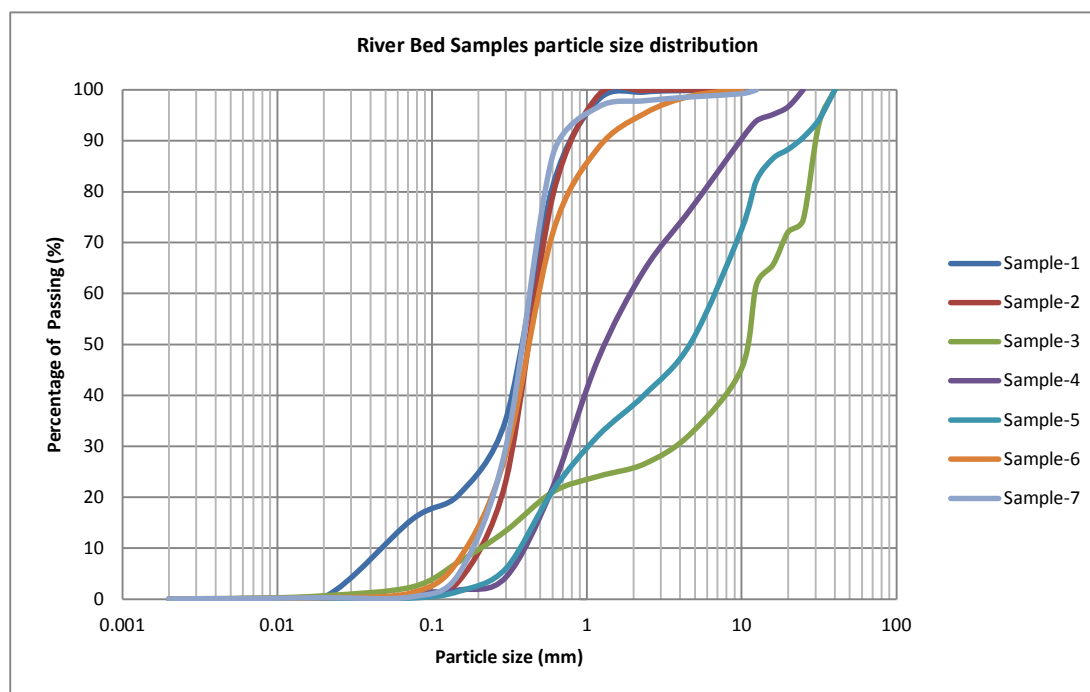
Details of grain size distribution of above samples are presented in table-8.44below.

**Table – 8.44**

	MECHUKA BED SAMPLES			Sae Chu	Pauk dam	Heo Barrage	Heo Barrage
	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5	Sample-6	Sample-7
IS Sieve							
40			100		100		
31.5			93.277		94.135		
25			74.531	100	90.668		
20			72.14	96.7	88.307		
16			65.676	95.2	86.536		
12.5			61.797	93.9	82.257		100
10	100	100	45.315	90.4	72.704	100	99.28
4.75	99.87	100	32.644	76.8	50.572	98.84	98.61
2.36	99.6	99.87	26.568	64.7	40.133	95.38	97.85
1.18	97.99	98.86	24.111	47.1	32.055	88.55	96.64
0.6	81.02	79.07	21.008	21.9	21.21	71.79	87.05
0.3	35.35	23.21	13.381	4.3	5.976	28.44	29.84
0.15	20.59	3.62	7.369	1.8	1.549	7.86	5.06
0.075	15.76	0.6	2.392	1.3	0.221	1.27	0.45
0.02	0.34	0.22	0.65		0.07	0.29	0.29
0.006	0.09	0.09	0.13		0.04	0.11	0.11
0.002	0.02	0	0.04		0.01	0.05	0.05



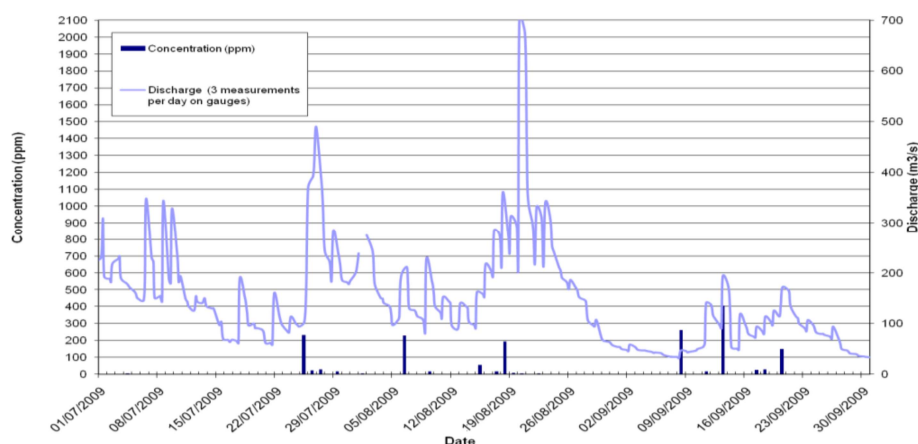
**Fig: 8.35 Grain size distributions for Bed sediment at Mechuka, Sae chu nala, Pauk dam and Heo barrage**



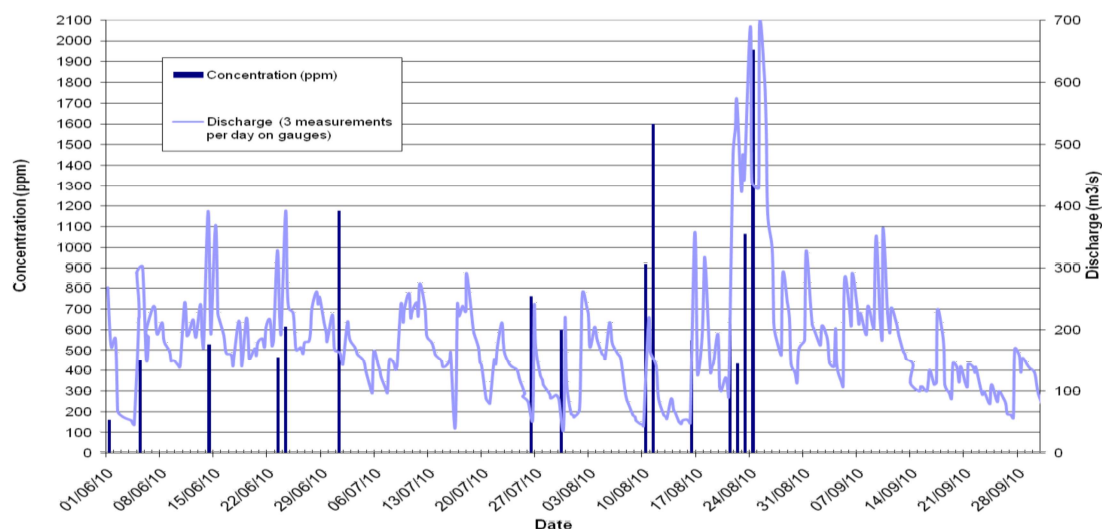
#### Study of river discharge vs Sediment concentration relationship

Daily discharge measurements (three times a day at 6.30am, 12.30pm and 4.30pm) are being taken at Mechuka steel bridge gauging station. Water samples for determination of sediment concentration have been collected at Mechuka bridge including monsoon season of 2009 to 2012 (refer **Appendix – D**). Observed daily river discharge and corresponding day sediment concentration for monsoon months of June, July, August and September have been plotted graphically for each of the four years and are presented in figure 8.36, 8.37, 8.38 and 8.39.

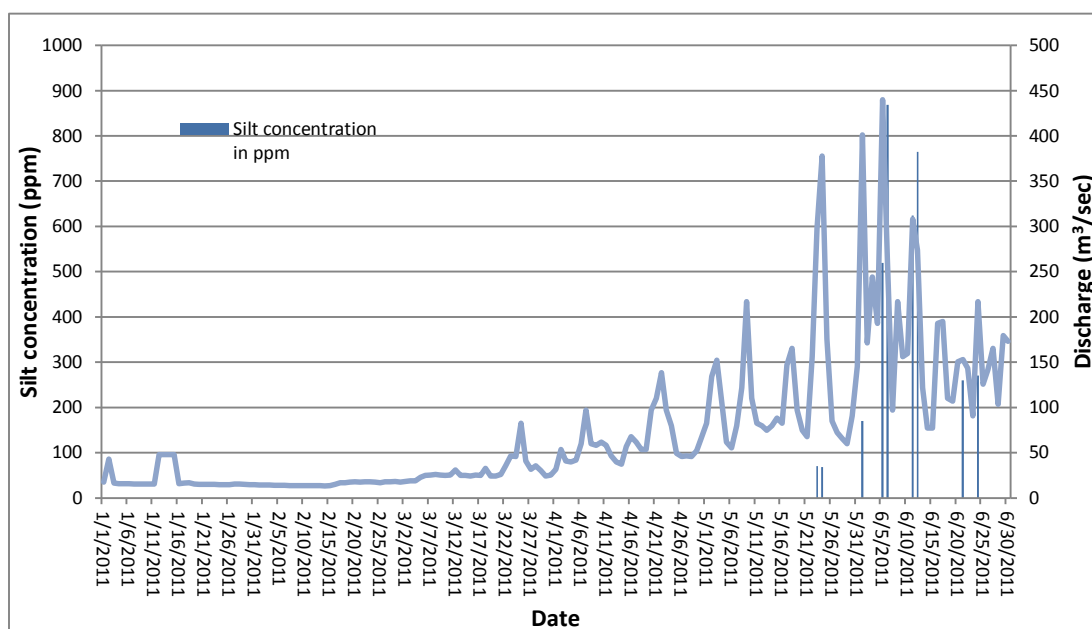
**Fig 8.36: Discharge and silt contents during 2009 monsoon at Mechuka steel bridge**



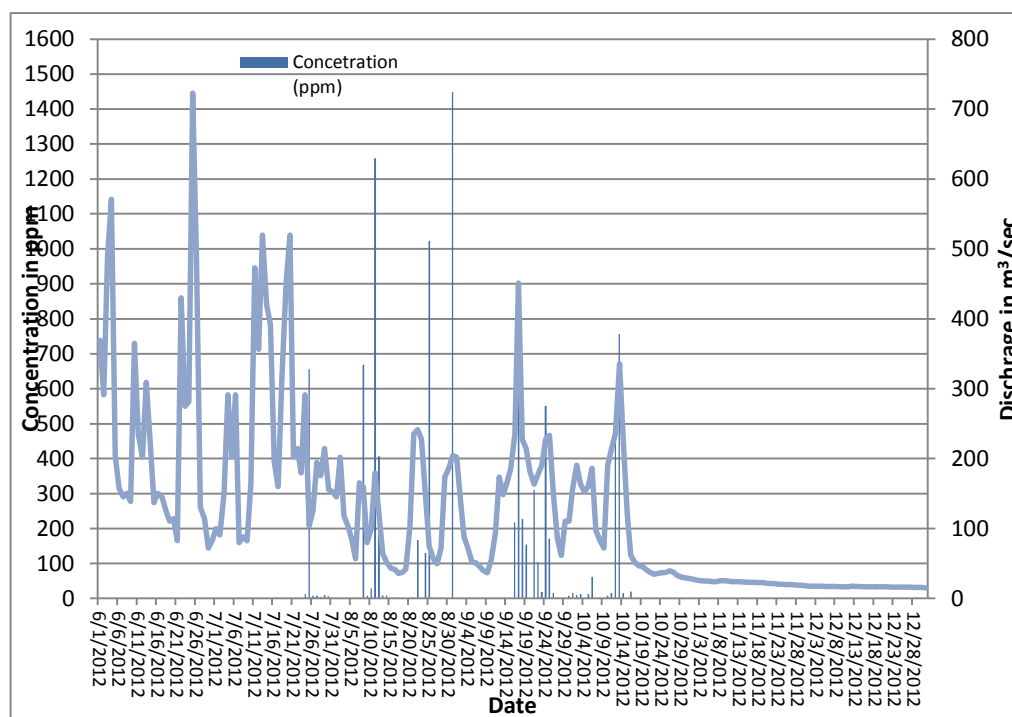
**Fig 8.37: Discharge and silt content during 2010 monsoon at Mechuka steel bridge**



**Fig 8.38: Discharge and silt content during 2011 monsoon at Mechuka steel bridge**



**Fig 8.39: Discharge Vs sediment concentration during 2012 monsoon at Mechuka Bridge.**

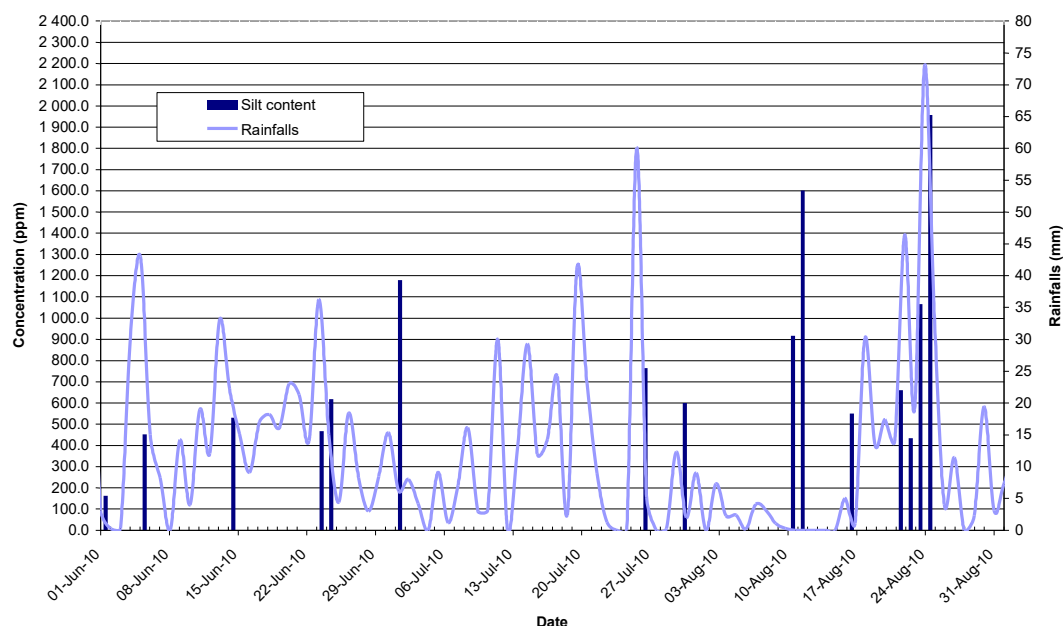


It is observed that river flow greater than 500 cumec is occasionally associated with higher sediment concentration. However for flows below 500 cumec, sediment concentration remains very low at almost all times.

#### **Study of Rainfall Vs sedimentation relationship**

The previous section discusses the relationship between sediment concentration and discharge. The impact of rainfall in project catchment on sedimentation concentration is discussed in this section.

Rainfall is being measured on daily basis since July 2008 at Mechuka, at Gapo since September 2007, at Segong (9 km upstream of Mechuka) and at Hanuman (20 km upstream of Mechuka) since March 2010. Relationship between rainfall and sediment concentration at Mechuka Bridge site during monsoon period for year 2010 is presented in figure 8.40.



**Figure 8.40: Sediment concentration and rainfall data at Mechuka for monsoon 2010**

From the graph, it can be seen that the maximum rainfall occurred on August 23, 2010 and the maximum sediment concentration was observed one day later. Similar pattern is seen for high rainfall days having rainfall more than 25mm in June and July 2010.

Rainfall may not be homogeneous in the entire catchment area. The rainfall records of Hanuman, Segong and Gapo rain gauge stations also indicate this phenomenon. Therefore comparing the rainfall only at Mechuka with sediment concentration may not always present the correct picture. Therefore daily sediment concentration at Mechuka is also compared with maximum rain fall recorded at all the four rain gauge stations at Segong, Hanuman, Mechuka and Gapo during the previous 48 hours. Table 8.45 presents a summary of rainfall data at Mechuka, maximum rainfall observed in catchment area in previous 48 hours and sediment concentration for select days during monsoon period of year 2010 wherein high sediment concentration is recorded.

**Table - 8.45 Summary of Rainfall data at Mechuka, Maximum Rainfall in Catchment Area and sediment concentration during monsoon period of 2010**

Date	Rainfall at Mechuka (mm)	Maximum Rainfall in the CA for the last 48 hours (mm)	Sediment Concentration (ppm)
01/06/10	3.1	37.4	162.0
05/06/10	43	43	451.7
14/06/10	22.2	33.1	530.0
23/06/10	36.2	36.2	466.7
24/06/10	15	36.2	616.7
01/07/10	6.2	60	1 178.0
26/07/10	5.2	60.1	763.3
30/07/10	2	2	600.0
10/08/10	0	0	916.7
11/08/10	0	0	1 600.0
16/08/10	1.1	1.1	550.0

Date	Rainfall at Mechuka (mm)	Maximum Rainfall in the CA for the last 48 hours (mm)	Sediment Concentration (ppm)
21/08/10	46.4	48.0	658.6
22/08/10	19	55.9	433.3
23/08/10	73	73	1 065.0
24/08/10	33.3	73	1 957.0

This analysis presents a more comprehensive picture of the physical link between rainfall and sediment rate in the river. It also shows the importance of two parameters: the temporal offset and the spatial unequal distribution of the rainfall over the catchment area.

The discharge vs. sediment concentration relationship as well as the rainfall vs. sediment concentration relationship cannot be generalised and can at best be used only as a guiding factor. It is very difficult to establish a quantitative relationship between discharge or rainfall and sediment concentration. Reason for lack of a quantitative relationship can be attributed to the fact that erosion process depends not only on the importance of the rainfall, but also on the past rainfall event, on the earth saturation, on the vegetal cover as well as on human activities in the area.

A typical example is the rainfall, discharge and sediment concentration data around August, 10th and 11th 2010. During this period, discharge measurements at Mechuka are fairly low (around 200 m<sup>3</sup>/s) and the rainfall in catchment area in preceding 48 hours is also negligible. However the sediment concentration on each of these two days exceeds 1000 ppm. The most probable explanation for this exception of very high sediment rate in spite of negligible rain and low discharge may be human activity in the form of road work excavation upstream of the gauging site (Refer figure 8.39). Another possible explanation is a landslide which could have directly reached the river (Refer figure 8.41).

**Fig: 8.41 Road construction activities above Mechuka Bridge leading to soil erosion**



### **Sediment Yield at Downstream End of Mechuka Plain**

Yarjep River flows in Mechuka plains for a distance of about 22 km (from RD 30km to RD 51.9km) with average river slope of 0.39%. This reach is characterised by wide river section and shallow water depth thus giving the appearance of a large lake. Within the Mechuka plain, Dutangphu Chhu joins Yarjep River from the left bank at RD 47.9 km. Dutangphu Chhu and Yarjep River from confluence point of Dutangphu to the end of Mechuka plain have a total catchment area of 80 km<sup>2</sup>. The characteristics of this tributary are identical to those of Yarjep River within Mechuka plain reach. The catchment area of Yarjep River at the downstream end of Mechuka plain at RD 51.9 km is 766km<sup>2</sup>.

The mountains surrounding Mechuka plains and Dutangphu consist of very gentle hill slopes (<350) with uniform dense vegetation. These gently sloped mountains are placed about 2kms apart from meandering Yarjep River. The topography, vegetation cover and river course are very conducive for settling of suspended sediments in flows. The lower velocity of flowing water through Mechuka plains also leads to settlement of sediments carried from upper mountainous river reach.



**Fig. 8.42 - Mountains surrounding Mechuka plain with gentle slopes**

Yarjep River at Mechuka contains sediment laden flows for an average of around 50 days in a year during the monsoon season. Higher sediment concentration is generally associated with high river discharge. In certain instances, high concentration of silt is found during low to moderate discharges. This phenomenon may be attributed to manmade activities of road works, cultivation and other construction activities.





**Fig: 8.43 - Wider, gentle river slope and shallow river course conducive for natural sedimentation.**



**Figure 8.44: Mechuka plain – View of upstream Mechuka village**





**Figure 8.45: Mechuka plain – view downstream of Mechuka village**

The sediment yield is estimated based on flood events occurring within duration of 48 hours. Corresponding to sediment concentration value for a particular flow event, the maximum rainfall measured over the preceding 48 hours period is considered for computing sediment load for that particular event.

Considering the sediment concentration to be constant during the day, the amount of suspended particles carried by river during flood event can be calculated as follows:

$$V_{\text{suspended sediments}} = V_{\text{water}} * C(\text{ppm}) / \text{density}$$

Where  $V_{\text{suspended sediments}}$  = Volume of Suspended Sediments ( $\text{m}^3$ )

$V_{\text{water}}$  = Volume of water ( $\text{m}^3$ )

$C$  = Sediment Concentration (ppm or mg/l)

Density of sediment =  $1.3 \times 10^6$  mg/l

Daily discharge and sediment concentration data at Mechuka Bridge for the years 2009, 2010, 2011 and 2012 is used to estimate the annual sediment yield at Mechuka. Sediment concentration is recorded in water flow at Mechuka during 2009 for 27 days, during 2010 for 22 days, during 2011 for 9 days and during 2012 for 47 days. Annual sediment yield is computed by adding the sediment load for each of the sediment observations in water flow during that year. Similarly, volume of water carrying the annual sediment load is computed by adding the volume of water during the event of occurrence of sediment in water flow. This exercise is carried out separately for 2009, 2010, 2011 and 2012 as indicated in Table 8.46.

**Table 8.46 Estimate of quantity of suspended sediment transported by Yarjeep river in 2009, 2010, 2011 and 2012 at Mechuka**

Estimation of Quantity of suspended Sediments transported by Yarje p river in 2009, 2010, 2011 and 2012 at Mechuka														
2009			2010			2011			2012					
Date of sediment laden water	Discharge (m <sup>3</sup> /sec)	Volume of water in 1 day 10 <sup>3</sup> km <sup>3</sup>	Sediments concentration ppm	Amount of sediments tonnes	Date of sediment laden water	Discharge (m <sup>3</sup> /sec)	Volume of water in 1 day 10 <sup>3</sup> km <sup>3</sup>	Sediments concentration ppm	Amount of sediments tonnes	Date of sediment laden water	Discharge (m <sup>3</sup> /sec)	Volume of water in 1 day 10 <sup>3</sup> km <sup>3</sup>	Sediments concentration ppm	Amount of sediments tonnes
01-07-2009	309.1	26.7	3	80.1	27-03-2010	188.3	16.3	12	195.3	23-05-2011	297.6	25.71	70	1804.1
03-07-2009	232.9	20.1	3	60.4	23-04-2010	148.6	12.8	74	949.8	24-05-2011	377.6	32.62	68	2232.1
04-07-2009	232.9	20.1	4	80.5	11-05-2010	197.4	17.1	73	1245.3	25-07-2012	108.5	8.9	656	5865.9
09-07-2009	347.9	30.1	1	30.1	12-05-2010	197.4	17.1	188	3207.0	26-07-2012	125.8	10.9	8	86.9
10-07-2009	343.8	29.7	1	29.7	15-05-2010	217.0	18.7	115	2156.0	27-07-2012	195.1	16.9	8	134.9
18-07-2009	327.9	28.3	3	85.0	21-05-2010	214.4	18.5	3	55.6	28-07-2012	175.5	15.2	4	60.6
25-07-2009	188.3	16.3	2	32.5	31-05-2010	207.0	17.9	5	89.4	29-07-2012	214.4	18.5	10	185.3
26-07-2009	489.8	42.3	23	9817.9	01-06-2010	207.0	17.9	162	2897.1	30-07-2012	158.9	13.5	7	94.3
27-07-2009	489.8	42.3	23	973.3	05-06-2010	219.6	19.0	452	8574.4	31-07-2012	152.3	13.2	2	26.3
28-07-2009	391.4	33.8	2	67.6	14-06-2010	241.3	20.8	530	11049.4	07-08-2012	165.4	14.3	2	28.6
29-07-2009	284.6	24.6	16	393.4	23-06-2010	222.2	19.2	467	8964.1	08-08-2012	159.7	13.8	669	9228.4
01-08-2009	274.7	23.7	4	94.9	24-06-2010	235.7	20.4	617	12563.2	09-08-2012	79.8	6.9	8	55.2
06-08-2009	211.9	18.3	230	4210.9	01-07-2010	224.8	19.4	1178	22880.3	10-08-2012	100.2	8.7	29	251.0
09-08-2009	227.5	19.7	16	314.5	26-07-2010	219.6	20.6	763	15720.4	11-08-2012	179.7	15.5	1259	19542.2
15-08-2009	284.6	24.6	54	1327.8	30-07-2010	219.6	19.0	600	11382.0	12-08-2012	121.8	10.5	407	4281.5
17-08-2009	360.4	31.1	18	560.5	10-08-2010	217.0	18.7	917	17719.4	13-08-2012	63.6	5.5	9	49.4
18-08-2009	706.1	61.0	194	11835.4	16-08-2010	356.2	30.8	550	16995.9	14-08-2012	52.3	4.5	9	40.6
19-08-2009	706.1	61.0	8	488.1	21-08-2010	571.0	49.3	659	32512.5	15-08-2012	43.1	3.7	3	3.7
20-08-2009	706.1	61.0	6	366.0	22-08-2010	571.0	49.3	433	21362.5	16-08-2012	41.9	3.6	3	10.9
22-08-2009	339.8	29.4	5	146.8	23-08-2010	620.2	53.6	1085	57067.3	22-08-2012	241.3	20.8	167	3481.6
08-09-2009	61.6	5.3	262	1394.4	24-08-2010	620.2	53.6	1957	104864.5	23-08-2012	227.5	19.7	1	19.7
11-09-2009	192.8	16.7	16	266.5	-	-	-	-	-	24-08-2012	150.5	13.0	131	1705.5
13-09-2009	192.8	16.7	405	6746.5	-	-	-	-	-	25-08-2012	74.8	6.5	1023	6609.4
17-09-2009	134.2	11.6	27	313.1	-	-	-	-	-	29-08-2012	173.4	15.0	1	15.0
18-09-2009	171.4	14.8	29	429.5	-	-	-	-	-	31-08-2012	204.6	17.7	1449	25608.6
20-09-2009	171.4	14.8	150	2221.3	-	-	-	-	-	16-09-2012	236.7	20.4	217	4418.5
-	-	-	-	-	-	-	-	-	-	17-09-2012	451.0	39.0	863	33626.5
-	-	-	-	-	-	-	-	-	-	18-09-2012	227.5	19.7	228	4481.0
-	-	-	-	-	-	-	-	-	-	19-09-2012	214.4	18.5	154	2853.2
-	-	-	-	-	-	-	-	-	-	21-09-2012	163.5	14.1	310	4378.4
-	-	-	-	-	-	-	-	-	-	22-09-2012	177.5	15.3	104	1595.3
-	-	-	-	-	-	-	-	-	-	23-09-2012	190.6	16.5	18	296.4
-	-	-	-	-	-	-	-	-	-	24-09-2012	227.5	19.7	550	10809.4
-	-	-	-	-	-	-	-	-	-	25-09-2012	232.9	20.1	171	3441.0
-	-	-	-	-	-	-	-	-	-	26-09-2012	150.5	13.0	16	208.1
-	-	-	-	-	-	-	-	-	-	30-09-2012	110.4	9.5	8	76.3
-	-	-	-	-	-	-	-	-	-	01-10-2012	155.9	13.5	16	215.6
-	-	-	-	-	-	-	-	-	-	02-10-2012	190.6	16.5	10	164.7
-	-	-	-	-	-	-	-	-	-	03-10-2012	163.5	14.1	12	169.5
-	-	-	-	-	-	-	-	-	-	05-10-2012	159.7	13.8	12	165.5
-	-	-	-	-	-	-	-	-	-	06-10-2012	186.1	16.1	62	997.0
-	-	-	-	-	-	-	-	-	-	10-10-2012	190.6	16.5	8	131.7
-	-	-	-	-	-	-	-	-	-	11-10-2012	214.4	18.5	16	296.4
-	-	-	-	-	-	-	-	-	-	12-10-2012	235.7	20.4	470	9570.0
-	-	-	-	-	-	-	-	-	-	13-10-2012	335.8	29.0	756	21931.9
-	-	-	-	-	-	-	-	-	-	14-10-2012	222.2	19.2	15	287.9
-	-	-	-	-	-	-	-	-	-	16-10-2012	61.6	5.3	20	106.5
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Although cumulative flow of water during flood events having sediment laden water flow was lesser in terms of volume of water in 2010 than in 2009 and 2012, more than 380 000 tons (293 200 m<sup>3</sup>) of sediments were transported across Mechuka steel bridge by the Yarjep River in 2010. This is about eight times more than sediments transported in 2009 and twice as much as in 2012. As indicated earlier, reason for increase in sediment concentration during 2010 can be attributed to substantial increase in human activity related mainly to new road construction in catchment area above Mechuka. The specific conditions of 2010 will certainly be repeated more often in future because of the economic development in the area. In order not to underestimate the amount of sediment yield for the purpose of this study, the measurement for year 2010 is proposed to be considered as the basis for calculating the annual quantity of sediments carried by the Yarjep River through the Mechuka plain.

Accordingly, the annual sediment yield for Yarjep River at Mechuka Bridge (RD 44.6 km) is adopted as 293,200 m<sup>3</sup> of suspended sediments for the purpose of this study. The total catchment area at RD 51.9 km is 766 km<sup>2</sup> (CA at Mechuka Bridge 686 km<sup>2</sup> + CA of Dutangpu Chu 80 km<sup>2</sup>).

In addition to the suspended sediments in flowing water, larger sediments are also transported by river flows along bed of the river. Bed load comprises mainly of larger sediment particles like pebbles, gravel and boulders and these sediment particles have a tendency to get deposited in the pondage area behind a storage dam thereby reducing its storage capacity. The bed load concentration mainly depends on the composition of riverbed material, river bed slope and to an extent on the size of suspended sediments. Bed load is thus an important source of sediment yield. However, no simple methodology exists to measure it. In absence of actual measurements for bed load, IS 12182 recommends using a percentage between 5 and 20% of the suspended load as bed load. Bulletin No. 67 of ICOLD gives a simplified table to estimate bed load in a stream based on the characteristics of the river bed and suspended sediments and the same is reproduced below.

**Table – 8.47: ICOLD recommendation for determination of bed load based on river characteristics**

Condition	Suspended sediment concentration (mg/L)	Streambed material	Size analysis of suspended material	Percent bed load in terms of suspended load
1	Less than 1000	Sand	20 to 50 % sand	25 to 150 %
2	between 1000 and 7500	Sand	20 to 50 % sand	10 to 35 %
3	Greater than 7500	Sand	20 to 50 % sand	5 %
4	Any concentration	Compacted clay, gravel, cobbles, or boulders	Small amount, up to 25 % sand	5 to 15 %
5	Any concentration	Clay and silt	No sand	Inferior to 2 %

The grain size analysis performed for suspended sediment particles sampled at Mechuka indicates their composition to be mainly silt and fine sand. Sand particles are very fine and almost at the limit of the category. Accordingly it is safe to assume that less than 25% of the suspended particles are sand. The streambed of the Yarjep River in the Mechuka plain comprises mainly of compacted silt with embedded gravel and pebbles of median diameter around 11 mm. In

addition, sand banks can be observed at very specific places. Condition No. 4 in the table above seems to be the most appropriate to the characteristics of the Yarjep River for estimation of bed load at Mechuka. Accordingly, the bed load is likely to be between 5 and 15% of suspended sediment load. However for the purposes of sedimentation study, bed load at Mechuka is considered as 15% of suspended sediment load. This figure is also consistent with the recommendation of IS 12 182.

$$V_{\text{bed load}} = 293\,200 \text{ m}^3/\text{year} * 15\% = \mathbf{44\,000 \text{ m}^3/\text{year}}$$

Total volume of sediments carried by Yarjep River at Mechuka Bridge is estimated as:

$$V_{\text{total}} = 293\,200 + 44\,000 = 337\,200 \text{ m}^3/\text{year}$$

Catchment area at Mechuka Bridge is 686 km<sup>2</sup> and the sediment rate is computed as 0.49 mm/year (or mm of sediment/ year/ m<sup>2</sup> of CA). The catchment area at the downstream end of Mechuka plains is about 766 km<sup>2</sup> and considering the same rate of sedimentation for the balance catchment of 80 km<sup>2</sup> including Dutangphu Chu, the annual sediment yield at end of Mechuka plain at RD 51.9 km of Yarjep River is estimated as:

$$V_{\text{total}} = 337,200 + 80,000,000 * 0.49 / 1000 = 376\,400 \text{ m}^3/\text{year}$$

$$\text{i.e., } V_{\text{total}} = V_{\text{suspended}} 327,300 + V_{\text{bed load}} 49,100 = 376,400 \text{ m}^3/\text{year}$$

#### **Sediment rate for Yarjep and Siyom River estimated in earlier studies**

The confluence of Yarjep and Siyom River is located near Tato village; about 20 km downstream of Pauk dam location. The diversion site of Tato II HEP (700 MW) is located immediately after the confluence of Yarjep and Siyom Rivers. Sediment rate has been computed in the DPR of Tato II HEP as 0.88 mm/yr by transferring sediment yield estimated at Raying gauging site. This rate includes bed load estimated at 20% of the suspended sediment load. The sediment rate of Tato is almost twice the rate computed at Mechuka.

Tato and Mechuka are in the same river basin. The difference in computed sediment rate for the two locations can be explained by their contrasting topography and characteristics of riverbed. Mechuka is located in a long and flat plain area, in a very wide valley. The longitudinal slope at Mechuka is only 0.39% spread over nearly 22 km length and this stretch is therefore conducive to deposition of sediments. The water velocity in Yarjep River near Mechuka village during floods rarely exceeds 2 m/s and accordingly facilitates sedimentation of most particles. The Mechuka plain thus acts as a desilting basin for downstream stretch of Yarjep River. This sediment rate can be assumed to be well representative of sediment rate for the catchment area up to Mechuka plain. However, because this result is very site specific, it cannot be used for the whole catchment area of Pauk Dam and Heo barrage. For catchment area below Mechuka plain, it is proposed to adopt sediment rate of 0.88 mm/year as has been adopted for Tato II HEP.

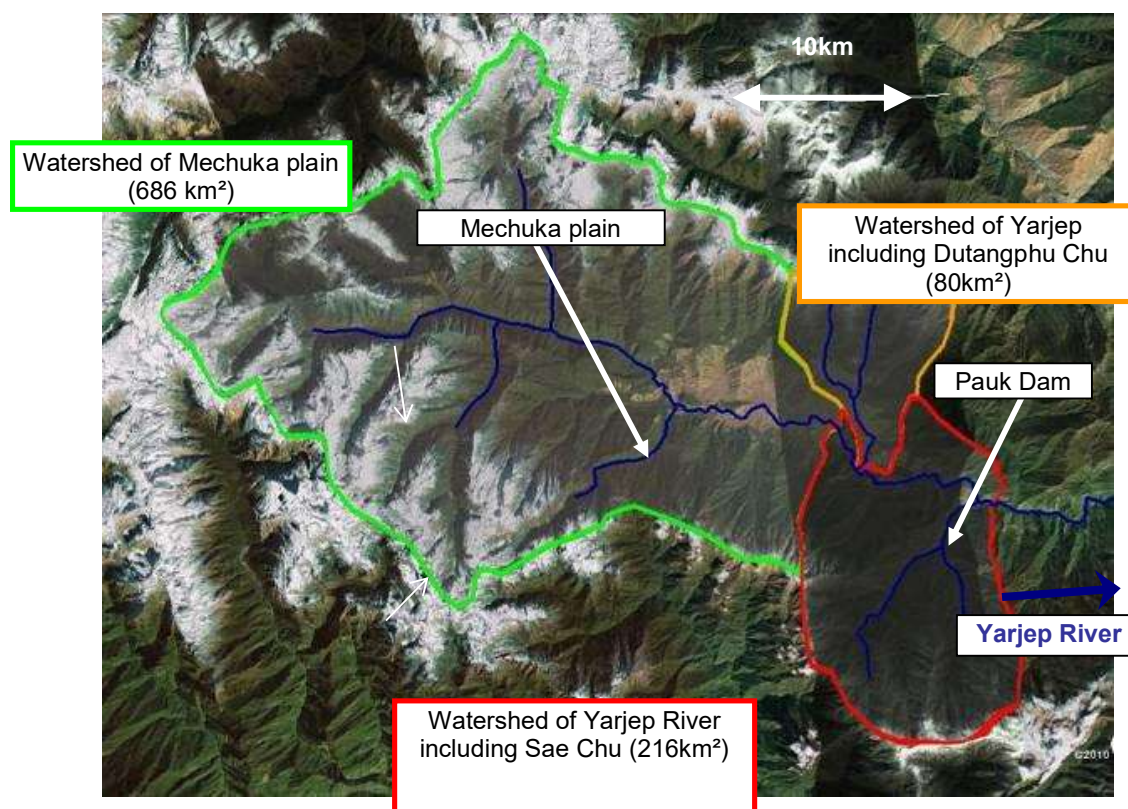
## Sedimentation study at Pauk Dam Location

### 8.8.11.1 Estimation of Sediment Load

According to topographic features, the Pauk Dam catchment area of 982 km<sup>2</sup> can be divided into two distinct classifications as indicated in figure 8.26:

- Catchment area of 766 km<sup>2</sup> at end of Mechuka plain, and,
- Catchment area in mountainous reach of Yarjep River between Mechuka plain and Pauk dam location at RD 60.3 km having catchment of 216 km<sup>2</sup> including Sae Chu nallah. In this watershed, the valley is relatively narrow and river bed slope averages 3.34% as against a slope of 0.39% in Mechuka plain.

**Figure 8.46: Division of the Yarjep River catchment area**



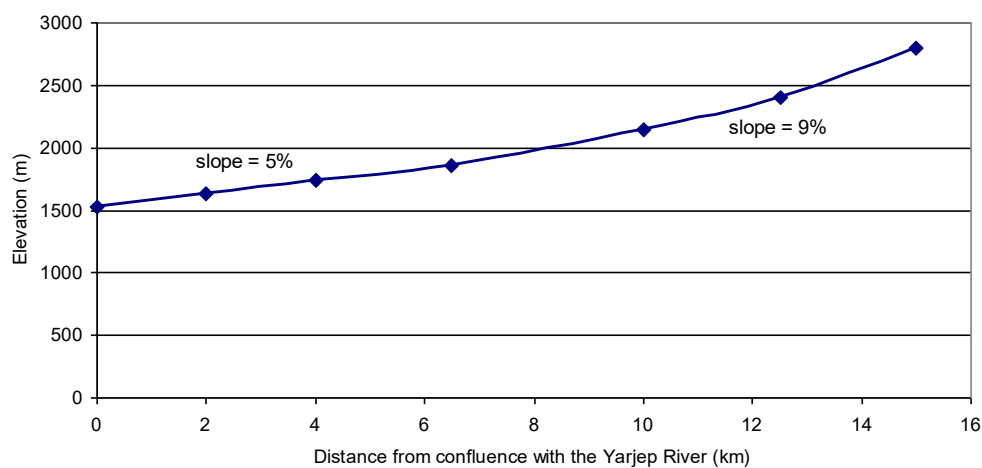
Sediment yield at the downstream end of Mechuka is estimated as 376,400m<sup>3</sup>/year. After Mechuka plain, the longitudinal slope of Yarjep River increases to 3.34% and the valley becomes narrow. Mountains around the valley are steep having slopes greater than 40% and vegetation is jungle type as shown in figure 8.47.



**Figure 8.47: Narrow valley near Pauk Dam Axis**

The watershed of Sae Chu, a right bank tributary of the Yarjep River having confluence point about 1.17 km upstream of Pauk dam, also has similar characteristics of steep banks, river bed slope of about 5% as shown in figure 8.48 and jungle type vegetation (Figure 8.49).

**Figure 8.48: Longitudinal profile of Sae Chu**







**Figure 8.49: Sae Chu nallah**

This part of Yarjep River watershed including Sae Chu is very classical for the Himalayan area and also similar to Siyom River catchment area. The sediment rate of Siyom River near Tato after the confluence of Yarjep and Siyom River can be considered representative of the sediment rate of hilly catchment area of Yarjep River downstream of Mechuka plain. The catchment area of Mechuka (766 km<sup>2</sup>) represents about 30% of the total catchment area at Tato (2560 km<sup>2</sup>). The impact of the low sediment rate of Mechuka on the sediment rate calculated for Tato II HEP is not expected to be significant and hence ignored.

Accordingly, sediment rate of 0.88 mm/yr adopted for Tato is used for estimating sediment yield for this part of the watershed:

$$V_{\text{sediment yield}} = 0.88 \text{ mm/yr} * 216 \text{ km}^2 = \mathbf{190\ 100 \text{ m}^3/\text{year}}$$

The bed load has been estimated as 20% of the suspended load. The division between suspended particles and bed load for intervening catchment is given below:

$$V_{\text{suspended particles}} = 190\ 100 \text{ m}^3/\text{yr} / 1.20 = \mathbf{158\ 400 \text{ m}^3/\text{year}}$$

$$V_{\text{bed load}} = 190\ 100 \text{ m}^3/\text{yr} - 158\ 400 \text{ m}^3/\text{yr} = \mathbf{31\ 700 \text{ m}^3/\text{year}.$$

Total sediment yield including Mechuka plain, Dutangphu Chu and mountainous catchment area up to Pauk dam is presented in Table 8.48.

**Table 8.48: Total sediment yield at Pauk Dam Location**

Description	WATERSHED		
	Mechuka at RD 59.1 km	Mechuka to Pauk Dam (RD 59.1 to RD 60.3 km)	Total at Pauk Dam
CA (km <sup>2</sup> )	766	216	982
Percentage of total CA	78%	22%	100%
Sediment yield of suspended particles (m <sup>3</sup> )	327,300	158,400	485,700
Bed load (m <sup>3</sup> )	49,100	31,700	80,800
% Bed load/ Suspended particles	15%	20%	17%
Total amount of sediment yield (m <sup>3</sup> )	376,400	190,100	566,500
Percentage of total sediment yield	66%	34%	100%
Sediment rate (mm/yr)	0.49	0.88	0.58

#### Impact of Mechuka Plain on Sediment Concentration in case of a major flood event

The sediment rate calculated above is based on four years of measurements and during this period, peak flood intensity of 700m<sup>3</sup>/s is observed. Based on sediment concentration study, it is proven that Mechuka plain acts like a desilting basin. This section examines the anticipated impact of Mechuka plain on sediment concentration rate in case of flood intensity corresponding to higher return period varying from 10 years to 1000 years as well as for PMF. High flows generally result in higher water velocity and this may result in erosion of deposited sediments. This process can mobilize additional sediment particles than presently anticipated and consequently change the volume of sediment carried to the Pauk reservoir.

In order to study the behaviour of sediment for various river flows, a model has been developed with HEC-RAS software. It computes the mean velocity of water in Mechuka plain corresponding to various flood discharges and is used to predict the behaviour of sediment erosion through Mechuka plain.

For this study, river cross-sections have been developed based on site topographic survey. The Yarjep River has been modelled for 11 km along the Mechuka plain - 9 km towards upstream and 2 km downstream of Mechuka Bridge. Water velocity was studied for the following return period flood discharges:



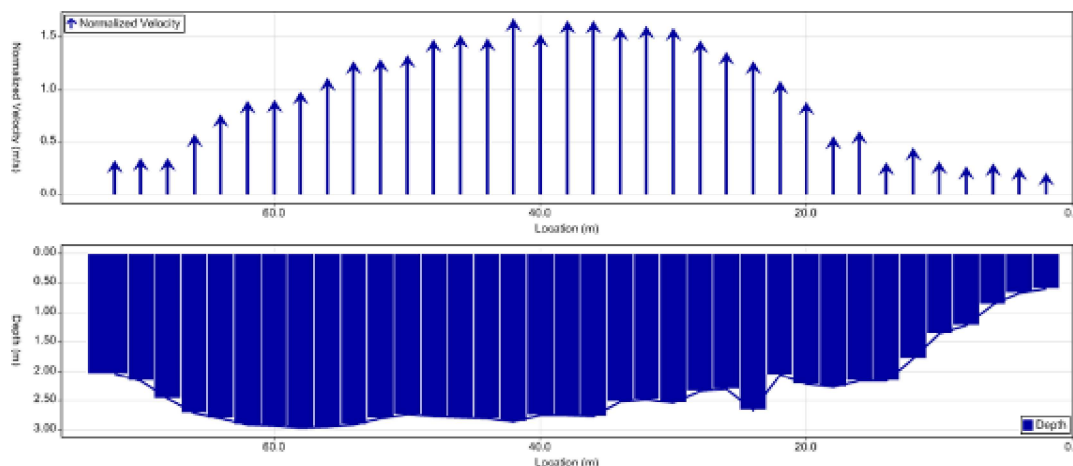
**Table 8.49**

Maximum flow measured at Mechuka	700 m <sup>3</sup> /s
2 year return period flood	780 m <sup>3</sup> /s
10 year return period flood	1330 m <sup>3</sup> /s
25 year return period flood	1600 m <sup>3</sup> /s
100 year return period flood	2000 m <sup>3</sup> /s
1000 year return period flood	2670 m <sup>3</sup> /s
PMF (Probable Maximum Flood)	2830 m <sup>3</sup> /s

The HEC-RAS software calculates uniform flow velocity on a whole cross-section. Due to friction and viscosity, water velocity is not the same in every segment of the cross section. In May 2011, measurements were made with River Surveyor device for developing water velocity profile across Yarjep River corresponding to flow of 178m<sup>3</sup>/s. While the mean flow velocity computed is 1.05m/s, the water velocity at different sections along the river cross section varies from 0.3 m/s on the banks to 1.6 m/s (refer figure 8.50) in the centre i.e. water velocity is higher in the middle and lower on banks and bottom of the river. As a result of this phenomenon, sediment particles deposited along river banks and river bed do not get eroded even though mean flow velocity may indicate adequate erosion potential.

To predict the erosion of deposited sediments, flow velocity on river banks and at the bottom of the riverbed, where particles are likely to be eroded needs to be determined. It is difficult to establish a link between mean flow velocity and water velocity on river bank. For this study, it is assumed that water velocity on edges and bottom evolves in the same way with respect to mean flow velocity as indicated in velocity profiles measured by river surveyor at Mechuka Bridge. The mean flow velocity is computed in HEC-RAS study at flood discharges corresponding to different return period floods. Water velocity on river banks and bottom of the river is accordingly taken as 30% of mean velocity and possibility of river bed erosion evaluated from the criteria provided by Hjulstrom (figure 8.51).

**Figure 8.50: Velocity profiles measured by the River Surveyor at Mechuka Bridge. The measured mean water velocity is 1.05 m/s and flow is 178m<sup>3</sup>/s.**



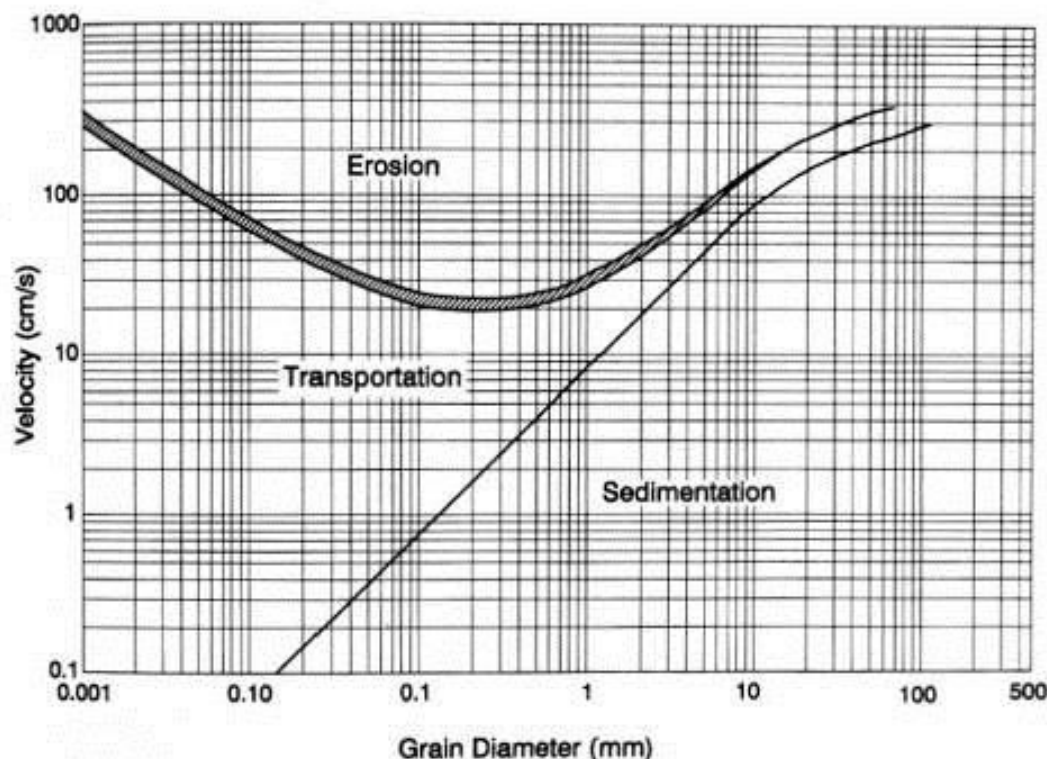
**Table 8.50: Variation in mean velocity at 5 km upstream of Mechuka Bridge for discharge varying from 700 to 2830 m<sup>3</sup>/s,**

Return period of flood (yrs)	Discharge (m <sup>3</sup> /s)	Mean velocity (m/s)	Assumed water velocity at banks and river bed (m/s)	Percentage difference in discharge	Percentage difference in velocity
-	700	2.02	0.61	-	-
2	780	2.04	0.61	11%	1%
10	1330	2.18	0.65	90%	8%
25	1600	2.19	0.66	129%	8%
100	2000	2.27	0.68	186%	12%
1000	2670	2.42	0.73	281%	20%
PMF	2830	2.45	0.74	304%	21%

Figure 8.52 and Table 8.50 show that the mean flow velocity increases very little with the flow. At five kilometres upstream from Mechuka Bridge, compared to a 700 m<sup>3</sup>/s flow, mean velocity increases by only 12% for 100-year flood (TR100 = 2000 m<sup>3</sup>/s) and 21% for probable maximum flood (PMF = 2830 m<sup>3</sup>/s) while the relative difference in discharge is respectively 186% and 304%. Similarly, the flow velocity along river banks and bottom of the riverbed does not change appreciably with increase in flood discharge.

This small change of velocity can be explained by the topography of the Mechuka plain. In this plain, Yarjep River streambed is quite wide and a small increase of the water level can absorb a large increase in discharge. Thus, the impact on velocity profiles is low. The increase in discharge is absorbed by flooding of the wide plain and does not result in significant increase in water velocity.

**Figure 8.51: Velocity criterion of erosion and deposition for uniform particles (Hjulstrom, 1935).**

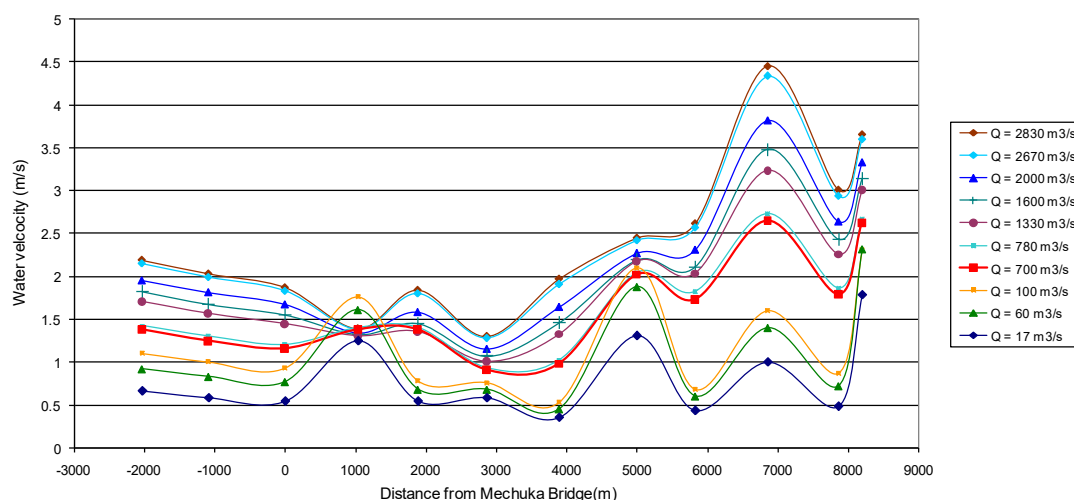


Hjulstrom has developed a relationship between flow velocity in a stream and sediment particles comprising river bed material and the same is presented in figure 8.51. Depending on flow velocity, the graph can be used to predict the behaviour of river bed in terms of erosion or sedimentation depending on grain size of river bed material. A higher flow velocity is more likely to erode the river beds whereas bigger size particles are less likely to be eroded even at higher velocity.

As can be seen from Figure 8.52, a 12% increase in water velocity does not result in any increase in the size of particles that can be eroded. It demonstrates that as velocity profiles are little changed by variations in flow and sediment erosion being dependent on water velocity, it is safe to assume that no significant increase in sediment concentration would occur in case of increase in river discharge beyond  $700\text{m}^3/\text{s}$ .

Major floods will therefore play no specific role in the amount of sediment carried in the plain of Mechuka and the sediment rate of  $0.49\text{ mm/yr}$  can be assumed as correct for this part of the watershed, even in case of a major flood. Further in case of a flood of even  $700\text{m}^3/\text{s}$ , the storage capacity available at Pauk dam will be filled up only in a couple of hours and the surplus water along with suspended and bed load sediments will be passed downstream through the spillway and will not result in reduction in live storage capacity at Pauk dam.

**Figure 8.52: Graphical Representation of mean velocity versus river flow in Mechuka plain**



## Sedimentation study after construction of Pauk Dam

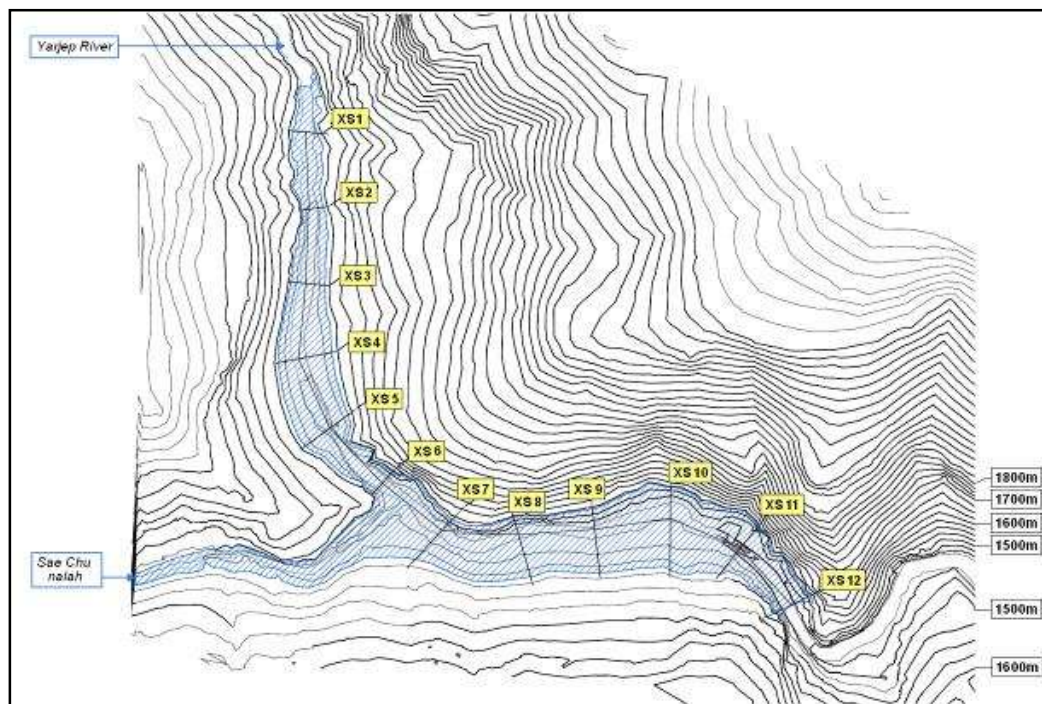
### 8.8.12.1 Assumptions for sedimentation study

It is assumed that the operations of turbines of Heo HEP and Tato-I HEP will be synchronized with operation of Pauk HEP operations. Heo dam receives flows from Pauk tail race, surplus water after sedimentation at Mechuka plain and in Pauk reservoir in addition to flows from intermediate catchment area of 83km<sup>2</sup>. Tato-I receives **flow directly from Heo tail race** and additional 2.7 m<sup>3</sup>/s flow from intermediate catchment area of 89km<sup>2</sup>. Sedimentation study for Heo Barrage is considered as applicable for Tato-I HEP also. During flushing operations from Pauk dam, Heo powerhouse and Tato-I powerhouse shall also have to be shut down.

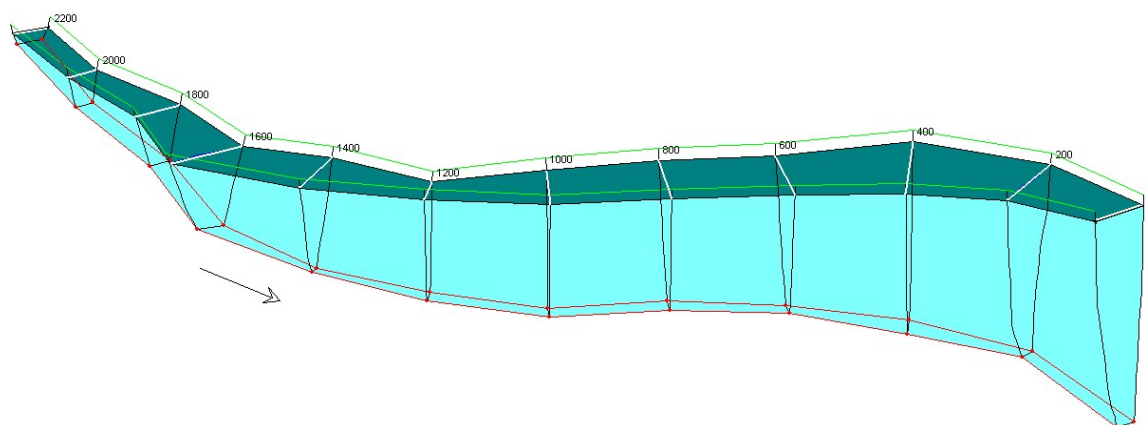
### 8.8.12.2 Sedimentation in Pauk reservoir

Pauk HEP envisages construction of a 95 m high arch dam at RD 69.30.km of Yarjep River. A live storage capacity of 1.67 Mcum is available in Pauk reservoir between FRL of 1540m and MDDL of 1520 m. A gated spillway with crest at El 1490 m is provided to pass a design flood of 3200 m<sup>3</sup>/s. Pauk reservoir spreads over a length of 2370 m into Yarjep River and about 800 m into Sae Chu nallah. Sae Chu nallah joins Yarjep about 1170m upstream of dam location. Area capacity curve for Pauk reservoir is shown in **Fig 8.55**. Cross sections of Yarjep River at a distance of 100m upstream of dam axis to a distance of 900 m upstream of dam axis are generated at a spacing of 100m for study of sedimentation process in Pauk reservoir.

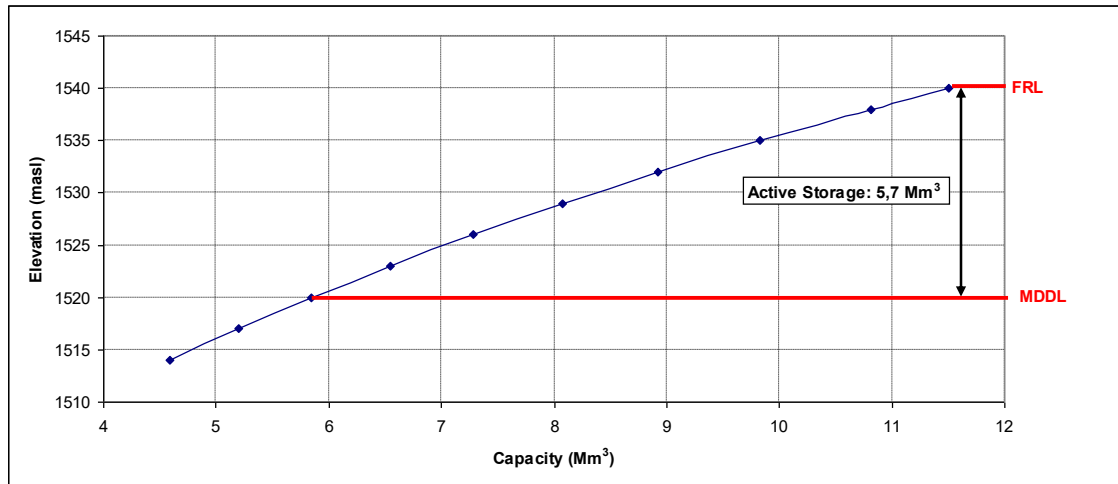
The maximum discharge of 50% dependable year (2003-2004) is 295m<sup>3</sup>/s and the peak discharge in past 4 years observed at Mechuka steel bridge gauging station is 700 m<sup>3</sup>/s. Sedimentation study is carried out for river flow varying from 200m<sup>3</sup>/s to 1000m<sup>3</sup>/s with incremental step of 100m<sup>3</sup>/s. Results are shown in Annexures.



**Figure 8.53: Plan showing spread of Pauk reservoir**



**Figure 8.54: 3D Sectional View of Pauk reservoir**



**Fig. 8.55: Pauk Area Capacity Curve**

Reservoir FRL i.e. 1540.0 m is considered for hydraulic calculations. For this study, it is assumed that river bed upstream of dam is silted up to crest elevation of sluice gates at EL 1490.0 m (about 35 m above river bed level at dam site) and attains a bed slope of 0.2% as per Lacey's slope formula.

Lacey's slope formula =  $f^{5/3} / (3340 Q^{1/6})$  (in mks units)

Considering Lacey's silt factor 1.5 for coarse sand

Flood Discharge = 3200 m³/s

Sediment deposited bed slope =  $1.5^{5/3} / (3340 \times 3200^{1/6}) = 1/6523 = 0.0001533$  (0.015 % say 0.02%)

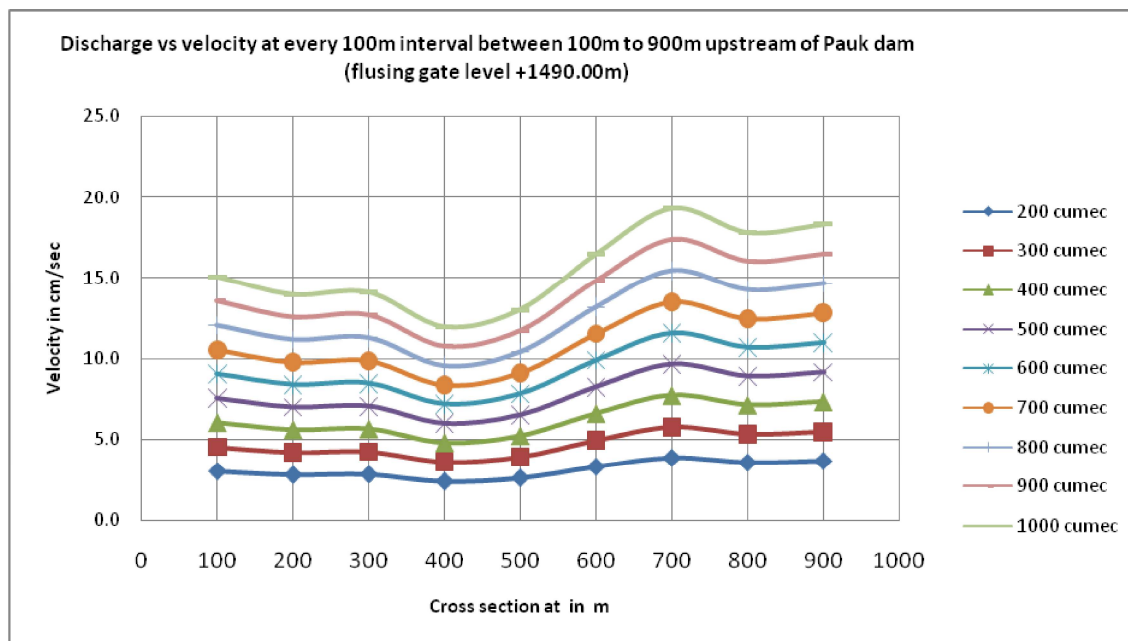
Therefore bed slope of deposited sediments of 0.02% is adopted for computation of cross section area for flow velocity computations.

In the analysis, flow velocity at each river cross section is computed and the distance travelled by various size particles in suspension before settling on river bed is computed. Water velocity at a particular cross section may marginally increase with the passage of time, as the siltation process will reduce the area of cross sections. However flushing of sediments deposited in live storage area of Pauk reservoir shall be done on annual basis.

Sae Chu nallah confluences with Yarjep at 1170m upstream from Pauk dam. Hence cross sections of Yarjep River about 900m upstream of Pauk dam have been considered as representative section for this study. Distance travelled by suspended particles of size 0.15 mm and above before settling is studied.

**Table 8.51: River section details on upstream of Pauk arch dam**

Cross section U/s (Pauk Dam)	400	500	600	700	800	900
Discharge in m <sup>3</sup> /s	1000	1000	1000	1000	1000	1000
FRL	1540	1540	1540	1540	1540	1540
Bed Level after siltation up to crest of spillway gates at +1490	1490.08	1490.1	1490.12	1490.14	1490.16	1490.18
Depth of flow in m	49.20	49.00	48.80	48.60	48.40	48.20
Area m <sup>2</sup>	8357	7669	6062	5200.3	5613	5514
Velocity = Q / A (m/s)	0.120	0.130	0.165	0.192	0.178	0.181



**Fig: 8.56 Graph of Discharge vs velocity at every 100m interval between 100m to 900m upstream of Pauk dam**

With reservoir silted up to EL 1490.00m, flow velocity up to a distance of 900m upstream of dam for discharge of 1000 m<sup>3</sup>/s does not exceed 20 cm/s. This flow velocity is conducive for settlement of sediment particles in Pauk reservoir.

Indicative settling distances of varied size particles reaching bed level of 1490.00 for a discharge of 1000 m<sup>3</sup>/s are shown in table 8.52 below.

Effect of turbulence in flow on deposition of sediment particles is also considered in the calculations. A correction factor on account of turbulence on falling velocity of particle is applied as per Mosonyi.

Falling velocity''  $w_{flow}$ '' in flowing water =  $w - w'$

$w' = \alpha U$  ;  $\alpha = 0.132 / \sqrt{D}$  where  $D$  = size of particle.



**Table 8.52: Section at 900m upstream of dam**

Particle size in mm	Falling velocity (cm/s)	Corrected falling velocity in flowing water (cm/s)	Velocity of flow cm/s	Depth (m)	Settling Time (s)	Settling Distance (m)	Settling Distance from dam face (m)
0.15	1.5	1.156	18.1	48.2	4170	754.8	145.2
0.2	2.1	1.756	18.1	48.2	2745	496.9	403.1
0.25	3	2.656	18.1	48.2	1815	328.5	571.5
0.3	4	3.656	18.1	48.2	1318	238.6	661.4
0.4	5.3	4.956	18.1	48.2	973	176.0	724.0
0.6	9	8.656	18.1	48.2	557	100.8	799.2
0.8	12	11.656	18.1	48.2	414	74.8	825.2
1	15	14.656	18.1	48.2	329	59.5	840.5
2	27.5	27.156	18.1	48.2	177	32.1	867.9
4	43	42.656	18.1	48.2	113	20.5	879.5
7	60	59.656	18.1	48.2	81	14.6	885.4
10	72.5	72.156	18.1	48.2	67	12.1	887.9

As per this study, duly considering the turbulence created by infall of Sae chu nala at 1170m upstream of dam, particle size of 0.150 mm and above get settled in Pauk reservoir at a maximum distance of about 755m (145m upstream of Pauk dam). Similarly, particles of size 0.2mm get settled in Pauk reservoir at a maximum distance of 497(403m upstream of Pauk dam). As the total length of reservoir extends for 2370 m from dam, particles of size 0.2 mm and above are not likely to be eroded in to suspension even due to gradual siltation during project operation. It is therefore considered that particles of maximum size 0.15 shall flow through intake and along with surplus water released from Pauk dam. As no grain size distribution of suspended sediments at Pauk dam site has been carried out, the grain size distribution of suspended sediments at Heo barrage location is considered to be applicable at Pauk dam site. Accordingly, it is considered that 70.61% (Table:8.32) of concentration of silt presence in downstream of dam surplus and tail race channel from Pauk power house will be having particle size 0.15 mm and below.

## Conclusions

Based on four years of sediment observations at Mechuka, it is observed that particles of size less than 600 microns are present in suspended form in water samples but majority of suspended sediments are less than 150 microns.

Suspended sediments of size 150 micron and below are likely to remain in suspension even after storage at Pauk reservoir and may flow downstream of Pauk dam either through the turbine or through the spillway.

Volume of sediment inflowing into Pauk reservoir is about 566,500 m<sup>3</sup>/year (Table:8.48) comprising of 485,700m<sup>3</sup> of suspended sediment and 80,800 m<sup>3</sup> of bed load. Sedimentation in



Pauk reservoir is about 29.39% ( $142,800\text{m}^3$ ) of suspended sediment and 100% ( $80,800\text{ m}^3$ ) of bed load, considering particle size more than 0.15 mm will be settled. Sediment volume flowing downstream of Pauk reservoir is about  $342,900\text{m}^3$  per year.

Annual average flow at Pauk dam annual yield is 2649. Average annual sediment concentration downstream of Pauk dam is about 126 ppm-

All sediment particles of size 200 microns and above are expected to settle in Pauk reservoir and therefore there is no impact of sediment particles is expected on design of Pauk powerhouse.

### **Heo Sedimentation Studies**

Heo barrage is proposed about 3.5 km downstream of Pauk Dam. The catchment area at Heo barrage location is about  $1065\text{ km}^2$ . Downstream of Pauk dam, the contribution to flow at Heo barrage is from additional catchment area of about  $83\text{ km}^2$ . For sedimentation study at Heo barrage, it is presumed that Pauk dam is in place and accordingly, the total sediments are contributed by following flows:

- Flow from Pauk dam comprising of:
  - Flows from Pauk Power house tail race
  - Surplus flows from spillway in Pauk Dam
- Intermediate catchment flows from an area of about  $83\text{ km}^2$

Based on sedimentation study at Pauk dam site as discussed above, it can be concluded that particles of size 150 micron and above are expected to settle in the Pauk reservoir and only particles below 150 micron are passed downstream either through Pauk HEP or in the surplus water through the spillway at Pauk dam. Flow from intermediate catchment is however likely to carry sediments even bigger than 150 microns.

#### **8.8.14.1 Quantifying sediment load**

As discussed in Pauk reservoir siltation process only particles size 0.15mm and below flow in the form of surplus and Tail race channel flows. The percentage of 0.15mm and below contained is only 59.2% of concentration.

- Total sediment yield per annum at Pauk reservoir = 566 500 cum
- Sediment volume having particle size 0.15mm and below = 342,900 cum

Considering intermediate Yarjep and Sae Chu nallah catchment area similar to mountainous catchment and attributing rate of sedimentation as 0.88mm /year including 20% bed load,

Annual sediment load from intermediate catchment =  $83 \times 10^6 \times 0.88/1000 = 73\,040\text{ cum}$

Annual Sediment load in suspension from intermediate catchment =  $73\,040/1.20 = 60867\text{ cum}$

- Annual bed load sediments at 20% of suspended load from intermediate catchment = 12173 cum
- Total annual average sediment yield at Heo Barrage site =  $342900 + 73040 = 416,000$  cum
- Catchment area at Heo HEP barrage =  $1065 \text{ km}^2$
- Annual average sediment rate at Heo HEP Barrage site =  $416000 / 1065 \times 10^6 = 0.39 \text{ mm/year}$

#### 8.8.14.2 Sediment Concentration at Heo Barrage location

A total of 51 water samples containing suspended sediments were collected at Heo barrage location in the year 2012 for determining sediment concentration and for grain size distribution of suspended sediments.

**Table 8.54**

Description	Days	%
Total sampling days	180	
No. of days with zero ppm	129	71.6
ppm <150	31	17.2
ppm >150 and <500	0	0
ppm >500 and <1000	4	2.2
ppm >1000 and <2000	15	8.4
ppm >2000 and <3000	1	0.6
ppm >3000	0	0

It is observed that Yarjep River at Heo Barrage has suspended sediment for about 51 days in a year. Yarjep River carries sediment concentration greater than 150 ppm for a maximum period of 20 days per year. Maximum observed concentration of suspended particles is 2300 ppm. As seen from table 8.54, (from AIMIL results), about 80 % of suspended sediments observed at Heo Barrage location are smaller than 0.2 mm.

From results of grain size distribution at Mechuka and Heo barrage, it can be concluded that the intermediate catchment between Pauk dam location and Puring (near Heo barrage) carries sediment particles only marginally bigger than sediment particles of Mechuka. The total amount of sediment yield at Heo barrage with particle size 0.2 mm and above is computed considering water released from Pauk reservoir has sediments particle of size 150 micron and below. Thus the entire sediment load having particles of size above 200 microns is contributed by intermediate catchment.

Sediment yield of suspended sediments from intermediate catchment	=	60867cum
% of sediments from intermediate catchment having particle size 200 micron and above	=	20%
Sediment yield at Heo barrage, having particle size 200 microns and above	=	12,200 cum

The sediment yield at Heo barrage for particles of size 0.2 mm and above for year 2012 is thus estimated as 12,200 cum. As per study for sediment yield at Mechuka, sediment yield in 2010 is about 2 times more than sediment yield during 2012. The maximum amount of sediment yield at Heo barrage for particle size 0.2 mm and above can therefore be expected as 25000 cum and is not likely to have any significant impact on design of Heo and Tato 1 HEP.

### Conclusions

- Heo HEP Barrage site receives discharges with low concentration of suspended particles during normal operation of Pauk HEP.
- Annual sediment yield at Heo barrage site is estimated as 416,000 cum comprising of 343,000 cum of suspended sediments and 73,000 cum of bed load sediments.
- As per grain size distribution study undertaken in 2012, the suspended load contains about 80% of sediments of size smaller than 0.20mm.
- It is evident that the presence of Pauk reservoir will further deplete the presence of suspended sediments of particle size 0.15 mm and above and also result in lower percentage of sediment concentration.
- Maximum annual sediment yield at Heo barrage for particles having particle size of 0.2 mm and above is expected as 25000 cum and is not likely to have any significant impact on design of Heo and Tato-1 powerhouse.
- However as a precautionary measure spare runners with protective coat of tungsten carbide will be provided to counter unforeseen erosion.

### Appendices

- Appendix-A = CWC Approved Flow Series
- Appendix-B = Design Flood Computation
- Appendix-C = IMD Report
- Appendix-D = Silt Measurements
- Appendix-E = Sedimentation Reports
- Appendix-F = List of References

**APPENDIX D**

**Silt measurement at Menchuka Bridge from July 1<sup>st</sup> 2009 until June 30<sup>th</sup> 2011  
and from June 1<sup>st</sup> 2012 until December 31<sup>st</sup> 2012**

Date	Water	Silt concentration (ppm)
01/07/2009	Muddy	3.3
02/07/2009	Clear	0.0
03/07/2009	Muddy	2.9
04/07/2009	Muddy	4.0
05/07/2009	Clear	0.0
06/07/2009	Clear	0.0
07/07/2009	Muddy	1.4
08/07/2009	Clear	0.0
09/07/2009	Muddy	1.3
10/07/2009	Muddy	3.3
11/07/2009	Clear	0.0
12/07/2009	Clear	0.0
13/07/2009	Clear	0.0
14/07/2009	Clear	0.0
15/07/2009	Clear	0.0
16/07/2009	Clear	0.0
17/07/2009	Clear	0.0
18/07/2009	Muddy	1.7
19/07/2009	Clear	0.0
20/07/2009	Clear	0.0
21/07/2009	Clear	0.0
22/07/2009	Clear	0.0
23/07/2009	Clear	0.0
24/07/2009	Clear	0.0
25/07/2009	Muddy	231.7
26/07/2009	Muddy	22.9
27/07/2009	Muddy	28.6
28/07/2009	Muddy	1.7
29/07/2009	Muddy	16.3
30/07/2009	Clear	0.0
31/07/2009	Clear	0.0
01/08/2009	Muddy	4.0
02/08/2009	Clear	0.0
03/08/2009	Clear	0.0
04/08/2009	Clear	0.0
05/08/2009	Clear	0.0
06/08/2009	Muddy	230.0
07/08/2009	Clear	0.0
08/08/2009	Clear	0.0
09/08/2009	Muddy	15.7
10/08/2009	Clear	0.0
11/08/2009	Clear	0.0
12/08/2009	Clear	0.0
13/08/2009	Clear	0.0
14/08/2009	Clear	0.0
15/08/2009	Muddy	54.0

16/08/2009	Clear	0.0
17/08/2009	Muddy	18.3
18/08/2009	Muddy	194.0
19/08/2009	Muddy	8.3
20/08/2009	Muddy	5.7
21/08/2009	Clear	0.0
22/08/2009	Muddy	5.0
23/08/2009	Clear	0.0
24/08/2009	Clear	0.0
25/08/2009	Clear	0.0
26/08/2009	Clear	0.0
27/08/2009	Clear	0.0
28/08/2009	Clear	0.0
29/08/2009	Clear	0.0
30/08/2009	Clear	0.0
31/08/2009	Clear	0.0
01/09/2009	Clear	0.0
02/09/2009	Clear	0.0
03/09/2009	Clear	0.0
04/09/2009	Clear	0.0
05/09/2009	Clear	0.0
06/09/2009	Clear	0.0
07/09/2009	Clear	0.0
08/09/2009	Muddy	261.7
09/09/2009	Clear	0.0
10/09/2009	Clear	0.0
11/09/2009	Muddy	15.7
12/09/2009	Clear	0.0
13/09/2009	Muddy	405.0
14/09/2009	Clear	0.0
15/09/2009	Clear	0.0
16/09/2009	Clear	0.0
17/09/2009	Muddy	26.7
18/09/2009	Muddy	28.6
19/09/2009	Clear	0.0
20/09/2009	Muddy	150.0
21/09/2009	Clear	0.0
22/09/2009	Clear	0.0
23/09/2009	Clear	0.0
24/09/2009	Clear	0.0
25/09/2009	Clear	0.0
26/09/2009	Clear	0.0
27/09/2009	Clear	0.0
28/09/2009	Clear	0.0
29/09/2009	Clear	0.0
30/09/2009	Clear	0.0
01/10/2009	Clear	0.0
02/10/2009	Clear	0.0
03/10/2009	Clear	0.0
04/10/2009	Clear	0.0
05/10/2009	Clear	0.0

06/10/2009	Clear	0.0
07/10/2009	Clear	0.0
08/10/2009	Clear	0.0
09/10/2009	Clear	0.0
10/10/2009	Clear	0.0
11/10/2009	Clear	0.0
12/10/2009	Clear	0.0
13/10/2009	Clear	0.0
14/10/2009	Clear	0.0
15/10/2009	Clear	0.0
16/10/2009	Clear	0.0
17/10/2009	Clear	0.0
18/10/2009	Clear	0.0
19/10/2009	Clear	0.0
20/10/2009	Clear	0.0
21/10/2009	Clear	0.0
22/10/2009	Clear	0.0
23/10/2009	Clear	0.0
24/10/2009	Clear	0.0
25/10/2009	Clear	0.0
26/10/2009	Clear	0.0
27/10/2009	Clear	0.0
28/10/2009	Clear	0.0
29/10/2009	Clear	0.0
30/10/2009	Clear	0.0
31/10/2009	Clear	0.0
01/11/2009	Clear	0.0
02/11/2009	Clear	0.0
03/11/2009	Clear	0.0
04/11/2009	Clear	0.0
05/11/2009	Clear	0.0
06/11/2009	Clear	0.0
07/11/2009	Clear	0.0
08/11/2009	Clear	0.0
09/11/2009	Clear	0.0
10/11/2009	Clear	0.0
11/11/2009	Clear	0.0
12/11/2009	Clear	0.0
13/11/2009	Clear	0.0
14/11/2009	Clear	0.0
15/11/2009	Clear	0.0
16/11/2009	Clear	0.0
17/11/2009	Clear	0.0
18/11/2009	Clear	0.0
19/11/2009	Clear	0.0
20/11/2009	Clear	0.0
21/11/2009	Clear	0.0
22/11/2009	Clear	0.0
23/11/2009	Clear	0.0
24/11/2009	Clear	0.0
25/11/2009	Clear	0.0



26/11/2009	Clear	0.0
27/11/2009	Clear	0.0
28/11/2009	Clear	0.0
29/11/2009	Clear	0.0
30/11/2009	Clear	0.0
01/12/2009	Clear	0.0
02/12/2009	Clear	0.0
03/12/2009	Clear	0.0
04/12/2009	Clear	0.0
05/12/2009	Clear	0.0
06/12/2009	Clear	0.0
07/12/2009	Clear	0.0
08/12/2009	Clear	0.0
09/12/2009	Clear	0.0
10/12/2009	Clear	0.0
11/12/2009	Clear	0.0
12/12/2009	Clear	0.0
13/12/2009	Clear	0.0
14/12/2009	Clear	0.0
15/12/2009	Clear	0.0
16/12/2009	Clear	0.0
17/12/2009	Clear	0.0
18/12/2009	Clear	0.0
19/12/2009	Clear	0.0
20/12/2009	Clear	0.0
21/12/2009	Clear	0.0
22/12/2009	Clear	0.0
23/12/2009	Clear	0.0
24/12/2009	Clear	0.0
25/12/2009	Clear	0.0
26/12/2009	Clear	0.0
27/12/2009	Clear	0.0
28/12/2009	Clear	0.0
29/12/2009	Clear	0.0
30/12/2009	Clear	0.0
31/12/2009	Clear	0.0
01/01/2010	Clear	0.0
02/01/2010	Clear	0.0
03/01/2010	Clear	0.0
04/01/2010	Clear	0.0
05/01/2010	Clear	0.0
06/01/2010	Clear	0.0
07/01/2010	Clear	0.0
08/01/2010	Clear	0.0
09/01/2010	Clear	0.0
10/01/2010	Clear	0.0
11/01/2010	Clear	0.0
12/01/2010	Clear	0.0
13/01/2010	Clear	0.0
14/01/2010	Clear	0.0
15/01/2010	Clear	0.0



16/01/2010	Clear	0.0
17/01/2010	Clear	0.0
18/01/2010	Clear	0.0
19/01/2010	Clear	0.0
20/01/2010	Clear	0.0
21/01/2010	Clear	0.0
22/01/2010	Clear	0.0
23/01/2010	Clear	0.0
24/01/2010	Clear	0.0
25/01/2010	Clear	0.0
26/01/2010	Clear	0.0
27/01/2010	Clear	0.0
28/01/2010	Clear	0.0
29/01/2010	Clear	0.0
30/01/2010	Clear	0.0
31/01/2010	Clear	0.0
01/02/2010	Clear	0.0
02/02/2010	Clear	0.0
03/02/2010	Clear	0.0
04/02/2010	Clear	0.0
05/02/2010	Clear	0.0
06/02/2010	Clear	0.0
07/02/2010	Clear	0.0
08/02/2010	Clear	0.0
09/02/2010	Clear	0.0
10/02/2010	Clear	0.0
11/02/2010	Clear	0.0
12/02/2010	Clear	0.0
13/02/2010	Clear	0.0
14/02/2010	Clear	0.0
15/02/2010	Clear	0.0
16/02/2010	Clear	0.0
17/02/2010	Clear	0.0
18/02/2010	Clear	0.0
19/02/2010	Clear	0.0
20/02/2010	Clear	0.0
21/02/2010	Clear	0.0
22/02/2010	Clear	0.0
23/02/2010	Clear	0.0
24/02/2010	Clear	0.0
25/02/2010	Clear	0.0
26/02/2010	Clear	0.0
27/02/2010	Clear	0.0
28/02/2010	Clear	0.0
01/03/2010	Clear	0.0
02/03/2010	Clear	0.0
03/03/2010	Clear	0.0
04/03/2010	Clear	0.0
05/03/2010	Clear	0.0
06/03/2010	Clear	0.0
07/03/2010	Clear	0.0

08/03/2010	Clear	0.0
09/03/2010	Clear	0.0
10/03/2010	Clear	0.0
11/03/2010	Clear	0.0
12/03/2010	Clear	0.0
13/03/2010	Clear	0.0
14/03/2010	Clear	0.0
15/03/2010	Clear	0.0
16/03/2010	Clear	0.0
17/03/2010	Clear	0.0
18/03/2010	Clear	0.0
19/03/2010	Clear	0.0
20/03/2010	Clear	0.0
21/03/2010	Clear	0.0
22/03/2010	Clear	0.0
23/03/2010	Clear	0.0
24/03/2010	Clear	0.0
25/03/2010	Clear	0.0
26/03/2010	Clear	0.0
27/03/2010	Muddy	11.7
28/03/2010	Clear	0.0
29/03/2010	Clear	0.0
30/03/2010	Clear	0.0
31/03/2010	Clear	0.0
01/04/2010	Clear	0.0
02/04/2010	Clear	0.0
03/04/2010	Clear	0.0
04/04/2010	Clear	0.0
05/04/2010	Clear	0.0
06/04/2010	Clear	0.0
07/04/2010	Clear	0.0
08/04/2010	Clear	0.0
09/04/2010	Clear	0.0
10/04/2010	Clear	0.0
11/04/2010	Clear	0.0
12/04/2010	Clear	0.0
13/04/2010	Clear	0.0
14/04/2010	Clear	0.0
15/04/2010	Clear	0.0
16/04/2010	Clear	0.0
17/04/2010	Clear	0.0
18/04/2010	Clear	0.0
19/04/2010	Clear	0.0
20/04/2010	Clear	0.0
21/04/2010	Clear	0.0
22/04/2010	Clear	0.0
23/04/2010	Muddy	74.0
24/04/2010	Clear	0.0
25/04/2010	Clear	0.0
26/04/2010	Clear	0.0
27/04/2010	Clear	0.0

28/04/2010	Clear	0.0
29/04/2010	Clear	0.0
30/04/2010	Clear	0.0
01/05/2010	Clear	0.0
02/05/2010	Clear	0.0
03/05/2010	Clear	0.0
04/05/2010	Clear	0.0
05/05/2010	Clear	0.0
06/05/2010	Clear	0.0
07/05/2010	Clear	0.0
08/05/2010	Clear	0.0
09/05/2010	Clear	0.0
10/05/2010	Clear	0.0
11/05/2010	Muddy	73.3
12/05/2010	Muddy	188.0
13/05/2010	Clear	0.0
14/05/2010	Clear	0.0
15/05/2010	Muddy	115.0
16/05/2010	Clear	0.0
17/05/2010	Clear	0.0
18/05/2010	Clear	0.0
19/05/2010	Clear	0.0
20/05/2010	Clear	0.0
21/05/2010	Muddy	3.3
22/05/2010	Clear	0.0
23/05/2010	Clear	0.0
24/05/2010	Clear	0.0
25/05/2010	Clear	0.0
26/05/2010	Clear	0.0
27/05/2010	Clear	0.0
28/05/2010	Clear	0.0
29/05/2010	Clear	0.0
30/05/2010	Clear	0.0
31/05/2010	Muddy	5.0
01/06/2010	Muddy	162.0
02/06/2010	Clear	0.0
03/06/2010	Clear	0.0
04/06/2010	Clear	0.0
05/06/2010	Muddy	451.7
06/06/2010	Clear	0.0
07/06/2010	Clear	0.0
08/06/2010	Clear	0.0
09/06/2010	Clear	0.0
10/06/2010	Clear	0.0
11/06/2010	Clear	0.0
12/06/2010	Clear	0.0
13/06/2010	Clear	0.0
14/06/2010	Muddy	530.0
15/06/2010	Clear	0.0
16/06/2010	Clear	0.0
17/06/2010	Clear	0.0



18/06/2010	Clear	0.0
19/06/2010	Clear	0.0
20/06/2010	Clear	0.0
21/06/2010	Clear	0.0
22/06/2010	Clear	0.0
23/06/2010	Muddy	466.7
24/06/2010	Muddy	616.7
25/06/2010	Clear	0.0
26/06/2010	Clear	0.0
27/06/2010	Clear	0.0
28/06/2010	Clear	0.0
29/06/2010	Clear	0.0
30/06/2010	Clear	0.0
01/07/2010	Muddy	1 178.0
02/07/2010	Clear	0.0
03/07/2010	Clear	0.0
04/07/2010	Clear	0.0
05/07/2010	Clear	0.0
06/07/2010	Clear	0.0
07/07/2010	Clear	0.0
08/07/2010	Clear	0.0
09/07/2010	Clear	0.0
10/07/2010	Clear	0.0
11/07/2010	Clear	0.0
12/07/2010	Clear	0.0
13/07/2010	Clear	0.0
14/07/2010	Clear	0.0
15/07/2010	Clear	0.0
16/07/2010	Clear	0.0
17/07/2010	Clear	0.0
18/07/2010	Clear	0.0
19/07/2010	Clear	0.0
20/07/2010	Clear	0.0
21/07/2010	Clear	0.0
22/07/2010	Clear	0.0
23/07/2010	Clear	0.0
24/07/2010	Clear	0.0
25/07/2010	Clear	0.0
26/07/2010	Muddy	763.3
27/07/2010	Clear	0.0
28/07/2010	Clear	0.0
29/07/2010	Clear	0.0
30/07/2010	Muddy	600.0
31/07/2010	Clear	0.0
01/08/2010	Clear	0.0
02/08/2010	Clear	0.0
03/08/2010	Clear	0.0
04/08/2010	Clear	0.0
05/08/2010	Clear	0.0
06/08/2010	Clear	0.0
07/08/2010	Clear	0.0

08/08/2010	Clear	0.0
09/08/2010	Clear	0.0
10/08/2010	Muddy	916.7
11/08/2010	Muddy	1 600.0
12/08/2010	Clear	0.0
13/08/2010	Clear	0.0
14/08/2010	Clear	0.0
15/08/2010	Clear	0.0
16/08/2010	Muddy	550.0
17/08/2010	Clear	0.0
18/08/2010	Clear	0.0
19/08/2010	Clear	0.0
20/08/2010	Clear	0.0
21/08/2010	Muddy	658.6
22/08/2010	Muddy	433.3
23/08/2010	Muddy	1 065.0
24/08/2010	Muddy	1 957.0
25/08/2010	Clear	0.0
26/08/2010	Clear	0.0
27/08/2010	Clear	0.0
28/08/2010	Clear	0.0
29/08/2010	Clear	0.0
30/08/2010	Clear	0.0
31/08/2010	Clear	0.0
01/09/2010	Clear	0.0
02/09/2010	Clear	0.0
03/09/2010	Clear	0.0
04/09/2010	Clear	0.0
05/09/2010	Clear	0.0
06/09/2010	Clear	0.0
07/09/2010	Clear	0.0
08/09/2010	Clear	0.0
09/09/2010	Clear	0.0
10/09/2010	Clear	0.0
11/09/2010	Clear	0.0
12/09/2010	Clear	0.0
13/09/2010	Clear	0.0
14/09/2010	Clear	0.0
15/09/2010	Clear	0.0
16/09/2010	Clear	0.0
17/09/2010	Clear	0.0
18/09/2010	Clear	0.0
19/09/2010	Clear	0.0
20/09/2010	Clear	0.0
21/09/2010	Clear	0.0
22/09/2010	Clear	0.0
23/09/2010	Clear	0.0
24/09/2010	Clear	0.0
25/09/2010	Clear	0.0
26/09/2010	Clear	0.0
27/09/2010	Clear	0.0

28/09/2010	Clear	0.0
29/09/2010	Clear	0.0
30/09/2010	Clear	0.0
01/10/2010	Clear	0.0
02/10/2010	Clear	0.0
03/10/2010	Clear	0.0
04/10/2010	Clear	0.0
05/10/2010	Clear	0.0
06/10/2010	Clear	0.0
07/10/2010	Clear	0.0
08/10/2010	Clear	0.0
09/10/2010	Clear	0.0
10/10/2010	Clear	0.0
11/10/2010	Clear	0.0
12/10/2010	Clear	0.0
13/10/2010	Clear	0.0
14/10/2010	Clear	0.0
15/10/2010	Clear	0.0
16/10/2010	Clear	0.0
17/10/2010	Clear	0.0
18/10/2010	Clear	0.0
19/10/2010	Clear	0.0
20/10/2010	Clear	0.0
21/10/2010	Clear	0.0
22/10/2010	Clear	0.0
23/10/2010	Clear	0.0
24/10/2010	Clear	0.0
25/10/2010	Clear	0.0
26/10/2010	Clear	0.0
27/10/2010	Clear	0.0
28/10/2010	Clear	0.0
29/10/2010	Clear	0.0
30/10/2010	Clear	0.0
31/10/2010	Clear	0.0
01/11/2010	Clear	0.0
02/11/2010	Clear	0.0
03/11/2010	Clear	0.0
04/11/2010	Clear	0.0
05/11/2010	Clear	0.0
06/11/2010	Clear	0.0
07/11/2010	Clear	0.0
08/11/2010	Clear	0.0
09/11/2010	Clear	0.0
10/11/2010	Clear	0.0
11/11/2010	Clear	0.0
12/11/2010	Clear	0.0
13/11/2010	Clear	0.0
14/11/2010	Clear	0.0
15/11/2010	Clear	0.0
16/11/2010	Clear	0.0
17/11/2010	Clear	0.0



18/11/2010	Clear	0.0
19/11/2010	Clear	0.0
20/11/2010	Clear	0.0
21/11/2010	Clear	0.0
22/11/2010	Clear	0.0
23/11/2010	Clear	0.0
24/11/2010	Clear	0.0
25/11/2010	Clear	0.0
26/11/2010	Clear	0.0
27/11/2010	Clear	0.0
28/11/2010	Clear	0.0
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01/12/2010	Clear	0.0
02/12/2010	Clear	0.0
03/12/2010	Clear	0.0
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06/01/2011	Clear	0.0
07/01/2011	Clear	0.0



08/01/2011	Clear	0.0
09/01/2011	Clear	0.0
10/01/2011	Clear	0.0
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18/01/2011	Clear	0.0
19/01/2011	Clear	0.0
20/01/2011	Clear	0.0
21/01/2011	Clear	0.0
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24/01/2011	Clear	0.0
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26/01/2011	Clear	0.0
27/01/2011	Clear	0.0
28/01/2011	Clear	0.0
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04/02/2011	Clear	0.0
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26/02/2011	Clear	0.0
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28/02/2011	Clear	0.0
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06/03/2011	Clear	0.0
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08/03/2011	Clear	0.0
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14/04/2011	Clear	0.0
15/04/2011	Clear	0.0
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18/04/2011	Clear	0.0
19/04/2011	Clear	0.0

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06/05/2011	clear	0.0
07/05/2011	clear	0.0
08/05/2011	clear	0.0
09/05/2011	clear	0.0
10/05/2011	clear	0.0
11/05/2011	clear	0.0
12/05/2011	clear	0.0
13/05/2011	clear	0.0
14/05/2011	clear	0.0
15/05/2011	clear	0.0
16/05/2011	clear	0.0
17/05/2011	clear	0.0
18/05/2011	clear	0.0
19/05/2011	clear	0.0
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21/05/2011	clear	0.0
22/05/2011	clear	0.0
23/05/2011	muddy	70.17
24/05/2011	muddy	68.42
25/05/2011	clear	0.0
26/05/2011	clear	0.0
27/05/2011	clear	0.0
28/05/2011	clear	0.0
29/05/2011	clear	0.0
30/05/2011	clear	0.0
31/05/2011	clear	0.0
01/06/2011	muddy	170.60
02/06/2011	clear	0.0
03/06/2011	clear	0.0
04/06/2011	clear	0.0
05/06/2011	muddy	519.14
06/06/2011	muddy	868.33
07/06/2011	clear	0.0
08/06/2011	clear	0.0
09/06/2011	clear	0.0

10/06/2011	clear	0.0
11/06/2011	muddy	624.29
12/06/2011	muddy	764.83
13/06/2011	clear	0.0
14/06/2011	clear	0.0
15/06/2011	clear	0.0
16/06/2011	clear	0.0
17/06/2011	clear	0.0
18/06/2011	clear	0.0
19/06/2011	clear	0.0
20/06/2011	clear	0.0
21/06/2011	muddy	259.43
22/06/2011	clear	0.0
23/06/2011	clear	0.0
24/06/2011	muddy	270.17
25/06/2011	clear	0.0
26/06/2011	clear	0.0
27/06/2011	clear	0.0
28/06/2011	clear	0.0
29/06/2011	clear	0.0
30/06/2011	clear	0.0

Date	Water	Concentration (ppm)
01-06-2012	Clear	
02-06-2012	Clear	
03-06-2012	Clear	
04-06-2012	Clear	
05-06-2012	Clear	
06-06-2012	Clear	
07-06-2012	Clear	
08-06-2012	Clear	
09-06-2012	Clear	
10-06-2012	Clear	
11-06-2012	Clear	
12-06-2012	Clear	
13-06-2012	Clear	
14-06-2012	Clear	
15-06-2012	Clear	
16-06-2012	Clear	
17-06-2012	Clear	
18-06-2012	Clear	
19-06-2012	Clear	
20-06-2012	Clear	
21-06-2012	Clear	
22-06-2012	Clear	
23-06-2012	Clear	
24-06-2012	Clear	
25-06-2012	Clear	
26-06-2012	Clear	
27-06-2012	Clear	
28-06-2012	Clear	
29-06-2012	Clear	
30-06-2012	Clear	
01-07-2012	Clear	
02-07-2012	Clear	
03-07-2012	Clear	
04-07-2012	Clear	
05-07-2012	Clear	
06-07-2012	Clear	
07-07-2012	Clear	
08-07-2012	Clear	
09-07-2012	Clear	
10-07-2012	Clear	
11-07-2012	Clear	
12-07-2012	Clear	
13-07-2012	Clear	
14-07-2012	Clear	
15-07-2012	Clear	
16-07-2012	Clear	
17-07-2012	Clear	
18-07-2012	Clear	
19-07-2012	Clear	

20-07-2012	Clear	
21-07-2012	Clear	
22-07-2012	Clear	
23-07-2012	Clear	
24-07-2012	Muddy	12
25-07-2012	Muddy	656
26-07-2012	Muddy	8
27-07-2012	Muddy	8
28-07-2012	Muddy	4
29-07-2012	Muddy	10
30-07-2012	Muddy	7
31-07-2012	Muddy	2
01-08-2012	Clear	
02-08-2012	Clear	
03-08-2012	Clear	
04-08-2012	Clear	
05-08-2012	Clear	
06-08-2012	Clear	
07-08-2012	Muddy	2
08-08-2012	Muddy	669
09-08-2012	Muddy	8
10-08-2012	Muddy	29
11-08-2012	Muddy	1259
12-08-2012	Muddy	407
13-08-2012	Muddy	9
14-08-2012	Muddy	9
15-08-2012	Muddy	1
16-08-2012	Muddy	3
17-08-2012	Clear	
18-08-2012	Clear	
19-08-2012	Clear	
20-08-2012	Clear	
21-08-2012	Clear	
22-08-2012	Muddy	167
23-08-2012	Muddy	1
24-08-2012	Muddy	131
25-08-2012	Muddy	1023
26-08-2012	Clear	
27-08-2012	Clear	
28-08-2012	Clear	
29-08-2012	Muddy	1
30-08-2012	Clear	
31-08-2012	Muddy	1449
01-09-2012	Clear	
02-09-2012	Clear	
03-09-2012	Clear	
04-09-2012	Clear	
05-09-2012	Clear	
06-09-2012	Clear	



07-09-2012	Clear	
08-09-2012	Clear	
09-09-2012	Clear	
10-09-2012	Clear	
11-09-2012	Clear	
12-09-2012	Clear	
13-09-2012	Clear	
14-09-2012	Clear	
15-09-2012	Clear	
16-09-2012	Muddy	217
17-09-2012	Muddy	863
18-09-2012	Muddy	228
19-09-2012	Muddy	154
20-09-2012	Clear	
21-09-2012	Muddy	310
22-09-2012	Muddy	104
23-09-2012	Muddy	18
24-09-2012	Muddy	550
25-09-2012	Muddy	171
26-09-2012	Muddy	16
27-09-2012	Clear	
28-09-2012	Clear	
29-09-2012	Clear	
30-09-2012	Muddy	8
01-10-2012	Muddy	16
02-10-2012	Muddy	10
03-10-2012	Muddy	12
04-10-2012	Clear	
05-10-2012	Muddy	12
06-10-2012	Muddy	62
07-10-2012	Clear	
08-10-2012	Clear	
09-10-2012	Clear	
10-10-2012	Muddy	8
11-10-2012	Muddy	16
12-10-2012	Muddy	470
13-10-2012	Muddy	756
14-10-2012	Muddy	15
15-10-2012	Clear	
16-10-2012	Muddy	20
17-10-2012	Clear	
18-10-2012	Clear	
19-10-2012	Clear	
20-10-2012	Clear	
21-10-2012	Clear	
22-10-2012	Clear	
23-10-2012	Clear	
24-10-2012	Clear	
25-10-2012	Clear	



26-10-2012	Clear	
27-10-2012	Clear	
28-10-2012	Clear	
29-10-2012	Clear	
30-10-2012	Clear	
31-10-2012	Clear	
01-11-2012	Clear	
02-11-2012	Clear	
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04-11-2012	Clear	
05-11-2012	Clear	
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07-11-2012	Clear	
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26-11-2012	Clear	
27-11-2012	Clear	
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08-12-2012	Clear	
09-12-2012	Clear	
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12-12-2012	Clear	
13-12-2012	Clear	
14-12-2012	Clear	

15-12-2012	Clear	
16-12-2012	Clear	
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18-12-2012	Clear	
19-12-2012	Clear	
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21-12-2012	Clear	
22-12-2012	Clear	
23-12-2012	Clear	
24-12-2012	Clear	
25-12-2012	Clear	
26-12-2012	Clear	
27-12-2012	Clear	
28-12-2012	Clear	
29-12-2012	Clear	
30-12-2012	Clear	
31-12-2012	Clear	

**APPENDIX E**

**Sedimentation Reports**



ADVANCED TECHNOLOGY  
&  
ENGINEERING SERVICES  
A Division of Aimil Ltd



Aimil Ltd.  
Infrastructure & Technology

## **Report on Sedimentometric Study on Samples from Yarjep River HEP in West Siang District in Arunachal Pradesh**

### **1.0 Introduction**

The client Velcan Energy India (VE) Pvt. Ltd., G-77, Sujan Singh Park, New Delhi-110003 entrusted the assignment to undertake the sedimentometric study on the river load samples from Yarjep river, HEP in West Siang District in Arunachal Pradesh to Advanced Technology and Engineering Services (ATES) (a division of AIMIL Ltd.), A8, Naimex House, Mohan Cooperative Industrial Estate, Mathura Road, New Delhi-110044 vide Work order 2: Sedimentological tests on samples from Yarjep river HEP in West Siang district in Arunachal Pradesh dated 17<sup>th</sup> March, 2011.

### **2.0 Scope of work**

The following are the scope of work mutually agreed to undertake sedimentometric study on samples from Yarjep river in Arunachal Pradesh.

- Grain size analysis
  - Sieve analysis-Particle size distribution
- Sedimentometric study (Wet Analysis)
  - Silt and clay contents
  - Mean diameter ( $D_{50}$  in mm)
- To carry out test on samples
- Compilation of test results
- Analysis on test results
- Concluding remarks

### **3.0 Supply of samples for testing in ATES Laboratory**

The client (VE) delivered 18 samples collected from various locations of Yarjep river, HEP in West Siang district in Arunachal Pradesh instead of 20 samples on 22<sup>nd</sup> March, 2011. The list is reproduced with the weight of samples received from the party and are given in Table1.

Table1: List of samples received

Sample	Location/Project	Date	Bank	Additional Information	Wt. of samples received in lab.
1	Mechukha	25-02-2011	Right	Under the bridge interior meander 50 cm above water level	745.5 gm
2	Mechukha	25-02-2011	Right	Under the bridge interior meander 30 cm below water level Speed: 0 m/s	745.5 gm
3	Mechukha	25-02-2011	Left	Under the bridge exterior meander outside the river Speed: 22 cm/s	773.5 gm
4	Pauk Dam Beach	25-02-2011	Right	50 cm above water level behind a boulder Speed: approx 1 m/s	1355.5 gm
5	Heo Dam Beach	26-02-2011	Left	Upstream axis exterior meander 30 cm below water level Speed: approx 1 m/s	432.5 gm
6	Hoo Dam Beach	26-02-2011	Left	Upstream axis exterior meander 20 cm below water level Speed: approx 1 m/s	1116.0 gm
7	Tato I Intake	27-02-2011	Left	Upstream small sample in very small pond beside the river 50 cm above the river Speed: approx 1.5 m/s	286.5 gm
8	Tato I Intake	27-02-2011	Right	Downstream 50 cm above water level	1015.5 gm
53		23-06-2010	n/a	Concentration: 467 ppm	0.12 gm
54		24-06-2010	n/a	Concentration: 617 ppm	1.07 gm
55		01-07-2010	n/a	Concentration: 1178 ppm	Samples not delivered
56		26-07-2010	n/a	Concentration: 764 ppm	0.18 gm
57		30-07-2010	n/a	Concentration: 600 ppm	2.542 gm
58		10-08-2010	n/a	Concentration: 917 ppm	1.826 gm
59		11-08-2010	n/a	Concentration: 1600 ppm	6.844 gm
60		16-08-2010	n/a	Concentration: 550 ppm	Samples not delivered
61		21-08-2010	n/a	Concentration: 659 ppm	1.958 gm
62		22-08-2010	n/a	Concentration: 433 ppm	0.438 gm
63		23-08-2010	n/a	Concentration: 1065 ppm	2.312 gm
64		24-08-2010	n/a	Concentration: 1957 ppm	0.434 gm



#### 4.0 Sedimentometric Study

The theory of sedimentation is based on the fact that large particles in suspension in liquid settle more quickly than small particles assuming all particles have similar densities and shapes. The velocity which a falling particle eventually reaches is known as its terminal velocity. If the particles are approximately spherical, velocity (V) and particle diameter (D) is given by Stokes Law. This states that the terminal velocity is proportional to the square of the diameter. The relationship is given below

$$V \propto D^2$$

All sedimentology methods like the pipette method, hydrometer method and laser particle size analyser are based on Stokes equation and laser diffraction method respectively. The results of sedimentometric study are dependable on spherical shape and density. It is mentioned that the particles finer than 75 micron were studied using pipette method followed internationally.

#### 5.0 Test on Samples for Sedimentometric Study

##### 5.1 Coarse samples

Eight numbers of samples (Sample nos. 1-8) were taken to carry out grain size analysis by dry sieving method according to IS:2720 (Part 4)1985: Methods of test for soils Part 4 Grains size analysis and the percentage passing through 75 micron IS sieve were separately taken to determine the percentage of silt and clay fractions using pipette method as per IS: 2720-Part 4-1985. The results on particle size distribution along with sedimentometric study (Wet analysis) as obtained are tabulated in Tables 2 to 9. Similarly on the basis of grain size analysis, the particle size distribution plots alongwith mean diameter ( $D_{50}$ -mm) are shown in Figs 1 to 8.

##### 5.2 Finer Samples

Ten samples (Sample nos. 53, 54, 56, 57, 58, 59, 61, 62, 63 and 64) collected from various locations by the client mentioning concentration were received in small quantities (Table 1) and all were found finer than 150 micron. Accordingly grain size analysis were first carried out using IS sieves 150 micron and 75 micron as per IS: 2720-Part 4-1985. Thereafter sedimentometric studies were carried out using pipette method for determining silt and clay contents.

The results on particle size distribution by dry sieve analysis and wet analysis (pipette method) are tabulated in Tables 10 to 19. The particle size distribution plots indicating silt and clay fractions along with mean diameter ( $D_{50}$ -mm) are shown in Figs 9 to 18).

#### 6.0 Test results

The sedimentometric study carried out in the ATES laboratory were compiled and tabulated in Tables 2 to 19 and the particle size distribution plots are shown in Figs. 1 to 18 and are self explanatory.

## 7.0 Concluding Remarks

Based on experimental results for sedimentometric study carried out, the following concluding remarks are offered:

- For coarser samples (Sample nos. 1-8) the silt content passing 75 micron which also contain minor percentage of clay fraction vary from 0.22 percent to 15.76 percent (Tables 2-9 and Figs. 1-8)
- The mean diameters ( $D_{50}$ -mm) as evaluated are also found in the range of 0.41 mm to 10.71 mm (Figs. 1-8). The  $D_{50}$  are varying from location to location.
- In case of finer samples the silt contents were found varying from 10.4 percent to 85.8 percent with low content of clay fractions (Tables 9 to 18 and Figs. 8 to 18)
- The mean diameter ( $D_{50}$ -mm) were found in the range of 0.03 mm – 0.11 mm indicating variation from location to location.
- The sedimentometric study provides an insight into sedimentological characteristics of samples collected from Yarjep river would prove useful database to the client.
- The report relates to 18 samples delivered to ATES Laboratory. Any change in location will require fresh study.

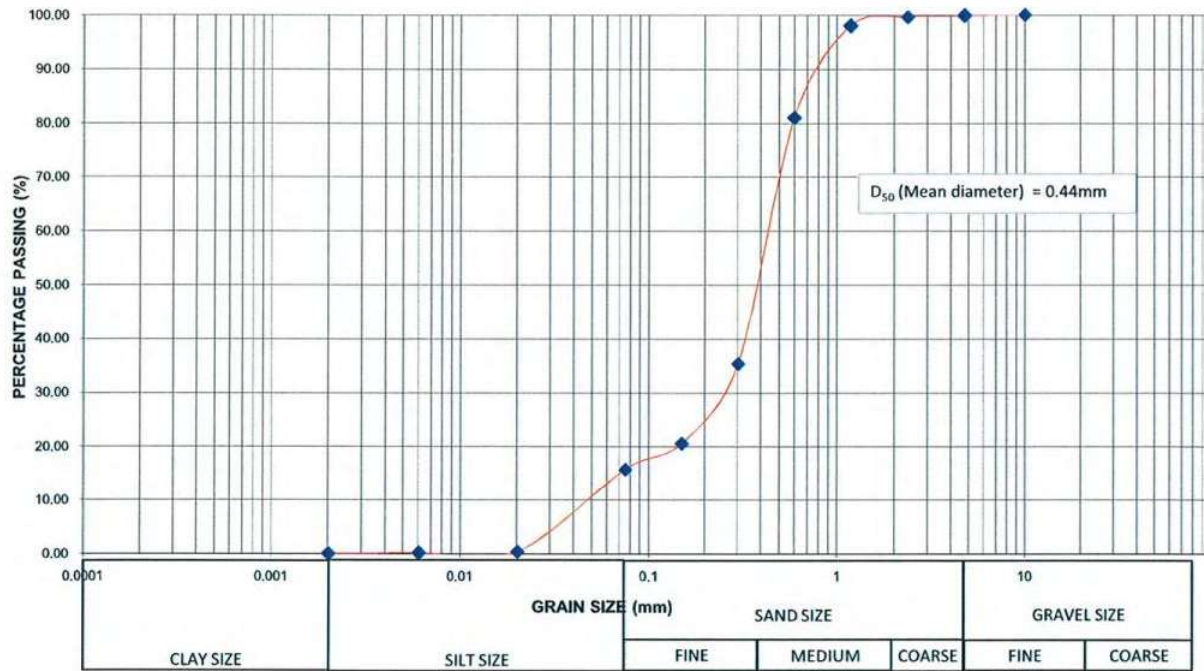


## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 1, Mechukha: Right bank  
 Weight of Sample received : 745.5 g

**Table No. 2: Result of Grain size Analysis of sample no. 1, Mechukha: Right bank**

IS Sieve Designation	% Passing	Remarks
10mm	100.00	Dry Sieve Analysis
4.75 mm	99.87	
2.36 mm	99.60	
1.18 mm	97.99	
600 $\mu$ m	81.02	
300 $\mu$ m	35.35	
150 $\mu$ m	20.59	
75 $\mu$ m	15.76	
20 $\mu$ m	0.34	Wet Analysis (Pipette Method)
6 $\mu$ m	0.09	
2 $\mu$ m	0.02	



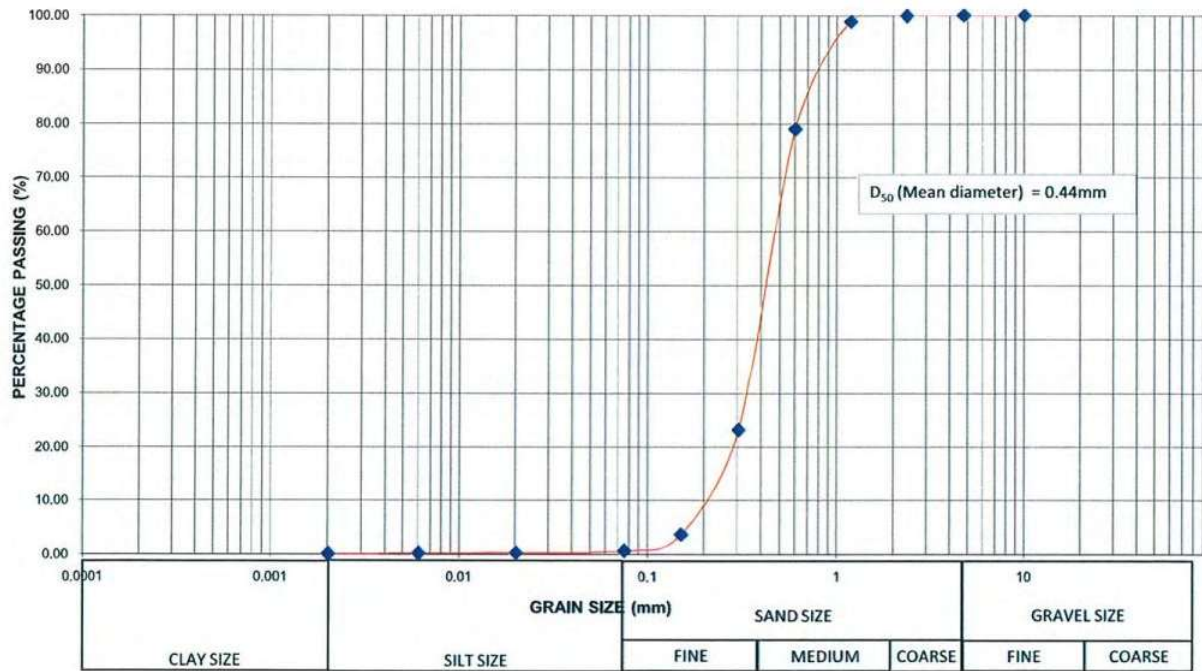
**Fig. No.01: Particle size distribution curve of sample no.1, Mechukha: Right bank**

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 2, Mechukha: Right bank  
 Weight of Sample received : 745.5 g

**Table No. 3: Result of Grain size Analysis of sample no. 2, Mechukha: Right bank**

IS Sieve Designation	% Passing	Remarks
10mm	100.00	Dry Sieve Analysis
4.75 mm	100.00	
2.36 mm	99.87	
1.18 mm	98.86	
600 $\mu$ m	79.07	
300 $\mu$ m	23.21	
150 $\mu$ m	3.62	
75 $\mu$ m	0.60	Wet Analysis (Pipette Method)
20 $\mu$ m	0.22	
6 $\mu$ m	0.09	
2 $\mu$ m	0.00	



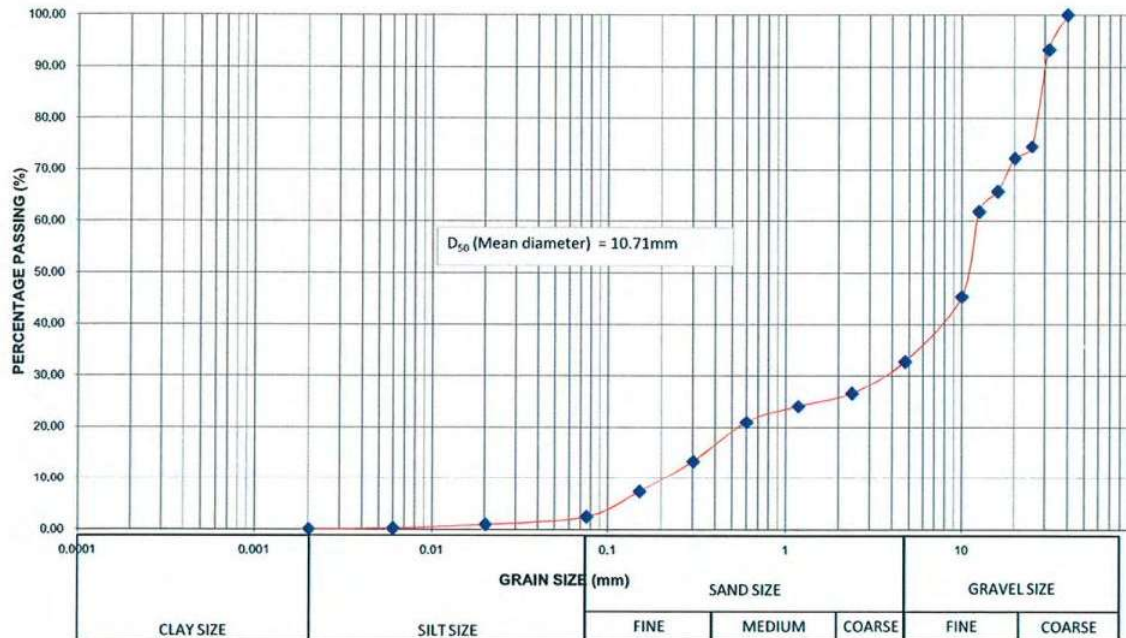
**Fig. No.02: Particle size distribution curve sample no. 2, Mechukha: Right bank**

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 3, Mechukha: Left bank  
 Weight of Sample received : 773.5 g

**Table No. 4: Result of Grain size Analysis of sample no. 3, Mechukha: Left bank**

IS Sieve Designation	% Passing	Remarks
40mm	100.000	Dry Sieve Analysis
31.5mm	93.277	
25mm	74.531	
20mm	72.140	
16mm	65.676	
12.5mm	61.797	
10mm	45.314	
4.75 mm	32.644	
2.36 mm	26.568	
1.18 mm	24.111	
600 $\mu$ m	21.008	
300 $\mu$ m	13.381	
150 $\mu$ m	7.369	
75 $\mu$ m	2.392	
20 $\mu$ m	0.850	Wet Analysis (Pipette Method)
6 $\mu$ m	0.130	
2 $\mu$ m	0.040	



**Fig. No.03: Particle size distribution curve of sample no. 3, Mechukha: Left bank**

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 4, Pauk Dam Beach: Rght bank  
 Weight of Sample received : 1355.5 g

**Table No. 5: Result of Grain size Analysis of sample no. 4,  
 Pauk Dam Beach: Rght bank**

IS Sieve Designation	% Passing	Remarks
40mm	100.000	Dry Sieve Analysis
31.5mm	94.135	
25mm	90.668	
20mm	88.307	
16mm	86.536	
12.5mm	82.257	
10mm	72.704	
4.75 mm	50.572	
2.36 mm	40.133	
1.18 mm	32.055	
600 µm	21.210	
300 µm	5.976	
150 µm	1.549	
75 µm	0.221	Wet Analysis (Pipette Method)
20 µm	0.070	
6 µm	0.040	
2 µm	0.010	

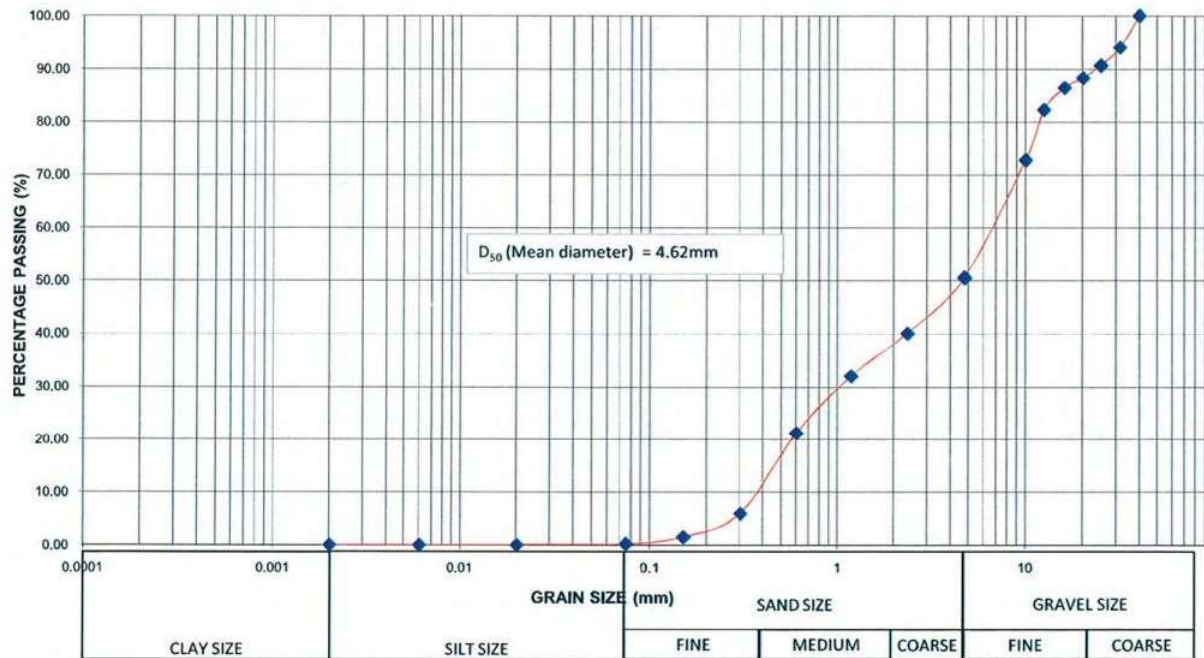


Fig. No.04: Particle size distribution curve of sample no. 4, Pauk Dam Beach: Rght bank



## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 5, Heo Dam Beach: Left bank  
 Weight of Sample received : 432.5 g

**Table No. 6: Result of Grain size Analysis of sample no. 5,**  
**Heo Dam Beach: Left bank**

IS Sieve Designation	% Passing	Remarks
10mm	100.00	Dry Sieve Analysis
4.75 mm	98.84	
2.36 mm	95.38	
1.18 mm	88.55	
600 $\mu$ m	71.79	
300 $\mu$ m	28.44	
150 $\mu$ m	7.86	
75 $\mu$ m	1.27	
20 $\mu$ m	0.29	Wet Analysis (Pipette Method)
6 $\mu$ m	0.11	
2 $\mu$ m	0.05	

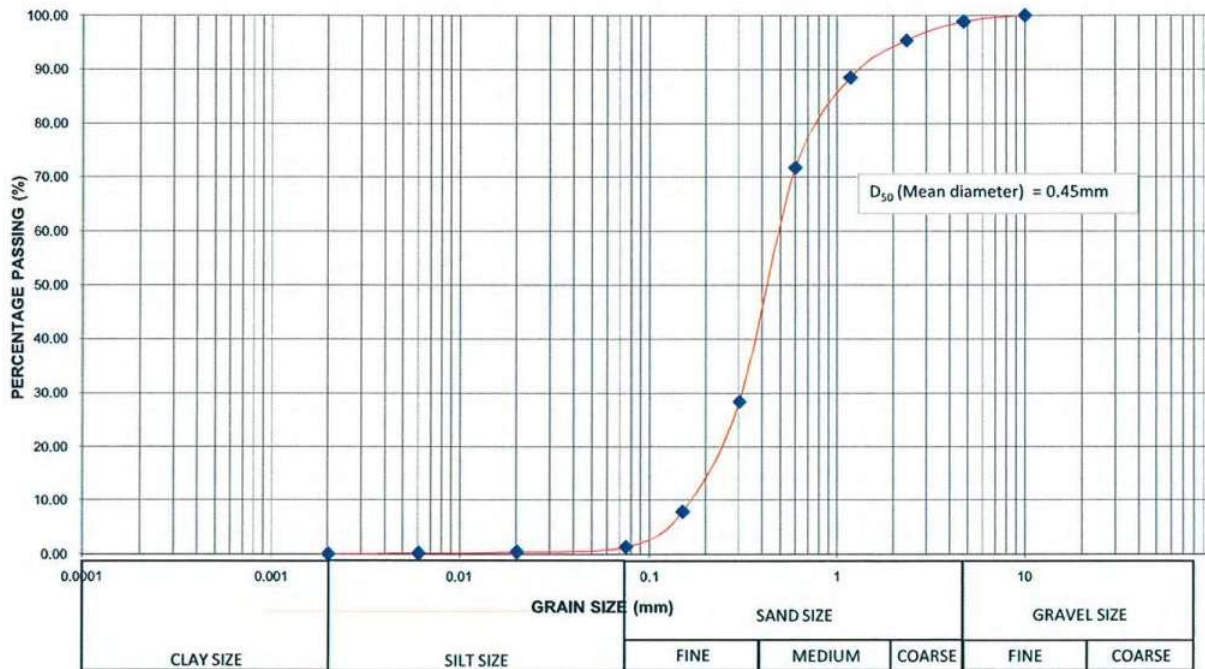


Fig. No.05: Particle size distribution curve of sample no. 5, Heo Dam Beach: Left bank

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 6, Heo Dam Beach: Left bank  
 Weight of Sample received : 1116 g

**Table No. 7: Result of Grain size Analysis of sample no. 6,**  
**Heo Dam Beach: Left bank**

IS Sieve Designation	% Passing	Remarks
12.5mm	100.00	Dry Sieve Analysis
10mm	99.28	
4.75 mm	98.61	
2.36 mm	97.85	
1.18 mm	96.64	
600 $\mu$ m	87.05	
300 $\mu$ m	29.84	
150 $\mu$ m	5.06	
75 $\mu$ m	0.45	
20 $\mu$ m	0.29	
6 $\mu$ m	0.11	Wet Analysis (Pipette Method)
2 $\mu$ m	0.05	

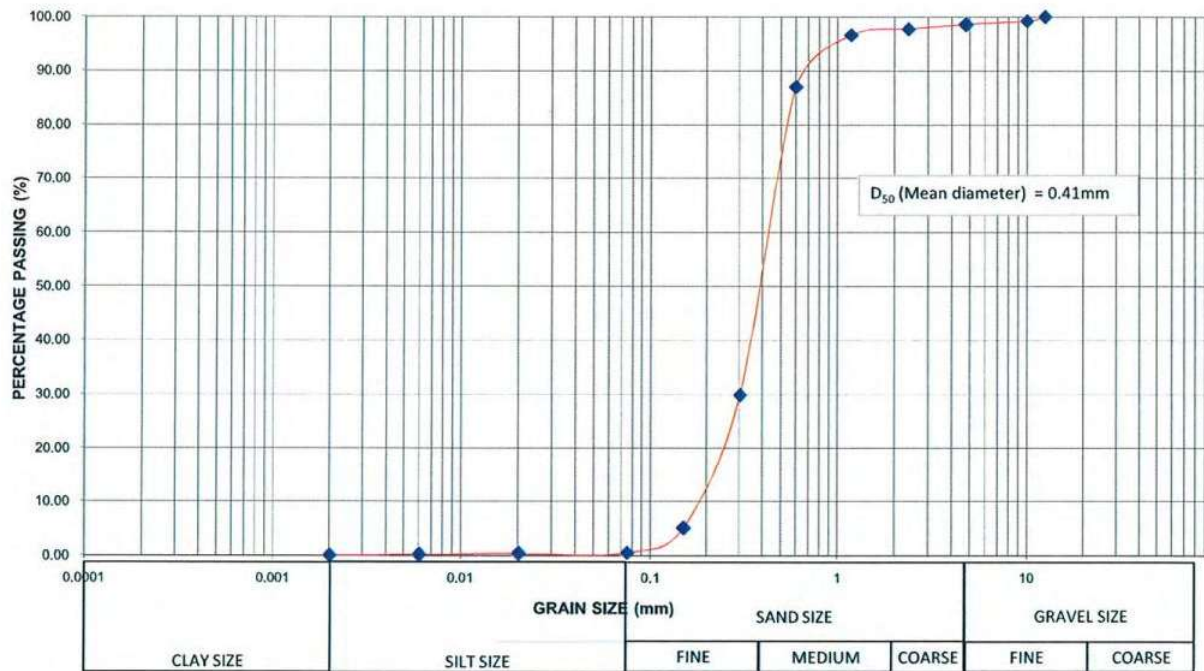


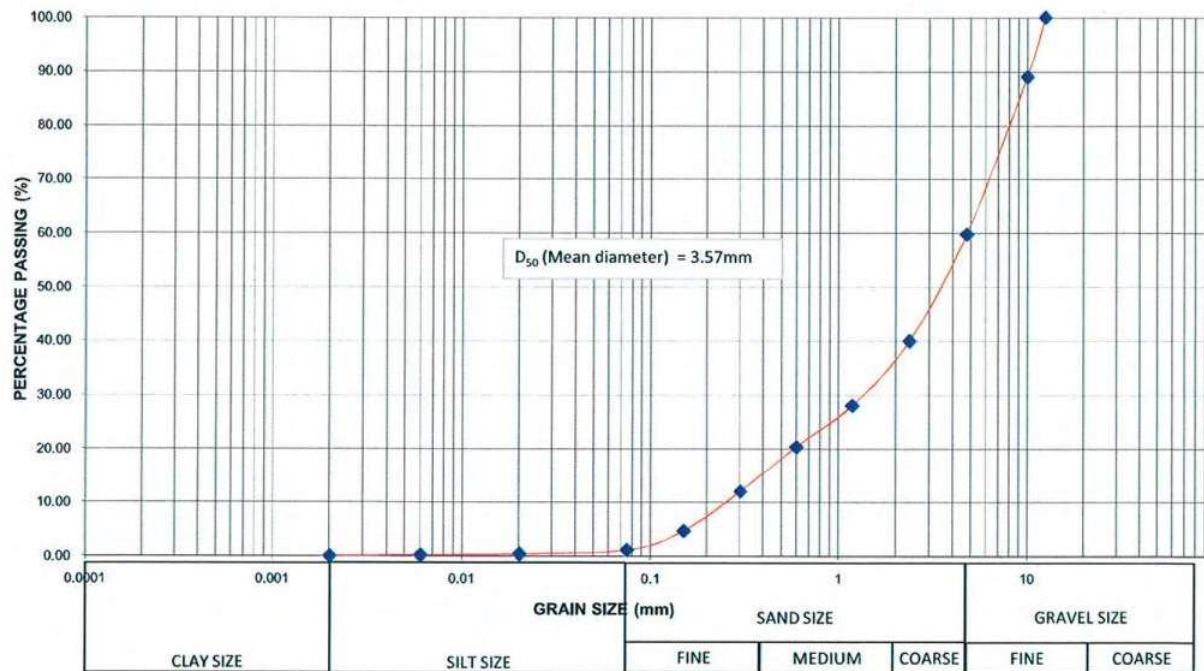
Fig. No.06: Particle size distribution curve of sample no. 6, Heo Dam Beach: Left bank

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 7, Tato 1 Intake: Left bank  
 Weight of Sample received : 286.5 g

**Table No. 8: Result of Grain size Analysis of sample no. 7,  
Tato 1 Intake: Left bank**

IS Sieve Designation	% Passing	Remarks
12.5mm	100.00	Dry Sieve Analysis
10mm	89.01	
4.75 mm	59.86	
2.36 mm	39.97	
1.18 mm	28.10	
600 µm	20.42	
300 µm	12.04	
150 µm	4.71	
75 µm	1.05	Wet Analysis (Pipette Method)
20 µm	0.29	
6 µm	0.11	
2 µm	0.05	



**Fig. No.07: Particle size distribution curve of sample no. 7, Tato 1 Intake: Left bank**



## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 8, Tato 1 Intake: Right bank  
 Weight of Sample received : 1015.5 g

**Table No. 9: Result of Grain size Analysis of sample no. 8,**  
**Tato 1 Intake: Right bank**

IS Sieve Designation	% Passing	Remarks
16mm	100.000	Dry Sieve Analysis
12.5mm	93.944	
10mm	89.069	
4.75 mm	74.495	
2.36 mm	59.478	
1.18 mm	43.476	
600 µm	26.194	
300 µm	14.279	
150 µm	6.844	
75 µm	1.182	
20 µm	0.060	Wet Analysis (Pipette Method)
6 µm	0.030	
2 µm	0.010	

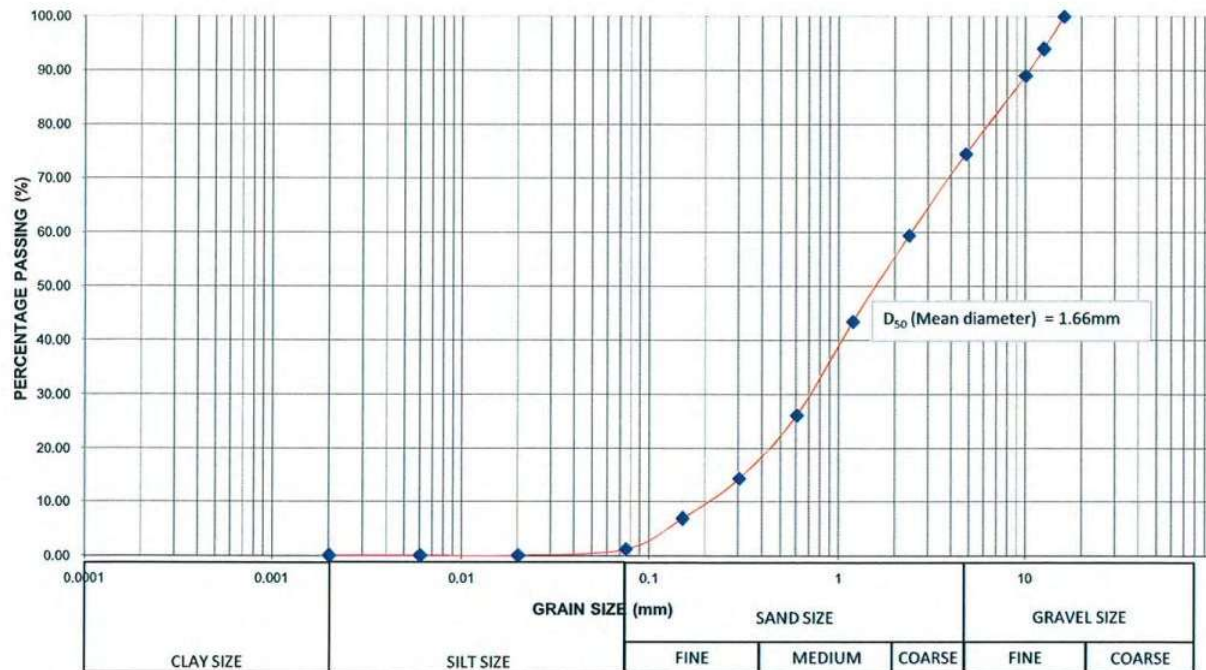


Fig. No.08: Grain size Analysis of sample no.8,Tato 1 Intake: Right bank

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 53,  
 Weight of Sample received : 0.12 g

Table No. 10: Result of Grain size Analysis of sample no.53

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	43.00	
20 $\mu$ m	0.00	
6 $\mu$ m	0.00	Wet Analysis (Pipette Method)
2 $\mu$ m	0.00	

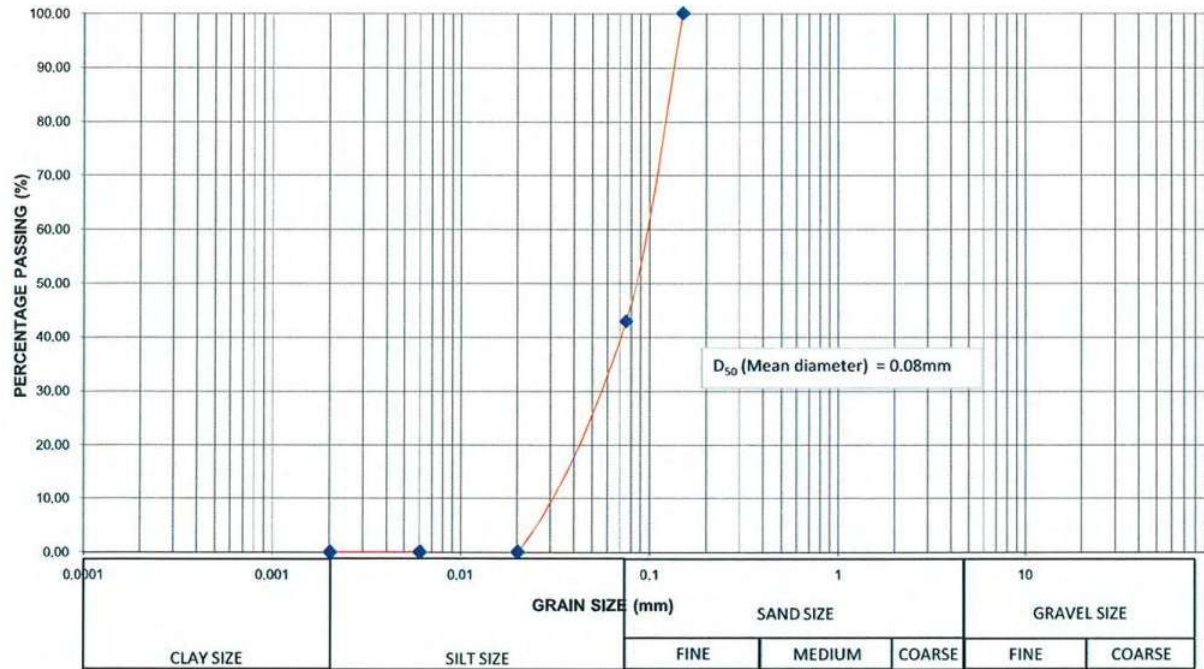


Fig. No.09: Particle size distribution curve of sample no.53

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 54,  
 Weight of Sample received : 1.079 g

Table No. 11: Result of Grain size Analysis of sample no.54

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	51.00	
20 $\mu$ m	19.83	
6 $\mu$ m	5.67	Wet Analysis (Pipette Method)
2 $\mu$ m	0.94	

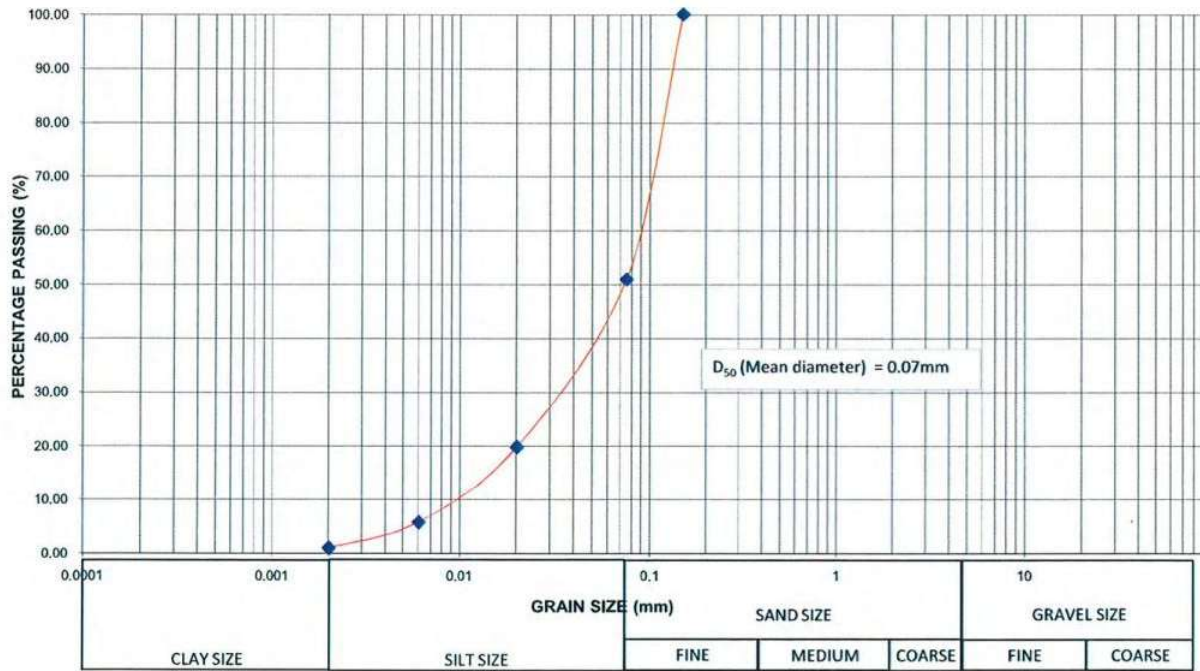


Fig. No.10: Particle size distribution curve sample no.54

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 56,  
 Weight of Sample received : 0.183 g

Table No. 12: Result of Grain size Analysis of sample no.56

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	29.10	
20 $\mu$ m	0.00	
6 $\mu$ m	0.00	Wet Analysis (Pipette Method)
2 $\mu$ m	0.00	

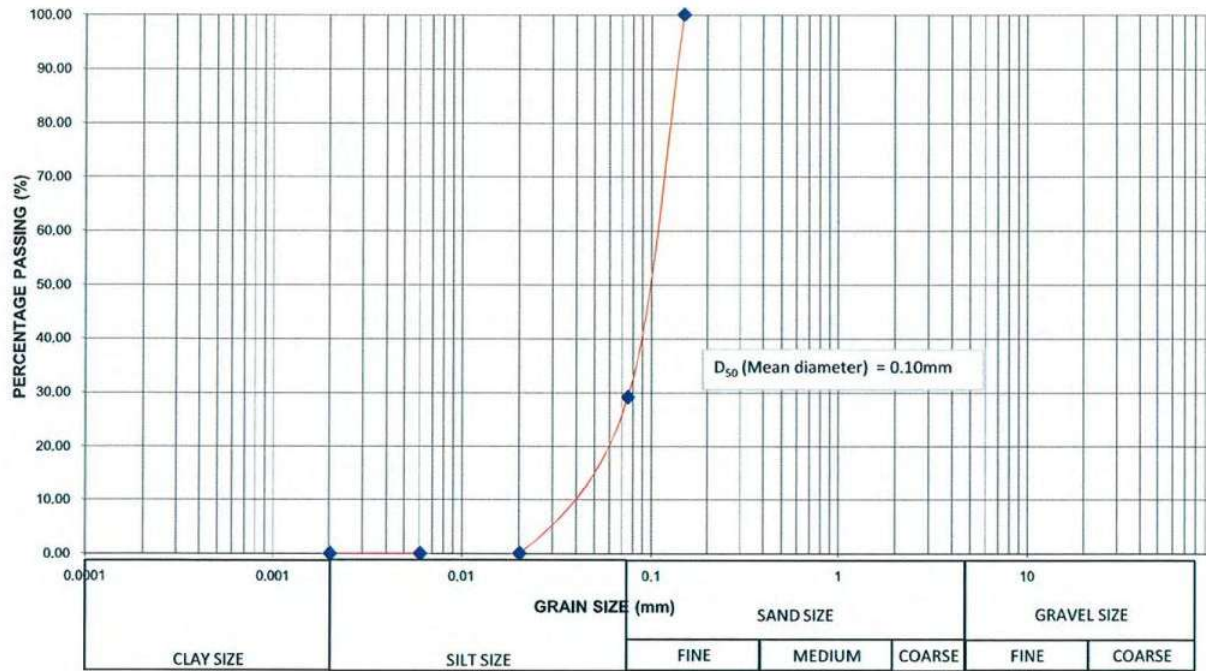


Fig. No.11: Particle size distribution curve of sample no.56

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 57,  
 Weight of Sample received : 2.542 g

Table No. 13: Result of Grain size Analysis of sample no.57

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	85.80	
20 $\mu$ m	45.77	
6 $\mu$ m	4.34	Wet Analysis (Pipette Method)
2 $\mu$ m	0.39	

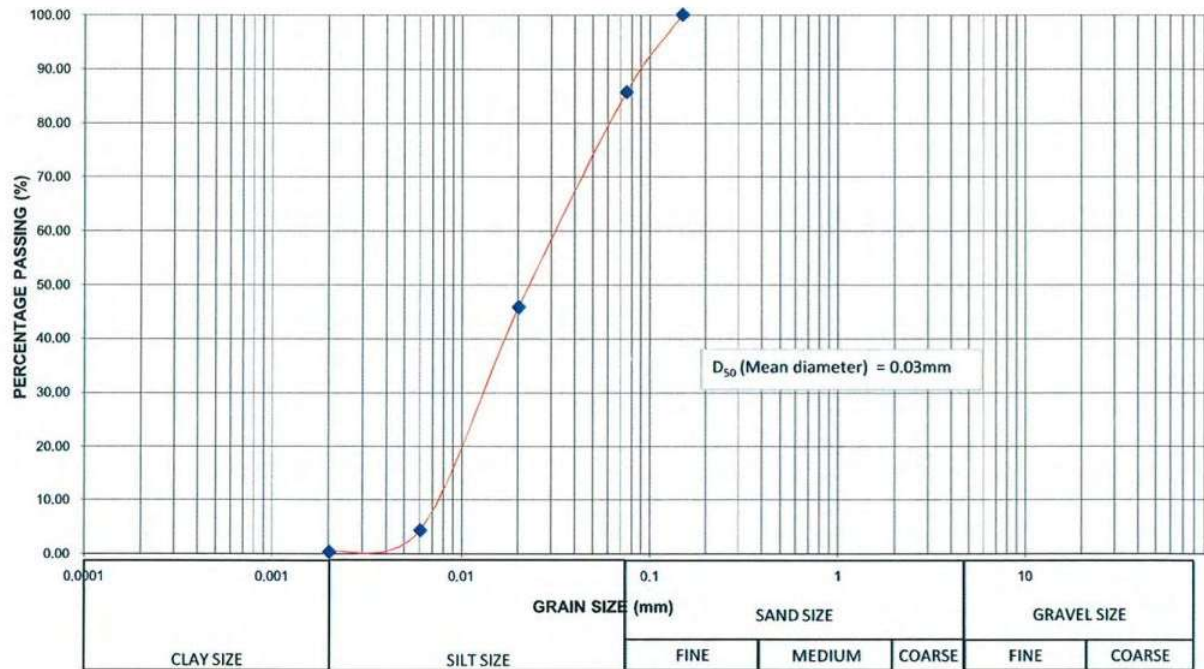


Fig. No.12: Particle size distribution curve of sample no.57



## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 58,  
 Weight of Sample received : 1.826 g

Table No. 14: Result of Grain size Analysis of sample no.58

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	85.80	
20 $\mu$ m	45.77	
6 $\mu$ m	4.34	Wet Analysis (Pipette Method)
2 $\mu$ m	0.39	

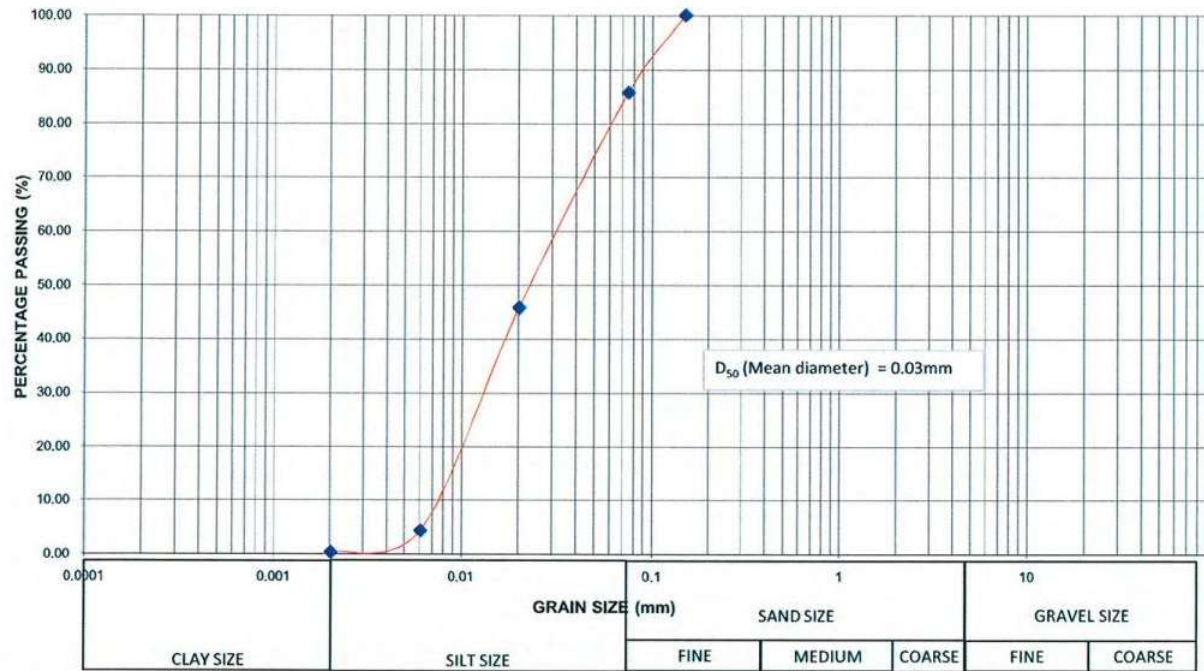


Fig. No.13: Particle size distribution curve of sample no.58



## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 59,  
 Weight of Sample received : 6.844 g

Table No. 15: Result of Grain size Analysis of sample no. 59

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	18.90	
20 $\mu$ m	4.54	
6 $\mu$ m	1.61	Wet Analysis (Pipette Method)
2 $\mu$ m	0.15	

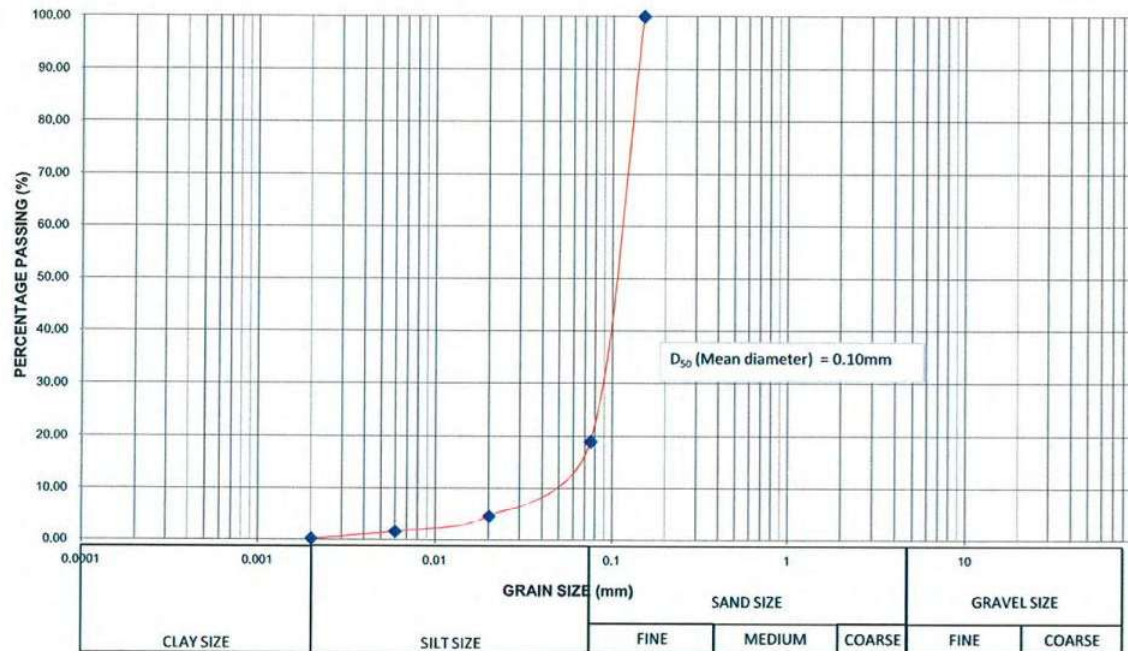


Fig. No.14: Particle size distribution curve of sample no. 59

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 61,  
 Weight of Sample received : 1.758 g

Table No. 16: Result of Grain size Analysis of sample no. 61

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	20.50	
20 $\mu$ m	7.69	
6 $\mu$ m	0.00	Wet Analysis (Pipette Method)
2 $\mu$ m	0.00	

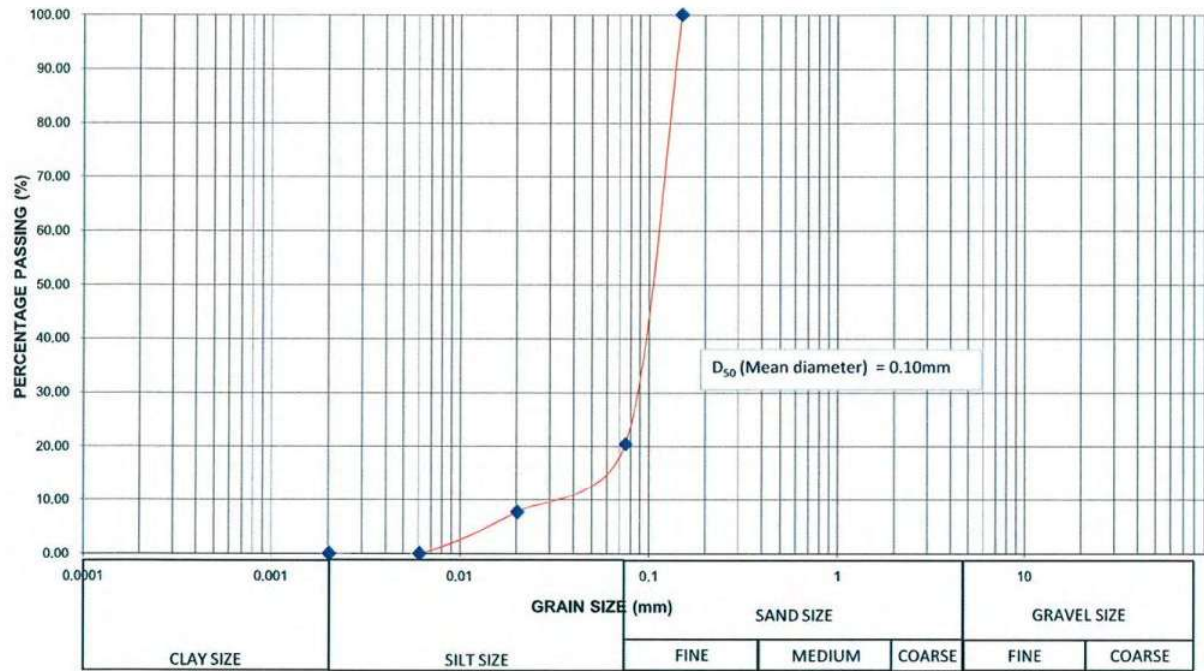


Fig. No.15: Particle size distribution curve of sample no. 61

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 62,  
 Weight of Sample received : 0.438 g

Table No. 17: Result of Grain size Analysis of sample no. 62

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	43.40	
20 $\mu$ m	0.00	
6 $\mu$ m	0.00	Wet Analysis (Pipette Method)
2 $\mu$ m	0.00	

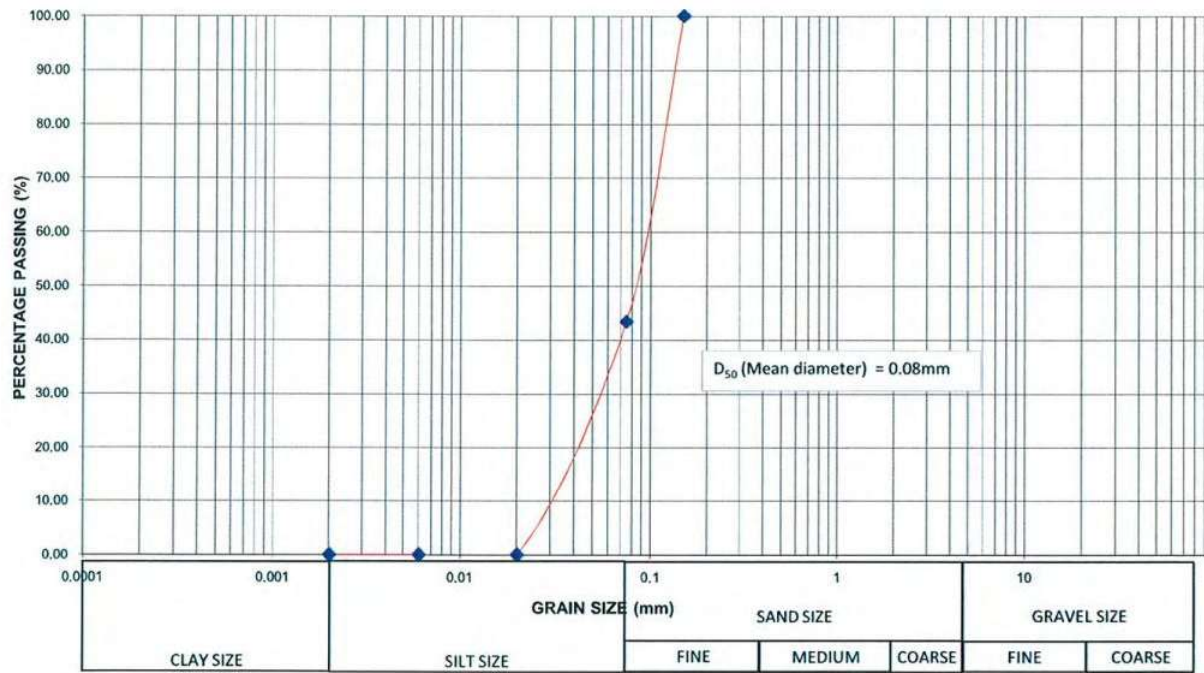


Fig. No.16: Particle size distribution curve of sample no. 62

### Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 63,  
 Weight of Sample received : 2.312 g

Table No. 18: Result of Grain size Analysis of sample no. 63

IS Sieve Designation	% Passing	Remarks
150 $\mu\text{m}$	100.00	Dry Sieve Analysis
75 $\mu\text{m}$	25.20	
20 $\mu\text{m}$	11.73	Wet Analysis (Pipette Method)
6 $\mu\text{m}$	3.04	
2 $\mu\text{m}$	0.87	

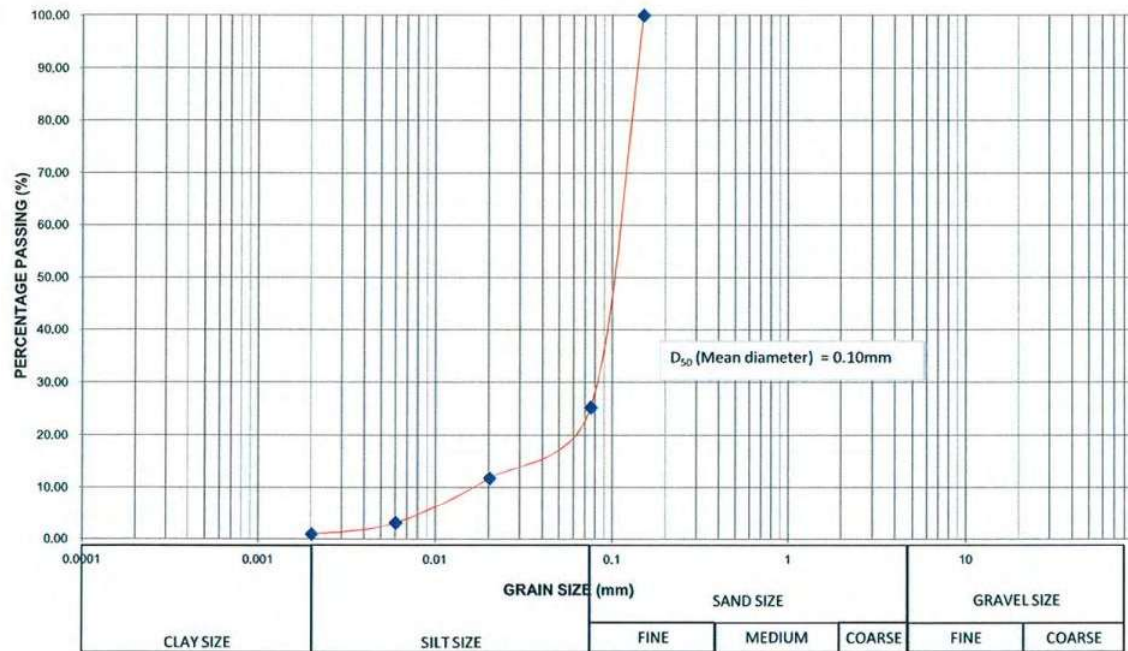


Fig. No.17: Particle size distribution curve of sample no. 63

## Grain Size Analysis

Project: Yarjep River HE Project  
 Location/ Sample ID: 64,  
 Weight of Sample received : 0.434 g

Table No. 19: Result of Grain size Analysis of sample no. 64

IS Sieve Designation	% Passing	Remarks
150 $\mu$ m	100.00	Dry Sieve Analysis
75 $\mu$ m	10.40	
20 $\mu$ m	0.00	
6 $\mu$ m	0.00	Wet Analysis (Pipette Method)
2 $\mu$ m	0.00	

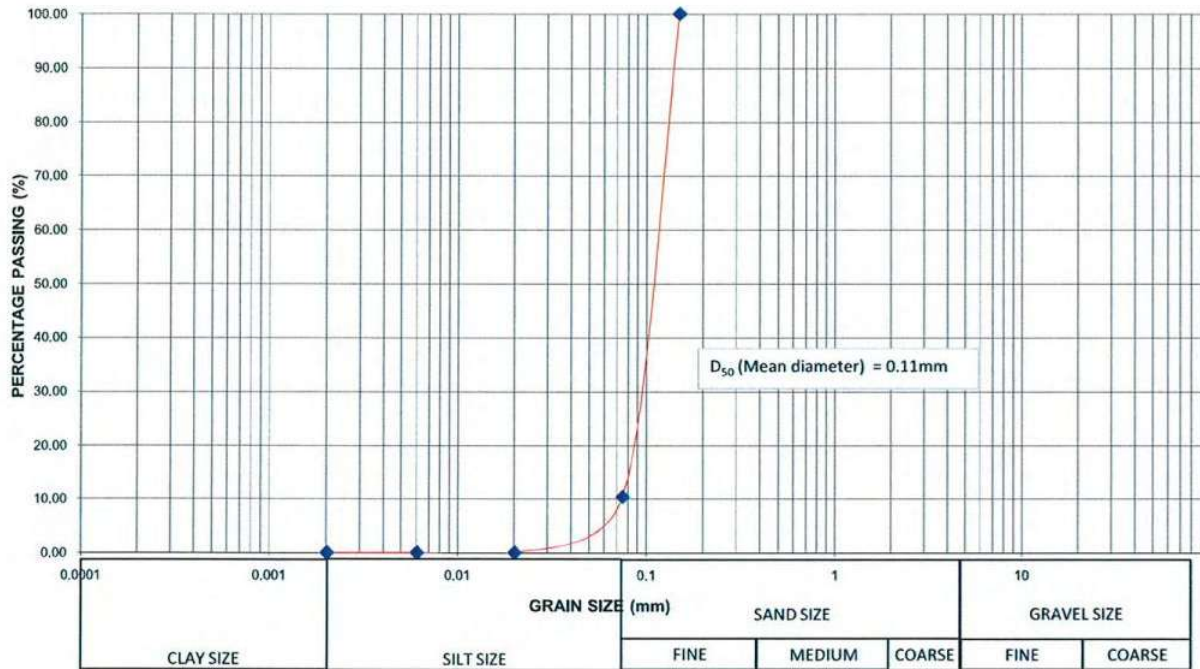


Fig. No.18: Particle size distribution curve of sample 64



Table-1: Grain Size Analysis

IS Sieve Designation	% Passing				
	Sample-1	Sample-2	Sample-3	Sample-4	Sample-5
25 mm	100.0	100.0	100.0	100.0	100.0
20 mm	100.0	96.7	100.0	100.0	100.0
16 mm	100.0	95.2	100.0	100.0	100.0
12.5 mm	100.0	94.0	100.0	100.0	100.0
10 mm	97.0	90.4	82.3	93.1	100.0
4.75 mm	87.5	76.8	55.1	77.0	98.7
2.36 mm	81.4	64.7	42.2	67.7	98.3
1.18 mm	77.9	47.1	31.6	62.5	97.0
600 $\mu$ m	75.3	21.9	18.6	52.0	84.9
300 $\mu$ m	53.2	4.3	6.3	21.4	35.6
150 $\mu$ m	21.6	1.8	3.3	8.5	8.7
75 $\mu$ m	5.6	1.3	2.2	4.0	2.4
Silt Content %	5.6	1.3	2.2	4.0	2.4

The sand samples did not contain clay fraction.

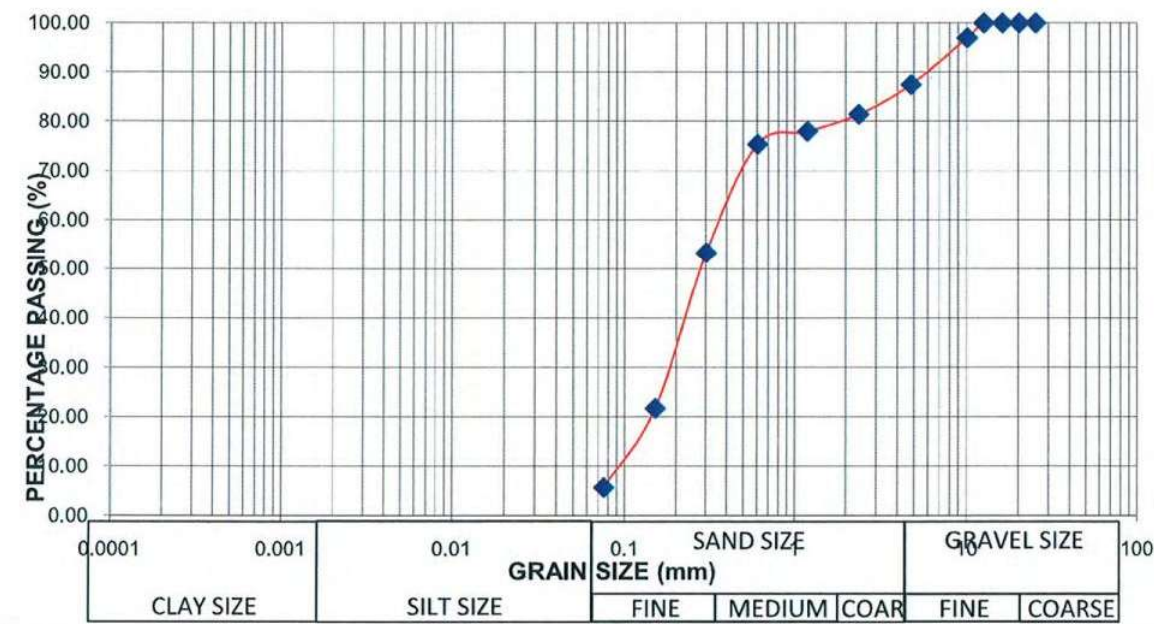


Fig.-1: Particle Size Distribution Curve of Sample-1



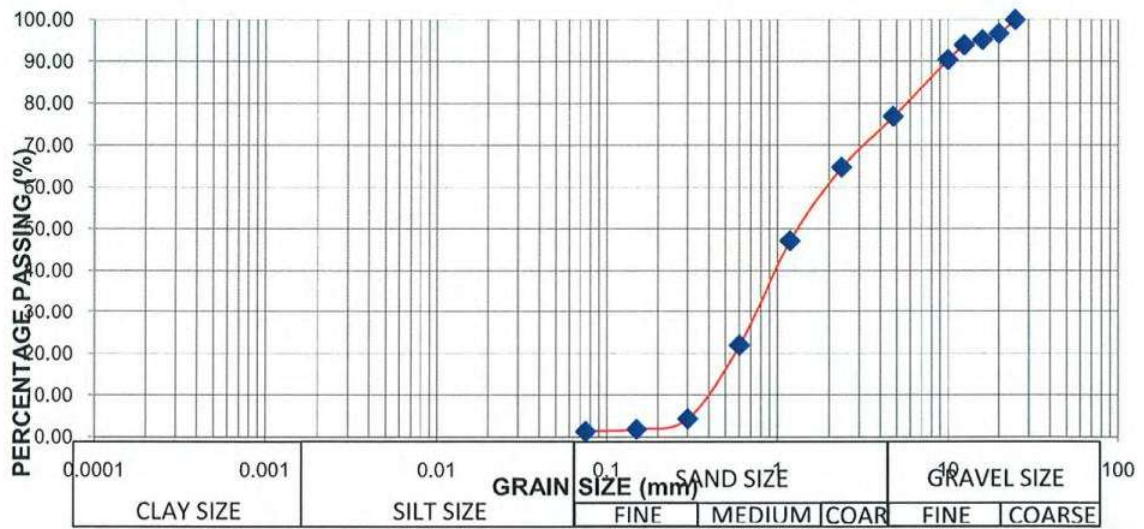


Fig.-2: Particle Size Distribution Curve of Sample-2

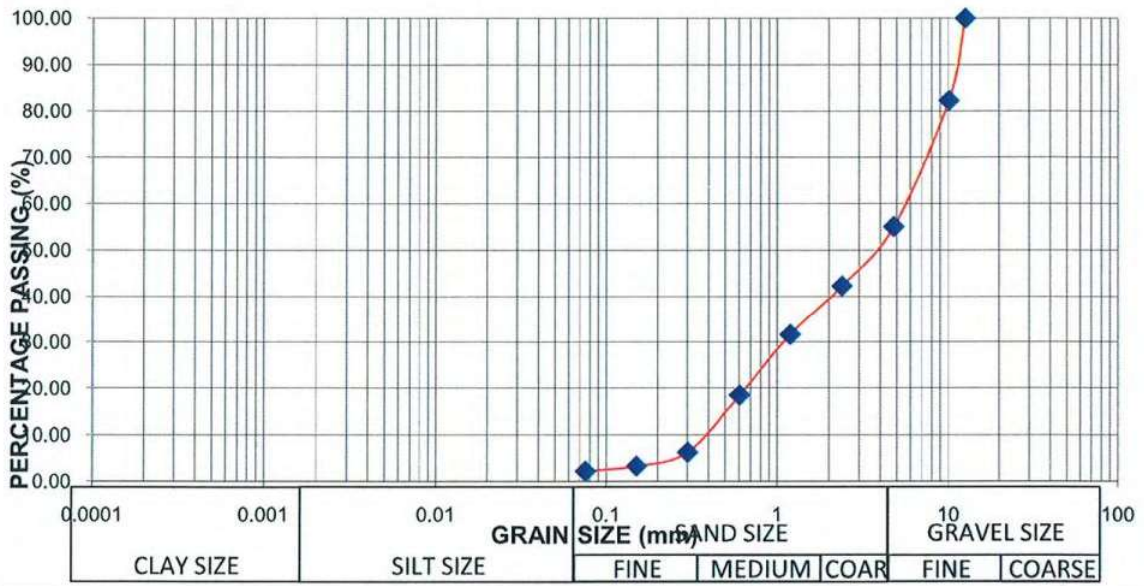


Fig.-3: Particle Size Distribution Curve of Sample-3

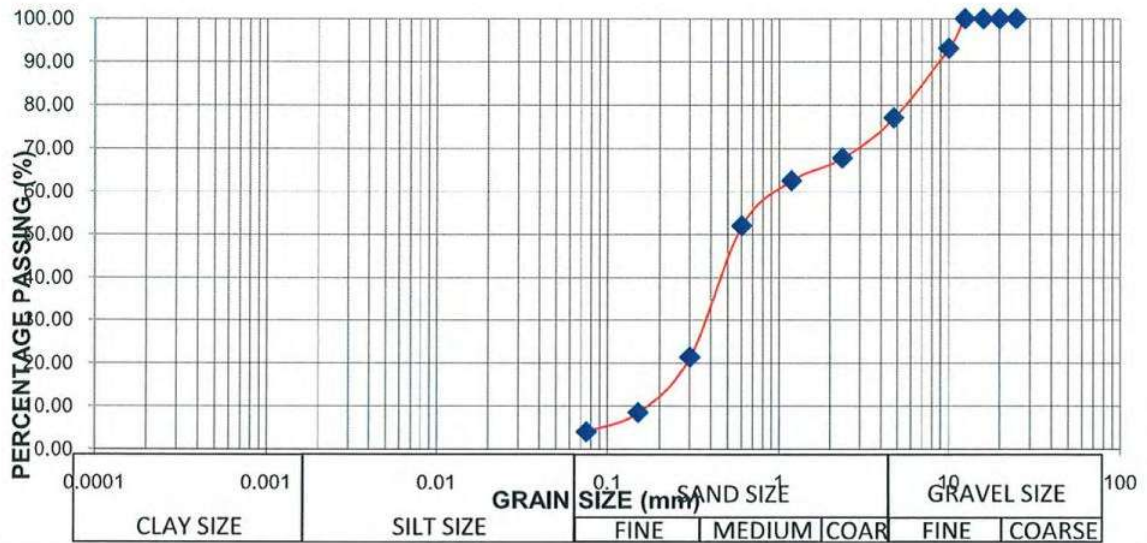


Fig.-4: Particle Size Distribution Curve of Sample-4

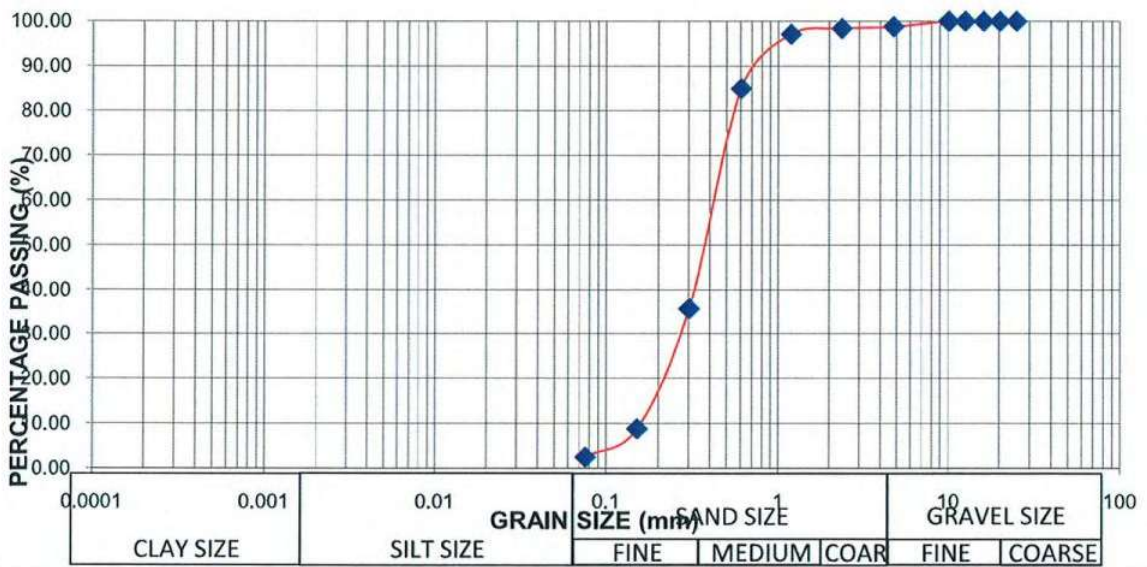


Fig.-5: Particle Size Distribution Curve of Sample-5





# Aimil Testing Laboratory



Advanced Technology & Engineering Services

**Corporate Office:** Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi 110044, INDIA  
Phone: 91-11-30810277/259, Fax: 91-11-26950011, Email: testinglab@aimil.com, atesdel@aimil.com, Website: www.aimil.com

Report No.: W-106  
Date: 04/02/13

## TEST REPORT

1.	Material Tested	:	Said to be Water (Lab Code: W/09-12/85/06/01 to 65)
2.	Name of Client	:	Velcan Energy India Pvt. Ltd.
		:	G-77, Sujjan Singh Park, New Delhi-110003, India
3.	Date of Receipt	:	27/09/12
4.	Condition of Sample	:	ok
5.	Date of Testing	:	01/09/12-09/09/12
6.	Environment Condition	:	Temp. $27 \pm 2^\circ \text{C}$ ; RH $60 \pm 10\%$
7.	Tested as per	:	-
8.	Results	:	-

### A. Silt Concentration

Sl. No.	Sample ID (Puring)	Silt Concentration (ppm)
1	02/08/2012	2.0
2	03/08/2012	4.0
3	04/08/2012	1.0
4	05/08/2012	23.0
5	06/08/2012	12.0
6	07/08/2012	29.0
7	08/08/2012	112.0
8	09/08/2012	34.0
9	10/08/2012	28.0
10	11/08/2012	2311.0
11	12/08/2012	142.0
12	13/08/2012	100.0
13	14/08/2012	14.0
14	15/08/2012	17.0
15	16/08/2012	17.0
16	17/08/2012	37.0
17	18/08/2012	26.0
18	19/08/2012	15.0
19	20/08/2012	77.0
20	21/08/2012	64.0
21	22/08/2012	97.0
22	23/08/2012	102.0
23	24/08/2012	55.0
24	25/08/2012	114.0
25	26/08/2012	20.0
26	27/08/2012	7.0
27	28/08/2012	7.0
28	29/08/2012	1872.0
29	30/08/2012	1305.0
30	31/08/2012	1375.0



**Corporate Office:** Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi 110044, INDIA  
Phone: 91-11-30810277/259, Fax: 91-11-26950011, Email: testinglab@aimil.com, atesdel@aimil.com, Website: www.aimil.com

Report No.: W-106  
Date: 04/02/13

## TEST REPORT

1. **Material Tested**

: Said to be Water (Lab Code: W/09-12/85/06/01 to 65)

Sl. No.	Sample ID (Mechuka)	Silt Concentration (ppm)
1	24/07/2012	12.0
2	25/07/2012	656.0
3	26/07/2012	8.0
4	27/07/2012	8.0
5	28/07/2012	4.0
6	29/07/2012	10.0
7	30/07/2012	7.0
8	31/07/2012	2.0
9	07/08/2012	2.0
10	08/08/2012	669.0
11	09/08/2012	8.0
12	10/08/2012	29.0
13	11/08/2012	1259.0
14	12/08/2012	407.0
15	13/08/2012	9.0
16	14/08/2012	9.0
17	15/08/2012	1.0
18	16/08/2012	3.0
19	22/08/2012	167.0
20	23/08/2012	1.0
21	24/08/2012	131.0
22	25/08/2012	1023.0
23	29/08/2012	1.0
24	31/08/2012	1449.0

Tested By

P.T.O.: Terms & Conditions

Checked By

Name:  
Designation:

Approved By  
**NITIN KOSHTA**  
Dy. Assignment Manager





Corporate Office: Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi 110044, INDIA  
Phone: 91-11-30810277/259, Fax: 91-11-26950011, Email: testinglab@aimil.com, atesdel@aimil.com, Website: www.aimil.com

Report No.: W-108  
Date: 04/01/13

## TEST REPORT

1. Material Tested : Said to be Water (Lab Code: W/12-12/124/08/01 to 57)
2. Name of Client : Velcan Energy India Pvt. Ltd.  
G-77, Sujan Singh Park, New Delhi-110003, India
3. Date of Receipt : 6/12/12
4. Condition of Sample : ok
5. Date of Testing : 12/12/12 – 21/12/12
6. Environment Condition : Temp.  $27 \pm 2^\circ \text{C}$ ; RH  $60 \pm 10\%$
7. Tested as per : IS 2386-Part-1-1963, IS 2386-Part-8-1963
8. Results :

### A. Silt Concentration

Sl. No.	Sample ID (Mechuka)	Silt Concentration (ppm)
1	16/09/2012	217.0
2	17/09/2012	863.0
3	18/09/2012	228.0
4	19/09/2012	154.0
5	21/09/2012	310.0
6	22/09/2012	104.0
7	23/09/2012	18.0
8	24/09/2012	550.0
9	25/09/2012	171.0
10	26/09/2012	16.0
11	30/09/2012	8.0
12	01/10/2012	16.0
13	02/10/2012	10.0
14	03/10/2012	12.0
15	05/10/2012	12.0
16	06/10/2012	62.0
17	10/10/2012	8.0
18	11/10/2012	16.0
19	12/10/2012	470.0
20	13/10/2012	756.0
21	14/10/2012	15.0
22	16/10/2012	20.0



Corporate Office: Naimex House, A-8, Mohan Co-operative Industrial Estate, Mathura Road, New Delhi 110044, INDIA  
Phone: 91-11-30810277/259, Fax: 91-11-26950011, Email: testinglab@aimil.com, atesdel@aimil.com, Website: www.aimil.com

Report No.: W-108  
Date: 04/01/13

## TEST REPORT

1. Material Tested

: Said to be Water (Lab Code: W/12-12/124/08/01 to 57)

Sl. No.	Sample ID (Puring)	Silt Concentration (ppm)
1	16/09/2012	75.0
2	17/09/2012	75.0
3	18/09/2012	135.0
4	19/09/2012	1100.0
5	20/09/2012	1897.0
6	21/09/2012	1243.0
7	22/09/2012	799.0
8	23/09/2012	113.0
9	24/09/2012	77.0
10	25/09/2012	1880.0
11	26/09/2012	1081.0
12	27/09/2012	1926.0
13	28/09/2012	1954.0
14	29/09/2012	1080.0
15	30/09/2012	1744.0
16	01/10/2012	1261.0
17	02/10/2012	1205.0
18	03/10/2012	977.0
19	04/10/2012	667.0
20	05/10/2012	1520.0
21	06/10/2012	570.0

B. For grain size analysis result please see annexure A.

C. For petrographic analysis result please see annexure B.

Tested By

P.T.O.: Terms & Conditions

Checked By

Approved By

Name:

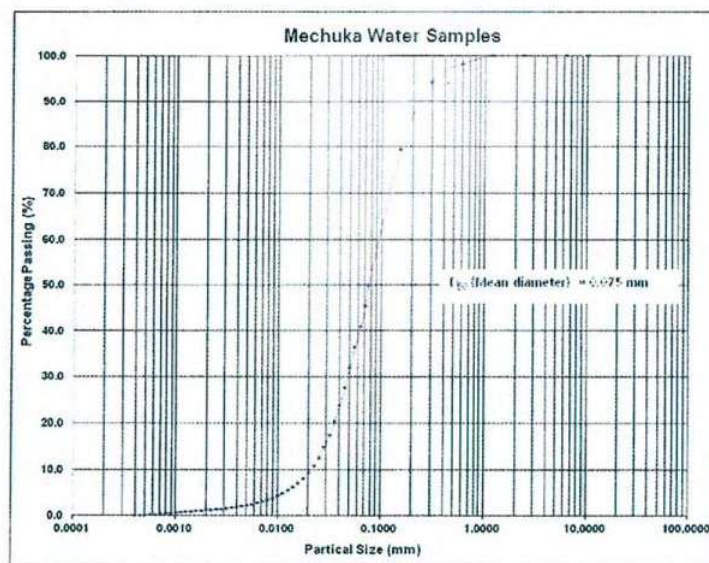
Designation: **NITIN KOSHTA**  
**Dy. Assignment Manager**

2/10



### ANNEXURE-A (Grain Size Distribution)

Sample ID	IS Sieve Designation	% Passing
Mechuka Water Samples	10 mm	100.000
	6.3 mm	100.000
	4.75 mm	100.000
	2.36 mm	100.000
	1.18 mm	100.000
	600 $\mu$ m	98.249
	300 $\mu$ m	94.261
	150 $\mu$ m	79.435
	75 $\mu$ m	49.825
	63.2 $\mu$ m	41.043
	50.2 $\mu$ m	32.012
	44.7 $\mu$ m	27.794
	35.5 $\mu$ m	20.474
	25.2 $\mu$ m	12.730
	15.9 $\mu$ m	7.141
	10.0 $\mu$ m	4.320
	7.1 $\mu$ m	3.064
	6.4 $\mu$ m	2.750
	5.0 $\mu$ m	2.244
	4.5 $\mu$ m	2.045
	3.2 $\mu$ m	1.583
	2.0 $\mu$ m	1.179
	1.0 $\mu$ m	0.673
	0.9 $\mu$ m	0.577
	0.8 $\mu$ m	0.468
	0.7 $\mu$ m	0.359
	0.6 $\mu$ m	0.256
	0.5 $\mu$ m	0.083
	0.4 $\mu$ m	0.000



**Fig. 1 Particle Size Distribution Curve**

Sample ID	IS Sieve Designation	% Passing
Puring Water Samples	10 mm	100.000
	6.3 mm	100.000
	4.75 mm	100.000
	3.35 mm	100.000
	2.36 mm	100.000
	1.18 mm	100.000
	600 $\mu$ m	95.101
	300 $\mu$ m	90.786
	150 $\mu$ m	70.608
	75 $\mu$ m	40.050
	63.2 $\mu$ m	30.661
	50.2 $\mu$ m	21.753
	44.7 $\mu$ m	17.907
	35.5 $\mu$ m	11.854
	25.2 $\mu$ m	6.655
	15.9 $\mu$ m	3.932
	10.0 $\mu$ m	2.557
	7.1 $\mu$ m	1.806
	6.4 $\mu$ m	1.616
	5.0 $\mu$ m	1.318
	4.5 $\mu$ m	1.209
	3.2 $\mu$ m	0.974
	2.0 $\mu$ m	0.745
	1.0 $\mu$ m	0.396
	0.9 $\mu$ m	0.327
	0.8 $\mu$ m	0.252
	0.7 $\mu$ m	0.183
	0.6 $\mu$ m	0.120
	0.5 $\mu$ m	0.011
	0.4 $\mu$ m	0.000

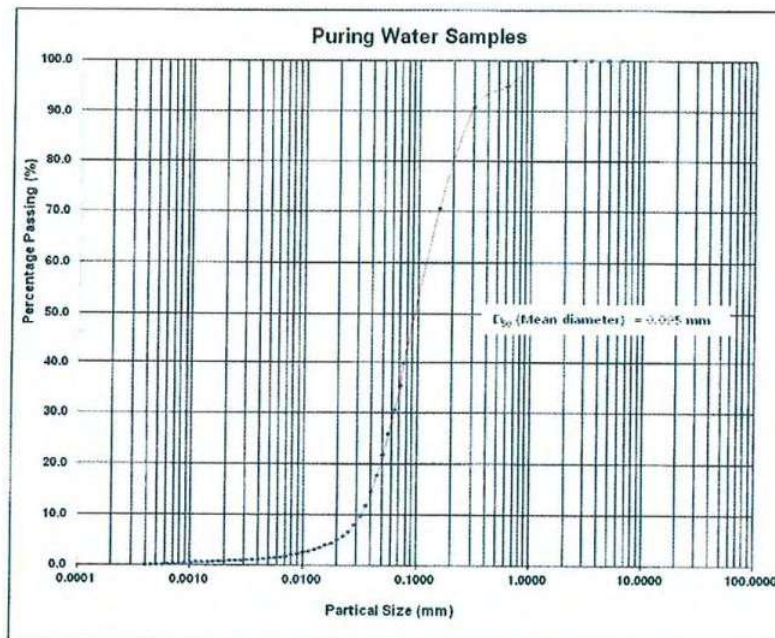


Fig. 2 Particle Size Distribution Curve

**ANNEXURE- B**  
(Petrographic Analysis)

- |   |                                |
|---|--------------------------------|
| 1. Sender's sample no.  | : Mechuka Water Samples        |
| 2. Field name of sample, if any<br>(assigned by the sender)         | : Silt                         |
| 3. Nature of the sample   | : River borne sediments        |
| 4. Location of the sample   | : Mechuka Site                 |
| 5. Lab code   | : W/12-12/124/08/01-57         |
| 6. Laboratory name of the sample<br>(assigned by the present study) | : Silt (river borne sediments) |

**Grain Size Analysis:**

Table-1 shows grain size analysis of the sample. From this table it is clear that the grain size varies from 0.600 mm to - 0.075 mm (pan). It is evident from the suspended material at above location; the fractions (i.e. 0.150 mm & 0.075 mm) constitute a major part of the sample that is about 44.44% of the suspended sediments. For microscopic studies two fractions namely 0.150 mm & 0.075 mm have been selected as they are most appropriate for textural studies. Graphical representation clearly brings out the weight % and grain size fraction relationship.

**Table –1 Grain Size Analyses – Mechuka Water Samples**

Weight of Total Sample taken: 11.709 g

IS Sieve Designation	Sediment Grain Size Classification (Wentworth 1922)	% Retained	Cumulative % Retained	% Passing
4.75 mm	Pebble	0.0	0.0	100.000
3.35 mm	Granule	0.0	0.0	100.00
2.36 mm	Granule	0.0	0.0	100.000
1.18 mm	Very Coarse Sand	0.0	0.0	100.000
600 µm	Coarse Sand	1.75	1.75	98.249
300 µm	Medium Sand	3.99	5.74	94.261
150 µm	Fine Sand	14.83	20.57	79.435
75 µm	Silt	29.61	50.18	49.825
-75 µm	Silt + Clay	49.82	100.00	0.000



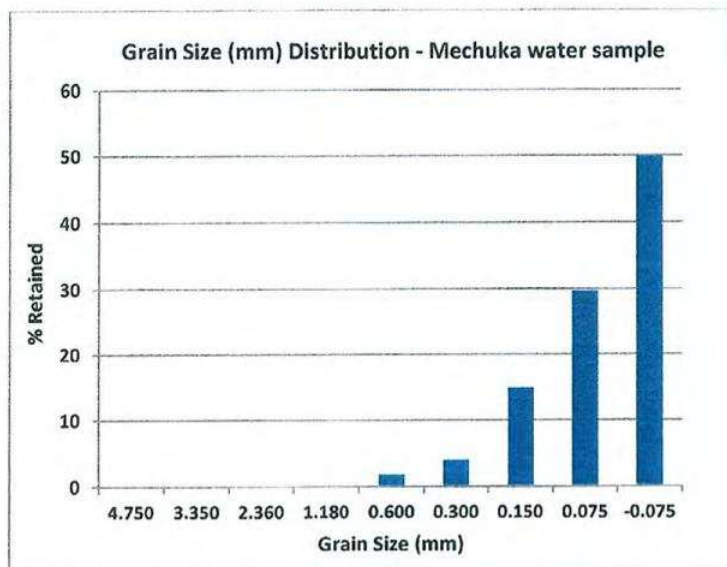


Fig. 3: Histogram of % Weight vs. Grain Size

#### Petrographic Analysis:

##### Megascopic Study of the sample (Study aid –naked eye & hand lens)

It is composed of loose grains of fine sand to fine silt. It is brown sand with white sheen imparted by the presence of white mica and black specks due to presence of biotite and other ferro-magnesium minerals. The given sample is river borne sediment.

##### Microscopic Study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)

Under microscope the grain mounts comprise of quartz, feldspar, mica (muscovite & biotite), hornblende, magnetite, kyanite and lithic fragments. Most of the quartz grains and lithic fragments are angular to sub angular in shape while feldspar grains appear sub rounded. Some of the grains of quartz have thin veins of ferruginous material. Hornblende grains are pleochroic in shades of light green and are sub-angular. The extinction angle of the quartz grains cannot be determined due to unnatural orientation. Biotite mica flakes are pleochroic in shades of yellowish brown and have broken edges. A few grains of kyanite are present only in +150 $\mu$  size fraction and are angular to sub-angular in shape. Opaque minerals are sub angular to sub rounded. Grain morphometry is quite explicit from the photomicrographs.

Table -2 represents the different minerals identified, their hardness (H, as per Moh's scale) and modal percentage (VE).

*\* It is suggested that the suspended sediments samples should be collected periodically i.e. pre-monsoon, monsoon and post monsoon, so as to get the actual nature and content of suspended load of sediments during the year.*

**Table - 2 Mineralogical composition (in %) of sediments of suspended material**

Sample No.	Grain Size ( $\mu$ )	Quartz/ Lithic fragments (H*=7) (Sp** 2.65)	Feldspar, (H*=6-6.5) (Sp** 2.57-2.76)	Hornblende (H*=5.5) (Sp** 3.05-3.47)	Mica (H*=2.5-4) (Sp** 2.7-3.0)	Magnetite (H*=5.5-6.5) (Sp** 4.9 - 5.2)	Kyanite (H*=4.5-6.5) (Sp** 3.58)
1	+150	69-71	6-8	2-4	15-16	2-4	1-2
2	+75	62-64	8-10	4-6	20-22	1-3	-

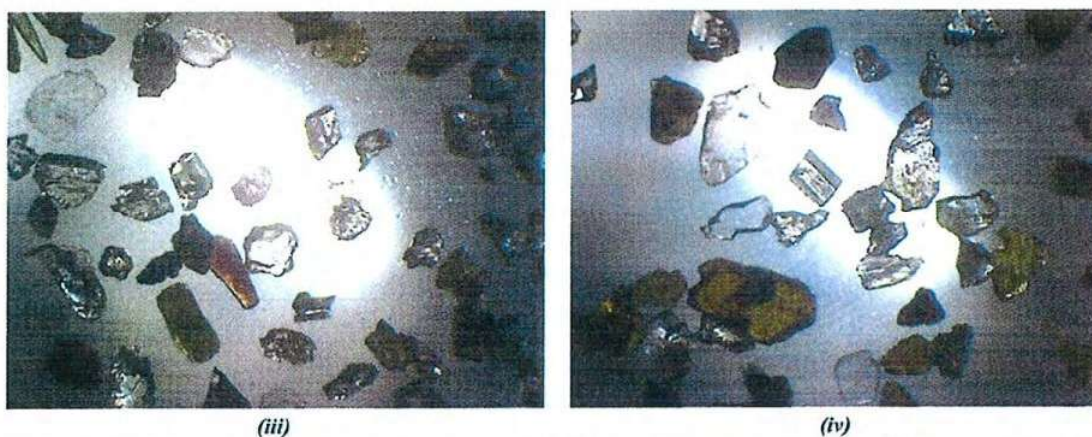
Abbreviations used:

H\*: Hardness & Sp\*\* Specific gravity: given values are standard for the minerals, and not the measured ones.

#### PHOTOMICROGRAPHS



**Fig. 4 Mgf X40 (+150 microns): Angular to sub-Angular grains of quartz, mica flakes and lithic fragments. Note some of the grains are coated with iron oxides.**



**Fig. 5 Mgf: X40 (+75 microns): Angular to sub-angular grains of quartz, feldspar and mica flake. Note some of the grains are coated with iron oxides.**



1. **Sender's sample no.** : Puring Water Samples
2. **Field name of sample, if any** : Silt  
(assigned by the sender)
3. **Nature of the sample** : River borne sediments
4. **Location of the sample** : Puring Site
5. **Lab code** : W/12-12/124/08/01-57
6. **Laboratory name of the sample** : Silt (river borne sediments)  
(assigned by the present study)

#### Grain Size Analysis:

Table-3 shows grain size analysis of the sample. From this table it is clear that the grain size varies from 0.600 mm to - 0.075 mm (pan). It is evident from the suspended material at above location; the fractions (i.e. 0.150 mm & 0.075 mm) constitute a major part of the sample that is about 50.74% of the suspended sediments. For microscopic studies two fractions namely 0.150 mm & 0.075 mm have been selected as they are most appropriate for textural studies for the suspended sediments. Graphical representation clearly brings out the weight % and grain size fraction relationship. The grain size analysis suggests that the sample collected is quiet heterogeneous which is evident from the histogram plot as well.

**Table - 3 Grain Size Analyses**

Weight of Total Sample taken: 60.017 g

IS Sieve Designation	Sediment Grain Size Classification (Wentworth 1922)	% Retained	Cumulative % Retained	% Passing
4.75mm	Pebble	0.00	0.00	100.000
3.35mm	Granule	0.00	0.00	100.000
2.36mm	Granule	0.00	0.00	100.000
1.18mm	Very Coarse Sand	0.00	0.00	100.000
600µm	Coarse Sand	4.90	4.90	95.101
300µm	Medium Sand	4.32	9.21	90.786
150µm	Fine Sand	20.18	29.39	70.608
75µm	Silt	30.56	59.95	40.050
-75µm	Silt + Clay	40.04	100.00	0.000



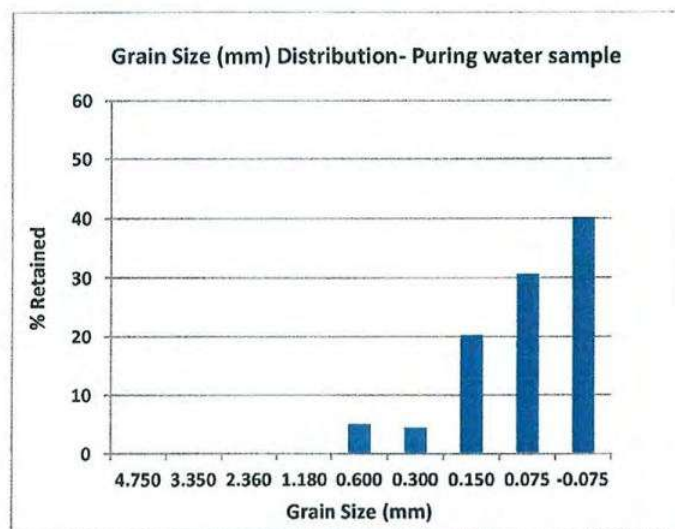


Fig. 6: Histogram of Weight % vs. Grain Size

#### Petrographic Analysis:

##### Megascopic Study of the sample (Study aid –naked eye & hand lens)

It is composed of loose grains of fine sand to fine silt along with a few grains of granule size. It is brown sand with white sheen imparted by the presence of white mica and black specks due to presence of biotite and other ferro-magnesium minerals. The given sample is river borne sediment. Most of the grains are sub angular to sub rounded as identified with the help of hand lens.

##### Microscopic Study of the sample (Study aids – Computer interfaced high resolution polarizing microscope with photographic attachment)

Under the microscope the minerals identified in the 0.150mm & 0.075mm fractions are quartz, feldspar, mica (biotite and muscovite), magnetite, lithic fragments and hornblende, however kyanite and garnet are reported in addition in 0.150mm fraction. Kyanite occurs in the form of blades with angular to sub-angular margin. Garnet grains are angular to sub-angular. Biotite mica flakes are pleochroic in shades of yellowish brown and have broken edges. Hornblende grains are prismatic in shape. Most of the grains of quartz, feldspar and lithic fragments are angular to sub angular, whereas opaque minerals are sub angular to sub rounded. The extinction angle of the quartz grains cannot be determined due to unnatural orientation. Some of the grains of quartz have thin veins of ferruginous material. Grain morphometry is quite explicit from the photomicrographs.

Table -2 represents the different minerals identified, their hardness (H, as per Moh's scale) and modal percentage (VE).

*\* It is suggested that the suspended sediments samples should be collected periodically i.e. pre-monsoon, monsoon and post monsoon, so as to get the actual nature and content of suspended load of sediments during the year.*

**Table - 4 Mineralogical composition (in %) of sediments of suspended material**

Sample No.	Grain Size ( $\mu$ )	Quartz/ Lithic fragments (H*=7) (Sp** 2.65)	Feldspar, (H*=6-6.5) (Sp**2.57- 2.76)	Hornblende (H*=5.5) (Sp** 3.05- 3.47)	Mica (H*=2.5-4) (Sp** 2.7-3.0)	Magnetite (H*=5.5-6.5) (Sp** 4.9 - 5.2)	Kyanite (H*=4.5-6.5) (Sp** 3.58)	Garnet (H*=6.5-7.5) (Sp** 3.1- 4.3)
1	+150	65-67	5-7	2-4	18-20	2-4	1-2	1-2
2	+75	66-68	8-10	4-6	16-18	1-3	-	-

Abbreviations used:

H\*: Hardness & Sp\*\* Specific gravity: given values are standard for the minerals, and not the measured ones.

### PHOTOMICROGRAPHS



(i)



(ii)

**Fig. 7 Mgf X40 (+150 microns): Angular to sub-angular grains of quartz, mica flakes and lithic fragments. Note some of the grains are coated with iron oxides.**



(iii)



(iv)

**Fig. 8 Mgf: X40 (+75 microns): Angular to sub-angular grains of quartz, feldspar and mica flake. Note some of the grains are coated with iron oxides.**

Report on

**Petrography of suspended slit Sediments collected from  
Yarjep River for Heo HE Project, Arunachal Pradesh**

Submitted by,

Dept. of Applied Geology

Dibrugarh University

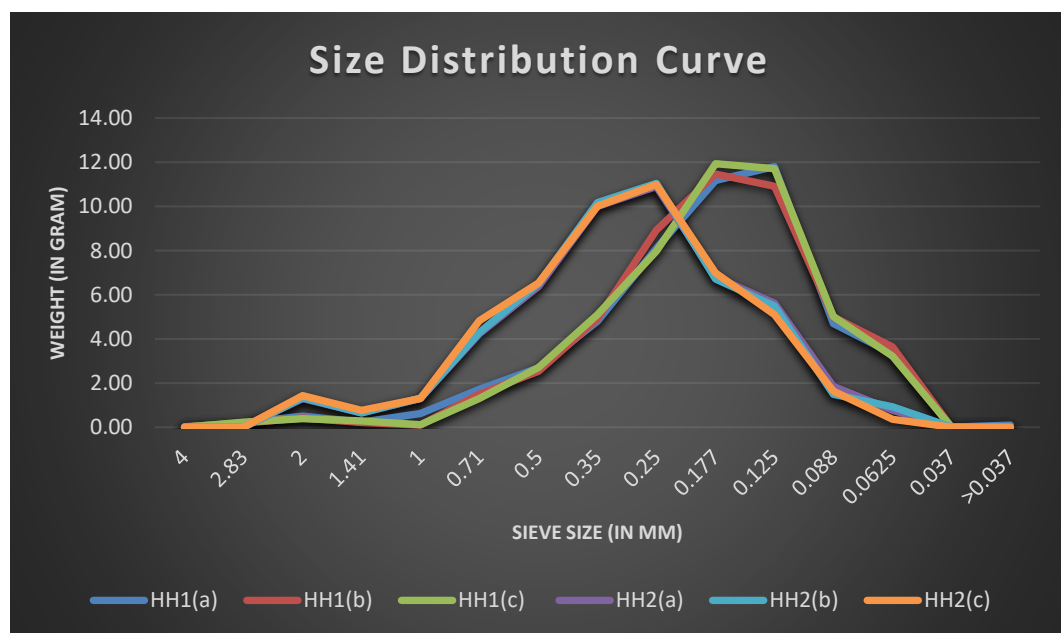
Dibrugarh, Assam



## 1. PARTICLE SIZE ANALYSIS:

The statistical parameter grain size plays a crucial role in characterizing cumulative curves and facilitating numerical comparisons related to grain size and depositional conditions. These parameters can be computed using the moment method (Krumbein and Pettijohn, 1938) or the graphic method (Folk and Ward, 1957; Folk, 1961). In this study, graphic method is primarily employed to describe the grain size distribution of the sample name Heo Hap 1 [HH1(a), HH1(b), HH1(c)] & Heo Hap 2 [HH2(a), HH2(b), HH2(c)] within the context of Yarjep River sediments. (in Table 1 & 2 and Figure 1)

Granulometric analysis was conducted on each sample three times, with the average of these measurements taken as the definitive result; each analysis used identical samples, each weighting 50 grams.



**Figure 1: Size Distribution Curve**

Sieve Size	5	7	10	14	18	25	35	45	60	80	120	170	230	325	PAN	TOTAL
in mm	4.000	2.830	2.000	1.410	1.000	0.710	0.500	0.350	0.250	0.177	0.125	0.088	0.063	0.037	>0.037	(-)
HH1(a)	0.016	0.200	0.500	0.225	0.625	1.725	2.691	4.793	8.100	11.172	11.805	4.695	3.338	0.006	0.100	49.990
HH1(b)	0.022	0.192	0.420	0.210	0.105	1.498	2.540	4.913	8.930	11.465	10.915	5.002	3.643	0.001	0.003	49.857
HH1(c)	0.000	0.228	0.395	0.289	0.110	1.305	2.705	5.094	7.975	11.935	11.705	5.007	3.212	0.000	0.002	49.960
Average	0.013	0.207	0.438	0.241	0.280	1.509	2.645	4.933	8.335	11.524	11.475	4.901	3.397	0.002	0.035	49.936

**Table no. 1: Sieve Analysis of Heo Hap 1**

Sieve Size	5	7	10	14	18	25	35	45	60	80	120	170	230	325	PAN	TOTAL
in mm	4.000	2.830	2.000	1.410	1.000	0.710	0.500	0.350	0.250	0.177	0.125	0.088	0.063	0.037	>0.037	(-)
HH2(a)	0.000	0.000	1.301	0.645	1.299	4.225	6.373	10.000	10.901	6.815	5.628	1.850	0.768	0.002	0.000	49.807
HH2(b)	0.000	0.000	1.325	0.650	1.312	4.290	6.500	10.180	11.045	6.703	5.491	1.492	0.925	0.007	0.000	49.919
HH2(c)	0.000	0.000	1.428	0.758	1.295	4.829	6.540	10.009	10.991	6.987	5.100	1.635	0.356	0.000	0.000	49.926
Average	0.000	0.000	1.351	0.684	1.302	4.448	6.471	10.063	10.979	6.835	5.406	1.659	0.683	0.003	0.000	49.884

**Table no. 2: Sieve Analysis of Heo Hap 2**

## **INTERPRETATION:**

### **A. for the sample no. Heo Hap 1 [Average of HH1(a), HH1(b), HH1(c)]**

1. The provided sample consists of granular grains restrained in sieve mesh number 5-10, corresponding to 2-4 mm is 1.32%.
2. The provided sample consists of very coarse sand grains restrained in sieve mesh number 14-18, corresponding to 1.41- 1 mm is 1.04%.
3. The provided sample consists of coarse sand grains restrained in sieve mesh number 25-35, corresponding to 0.71- 0.5 mm is 8.33%.
4. The provided sample includes medium-sized sand grains restrained in sieve mesh number 45-60, corresponding to 0.35-0.25 mm is 26.57%.
5. Additionally, the sample comprises fine-sized sand grains restrained in sieve mesh numbers 80-120, corresponding to 0.177- 0.125 mm is 46.035%.
6. In sieve mesh numbers 170-230, corresponding to 0.088- 0.0625 mm, there are 16.6% of very fine sand grains restrained, respectively.
7. In sieve mesh number 325 and less, corresponding to 0.044 mm and less, there are 0.1% of silt restrained, respectively.

### **B. for the sample no. Heo Hap 2 [Average of HH2(a), HH2(b), HH2(c)]**

1. The provided sample consists of granular grains restrained in sieve mesh number 5-10, corresponding to 2-4 mm is 2.71%.
2. The provided sample consists of very coarse sand grains restrained in sieve mesh number 14-18, corresponding to 1.41- 1 mm is 3.97%.
3. The provided sample consists of coarse sand grains restrained in sieve mesh number 25-35, corresponding to 0.71- 0.5 mm is 21.89%.
4. The provided sample includes medium-sized sand grains restrained in sieve mesh number 45-60, corresponding to 0.35-0.25 mm is 42.18%.
5. Additionally, the sample comprises fine-sized sand grains restrained in sieve mesh numbers 80-120, corresponding to 0.177- 0.125 mm is 24.54%.
6. In sieve mesh numbers 170-230, corresponding to 0.088- 0.0625 mm, there are 4.69% of very fine sand grains restrained, respectively.
7. In sieve mesh number 325 and less, corresponding to 0.044 mm and less, there are no grains of silt restrained.



## **CONCLUSION:**

In conclusion, the granulometric analysis of the Heo Hap 1 and Heo Hap 2 samples reveals distinct sediment characteristics within the Yarjep River system, illustrating variations in grain size distribution and depositional environment. Heo Hap 1 is predominantly composed of fine to medium sand grains, while Heo Hap 2 exhibits a relatively higher content of coarser to medium sand grains, indicating differing hydrodynamic conditions at their respective depositional sites. The use of the graphic method has provided a detailed understanding of the particle size distribution, enabling insights into the sedimentological processes shaping these river sediments. Given that a considerable amount of granular, very coarse sand, along with coarse sand grains, has been detected in the samples, there is substantial doubt regarding their classification as suspended load. Additionally, the silt content appears very low in both the samples, further intensifying this scepticism. The fine sand found in both samples indicates the presence of sediments derived from the suspended load sediments, while the granular and coarser sands observed in both samples suggest sediments associated with the bedding load sediments.

## 2. PETROGRAPHIC ANALYSIS (Total Silt content in percentage):

For petrographic studies, samples were collected from the Yarjep River section of Arunachal Pradesh.

**Analysis:** To prepare thin sections of river sediments, one must initially select a representative portion of the samples using the coning and quartering method. Subsequently, the samples are subjected to sieving in a machine to separate grain sizes and eliminate unwanted materials intertwined with the samples. For the purpose of analysis, samples were meticulously chosen to ensure the consistent and representative nature of each constituent. In this analysis concentrated on examining distribution of predominant mineral types against the grain size distributions. To achieve this, slides were prepared for each sample, from coarse grains to finer grains. From the given each sample, three (03) thin section slides are prepared and studies under the Petrographic Microscope. Each sample were named as HH1(X), HH1(Y), HH1(Z) for sample Heo Hap 1 and HH2(X), HH2(Y), HH2(Z) for sample Heo Hap 2. Upon successful verification, the slides are deemed suitable for petrographic analysis.

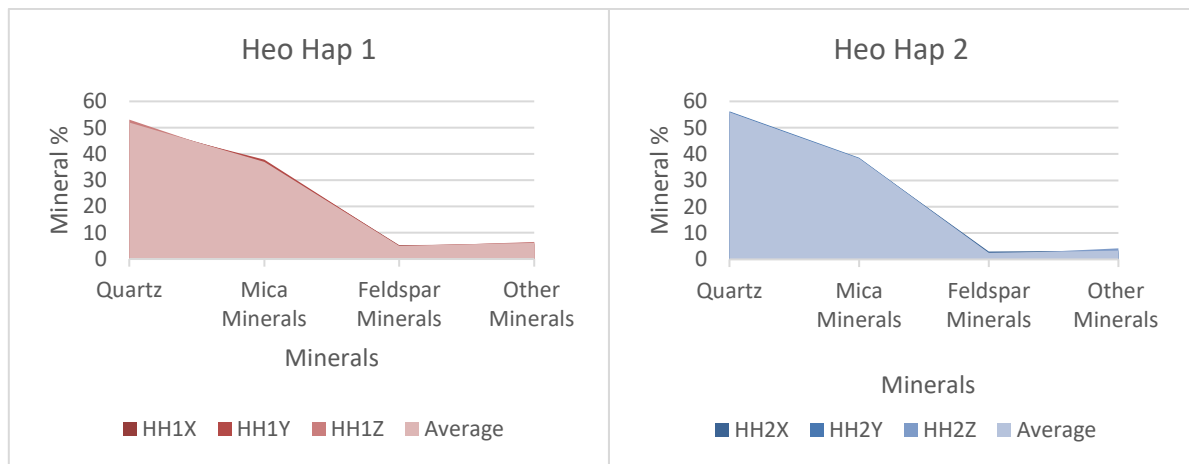
From the provided samples, a total of three (03) thin section slides are meticulously crafted and subjected to examination beneath the Petrographic Microscope. Employing the Model Counting method as delineated by Carver (Robert E., 1971) in "Procedures in Sedimentary Petrology" (pp. 79-88, Published by John Wiley & Sons, Inc., New York), a systematic point counting approach is adopted. This method facilitates the acquisition of statistical measurements pertaining to the constituent minerals, namely Quartz, Mica, Feldspar and other Minerals. These measurements are quantified as percentages and meticulously documented in Table 3 & 4 and Figure 2.

Slide No.	Quartz	Mica Minerals	Feldspar Minerals	Other Minerals	Total
HH1X	51.85	37.20	5.25	5.70	100.00
HH1Y	50.94	37.78	4.98	6.30	100.00
HH1Z	53.06	35.74	4.70	6.50	100.00
Average	51.95	36.91	4.98	6.17	100.00

**Table 3: Point counting of Slides of Heo Hap 1**

Slide No.	Quartz	Mica Minerals	Feldspar Minerals	Other Minerals	Total
HH2X	55.38	38.35	2.94	3.33	100.00
HH2Y	56.21	38.65	2.50	2.64	100.00
HH2Z	55.95	37.98	1.92	4.15	100.00
Average	55.85	38.33	2.45	3.37	100.00

**Table 4: Point counting of Slides of Heo Hap 2**



**Figure 2: Gain Distribution Diagram**

### INTERPRETATION FOR TABLE NO. 1:

This table provides a summary of mineral composition across three slides (HH1X, HH1Y, and HH1Z) from a rock sample, showing the percentage of each mineral type (Quartz, Mica, Feldspar, and Other Minerals) in the sample.

1. Quartz: Quartz is the dominant mineral, averaging around 51.95%.
2. Mica Minerals: Mica minerals, which make up an average of 36.91%, are the second most abundant group.
3. Feldspar Minerals: The feldspar content averages at 4.98%, which is relatively low.
4. Other Minerals: This category, averaging 6.17%, likely includes accessory minerals and potentially heavy minerals. Here, Hornblende and pyroxene are observed in little greater

abundance, while rutile, chlorite, tourmaline, and amphibole are present in comparatively lower quantities. The percentage of heavy minerals found in this samples is significantly lower compared to the abundance of quartz and mica minerals.

### **INTERPRETATION FOR TABLE NO. 2:**

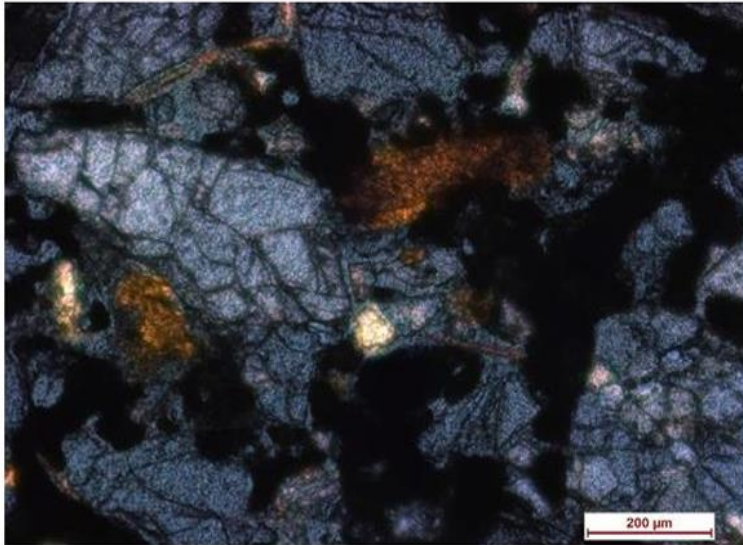
This table details the mineral composition across three slides (HH2X, HH2Y, and HH2Z) from a rock sample, indicating the percentage distribution of Quartz, Mica, Feldspar, and Other Minerals.

1. Quartz: Quartz is the most abundant mineral, with an average of 55.85%.
2. Mica Minerals: Mica minerals are the second most prominent component, averaging 38.33%.
3. Feldspar Minerals: Feldspar content is relatively low, averaging only 2.45%.
4. Other Minerals: The 'Other Minerals' category averages at 3.37%, which includes minor or accessory minerals. In this sample, hornblende, Rutile and pyroxene are present in slightly higher amounts, while rutile, chlorite, tourmaline, and amphibole appear in comparatively smaller quantities. As like as table no. 1, the percentage of heavy minerals is notably lower than the abundance of quartz and mica minerals.

### **CONCLUSION:**

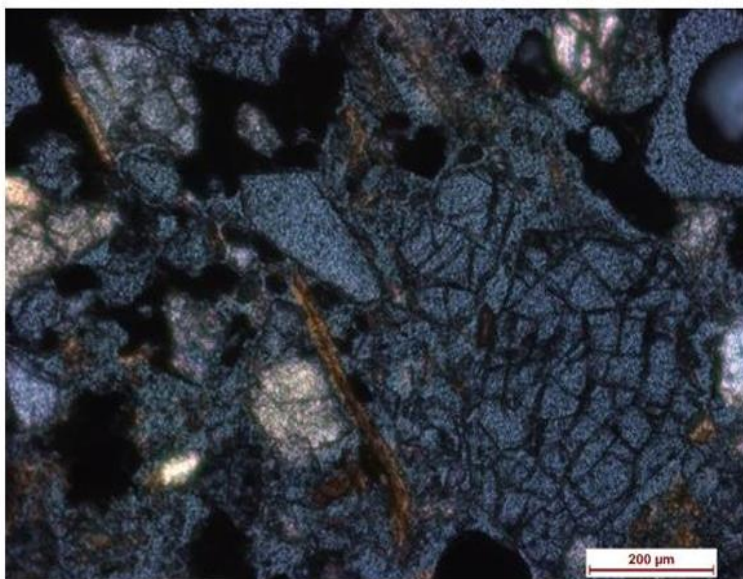
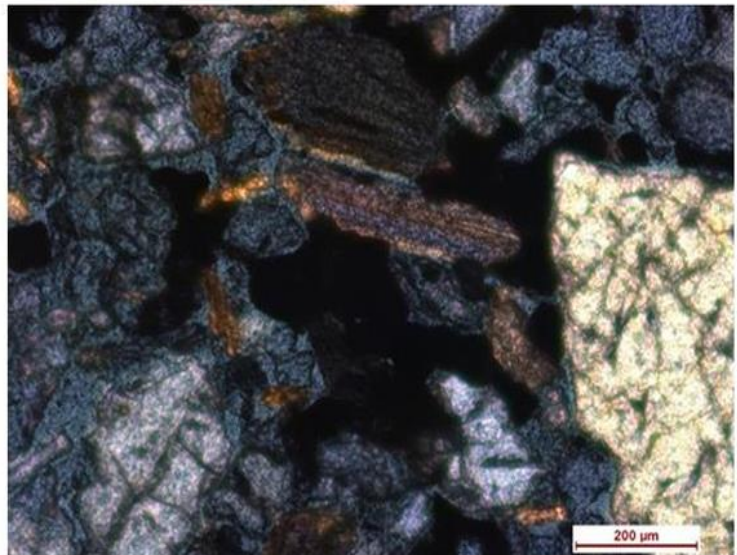
The petrographic analysis of the Yarjep River sediments from samples HH1 and HH2 reveals little distinct mineralogical compositions and textural differences. HH2 displays a higher quartz content (average 55.85%) compared to HH1 (average 51.95%), suggesting a more mature or quartz-enriched sedimentary source in HH2. Mica content remains relatively consistent across both sample sets, indicating stable depositional condition or metamorphic provenance favoring mica retention. The greater feldspar abundance in HH1 (average 4.98%), specifically of microcline and plagioclase, suggests a closer proximity to a feldspathic source, potentially less weathered than HH2, which shows signs of more advanced alteration with reduced feldspar levels. Furthermore, HH1 contains slightly more accessory minerals, with hornblende and pyroxene prevalent, whereas HH2 has fewer accessory phases. These observations imply varying weathering history and metamorphic provenance for each sample.

## **PHOTOMICROGRAPH OF THE THIN SECTION OF SLIDES**



**Figure 3: Polycrystalline quartz and Mica Minerals**

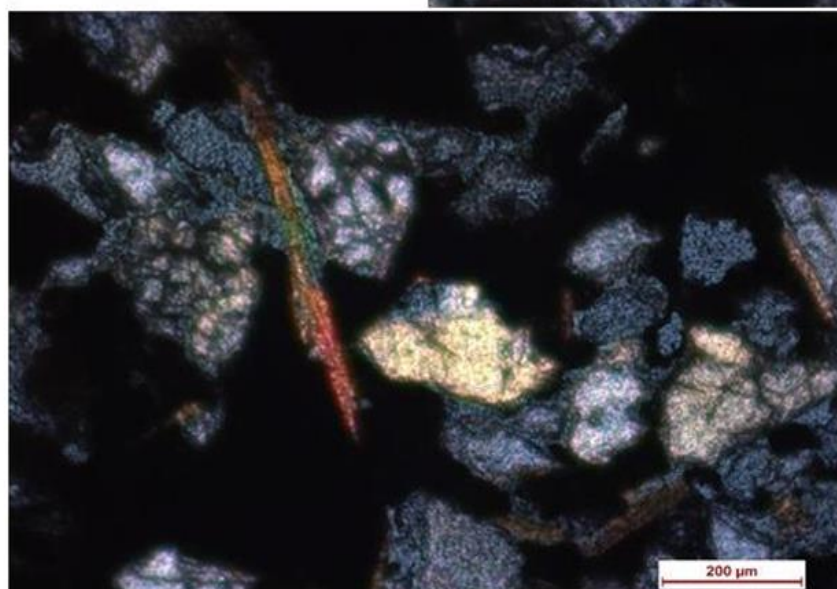
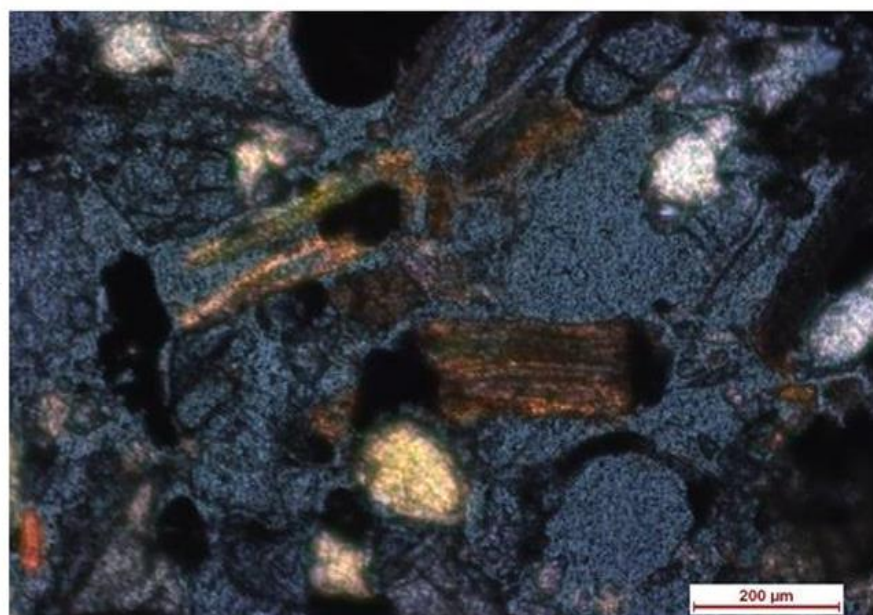
**Figure 4: Quartz, Feldspar and Mica Grains**



**Figure 5: Quartz, Mica and Heavy Minerals Grains**

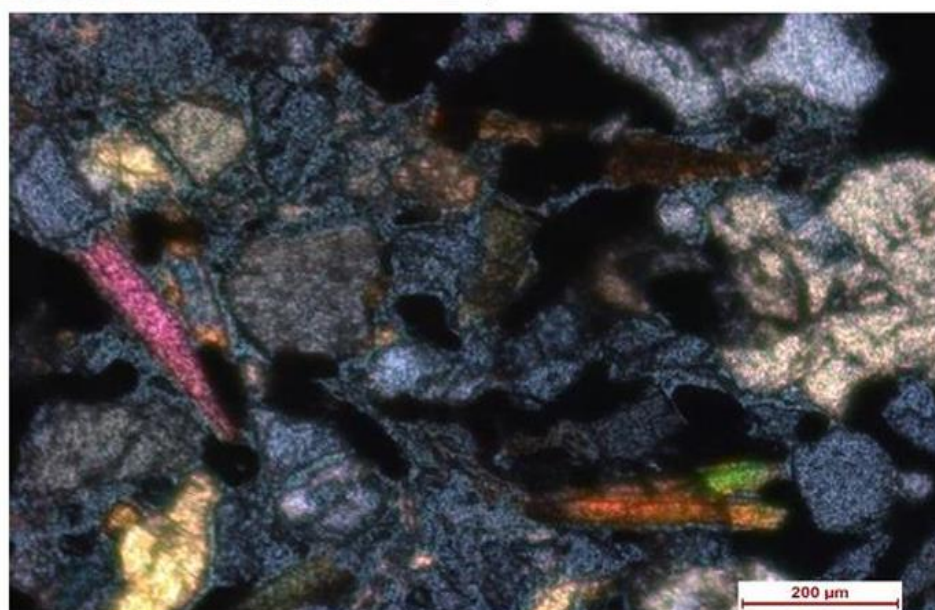


**Figure 6: Quartz, Mica and  
Hornblende Grains**

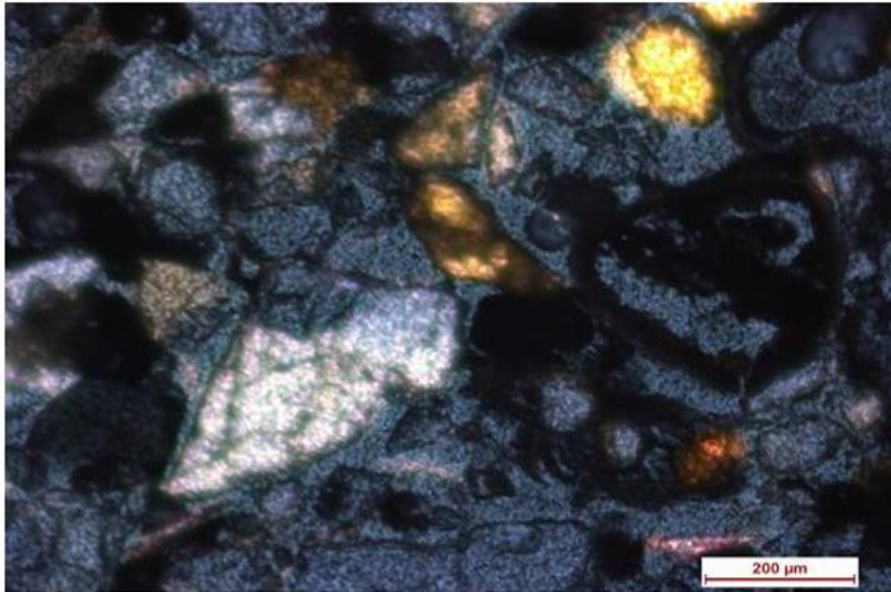


**Figure 7: Quartz and Mica  
Grains**

**Figure 8: Quartz and  
Mica Grains**

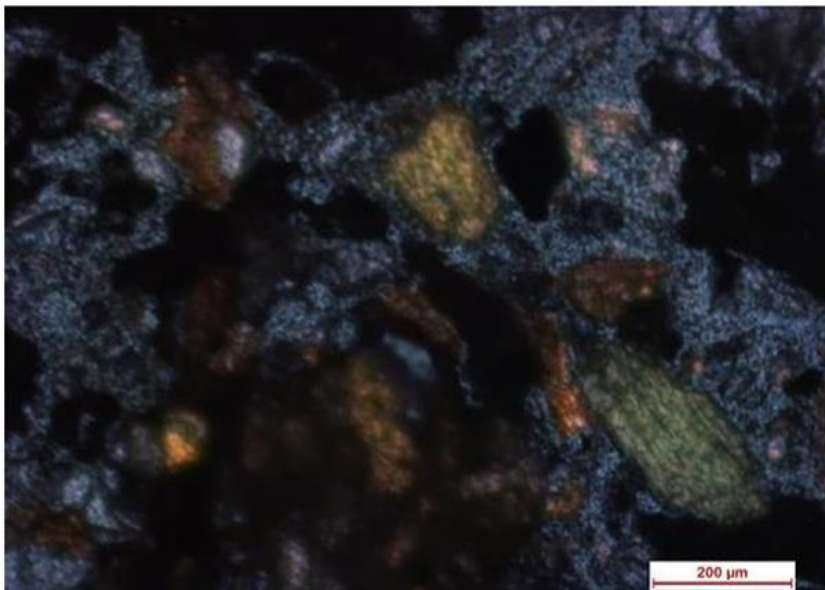
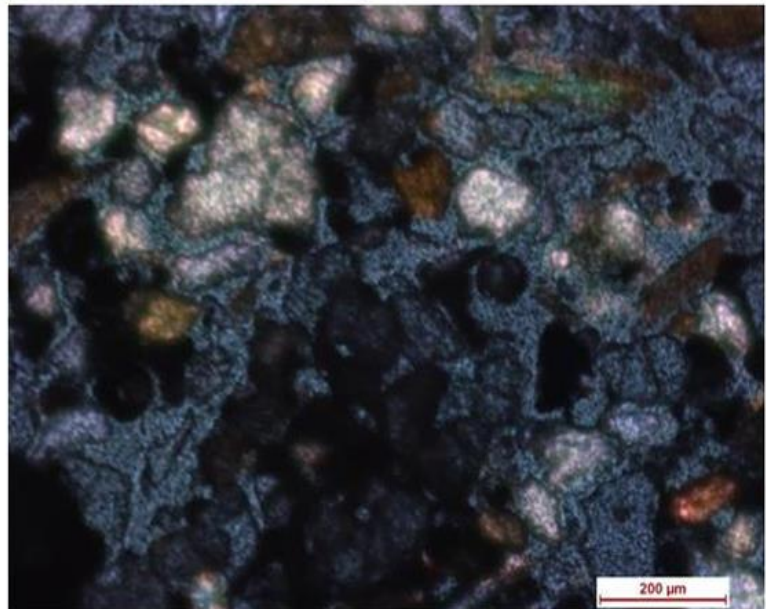




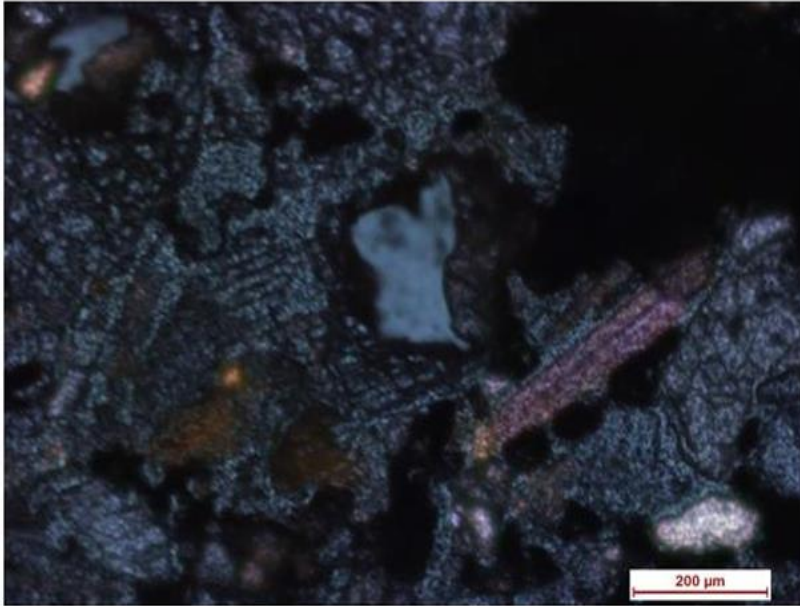


**Figure 9: Quartz, Mica,  
Pyroxene Grains**

**Figure 10: Quartz, Mica,  
Rutile, Pyroxene and  
Amphibole Grains**

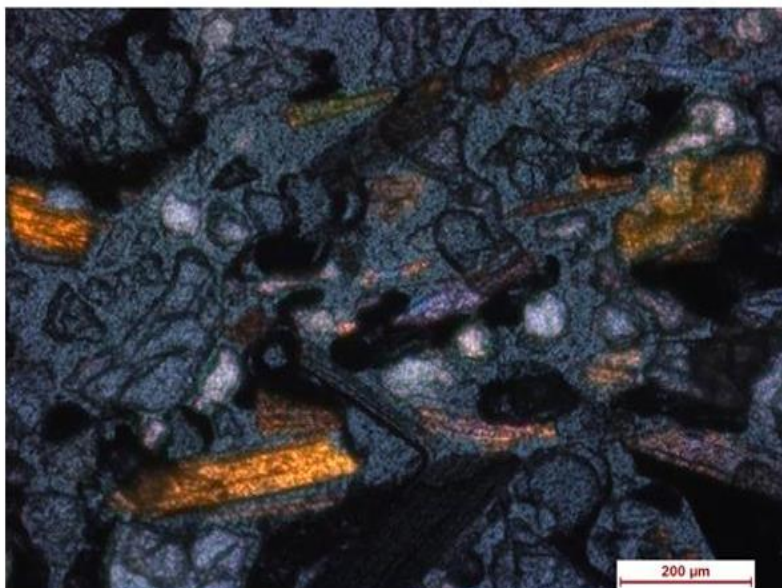
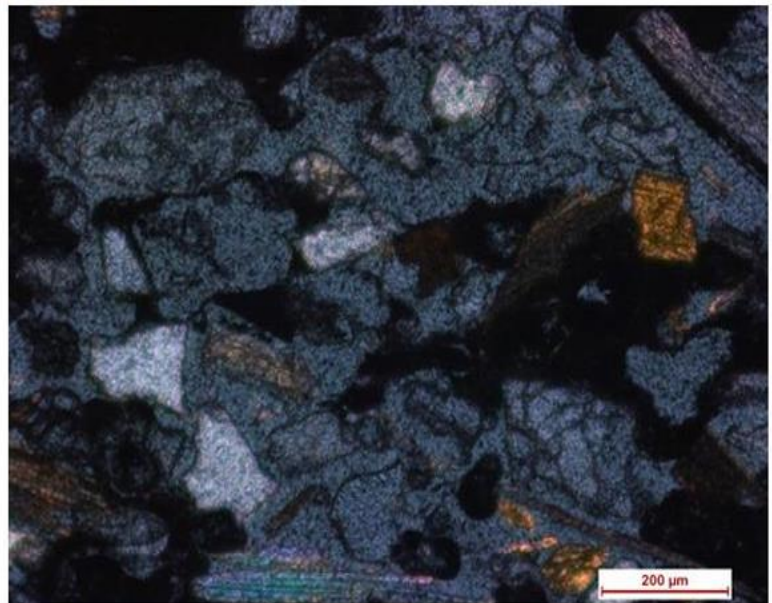


**Figure 11: Quartz,  
Rutile and Chlorite  
Grains**



**Figure 12: Quartz, Feldspar and Mica Grains**

**Figure 13: Monocrystalline and polycrystalline Quartz, Feldspar and Mica Grains**



**Figure 14: Quartz, Mica Feldspar and tourmaline Grains**



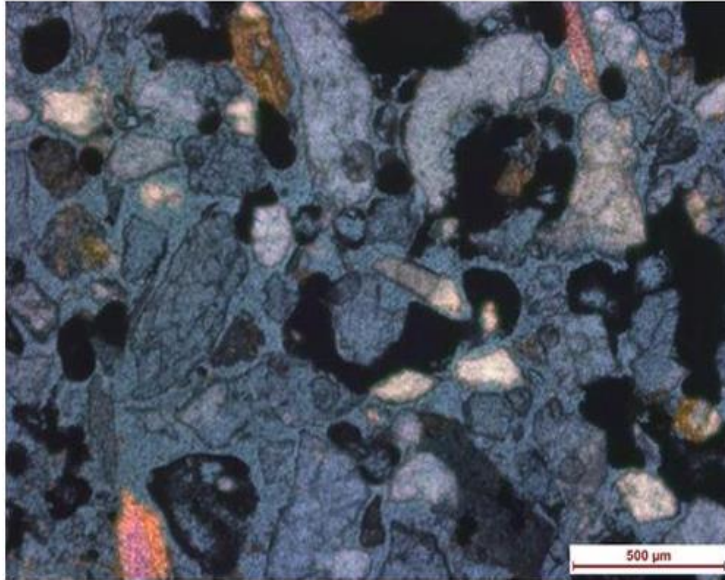


Figure 15: Quartz, Heavy Minerals and Mica Grains

Figure 16: Quartz, Microcline, Amphibole and Mica Grains

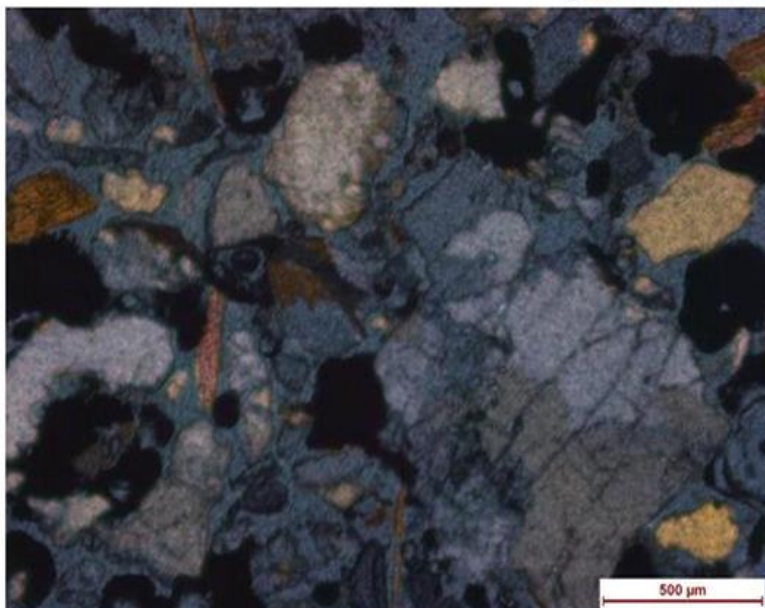
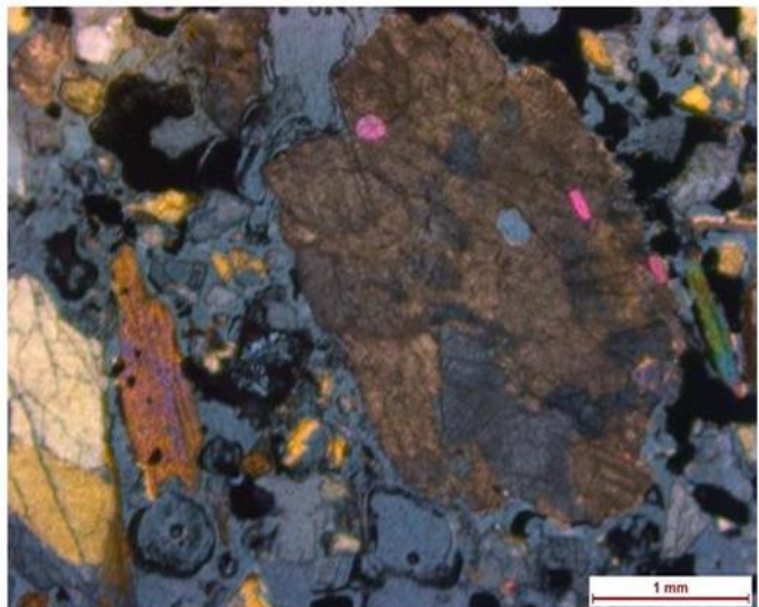


Figure 17: Fractured Quartz and Mica Grains, Feldspar Grains

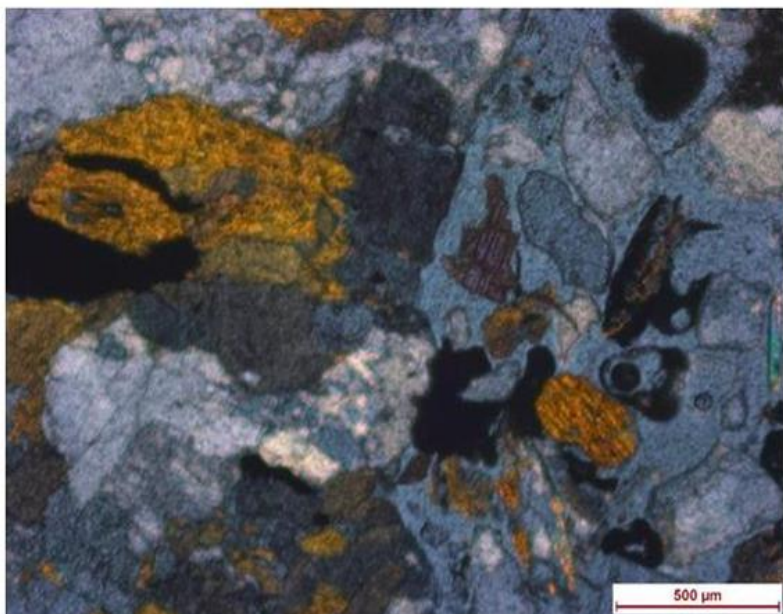


Figure 18: Quartz, Mica Grains and Feldspar Grains

Figure 19: Quartz and Mica Grains, Tourmaline and Rutile Grains

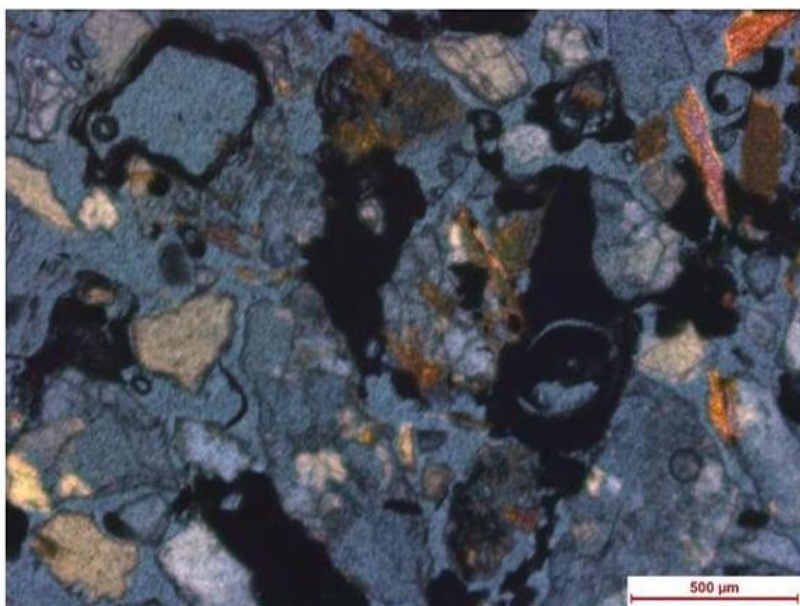
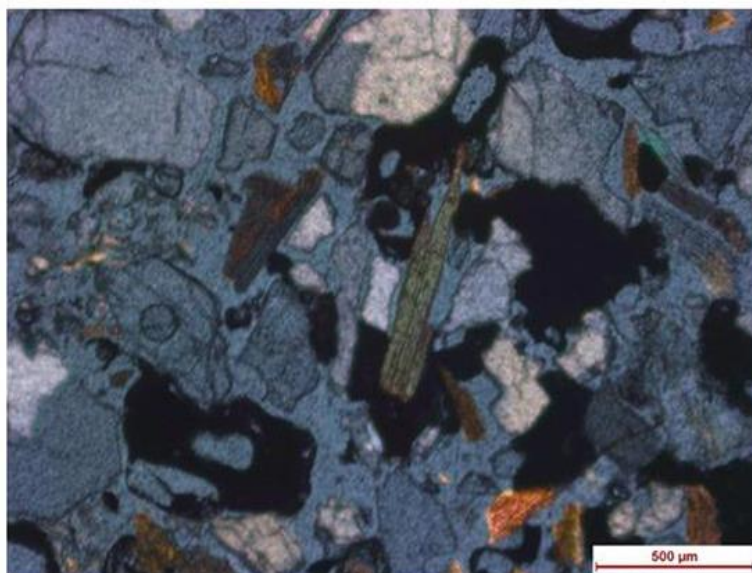


Figure 20: Quartz and Mica Grains, Feldspar Grains



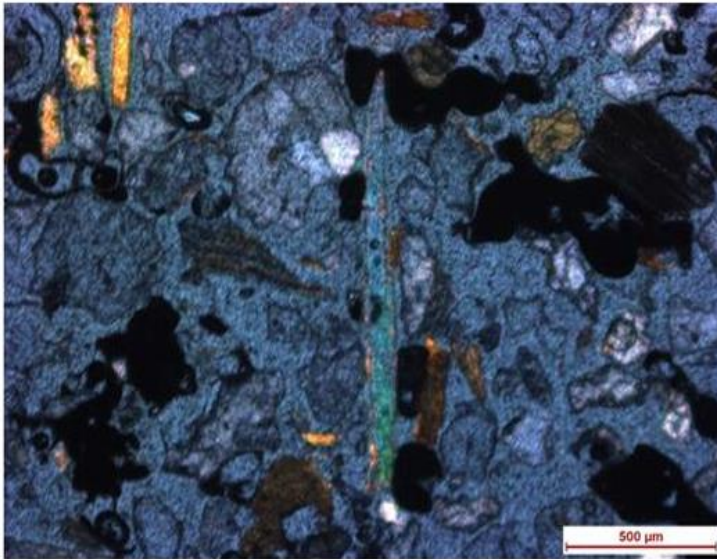


Figure 21: Quartz and Mica Grains,  
Feldspar, Plagioclase Grains

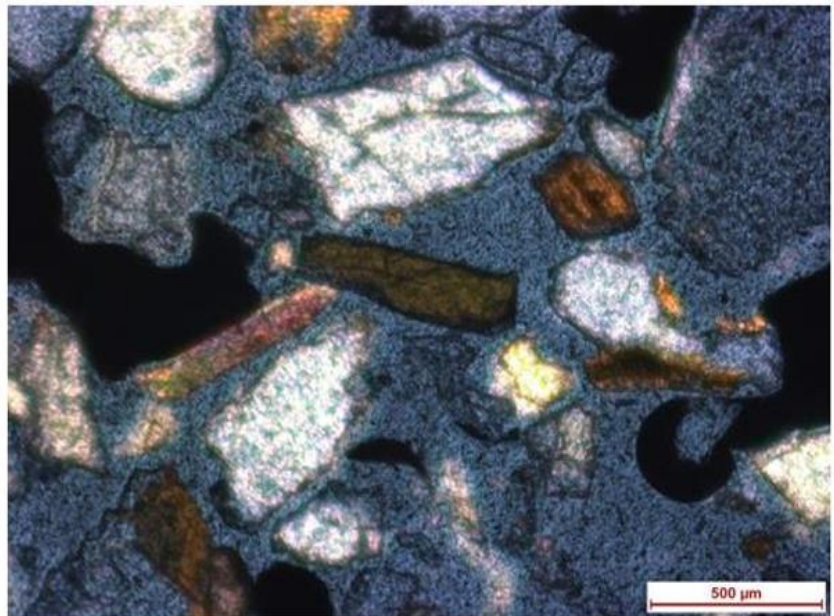


Figure 22: Quartz and Mica Grains,  
Hornblende, Rutile Grains

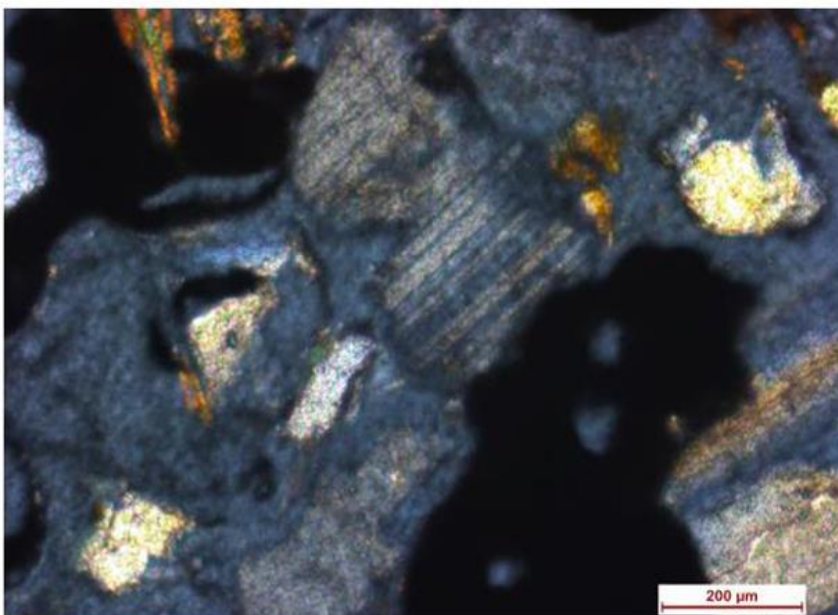


Figure 23: Quartz and Mica Grains,  
Feldspar, Plagioclase and Pyroxene  
Grains

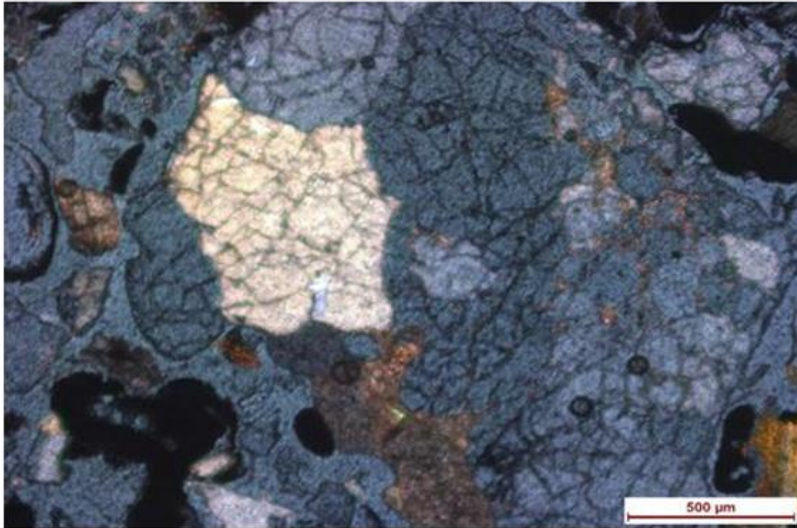


Figure 24: Fractured Quartz and Mica Grains

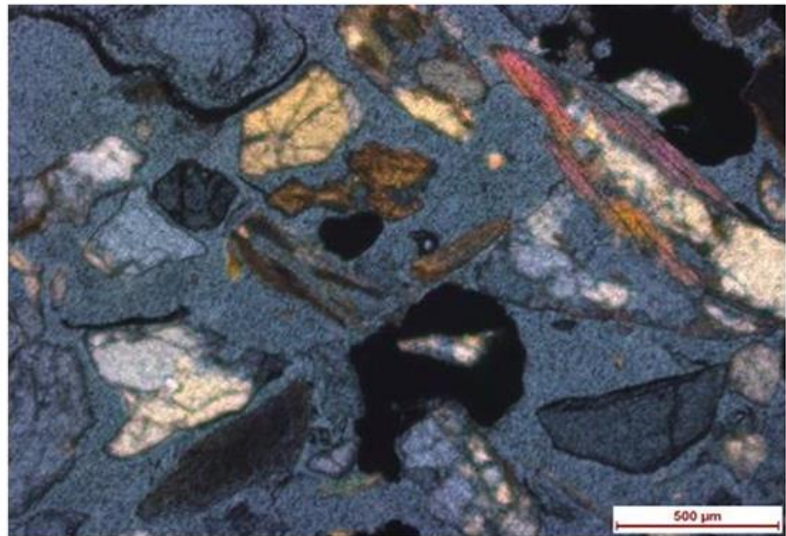


Figure 25: Quartz and Mica Grains

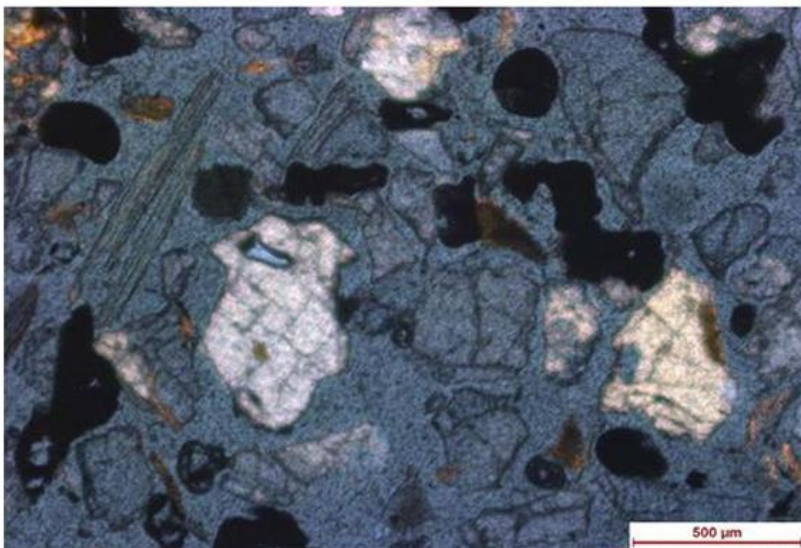


Figure 26: Quartz, Pyroxene and Mica Grains

**Figure 3-14: From Slides of Heo Hap 1 & Figure 15-26: From Slides of Heo Hap 2**



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EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.02 Generator and Excitation System

## Volume-II

### Section II Sub-Section 2

### Generator and Excitation System\_HEO

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
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## TABLE OF CONTENTS

<b>2.</b>	<b>GENERATOR AND EXCITATION SYSTEM</b>	<b>3</b>
<b>2.1.</b>	<b>Scope</b>	<b>3</b>
<b>2.2.</b>	<b>Standards and Codes</b>	<b>3</b>
<b>2.3.</b>	<b>Generator</b>	<b>6</b>
2.3.1	Rating, Type and Description	6
2.3.2	Mode of Operation	6
2.3.3	Manufacturer's Past Experience	7
2.3.4	Technical Parameters	7
2.3.5	Characteristics & Operational Requirements	9
2.3.6	Efficiency and Output Guarantees of the Generator and TG Unit	12
2.3.7	Design and Construction	13
2.3.8	Turbine-Generator Gauge Panel	35
2.3.9	Fire Protection System for Generators	35
2.3.10	Miscellaneous Accessories	36
2.3.11	Generator Tests	42
<b>2.4.</b>	<b>Static Excitation System</b>	<b>46</b>
2.4.1	Characteristics and Operation of the Excitation System	47
2.4.2	Description of Excitation Equipment	48
<b>2.4.3</b>	<b>Excitation System Tests</b>	<b>63</b>
<b>2.5.</b>	<b>Drawings, Design Calculations and O&amp;M Manuals</b>	<b>65</b>
<b>2.6.</b>	<b>Name Plate &amp; Labels</b>	<b>67</b>
<b>2.7.</b>	<b>Packing &amp; Transportation</b>	<b>67</b>
<b>2.8.</b>	<b>Painting</b>	<b>68</b>
<b>2.9.</b>	<b>Spare Parts and Special Tools</b>	<b>68</b>
2.9.1	Mandatory Spares part	68
2.9.2	Special Tools and Maintenance Equipment	71

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

## 2. GENERATOR AND EXCITATION SYSTEM

### 2.1. Scope

The Scope of work under this section covers the detailed requirements for the design, manufacture, quality assurance, quality control, shop assembly and shop testing, packing, transportation & delivery at Site, site storage and preservation, installation, erection, testing, trial run and Commissioning, of three (3) synchronous vertical shaft hydroelectric Generators driven by Francis Turbines, along with all associated accessories & static excitation system including all associated equipment at Heo HEP Power House.

The excitation system shall include all parts, devices, accessories and special tools, which though not individually specified, but are necessary to construct, operate and maintain a complete excitation system.

The scope shall also include training of Employer's personnel and supply of spare parts. The details of scope of work shall be as per Schedule of Requirements. All parts, devices, accessories and special tools necessary for the equipment to construct and complete the units ready for operation, shall be supplied by Contractor, even if they are not individually specified or listed in the items mentioned in Schedule of Requirements.

The Contractor shall coordinate and co-operate fully with Civil contractor and other contractors involved in carrying out other works at the site. He shall supply all information and details for civil design of the power station structure including embedded parts for the equipment foundations as per prevalent practice and relevant IS or equivalent codes.

### 2.2. Standards and Codes

The generators & Excitation system covered under these specifications shall conform to the latest editions of:

IEC: 60034	Rotating Electrical Machines All the parts in latest edition
IEC 60 044-1	Instrument transformer – Part 1: Current transformer
IEC 60 071	Insulation co-ordination.
IEC 60 072	Dimensions and output series for rotating electrical machines
IEC 60 085	Thermal evaluation and classification of electrical insulation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

IEC 60 129	Alternating current dis-connectors and earthing switches
IEC 60 136	Dimensions of brushes and brush-holders for electrical machinery
IEC 60 137	Insulating bushing for alternating voltages above 1000 V
IEC 60 751	Industrial platinum resistance thermometer sensors
IEC 60 865-1	Short circuit current. Calculation of effects- Part 1: Definition and calculation methods
IEEE 43	Recommended practice for Testing Insulation resistance of rotating machinery
IEEE 115	Test procedures for Synchronous machine
IEEE 4	Techniques for HV testing
IEEE 118	Standard test Code for resistance measurement
IEEE 286	Recommended Practice for Measurement Of Power factor Tip-up of Rotating Machinery stator coil Insulation
IEEE 433	Recommended Practice for Insulation testing of Large AC Rotating Machinery with high voltage and very Low Frequency
IEC 60 909	Short circuit current calculation in three phase AC systems
ANSI B49.1	Shaft coupling Integrally forged flange type shaft couplings for hydroelectric units
IEEE 1043	Recommended Practice for Voltage Endurance Testing of Form Wound Bars and Coils
IEEE 62	Guide for field testing power apparatus insulation
ISO 4287	Geometric product Specification (GPS) Surface Texture: Profile method, Terms, Definitions, & Surface Texture parameter
IEC 60 317	Specifications for particular types of windings wires
IEC 60 851	Methods of Tests for Winding wires.
IEC 60 270	High voltage test techniques – Partial discharge measurement IEC 60 894 Guide for test procedure for the measurement of loss tangent of coils and bars of machine winding
ISO 10 816-5	Mechanical vibration – Evaluation of vibration by measurements on non-rotating parts- Part 5: Machine sets in hydraulic power generating and pumping plants
ISO 7919-5	Mechanical vibration of non-reciprocating machines Measurements on rotating shafts and evaluation criteria- Part 5: Machine sets in hydraulic power generating and pumping plants

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

IS: 12075	Mechanical vibration of rotating electrical machines with shaft at height 56 mm and higher measurement, evaluation and limits of vibration severity
IS: 4722	Rotating Electrical Machines Specification
IS: 4889	Method of determination of efficiency of rotating Electrical Machines
BS:5000	Requirements of rotating Electrical machine without limitation of output or voltage
IEEE 810	Hydraulic Turbine and Generator Integrally Forged Shaft Couplings and Shaft Run out Tolerances
IS 3646	Code of Practice for Interior Illumination
IS 12802	Temperature Rise Measurement of Rotating Electrical Machines
ANSI C34.2	Practices and Requirements for Semi-Conductor Power Rectifiers
ANSI / IEEE C34.12.01	General Requirements for Dry-type Distribution and Power Transformers
ANSI C37.18	Requirements for Field Discharge Circuit Breakers for Rotating Electric Machinery
ANSI C37.20	Metal-Enclosed Low-Voltage Power Circuit Breaker Switchgear
ANSI C37.20.3	Metal-Enclosed Interrupter Switchgear
ANSI C37.9.1	Guide for Surge Withstand Capability (SWC) Tests
ANSI C39.1	Requirements for Electrical Analog Indicating Instruments
ANSI C57.96	Guide for Loading Dry Type Distribution and Power Transformers
ANSI C57.12.55	Dry type Transformers Used in Unit Installations, including Unit Sub-stations Conformance Standard
ANSI C57.12.91	Tests
IEEE 421	Standard Criteria and Definitions for Excitation Systems for synchronous Machines
IEEE 421A	Guide for Identification, Testing and Evaluation of the Dynamic Performance of Excitation Control Systems
IEC 60034-16-1	Rotating electrical machines - Part 16: Excitation systems for synchronous machines - Chapter 1: Definitions
IEC 60034-16-2	Rotating electrical machines - Part 16: Excitation systems for synchronous machines - Chapter 2: Models for power system studies
IEC 60034-16-3	Rotating electrical machines - Part 16: Excitation systems for synchronous machines - Section 3: Dynamic performance



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

IEC 60044-1	Instrument Transformers - Part 1: Current transformers
IEC 60044-2	Instrument Transformers - Part 2 : Inductive voltage transformers
IEC 60044-6	Instrument transformers - Part 6: Requirements for protective current transformers for transient performance
IEC 60076-1	Power transformers - Part 1: General
IEC 60076-11	Power transformers - Part 11: Dry-type transformers
IEC 60076-12	Power transformers - Part 12: Loading guide for dry-type power transformers
IEC 60146-1-3	Semiconductor convertors - General requirements and line commutated convertors - Part 1-3: Transformers and reactors

## 2.3. Generator

### 2.3.1 Rating, Type and Description

The Generator shall be rated for 94.117 MVA (80 MW), 0.85 power factor, 50 Hz, 11 kV, 3 phase with Class F insulation of the stator and rotor windings, for coupling to Francis turbine. The Generator shall be capable of delivering the guaranteed maximum continuous overload output of 103.5 MVA continuously at its terminals (to allow 10% of overload above the rated MVA), at power factor of 0.85 and any voltage and frequency in an operating range of - 5% to +3% for both, without exceeding class B insulation temperature rise limits over an ambient air temperature of 40°C conforming to IS / IEC standards. The direction of rotation shall be clockwise when viewed from above. The adequate consideration for temperature rise, insulation level as per LOV study and clearances at higher altitude (greater than 1000 meters) and ambient temperature shall be taken care by the Contractor.

### 2.3.2 Mode of Operation

The generator shall operate satisfactorily in parallel with each other and with other machines connected to grid.

The Generator units shall be designed for peaking load, minimum 4 hours per day, during lean water availability period and continuous rated load & overload for rest of the period. Generator components exposed to fatigue shall be designed for two (2) daily starts and stops and one (1) maximum runaway speed condition per year and about 104 tripping per year, and a useful life of 50 years.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The Generating units shall be capable of operating individually and in parallel with each other as well as with other units connected to the grid. The Generator shall be able to operate on sudden application or loss of maximum load and during momentary short circuits and sustained ground faults without causing any abnormal vibration or resonant conditions.

### 2.3.3 Manufacturer's Past Experience

Generator Manufacturer should have designed, manufactured, erected / supervised erection, commissioned / supervised commissioning of at least two (2) nos. of Vertical hydro-generators each of rated output 50 MVA or higher and speed around 200 rpm which are in successful operation for a period of not less than two (2) years as on the date of bid opening. For further details, refer to "qualifying criteria".

### 2.3.4 Technical Parameters

The generator shall be designed and manufactured on the basis of the following technical parameters / characteristics:

S.No	Type	Description
1	Numbers required	Three (3) sets
2	Type	Salient Pole / Suspended Vertical shaft type synchronous generator
3	Rating	94.117 MVA (80MW)
4	Maximum Continuous rating (110% of rated output plus upward tolerance for dip in generator voltage and for turbine design)	103.5 MVA
5	Power factor	0.85
6	Frequency	50 Hz
7	No. of phases / Connection	3 (three) / Star
8	Stator / Rotor Insulation	Class F with Class B Temperature rise over an ambient of 40°C
9	Rated terminal voltage	11 kV

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

	between the phases	
10	Range of voltage within which rated output must be available	+10 to -10% of Rated Voltage
11	Range of frequency	-5% to +3% of Rated Frequency
12	Rated speed	300 rpm (indicative. It shall match turbine speed)
13	No. of Poles	To suit turbine speed
14	Direction of rotation	Clockwise when viewed from top (Matching with Turbine)
15	Runaway speed	Not more than 180% of rated speed
16	Short circuit ratio	1.10
17	Ratio of quadrature axis sub transient reactance to direct axis sub transient reactance ( $x''_q / x''_d$ )	More than 1.1 and less than 1.35
18	Generator earthing	Star point earthed through neutral earthing transformer with a secondary resistance
19	Maximum cooling water temperature at inlet of generator cooler	30°C
20	Generator $WR^2$ H Constant.	Not less than 3.0 kW-SEC / kVA (exact value to be based on hydraulic transient and stability studies).
21	Degree of Protection	Generator will be enclosed in a concrete housing
22	Terminations	Separate Line / Neutral side in Terminal Cover Boxes located to match isolated phase bus requirements.
23	Fire Protection System	CO <sub>2</sub>
24	Bearings	Combination of Thrust and / or Guide bearings at NDE / DE
25	Cooling System	CACW -Closed Air System. Water cooled by air-to-water heat exchangers (adequate redundancy to operate at 103.5 MVA with one cooler out of

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

		service and 10% cooler tubes out for maintenance) mounted on the Stator frame
--	--	--

## 2.3.5 Characteristics & Operational Requirements

### 2.3.5.1 Line Charging Capability

The line charging capacity of the machine when operating under excited (zero p.f. lead) at rated frequency and voltage should not be less than the following value:

$kVAR = 0.8 \times SCR \times \text{Maximum kVA output} / 1.15$ , or 70 of its rated capacity at zero p.f. subject to Engineer's approval.

(Where SCR = Short Circuit Ratio)

The above line charging capacity should be achieved without exceeding the value of permissible temperature rise as specified elsewhere in the specification and without machine becoming self-excited or unstable.

### 2.3.5.2 Insulation and Temperature Rise

The stator and rotor pole windings shall be of epoxy type pertaining to class "F" insulation with temperature rise over the ambient limited to class B.

When the Generator, equipped with Class-F insulation, operates continuously, at any load, including specified overload, at 0.85 PF and any working voltages and frequencies in the range stipulated, the temperature rise shall not exceed the limits required for "Class-B" insulation.

Measurement of temperature shall be made as specified in the IEC 60034-1 standard. An ambient air temperature of 40 °C and cooling water inlet temperature of 30 °C shall be used as a basis for the guaranteed temperature rises.

The maximum temperature rises in condition of one cooler out of service and unit operating at specified overload shall be guaranteed as the following while operating at maximum continuous overload rating of 103.5 MVA

Stator winding by embedded temperature detectors	75°C
Rotor winding by resistance	80°C
Collector rings by thermometer	75°C

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The maximum temperatures shall not exceed the following:	
Guide bearing Babbitt temperature	65°C
Thrust bearing Babbitt temperature (if applicable)	65°C
Oil sump temperature	55°C.

Employer reserves the right to reject the unit if the above-mentioned temperatures or temperature rises are exceeded by more than 10 °C.

In case of failure to meet these requirements, a reasonable opportunity shall be given to Contractor to repair / change the machine within 3 months of the measurements, in order to meet the guarantees. However, no extension of delivery period will be granted.

#### 2.3.5.3 Short Circuit Capability

The generator shall be capable of withstanding three phase short circuit at the generator terminals when operating at 103.5 MVA and rated power factor with 15% over voltage for a period not less than 3 sec.

#### 2.3.5.4 H Constant and Fly wheel effect ( $WR^2$ )

Inertia constant H of the generating unit shall not be less than 4.0 KW-sec. / kVA based on rating of 103.5 MVA.

The actual value shall be based on hydraulic transient and stability study, based on the requirements, of speed and pressure rise limits, the flywheel effect of the generating unit and governor closing time shall be suitably adjusted so that the speed rise shall not exceed 45% of the rated speed at any operating condition including maximum continuous overload with single stage closing, and pressure rise shall not exceed 35% of the maximum static head.

#### 2.3.5.5 Short Duration Overloads

The generator shall be capable of withstanding overloads upto 1.5 times the rated current for short durations not exceeding 30-45 second each time.

#### 2.3.5.6 Wave Form & Telephone Influence Factor (TIF)

The waveform of the voltage between terminals of generator on open circuit shall be sinusoidal. The waveform will be accepted as practically sinusoidal if none of its instantaneous values of the wave vary from the same phase of the fundamental wave (50 Hz) by more than 5 percent of the amplitude of the fundamental. The poly-phase



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

voltage system of each generator is practically symmetrical. Poly-phase voltage system is considered as practically symmetrical if neither the negative sequence nor the zero sequence components exceeds 5 percent of the positive sequence component.

Special steps shall be taken to eliminate harmonics from voltage wave harmonics, which may cause inductive interference with communication circuits or resonance in the transmission system.

The total harmonic distortion shall not exceed 1.5 percent according to IS.

#### 2.3.5.7 Stability & Performance

The generator shall be able to operate on sudden application or loss of maximum load and during momentary short circuits and sustained ground faults without causing any abnormal vibrations or resonant conditions.

The generator shall be capable of operating continuously on an unbalanced system such that with none of the phase currents exceeding the rated current, the ratio of negative sequence component ( $I_2$ ) to the rated current ( $I_n$ ) does not exceed 0.08, and under fault conditions shall be capable of operation with the product of  $(I_2/I_n)^2$  and time in seconds (t) not exceeding 20.

As an option, the generator shall be suitable for synchronous condenser operation for supplying capacitive / reactive power as per system requirement. The Contractor shall make necessary arrangements in generator and excitation system, unit control and protection, including piping / embedment, compressor system etc. if any for operation of the unit in the above mode.

#### 2.3.5.8 Runaway Speed Withstand Capability

The Generator shall be designed to withstand runaway speed of 180% (or as specified for turbine) for duration of 30 minutes (without including the acceleration and deceleration periods). All parts of the Generator and other equipment shall fully and safely withstand stresses resulting from operation without any damage to the machine.

The critical speed calculation for Generator and Turbine shaft system shall be carried out by Contractor and reviewed by Engineer. The critical speed of the shaft at balanced condition shall be 25% over the runaway speed.

The runaway speed test shall be conducted at site and shall be considered successful if, after undergoing the test for two (2) minute, no damage or injury is apparent. The Contractor shall furnish the detailed calculations to prove the Runaway speed withstand

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

capability of the generators at the time of submitting the bid. The generator shall, after undergoing the test, be able to withstand the high voltage test at eighty five percent of the dielectric test voltage.

### 2.3.6 Efficiency and Output Guarantees of the Generator and TG Unit

The Contractor shall supply a Generator having the specified ratings and highest possible efficiencies in the permissible range of operation.

Contractor shall guarantee the average weighted efficiency for the Generator EvG. The average weighted efficiency for the Generator is calculated as follows:

$$AWEFFG = \frac{\sum (EffG * WT)}{\sum WT}$$

$$EvG = K1 * E110\% + K2 * E100\% + K3 * E75\% + K4 * E50\%$$

The weighting factor for the Generator outputs at 110%, 100%, 75% & 50% of rated output at rated terminal voltage (11kV), rated power factor (0.85 lag) and rated frequency to be used in the above formula will be as follows:

$$K1 (WT 110\%) = 0.2; K2 (WT100\%) = 0.4, K3 (WT75\%) = 0.15; K4 (WT50\%) = 0.25$$

The weighted average efficiency of the Generator at rated voltage, rated power factor and rated frequency shall not be less than 98%.

Efficiencies at rated conditions below 94.5% for Turbine, 98.5% for Generator and 93.08% Overall TG, shall not be accepted. No weightage shall be given during evaluation for efficiencies better than above

Field efficiency tests shall be carried out on one of the Generators, in accordance with the IEC 60034-2 and IEC 60034-2A standards, and the weighted average efficiency will be determined. Individual losses shall also be established using those standards. No positive tolerance in the guaranteed efficiency shall be permitted. The Generator to be tested will be chosen by Employer. Losses to be considered for calculation of efficiency, shall be summation of individual losses as per IEC-34-2 or IS-4889 including static excitation losses. The losses shall be based on reference temperature of 90 deg. C and shall also be include bearing losses.

#### 2.3.6.1 Penalties and Rejection Limit for Shortfall in Output and Weighted Average Efficiency of Generator

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
---	--	--

- Max Output (Turbine Generator TG):

Refer Penalty clauses forming part of Turbine Section.

- Weighted Average Efficiency of Generator:

For each one hundredth of one Percent (0.01%) shortfall in test value of weighted average efficiency of Generator vis-à-vis guaranteed value, a penalty shall be applied at the rate of INR 10,94,000 (Indian Rupees Ten Lakhs Ninety-four thousand) for each unit.

For fractional values of shortfalls in percentage, the penalty amount will be computed on pro-rata basis.

The weighted average efficiency of TG unit (EvTG) shall be calculated as per the following formula:

$$EvTG = EvT \times EvG$$

Where EvT is the Weighted average efficiency of turbine and EvG is the weighted average efficiency of the Generator.

The weighted average efficiency and maximum rating of generator will be verified after commissioning of the generating units on the basis of field acceptance tests on any unit, to be decided by the Employer.

No tolerance shall be permissible over the test figures of maximum rating of generator. In case of efficiency, tolerance will be allowed as per appropriate International Standard IEC codes. The efficiency for the purpose shall be measured according to the IEC codes 60041 & IEC-60034.

The penalty amount for maximum Turbine Generator output and generator efficiency shall be computed separately and the total amount of penalty shall be the sum of these two multiplied by no. of units i.e. three (3) nos.

**Rejection Limit:** The Employer has the right to reject the Generator, if the test value of either average efficiency or the maximum output of Generator at rated voltage and rated frequency is less than the corresponding guaranteed values by two (2) percent or more.

### 2.3.7 Design and Construction

#### 2.3.7.1 General

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The generator shall be suspended type equipped with one suitable combined thrust bearing and guide bearing located above the rotor, and one guide bearing below the rotor. The generators shall be capable of safely withstanding:

- maximum stresses during normal operation while delivering maximum output continuously;
- over speed and runaway-speed conditions with 100% load rejection;
- phase to phase and three phase short circuit conditions or single-phase earth fault in stator at maximum output;
- rotor earth fault;
- forces arising due to 180 deg and 120 deg out-of-phase synchronization;
- magnetic unbalance with 50% of the poles short circuited with machine connected to the Grid at rated speed as well as at maximum runaway speed without excitation;
- sudden brake application at 50% load;
- Seismicity;

Consideration of seismic forces for design of the generators and foundations (0.24g horizontal, 0.16g vertical); However, long-term fatigue effects under cyclic seismic loads shall be examined for stresses over the expected 50-year operational life, ensuring compliance with IS 1893.

- The thrust bearing and its bracket shall be capable of withstanding static / dynamic loads corresponding to generator, Turbine-shaft and runner as also the maximum hydraulic thrust loads during start up, running and shutdowns. The generator pneumatic brakes shall be supported on the lower bracket. For the rated operating conditions specified above, the unit maximum material stresses in the equipment and embedded parts under the combination of all loads during continuous operation shall not exceed 30% of the yield point strength or 20% of the ultimate strength of the material whichever is lower. For other rotating parts of the generator, the maximum stresses due to severe operating conditions (such as runaway speed, short circuit etc.) shall not exceed 60% of the material's yield point.

Following operating conditions shall be considered as severe:

- Shop test and site test at 50% above design pressure;
- Earthquake effects;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- Emergency situations, complete short circuit of the generator;
- Continuous runaway of the generating unit.

In addition to the above, Contractor may also consider other severe conditions as applicable for the equipment. In pre-tensioning bolts, the pre stressed level shall be between 33% and 60% of yield point strength.

The generator foundations and housing (barrel) would be of concrete. Necessary generator sole plates, dowels etc. required for erection of stator, upper bracket, lower bracket etc. shall be interchangeable and shall be located at the same level for all the units and suitably machined for use at site with minimum amount of work.

The construction of the generator shall be such that the rotor poles and stator bar and generator coolers can be handled out or in without removal of the rotor and without disturbing the upper bearing bracket. The rotor poles shall be interchangeable.

The design of the generator components shall be so proportioned as to avoid the possibility of resonance with either rated frequency or multiple thereof. Maximum vibration levels at the shaft and other points shall be within specified limits, to be agreed with the Engineer.

The thrust and guide bearing housing shall be so designed as to provide easy access to the bearing pads. The bearing pads shall be capable of being reached and inspected.

The guide bearings shall be self-lubricating type and shall be of such construction that these can be removed / dismantled without disturbing the thrust bearing, rotor, stator etc.

Segmenting / sectionalizing of large and heavy components shall be confined only in case of transport limits. The transport limits as to size and weight of the components / packages is limited to 40 tons maximum (indicative) including the weight of the truck / trailer and packaging. The large and heavy components of generator shall be suitably sectionalized / segmented (to the minimum extent only) to satisfy the transport limits, and shall be assembled at site.

The equipment shall be assembled at manufacturer's works to ensure matching and reducing assembly works at the service bay to a minimum. This should be done keeping in view transport limitations.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The rotor shall be supplied in the maximum possible assembled condition within the transport limits given elsewhere in the specifications / GCC / SCC. All nuts shall be mechanically locked using a locking tab or equivalent. Welding shall not be permitted.

#### 2.3.7.2 Stator Frame

The stator consists mainly of a frame, a core and a winding. The stator frame shall be in two or more sections so as to work within constraints as regards transport limits of 40 T including packing material and transporting vehicle weights. The stator frame shall be fabricated of steel plate, suitably ribbed for rigidity and shall be of robust design to withstand maximum forces acting on it under worst condition of operation or accidental conditions, with bolted and dowelled joints between the sections. The various segments shall have bolted flanged faces and shall be bolted / Welded together at site. The frame shall have suitable openings for mounting generator air coolers at the periphery. The stator frame shall have robust foundation plate rigidly attached to the frame for mounting on and bolting on to the foundations. The stator frame shall be designed so that it can withstand the core clamping pressure and be suitable for lifting with the assembled core from the service bay to the machine pit and the machine pit to the service bay. The frame shall be provided with suitable lifting lugs and devices for handling.

The stator frame shall be mounted on sole plates and shall be sufficiently rigid to withstand the stresses due to electrical and mechanical loadings covered by this Specification. It shall be designed to withstand the magnetic force waves resulting from harmonic fluxes due to the air gap and the stator slots and shall not achieve resonance when excited by these waves. The stator foundation plates shall have provision for levelling, centering and bolting on to foundations. The fastening of the stator frame to the foundation plates shall have provision for radial movement of the stator due to thermal expansion. The foundation plates may be anchored to the concrete, or preferably, mounted directly onto a steel support structure, which, in turn, is mounted onto the Turbine pit liner, in order to facilitate alignment.

#### 2.3.7.3 Stator Core

The stator core shall be made of silicon steel laminations which shall not be subject to significant increase in losses due to ageing. The laminations, having high permeability, low hysteresis coefficient and high resistibility, shall be so arranged that

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

there will be no continuous vertical butt joints, thereby forming a circumferentially continuous magnetic circuit. The stator core of laminated construction shall be of high-grade non-ageing cold rolled silicon steel. The core lamination shall, after punching, be coated on both sides with insulation varnish of class F type (or any other equivalent coating) to minimize eddy current losses. The lamination insulation shall be varnish type, capable of withstanding a temperature of at least 150 °C without deterioration that might lead to interlaminar currents.

The stator core shall have ducts designed to facilitate flow of cooled air into and through ducts for ventilation with minimum friction and noise. Ventilating ducts shall be arranged at frequent intervals so that the temperature of the interior of the core shall not be significantly greater than that of the surface. The overall design shall ensure that there is no more than a 5 °C temperature difference between any two points of the core.

The core laminations shall be piled on dovetail key ribs which are accurately and securely welded to the stator frame. The core-laminations shall be adequately dovetailed or keyed to stator frame and shall be adequately clamped to prevent any vibration or objectionable noise in operation.

During the stacking process, the laminations shall be compressed at regular intervals (approximately every 500 mm of core thickness). The stator core shall be clamped by means of flange and finger assemblies at both ends of the core. The assemblies are constructed by welding the fingers to the flanges and together they bridge the core and stator frame. The required pressure is provided and maintained with through studs. Cast iron fingers or finger supports for the laminations will not be accepted. After stacking and final compression, the tightening studs shall be permanently locked.

All the necessary tests shall be conducted after stacking and before winding for detection of hot spots.

#### 2.3.7.4 Stator Windings

The stator winding shall be bar type insulated throughout with class 'F' insulation. The bars shall have suitable transposition in the slot portion to reduce the eddy current loss. The winding shall be given low resistance / semi conducting coating in the slot portion and graded where the winding bars leave the slot. This shall ensure

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

an essentially corona free winding at rated voltage. The bars shall be so installed that removal and replacement is possible without damaging the stator core.

The winding design shall be such that bars can be replaced in case of fault by removing one or two rotor poles thus creating space between stator and rotor for carrying out replacement of the bars without taking out the rotor and upper bracket.

The stator winding shall be star (Y) connected. Each phase winding shall be distributed around the stator such as to minimize the unbalanced magnetic pull. The stator winding, end connections, parallel connection rings, main and neutral leads, etc. shall be insulated with Class-F insulation as specified in the IEC 60034-1 Standard. All portions of the winding shall be adequately supported and braced to withstand the full stresses developed due to specified electrical fault conditions including sudden short circuit of one-half the field poles, any movement caused by forces arising out of short circuit at the terminals, over speed etc. The phase and neutral terminals shall be brought out in desired locations and be suitable for connection to isolated phase bus ducts, generally as shown in the Drawings, and shall be brought out as insulated and protected copper bus. The terminals shall have sealed non-magnetic metal barriers for preventing air exchange between inside and outside of generator housing. The windings shall be such that circulating current losses shall be kept minimum. The end connections of the windings shall be rigidly supported & braced to prevent vibrations or displacement.

The radial packing system shall comprise a spring element (ripple spring by Krempel or approved equivalent) made of NEMA G-11 material applying a pressure towards the bottom of the slot. After the initial settlement, the spring deflection shall not be less than 65% nor greater than 80% of the maximum ripple spring deflection on two adjacent wedges or a total of three wedges in a single slot.

The support rings to which the bars are lashed and supported shall be made of non-magnetic metal. The end connection joints shall be made by brazing with high temperature silver soldering. The stator windings shall be treated with anti-corona varnish. End connections of the stator bars shall be made at the top of the winding.

Dissipation factor (tip-up) tests shall be carried out in the shop on each Roebel bar to establish the variation in power factor as a function of applied voltage within the range of 4 kV to 8 kV:

- Bars having a dissipation factor in excess of 1.0 shall be rejected;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- 80% of bars on each unit shall have a dissipation factor less than 0.6;
- Bars with a dissipation factor between 0.5 and 1.0 shall be installed close to the neutral point.

Alternatively, for stator bars produced with vacuum pressure Impregnation (VPI) technology, dissipation factor (tip-up) is an invasive / destructive test. Hence, in-lieu, partial discharge (PD) test shall be carried out for each VPI bar purchased. The dissipation factor or tan delta test shall be carried out on 4 sample bars from each lot. During the production of bars, at the start of each batch, two inner bars and two outer bars shall be randomly selected and subjected to a 25kV, 50Hz accelerated aging test over the full length of the bar for a minimum of 300 hours at a temperature of 115 °C. If one or more bars fail the first test, a second one shall be performed with a new set of four bars. If one or more bars fail the second test, the entire batch shall be rejected.

#### 2.3.7.5 Temperature Indication

Contractor shall provide not less than 24(12 duplex) resistance temperature detectors embedded in the stator winding, evenly spaced around the stator, having a resistance of 100 ohms at 0°C, with a resistance coefficient of 0.00385 °C<sup>-1</sup>, class A. They shall be thermo-electric platinum strip, or equivalent. At least 12(6 duplex) additional resistance temperature detectors shall be embedded in the stator core iron for measurement of end iron heating. All these RTD's shall be terminated in a junction box located near the Generator pit.

Resistance temperature detectors (RTDs) shall be embedded in the generator stator. The leads from these detectors shall be brought to the marshalling box for connection to unit control system for monitoring in Turbine & Generator Gauge Panel and remotely at UCB / SCADA.

#### 2.3.7.6 Anti condensation heaters

Low temperature heaters to prevent condensation on the windings during periods of shutdown shall be mounted suitably inside the barrel. They will be of box type construction consisting of a coiled resistance wire embedded in an electrically insulating and heat conducting compound and protected with a metal sheath. They will form a balanced 3-phase load. These will be switched automatically when the machine is stopped and controlled with an adjustable thermostat for regulating

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

temperature of winding at least 5 deg C above the ambient temperature. Winding temperature shall be monitored through two number dedicated RTDs in each phase.

#### 2.3.7.7 Rotor

##### i. General

The rotor shall comprise the hub, spider, rim and the poles with their windings. The design and construction of the rotor shall be in accordance with best modern practice. The pole winding inter-turn insulation shall be of special epoxy impregnated mica / synthetic paper/ nomex and insulation to ground of glass laminates. The field poles shall be provided with adequate amortisseur (damper) windings to improve stability under fault conditions and to reduce voltage distortions under conditions of line to line and single phase to ground faults.

The design and construction of the rotor shall be of a proven design, in accordance with the most modern practices and shall be fully described in Contractor's Bid.

The rotor shall be designed for assembly on the rotor assembly bay in the erection area of the powerhouse. The Contractor shall provide all suitable rotor erection pedestals and sole plate adapters for the permanent use by the Employer.

##### ii. Rotor Spider

The rotor spider shall be of steel construction and fully capable of withstanding the rim shrinkage without undue or asymmetric distortions. The rotor spider may be constructed with a central hub and arms or may be of the disc type, centering and supporting a rim to which the poles are attached. The spider arms shall be radial.

The brake ring on the rotor shall be supplied in segments which are easily replaceable without lifting out the rotor. The brake ring of the rotor shall be designed to withstand all loads / vibrations / stresses, etc. for the braking at 50% of the rated speed. Provisions shall also be made for rotor fans and air baffles at the top and bottom.

##### iii. Rotor Rim

The rotor rim shall be made by stacking thin steel lamination segments secured by fine clearance studs and clamped between heavy steel plates. The studs shall be hydraulically tensioned for assembly. Nuts shall be secured by bent keeper plates. Nuts which are to be permanently fixed shall be welded. The laminations shall allow



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

for dovetail slots to which the poles shall be installed. Alternative designs, using forged discs, will be considered, if detailed in the Bid.

Cooling fan blades shall be cast aluminum and constructed to preclude vibration.

The rim shall be shrunk on the rotor spider and shall remain shrunk on the hot rotor when unit is rotating up to 110% of synchronous speed. The driving torque shall be transmitted from the rim to the rotor spider / disc through taper keys. The taper keys between the rim and rotor spider arms / discs shall be rigid, be rigidly supported, and in contact over the full axial length of the rim.

Alternative designs of cooling fans and rotor rim will be considered, if detailed in the Bid.

#### **iv. Pole Construction, Insulation and Windings**

The design of the rotor shall be such as to permit the removal and replacement of field poles without the removal of the rotor from the stator. The windings of the rotor poles, interpolar connections, rotor main leads, etc. shall be insulated with Class F, non hygroscopic insulation, as defined in the IEC 60034-1 Standard. The coil insulation between turns shall be made of two layers of “Nomex” film. After full completion of each pole, the winding shall be subjected to the following tests according to IS: 4722:

- Dielectric test at ten times the rated field voltage with a minimum of 1500 V;
- Shock-wave test to verify insulation between turns;
- Resistance and impedance tests.

The poles shall be equipped with non-interconnected dampers designed to withstand the maximum runaway speed. The factor of safety at runaway speed shall not be less than 1.5.

The field winding temperature rise limit shall be 75°C. The field coils shall be adequately braced to withstand the stresses due to worst condition of short circuit and also due to centrifugal forces. The connections from the field coils to the collector ring shall be braced against mechanical forces. The drive taper key shall project above the rotor rim a sufficient distance to facilitate removal of this key by means of a key puller and to permit checking for tightness. Suitable blocking shall also be provided to ensure that the keys do not get loose in service.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The slip rings shall be made of steel ST 330 as per DIN standard or equivalent or mild steel and shall have helically grooved surface. These shall be well insulated with epoxy glass insulation and designed for use with carbon brushes. The slip rings shall be spaced sufficiently apart or separated from each other by a barrier to prevent any accidental short circuit. The slip rings shall be located so as to be easily accessible for inspection during operation and for maintenance. The brushes shall consist of a number of carbon graphite and copper blocks placed in heavy box type holders of approved design and mounted on massive rings. The field leads shall be arranged and shall have sufficient length so that connections to the slip rings can be reversed for polarity without removing and dismantling either the field leads or collector rings. Field leads from the collector rings to the field breaker cubicle shall be brought in suitable ducts.

The brushes and collector rings shall be so positioned as to avoid contamination by oil vapour or leakage from the bearing.

The rotor shall be provided with a suitable brake ring with which the brake shoes shall make contact. The wearing surface of the brake ring shall be made in segments, which shall be easily removable and renewable.

**v. Rotor Temperature Measurement**

One shunt to be mounted on the generator field leads shall be provided complete with the calibration shunt leads for connection to a field temperature recorder for measurement of rotor temperature. Voltage for measurement to be tapped from slip rings. It shall be suitable for indication in SCADA.

**vi. Carbon Dust Collector**

Suitable shield / filter shall be provided to prevent escape of carbon dust on to the generator windings. Alternatively, carbon dust collectors shall be provided.

**2.3.7.8 Generator Shaft**

The generator shafts shall be made of the best quality forged carbon steel confirming to ASTM A668 class E, properly heat-treated. A single shaft shall be offered with the condition that there is no change in the height of the power house and no pit shall be allowed in the service bay. Any alternative material offered must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and material properties. However, the detailed comparison of Chemical

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

composition and material properties much be submitted to the Purchaser for approval during detail engineering stage. The shaft shall be of ample size to match with the turbine shaft to operate at all speeds, including maximum runaway speed without vibration or distortion and shall be able to withstand short circuit and other stresses without damage. The generator shaft shall be machined accurately and polished, where it passes through the guide bearings and at accessible points, for alignment checks. The shaft shall have a hole of adequate size bored axially throughout its entire length sufficiently smooth to permit inspection of the metal in the interior of the shaft and possible handling of the turbine runner by use of overhead crane. The generator shaft shall have integral flange matching for friction type coupling to the turbine shaft flange by means of hydraulically pre-stressed bolts and conforming to the latest revision of standard IEEE 810 "Standard for Hydraulic Turbine and Generator Integrally Forged Shaft Coupling and Shaft Run-out Tolerances". Alternatively, Tenderers can also offer friction type coupling of proven design which shall be subject to Employer's approval. The face of the coupling shall be at a minimum distance below the generator, compatible with accessibility. All coupling bolts, nuts and nut guards for coupling, conforming to the above-mentioned standard shall be in the scope of supply. Contractor shall ensure proper alignment of the generator and turbine shafts at site. The alignment limit for the shaft shall be as per the latest NEMA or equivalent standard. The Contractor shall submit data, computation and analysis for critical speed and shaft diameter to Employer for approval.

The critical speed of the shaft at balanced condition shall be over 25% of the runaway speed. The turbine manufacturer shall furnish all the turbine data necessary for such computation, if so required to the Employer prior to the starting of manufacturing. The shaft shall be ultrasonically tested throughout its length as per ASTM A-388. The Contractor shall furnish complete report covering metallurgical strength, crystallographic ultrasonic and baroscopic tests performed on generator shaft during manufacture.

#### 2.3.7.9 Thrust & Guide Bearings

The generator coupled to francis turbine shall be suspended type i.e. with the thrust and upper guide bearings located above the rotor and lower guide bearing below the rotor. The thrust bearing shall be of Babbit-metal fully lubricating type. The bearing shall be lined with ASTM-B23, type 2 antifriction Babbit metal. The thrust bearing shall be of the manufacturer's standard design, with flexible self-adjusting pad, support (spring mattress type, tilting pad type or of other proven and reliable design), providing sufficient

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

references for long-term satisfactory operation. The thrust bearing shall have sufficient capacity to support the total weight of the rotating parts of the unit together with unbalanced hydraulic thrust of the turbine, runner under all conditions of operation (Starting, Normal and emergency stopping, continuous rating or maximum continuous rating and runaway condition). The thrust bearing shall be designed so that specific pressure applied to pad does not exceed 6 MPA. The design of the bearings shall be based on limiting the bearing metal operating temperatures for operation at 103.5 MVA, as given below:

- |      |   |          |
|------|---|----------|
| i.   | Maximum permissible operating temperature | ≤ 70 °C; |
| ii.  | Alarm temperature                         | 75 °C;   |
| iii. | Trip temperature                          | 80 °C.   |

No damage shall occur to bearings even if temperature reaches 105°C. The expected bearing temperature shall be indicated in the offer. The temperature of the metal and oil of the bearings shall be monitored with the help of double element 100 ohms platinum RTDs. Further, the bearings shall be capable of safe operation without any damage under the following conditions:

- Continuous operation at any speed from 50% to 110% of rated speed;
- Operation for a period of at least 15 minutes under maximum runaway condition with cooling water on.
- Operation for a period of at least 15 minutes at maximum allowed load and rated speed without cooling water, followed by safe shut-down;
- Operation for a period of at least 30 minutes at a low speed of 4 to 5% of rated speed;
- Operation at the runaway speed without cooling water for two (2) minutes.

The combined thrust & guide bearings and lower guide bearing shall be of the immersed in oil bath type in which water-cooled oil coolers are placed. The coolers of lower guide bearing will be of plug-in type. The location of the coolers of the combined thrust and guide bearing shall be planned for giving the best results and shall be replaceable without removing the generator rotor.

The coolers shall be designed on the basis of cooling water temp not exceeding 30 deg C. The maximum ambient air temperature is expected to be 40 deg C. The tubes of the oil coolers shall be of Cupro-Nickel (90 / 10 composition) and shall have adequate excess capacity to allow for 10% plugging of cooler tubes, plus one complete cooler out

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

of service when unit is operating at maximum capacity (103.5 MVA) at rated power factor and rated voltage.

The cooling system shall be complete with cooling water pipes, fittings, flow indicating devices, flow relays and all other accessories. All internal pipes shall terminate in a flange on the generator barrel for connection with plant cooling water system as specified elsewhere in specification. Oil filling and draining shall be grouped at a centralized point common for lower guide bearing and common upper guide-and thrust bearing. It shall be possible to drain the bearings completely in less than 30 minutes. Any recesses that may create spaces in which oil might accumulate shall be fitted with drains.

Baffles and guides shall be provided in the oil baths to assist correct oil distribution and to prevent splashing. The bearings shall also have provisions to prevent oil vapour from entering into the generator. The oil reservoirs shall have suitably protected sight gauges fitted with isolation valves for visual inspection of the oil level.

The thrust and guide bearings shall be adequately insulated to prevent any harmful circulating currents from passing through the bearing surfaces. This insulation shall be arranged to break the possible path of such currents in not less than two (2) places in series so that positive test for ground currents can readily be made. Monitoring of shaft current shall be provided on demand through a series connected current measuring device and contacts shall be provided for alarm purpose in case of excessive shaft current. A suitable shaft earth brush will be provided at a suitable location on the shaft supported by the bearing housing to bypass harmful currents from damaging the bearings pads. The contractor shall co-ordinate for integrating / matching the control / data acquisition of this system with 'SCADA' for shutdown and annunciation. If during operation of the generator any circulating currents passing through the the bearing surface are noticed, the Contractor shall take necessary steps, at his own expense, to rectify the defect.

#### 2.3.7.10 High Pressure lubricating oil system

It babbitted thrust pads are used, the thrust bearing shall be provided with a high pressure oil-lift system which shall automatically inject oil directly between the thrust bearing segments & the thrust block, during start-up & shut down between zero RPM & 30% of synchronous speed. Control equipment for the high pressure oil system shall be mounted inside the turbine / generator cubicle, A manual ON-OFF auto selector switch &



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

manual ON, Auto, system operating indicating lamps shall be provided on the front of the cubicle. A pressure switch, with contacts wired to the T/G cubicle shall be provided to prevent unit start up until the oil lift system is operating satisfactorily.

### **Type of lubrication oil**

Oil for first filling of the generator lubricating system etc. with 10% as extra shall be supplied by the Contractor. The quantity required and detailed specifications of the oil to be used for lubrication of generator bearings shall be provided. However, subject to the requirements of the Contractor's specifications being fulfilled, the actual trade mark / brand name of the oil shall be at the discretion of the Employer.

### **Oil Flow**

Design of lube oil system will be based on inputs received from the bearing mfr and will be frozen during detailed engineering.

Tenderer shall submit detail design memorandum for the approval of Engineer

#### **2.3.7.11 Bracket**

##### **i. General**

The structure of brackets shall be adapted to cope with axial and transverse flexibility constraints and expansion problems. The Contractor shall submit the calculation showing the construction conditions of the brackets.

##### **ii. Bottom bracket**

The bottom bracket shall be of a fabricated steel structure. Jacking screw shall be provided for centering. The bracket shall be designed in such a way that it will be possible to lift it through the stator bore. Brake and jack units will be mounted on the bracket for rotor braking and jacking. The bracket shall be designed to transform radial forces into tangential forces and to transmit these to civil works without affecting the stability of the construction. Guide bearing housing and oil bath will be formed in the center of the bracket.

Its axial bending shall be limited and consistent with the operation of the unit.

##### **iii. Top bracket**

The top bracket shall also be of a fabricated steel structure. It shall be designed to support the hydraulic thrust from the turbine in addition to weight of the rotating parts of the generator and turbine. It shall also support the weight of stationary parts of

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

brush gear and over speed device and flooring. Jacking screw shall be provided for adjusting the bracket during levelling and centering of bracket. The thrust and guide bearing housing and oil bath shall be formed in the center of the bracket.

The bracket shall be designed to transform radial forces into tangential forces and to transmit these to civil structure without affecting the stability of the construction. Its axial bending shall be limited and consistent with the operation of the Unit.

#### 2.3.7.12 Ventilation and Generator Cooling

The unit shall be self-ventilating. The generator shall have a closed-circuit system of ventilation. Pit seals shall be provided for separation of the generator air-cooling system from the turbine pit. The air coolers shall be of frame-mounted type with air cooler tubes made of Cupro-Nickel alloy (90 / 10 composition) and cooled air will be circulated into the annular space surrounding the stator. The cooling system shall be complete with air coolers, cooling water pipes, fittings, valves, flow indicating device, flow relays and all other accessories. All internal piping shall be terminated in a flange on the generator barrel for connection with plant cooling water system, as detailed in Associated mechanical unit auxiliaries of these specifications. The generator air coolers shall have sufficient capacity to maintain an air temperature not exceeding 10°C higher than the specified secondary cooling water temperature when one cooler is out of service and the unit is operating at maximum MVA at rated power factor and rated voltage. The number of coolers provided, the normal working pressure and pressure drop through the coolers shall be indicated and supported by calculations. Pressure drop across each cooler shall be limited to 0.5 kg / cm<sup>2</sup>. Connections shall be provided at the bottom of the air coolers to facilitate complete drainage. The coolers shall be designed for at least 10 kg / cm<sup>2</sup> nominal pressure. Each cooler shall be provided with 15% additional cooling coils to maintain adequate cooling even when some cooler tubes get plugged.

Automatic air vents with drain pipes shall be provided at the top to prevent air locks in the coolers. Lifting lugs shall be provided to facilitate the removal of any cooler (through the top of the generator cover). Each cooler shall be provided with a pocket for inserting thermometer on discharge end. Pipes for coolers shall be made from material with anti-corrosive properties consistent with the quality of the water used. The system shall be designed so that at shutdown the coolers remain full. The connections between the exchangers and the cooling water pipes shall be of the flanged type. The valves on the cooling circuit shall allow:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- isolation and drainage of a cooler while the others remaining in operation;
- drainage of the entire circuit;
- purging of a cooler circuit.

Proper means shall be provided for draining all piping and heat exchangers and safely discharge the leakage water, without any risk of contact with the generator windings.

The Contractor shall provide a device to allow adjustment of the cooling system flow-rate.

The cooling water pipes inside the barrel shall be suitably coated with adequate thickness of anti-condensation paint to prevent condensation on pipes. Circulation of cooling air shall be accomplished by means of rotating rim or other efficient established method. Various sensors and instrumentation for supervisory control and data acquisition (SCADA) shall be provided.

#### 2.3.7.13 Rotor Fan

The Axial Fans will consist of a large number of specially shaped aerofoil aluminum blades assembled to the fabricated support segments. These segments will be mounted on the top and bottom of rotor. Suitable guides and air baffles will also be provided to ensure proper distribution of air in the machine. Necessary plates shall be provided for the closing of space vacated by the coolers removed for overhaul. However, the manufacturer may use their standard design by providing reasons and advantages, subject to prior approval, during detailed engineering.

#### 2.3.7.14 Speed Signal Generator (SSG) Mounting Arrangement

A toothed wheel type speed signalizer mounted on the generator shaft and magnetic pick up mounted near the toothed wheel shall provide the speed signal for governing system. The signal generated by the magnetic pick interaction with rotating toothed wheel (signal frequency proportional to the number of teeth it cuts per second) is fed to the electronic speed sensing circuitry within governor controls which in turn generates a speed raise or lower signal to the actuators. Separate set of pickups with electronic speed sensing circuitry shall be provided for speed monitoring, overspeed tripping device and to energize various speed relays which generate signals for various functions like brake application, unit shutdown etc. These pickups shall also be used in creep detection card for detection of creep.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The speed signal generator complete with toothed wheel, magnetic pick up and internal wiring up to the terminal box on generator barrel will be a part of the Governor supply. The shaft extension and monitoring of SSG, shall be done by the Generator Contractor. Co-ordination for integrating / matching the control / data acquisition of this system with SCADA shall be done by the Generator Contractor. The connection between the SSG and the governor shall be by special cable so that signal is not affected by any switching in the power house.

#### 2.3.7.15 Brakes and jacks

##### i. Brakes

Each generator shall be provided with pneumatically operated brakes of sufficient capacity to bring the rotating parts of generator and turbine to stop from 20% of rated speed in normal operation. However, under emergency conditions it shall be possible to apply the brakes at 50% of rated speed without any damage to the brakes. The brakes shall normally be applied automatically. It shall also be possible to apply the brakes from unit control board by means of a push button or from brake control panel. Since SCADA is also to be supplied for this project, necessary co-ordination for automatic application of brakes from unit process computer is to be done by generator Contractor for proper integration / matching the control / data acquisition of this system with the 'SCADA'.

The brake shoes shall be provided with suitable lining, which shall be easily removable. The brake lining shall be highly wear resistant, shall not contain metals or electrically conducting material and shall be asbestos-free. These shoes shall operate against a polished circular steel brake track (brake ring) bolted to the underside of rotor spider hub.

The compressed air at adequate pressure required for operation of the brakes shall be provided from the compressed air system covered in the Section - Associated Mechanical Unit Auxiliaries of these Specifications. The air receiver of requisite capacity along with pressure gauges, piping and all fittings required for braking of each unit shall be provided and terminated with a valve at the generator barrel. The generator Contractor shall indicate all the requirements to be taken into consideration for designing the capacity of air compressor to the turbine Contractor.

Each brake cylinder shall be provided with a limit switch with auxiliary contacts to provide starting interlocks and 'ON', 'OFF' annunciation on the unit control board. A

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

pressure switch shall also be provided for starting interlock. All these starting interlocks and annunciation are also required for data acquisition / control of unit from unit processor, operator control processor and remote control of unit (future option), equipment for which are also to be supplied as part of SCADA'. The requisite R.T.U.s are to be supplied by Contractor for termination of starting interlocks and annunciation signals and the requisite co-ordination is required to be done by the Contractor for proper integration / matching the control / data acquisition of these with "SCADA" controls.

## ii. Jacks

The brake cylinder shall also be designed to serve as hydraulic jack to lift the generator rotor to a sufficient height to facilitate removal and adjustment of bearing pads. Provision shall be made for mechanically locking the rotor in raised position for an extended period of time without the oil pressure being maintained. A limit switch for operation of an indicating lamp shall be provided to indicate when maximum permissible raised position of the rotor is reached. Mechanical indication shall also be provided in case of failure of electrical indication. For the purpose of jacking 3 ph, 50 Hz, 415 V motor operated high pressure oil pump along with pressure gauge on the discharge side of the pump, an oil level sight gauge with isolation valve for oil reservoir, necessary piping and fittings shall be provided for each unit.

The Contractor shall furnish all necessary piping connections, valves, control switches, interlocks etc. so as to make braking and jacking complete in all respects. The control system offered shall be suitable to fit into the automatic control of the unit. The requisite co-ordination is required to be done by generator Contractor for proper integrating / matching the control / data acquisition of this system with 'SCADA'.

### 2.3.7.16 Brake / Jack Control Panel, Brake Dust Collection Equipment& Hydraulic Power Pack

Each generator shall be provided with Brake / Jack Control Panel, Brake Dust Collection Equipment. Hydraulic Power Pack shall be used for jacking of the rotor during maintenance.

### 2.3.7.17 Control & Monitoring Devices

#### i. Vibration Monitoring System



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

A continuous vibration monitoring system complete with proximity probes, input / output module, control / processor unit, relays, junction boxes, cabling and associated accessories shall be supplied for on-line monitoring of vibration in generating unit.

It shall be composed of:

- 2 nos. non-contact type proximity probes each for all the guide bearings i.e. upper, lower and turbine guide bearing to measure radial displacement in both directions (Upstream-Downstream / Right-Left);
- 2 nos. non-contact type proximity probes for turbine and generator shaft coupling;
- Synchronization probe;
- Set of input / output model, control / processing / communication unit, relays, junction boxes, cabling and associated accessories. The monitor with its control accessories shall be located at the respective unit control panel.

The system shall have the provision to monitor, record, analyze, diagnose, indicate, and trip etc. as provided in the sections – Control and Monitoring Protection System. The details and scope of the system shall be subject to approval by the Engineer.

The vibration system monitoring shall be located in the UCB and will be interfaced with the UCB DCS and SCADA for monitoring and shutdown signals.

The vibration monitoring system shall be supplied by reputed manufacturers like VibroSystM or GE Bentley Nevada as approved by the purchaser. The vibration analyzer system, common to three units, shall be offered as optional.

## ii. **Anti-Condensation Heating & Lighting**

Suitable, evenly distributed space heaters or air dryers shall be provided on lower bearing bracket to prevent condensation of moisture on the windings during shut down period. The heaters of various sections shall be connected together to form a balanced 3-phase load. A suitable terminal box shall be provided at a convenient location for connection to 3 phase, 50 Hz, 415 V, AC supply. ON / OFF control device along-with suitable thermostats shall be provided for the heaters for automatically maintaining sufficient temperature difference between generator and outside air. The heater control gear shall be mounted on a panel to be located

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
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outside the generator enclosure. The temperature range for automatic operation of the heaters shall be stated by the Contractor.

Sufficient lighting fixtures to provide general lighting inside generator housing, lower brackets, collector ring, dome light etc. and a minimum of four convenient outlets for small power tools and extension light shall be provided within the generator housing. The wiring shall be neatly arranged and connected to a terminal box for single phase, 50 Hz, 240 V AC. supply.

### iii. **Partial Discharge Analyzer:**

#### **General**

A panel mounted partial discharge analyzer (common to all units) along with permanent couplers mounted on the stator windings of all three units to continuously monitor the conditions of the stator insulation shall be provided. This shall include PD monitoring device, signal cables, PDA termination boxes, PDA instrumentation, server, software for on board data processing (including noise rejection). The brief technical requirement shall be as below.

The PDA system monitoring shall be interfaced with the UCB DCS and SCADA for monitoring and shutdown signals.

The PDA system monitoring shall be supplied by reputed manufacturer like GE Energy, Megger as approved by purchaser. Bidder may choose alternative equivalent vendor subject to purchaser's approval.

#### **Technical Data**

	PD Measuring System	Our Requirement
<b>A</b>	<b>PD sensor (To be provided on each generator)</b>	
1	Type	Permanently Installed Capacitive Couplers
2	Characteristics	Ratings: 250 pF or more @ 24kV 1 nF or more @ 12 kV
<b>B</b>	<b>PD Acquisition Unit (Common to all units)</b>	
1	Protection class of cable termination box	IP 67

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

2	Power Supply	
3	Temperature operation range	0 to 55 °C
4	Humidity operation range	5 to 99% (non-condensing)
5	Sampling rate	>100 MS/s / 14 Bit
6	Upper frequency cut-off	20 MHz
7	Number of channels	16
8	The system support frequency selective PD measurements (frequency of measurements and bandwidth adjustable)	Required
9	Integrated oscilloscope and spectrum analyzer feature	Required
10	Certificate of the characteristics of measuring system according to IEC60270 (par. 7)	Required
11	Alarm feature for unusual conditions and PD levels or for critical patterns of PD discharge	Required
<b>C</b>	<b>Communication system</b>	
1	Type	Fiber Optics
2	Accuracy of synchronization in between two PD measuring units	± 2 ns
<b>D</b>	<b>PD termination box – Monitoring Server / DESKTOP / LAPTOP</b>	
1	Hard disk Capacity	2 TB
2	UPS required	Yes
3	Screen Monitor	TFT 19" for Server / Desktop and 15" for Laptop
4	Printer	Yes
<b>E</b>	<b>Software characteristics</b>	
1	Noise rejection and selective filtering available	Required

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

2	On-board data processing capabilities to efficiently separate PD phenomena from noise on the basis of the PD-pulse shape and split in different clusters relevant to homogenous PD sources, so that further analysis can be carried out on each data set separately.	Required
3	Trends and PRPD pattern	Required
4	Recording of different quantities during the acquisition phase with phase, amplitude, time and pulse feature of each signal	Required
5	Storage of the data, remotely accessible from a remote computer via a TCP / IP connection	Required
<b>F</b>	<b>General</b>	
1	Testing and calibration of system at works	Required
2	The system shall remain unaffected by high electro-magnetic environmental interferences and interferences from the power system	Required

#### iv. Air Gap Monitoring System

An air gap measuring system for on-line monitoring of generator air gaps shall be supplied. The system supplied must be proven in the field. The system shall be submitted to Engineer for approval during detailed engineering.

The system shall provide dynamic air gap measurements, permit static measurements, to continuously monitor the condition of the generator air gap without requiring a service outage. The systems provided shall not compromise the reliability and safety of the generator.

Capacitive type air gap sensors for the protection system shall be permanently installed in the air gap on the stator iron packets of the stator wall. The sensor frequency response shall range from 0 to 1000 Hz for static and dynamic air gap

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

measurements. Maximum operating temperature of the sensor shall be at least 125°C. The sensors themselves shall be unaffected by the magnetic fields created in the generator. Calibration charts for each sensor shall be provided by the Contractor. A key-phasor, used for rotor pole reference purposes, shall be installed in the turbine pit or in the exciter housing near the rotor shaft.

The Contractor shall furnish an air gap monitoring system (AGMS), which is specifically designed and equipped for use with the permanently installed capacitive sensors mentioned above. The system furnished shall be integrated with the DAC system for monitoring, alarm and diagnostic purpose. The AGMS shall measure the static and dynamic air gap and shall be controlled by a user-friendly software package to display results in a polar, rectangular and tabular form. The AGMS shall provide a polar view of the rotor shape inside the generator stator. The AGMS shall provide software and / or hardware alarm when the air gap reaches set alarm levels. Contractor shall provide a complete installation, test and operation guide with the AGMS for operating personnel.

The Air Gap monitoring system shall be located in the UCB and will be interfaced with the UCB DCS and SCADA for monitoring and shutdown signals.

The Air Gap Monitoring system shall be supplied by reputed manufacturer like VibroSystM or GE Bentley Nevada as approved by the purchaser. However, Bidder may choose alternative vendors, subject to prior approval (equivalent to suggested vendor)

### 2.3.8 Turbine-Generator Gauge Panel

#### Generator Gauge Board

A generator gauge board preferably mounted on the concrete housing shall be supplied on which all dial type thermometers pertaining to generator shall be mounted. The fixtures required for mounting the gauge board on the concrete housing shall be included in the scope of supply.

### 2.3.9 Fire Protection System for Generators

Automatic fire extinguishing equipment will be of the carbon-dioxide type and common for all THREE Generators. In the event of a fire, smoke detectors will first operate to give early warning signal to the operator. For deep seated fires of hazardous nature, release



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

of CO<sub>2</sub>, gas will be initiated by heat detectors located inside the generator in the hot air zone or by the operation of the generator differential relay.

Protection will be effected by filling the generator air circuit with CO<sub>2</sub>, at a concentration sufficient to dilute the oxygen content to a point where combustion cannot continue. The extinguishing system will be designed in accordance with NFPA: 12. Two CO<sub>2</sub>, banks, each consisting of an adequate number of CO<sub>2</sub> cylinders will be provided. One acting as main and the other as standby.

The bank of CO<sub>2</sub>, cylinders would be of sufficient capacity to provide rapid total flooding of the one generator air circuit at high concentration within 2 minutes (i.e. initial discharge) and slow release of CO<sub>2</sub>, gas to maintain concentration ' of about 30% during deceleration period (i. e. Delayed discharge) of the generator or 20 minutes, whichever is more.

Each bank will have CO<sub>2</sub>, cylinders (for initial and delayed discharge) fitted with pressure operated valves and two numbers of master CO<sub>2</sub>, cylinders (both for initial & delayed discharge) fitted with electrical control head and valve. Outlet from master CO<sub>2</sub>, cylinders will be connected to respective battery of initial and delayed discharge slave CO<sub>2</sub>, cylinders with their outlets finally connected to a common header via a non return valve. Initial and delay discharge headers from the main and standby banks will be connected to the common manifold of the generator through pressure operated directional valve fitted with tripping mechanism. Downstream side of the direction valve will terminate with suitable number of initial & delayed discharge nozzles.

Automatic weighing provision for each cylinder of CO<sub>2</sub>, with electrical contact will be available to indicate / annunciate against any leakage of CO<sub>2</sub>, beyond 10% in any bank.

### 2.3.10 Miscellaneous Accessories

#### 2.3.10.1 Terminal Boxes, Control Wiring & Conduits

##### Terminal Boxes

The contractor shall supply terminal boxes to be located outside the generator pit, for connection of control and secondary leads from the generator equipment and auxiliaries located in the generator enclosure. All leads including control and indications shall be wired to this terminal box.

##### Control Wiring & Conduits

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

All internal wiring and conduits for control, relaying, fire protection, internal illumination and other systems shall be brought out to terminal boxes, and shall be suitably labeled.

#### 2.3.10.2 Instrumentation, Control & Safety Devices

Necessary sensors / sensing elements, signalizers for sequential control and interlocks, measurement (indication, recording of quantities), monitoring of abnormal conditions of operation of generator (for safety alarm annunciation and shutdown) and related instrumentation which are embedded in and / or mounted on the generator or its adjacent (local) gauge panel shall be included in the scope of supply of the generator Contractor as an integral part. The measurements shall generally pertain to the following. Necessary co-ordination shall be made for automatic operation / data acquisition of unit from unit control processors and main control room processors covered under 'SCADA'.

Temperature	Stator, Rotor, Bearings, Air for ventilation of Generator, Cooling Water.
Liquid Level	Oil in bearing oil baths
Pressure	Brake Air, Cooling Water.
Flow	Cooling water for Generator Air Coolers, Bearing Oil Coolers.
Creep / vibration, fire	Generator, bearing bracket
Moisture content	Oil in bearing oil reservoir.

Duplex resistance type temperature detectors (RTDs) shall be embedded in the stator windings and stator core, ventilation air circuit, cooling water for air and oil coolers, bearing pads and oil baths etc.

The rotor winding temperature shall be measured through a special device integrated in the excitation system. The rotor voltage is to be measured in the excitation system. Voltage drop in the field leads from excitation cubicle to slip rings is also to be adjusted in the design calculations for rotor winding temperature detection. Hence additional insulated brushes should not be necessary.

The vapour pressure principle dial type thermometers (DTTs) with two contacts for high and very high temperature alarm shall be provided.

For measuring hottest metal temperature of all bearings, thermal relay having range 60°C to 120°C with two 'NO' contacts shall be provided. Bulbs / sensing elements of the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

relay shall be located in the bearings to measure babbit lined temperature. Connections shall be brought out to generator terminal box for further wiring to temperature monitoring device of UCB / SCADA. The bulbs / sensing elements and tubing shall be insulated to prevent stray currents, where required Relays shall be located at convenient location in generator barrel.

The cooling water supply and discharge pipes for the generator air cooler and bearing oil coolers shall have necessary pressure gauges, thermometers, flow relays, electromagnetic type flow meters and pressure switches etc.

All necessary tubing with connections between DTTs on the generator gauge board and sensing elements shall be part of the generator supply.

All instruments, signalizers, sensors, sensing elements shall be of the best quality and makes Subject to approval by the Employer.

Instruments, Control & Safety Devices per Generator shall be as below:

#### **Resistance Temperature Detector (RTD) (Duplex Type)**

Stator winding	4 RTDs per phase spaced at 120 deg
Stator Core	6 Nos
Stator Teeth	6 Nos
Hot air	1 RTD in hot air zone of each air cooler
Cold Air	1 RTD in cold air zone of each air cooler
Thrust pads	1 RTD in each thrust pad
Upper Guide Pads	1 RTD in each guide pad
Lower Guide Pads	1 RTD in each guide pad
Bottom oil reservoir	2 RTDs diagonally opposite
Top oil reservoir	2 RTDs diagonally opposite
Common cooling water inlet to air & oil coolers	1 No RTD
Common cooling water outlet of air coolers	1 No RTD at each outlet of air and each outlet of oil coolers
Common cooling water outlet of bottom oil coolers	1 No RTD in each cooler

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Common cooling water outlet of top oil coolers	No RTD in each cooler
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#### Dial Type Thermometer

Thrust bearing pad	Alt pads
Lower guide bearing pad	Alt pads
Top guide bearing pad	Alt pads
Bottom oil reservoir	2 Nos (diagonally opposite)
Top oil reservoir	2 Nos (diagonally opposite)
Hot air inlet to air coolers	Alternate coolers
Cold air outlet from air coolers	Alternate coolers
Common Cooling water inlet to air and oil coolers	1 No
Common Cooling water outlet of each air coolers	1 No
Common Cooling water outlet of top oil cooler	1 No
Common Cooling water outlet of bottom oil cooler	1 No

#### Thermostat

Thrust bearing pads	1 no on each alternate pad
Lower guide bearing pads	1 no on each alternate pad
Upper guide bearing pads	1 no on each alternate pad
Hot air inlet to air coolers	1 no on each alternate cooler
Anti condensation heaters	2 nos diagonally opposite

#### Oil Level Switch

lower guide bearing oil reservoir	2 Nos
Upper bearing oil reservoir	2 Nos

#### Limit Switch

Brakes ON / OFF indication	1 No on each brake pad
Rotor jacking limit switch	1 No on each jacking pad

#### Visual Flow Indicator

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Cooling water outlet from each air coolers	8 No's, Magnetic type with digital output to indicate in SCADA.
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#### **Electromagnetic Flow Meter**

Common cooling water outlet from air coolers	1 No
Common cooling water outlet from top oil coolers	1 No
Common cooling water outlet from bottom oil coolers	1 No

#### **Pressure Gauge - Digital / Numerical-capable to indicate in DCS / SCADA**

Common cooling water inlet to air and oil coolers	1 No
Common cooling water outlet from air coolers	1 No
Common cooling water outlet from top oil coolers	1 No
Common cooling water outlet from bottom oil coolers	1 No

#### **Other Instruments / Devices**

Multi Chartless temperature recorder with logging in DCS / SCADA	As per no of RTDs finalized
Chartless Rotor Temperature recorder with logging in DCS / SCADA	1 No
Over speed devices	1 No each of Mechanical as well as Hydraulic type (directly acting on Governor)
Mechanical Vibration Monitoring system No of vibration sensors: 6 nos non contact sensors(2 per bearing) 3 nos contact sensors (1 per bearing) 1 no phase reference sensor.	1 Set
On line air gap monitoring system (Optional) No of air gap sensors	1 set per generator 8 Nos per generator
On line partial discharge monitoring system  No of PD couplers	1 set (wheel mounted) common to all units  One no per phase per generator
Shaft current monitor	1 No. per generator

#### **2.3.10.3 Miscellaneous Piping, Tubing & Valves**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

All internal piping and valves for the following functions shall be included in the scope of generator supplies.

- Cooling water inlet, outlet and drain for generator air and oil coolers;
- Oil fill and drain connection at the bearings;
- Piping for brakes and jacks;
- Tubing for connections between temperature sensing elements (vapour bulbs) to dial type thermometers, pressure gauge tubing;
- Any other essential piping, tubing etc.

For cooling water inlet and return from the generator, piping of required size shall be provided with manually operated valves and required instrumentation. These piping shall be terminated at suitable convenient points (in consultation with Employer) outside the generator with flanges. These flanges shall also be provided with their companion flanges, gaskets & bolting. Piping system beyond the termination flanges shall be part of the cooling water system.

The cooling water piping shall be ERW or seamless of requisite class and standards. The cooling water pipe shall be covered with Armaflux insulation with Aluminium cladding.

The piping shall be of hot dip galvanized steel of requisite class and standards. The valves shall be of cast steel, bronze / brass as per proven practice

All tubing required for the purpose of connections to and between generators to instruments shall be of the requisite size and material.

#### 2.3.10.4 Generator Housing and Structural Details

The concrete housing for the generator shall be airtight. The generator manufacturer shall supply a fabricated steel top cover, which shall not require bolting into position and shall be provided with tapped holes or equivalent for lifting. To prevent damage to the threads, the tapped holes shall be provided with threaded plugs. Openings with suitable covers shall be provided in the top cover for removal of field poles, stator bars and surface air coolers etc. vertically from above.

Suitable platforms, walkways, stairs, hand -rails and inspection door in generator housing shall be provided for inspection and maintenance of bearings, slip rings, coolers etc. The housing shall be equipped with at least two steel doors with locks operative from inside the housing. All platforms, walkways, stairs shall have safe non-slip surface.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

### 2.3.10.5 Cabling

The following control and auxiliary power cables and wiring shall form part of the supply. Signaling cables shall be screened.

All wiring within the generator housing for the speed signal generator connections, thermostats, flow meters, RTDs / DTTs, all alarm, control and metering circuits associated with the generator.

Field leads between the generator collector rings and field breaker located along with excitation switchgear.

Capillary tubes / cables between generator and the gauge board.

All 240V AC wiring, lighting fixtures and convenience outlets within the generator housing.

A cable marshalling box with approved disconnecting links to terminate all cables leading to the exterior of the generator.

A remote terminal unit of all exterior connections for automatic control and protection of unit provided in SCADA.

All cabling shall be of screened type so that no switching impulses of the power house affect the signals in any way.

### 2.3.11 Generator Tests

#### 2.3.11.1 General

The generators shall be completely pre-assembled to maximum extent at shops, suitably tested and match-marked and shall be transported to the site in disassembled conditions due to transport limitations on the road. The generator shall be reassembled at site and the following tests as per IS 4722 / IEC 60034 shall be conducted on the assembled unit.

#### 2.3.11.2 Shop Tests

The materials, parts and assemblies shall be tested to comply with the Standards accepted by Employer and shall be in accordance with the best commercial methods applicable to the relevant type and class of work. The tests and trials shall be recorded and certified by Contractor. In cases where doubt exists regarding Contractor's tests, Employer may request repetition of such tests in his presence. All tests and retests, if required, shall be done by Contractor at no extra cost to the Employer.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Within 30 days of completion of each and every test required as proof of compliance with the Specifications and / or each and every specified test, Contractor shall submit a report covering such tests. Employer reserves the right to witness any tests.

The test records for materials shall identify the component parts in which the materials are to be used and the certificate shall be prepared in such a way that it can be easily determined if the applicable Specifications or standards have been complied with.

Shop QA plan shall be subject to approval by the Employer / Engineer.

In addition to, and notwithstanding any requirements covered above, Contractor's inspection and / or tests shall include the following:

- Stator and field copper- conductivity, mechanical properties, and insulation tests including breakdown voltage (where applicable);
- Stator core iron - B / H curve points, Eddy current loss tests (or equivalent), interlaminar resistance;
- Pole and rim punching - mechanical properties and B / H curve points;
- Shaft forging - chemical content, and physical and mechanical properties;
- Thrust and guide bearings white metal- physical and mechanical properties;
- Thrust collar and brake ring - physical and mechanical properties;
- Stator bars - power factor tip-up tests on 5% of the total number of bars supplied (before winding in). Actual bars tested shall be selected by Employer;
- Field coils and stator bars - winding resistance, insulation resistance, high potential tests. These tests shall be done on coils and bars before and after "winding in";
- All heat exchanger cooling coils - pressure tested at 1.5 times the maximum operating pressure for half an hour without leakage, damage or failure;
- Controls and instruments - operational tests on all controls and instruments to demonstrate that the Specification requirements have been met;
- Each bar of stator winding as per standards.

#### 2.3.11.3 Pre-Commissioning Tests

##### i. During Installation

During erection and before start-up the following measurements and tests shall be performed as a minimum and all other tests, which are deemed necessary by the Employer:

- Visual inspection and dimensional check;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- Check of stator bore for exact roundness at the upper and lower edges of the iron core;
- Checking of the uniformity of the air gap;
- Checking of the alignment of the ready assembled turbine and generator shaft. The generator Contractor is responsible for the execution of the alignment check, and the turbine Contractor shall assist;
- Checking of all bearing clearances;
- Checking of the bearing oil cooling installation for complete and correct assembly;
- Checking of the entire generator cooling system for complete and correct assembly;
- 30 minutes hydrostatic pressure and tightness tests of all equipment containing / carrying water, oil and compressed air;
- Checking of jacks in braking and lifting operation respectively;
- Measurement of the D.C. resistance of the field winding;
- Measurement of the stator winding D.C. resistance per phase;
- Megger test and H.V. test of the field winding;
- Megger test (1 min. and 10 min. value) of the stator winding and determination of polarization index;
- Performance of operational tests on all generator auxiliary equipment, including calibration of related electric indicating, control and metering instruments, and checks for correctness of wiring and piping;
- Checking of alarm and protection devices;
- Any other tests deemed necessary, before commissioning of the unit.

## ii. Pre-start Tests

- Insulation resistance test - stator and rotor;
- Dielectric tests - stator and rotor.

### 2.3.11.4 Wet Commissioning Tests

Contractor shall provide and calibrate all necessary test instruments and equipment, including the short circuit test breaker.

In addition to commissioning tests required by other equipment, the following tests shall be carried out by Contractor on each unit according to the indicated standards:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- Shaft current and bearing insulation test.
- Phase sequence test.
- Waveform and telephone interference tests.
- Short circuit characteristic curve and losses - determination of.
- Open circuit characteristic curve and losses - determination of.
- Zero power factor saturation test.
- Deceleration curve - determination of moment of Inertia.
- Sudden short circuit test from not less than 0.50 rated terminal voltage to determine reactance and time constants.
- Sustained short circuit test to determine reactance.
- Voltage balance and intra phase no load circulating current test;
- Deceleration loss test;
- Heat run tests at 100% and 110% (103.5 MVA) of rated power;
- Load tests from no load to maximum overload and interphase circulating current;
- Load rejection tests at 50%, 75%, 100% and 110% of full load;
- Mechanical and bearing run tests, including mechanical balancing, bearing temperature checks, shaft eccentricity, vibration checks;
- Start-up and shut-down sequence including mechanical braking;
- Overspeed tests;
- Full runaway speed test for 2-minute duration;

After continuous operation for 72 hours, the generator shall be free from overheating, detrimental vibration, leakage, failures, damage, etc. Complete commissioning test reports shall be provided at the end of the commissioning period.

Following tests in operation without any harmful damage to the machine

- Guide bearings and the thrust bearing to be able to operate for 15 minutes at maximum load conditions without any water-cooling auxiliaries and followed by safe shutdown;
- Thrust bearing to be able to withstand a machine shutdown without any oil injection system;
- Generator to be able to run at continuous overload apparent power with one of the air-to-water exchangers out of service.

#### 2.3.11.5 Field Acceptance and Performance Tests

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Prior to acceptance of the equipment by Employer, a series of tests shall be carried out by Contractor to determine the performance and operating characteristics of each complete unit and to verify that all guarantees have been met.

The following tests shall be performed on generator:

- Impulse short-circuit test at reduced voltage acc. to IEC60034-1, Para. 24;
- Determination of the values for  $X_d$ ,  $X'_d$ ,  $X''_d$ , and  $X_q$ ;
- Determination of the following constants:  $T'_{do}$ ,  $T'_d$ ,  $T''_d$  and  $T_a$  in accordance with IEC 60034-4;
- Determination of the nominal exciter Response Measurement of the telephone harmonic factor (THF) and evaluation of waveform irregularities in accordance with IEC 60034-1, Para. 28;
- Plotting of oscillograms for the examination of the no-load voltage sine wave;
- Measurement of the individual losses and determination of the efficiency in accordance with IEC 60034-2. The losses to be considered for calculation of the efficiency shall be the sum of individual losses as per IEC 60034-2 or IS 4889 including static excitation losses and bearing losses attributable to generator.

#### 2.4. Static Excitation System

The excitation equipment shall comprise of Excitation power transformer, thyristor rectifier banks, filter circuits, field circuit breaker with discharge resistor, field flashing controls, dual channel hot redundant automatic and one manual channel voltage regulator, flexible copper cable connections between field breaker and slip rings and flexible copper cables between rectifier and transformers cubicles and also pulse cables between digital AVR and thyristor cubicles, and protection & control devices for entire excitation system.

The static excitation system shall include all necessary devices so as to continuously supply the maximum excitation power required to produce continuously 103.5 MVA output, and shall be capable of controlling the generated voltage within permissible generator voltage range of  $11kV \pm 10\%$  under all operating conditions.

The excitation shall be provided with 100% redundancy for all firing control circuit, protection etc. Power converter redundancy shall be provided using a N+1 configuration.

The equipment shall have sufficient capacity to provide ceiling voltage and current required by generator.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The excitation system shall be microprocessor based digital control system and will interface with system for monitoring and control from the local Unit Control Board HMI or from the Control Room OWS (Operator Work Station). Manual controls of the AVR and metering shall be provided in the Synchronizer cubicle of the UCB.

## 2.4.1 Characteristics and Operation of the Excitation System

### 2.4.1.1 Ratings

- Rated current

The rated current of the excitation system is defined as the current required at its output terminal when the associated generator supplies 103.5 MVA at rated power factor, rated frequency and 115% of rated voltage.

- Rated Voltage

The rated voltage of the excitation system is defined as the voltage required at its output terminals when the associated generator supplies 103.5 MVA at rated frequency and rated power factor, with terminal voltage at 115% of rated voltage and field winding at maximum temperature of 95 °C.

### 2.4.1.2 Ceiling Voltage

The ceiling voltage shall be based on the no-load field voltage as measured on the air gap line and field resistance at 100 °C. Negative current is not required, but the excitation system shall be able to supply ceiling negative excitation up to the limit of zero excitation current. In order to achieve the required voltage stability, the AVR shall be able to reach a maximum ceiling voltage of 3.0 p.u., with an option of maximum ceiling voltage of 5.5 p.u.

### 2.4.1.3 Ceiling Current

The ceiling current shall be at least 1.6 times the rated current. Each system shall be able to supply this current with “n-1” rectifier bridges for at least

30 seconds. However, with “n” rectifier bridges, the system shall be able to supply for the same duration, “n/(n-1)” times the ceiling current.

### 2.4.1.4 Temperature Rise

The system shall be designed for operation in a 40 °C ambient temperature with a maximum temperature rise on conductors of 45 °C.

### 2.4.1.5 Operating Ranges



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The excitation system shall work satisfactorily over the following ranges:

Voltage at the generator terminals : 30% to 150% of the rated voltage;  
Frequency : 80% to 150% of the rated frequency.

#### 2.4.1.6 System Response

The excitation system shall be equipped with a static voltage regulator having a time constant of less than 0.02 second and a gain continuously adjustable from 10 to 200 p.u. (based on the excitation voltage corresponding to the rated air gap line field voltage at no load and the field resistance at 100 °C). The circuit supplying to the regulator a voltage proportional to the generator voltage shall have a filter giving an attenuation factor of at least 20 dB at 50 Hz.

Each limiting device of the voltage regulator shall be of the dynamic type, i.e. the output shall turn down when the error at the input of the functional block changes polarity.

#### 2.4.1.7 Operating Conditions

##### A. Local and Remote Control

The equipment shall offer the possibility of local voltage control from the excitation cubicle HMI, from the SCADA either from the Control Room OWS (Operator Work Station) or from the local Unit Control Board HMI. Manual controls of the AVR and metering shall be provided in the Synchronizer cubicle of the UCB. The local and / or manual control shall be such that there is no interlocking with digital portion of the AVR. In manual mode it should be possible to close the field breaker without interlocks provided in automatic control and also possible to maintain the desired voltage at generator terminal to facilitate synchronization. In the Manual position the Synchronizer will interlock with the Generator Circuit Breaker control to insure safe operation.

##### B. Faulty Synchronization

The excitation system shall be designed to withstand and correct any untimely or accidental out of phase synchronizing.

#### 2.4.2 Description of Excitation Equipment

##### 2.4.2.1 Power Supply

##### A. Normal Operation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The excitation system is directly connected to the generator isolated phase bus duct (11 kV, 50 Hz) via the Rectifier Transformer.

The excitation system shall be designed in such a way that it is easy to reverse the polarity, from the inside of the excitation cubicle, to allow an equal wear of the collector rings.

The system operation shall be self-sustained without any other AC or DC power supply, except for the field flashing current, local alarms, remote control, and protection.

#### B. Starting Conditions

Under starting conditions, a 220 V station battery will be utilized for field flashing until sufficient voltage appears at the generator terminals to supply the rectifier excitation equipment. The field flashing shall then be automatically isolated from the excitation system.

#### C. Power Supply for Test Purposes, Field Flashing and Cooling Fans

For test purposes, Contractor shall supply a two-position switch for switching the “Normal” source to the “Test” auxiliary source when the generator is stopped.

The 415 V AC, three-phase, three-wire, 50 Hz “Test” without neutral will be supplied from the powerhouse auxiliary services and Contractor has to make its own arrangement for the control transformer, etc., to meet its own requirements.

A field flashing 415 V AC circuit shall be included. An interlock shall be provided with the DC field flashing circuit to avoid simultaneous operation.

Cooling system shall be provided from a redundant 415 VAC supply; the primary being provided by incorporating power supply derived from the 11kV bus through excitation transformer and from a backup supply derived from the unit auxiliary board (UAB).

On “Test” position, all auxiliary and electronic circuits for the control and command of the excitation system shall be operational, including:

- Cooling system;
- Annunciators and alarms.

#### D. Excitation System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The excitation system including digital system shall be designed and supplied in such a way so that when unit is in operation and one set of AC and DC power supplies to excitations fail, the machine should not trip but should continue to generate and give alarm. However in case there is a tripping command due to some fault the machine should trip even if one set of AC & DC auxiliary power is not available.

#### 2.4.2.2 Rectifier Transformer

##### A. Description

The Rectifier Transformer shall be cast resin dry type, natural cooled, for indoor installation. It shall be in a self - enclosed cubicle in addition to the other excitation cubicles. This cubicle shall be made of removable panels. The arrangement shall be such, that it is possible to remove the transformer without dismantling the cubicle completely. The rectifier transformer shall be provided with an auxiliary transformer to supply the excitation system 415 V AC auxiliaries.

##### B. Terminals and Current Transformers

The primary supply comes from three phases of Isolated Phase Bus Duct tap-off. Flexible braids shall be supplied by the Contractor. Coordination of the primary connection is the responsibility of the Contractor. The transformer cubicle shall house phase and zero sequence current transformers for phase and ground over current protections of the Rectifier Transformer. Contractor is responsible for adapting this equipment for connection to the incoming tap offs from respective Isolated phase bus duct (IPBD) or cables. Contractor shall provide sufficient space for floor entrance with gland connector.

Protection Current transformer precision shall be 5P20 and their ratio shall be selected to avoid any saturation possible at maximum fault current. Contractor shall submit calculation to justify the selected ratio.

The high voltage terminals shall be phase-segregated using insulated corona free barriers to minimize / eliminate the possibility of phase to phase faults. Current transformer secondary terminal shall be wired to a common Marshalling box mounted near the excitation cubicle.

The low voltage terminals shall be arranged for connections to rectifier cubicle main Bus bars with copper conductor bus ducts and braids. These low voltage

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

bus ducts or flexible copper cables, including the connection accessories, shall be supplied by Contractor as required.

#### C. Construction

Generally, the transformer shall be built to give the best guarantees of reliability and performance with main features as follows:

- Enclosure Protection

The transformer enclosure protection shall be IP23 or better.

- Insulating materials

The insulating materials shall be non-hygroscopic, in order to ensure a good resistance to humidity. Class H insulation shall be provided. The thermal rating of the windings shall be based on class B insulation.

- Conductors

All conductors shall be made of copper. The terminals to be connected to the isolated phase Busbars shall be silver-plated.

- Alarms and tripping

Temperature detectors and hot spot indicators for the transformer windings shall be supplied. These detectors shall be such that their replacement can be carried out easily. The temperature detectors shall be provided with redundant contacts.

#### D. Electrical Characteristics

Rated capacity	To be determined by Contractor
Primary voltage	11 kV, Unearthed
Secondary voltage	To be determined by Contractor
Average temperature rise of conductors, determined by resistance measurement at rated voltage	70°C
Maximum temperature of conductors at rated voltage	110°C
Lightning impulse withstand voltage / power frequency	95kVp / power frequency-38kVrms
Nominal impedance	To be determined by Contractor

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Insulation class	H
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#### 2.4.2.3 Rectifiers

The equipment shall consist of three phase, full wave bridges, silicon controlled rectifiers with electronic gate control (thyristors). Each leg of the bridge shall be composed of one, or more cells connected in series or parallel as required.

Each leg shall be protected by a high speed current limiting fuse. It shall be possible to safely replace a bridge section with power ON. Each bridge shall be mounted in an individual draw-out compartment. Appropriate shutters shall be provided to hide exposed live parts. No live parts shall be exposed during the complete process of removal and replacement. The equipment shall be capable to operate normally even if a certain number of fuses have blown.

The rectifier bridges shall be rated for the following duty cycles:

- The rectifiers shall be capable of supplying continuously the rated continuous current of the excitation system, even if a rectifier power converter is out of service. The redundancy of the power converters shall be of the N+1 type, meaning that one complete back-up bridge shall be in operation during the operation of the main power converters. The excitation current shall be equally distributed among all the power converters. Whenever a power converter fail, an alarm shall occur and the excitation current shall be distributed among the remaining power converters;
- Capable to withstand maximum ceiling current of 1.6 p.u. and maximum ceiling voltage of 3.0 p.u. for at least 30 seconds with an option of maximum ceiling voltage of 5.5 p.u;
- Capable to withstand the three phase fault adjacent to the HV terminals of the generator;
- Capable to withstand short circuit on the high voltage side of the transformer with a duration of 2 seconds;
- As a minimum, the following monitoring and protection features shall be included:
  - Temperature monitoring of thyristors;
  - Thyristors bridge failure;
  - DC short circuits;
  - Thyristor and field circuit over voltage protection;
  - AC system over voltage and over current;
  - Transient over voltage originating from the AC system, lightning or switching

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
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surges.

Calculation for the capacity of the rectifiers shall be submitted to the Employer or its representative. While determining the capacity, effect of aging shall also be considered as well as the inclusion of a safety margin in agreement with the industry practices. The rectifier PIV (Peak Inverse Voltage) rating shall not be less than 4 times the maximum RMS voltage of the inputs.

#### 2.4.2.4 Field Circuit Breaker

Contractor shall supply for each system, a two-pole field circuit breaker of a rating suitable for the generator.

The field circuit breaker shall be electrically operated and shall be equipped with a spring loaded trip device operated by a 220 V DC motor.

The circuit breaker shall be fixed air type and be rated 1 kV or above as required to support the Ceiling Voltage and shall have a interrupting capacity of 25 kA. The current rating of the circuit breaker shall be so selected that the contacts can carry the maximum Ceiling Current continuously. The circuit breaker will have two continuously rated poles. The Contractor may also supply a 4 pole circuit breakers with poles connected in series in pairs to obtain the required voltage level rating. Three pole arrangements (2 series + 1 single) are not acceptable. A Digital Trip Unit complete with sensors for DC application shall be factory mounted on the circuit breaker.

The field breaker shall be capable of at least 25,000 mechanical operation and 15,000 electrical operations at full capacity

The field breaker shall be interlocked with the unit circuit breaker (provided by others). The opening of the field circuit breaker shall cause tripping of the unit circuit breaker.

#### A. Field Discharge and Protection Resistors

##### Description

A non-linear field discharge resistor shall be connected across the field circuit, by the discharge contact of the field breaker when the field breaker is opened. A second non-linear resistor shall be supplied and connected permanently to the field circuit to protect it against over voltages from the stator side.

##### Electrical Characteristics



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The volt-ampere characteristic of the discharge resistor shall permit a quick field current damping.

#### 2.4.2.5 Automatic Voltage Regulator (2A + 1M))

##### A. Type

The Automatic voltage regulator (AVR) shall be of the digital micro-processor based DVR, high speed, automatic and shall include all necessary accessories for its proper operation. It shall maintain the generator voltage for steady state load conditions, without hunting, with 0,5% accuracy for any excitation level within the operating range of the generator.

##### B. Range of Setting

The regulator shall be designed so that the range of voltage setting may be varied between 6.5 kV and 15 kV under all loading conditions

##### C. Components and Operation

The following devices / features shall be included:

- The Automatic Voltage Regulator shall be 100% hot redundant. Each AVR module shall be independent and powered by two different DC supplies. The modules shall be mounted in individual isolated compartments to permit safe maintenance on one module while the other is in operation;
- A three-element voltage sensing device which shall work from a three phase voltage derived from the generator terminals;
- A manual voltage adjustment device electrically operated (by bypassing micro-processor), permitting a variation of the generator voltage between 0 and 125% of its nominal voltage (for test purposes). Contractor shall indicate the minimum level of the voltage setting when generator gets self-excited;
- The “manual” rheostat shall follow the “automatic” rheostat in order to eliminate any change in the reactive load of the generator when the regulator is switched to the “manual” position;
- The changeover from “automatic” position to “manual” position shall occur instantaneously from a single signal, or by a protective relay, directly to the regulator or by remote control. However, the reverse operation may require an adjustment by the operator. In any case, when the generator is stopped normally, with the regulator in the “automatic” position, it shall remain in this position during

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

the shutdown and subsequent restart. In the case of tripping to “manual” position, a local signal shall be provided. A changeover from the “automatic” voltage control to “manual” control and vice versa shall be possible when generator is in operation and shall be bump less;

- A current limiter that will automatically lower the value of ceiling current in the case of a faulty circuit in a bridge;
- A device permitting remote control. Remote control, however, shall be limited to functions such as “stop-start” and “raise-lower” voltage.

For steady-state conditions with the generator circuit breaker open, the regulator shall maintain the generator terminal voltage at or below 105% of its rated for speeds ranging from rated speed up to an over speed of 120% rated speed. An exciter limiting control shall be provided to limit the generator voltage to max. 125% of rated voltage in the event that the automatic voltage regulator is tripped coincidentally with maximum continuous overload rejection condition and the generator speed rising to runaway speed. The voltage regulator shall be provided with over- and under excitation limiters. The intervention of the limiters shall not cause perceptible deviations or oscillations of the generated active and reactive power.

The characteristics of the under-excitation-limiting curve shall match the static and dynamic stability curves of the generator. Such devices shall allow the regulator to reduce the exciter voltage to zero or to negative values in order to prevent over-voltages in case of operation under line reactive load conditions and over speeding of the unit.

The following features shall be included:

- stator current limiter;
- field current limiter;
- load angle limiter;
- Over fluxing limiter;
- Active and reactive load compensation;
- PF regulation.

The field current limiter shall act on AVR with a time delay so as not to disturb transient response of the system during voltage dips / faults.

A slip stabilizer unit shall be provided to suppress the low frequency power oscillation during the operative conditions.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

All corresponding protective devices shall be provided, including a generator field earth-fault detector.

The voltage regulator shall be equipped with a sensitivity-adjusting device and with an adjustable voltage droop compensation (compounding).

After the generator voltage attaining initial maximum value neglecting the instantaneous rises following any load rejection up to 115% of the rated load, AVR shall restore the generator terminal voltage to a value not more than 5% above or below the voltage being held before load rejection and shall maintain the voltage within these limits throughout the period of the generator over speed.

The excitation system shall be capable of operation on joint control maintaining even distribution of the reactive load between machines. Reactive power joint control function devices to ensure satisfactory load sharing during parallel operation of the generators shall be integrated in the station control computer. Paralleling of generators shall be achieved on 220 kV side of Generator Step Up transformers.

The voltage regulating system shall include device for improving the damping of active electromechanical oscillations. These devices shall operate to supplement the voltage regulating action by addition of an additional control signal into the excitation system input. This supplemental input signal shall influence the excitation system as to cause a change in field current of the machine for stabilized operation. An adaptive control function feature to the slip stabilizer shall be included for each unit. The function of the control is to optimize the setting of the slip stabilizer to suit the different configuration system. The setting of device shall be determined by Contractor.

#### 2.4.2.6 Field Flashing Equipment

All equipment necessary to automatically flash the field shall be provided to ensure proper build up of voltage on manual and automatic start-up.

The power for field flashing equipment shall normally be taken from 415V, 3 phase, 50 Hz auxiliary supply and in case AC source is not available, alternatively from the station 220V battery supply till the time the generator has built up sufficient voltage when automatic changeover of field supply has taken place as per the provision made by the generator supplier in this regard. The kVA rating and voltage ratio of field flashing transformer (forming part of supply) and requirement of AC / DC power and its duration for field flashing shall be indicated in the tender. While using batteries for field flashing the corresponding over voltage protection shall be provided as a part of excitation equipment.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

#### 2.4.2.7 Control Protection, Alarms and Metering

##### A. Equipment

The following equipment shall be supplied:

- Control equipment;
- Protective relays (numerical type); and;
- Metering instruments (analog), multifunction type power meter with communication port for interface with the SCADA.

##### B. Control

All equipment shall be electrically and electronically controlled.

The equipment shall include the necessary relays and contactors for initiating and performing the automatic transfer of the generator starting field flashing source to the normal supply source (rectifiers) when the generator terminal voltage has increased to a sufficient value. An interlock shall prevent any field flashing if the unit is synchronized to the system.

##### C. Protection

All protective relays and controls shall be flush or semi-flush mounting type. An alarm point shall be given for each fault.

The equipment shall include the following items without being limited to:

Generator field ground protection that shall detect intermittent and permanent grounds in the generator field circuit (including the generator field windings). For single ground fault annunciation should be provided for double earth fault tripping should be initiated with alarm. The protection shall cover 100% of the field circuit. The protection shall not be in operation during voltage build-up. A test and reset switch shall be provided with this protection and mounted adjacent to the ground relay.

- Time and instantaneous over-current phase and ground protections for the rectifier transformer. The time protection must detect a fault on the transformer secondary. Current transformers for the same shall be provided on the incoming side of transformer primary as specified. The protection relays shall be state of the art digital type that will be interfaced with the monitoring system through communication links;
- Low voltage breakers, fuses, etc., for protecting the equipment against overloads

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

and short-circuits;

- Surge voltage suppression equipment;
- Excitation equipment protection for any internal faults;
- Current asymmetry protection more than two stacks faulty;
- Over voltage protection for detection of sustained field over voltage (Crowbar type).
- Over current protection for overload and short circuit protection of the Rectifier Transformer and rectifiers;
- Cooling fan failure (main and reserve);
- Loss of regulator DC power;
- Failure of thyristor firing circuit;
- Failure of AVR;
- Individual cooling fan failure;
- Rectifier cubicle exit air high temperature;
- Operation at minimum excitation limit;
- Operation at maximum excitation limit;
- Rectifier Transformer winding temperature;
- Operation of slip stabilizing unit;
- Failure of field flashing circuit equipment;
- Prevent over fluxing of the transformer.

#### D. Alarm

An annunciator, for local use, shall be supplied and installed on each excitation system. It shall indicate all individual alarms related to the excitation system.

The alarm signals shall also be transmitted to the SCADA system for recording through a serial communication link. The annunciation function shall be integrated in a Human Machine Interface (HMI) of the 350 mm LCD color touch screen mounted on the front of the excitation control cubicle.

Under alarm conditions, the indicator involved shall be turned on and shall remain so until the “acknowledge” push-button is pressed. In that case, the indicator shall be turned off if the alarm condition has disappeared, otherwise it shall stay on.

Each alarm circuit of the annunciator shall have an adjustable time delay set at about 10 ms to prevent any untimely alarms. The equipment shall include a conduction monitoring circuit for each bridge leg (thyristor fuse assembly) which can detect that:

- A fuse has blown;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- This branch does not conduct because of an open circuit or lack of gate control.

This monitoring circuit shall indicate the defective branch and its associated bridge and shall be capable of transmitting a local and a remote alarm.

#### E. Metering

Field amperage and field voltage shall be displayed on analog ammeter and volt meter located on the front of the excitation control cubicle. The same amps and volts indications can be achieved on a LCD color screen mounted on the front of the excitation control cubicle. Multi-function meter such as the Satec-PM 130 EH Plus Model or equivalent shall be provided for the excitation transformer input power measurement and display of other parameters. The accuracy class shall be CL 0.2S. IEDs with IEC 61850 shall be supplied for compatibility with other systems.

#### F. De-excitation (Negative Excitation)

To achieve a quick suppression of the generator field and thus the voltage, the field winding shall be shunted by a discharge resistor (voltage dependent type). After tripping the generator circuit breaker, the opening of field breaker shall connect the discharge resistor.

### 2.4.2.8 Cooling System

#### A. Description

The cooling system of the excitation cubicles shall be natural, with cooling system for the thyristor cubicles shall be forced air cooled. Cooling system shall be fully redundant with automatic switchover upon failure of the main system. An air flow switch shall be used for alarming purposes. In all cases, a high air temperature switch shall be supplied for alarming purposes.

The ventilation system shall be automatically controlled and supervised with 100% stand-by capacity of ventilation fans. Design shall be such, that failure of the cooling system does not require a unit shutdown. The cubicles shall be closed, so that no dust can enter into the inner part of it.

The ventilation system shall be designed to feed air into the different cubicles independently without mixing of the air with other cubicles.

The ventilation systems shall be provided with washable filters. An alarm system will be provided to signal when filters require cleaning.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

#### B. Excitation Cubicles

The excitation components shall be installed in free standing steel cubicles individually compartmented to insure that any internal fault will be limited to one cubicle. The excitation board shall comprise 2 or 3 thyristor cubicles, 1 field flashing cubicle, 1 field breaker and protection & monitoring cubicle, 2 AVR cubicles. Full top to bottom and front to back steel separators shall be provided for electrical shielding between all cubicle including the thyristor cubicles. Cubicles shall be IP33 or better protection.

#### C. Terminal Blocks

The terminal blocks shall be installed in easily accessible locations. These terminal blocks are used for the connection of internal and external power and control cables. Terminal block shall be rail mounted and Heavy Duty construction. Output control terminal shall accept conductors ranging from 2.5 to 6 mm<sup>2</sup>. Terminal shall be preapproved by purchaser. The terminals shall be shrouded to avoid accidental touch.

#### D. Excitation Connections

Excitation power cable connections between the generator slip rings and the DC field breaker cubicles shall be provided. The power cables shall be of adequate flexible copper cross-section to continuously carry the rated current of the excitation system and the maximum current for 30 seconds. They shall be made of highly flexible conductors and the cable insulation shall be of the heat-resistant type, taking into account the maximum temperature rise of 65°C at 40°C ambient temperature in the slip-ring compartment. The field cables shall be unshielded and rated 5 kV or more.

The cables shall be adequately spaced and supported with consideration to the electro-mechanical forces involved and designed to prevent undue heating during continuous operation.

#### E. Wiring

All wiring inside the cubicles shall be supplied and installed by Contractor. However, Contractor shall use 2.5sq mm, 19 strand copper conductors, insulated at 1100 V, 150 °C with fluoropolymer, or equivalent.

All electrical wiring shall be made of stranded conductors having at least 1100 V minimum insulation or more, with appropriate insulation for the type or the function of

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

the cable. Each conductor shall be numbered. All wires shall be grouped in flat or rectangular sets and shall be suitably supported.

Wiring between the potentiometers shall be carried out using twisted shielded cables.

No splice joints shall be permitted and all connections shall be made on terminal blocks. Particular care shall be taken not to damage conductors from which insulation has been removed.

It shall not be possible for the return current of power devices (lights and relays) to take the same path as the feed circuit of logic devices. In addition, all returns shall be connected to a common point at the power supply terminal.

#### F. Electronic Circuits

A capacitor connected between the feed of the logic circuit and the common return shall be provided for the filtering of the input signal.

All semi-conductors shall be exclusively of the silicon type. They shall be of the 0 °C to 70 °C class or better.

All electrolytic capacitors shall be tantalum or aluminum type of high quality (computer type) or approved equivalent.

Resistors shall have characteristics equivalent to the metallic envelope type. The operating temperature range of these components shall be 0 °C to 70 °C minimum.

All electronic wiring shall be done by 1.5 sq mm shielded two stranded flexible copper conductors.

#### Electrical Interference and Noise

All circuits shall be fully EMC compatible in accordance with the latest standards.

Extreme care shall be taken that all control circuits including solid state circuits used in the control of bridges and firing of the thyristors shall be adequately protected from all external interference such as induced currents and voltages from other adjacent control panels or high power circuits and voltage spikes that propagate in the system. The contractor shall submit the proposed method of screening of control cables and surge protection of these circuits.

The audible noise generated by the cooling fans in the exciter shall not exceed 70 dB adjacent to the cubicles housing these fans.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The exciter shall be protected against high frequency transient interference as well as radiated radio frequency signals. No malfunction shall occur from radio interference produced by household portable radios.

Electronic board shall be heavy duty using state of the art design. Circuit board modules are to be individually housed to permit easy removal and replacement without fear of damaging adjacent modules.

#### G. Grounding

Contractor shall ground all electronic devices and the cubicles. All ground wires shall be connected to one ground bus. In addition, this bus shall be provided a suitable connectors. There shall be separate earthing for Electronic circuit and power circuit

#### H. Test Points

Test points shall be provided on the face of the drawers, inside the cubicle, in order to facilitate checking of the excitation behavior, the feedback signals and the external signals.

#### I. Indicators

All indicators shall be of an approved model. The dials of all indicating devices shall be graduated in International System of Units (SI) and shall have a diameter of approximately 10 centimeters.

The indicators shall have a proportional scale and shall have a precision of 1% at full scale.

### 2.4.2.9 Identification

#### A. General

The inscriptions on these plates shall be in English. The characters used shall be easy to read.

The wording of all nameplates outside the cabinet shall be submitted to the Engineer for approval.

#### B. Nameplates

Nameplates shall be supplied and installed for all functions, regulating parameters and all components. These shall be got approved during detailed engineering.

#### C. Markers

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

Each wire terminated in a control device, junction box or terminal block shall be clearly identified at both ends by cable markers.

#### 2.4.2.10 Operating Instructions

All devices or equipment, locally controlled, shall be provided with operating instructions.

### 2.4.3 Excitation System Tests

#### 2.4.3.1 Factory Routine Tests

The excitation system equipment including spares shall be subjected to routine tests as per detailed test list submitted by the Contractor and approved by the Engineer, and as required in the IEC, IS and ANSI / IEEE standards and shall include the following. These tests shall be subject to approval by the Employer / Engineer prior to dispatch of the equipment.

##### a. Control equipment:

- Static characteristics;
- Operation of all relays and control devices;
- Insulation withstand tests.

##### b. Transformer / converter:

- Transformer ratio tests and winding resistance measurements;
- No load and load loss measurements;
- Temperature rise test on one unit;
- Insulation withstand tests;
- Other routine tests as per applicable IS / IEC.

##### c. Any additional tests deemed necessary by the Contractor for satisfactory performance of this equipment.

#### 2.4.3.2 Factory Type Tests

The first set of excitation equipment to be commissioned shall be subject to the following series of tests, in addition to the above Routine Tests, to prove compliance with this Section:

- static and dynamic characteristics of each amplifier and converter control device; sensitivity of the amplifiers to changes of  $\pm 10\%$  of rated frequency;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
---	--	--

- changes in the equipment characteristics due to an increase in temperature caused by the application of load current;
- the overall range of the regulator voltage setting device and the manual control setting device;
- the DC output / AC input voltage characteristic of the power supply units;
- demonstration of the time to reach buck and boost excitation ceiling voltage after a  $\pm 0.5\%$  step input change;
- Heat Run test of the assembled excitation unless the contractor can submit the tests result conducted on an identical excitation system. The heat run test shall replicate the most severe operation conditions.

#### 2.4.3.3 Site Pre-commissioning and Commissioning Tests

##### A. Pre-commissioning Tests:

- Operation check of auxiliary cooling system for the thyristor cubicles;
- The excitation system shall have a performance check of all auxiliary, stabilizing, limiting and protective circuits after adjustment to the correct settings. Operation of protection device is to be tested by current injection at the sensor terminal;
- Functional test on all modules;
- Adjustment of AVR;
- All routine / site tests on excitation transformer as per applicable standard.

##### B. Commissioning Tests

1. Load rejection tests at:
  - 0 MW at rated MVAR;
  - 50% of maximum continuous rated output at rated power factor;
  - 100% of maximum continuous rated output at rated power factor.
2. With the minimum excitation setting and the generator operating at various loads just within the limit, the stability margin shall be demonstrated by the response to a 5% step injection to the voltage regulator. The sense of the step injection shall be to attempt to reduce the excitation;
3. Overall response of machine and excitation system to system voltage change;
4. Continuity and insulation testing of all wiring and devices;
5. Tests of maximum and minimum excitation limiters;
6. Adjustment of AVR.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 02 Generator and Excitation System
---	--	--

### C. Commissioning Type Tests

The excitation system type tests, to be conducted on the first unit to be commissioned shall include the following:

- Static and dynamic characteristics of each amplifier and converter control device;
- The control range of the voltage setting devices for automatic and manual operation;
- Demonstration of changeover from automatic to manual control and vice versa;
- Demonstration of the time to reach buck and boost ceiling voltage following  $\pm 2.5$  percent step changes in reference voltage.

## 2.5. Drawings, Design Calculations and O&M Manuals

Contractor shall provide its drawings in conjunction with its calculations as well as references, showing the detailed design of Generator and excitation system as required by the Employer or Engineer for its review / approval.

Contractor shall furnish four (4) sets of all the Generator and excitation system drawings for approval. After approval and after work completion at site, six (6) sets of as-built drawings and one set of reproducible print sheets shall be supplied.

### 2.5.1 Drawings

The Contractor shall submit the all the drawings and documents as required by the Employer or Engineer. These drawings and documents should include at least the following:

- General arrangement, outline and foundation drawings;
- Detailed information and descriptive literature, explaining various safety, protective and regulation features of equipment / components;
- Drawings, showing general arrangement, sections of all major assemblies, sub assemblies and major components;
- Control schematic drawing showing provision of all instruments, devices, and functioning of generator regulating functions;
- Electrical control schematic drawings;
- System drawing;
- Erection, commissioning, operation and maintenance instructions for the generator & excitation system.

### 2.5.2 Design Calculations



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The Contractor is required to submit the design calculations for the generator & excitation system to the Engineer for approval during detailed engineering:

- Structural analysis of different generator parts;
- Foundation loads including overload, short-circuit, load rejection and runaway speed forces;
- Runaway speed;
- Critical speeds;
- Strength of all rotating parts to withstand run away speed and vibration;
- Number of coolers for stator & all bearing, the normal working pressure and pressure drop through the coolers;
- $GD^2$  calculations;
- Coupling bolts size;
- Stress calculation on shaft & rotor;
- Size of the thrust bearing, effective surface area / specific load on thrust bearing with respect to total loa(static / dynamic), etc. under worst conditions / runaway condition;
- Maximum stresses / loads during normal operation, runaway-speed conditions, two phase and three phase short-circuit conditions or single phase earth fault at maximum output for which generators are capable of, 180 deg and 120 deg out-of-phase synchronization, magnetic unbalance at runaway speed with 50% of the poles short circuited and brake application, etc.;
- Ventilation of generator;
- Size & no. of brake / jack assemblies.

Other calculations as required by Engineer for approval of the Contractor's design.

### 2.5.3 Design memorandum

The contractor shall prepare and submit to the Employer a "Design Memorandum" of the proposed equipment / system fulfilling the contract specification / requirement given in the section for approval prior to submission of any drawings and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, major technical features, basic arrangement / layout etc.

### 2.5.4 Operation and Maintenance Manuals

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

The contractor shall furnish to Employer four (4) sets of O&M manuals for review / approvals. After approvals, and incorporating the Employer comments, the Contractor shall submit twelve (12) sets of the final O&M manuals and one (1) set of electronic files on a CD.

#### 2.5.5 Operation and Maintenance Personal Training

The contractor shall arrange training sessions for O&M personal of the employer at site, using the O&M manuals supplied.

### 2.6. Name Plate & Labels

All the equipment and their operating devices shall be provided with a nameplate. The nameplate shall be weather proof and corrosion resistant. It shall be mounted in a position that it shall be visible in the position of normal service and installation. The nameplate shall conform to the requirements of relevant IEC / IS and as per stipulations of General Technical Requirements and shall incorporate the following information:

- Manufacturer's Name or trade Mark;
- Type Designation or Serial Number;
- Applicable Rated values;
- Relevant Standard.

All name plates shall be of non rusting metal or three (3) ply laminated with white engraved lettering on black back ground, inscription and lettering sizes shall be subjected to Employer's approval.

Caution name plate "Caution Live Terminals" shall be provided at all points where the terminals are likely to remain live and isolation is possible only at remote end.

### 2.7. Packing & Transportation

All equipment and supporting structures shall be suitably packed as per the standard practice, while dispatching from the works. Although the method of packing is left to the discretion of the manufacturer, it should be robust enough for rough handling as the equipment shall be moving in hilly region. Manufacturer shall take additional care in packing of material for transportation, so that it does not get damaged during transit due to vibration / jerks / tilting, etc normally encountered during transportation by sea / road / rail in hilly terrain.

All accessories shall be dispatched in suitable boxes or crates. They shall be securely

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

bound with wire and shall have all descriptive marking stamped thereon.

## 2.8. Painting

All metal surfaces shall be chemically cleaned, degreased and pickled in acid to produce a smooth clean surface, free of scale, grease and rust.

After cleaning, phosphating and passivation treatment, the surface shall be given two coats of zinc rich epoxy primer and baking in the oven.

After primer, it shall be given two coats of stoving type epoxy based paint. Alternatively powder coating can be offered.

Sufficient quantity of touch-up paint shall be furnished for application at site.

## 2.9. Spare Parts and Special Tools

The spare parts mentioned hereunder are meant for use by the employer for 5 yrs trouble free operation & shall not be used as erection / commissioning spares required during installation. All the spare parts shall be interchangeable & shall be of the same material and workman ship as corresponding parts of the main equipment.

If any additional spare parts required for a 5 years trouble free operation period are recommended by contractor, These shall be listed and the unit price shall be quoted in the price schedule. The employer reserves the right to order any or all of such spares.

All spare parts shall be suitably packed, clearly marked and ready for long term indoor storage.

### 2.9.1 Mandatory Spares part

The following spare parts shall be mandatorily included in the supply. A set in the list below, shall imply quantity provided for one (1) generator & Excitation System:

S. No	Item	Quantity
<b>Generator</b>		
1	Stator winding including installation material	33% of total coils / 1 / 3rd of total coil for one generator
2	Pole assembled with winding	4 nos. (2 North, 2 South polarity)
3	Upper Guide Bearing Pads	2 sets

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

4	Thrust bearing pads	2 sets
5	Lower guide bearing pads	2 sets
6	Carbon Brushes	Nine (9) sets
7	Brush holders with all necessary insulating material	Three (3) sets
8	Brake lining / Brake pads	Six sets
9	Stator Cooler unit	1 set
10	Air filter unit	1 set
11	Oil cooler for lower guide bearing	1 set
12	Oil cooler for combined thrust and guide bearing	1 set
13	RTD for cooling air inlet	1 set
14	RTD for hot air outlet	1 set
15	RTD for upper guide bearing	1 set
16	RTD for combined thrust and guide bearing	1 set
17	Dial type thermometer	1 set
18	Water flow relay for cooling circuits	1 set
19	Gasket for brake cylinders	Three (3) sets
20	Gasket, washer for air coolers	Three (3) sets
21	Pole fastening Wedges (pole Keys)	1 set
22	Damper connectors	1 set
23	Rotor field coils	4 Nos
24	Friction Brake (Cushions) Pads	4 sets
25	Gate valves & valves for water & oil pump	two (2) for each type
26	Vibration sensor	1 set.
27	Relay for bearing current	2 Nos.
28	Oil moisture detector	1 set
29	Coils, contacts, spring for relays, contractors, breaker, switches	1 set
30	Level switch, pressure switch, pressure gauge with electrical contacts	2 sets each
31	Filter bags for brake dust collector	9 sets
32	Rotor pole body insulation	2 sets
33	Rotor field coils epoxy insulating washer	10 Nos.
34	Bearing oil level indicator	2 sets

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

35	Rotor collector assembly (slip ring) with all insulation material	2 sets
36	Generator speed sensor	3 Nos.
37	Mechanical over speed device	3 Nos.
38	Hydraulic over speed device	3 Nos.
39	Air cooler water flow indicator	2 sets
40	Automatic air vent valves for Bearing oil coolers, Air coolers etc.	2 sets
41	Air gap sensor	1 set
<b>Excitation System</b>		
1	Modules of DVR like DC-DC converter, ac-dc converter, digital control unit, pulse supervision unit, pulse final stage unit, analog input-output modules, etc.	1 set
2	Spare parts of field discharge breaker comprising of : <ul style="list-style-type: none"> <li>• Opening coils</li> <li>• Closing coils</li> <li>• Main contact</li> <li>• Discharge contact</li> <li>• Field discharge resistor</li> <li>• Latch and trigger assembly</li> <li>• Auxiliary contact block</li> </ul>	2 sets
3	Spare Parts of Rectifier bridge: <ul style="list-style-type: none"> <li>• Complete Thyristor bridge c / w racking components</li> </ul>	2 nos
4	Spare Parts of Rectifying equipment: <p>Thyristors</p> <ul style="list-style-type: none"> <li>• Thyristors fuses</li> <li>• Cooling fan for thyristor bridge</li> <li>• Field flashing contactor</li> <li>• Fuses of various ratings</li> <li>• MCBs of various ratings</li> <li>• Air flow sensor</li> <li>• MCCBs of various ratings</li> </ul>	1 Set

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

	<ul style="list-style-type: none"> <li>• Micro terminal for MMI Aux relays / contactor</li> <li>• AC and DC isolator with micro switch</li> <li>• Heat sinks for Thyristors</li> <li>• Clamps for Thyristors</li> <li>• Snubber Assemblies for Bridge</li> <li>• Pulse transformers</li> <li>• Power transistors</li> </ul>	
5	Protection Relays <ul style="list-style-type: none"> <li>• Rotor earth fault relay (I / II stage)</li> <li>• Transformer O / C relay</li> </ul>	1 No 1 No
6	Spare Parts for circuit breakers: <ul style="list-style-type: none"> <li>• Closing Coil</li> <li>• Tripping Coil</li> <li>• Arcing contact</li> <li>• Arc Chute</li> <li>• 4 Pole aux. Switch</li> </ul>	2 Sets
7	Varistor Discs	1 set
8	Plug in Circuit cards	1 set
9	Terminal Blocks (100 Nos)	1 set
10	Contactors <ul style="list-style-type: none"> <li>• DC Contactors</li> <li>• Ac Contactors</li> </ul>	1 set
11	Spare parts for Excitation Transformer such as temperature scanner, insulator, braided connector etc.	1set

#### 2.9.2 Special Tools and Maintenance Equipment

Contractor shall supply, for hand over to Employer one set of special tools and maintenance equipment, recommended by Contractor for generator & Excitation System. The list of these tools shall be approved during detailed engineering.

However, it shall include at least the following maintenance equipment for repairs and maintenance with descriptions and quantities of the following:

- Three (3) sets of all spanners including D ring and box type of all sizes;
- Two (2) sets of torque wrenches of each size and hydraulic bolt tensioner for coupling bolts having the complete set of drives / boxes mounted on the cabinet;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 02 Generator and Excitation System

- One (1) set of all precision tools required for assembly, alignment and maintenance of the hydro generator as per the indicative list mentioned below:
  - Ten (10) Dial indicators (accurate to 0.01mm) with magnetic base;
  - One (1) set of 200mm and 300mm master block level (least count 0.02mm / m) each;
  - One (1) complete set of micrometers (inside and outside) (0-50, 50-100, 100-150, 150-300);
  - Two (2) sets of Height gauges;
  - One (1) set of vernier callipers (150 mm to 1000mm);
  - Three (3) sets of knife-edges up to 1 m;
  - Three (3) set of Straight edge 1000mm;
  - Six (6) sets of feeler gauges from 0.05mm to 1mm in denomination of 0.05 mm, 300 mm long;
  - All special tools for measurement of magnetic axis, air gap, rotor and stator from, etc.;
  - Any other special tool required for erection and maintenance.
- One (1) set of special turning and lifting devices along with hardware, etc. for stator, rotor, rotor poles, etc.;
- One (1) set of pole assembly and removal devices / tools;
- Two (2) set of brazing / soldering equipment / device for stator bars / rotor including all tools, etc. (may specify the list of included items);
- Three (3) sets of all types and sizes of eye bolts and D shackles and special slings.
- Two (2) sets of removal / assembly arrangement devices and tools for all of the thrust and guide bearings;
- Two (2) sets of coupling assembly and dismantling arrangements, special devices, tools, elongation measurement, instruments, including hydraulic and mechanical jacks, etc.;
- Any other tools / special devices specially required for erection and maintenance of the proposed design of the generator;
- Any special tools & maintenance equipment required for maintenance of Thyristors / Excitation equipment in Hot & Cold state shall form part of this specification & shall be supplied for handing over to employer. The list of these items shall be furnished with offer & finalized during detailed engineering.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

## **VOLUME- II**

### **SECTION II SUB-SECTION 03 COOLING WATER SYSTEM**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
---	--	--

## TABLE OF CONTENTS

<b>3</b>	<b>COOLING WATER SYSTEM .....</b>	<b>3</b>
3.1	SCOPE OF WORK.....	3
3.1.1	<i>Design and Layout Conditions .....</i>	<i>3</i>
3.2	BASIC DIMENSION AND RATINGS .....	5
3.2.1	<i>Cooling System.....</i>	<i>5</i>
3.2.2	<i>Control System.....</i>	<i>6</i>
3.2.3	<i>Protection Equipment .....</i>	<i>6</i>
3.3	PERFORMANCE CRITERIA AND GUARANTEES.....	7
3.4	TECHNICAL PARTICULARS OF THE EQUIPMENT .....	7
3.4.1	<i>Cooling Water System and Turbine Shaft Seal system.....</i>	<i>7</i>
3.4.2	<i>Valves and Piping For Cooling Water And Shaft Seal Water Systems.....</i>	<i>10</i>
3.5	QUALITY CONTROL AND ASSURANCE .....	11
3.6	DRAWINGS, DOCUMENTS AND CALCULATIONS.....	11
3.7	WORK SHOP TEST.....	12
3.8	INSTALLATION AND COMMISSIONING.....	12
3.9	FIELD TESTS .....	12
3.10	SPARE PARTS: .....	13
3.10.1	<i>General Spare Parts:.....</i>	<i>13</i>
3.10.2	<i>Recommended Spare Parts:.....</i>	<i>13</i>
3.10.3	<i>Specified Spare Parts:.....</i>	<i>13</i>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

### 3 COOLING WATER SYSTEM

#### 3.1 Scope of Work

This section of the specification covers the provision of all labour, plant and material and performance of all works necessary for the detailed design, manufacture, shop testing, delivery, erection, testing and commissioning and handing over to NEEPCO and guarantee for two years of:

- A) 3(Three) sets of cooling water systems (one set for each unit) for generator air coolers, thrust bearing oil coolers, guide bearing oil coolers and Oil Pressure Units of Turbine & MIV complete with pumps, duplex strainers, filters, heat exchangers, piping, valves, fittings etc. and other accessories for making the systems complete and for warranting a trouble free and safe operation.

This system shall also cater for Cooling Water needs of Main Unit Step up Transformers/ Other Transformers (Three Nos of 220/√3/11 kV Single phase unit of matching MVA capacity) and shall be installed at the Transformer Hall. The cooling water requirement of the Main Step Up Transformers shall be estimated during the detailed engineering stage. Provisions of cooling water if required for any other system which may arise during detailed engineering shall be kept with suitable tapping& control valves.

- B) Clean water system for shaft sealing of all the units complete pumps, filters, cyclone separators, piping, valves, fittings etc. and other accessories for making the systems complete and for warranting a trouble free and safe operation.
- C) As well as, supply of sufficient quantity of water for Air Handling Units of the HVAC System (if required) and Fire Water Storage Tank. The fire water tank shall be filled up from Cooling Water header from time to time, by running the cooling water pumps.

The contractor shall supply complete system including all the pipings within the machine hall & transformer yard as well as pipe line from the outside clean water storage tanks including filters, valves etc.

The Bidder shall also include Chain Pulley Block of adequate capacity complete with monorail and other accessories for handling of pump –motor sets to be installed in the machine hall.

#### 3.1.1 Design and Layout Conditions

- A) COOLING WATER SYSTEM

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

Water in required quantity & pressure shall be provided for the generating units and the requirements of the station. As an open circuit, it shall draw the raw water from the Tail Pool and shall be discharged back into the tail race at a suitable elevation & location. Open loop cooling water system shall be provided. Cooling Water system for each TG unit shall be of open loop type, drawing water from Tail Pool and shall comprise of Pumps (1W+1SB) for each unit followed by Cyclone Separator and Motorized Automatic Self Cleaning Simplex Strainers (1W+1SB) for each unit. The system shall also be equipped with flow meters/flow relays, flow indicators, pressure gauges, pressure switches etc. Its straining element shall be of wedge wire type of stainless steel SS-304 and shall have screening area not less than 3 times the pipe cross-sectional area. Also the pressure drop across the straining element shall be less than 50 kPa. Backwash of each strainer shall be controlled by individual differential pressure switches as well as adjustable timer.

The intake pipe of each unit after pumps shall be connected to Cyclone Separators and Motorized Automatic Online Self Cleaning Strainers having suitable capacity. The cooling water requirement of turbine shaft seal of each unit shall also be included in this system. The system shall also be designed to supply cooling water requirements of Ventilation system, (if required) and Fire Water Storage Tank.

The unit wise cooling water supply system has been envisaged. One Turbine Generating Unit is to be treated as a unit. The Contractor shall supply system complete with Cyclone Separators, Strainers/Filters, Pressure Reducing Valves, Piping, Valves, Fittings, Embedded Pipes, suitable Starters/MCC, Protective Devices, Controls & Instrumentations etc. and other accessories for making the system complete and for warranting a trouble free and safe operation. Exact requirement of water for the cooling water system for all the Turbines & Generators shall be finalized during detailed engineering.

The requirements of cooling water for shaft seal of each unit shall also be met from this circuit. To monitor the choking of fine strainer, a differential pressure gauge (with contacts/switch) for alarm shall be provided across fine strainers. Necessary flow relays shall also be provided in the shaft seal cooling water circuit.

A separate water intake shall be taken for supply of water to cooling coil of Air Handling Units of HVAC and Fire Water Storage Tank. The intake for supply of cooling water to Cooling Coils of AHU's of HVAC system shall be followed by Motorized Automatic Online Self Cleaning Strainers and Pressure Reducing Valves. Also the required water quantity shall be supplied / delivered to Fire

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
---	--	--

Water Storage Tank through separate set of Motorized Automatic Online Self Cleaning Strainers and if required pumps (1 no. working + 1 no. standby).

Tenderer shall furnish in their technical offer, a proposed arrangement of Cooling Water System, equipment details and suggested pipe routing.

#### B) SHAFT SEALING WATER SYSTEM

Water supply for the shaft seal clean water system shall also be taken from cooling water circuit utilizing small booster pumps (if required) to achieve the desired pressure. Additional line filter(s) and cyclone separator(s) to obtain the required cleanliness shall be provided.

The layout of equipment and scheme shall be as per flow diagram for open loop cooling water system and shaft sealing clean water system as shown in Cooling water system schematic drawing. The schematic is only indicative and does not show all elements of the cooling system described further below.

### 3.2 Basic Dimension and Ratings

#### 3.2.1 Cooling System

The cooling water system for each unit and shaft sealing clean water system capacities shall be designed to meet the requirements of the following equipment as detailed in the following list:

1. Generator air coolers.
2. Generator Thrust and Upper Guide Bearing.
3. Generator Lower Guide Bearing.
4. Turbine Guide Bearing
5. OPU Oil-Water Heat Exchanger (if applicable)
6. Turbine Shaft Seal
7. Generator transformers
8. HVAC Air Handling Units (if required)
9. Fire Water Storage Tank

The design capacity shall have a minimum safety margin of 10% .

Keeping in view the condition of the water in the river, which is silt laden, the maintenance and operational flexibility, it has been decided to provide Cyclone



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
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Separators as well as Motorized Automatic Online Self Cleaning Strainers for each unit . The cooling water system of TG units comprising of Cyclone Separators, Strainers, etc shall be placed, as shown in the enclosed Flow Diagram.

The system shall be designed to overcome the loss of head due to friction & static head. The velocity of water in the Heat Exchangers for OPU Oil shall be selected so as to prevent sedimentation of silt inside the Heat Exchangers. The maximum fluid velocity in the piping shall not exceed 2 m/sec.

The cooling water system shall operate automatically i.e. starting and stopping in sequence with the units start and stop commands. The stopping operation shall be delayed with the help of timer provided in the circuit to protect the bearings against starvation of cooling water during unit stop operation

The Contractor shall carry-out data/design of the system and shall include those equipment/devices also which are not mentioned specifically in the technical specification but are necessary for smooth and satisfactory operation of the system and shall prepare schematic/layout drawing and submit along with his offer.

### 3.2.2 Control System

The Contractor shall provide and install all the sensory and operating devices necessary to fulfil the functional requirement for control system.

A local wall mounted control and indication panels shall be installed for the cooling water and shaft sealing water systems at the Turbine floor. Following controls and indications shall be provided:

- i) Manual/Automatic/off switch for manual/automatic operation of pumps.
- ii) Remote/local selector switch
- iii) Pump selector switch
- iv) Start/stop push buttons
- v) Emergency stop push button switch
- vi) Lamp test push buttons.
- vii) Pump running
- viii) Water no flow
- ix) Pumps inlet choked
- x) Any other provision required

### 3.2.3 Protection Equipment

The motor for each pumping unit shall be provided with at least the following devices:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

- i) Over load protection
- ii) Under voltage protection
- iii) Single phasing

### 3.3 Performance Criteria and Guarantees

The cooling water system and shaft sealing clean water system shall be capable of performing all intended duties and it is the responsibility of the Contractor to supply the equipment as per guaranteed technical particulars.

### 3.4 Technical Particulars of the Equipment

#### 3.4.1 Cooling Water System and Turbine Shaft Seal system

##### 3.4.1.1 Motorized Automatic Online Self Cleaning Strainers

The Strainers shall be of Motorized Automatic Self Online Cleaning type. These shall be of welded steel fabrication conforming to Boiler Quality steel plates with screening elements made of stainless steel (SS 304), wedge wire type. The water Strainer supplied shall be tested at a hydrostatic test pressure of 1.5 times the maximum working pressure. The Strainers shall be provided/ installed having positive pressure at their inlet.

The water Strainer shall be provided with automatic self-cleaning device and connections, pressure gauges, differential pressure switch and draining through automatic motorized purging valve, with its own control panel.

The design of the Strainer shall be such that the Strainer elements can be easily taken out for maintenance purposes. Suitable gasket shall be provided for making the Strainer shell-top cover tight. The Strainer shall be a complete unit. The pressure drop across the Strainer shall not be more than 50 kPa, when dirty and adequate sensing arrangement shall be provided to sense the pressure drop across Strainer for further integration with plant SCADA system. The automatic cleaning shall be initiated through differential pressure switch (adjusted to a set point) or through a timer, whichever reaches earlier.

Pressure gauges shall be provided to measure difference of pressure across the Strainer.

The technical data of Motorized Automatic Online Self Cleaning Strainers shall be as under:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

a	For each of Cooling Water Circuit for TG Units	-1 no. working + 1 no. Standby; -Filtration efficiency 98% down to 100 microns. -Pressure Drop across Strainers in dirty condition not to exceed 50 kPa.
b	For cooling water circuit of HVAC Cooling Coils	- 1 no. working + 1 no. Standby; -Filtration efficiency 98% down to 200 microns. -Pressure Drop across Strainers in dirty condition not to exceed 50 kPa.
c	For water supply to Fire Water Storage Tank	- 1 no. working + 1 no. Standby; -Filtration efficiency 98% down to 500 microns. - 50 kPa. Pressure Drop across Strainers in dirty condition not to exceed

#### 3.4.1.2 Pot / Basket type Strainers

The Strainers provided for the turbine shaft seal system shall be of 'Pot Strainer type'. Free Open Area Ratio (OAR) shall not be less than 6 times the pipe cross-sectional area. Suitable vent & drain connections with valves shall be provided. The Strainer element shall be of SS-304/316. The pressure drop across strainer shall not exceed 10 kPa in clean condition and 30 kPa with 50% blocked condition.

The technical data of proposed Pot Strainer shall be as under:

a	For each circuit of Turbine Shaft Seal	-1 no. working + 1 no. Standby; (Alternatively 1 no. Duplex Strainer) - Filtration efficiency of 98% down to 50 microns & above particles. - pressure drop across strainer shall not exceed 10 kPa in clean condition and 30 kPa with 50% blocked condition.
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#### 3.4.1.3 Y type Strainers

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

For the Y type Strainers, in case provided, in the water circuit, the Free Open Area Ratio (OAR) shall not be less than 3 times the pipe cross-sectional area and blowing arrangement shall be provided with removable plug at the outlet. The Strainer element shall be of SS-304/316.

#### 3.4.1.4 Cyclone Separators

The Contractor shall supply the Cyclone Separators of required capacities, as per specification detailed below.

Cyclone Separator shall be installed for open loop circuit to cater for TG Unit Cooling Water requirement, AHU's and Fire Water Storage Tank.

Each Cyclone Separator shall be equipped with Motorized Automatic Purging System, Isolation Valves, Instrumentation, Controls and other accessories for unit cooling water system.

The casing of Cyclone Separators shall be made of Carbon Steel or Stainless Steel and be adequately hardened/coated in order to resist silt abrasion.

The technical data of proposed Cyclone Separator shall be as under:

a	For each cooling water circuit TG Units	-1 no. working + 1 no. Standby;  -Filtration efficiency 85% down to 100 microns of particles with specific gravity 2.6 & above.
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#### 3.4.1.5 Pumps

The Pumps shall be of Centrifugal type conforming to Hydraulic Institute Standards, USA or International Standards with the following characteristics:

- Casing : Cast Steel
- Impeller: Cast Stainless Steel (CF8M)
- Shaft : SS-316
- Seals: Mechanical type
- RPM : 1500

The Pumps shall be of self-priming type. The Pumps shall meet the required flow without any cavitations. The operating characteristics of each pump and rated

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
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capacity of its motor shall be such that the motor shall not exceed its rated temperature rise.

Each Pump shall be mounted with electric motor & common base plate. Pumps shall be coupled to electric motor by a flexible coupling.

The equipment furnished with the pump units shall include the required automatic transfer circuits, selector and control switches, motorized valves, non-return valves, pressure regulator valves, bypass valves, pressure switches, pressure sensors, temperature detectors, thermometers and indicating lights for the local fully automatic and manual control of operation of the pumps plus indicating lights and alarms for remote supervision. The motor starter for each pump motor shall be furnished by the Contractor. Any other necessary devices shall also be supplied. All the controls shall be implemented in the control system for each unit. The pumps shall be operated in auto/manual mode from local control board through conventional hardwired operation interface devices or from Central Control Room depending on the position of the remote/local selection switch mounted in LCB.

The cooling water system shall be monitored by SCADA system. All information (such as faults, alarms, measurements, status of equipment, external orders, running time, number of operations) that is necessary for effective and convenient control and Monitoring by the f system shall be transmitted through SCADA local Control Boards.

#### 3.4.1.6 Distributing Manifolds

A distributing manifold shall be provided on the turbine floor for each unit. Flow indicators for each shaft sealing according to required parameters, shall be located on the distributing manifold.

All flow indicators shall be provided with two independent, adjustable, potential free contacts for alarm and protection purposes. The contacts shall close if the water flow becomes less than minimum required flow, as established by the Contractor.

### 3.4.2 Valves and Piping For Cooling Water And Shaft Seal Water Systems

Control valves and shut off valves of various sizes and types shall be provided in the system for control and regulation of the cooling water supply to the generating units, transformers and other services. Valves larger than 80mm shall be of butter fly type. Reflex or check valves shall be provided at needed locations to prevent reverse flow. The valves shall be of modern sleek design with minimum space requirement for installation and easy to operate. All valves shall meet the specification as detailed in the General Particular Technical Specification.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
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All piping shall be of seamless carbon steel material and medium class. Piping embedded in the concrete shall be of wrought steel for corrosion resistance. At each point the supplier shall provide adequate air vent arrangement. The piping s shall be provided with necessary instrumentation like flow relays, pressure gauge, pressure switches, thermometers etc. All fittings such as elbows, tees, reducing tees, reducers etc shall be of carbon steel. The material of the pipes shall conform to relevant Indian Standard or equivalent International Standard.

If unacceptable water hammer effects are expected in the pipings, the supplier shall provide suitable means to acceptable limits.

### **3.5 Quality Control and Assurance**

The supplier has to supply the equipment for cooling water and shaft sealing clean water system of best quality. The supplier has to maintain control and quality assurance during the manufacturing, installing, testing and commissioning of equipment as per the approved quality assurance plan.

### **3.6 Drawings, Documents and Calculations**

The Tenderer shall submit the following drawings / documents at the time of bid submission:

- Flow Diagram
- Technical data sheets of all main equipment
- Catalogues of proposed main equipment

Some of the major drawings/documents to be furnished after award of the Contract are listed below:

- DBR (Design Basis Report), including design calculations
- Flow Diagram / P&I Diagram
- Sizing/selection calculations of Pumps, Automatic Motorized Water Strainers, Cyclone Separators, Piping etc.
- Pumps – Performance Curves
- Manufacturing Data Sheet/ Specifications of Pumps, Automatic Motorized Water Strainers, Cyclone Separators, Pressure Reducing Valves etc.
- GA & Foundation Drawings of Pumps, Automatic Motorized Water Strainers, Cyclone Separators etc.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

- Control Panel – GA
- Control Panel –Power and Control wiring diagram
- QAP- Pumps, Automatic Motorized Water Strainers, Cyclone Separators, Pressure Reducing Valves
- Pipe routing, Isometric drawings and As-built drawings.
- Piping Supports
- Equipment Catalogues
- Testing & Commissioning Procedures
- O & M Manuals

The supplier is required to submit the calculation for selecting the pump / motor capacity and working head for pumps for cooling and shaft sealing water and make up water requirements. Also calculations for losses in the pipe as well as selection of pipe sizes etc. are to be submitted.

### **3.7 Work Shop Test**

The pump, pipes and valves shall be routine tested as per relevant IEC/IS at the works of supplier. The Supplier is required to submit type test report and routine test reports of equipment.

### **3.8 Installation and Commissioning**

The Contractor has to do all the works related to assembly, erection, testing and commissioning of open loop cooling water system and shaft seal clean water system.

All installation shall be done by skilled workers in a workman like manner. Pipe fixtures shall be spaced according to accepted standards and provisions made for thermal expansion and contraction of piping. Before installation all system components shall be checked for cleanliness and after installation the systems shall be effectively flushed out with clean water and filled up for testing.

Supply of all type of consumables and other materials including welding electrodes etc. required for all the above works shall be in the scope of the Contractor.

### **3.9 Field Tests**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.03 Cooling Water System
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1. After installation of all equipment the complete systems shall be leakage tested as per field test in general technical specifications as per IEC/IS. If the systems are tested in sections, the same shall be applicable for each section.
2. Test to demonstrate operational capabilities as per the intended requirements

The Contractor shall furnish a complete outline of the proposed methods and procedures to be followed for field testing, including a list of equipment and instruments to be used, to the owner's representative for review at least 60 days before the scheduled testing.

All test equipment and instruments shall be furnished by the contractor and will remain the contractor's property after the fulfilment of all tests.

The Contractor shall furnish a complete report of the field tests of the equipment.

The tests at site should at least include the following:

- Pressure test of all field installed piping at 50% greater pressure than maximum working pressure
- Leakage test of all field piping
- Opening and closing of valve
- Operation of all controls including the mechanical locking device
- Other tests as deemed necessary by the Engineer
- All necessary materials and labour for performing all the above tests shall be provided by the Contractor.

### **3.10 SPARE PARTS:**

The spare parts mentioned here under are meant for use by the Employer during operation and maintenance stage and shall not be used as erection spares required during installation

#### **3.10.1 General Spare Parts:**

The Contractor shall supply the general spare parts as per as per relevant clause of Bid Document. The supply of this spares shall be as per the approved list of spares for each component / equipment / item during detail engineering.

#### **3.10.2 Recommended Spare Parts:**

The Contractor shall furnish the list of recommended spare parts as per relevant clause of Contract Document.

#### **3.10.3 Specified Spare Parts:**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.03 Cooling Water System

The following specified spare parts, as defined in relevant clause of Contract Document, which shall comprise the total requirement of Cooling Water System under this Contract, shall be supplied.

Sl. No.	Description of Items	Quantity
<b>1.0</b>	<b>Cooling Water Pump</b>	
1.1	Complete pump with motor	2 nos
1.2	Impeller	3 nos.
1.3	Wear rings set	6 nos.
1.4	Pump mechanical seal	4 nos. of each type
1.5	Motor bearings	6 nos. of each type
1.6	Pump bearings	6 nos. of each type
1.7	Set of seal and gasket for pump	3 nos.
<b>2.0</b>	<b>Automatic Backwash Duplex Strainer</b>	
2.1	Set of complete wedge wire filter element assembly consisting of multiple candles, as per design	Cooling water circuit - 2 nos.
<b>3.0</b>	<b>Automatic self-cleaning filter</b>	
3.1	Set of complete wedge wire filter element assembly consisting of multiple candles, as per design	Shaft seal circuit-2 nos.
3.2	Motorized and pneumatic valve	2 nos. of each type and size
3.3	Motor	2 nos. of each type and size
3.4	Set of seal and gasket	2 nos. of each type and size
<b>4.0</b>	<b>Cyclone Separator</b>	
4.1	Purging valve	2 nos. of each type and size
4.2	Solenoid valve	2 nos. of each type
5	Valves of size 80mm and above	2 nos. of each type
6	Pressure gauges and pressure switches	2 nos. of each type
7	Flow meters and flow switches	2 nos. of each type & size
8	Temperature gauges and temperature transmitter	2 nos. of each type & size
9	Motorized valves of each type along with motor/ panel and other accessories	2 nos. of each type & size

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 04 Unit Dewatering & Station Drainage Systems

## VOLUME-II

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### SECTION II SUB-SECTION 04 Unit Dewatering & Station Drainage Systems

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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## TABLE OF CONTENTS

<b>4</b>	<b>UNIT DEWATERING &amp; STATION DRAINAGE SYSTEMS .....</b>	<b>3</b>
4.1	UNIT DEWATERING SYSTEM.....	3
4.1.1	<i>General .....</i>	3
4.1.2	<i>Description of Scheme .....</i>	3
4.1.3	<i>Operational Details of System .....</i>	4
4.1.4	<i>Technical Particulars of Equipment .....</i>	5
4.2	STATION DRAINAGE SYSTEM .....	8
4.2.1	<i>General Description of Scheme.....</i>	8
4.2.2	<i>Operational Details of System .....</i>	9
4.2.3	<i>Technical Particulars of Equipment .....</i>	9
4.3	FLOOD DEWATERING SYSTEM.....	9
4.3.1	<i>General Description of Scheme.....</i>	10
4.3.2	<i>Operational Details of System .....</i>	10
4.3.3	<i>Technical Particulars of Equipment .....</i>	10
4.4	MONORAIL FOR THE PUMPS .....	11

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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## **4 UNIT DEWATERING & STATION DRAINAGE SYSTEMS**

### **4.1 Unit Dewatering System**

#### **4.1.1 General**

The scope of work under this specification shall consist of the design, engineering, manufacturing, shop test, supply, loading at manufacturer's works, transportation & delivery of various items along with their spares to the project site, storage at site, erection and commissioning of the complete Dewatering System.

The Dewatering System shall be designed for dewatering of Penstock, partial dewatering of draft tube (for Turbine, Runner inspection) and complete dewatering of draft tube. The system shall include the Dewatering Pumps, Piping, Valves, suitable Starters/MCC, Protective devices, Control & Instrumentation etc. and associated accessories required for the completeness of the system.

The scheme shall also include hoisting mechanisms (mono rail hoist) for Drainage. Dewatering and Flooding pumps.

Other items not specified above but found necessary to complete the system in all respects shall be in the scope of the Tenderer.

#### **4.1.2 Description of Scheme**

Dewatering system shall be provided in the Powerhouse for dewatering of Penstock, Scroll Case and Draft Tube up to Draft Tube Gate for access to Turbine for inspection and maintenance.

Water to be drained out from the Turbine space and the lowest part of the Penstocks below tail water level shall be drained through unit piping up to Dewatering Sump passing through Dry Valve Pit, from where it shall be simultaneously pumped out of the Powerhouse through Submersible Sump Pumps. The water shall be discharged downstream of the draft tube gates above High Flood Level.

The piping shall comprise of the following.

1. Draft tube drain piping from each unit at bottom most point shall be provided with stainless steel debris grating and connected to a common Dewatering Sump located at one end of the Powerhouse.
2. For each draft tube, Spindle Butterfly valve connected to the draft tube drain pipe mentioned above shall be located inside the Dry Valve Pit. The spindle gate valve shall be operable from Pit's top level.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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3. Submersible Sump Pumps (1 no. working + 1 no. standby) for dewatering.
4. Delivery pipe leading from the Submersible Sump Pumps installed in the Dewatering Sump in the Powerhouse to the tail race. Fluid velocity in piping shall not exceed 2 m/sec when one pump is running and 3.5 m/sec with both pumps running.
5. A Portable Submersible Sump Pump to evacuate Valve Pit's Floor drains / leakages.

The details of water volumes to be emptied and the expected leakages through Penstock Protection butterfly valve and Main Inlet Valve shall be furnished by the Contractor. The leakage through Draft Tube Gates shall be estimated as per latest edition of IS: 4721 or its equivalent national/international standard. However minimum leakage of 0.1 L/sec/m throughout the Gate perimeter with an additional 0.1 L/sec/m in corner section of 1m length shall also be considered.

The Contractor shall select such designs, constructional features and materials of the dewatering equipment which would resist silt abrasion effects and shall be capable of handling muddy/ turbid water.

The capacity of the dewatering pumps (2x100%) shall be such that with the main dewatering pump working (without aid from standby pump), the Turbine water passage between the downstream MIV and the Draft tube Gate can be emptied within about six (6) hours, taking into account maximum anticipated leakages through the MIV seals and through the Draft tube Gate seals. Time for partial dewatering shall be considered as three (3) hours.

Necessary calculations shall be furnished by the Contractor to determine the pumping capacity & the rated dynamic head and shall be subject to approval by the Employer/ Engineer. The Contractor shall work out the required pump heads on the basis of details of the system layout.

Drainage Sump and Dewatering Sump shall be interconnected by piping having Manual spindle operated interconnecting valve (Normally Closed) and an NRV. In case of failure of Drainage Pumps, Dewatering pumps can be manually put into operation for emergency drainage by manually opening spindle operated valve from Turbine Floor Level.

In the eventuality of a major leakage / flooding condition of the Powerhouse both Pumps of Drainage System as well as both Pumps of Dewatering System can work simultaneously. The logic of the start-up of these Pumps as well as the size of discharge pipes shall be designed accordingly.

#### **4.1.3 Operational Details of System**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
---	--	--

The automatic operation of the pumps shall be effected with the help of level switches installed in the sump working on the basis of prefixed water levels. The pumps shall start with the rise of water level in the sump when turbine is being drained and shut off when the level in the sump falls to the minimum allowed level.

If for any reasons the water level continues to rise beyond the start level of the 2nd pump, high water level alarm and annunciation shall be sounded at the local control panels, machine level (UCB) and control room level (CR).

The main and standby duty of the pumps shall be interchangeable with the help of selected switches provided for the purpose.

#### 4.1.4 Technical Particulars of Equipment

The pumping equipment shall comprise pumps with driving electric motors, piping, valves, piping flow instrumentation, level relay to auto start-stop of pumps, high water level alarm, water level gauge, inter connection with control valves including check valve for connecting drainage sump with dewatering sump, motor switchgear, starters, protection and controls etc. complete in all respects.

Details of the system have been shown in the Drawings “Drainage & Dewatering System, Flow Diagram” enclosed along with this tender document.

##### 4.1.4.1 Pump Sets

- a) The pump sets shall be Submersible Sump type to be installed in the sump.
- b) The pump impellers shall be of cast stainless steel (CF8M) hydraulically balanced. The impeller wear rings shall be of wear resistant stainless steel. The pump shaft shall be made of corrosion resistant stainless steel (SS-410), ASTM A217 and adequately sized to carry torque requirements. The fasteners in liquid shall be made of SS-304.
- c) The suction and discharge casings shall be of rugged cast iron construction/ductile iron. Means for preventing reverse flow shall be provided. The speed of pumps shall be 1450 rpm.
- d) The pumps shall be capable of handling muddy/turbid water.
- e) The motor shall be suitable for 415 V, 3 phases, 50 Hz. AC supply and for control the AC supply shall be 240 V, 1 phase, 50 Hz.
- f) The thrust bearing shall be designed to carry all the thrust and shock load that could be imposed by the pump. Mechanical Seals of suitable design shall be provided to prevent water from entering into the motor.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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#### 4.1.4.2 Piping, Valves & Gauges

- a) Piping shall be of steel, electric resistance welding (ERW) type of medium class. Various control and check valves of pressure class 10 bar shall be provided in accordance with the specification as detailed in General Particular Specification. The valves shall be of modern sleek design with minimum space requirement for installation & easily operable type.
- b) The piping system shall have pressure gauges, flow indicators etc. The sump shall have a water level gauge for indication of instantaneous level of water in the sump. Float switches/level relays shall be provided for control of pumps and to sound high water level alarm & annunciation.
- c) Insulation with non-combustible material on the surface piping located in the power house caverns shall be provided to avoid the problem of dripping of water due to condensation.

#### 4.1.4.3 Switchgear & Controls

- a) The switchgear and controls shall be mounted in metal enclosed cubicles and suitable for automatic and manual operation of the pumps from local control panel.
- b) The switchgear and controls shall comprise circuit breakers suitable motor starters, auxiliary relays, thermal and over load protection, single phase prevention devices, selector switches, push buttons, meters, status indicating lamps etc.
- c) The selector switches shall be provided for mode change over, auto-manual operation and main and standby duty selection.
- d) Float switches/ level relays shall be provided in the sump for enabling auto pump operation and high water level alarm / annunciation.
- e) The switchgear and controls shall be housed in a panel which shall be located at the turbine floor.

#### 4.1.4.4 Site Inspection and Performance Tests

Contractor's Site Inspection, Testing & Commissioning program for the Dewatering system shall include but not limited to the following:

- Inspection and testing of all lines and connections to ensure their proper installation according to drawings and verification that they are free from debris or obstructions;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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- Testing of pumps, level sensors, instruments and alarms to ensure proper operability of all components and correct mutual function or interrelated parts;

All Test procedures, Test results & equipment settings shall be recorded on data sheets and shall be submitted to the Employer.

#### 4.1.4.5 Drawings/Documents for Dewatering System

The Tenderer shall submit the following drawings / documents at the time of bid submission:

- Flow Diagram
- Technical data sheets of all main equipments
- Catalogues of proposed main equipments

The main drawings/documents to be furnished after award of contract shall include but not limited to the following:

- DBR (Design Basis Report), including design calculations.
- Flow Diagram
- Sizing/selection calculations of Pumps
- Pumps - Performance curves
- Manufacturing Data Sheets/Specifications of Pumps, Level Sensors, Valves
- GA & Foundation Drawings of Pumps
- QAP – Pumps, Level Sensors, Valves
- Pipe routing, Isometric drawings and As-Built drawings.
- Pipe supports
- Equipment Catalogues
- Testing and Commissioning Procedures
- O & M Manuals

#### 4.1.4.6 Mandatory Spare Parts

The following spare parts shall be included in the supply:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 04 Unit Dewatering & Station Drainage Systems

S. No.	Description	Type/size	Quantity	
<b>I</b>	<b>Dewatering Pump</b>		<b>Main Pump</b>	<b>Portable Submersible</b>
1	Impeller		2 nos.	1 no.
2	Rotor Shaft		2 nos.	1 no.
3	Upper Bearing		2 nos.	1 no.
4	Lower Bearing		2 nos.	1 no.
5	Upper Mechanical Seal		2 nos.	1 no.
6	Lower Mechanical Seal		2 nos.	1 no.
7	Cable Entry Kit		2 nos.	1 no.
8	O-Ring		2 nos.	1 no.
9	Fasteners in Liquid		2 nos.	1 no.
<b>II)</b>	<b>Valves &amp; Instruments</b>			
1	Valves	each type / size	1 no.	
2	Pressure Gauge		1 no.	
3	Pressure Switch		2 nos.	
4	Components of Starters for Pumps & Control		1 set	

## 4.2 Station Drainage System

The scope of work under this specification shall consist of the design, engineering, manufacturing, shop test, supply, loading at manufacturer's works, transportation & delivery of various items along with their spares to the project site, storage at site, erection and commissioning of the complete Station Drainage System.

The Drainage System shall be designed for drainage of all water discharge, outlets, returns, effluents/ drainage leakages from equipment and any seepages from rock surroundings the Powerhouse, etc.

Other items not specified above but found necessary to complete the system in all respects shall be in the scope of the Tenderer.

### 4.2.1 General Description of Scheme

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 04 Unit Dewatering & Station Drainage Systems

The automatically operated station Drainage System is required for drainage of all water discharge, outlets, returns, effluents/ drainage leakages from equipment and any seepage from rock surroundings the Powerhouse etc into drainage sump.

All such water will be arranged to be led into a common station drainage sump provided in the Powerhouse adjacent to the Dewatering Sump. The quantity of all effluents at its peak into the sump shall be considered, and the station drainage pumping system shall be sized to handle the same. All such water shall be pumped out from the sump by means of Submersible Sump Pumps into the tailrace downstream of the tail race gates above High Flood Level (HFL).

The scheme shall comprise of minimum two (2) number Submersible Sump Pumps of equal capacity for handling station drainage requirement. One of the pumps shall act as main pump and the second pump shall act as standby pump

The pumps shall be capable of handling muddy/turbid water.

Necessary calculations shall be furnished by the Contractor to determine the pumping capacity & the rated dynamic head and shall be got approved from the Employer. The drainage pumps shall be designed for maximum four (4) starts & stops per hour.

The piping shall comprise of the pipe leading from the pumps installed in the sump well in the Powerhouse to the tail race after the closed tail race gates. Fluid velocity in the piping shall not exceed 2 m/sec when one pump is running and 3.5 m/sec with both pumps running.

Drainage and Dewatering Sumps shall be interconnected by piping having Manual Spindle Operated Interconnecting Valve (Normally Closed) and a NRV.

A Portable Submersible Sump Pump of capacity 5 L/sec shall also be supplied to evacuate water from various pits/low areas, whenever required.

#### **4.2.2 Operational Details of System**

Details shall be similar to those indicated for the unit dewatering system.

#### **4.2.3 Technical Particulars of Equipment**

Details shall be similar to those indicated for the unit dewatering system.

### **4.3 Flood Dewatering System**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 04 Unit Dewatering & Station Drainage Systems
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The scope of work under this specification shall consist of the design, engineering, manufacturing, shop test, supply, loading at manufacturer's works, transportation & delivery of various items along with their spares to the project site, storage at site, erection and commissioning of the complete Flood Dewatering System.

One (1) sets of submersible type flood pumps with all the necessary accessories, to be installed at main inlet valve floor along with continuous duty motors, starter for auto operation through float switch, power cable, stainless steel discharge pipe line and hardware, anchor bolts and other mounting materials.

The Flood Dewatering System shall be designed for emergency condition when the water starts to flood the powerhouse.

Other items not specified above but found necessary to complete the system in all respects shall be in the scope of the Tenderer.

#### **4.3.1 General Description of Scheme**

The proposed scheme shall work in tandem with the drainage and dewatering system to ensure operational safety and efficiency. Submersible dewatering pumps of sufficient capacity in the dewatering sump, along with additional submersible pumps at the MIV floor equipped with automatic start mechanisms using level switches shall be installed to pump out water from the Powerhouse Station.

Control panels for these pumps will be located on floors higher than the turbine floor to prevent damage during flooding.

Float switches will be installed at the MIV floor to signal the closure of the Main Inlet Valve (MIV) in the event of penstock leakage, rupture, or other inundation scenarios.

Key equipment such as unit control panels, protection panels, DC batteries, chargers, and station service transformers will be strategically placed on higher floors for added protection, alongside a DG set to ensure pump operation during power failures.

#### **4.3.2 Operational Details of System**

Details shall be similar to those indicated for the unit dewatering system.

#### **4.3.3 Technical Particulars of Equipment**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 04 Unit Dewatering & Station Drainage Systems

Details shall be similar to those indicated for the unit dewatering system.

#### **4.4 Monorail for the Pumps**

Standard Hoist and chain blocks designed for travel along monorail beams and travelling rollers shall also be provided for installation/removal/movement/repair of the above mentioned pumps. Designed for manual operation, the monorail hoist (1 tonne capacity) be placed at such a location that all the pumps are easily accessible and within the range. The design shall include load chain, hand chain load dependent pressure broke, steel hook and spring-loaded safety catch. The chain block weight shall allow easy displacement from one monorail beam to another. Lifting ropes with rope slings shall be included in the supply.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec.05 HP & LP Compressed Air System

## VOLUME- II

### SECTION II SUB-SECTION-05 HP & LP Compressed Air System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
---	--	---

## TABLE OF CONTENTS

<b>5</b>	<b>HP &amp; LP COMPRESSED AIR SYSTEM .....</b>	<b>3</b>
5.1	SCOPE OF WORK .....	3
5.2	GENERAL REQUIREMENTS.....	3
5.3	PIPING & VALVES .....	5
5.4	SITE TESTING AND COMMISSIONING TESTS .....	6
5.5	DRAWINGS/DOCUMENTS FOR COMPRESSED AIR SYSTEM.....	6
5.6	SPARES FOR COMPRESSED AIR SYSTEM .....	7

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
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## 5 HP & LP COMPRESSED AIR SYSTEM

### 5.1 Scope of Work

The scope of work under this specification shall consist of the design, engineering, manufacturing, shop test, supply, loading at manufacturer's works, transportation & delivery of various items along with their spares to the project site, storage at site, erection and commissioning of the complete High & Low Pressure Compressed Air System as described below with the first Turbine furnished under the Contract. The Compressed Air system shall be provided complete with starter, control panel and disconnect switch, associated cabling, wiring etc and all the associated items whether or not specified herein.

### 5.2 General Requirements

A common HP & LP compressed air system shall be supplied for all the units of the Powerhouse. The compressed air system will be required for continuous or intermittent supply of air to cater the requirements of governor oil pressure for governing of turbine and low pressure air supply for generator braking for all the units.

A separate compressed air system, shall be provided to supply the compressed air to run the machine in synchronous condenser operation mode.

Air Compressors shall be of reciprocating type to generate pressure of at least 6.9 MPa or higher as per requirement. The high Pressure receiver shall be of adequate capacity for total 3 starts and 3 stops without recharging of the air in the Air Receiver. The control shall be totally automatic to make up the losses of air in the pressure tank. The Compressors shall have the following ratings.

Compressor running time required for initial charging of one Governor tank with both Compressors 'ON'	180 minutes
Duty cycle of each Compressor under rated condition	30 Minutes start followed by 30 minutes stop

The LP Brake Air Receiver, common to all TG units, shall be of sufficient capacity with adequate margins to stop the unit. Pressure of the air supplied for the generator brake system, shall be 860 kPa (gauge). However, the same may be finalized considering the generator brake system requirements during detail design. The LP air system shall be fitted with safety valve and manual drain traps, as required.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
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A Pressure Regulation Panel shall be provided which shall be equipped with necessary Instrumentation, in order to meet the pressure requirements of the system.

The Contractor shall furnish the detailed calculation for the selection of Compressor capacity, motor, Air Receiver's calculation, etc. for the Employer's approval. Further, complete datasheet / specification of Compressors, motors, Air Dryers etc. shall be reviewed / approved by the Employer during detailed engineering.

The system shall comprise of the following:

- AC motor driven air cooled reciprocating air Compressors, one acting as main and one acting as stand by for HP System, one acting as a main and one acting as stand by for LP system, and another one for the synchronous condenser mode; each of adequate capacity to cater above needs for the Powerhouse; the standby Compressor shall start automatically on failure of the main Compressor. Provision for manual rotation of duty between the main and standby Compressors for HP & LP system shall also be provided. These High Pressure Compressors shall be alternated after each pre-set operating cycle.
- The air from individual Compressor shall be air-cooled and then passed through Air Dryers (regenerative/refrigerant type to dry humid air) and accumulated in one High Pressure Air Receiver fitted with pressure gauge, safety valve and manual drain trap. For automatic starting/stopping of motor and low air pressure alarm, pressure switches shall be provided.
- The compressed air system shall be provided with two regenerative/refrigerant Air Dryers (2x100%) to dry the humid air. Normally one Air Dryer shall be used and shall have sufficient capacity to dry the air. The second Air Dryer shall be kept in standby mode for operation as and when required.
- HP Air Receiver along with necessary piping and adequate nos. of isolating valves shall be supplied.
- Two (2) Pressure Reducing Stations (1 no. working + 1 no. standby) each comprising of solenoid valve controlled by pressure switches, orifice, pressure gauge, safety valve and adequate nos. of isolating valves, piping shall be supplied.
- LP Air Receiver for Break & Service Air, One (1) no. of minimum 1000 L capacity along with necessary piping for supply of low pressure air to generator braking system.

The following tapping points for supply of service air shall be provided:

- four (4) tapping points at service bay.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
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- four (4) tapping points at the transformer yard.
- four (4) tapping points at each of the power house floors.

The above requirement is tentative and shall be finalised during detail engineering.

- Complete piping, fittings, pipe supports, adequate number of isolating valves, non-return valves, local control panel, etc. shall be provided
- The Compressor motor shall be provided with suitable starter, protective devices and indicating lamps.
- Necessary piping, fittings to discharge condensate from Compressors, Air-Dryers & HP Air Receiver to the drain

The main technical features of the service air system shall be as under:

HP Air Receiver	Nominal Pressure : 6.9 MPa Capacity : 2500 L Pressure Rating : 7.9 MPa
LP Air Receiver for Generator Braking System & Service Air	Nominal Pressure : 860 kPa Minimum available pressure : 620 kPa Capacity: 1000 L (min.)
Service Air-Piping Header	50 mm
Service Air Connectors	50 / 18 mm
Air Filter	4 microns particles & 5 ppm Oil carry over.

### 5.3 Piping & Valves

Control & Shut-off valves of various types & sizes shall be provided in the system for control & regulation of the Compressed Air supply to Governor Oil Pressure Receivers, Generator Braking, Utility connections etc.

All the valves for HP & LP circuit shall be of cast steel body with trim of SS. Brass trim can be considered for LP circuit valves. This shall comply with the relevant International Standards or equivalent Standard.

All brake air piping shall be of Stainless Steel & while all other piping shall be heavy duty Galvanised Carbon Steel material, ASTM A53 Gr B / A106 gr B. All fittings such

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
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as Elbows, Tee's, Reducers shall be of carbon steel seamless type, galvanized of class 3000. However, all piping & fittings embedded in the concrete shall be of Stainless Steel.

The necessary instrumentation like Pressure Gauges, Pressure Switches, Pressure Transmitter, Temperature Gauges / Temperature Switches shall be provided as required.

#### 5.4 Site Testing and Commissioning Tests

Contractor's Site Inspection, Testing & Commissioning program for the compressed air system shall include but not limited to the following:

- Inspection and testing of all lines and connections to ensure their proper installation according to drawings and verification that they are free from debris or obstructions;
- Testing of Compressors, receivers, relief valves, valve controls and alarms to ensure operability of all components and correct mutual function or interrelated parts;

All Test procedures, Test results & equipment settings shall be recorded on data sheets and shall be submitted to the Employer as site commissioning report.

#### 5.5 Drawings/Documents For Compressed Air System

The Tenderer shall submit the following drawings / documents at the time of bid submission:

- Flow Diagram
- Technical data sheets of all main equipments
- Catalogues of proposed main equipments
- The major drawings/documents to be furnished after award of contract shall include but not limited to the following:
  - DBR (Design Basis Report), including design calculations.
  - Flow Diagram
  - GA & Foundation Drawings of Compressors, Air Dryers and Air Receivers
  - Sizing /selection calculations of Compressor, Air Dryers, Air Receiver & Piping
  - Manufacturing Data Sheets/Specifications of Compressor, Air Dryers and Air Receivers

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec.05 HP & LP Compressed Air System
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- QAP - Compressors, Air Dryers, Air Receivers
- Pipe routing, Isometric drawings and As-built drawings.
- Equipment Catalogues
- Testing & Commissioning procedures
- O & M Manuals

## 5.6 Spares for Compressed Air System

The following spare parts shall be included in the supply:

	Description	Type/size	Quantity
<b>I</b>	<b>HP COMPRESSED AIR SYSTEM</b>		
1	Piston		1 no.
2	Piston Rings		1 set
3	Cylindrical Valves		1 set
4	Bearings		1 set
5	Gudgeon Pin		1 no.
6	Springs		1 set
7	Packing, Sealing & Gaskets etc.		1 set

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

## Volume-II

### Section II Sub-Section 6

### Isolated Phase Bus Duct & Associated Equipment

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

## **TABLE OF CONTENTS**

<b>6</b>	<b>ISOLATED PHASE BUS DUCT AND ASSOCIATED EQUIPMENTS .....</b>	<b>3</b>
6.1	Scope .....	3
6.2	Standards .....	3
6.2.1	International Standards.....	4
6.2.2	North American Standards.....	4
6.2.3	Indian Standards .....	5
6.3	Life Expectancy .....	5
6.4	General Description of Installation .....	6
6.4.1	Auxiliary Power Supplies .....	6
6.4.2	Locks and Keys .....	6
6.5	Main Isolated Phase Bus and Disconnect Switches- Ratings / Requirements.....	7
6.5.1	Electrical Characteristics.....	7
6.5.2	Temperature Rise Characteristics.....	7
6.5.3	Cooling Method .....	7
6.5.4	Isolated Phase Bus Duct.....	7
6.5.5	Isolated Phase Bus Taps .....	11
6.5.6	Current Transformers .....	11
6.5.7	Potential Transformer and Surge Protection Cubicles (PTSP / LAVT) .....	13
6.5.8	Neutral Grounding Cubicle.....	15
6.5.9	Connections of Isolated Phase Bus Duct and Apparatus .....	18
6.5.10	Control Panels and Junction Boxes .....	19
6.5.11	Painting and Finishing .....	20
6.5.12	Quality Control, Inspection and Tests .....	21
6.5.13	Drawings, Data, Manuals and Guaranteed Particulars.....	23
6.5.14	Packing and Transport.....	26
6.5.15	Spare Parts and Special Tools.....	26

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
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## 6 ISOLATED PHASE BUS DUCT AND ASSOCIATED EQUIPMENTS

### 6.1 Scope

This section covers the criteria for design, manufacture, supply, transportation up to site, handling and storage at site, erection, testing and commissioning of Isolated phase bus duct (IPBD) as per the schedule of requirements along with their auxiliaries, spare parts for 5 years trouble free operation of the system special tools and tackles as described in the specification.

The bus duct shall be suitable in every way for operation on the system and under the conditions specified in this specification. The scope shall broadly include all items required starting from Generator terminals up to terminals / bushings on Generator Transformers including Potential Transformer & Surge Protection (PTSP / LAVT) Panel, Excitation Transformer, Unit Aux. Transformer (UAT) and Neutral Grounding Transformer (NGT) Cubicle.

A hot air blowing system or air pressurization system shall be provided to prevent moisture deposition.

### 6.2 Standards

The Isolated phase bus duct shall be designed, manufactured, tested and erected in conformance with applicable International, North American, and Indian Standards. Many standards may be similar or redundant from one organization to the other. The Bidders shall conform to International Standards at base. American Standards shall be used for items not covered by the International Standards. Indian Standards shall be considered for regional requirements and when legally binding.

Isolated phase bus duct, accessories, etc., meeting any other authoritative standard, which ensures equal or better quality than the Standards mentioned below, shall also be acceptable. However, where the equipment offered conforms to any other standards, the salient points of difference between standards adopted and provision of this specification



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

and standards referred above shall be clearly brought out in the bid. Copies of such standards in English language or fair English Translation shall be attached with the bid.

#### 6.2.1 International Standards

IEC 99-4	Lightning Arresters
IEC 298	Switchgear assemblies including metal enclosed bus
IEC 60044-1	Instrument Transformers (Part 1: Current Transformers including amendments 1 & 2)
IEC 60044-6	Instrument Transformers (Part 6: Requirements for Protective Current Transformers for Transient Performance)
IEC 60060-1	High Voltage Test Techniques (Part 1: General Definitions and Test Requirements)
IEC 60060-2	High Voltage Test Techniques (Part 2: Measuring Systems)
IEC 60085	Electrical Insulation - Thermal Classification
IEC 60137	Insulated Bushings for Alternating Voltages above 1000 V
IEC 60270	High Voltage Test Techniques (Partial Discharge Measurements)
IEC 60529	Degrees of Protection Provided by Enclosures

#### 6.2.2 North American Standards

ANSI C37.20, C37.20A C37.21B C37.C0C	Switchgear assemblies including metal enclosed bus
ANSI C37.23	Guide for Metal enclosed bus and calculating losses in isolated phase bus
ANSI C57.13	Standard Requirements for Instrument Transformers
ANSI C57.13.1	Guide for Field Testing of Relaying Current Transformers
ANSI C57.13.3	Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases
ANSI C57.13.5	Trial-use Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 V and above
IEEE-32	Requirements, terminology, and Test procedure for Neutral grounding devices

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

### 6.2.3 Indian Standards

IS:5	Colours for Ready Mixed Paints and Enamels
IS:104	Ready Mixed Paint, Brushing, Zinc Chrome, Priming
IS:1554	PVC Insulated (heavy duty) Electric Cables (Part 1 for Working Voltages up to and Including 1100 V)
IS:2062	Steel for general structural purpose
IS:2147	Degree of Protection Provided by Enclosures for Low Voltage Switchgear and Control Gear
IS:2544	Porcelain post- insulators for systems with nominal voltage greater than 1000V
IS:2633	Method of testing uniformity of coating on zinc coated articles
IS:2705	Current Transformers
IS:2705	Current Transformers (Part 1 General Requirements)
IS:2705 : Part 3	Current Transformers: Part 3 Protective Current Transformers
IS:2705 : Part 4	Current Transformers: Part 4: Protective Current Transformers for Special Purpose Application
IS:2932	Enamel, Synthetic, Exterior: (a) Undercoating (b) Finishing Specification
IS:3043	Code of practice for earthing
IS:3151	Specification for Earthing transformer
IS:3156	Voltage Transformers
IS:3347	Dimensions for Porcelain Transformer Bushings
IS:4759	Hot dip zinc coating on structural steel and allied products
IS:5082	Wrought aluminum and aluminum bars, rods, tubes and sections for electrical purposes
IS:8084	Specification for interconnecting bus-bars for AC voltage above 1 kV up to and including 36 kV

**Note:** In case of any conflict between the here above listed reference documents, codes and Standards, the manufacturer has to point out these conflicts and refer to Employer whose decision shall be final and binding.

### 6.3 Life Expectancy

The bus duct must be maintainable for a period of at least 40 years.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

#### 6.4 General Description of Installation

The three (3) generators are separately connected to nine (9) 11/220/ $\sqrt{3}$  kV single phase transformers located on a concrete slab in the upstream of the powerhouse, by three (3) sets of main 11 kV isolated phase bus ducts. It shall include seal off bushings for generator barrel as well as at wall / floor crossing, bends, flexible connectors, expansion joints, termination arrangement, support structure etc. as well to make it complete.

A disconnect link is integrated to each isolated phase bus.

Isolated phase bus duct shall be provided with taps / tapping to the Rectifier / Excitation Transformer, the LAVT cubicles, unit auxiliary transformers.

Connection to generator transformers including delta formation also forms the part of scope and shall be coordinated with the transformer manufacturer/ contractor by the successful Bidder.

Generator neutral cubicle and grounding transformer are installed near the generator neutral terminals.

##### 6.4.1 Auxiliary Power Supplies

Auxiliary circuits shall be capable of operating at 415 / 240  $\pm$  10% V, 50 $\pm$  5%Hz AC supply available in Power House. The control / interlock circuits shall operate at 220V DC available from a station battery system.

##### 6.4.2 Locks and Keys

All doors and drawers of cubicles described in this Specification shall be equipped with a key operated lock. There shall be a common key for the whole supply. Five copies of the common key shall be supplied.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

## 6.5 Main Isolated Phase Bus and Disconnect Switches- Ratings / Requirements

### 6.5.1 Electrical Characteristics

Rated voltage	11 kV, $\pm 10\%$
Rated frequency	50 Hz, $\pm 5\%$
Rated continuous current	6300 A
Basic impulse level	75 kV peak
Power frequency withstand voltage	35 kV RMS
Ambient Temperature	40°C
Short-time overcurrent's (RMS):	
Rated (1 sec.)	63 kA (symmetrical)
Peak value	150 kAP (crest)

\* Adequate consideration for temperature rise, insulation level as per LOV study clearances at higher altitude (greater than 1000 metres) and ambient temperature to be taken care by the Contractor.

The fault current values shall be reviewed at the time of short circuit studies during detail engineering.

### 6.5.2 Temperature Rise Characteristics

The temperature rise of any component of the isolated phase bus including bolted joints of flexible braid connectors shall conform to values given in Table 1 of ANSI / IEEE C37.23, under rated operating conditions. The enclosure temperature rise shall not exceed the values as per latest relevant IEEE/IS standards.

### 6.5.3 Cooling Method

Isolated phase bus duct and disconnect switches shall be self-cooled.

### 6.5.4 Isolated Phase Bus Duct

#### a) Description:

- The isolated phase bus duct shall be of the isolated phase type, with housing. The isolated phase bus duct assemblies shall include all necessary materials, such as: straight sections, elbows, tees, bus taps, joints, expansion joints, short-circuiting plates, flexible braid connectors, grounding connectors, seal-off bushings, bus connection boxes, cable connection boxes, fire barriers, support structures for insulated phase bus, disconnect link, connection boxes, wall and floor plates,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

anchors, etc. to complete the layout indicated on the drawings which are part of this Specification;

- The bus duct shall be designed to withstand without deformation and without causing stresses to connected equipment, the maximum thermal expansions or contractions likely to occur;
- Openings or hand holes shall be supplied in sufficient quantity and at appropriate locations to allow easy access to joints, connectors, seal-off bushings, insulators and current transformers for inspection or replacement.

b) Conductors and Insulators:

- Isolated phase bus conductors shall be of aluminum alloy and mounted on porcelain insulators/ epoxy resins insulators;
- The general design of isolated phase bus, the choice of mounting method for fixing conductors to insulators, and appropriate spacing of insulators along conductors shall be such, that conductors can withstand short-time overcurrent without permanent deformation and at the same time no insulator shall be damaged;
- Connections between bus sections shall be made with welded flexible laminated aluminum connectors as required to allow expansion. Bus conductor connections to various equipment such as generators, generator transformer connection boxes, and LAVT cubicles etc., described in articles shall be made with flexible copper connectors complete with lock washers at both ends.
- The method for bolt tightening shall be given in the Tender. Bidder shall show on his drawings, in each particular case, the required bolt torque. For field welded connections, Bidder shall specify the exact type of welding and the procedures and welding code that are used to be followed.

c) Bus Housing

- The circular bus housings shall be constructed in aluminum and shall be sufficiently rigid to prevent distortion under all operating conditions. They shall be dust-proof and watertight on their entire length. No air intake is permitted for free air circulation. However minimum two breathers (silica gel) shall be provided for each phase / circuit;
- A continuous drainage of the condensation, formed within each bus housing, shall be supplied in its entire length. Location and type of drains used shall be indicated

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

on Bidder's drawings and submitted for Engineer's approval;

- The bus housing shall be of the continuous enclosure design, to contain as much as possible the magnetic field, to prevent heating of supports and reinforcement in adjacent concrete. Precautions shall be taken to prevent current flowing from the housing to the apparatus to which it is connected, except for the disconnect switches, the envelope of which shall form part of the bus housings;
- On the housings and at locations he considers necessary, Bidder shall provide grounding connectors for flat galvanized steel plates, copper conductors and coppers flexible braids;
- IPBD enclosure shall be provided with shorting links near all equipment termination such as Generator end, transformer end, UAT, LAVT, excitation transformer etc.

d) Plates and Seal-off Bushings

- Plates:

A plate shall be provided at places where isolated phase bus go through the wall of the powerhouse, in order to prevent air infiltration between the bus housing and the wall. This plate shall be heat-insulated in order to avoid any condensation. A plate shall also be supplied at generator terminals and at places where isolated phase bus go through the floors of the powerhouse. Gaskets shall be supplied with plates. Plates shall be pre-assembled and ready for installation in the field. Seal Off bushings / Fire barriers shall be provided along with plates at top places where the isolated phase bus go through the floors of the Power house.

- Seal-off bushings:

Porcelain/Epoxy seal-off bushings shall be supplied at cubicle feeding auxiliary transformers, excitation Transformers, generator terminals, potential transformers and surge protection cubicles.

e) Fire barriers:

Two-hour resistant fire barriers shall be provided each time the isolated phase bus duct and the delta connections cross a transformer enclosure fire wall. Typical for each bus set, three phase fire barriers are required for crossing the generator transformer enclosures and four barriers for the delta connections crossing the lateral walls. Products used for internal and external fire barriers shall be tested by a recognized independent authority. The fire barriers shall in no way reduce the current carrying



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
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capacity of the bus nor increase the temperature rise nor exceed design hot spot temperature. The Bidder shall provide to the Employer his requirement regarding the size and location of openings in the fire walls.

f) Disconnect Link

An isolated phase disconnect link shall be integrated to each isolated phase duct.

g) Support Structures and Access Platforms

The isolated phase bus duct including the disconnect switch, the cable and bus connection boxes shall be supplied with supporting structures and other materials required for the installation. Supporting structure shall be floor anchored. Anchoring to ceiling and walls is to be avoided.

All structures shall be made of galvanized steel.

Bolted type assemblies with galvanized steel bolts shall be used for ease of erection throughout the installation. Supports shall be sufficiently strong to withstand short-circuit forces in addition to their own mechanical loading.

Bidder is responsible for the exact location of the supports.

The support structures and bus design shall allow the easy adjusting and line-up of bus during erection without further modifications, such as re-drilling of holes.

A permanently installed access platform shall be provided for each disconnect switch for maintenance and inspection.

h) Shorting Links

Shorting jumpers for testing purpose will be provided for IPBD. Shorting links will be rated same as the main bus conductor and will be supplied loose and will be connected in the circuit whenever need arises.

i) Temperature Indication

The following instruments shall be supplied:

- Resistance temperature detectors, (platinum, 100 ohms at 0 °C) to be installed, on each phase housing of the first unit, at points likely to present the highest temperature rise (location to be given in Bid). They shall be connected to junction boxes for the use of the Employer. These boxes shall be installed in accessible locations, and the cables shall be brought to a main junction box;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

- Dial-type indicating thermometers, to be installed on each phase conductor of the first unit, at points likely to present the highest temperature rise (location to be given in Tender), and with observation windows.

#### 6.5.5 Isolated Phase Bus Taps

- The construction criteria for conductors and housings of bus taps are the same as those for the main bus;
- Short-circuit plates shall be supplied and installed at tap ends to prevent housing current from flowing through the connected apparatus. Moreover, insulating sheath shall be supplied for the connection of bus taps to apparatus cubicles;
- Bus taps for unit Rectifier / Excitation Transformers, unit auxiliary transformers (UAT) shall be provided.

##### 6.5.5.1 Support Structures for Taps

- Support structures meeting the same criteria as those of the main bus shall be supplied where required.

##### 6.5.5.2 Electrical Characteristics of Taps

Rated voltage	11 kV, $\pm 10\%$
Rated frequency	50 Hz, $\pm 5\%$
Rated continuous current	200 A
Basic impulse level	75 kV peak
Power frequency withstand voltage	35 kV
Short-time overcurrents (RMS):	
Rated (1 s.)	63 kA (symmetrical)
Peak value	150 kA (crest)

The fault current values shall be reviewed at the time of short circuit studies during detail engineering

#### 6.5.6 Current Transformers

Current transformers shall be integrated to the isolated phase bus duct and bus duct taps at the following locations as shown on the main single line diagram:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

- At the generator terminals;
- Near the LV terminals of generator transformers;
- Near the terminals of the generator static excitation transformer;
- Near the terminals of Unit auxiliary transformers supply cubicle;

#### 6.5.6.1 Electrical Characteristics

##### Generator Current Transformers

Two (2) transformers per phase:

Ratio	6300: 5/ 5 A each
Accuracy for Protection	PS / 5P20
Metering	0.2s

##### Excitation System Current Transformers

Four (4) transformers per phase:

Ratio	6300 :5 / 5 A each & 200: 5 / 5 A each
Accuracy for Protection	PS / 5P20 (6300 :5 A) PS / 5P20 (6300 :5 A) PS / 5P20 (200 :5 A) 0.2s (200 :5 A)

##### Current Transformers for Unit Auxiliary Transformers

Four (4) transformers per phase:

Ratio	6300 :5 / 5 A each & 200 : 5 / 5 A each
Accuracy for Protection	PS / 5P20 (6300 :5 A) PS / 5P20 (6300 :5 A) PS / 5P20 (200 :5 A) 0.2s (200 :5 A)

##### Current Transformers (Near Generator Transformer)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

Three (3) transformers per phase:

Ratio	6300 : 5/ 5/ 5 A each
Accuracy for Protection	PS / 5P20 each

#### 6.5.6.2 Description

The transformers shall be window type, the primary being formed by the bus conductor passing through their core.

The insulation shall be dry type.

They shall be mounted with anti-vibration and anti-rotating devices. Moreover, a lifting ring made of nylon linen, installed beside each current transformer, is required for handling purposes.

#### 6.5.7 Potential Transformer and Surge Protection Cubicles (PTSP / LAVT)

Bidder shall supply the following cubicles:

- For each generator: 1 set of 3-single phase cubicles near the generator terminals, each cubicle containing 2 draw-out potential transformers, 1 lightning arrester and 1 capacitor.

##### 6.5.7.1 Electrical Characteristics

##### A. Potential Transformers

The potential transformers shall be epoxy molded draw-out type. They shall be mounted in the compartments of the cubicle and connected to the main isolated phase bus by bus taps. For the first set of 3-single phase potential transformers, connections will be Yn at primary and Yn-Yn- open delta at secondary. For the second set of three single phase potential transformers, connections will be Yn at primary and Yn-Yn-Yn at secondary. In the drawn-out position, the high and low voltage terminals shall be automatically grounded by spring contacts. A damping resistance adjustable from 0 to 50 ohms shall be installed in one open delta winding and it shall withstand continuous 208 volts without saturation

Two PTs on each phase for Protection, Metering, AVR and speed detection as shown

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

in Single Line Diagram.

Rated voltage	11 kV $\pm$ 10%
Rated frequency	50 Hz $\pm$ 5%
Basic impulse level	75 kV peak
Power frequency withstand voltage	35 kV
Ratio	11000 / $\sqrt{3}$ – 110 / $\sqrt{3}$ / 110 / $\sqrt{3}$ / 110 / $\sqrt{3}$
Accuracy	0.2, 0.2 / 3P, 0.2 / 3P
Type	Epoxy
Rated Voltage Factor	1.2 Continuous, 1.9 for 30 Sec.

Current limiting type fuses shall be installed on high voltage side and have the following characteristics:

Rated voltage	11 kV
Rated frequency	50 Hz

The potential transformers shall be fully insulated and able to sustain without saturation nor over current, the over voltages resulting from switching and line to ground faults. The potential transformer shall not saturate below a 2 p.u. applied voltage.

#### B. Lightning Arresters

Lightning arresters shall be “station” class type, zinc oxide, gapless and equipped with an external porcelain envelope. Lightning arresters shall be installed in non-draw-out compartments under the compartments of potential transformers inside the cubicles. MCOV shall be selected so that arrester shall not operate during a ground fault condition.

Type	ZnO gapless
Maximum continuous operation voltage (MCOV)	12 kV
Rated frequency	50 Hz

Above details are preliminary and subjected to minor changes during detail engineering.

#### C. Capacitor

Single phase capacitor rated continuous voltage of 18 kV. Value to be selected by

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

Bidder.

#### D. Cubicles

The cubicles shall be self-supporting and contain compartments to house the above mentioned equipment. Clearances between live items and the mass shall provide adequate insulation. The electrical characteristics shall correspond to those of the bus taps which supply them.

The cubicles shall have rigid frames of rolled steel sections supported on a steel channel base. Welded parts shall be carefully cleaned and phosphated after assembly. Panels shall be removable single piece steel plates, with a minimum thickness of 11 gauge, bolted to the frame. No part shall be subject to excessive heat rise and natural ventilation shall be supplied.

Precautions shall be taken to prevent galvanic action between the aluminum housing and the cubicle steel panels.

Doors and drawers shall be equipped with key operated locks.

For each potential transformer drawer, an inspection window with security glass shall be supplied for verification of fuse conditions.

Grounding of equipment within the cubicles shall be effected by a common copper grounding bar with a minimum transversal section of 50 mm x 6 mm connecting all 3 cubicles.

A connector shall be supplied at each end of the common grounding bar.

#### 6.5.8 Neutral Grounding Cubicle

The three conductors of the generator neutral side shall be brought out to a cubicle that shall include the following:

- One set of three phase aluminium Bus bars 6300A, 63kA RMS short-time overcurrent withstand, mounted on 11 kV insulators which shall incorporate Four (4) sets of current transformers per phase with a ratio of 6300:5 A;
- Four sets of CT, each shall have an accuracy class PS / 5P20 for protection. Phases shall be separated by insulating barriers (CT Ratio : 6300 / 5 / 5 / 5 / 5 A);
- The three Bus bars described above shall be shorted and brought out to an adjacent metallic cubicle by an insulated cable. The metallic cubicle shall house the following



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
--	--	---

equipment for each generator and two (2) Neutral CTs (Ratio : 25 / 5 / 5 A)\*:

\* To be decided during detailed engineering.

A single pole grounding disconnect switch, indoor type, with manual operating handle and padlocking device;

- A single-phase dry type epoxy insulated grounding transformer, conforming to CSA standard C9-M;
- An edge-wound steel grounding resistor;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

#### 6.5.8.1 Cubicles shall be designed according to present specification. Electrical Characteristics

##### Grounding Disconnect Switch

Type	Single pole
Rated current	6300 A
Rated voltage	11 kV $\pm$ 10%
Frequency	50 Hz $\pm$ 5%
Basic impulse level	75 kV peak
Power frequency withstand voltage	35 kV

##### Grounding Transformer

Type	Dry type encapsulated
Rating	to be established by Bidder
Transformation ratio	11000-220 /110 V (Secondary Voltage is selectable by Bidder)
Basic impulse level	75 kV peak
Power frequency withstand voltage	35 kV
Insulation class	H
Frequency	50 Hz $\pm$ 5%

##### Grounding Resistor

Resistance	by Bidder
Rated current (10 minute)	by Bidder
Voltage	220 V or higher to suit grounding transformer secondary voltage selected.

#### 6.5.8.2 Construction

The equipment shall be housed in a floor mounted cubicle steel frame and bolted panels, as shown on the drawings. The cubicle is arranged and built to provide adequate natural ventilation of the equipment.

Bidder shall supply and install the material for connection, between the switch and the transformer primary, and between the transformer secondary and the resistor. Connection at transformer primary shall be done by means of a copper bus with insulating supports, whereas a cable shall do the connection between the transformer secondary and the resistance. The insulation level shall be according to the maximum voltage arising in the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

circuit. All wiring inside neutral cubicle shall be done by Bidder at the shop.

One terminal of the transformer primary winding, one point of the secondary, the transformer frame, the resistor housing, one point of the manual operating handle, and all non-current carrying metal parts shall be connected to 50 mm x 6 mm copper grounding bar.

This bar shall have on each end a copper connector connection to the powerhouse grounding system.

Terminal blocks shall be supplied for connection of the transformer secondary to the ground fault detection relay. The terminal blocks shall be housed in a junction box inside the cubicle.

#### 6.5.9 Connections of Isolated Phase Bus Duct and Apparatus

##### 6.5.9.1 Flexible Connectors

Flexible braid connector pads shall be silver-plated copper.

##### 6.5.9.2 Flexible braid connectors shall be adapted for connecting to a connection pad.

Bidder shall supply flexible braid copper connectors complete with bolts, nuts and flat washers and lock washers required for connection of the isolated phase bus duct to the generator terminals, generator transformer terminals, LAVT cubicle terminals, excitation transformer cubicles etc.

All incoming terminals of apparatus included in the above shall be provided with a silver plated with a silver plated pad if the terminal is made of copper or aluminum.

##### 6.5.9.3 Connection to Generators

The isolated phase bus duct will be connected to generator terminals by flexible connectors as described above.

##### 6.5.9.4 Connection to Generator Transformers

To permit the connection of the isolated phase bus duct to the generator transformer, a transformer connection box shall be supplied for each 11 kV bushing. The connection box shall provide an adaptor to connect the transformer bushing and a set of flexible braids in sufficient number to obtain the specified current rating. The connection box shall also electrically insulate the bus enclosure from the transformer flange. The isolation scheme shall accept a displacement of at least 3 cm on all axes. Bidder shall carry out the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

connections to generator transformers according to the position of the 11 kV side bushings and the shape and size of the flanges. For this purpose, Bidder has to coordinate with the transformer contractor for necessary interface dimensions.

In order to avoid any transmission of the bus enclosure current to power transformer flange and other grounded components, an insulation scheme shall be provided by means of a cloth reinforced neoprene isolated sheath. Bidder shall supply bolts, nuts and washers required for connection of the bus housings, as well as the necessary insulating parts. An insulation level equal to the bus voltage shall be provided.

High resistance zinc plated steel bolts shall be used with lock and plain washers where the isolated phase bus connect to equipment. The bolts shall be tightened with a torque wrench. For all connection points, details of terminals, connecting flanges and the applicable tightening torque shall be clearly indicated on the drawings submitted to Engineer for approval.

The Bidder shall take into account the fact that in the transformer area, the space is limited, and consequently, the length of the isolated bus sections shall be designed to be easily installed into recessed space.

#### 6.5.9.5 Rectifier / Excitation Transformer, Auxiliary Transformer Connection

The connections shall be through tap off busduct.

#### 6.5.9.6 Connection to LAVT Cubicle

Isolated phase bus taps shall connect by the top to the LAVT cubicles using flexible braids in sufficient quantity to withstand the maximum 1 second short circuit criteria.

Connection to Cubicles shall be from the top.

#### 6.5.10 Control Panels and Junction Boxes

##### 6.5.10.1 Control Panels

Control panels shall have a door with a lock and shall be maneuverable from the floor. No holes shall be cut in the panels for incoming or outgoing conduits. The panels shall include removable sealed plates on the top and bottom.

##### 6.5.10.2 Junction and Marshalling Boxes

Doors for these boxes shall have neoprene gaskets. Unless otherwise specified, the boxes shall be equipped with a copper grounding strip installed at the bottom, having a length of

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

90% of the length of the box. This bar shall be 6 mm x 25 mm, tapped M5 every 25 mm. A connector for copper cable shall be supplied for connection to the main grounding system. Grounding through a metal piece (frame or other) will not be accepted. All connections shall be properly identified.

A Marshalling box shall be provided to orderly regroup the disconnect switch control and monitoring functions into a single interface point.

#### 6.5.10.3 Terminals and Wiring

For the wiring inside control cubicles and junction boxes, Bidder shall use minimum 2.5 sq. mm copper electrical wire insulated with fluoropolymer, or equivalent, 1100 V, 150 °C.

Each wire shall be clearly identified at both ends with cable markers.

No splice joints shall be permitted and connections shall be made on terminal blocks. Particular care shall be taken not to damage conductors from which insulation has been removed.

#### 6.5.11 Painting and Finishing

##### 6.5.11.1 Bus Conductors

The conductors of the isolated phase bus shall have one coat of black paint. The type of paint and the method of application shall be submitted to the Engineer for approval. Bus current rating shall be based on bare bus dissipation. Bidder shall have to demonstrate this feature to the Employer's satisfaction.

##### 6.5.11.2 Bus Housings

The type of paint and the method of application shall be submitted to the Engineer for approval.

The exterior surface of the housings inside the powerhouse shall be light green. Outside of the powerhouse, the exterior surface of the housings shall be dark green. The gloss of the paint shall be between 25% and 35% and measured under a reflecting angle of 60 degrees.

All welds shall present an esthetically acceptable look.

##### 6.5.11.3 Cubicles

The type of paint and the method of application shall be submitted to the Engineer for

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
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approval.

#### 6.5.12 Quality Control, Inspection and Tests

The Bidder shall be responsible for all quality control including inspection, examination and testing of the equipment.

All the tests shall meet the requirements stated herein, EMPLOYER requirements and the requirements of relevant IEC standards generally. Detailed MQP's in the specified format shall be submitted by Bidder to EMPLOYER for Approval.

##### 6.5.12.1 Type Tests

Valid type test reports for identical equipment, as acceptable to the ultimate customer shall be furnished. If the same is not available, then type tests shall be carried out free of cost and type test certificates shall be furnished.

Type test charges shall be furnished in the offer. In case type tests are requested to be repeated, charges indicated shall be made applicable for payment purposes.

The type tests shall be as per the relevant IEC standards. The following type tests are envisaged on a representative section of bus assembly. The test set up shall be as per final approved configuration:

- Impulse voltage withstand test;
- One minute PF withstand test;
- Heat run test;
- Short circuit test;
- Water tightness test;
- Panels, cubicles and marshalling boxes shall be type tested for degree of protection specified;
- Test for radio interference according to the procedure of measurement set forth in NEMA publication No. 107 "Method of measurement of Radio influence voltage (RIV) of high voltage apparatus" unless such measurement has been made on metal clad bus including at least one flexible or expansion connector and one "L" of substantial design;
- The maximum radio influence voltage shall not exceed 100 micro volts at 1000kHz;
- Air leakage rate test on typical section of the busduct including an inspection opening, drain plug and CT terminal box along with wiring to establish guaranteed leakage rate;
- Partial discharge test on bushings / insulators / transformers etc. to ensure insulation



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

free from voids and defects.

Apart from above, the bidder to provide:

- Calculations for design of Support structures;
- Temperature rise calculations for sizing of busducts;
- Type tests certificates of all equipment and materials supplied by bidder such as grounding transformer, resistors, insulators etc as per respective standards;

#### 6.5.12.2 Factory Tests

The bus duct shall be assembled and checked at the factory for correctness of alignment between various pieces.

Bus duct shall be subjected to the following routine tests:

- Visual inspection and verification of dimensions;
- Dry power frequency voltage withstand test for 1-min;
- Insulation resistance measurement;
- Milli volt drop test on samples;
- Routine tests on all equipment and cubicles as per relevant standards;
- Dye penetration examination of all shop welded joints and radiographic examination on 2% butt weld joints including joints on flexible and plates / busbars / enclosures.

Any other routine test not mentioned above but included in the relevant standards will also have to be performed.

#### 6.5.12.3 Site Commissioning Tests

The following tests shall be carried out at site as commissioning tests:

- 2% radiography and 100% DP test on all site welded joints of busbars and enclosures;
- Milli-volt drop test on all joints;
- Ratio and polarity tests on current and voltage transformers;
- Insulation measurements on equipment and wiring;
- One minute high potential power frequency withstand test at full test voltage.
- Air tightness of a complete assembly of Busduct shall be checked at site as per

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
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provisions of IS: 8084

#### 6.5.13 Drawings, Data, Manuals and Guaranteed Particulars

##### Documentation Requirements

##### **a. Language**

All documents and drawings shall be written in English language.

##### **b. Units**

The international metric system (SI) shall be used for all physical and electrical units.

##### **c. Presentation of documents**

The standard sizes of documents will be A0, A1, A2, A3 and A4 according to international standard ISO 5457.

All documents shall be made in accordance with Employer's general numbering and codification standards.

All documents shall individually incorporate the contractual title blocks, to be provided by Employer along with the necessary titles and numbers to be added in the title blocks.

All documents must be executed under Autocad2004 / 2006, MS Word or MS Excel formats.

##### **d. Approval of documents**

All the Bidder's drawings and documents shall be initially submitted to Employer for initial approval through hardcopy and soft file. Such documents shall be initially approved or commented by Employer within 15 days after their receipt. The Bidder shall incorporate such possible comments and resubmit the revised documents within 15 days after the receipt of these comments.

The starting of manufacturing and procurement activities prior to Employer approval shall be at the Bidder's risks.

Employer shall not unnecessarily delay the approval of the Bidder's documents, however the Bidder shall ensure that the issuance and approval of all drawings do not jeopardise the delivery and inspection dates of the equipment described in this

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

specification.

The approval of his documents by Employer shall in no way relieve the Bidder from his responsibilities.

**e. As-built drawings**

The Bidder shall be responsible for the issuance of the As-built drawings, to be issued after the end of the commissioning of the equipment described in this specification.

**f. Drawings, data and guaranteed particulars to be furnished with the Bid.**

The following drawings and test reports for each item are to be supplied as part of the contract along with the Bid Document:

- Layout drawings (overall busduct routing layout with relevant sections);
- Filled data sheet (Technical particulars);
- General arrangement drawing of NGT, LAVT, etc.;
- Technical Specification;
- Descriptive brochures for all auxiliary equipment;
- Temperature rise calculation for conductor and enclosure;
- A complete Bill of Material for the devices, components, accessories and parts of the busduct. The Bill of Material can be integrated to the drawings for convenience;
- Type tests and special test reports conducted on similar rating of busduct;
- Quality Assurance Program.

The Bidder shall submit the dimension and clearance drawings in a floppy or CD-ROM also.

Any Bid lacking complete information in this respect is likely to be rejected.

**g. Drawings, data manuals, etc., and documentation to be furnished by the Bidder after award of contract:**

After award of contract, the Bidder shall supply five (5) copies of the following drawings, for approval as per agreed time schedule and shall subsequently provide ten (10) complete sets of final drawings, one of which shall be auto-positive suitable for reproduction:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II  Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment
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- Technical particulars for Isolated phase bus duct & associated accessories;
- Civil assignment drawing of Isolated phase busduct;
- Layout drawing of Isolated phase busduct;
- Details of Cast resin ring type busduct CT & wiring diagram;
- GA drawing for Star formation cubicle / Neutral side adopter box;
- Details of Adopter box at Generator phase side;
- Details of copper flexible terminations;
- General arrangement drawing for Neutral Grounding Cubicle;
- Cross section details of Main isolated phase busduct;
- Cross section details Tap off isolated phase busduct;
- Details of Seal off Bushing;
- Details of Rubber Bellow assembly for Generator phase / Generator Neutral / Generator transformer;
- General Arrangement drawing for LAVT cubicle;
- Details of Wall Frame assembly;
- Typical support arrangement details;
- Enclosure end Shorting arrangement;
- CT Fixing details for Isolated phase busduct;
- Details of Disconnecting Links;
- Design calculations for sizing of busduct including S.C. withstand capability, Temp rise, losses and voltage drop;
- Erection, Testing, Commissioning Manual for busduct;
- Operation and maintenance manual for Isolated Phase busduct;
- Earthing layout drawing for Busduct;
- Erection key diagram;
- Spare parts list;
- Packing, loading, Transportation & Unloading Manual;
- Details of Silica Gel Breather assembly;
- Bus duct plan layout-including bends, rubber bellows, expansion joints indicating the complete Bill of material;
- List of CT's & VT's indicating the location, quantity, acc. Class etc.

Operation, maintenance and erection manuals (10 copies) shall be supplied by the manufacturer one month prior to the shipment of the Busduct. The manuals shall contain all the drawings and information required for erection, operation and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

maintenance of the busduct.

Descriptive literature and data on busduct, CT's, NGT, LAVT, other accessories, etc., shall also be supplied by the manufacturer along with the instruction manuals.

#### 6.5.14 Packing and Transport

The packing may be in accordance with the Bidder's standard practice but he shall give full particulars of packing for the approval of the Employer keeping in view the transport limitations. Special arrangement shall be made to facilitate handling and to protect the projecting connections from damage in transit.

All parts shall be adequately marked to facilitate field erection. Boxes and crates shall be marked with the contract number and shall have a packing list enclosed, showing the parts contained therein.

It is proposed that the Bidder make route survey / Dummy trials prior to dispatch of the Goods.

#### 6.5.15 Spare Parts and Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 6: Isolated Phase Busduct & Associated Equipment

#### 6.5.16.1 Mandatory Spares

Bidder shall supply the price of Mandatory spare parts listed hereafter:

- Three current transformers PS / 5P20 class accuracy;
- Three current transformers for metering;
- Three potential transformers;
- Three lightning arresters;
- Ten insulators of each type used;
- Three seal-off bushings.

If any additional spare-parts are required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.

#### 6.5.17 Tests to measure losses in bus conductor and enclosure of main and tap-off runs:

This test at factory shall be carried out by the manufacturer to prove that actual measured losses during testing are within the calculated values quoted in the bid. The losses shall be calculated by measuring the temperature of the conductor and enclosure as per the guidelines specified in ANSI/IEEE. The losses shall be ascertained taking into account the recommendations of ANSI clause 37.23 of IEEE Standard 298-1987. The loss calculations shall be submitted in line with ANSI/IEEE standards.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

## Volume-II

### Section II Sub-Section 7

#### Unit Control, SCADA, Automation & Communication

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

## **TABLE OF CONTENTS**

<b>7</b>	<b>UNIT CONTROL, SCADA, AUTOMATION &amp; COMMUNICATION .....</b>	<b>3</b>
7.1	SCOPE.....	3
7.2	STANDARDS AND CODES .....	5
7.3	UNIT CONTROL, SCADA AND AUTOMATION .....	8
7.3.1	Components Details .....	11
7.3.2	Copyrights and Software Licenses:.....	17
7.3.3	Programming & Application Software:.....	18
7.3.4	Abbreviations.....	19
7.3.5	Design Requirements .....	21
7.3.6	Product Description .....	26
7.3.7	Shop Assembly and Tests .....	86
7.3.8	Installation and Field Test.....	88
7.4	OPTIC FIBRE COMMUNICATION SYSTEM.....	94
7.4.1	Communication System Description .....	95
7.4.2	Site Acceptance Testing .....	95
7.5	DRAWINGS & DOCUMENTS SUBMITTALS .....	95
7.6	OPERATION AND MAINTENANCE MANUALS .....	101
7.6.1	Operation and Maintenance Manuals .....	101
7.6.2	Operation and Maintenance Personnel Training .....	102
7.7	SPARE PARTS, CONSUMABLES & SPECIAL EQUIPMENT.....	102
7.7.1	List of “Mandatory Spare” parts.....	104
7.7.2	Special tools and maintenance equipment.....	107

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

## 7 UNIT CONTROL, SCADA, AUTOMATION & COMMUNICATION

### 7.1 Scope

The scope covers the detailed requirements for the design, manufacture, factory testing, transport, delivery, installation, site testing and commissioning of the Unit Control, SCADA and Automation hot redundant systems including all associated equipment and cabling including integration of the electrical and mechanical equipment for their monitoring and control from the main SCADA in the powerhouse control room. Included in the scope is the integration of monitoring and controls of the equipment at remote sites (viz. the Intake area, Valve house, Heo PH etc.) from the Powerhouse control room SCADA. Plant SCADA shall also include integration with GIS SCADA & automation. The supply shall include all software, parts, devices, accessories and special tools, which though not individually specified, but are necessary to construct, operate and maintain the complete Unit Control, SCADA, automation and communication systems as described hereafter. All hardware and Software shall be 100% compliant to OPC Specifications and shall be OPC Certified.

The Contractor shall design and commission a complete communication system such as described below. All devices, parts, accessories and special tools necessary for the equipment and contract complete system shall be supplied by the Contractor, even if those are not individually listed or specified.

- An Optic Fiber communication system between the Control Room and the remote locations. The Fiber Optic cable shall be supplied and laid under this package and shall be terminated, tested and commissioned by the Contractor;
- ADSS / OFC (type selection during detailed engineering) along with all accessories required for installation (overhead / underground).
- The Fiber Optic Server Station (OWS4) located in the Control Room;
- At each site, the Optic Fiber Cables will be connected to Fiber Patch Panels;
- At the Powerhouse, the Optic Fiber communications integration to the powerhouse LAN-1 and LAN-2 networks.

The Contractor shall ensure that the data flowing between the different locations, and issued from two different communication systems, are correctly transferred to the final points without collision.

All equipment/ components shall be suitable for operation at an altitude up to 1200 m

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

above MSL.

Further, The Tato-I HEP and The Heo HEP (The Tato-I HEP is located at the downstream of the Heo HEP) will operate in Tandem operation. The contractor must meet the following conditions for the tandem operation of hydro power plants: -

- Fundamental principle for tandem operation is that the water of upstream power house is used to generate power at downstream power house.
- The design of both projects shall be such that the design discharge for both plants is nearly same.
- The design as well as working head to be nearly in same ratio as that of their unit as well as plant rating.
- The number of units in both plants shall be same.
- Each unit of upstream plant corresponds to one unit of downstream plant.
- During initial start up the time required to fill and reach from Upstream (U/S) plant to downstream (D/S) plant shall be assessed.
- Dual and Positive communication link to be available between both plants. This is required for VOICE, DATA and CONTROL COMMAND to and fro transfer (both ways).
- Up-stream Power house i.e Heo shall be a master station and Down-stream Powerhouse i.e. Tato-I shall be slave station.
- There is escape between water conductor connecting U/S and D/S stations.
- This escape is sufficient for escape of discharge from all units of U/S power plant.
- Governors of both shall operate in tandem and programmed in such a manner that there is proportionate increase/decrease in output of D/S plant as soon as the U/S plant output increases/decreases.
- The D/S plant shall be a follower station with U/S plant being a lead station. Hence the D/S plant to be remote controlled from U/S plant.
- Dual Fibre link to be established (2 separate FO cable). OPGW and OPGW terminal equipment shall not be within present scope of work. Required interfacing with OPGW terminal equipment shall be within the contract scope.

Based on above, the Heo Control room will be designed as master control room for both Heo & Tato-I and will exercise overall/Master control on the Tato-I units. Any tripping/

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

non-operation of a unit at Heo plant will ensure that the corresponding unit at Tato-I also doesn't generate. For communication of Voice, Data & Control command between the two stations, two nos. Optical fibre cable (OFC) between the two stations is not included in the scope of this package. Separate fibres of both the FO cables will also be used to provide redundancy for the communication link. The DCS/SCADA system for the two stations will be designed satisfying the above requirements for both remote and local modes. OFC link between Powerhouse and Barrage site and Valve house site shall be in the scope of the bidder. Site survey is under bidder's scope and required cable length shall be assessed. The distance between the barrage and power house is approximately 5KM.

All equipment and components required to complete the above-mentioned work, including integration with the Heo HEP, shall be supplied, installed, tested, commissioned by the contractor.

## 7.2 Standards and Codes

The equipment covered under these specifications shall conform to the latest edition of the following standards:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

IEC 61850-3	Communication networks and systems in substations - Part 3: General requirements
IEC 61850-4	Communication networks and systems in substations - Part 4: System and project management
IEC 61850-5	Communication networks and systems in substations - Part 5: Communication requirements for functions and device models
IEC 61850-6	Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs
IEC 61850-7-410	Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control
IEC 61850-7-1	Communication networks and systems in substations - Part 7-1: Basic communication structure for substation and feeder equipment
IEC 61850-7-2	Communication networks and systems for power utility automation - Part 7-2: Basic information and communication structure - Abstract communication service interface (ACSI)
IEC 61850-7-3	Communication networks and systems for power utility automation - Part 7-3: Basic communication structure - Common data classes
IEC 61850-7-4	Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes
IEC 61850-10	Communication networks and systems in substations - Part 10: Conformance testing
IEC 61131-1	Programmable controllers - Part 1: General information
IEC 61131-2	Programmable controllers - Part 2: Equipment requirements and tests
IEC 61131-3	Programmable controllers - Part 3: Programming languages
IEC 61131-5	Programmable controllers - Part 5: Communications
IEC 61131-7	Programmable controllers - Part 7: Fuzzy control programming
IEC 60870-1 series	Telecontrol equipment and systems. Part 1: General considerations. Section One: General principles



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

IEC 60870-2 series	Telecontrol equipment and systems - Part 2: Operating conditions
IEC 60870-3	Telecontrol equipment and systems. Part 3: Interfaces (electrical characteristics)
IEC 60870-4	Telecontrol equipment and systems. Part 4: Performance requirements
IEC 60870-5 series	Telecontrol equipment and systems. Part 5: Transmission protocols
IEC 60870-6 series	Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations
IEC 60338	Telemetry for consumption and demand
IEC 60381-1	Analogue signals for process control systems. Part 1: Direct current signals
IEC 60381-2	Analogue signals for process control systems. Part 2: Direct voltage signals
IEC 61000 series	Electromagnetic compatibility (EMC)
IEC 60255-5	Electrical Relays - Part 5: Insulation coordination for measuring relays and protection equipment - Requirements and tests
IEC 60255-22-1	Measuring relays and protection equipment - Part 22-1: Electrical disturbance tests - 1 MHz burst immunity tests
IEEE 488.1	Standard Digital Interface for Programmable Instrumentation
IEEE 488.2	Standard Codes, Formats, Protocols, and Common Commands for Use with IEEE Std. 488.1-1987, IEEE Standard Digital Interface for Programmable Instrumentation
IEEE 762	Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity
IEEE 1010	Guide for Control of Hydroelectric Power Plants
IEEE 1046	Application Guide for Distributed Digital Control and Monitoring for Power Plants
IEEE 1050	Guide for Instrumentation and Control Grounding in Generating Stations
IEEE 1059	Recommended Practice for Monitoring Electric Power Quality
IEEE 1174	Standard Serial Interface for Programmable Instrumentation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

IEEE 1222	IEEE standard for All-Dielectric self-supporting Fibre Optic Cable
IEEE 1249	Guide for Computer-Based Control for Hydroelectric Power Plant Automation
IEEE 1344	Standard for Synchrophasors for Power Systems
IEEE 1346	Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment
IEEE 1451.1	Standard for a Smart Transducer Interface for Sensors and Actuators--Network Capable Application Process (NCAP) Information Model
IEEE 1451.2	Standard for a Smart Transducer Interface for Sensors and Actuators - Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats
IEEE1588	Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
IEEE 1590	Recommended Practice for the Electrical Protection of Optical Fiber Communication Facilities Serving, or Connected to, Electrical Supply Locations
ANSI C57.13.3	Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases
OPC UA- Parts 1 to 11	Unified Architecture Products Specifications
OPC TEST LAB Parts 1 to 11	OPC Lab Certified Products
BS EN 55011	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific, and medical (ISM) radio-frequency equipment

### 7.3 Unit Control, SCADA and Automation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- a. The Unit Control, SCADA and DCS Automation systems shall be referred in this specification as the Plant Control System (PCS). The PCS shall conform to the General SCADA Architecture drawing (attached with tender drawings);
- b. This section specifies the general requirements for the design, manufacture, integration and factory testing of the PCS comprised of the Unit Control Boards (UCB), the Common Control Board (CCB), the Intake Control Board (ICB), the PPV Control Board (PPVCB), SCADA Work Stations and the Optic Fibre Network to be supplied under this contract complete with all the appurtenances, spare parts and shop drawings;
- c. The Contractor shall include all the software, data bases, computers, screens, interfaces and hardware necessary for the control and monitoring of the entire plant and facilities from any of the Human Machine Interfaces (HMI), Operator Work Stations or Engineering Work Stations as specified;
- d. The Contractor shall integrate the equipment furnished under this Contract;
- e. All control and monitoring signals for the equipment and systems provided under this contract shall be wired to Input & Output Modules and / or Programmable Logic Controllers (PLC) identical or compatible to the redundant master PLC controllers supplied within each Control Board. Interposing control relays shall be supplied as required to interface with external control systems. For Electrical Protection interfaces, Heavy Duty high speed lockout, tripping and control relays shall be provided. The preferred interfaces, with the master PLC of systems supplied by others shall be done via a fibre optic links through the SCADA Communication Network. The Contractor shall be responsible for defining the minimum technical specifications and interfacing requirements of the systems, and for the creation, integration and testing of the data base, HMI screens, reports, alarms, diagnostics and other features required to ensure the same overall functionality of the Master PLC. The Contractor shall review and ensure full compatibility of hardware and communication interfaces of systems and devices being supplied with the SCADA and LAN network. Any interfacing equipment not specifically included but required during execution for smooth functioning of the SCADA system, shall be deemed to be included in this package;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- f. The interfaces with the SCADA Communication Network shall include:
- The fibre optic communication system for remote sites as described in present specification;
  - The Vibration Monitoring System;
  - The Electrical Protection System;
  - The Generator Transformer monitoring RTU;
  - The Station Aux. Transformer RTU ;
  - The Power Line Carrier System (PLCC);
  - The Energy Monitoring system (EMS);
  - The Voice over IP system (VoIP). The VoIP system shall include a Server Computer and VoIP routers. These routers shall be installed in separate panels (800X800X2300 mm approx). The system shall establish telephone communications throughout the Power Plant and Remote Site and to the Utility Dispatch via the PLCC system;
  - The Closed Circuit TV system (CCTV). The system shall send video pictures from the Remote Sites to the Control Room. The CCTV system will be provided by the Contractor;
  - The monitoring of the Auxiliary Transformers, DG sets, the auxiliary AC system, the auxiliary DC system, the UPS system, the fire alarm system, the intrusion alarm system;
  - The monitoring RTU and / or SCADA of the HVAC system, the Fire Fighting system, the Drainage, Dewatering and Drainage, Dewatering and Domestic Water system and other mechanical systems;
  - The Common Control Board shall be provided with digital and analogue I / O modules to interface with the Auxiliary Electrical systems and Auxiliary Mechanical systems provided by the Contractor shall provide the necessary number of I / O points.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- g. The design and assembly of the Unit Control, SCADA and Automation systems shall follow the following rules:
- The Unit Control, SCADA and Automation systems shall be fully hot redundant. Systems A and B shall be provided throughout;
  - In each Control Board, Master PLC-A and Master PLC-B shall be fully synchronized and shall operate simultaneously without interference;
  - In each Control Board, Master PLC-A shall be interfaced with System-A of other redundant systems including DC and UPS supplies. Master PLC-B in turn shall be interfaced with System-B of other redundant systems including AC, DC and UPS supplies;
  - Master PLC A and B shall be totally isolated from one-another and shall consequently be installed in separate panels;
  - System-A interface relays and System-B interface relays shall be isolated from one another and be located in the rear panel section of the relative Master PLC;
  - The HMI shall be installed in a separate panel along with the Energy Meter. Common I / O modules shall be installed in the HMI panel. Common interface relays shall be installed in the rear panel section;
  - No common I / O modules or interface relays shall be installed in the Master PLC-A and Master PLC-B sections;
  - The Unit Control Boards (UCB) shall include a section that shall house the Automatic synchronizer as well as the manual synchronization controls and meters;
  - The Unit Control Boards shall include the redundant AVR (2 panels) and the redundant Governor Control (2 panels);
  - Unit Control Board panels shall measure 800 mm wide by 800 mm deep by 2300 mm high (approx). Width may be increased to accommodate the interface relays if need be. Nevertheless, the overall length of the UCB shall not exceed 7200 mm including the AVR and Governor Control panels;
  - The Fibre Optic Network will be designed so that Circuit A and B shall be interfaced to both LAN-1 and LAN-2.

#### 7.3.1 Components Details

The main components comprising the Unit Control, SCADA and DCS Automation systems shall include but not limited to the following. The Contractor shall supply all components

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

required to satisfy the requirements for the control and SCADA system of the overall complete project as per the present specifications. All components shall be OPC certified.

a. Unit Control Boards (UCB-1, UCB-2 and UCB-3):

- Panel-1 to include Master PLC-A and, I/O modules and interface relays relative to Systems-A;
- Panel-2 to include Master PLC-B and, I/O modules and interface relays relative to Systems-B;
- Panel-3 to include the Human Machine Interface (HMI), a GPS slave clock, a VoIP telephone, Channel-A and B Ethernet Switches, the Energy Meter and I/O modules and interface relays common to Systems-A and B;
- Panel-4 to include the Automatic Synchronizer, the Synchro-check relay and the controls and meters for manual synchronization;
- Panel-5 to include the System-A Governor Controls and interface relays with the HPU unit;
- Panel-6 to include the System-B Governor Controls and interface relays with the HPU unit;
- Panel-7 to include the System-A Automatic Voltage Regulator (AVR);
- Panel-8 to include the System-B Automatic Voltage Regulator (AVR);
- The Fibre Optic cable and Patch Cords to connect all SCADA Element.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

b. Common Control Board (CCB):

- Panel-1 to include Master PLC-A and, I/O modules and interface relays relative to Systems-A. Number of I/O modules required is to be defined by Contractor as required for the monitoring of the CCB components;
- Panel-2 to include Master PLC-B and, I / O modules and interface relays relative to Systems-B. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the CCB components;
- Panel-3 to include the Human Machine Interface (HMI), a VoIP telephone, Channel-A and B Ethernet Switches, and I / O modules and interface relays common to Systems-A and B;
- Panel-4 to include the additional I / O modules and interface relays common to Systems-A and B. This panel shall be provided with I / O modules for 600 digital I / O and 36 analogical I / O and additional space to double the number of I / O;
- The Fibre Optic cable and Patch Cords to connect all SCADA Element.

c. Generator Floor Patch Panels:

- Channel-A and Channel-B Patch Panels. One pair located on the Generator floor between Unit 1 and the service bay and a second pair located between Units 2 and 3. Patch Panels shall house Converters, Routers, Ethernet Switches, etc. within 2-rack mount type panels of 800 mm by 800 mm by 2300 mm (approx);
- Patch Panels to serve UCB-1, UCB-2, UCB-3, CCB as well as Unit Protection Boards UPB-1, UPB-2 and UPB-3 and Transformers Monitoring and Metering RTU-1, RTU-2, RTU-3, RTU-4 & RTU-5

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

d. Intake Control Board (ICB):

- Panel-1 to include Master PLC-A and I / O modules. Space shall be provided for any interface relays required in the future relative to Systems-A. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the CCB components;
- Panel-2 to include Master PLC-B and I / O modules. Space shall be provided for any interface relays required in the future relative to Systems-B. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the CCB components;
- Panel-3 to include the Human Machine Interface (HMI), a VoIP telephone, and, I / O modules and interface relays common to Systems-A and B. This panel shall be provided with 4 communication ports, I / O modules for 124 digital I / O and 26 analog I / O and additional space to double the number of I / O;
- Channel-A and Channel-B Patch Panels to house Channel-A Ethernet Switches, Channel-B Router, etc. within 2-rack mount type panels of 800 mm by 800 mm by 2300 mm;
- The Fibre Optic cable and Patch Cords to connect all SCADA Element.

e. PPV Control Board (PPVCB):

- Panel-1 to include Master PLC-A and I / O modules. Space shall be provided for any interface relays required in the future relative to Systems-A. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the components;
- Panel-2 to include Master PLC-B and I / O modules. Space shall be provided for any interface relays required in the future relative to Systems-B. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the components;
- Panel-3 to include the Human Machine Interface (HMI), a VoIP telephone, and, I / O modules and interface relays common to Systems-A and B. This panel shall be provided with 2 communication ports, I / O modules for 40 digital I / O and 10 analog I / O and additional space to double the number of I / O;
- Channel-A and Channel-B Patch Panels to house Channel-A Ethernet Switches, Channel-B Router, etc. within 2-rack mount type panels of 800 mm by 800 mm

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

by 2300 mm;

- The Fibre Optic cable and Patch Cords to connect all SCADA Element.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

f. Control Room:

- Three (3) Operator Work Stations c / w Desktop Computers, Keyboard, mouse and three (3) 22 inch LED Screens;
- One Video Matrix Switcher to Control the LVS Screens;
- Four (4) Large Video Screens (LVS) 55 inch LED Screens arranged to form a matrix with narrow bezels c / w hardware for wall mount assembly and the necessary high quality enclosure to hide supports and cables;
- One (1) Engineering Work Stations c / w Desktop Computers, Keyboard, Mouse and one (1) 22 inch LED Screen;
- One (1) Portable Engineering Work Station c / w Laptop Computer complete with separate lockable Docking Station, 22 inch LED Screen, Keyboard and Mouse;
- One (1) Historian Work Station c / w redundant Raid Servers, Keyboard, Mouse and one (1) 22 inch LED screen;
- One (1) multi functional B / W Laser Printer / Copier / Scanner / Fax suitable for A3 and A4 formats;
- One (1) desktop Colour Laser Printer suitable for A3 and A4 formats;
- One (1) desktop Dot Matrix Printer;
- One (1) Router / Server for Printer;
- Channel-A and Channel-B Ethernets Switches as required to serve the Work Stations and Servers within the Control Room including the Work Stations being provided under other Packages and listed below in paragraph of the Scope;
- Channel-A and Channel-B Patch Panels housing Convertors, Routers, Ethernet Switches, etc. within 2-rack mount type panels of 800 mm by 800 mm by 2300 mm;
- The GPS Clock, Antennas and IRIG-B distribution coax cabling;
- Control Room top quality Heavy Duty furniture including desks, tables, stands, cabinetry and chairs. The furniture shall include accommodation for Work Stations and equipment provided herein and by others including: the Operator Work Stations c / w 2-22" screens (OWS1,2,3), the Large Video Screen Work Station (LVSWs), the Historian Work Station (HWS), the SCADA Engineering Work Stations (EWS1,2), the Energy Management Work Station (EMS), the Zoom Processor Vibration Analysis Work Station (ZCS), the closed circuit TV Work Station c / w 2-22" screens (CCTV), the three desktop printers c / w routers, Voice over IP (VoIP) Router Cabinet and filing cabinetry in the location shown

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

on the arrangement drawing;

- The Fibre Optic cable and Patch Cords to connect all SCADA Element.

g. Control Room equipment for GIS & Remote sites:

- One (1) Operator Work Stations (OWS4) for Remote Sites Fibre Optic Communication Channels c / w Desktop Computers, Keyboard, mouse and one (1) 22-inch LED screens as required for the Optic Fibre Communication systems;
- One (1) Multimode / Monomode converter to interface with the Optic Fibre Communication systems;
- Channel-A and Channel-B Ethernets Switches as required to serve the Work Stations and Servers within the Control Room including the Work Stations;
- Channel-A and Channel-B Patch Panels housing Convertors, Routers, Ethernet Switches, etc. c / w 2-rack mount panels of 800 mm by 800 mm by 2300 mm. The Patch Panels shall serve also the Protection Operator Work station (OWS5), the Protection Engineering Work Station (EWS3), the five panel GIS Protection Board, the Monitoring and Metering RTU, etc;
- Control Room top quality Heavy Duty furniture including desks, tables, stands, cabinetry and chairs. The furniture shall include accommodation for Work Stations and equipment provided herein including: the Remote Site Optic Fiber Work Station (OWS4), the Protection Operator Work station c / w 2 (Two) -22" screens (OWS5), the Protection Engineering Work Station (EWS3), the Dispatch Work Station (DWS), Voice over IP Server Work Station (VoIP WS), Router Cabinet and filing cabinetry in the location shown on the arrangement drawing;
- The Fibre Optic cable and Patch Cords to connect all SCADA Element.

h. The Optic Fibre cable Network for the complete system including all provisions for interfacing equipment and systems provided under this packages. The Optic Fibre cables shall be installed in rigid steel conduit throughout. Optic Fibre extension and Patch Cords to interface Control Boards, Protection Boards, Work Stations, RTU, etc. shall be provided and laid in dedicated cable trays or conduits.

### 7.3.2 Copyrights and Software Licenses:

- a. The Employer shall own the copyrights for all documentation and software developed for the project;
- b. All software licenses and vendor support agreements shall be in the name of the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Employer;

- c. The programming software, instruction manuals, application software and data files shall become the property of the Employer at completion of the project;
- d. All program documentation shall be reviewed and approved by the Employer prior to implementation. Refer to submittal requirements specified herein;
- e. The Contractor shall submit a full copy of the application software updates once a month until the warranty period expires to the Employer and / or its designee to be kept in case of force major events or bankruptcy of the Contractor.

### 7.3.3 Programming & Application Software:

- a. The senior system programmers shall be experienced in the type of programs and application Softwares provided and have a minimum of 5 years experience in programming similar type systems. The screen graphics shall match as close as possible with the actual device(s) arrangement being controlled;
- b. Review meetings shall be setup between the Contractor, the Employer, and the Engineer In-charge to coordinate the autosequencer program, the control, monitoring and interface features,, the various HMI screen control, monitoring, and arrangement details. The meetings shall be held at the Engineer In-charge's office. As a minimum, the following meetings shall take place:
  - i. Pre-design meeting to define the initial scope details for the various screen content



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

& arrangement;

- ii. Review meeting at 50% design;
- iii. Review meeting at 75% design;
- iv. Review meeting at 100% design.

#### 7.3.4 Abbreviations

The following are common abbreviations used in this Section:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

1. PCS: Plant Control System;
2. DCS: Distributed Control System;
3. MMI: Man Machine Interface (includes HMI and OWS);
4. HMI: Human Machine Interface (in Control Boards);
5. OWS: Operator Work Station (in Control Rooms);
6. EWS: Engineer Work Station;
7. VWS: VoIP Work Station;
8. DWS: Dispatch Work Station;
9. HWS: Historian Work Station;
10. EMS: Energy Management Work Station;
11. CCTV: Closed Circuit TV;
12. ZCS: Zoom Processor Analysis Work Station;
13. LVS: Large Video Screen;
14. LSB: Less Significant Bit;
15. MFM: Multifunction Meter. Also referred as Energy Meters or Power Measurement Device ;
16. NTP:
  - (1) Network Time Protocol (Time Synchronization);
  - (2) Notice to Proceed (Submittals).
17. OPC:
  - (1) Open Protocol Compliance (open connectivity, open standards);
  - (2) Object-Linking and Embedding (OLE) for Process Control.
18. OPGW: Optical Ground Wire;
19. PC: Personal Computer (Desktop Computer);
20. PLC: Programmable Logic Controller;
21. RTU: Remote Terminal Unit;
22. PMD: Power Measurement Device. Also referred as Multifunction Meter;
23. SCADA: Supervisory Control and Data Acquisition;
24. SNTP: Simple Network Time Protocol;
25. UTC: Coordinated Universal Time;
26. VESA: Video Electronics Standards Association;
27. UCB: Unit Control Board;
28. CCB: Common Control Board;
29. PPVCB: Penstock Protection Valve Control Board;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

30. ICB: Intake Control Board;
31. UPB: Unit Protection Board;
32. GPB: GIS Protection Board;
33. PLCC: Power Line Carrier Communication;
34. VoIP: Voice over IP;
35. ODBC: Open Data Base Connectivity;
36. IRIG: Inter-Range Instrumentation Group;
37. LAN: Local Area Network;
38. IGMP: Internet Group Management Protocol;
39. RSTP: Rapid Spanning Tree Protocol;
40. HDM: Historical Data Management;
41. VLAN: Virtual Local Area Network.

#### 7.3.5 Design Requirements

- a. The Plant Control System (PCS) shall monitor and control independently and redundantly each of the three generating units of the Hydro Electric Plant and associated facilities. The PCS shall include all necessary hardware and software for measurement indication, recording and automatic & manual control of the plant equipment and auxiliary systems;
- b. The Man Machine Interface (MMI) refers to the Control Room Operators Work Stations (OWS) and to the Control Board Human Machine Interfaces (HMI). All MMI shall operate independently and have full Unit Control and Monitoring capability. The Control Board HMI's shall have priority over the Control Room OWS's. A local-remote switch shall be provided at the local HMI's;
- c. The PCS shall provide local and centralized control and monitoring of the power plant & associated facilities from the MMI located in the plant control room. The PCS shall provide capabilities for full remote control of the generating units, kW and MVAR set point control, 220kV Gas Insulated switchgear operation, the Intake area, the Valve House;
- d. The PCS shall be configured to provide the following control functions:
  1. Local Control: In this mode of operation, the equipment and systems are locally and manually operated at each device. This control mode does not have automatic sequences; the operators shall follow the manual operation procedure to place the unit in the desired mode;
  2. UCB Control: In this position the Unit can operated in manual and automatic with

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

all start permissives and interlocks functional. The UCB Control position shall override the Central Control position and shall remain fully functional if the Central Control crashes;

3. Central Control: Central Control from the Control Room is the normal position. This mode offers the same operation facilities as UCB mode;
4. When in the UCB Control or Central Control positions, the following modes shall be available:
  - Manual / Discrete Operation: This mode provides individual control over each individual system and / or devices utilizing the MMI screens. The operator shall follow manual operation procedure to place the unit or auxiliaries in the desired mode. Important safety interlocks and permissive shall be active in this mode with option of overriding them from the HMI screens;
  - Automatic Step-By-Step Sequence: In this mode the unit starting and stopping sequences are executed step by step. All prerequisites and conditions shall be displayed on the screen and when all of them are met, the operator can initiate the next step;
  - Automatic Continuous Sequence: In this mode, the units start and stop sequences are initiated by the operator, but no additional operator intervention shall be required. The operator shall be able to monitor all conditions and actions on the operator's screens.
- e. The PCS shall be PLC and Personal Computer PC based, completely integrated industry standard state-of-the-art system. The system shall have an "open architecture" which shall permit reconfiguration, expansion, interface with third party equipment and future upgrades;
- f. The PCS shall include as a minimum the following subsystems (per Unit):
  1. One Unit Control Board (UCB), including redundant PLC based Controllers, HMI interface local input-output modules and remote input-output modules, GPS slave clock and power supplies as shown on the PCS block diagram;
  2. One Unit Control Station including the Operator Work Station, the server, a dedicated large-scale video display screen as shown on the PCS block diagram;
  3. The common large video display, video matrix and a forth large video display screen. This forth screen is for displaying the GIS single line and control and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

monitoring functions;

4. The two total Engineer Work Stations including one portable common for all units;
5. One Common Global Positioning System (GPS) based Time Systems to provide a time and frequency reference signal;
6. The Intake Control Board (ICB) and Penstock Protection Valve Control Board (PPVCB) each including redundant PLC based Controllers, HMI interface local input-output modules and remote input-output modules and power supplies as shown on the PCS block diagram. These boards will provide the instrumentation readings, start permissive signals, control and monitoring signal to be interfaced with the autosequencers.
7. One Historian Work Station (HWS) including server to store all time stamped incidents of the SCADA system and of other control and monitoring systems interfaced with the SCADA network;
8. Three printers are networked and serve all work stations;
9. Fault-tolerant Industrial Grade Ethernet LANs and industry standard instrumentation or field bus;
10. All other hardware and software necessary to fulfill the requirements of these Technical Specifications and to provide for a fully functional PCS.

g. Design and Performance Criteria;

1. Availability:

- The PCS shall be designed to minimize the consequences of failures by providing sufficient failure detection, and recovery procedures, such that no single device failure shall result in the loss or degradation of any other station in the system;
- The PCS shall be designed to minimize the duration of failures by the ability to diagnose and resolve problems quickly and to replace any failed part easily;
- The Average System Availability for two consecutive 500-hour periods shall be 99.98% or better.

2. Maintainability

The hardware and software elements of the PCS shall be easy to maintain by Employer using the maintenance facilities, hardware and software tools, and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

recommended spare parts provided by the Contractor.

### 3. Expandability:

- The PCS shall be capable of being expanded by adding more stations, controllers, functions, input-output modules, or intelligent devices such as metering modules, etc. The expansion of the data base and components shall not degrade the performance of the specified system;
- For ease and flexibility in expanding the PCS, the Contractor shall conform to the industry standard open architecture concept as described herein;
- Space is to be provided in all boards for expansion of I / O modules by 50% minimum or as indicated in the scope.

### 4. Quality and Technology:

- The hardware and software products shall be of high quality in design, fabrication, and performance;
- The standard hardware equipment (such as PLC, HMI, computers, screens, printers, etc) and devices of the PCS shall be brand-new and shall be the latest design technology. In order to meet this requirement, the Contractor shall defer the procurement of all standard hardware until one month prior to system integration. The Contractor shall not use project laptops and workstation as development tools during the design and applications engineering phase of project;
- The Contractor shall use and provide the latest versions of all the standard software, e.g., the operating system, utilities, language compilers, graphics software, picture editor, networking software, database management system, which are available at the time of system integration, as long as there is full upward compatibility with the PCS software;
- All software shall be standard. Therefore, Contractor's code modification on standard software packages shall not be permitted;
- At the end of the project, the Contractor shall upgrade all firmware and software to latest editions. Controller flash memories shall also be updated if required.

### h. Testing Requirements:

1. The Contractor shall meet the system functional and performance requirements as given in these Documents. The verification of compliance with the requirements shall be done through a series of tests focused primarily on functionality, response,



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

CPU utilization, and system availability;

2. The testing sequence of the complete system shall consist of the following:

- Pre-Factory Acceptance Test (Pre-FAT);
- Factory Acceptance Test (FAT);
- Site Acceptance Test (SAT);
- Availability Demonstration (AD);
- Network efficiency Test (NET);
- All system testing shall be made with all the control nodes and stations and the ultimate number of points simulated.

i. Software: All software including operating licenses, manuals, documentation, and electronic files used for developing and implementing the automation system Controllers and MMI stations shall be furnished to and become the property of the Employer.

j. Training and Support:

1. Training shall include sessions and courses in the theory, detailed operation, testing, and maintenance and troubleshooting of the automation system and as a minimum shall include the following hardware and software training modules: System Overview, System User, Basic System Maintenance, Advance System Maintenance, Engineering Tools, System Configuration, Historian and Specific Applications;
2. The Contractor shall submit a training plan, instructor's background and qualifications, course outline, course material and subject matter. Training course material shall include the use of site-specific Operations and Maintenance Manuals, to the maximum extent possible.
3. The Contractor shall provide off-site and on-site training for the Employer's staff

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

including, but not limited to:

- On-site training for a minimum of 3 operators;
  - System overview and hardware maintenance and troubleshooting for maintenance personnel;
  - System overview, application software development, modifications, troubleshooting for engineering personnel;
  - On-the-Job-Training (OJT) for engineering and maintenance personnel.
4. Continuous on site support shall be provided for the first four weeks after the first unit is in commercial operation, and for two additional non-sequential one week periods selected by the Employer during the duration of the warranty period.

### 7.3.6 Product Description

#### 7.3.6.1 Controller Stations (CS) Hardware

##### a. General Requirements:

1. The CS shall be redundant; PLC and PC based, and shall include a local panel mounted HMI and software and hardware interfaces with multifunction meters, excitation system, governor system, auto and manual synchronization, protective relays and others as shown on the PCS architecture Diagram;
2. Each CS shall be a designed to be standalone system to operate independently from other components in the PCS. Therefore, all functions shall be available in each CS at any time whether the Process Control Network is in service or not;
3. The Contractor shall provide hot redundant CPU's; power supplies and communication processors. Redundant I / O modules are required for interfacing the redundant Interfaces including the AVR, the Governor Control, the Electrical Protection and the Mechanical Protection. No redundancy is required for other input-output modules;
4. The Programmable Logics Controllers (PLC) of the Control Boards shall be in redundant configuration. The CPU of system-A shall be synchronized the the CPU of system-B to allow seamless and bumpless switchover between the active and the standby CPU. The standby CPU shall allow replacement under power conditions without shutting down the station and without affecting the performance

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

of the CS. Both CPU shall include the following features:

- The same hardware and accessories;
  - The same application firmware and software;
  - The same data blocks;
  - The same image content;
  - The same program and the same memory program;
  - Data updating is event driven and done simultaneously and in synchronism.
5. All CPU's and modules shall be provided with flash memory cards to hold the up-to-date application programming without any need for a module battery backup.
  6. The CS shall communicate with input-output modules, intelligent electronic devices, multifunction meter modules, multifunction relays, digital exciter, digital governor and other PLC-based controllers independently using industry-standard field bus protocols. All components shall be seamlessly integrated in the PCS.
  7. The CS shall communicate with other nodes and systems over the Process Control Networks using industry-standard communication protocol.
  8. All CS functions shall be programmed in IEC 61131 compliant language.
  9. The CS shall have on-line, self-checking diagnostic routines periodically checking each component in the architecture. Error conditions shall identify the area where the malfunction is located and the specific problem shall be reported to the operator on a dedicated screen.
  10. The CS shall have the capability of automatic start-up and initialization following restoration of power after an outage without manual intervention. All restarts shall be reported to the operator.
  11. Software maintenance activities at a CS shall not affect other CS in the PCS. All compilers, utilities, management software, and storage media required for software maintenance shall be provided.
  12. The CS shall have the necessary processing power, memory, and peripheral facilities to accommodate the software tools and application software as described in this section. The final application software shall not occupy more than 30% of the PLC and PC memory taking into account the expansion provisions.
  13. The CS shall periodically synchronize their clock time using the standard time signal transmitted by the GPS Synchronized System. The plant wide time

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

synchronization error shall not exceed  $\pm 100$  nanoseconds.

b. Product specifications

i. Large Video Screens (LVS)

High Resolution Color, flat Video Monitors shall be furnished as shown on the SCADA SYSTEM ARCHITECTURE drawings. The video wall shall be mounted on the wall in a 2x2 matrix. Supports and hardware required to mount them along with the enclosure furniture shall supplied by the Contractor. The monitors shall be the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

latest available Heavy Duty commercial grade and have, as a minimum, the following characteristics:

- LED
- 55 inch screen;
- Resolution : 1920 x 1080;
- Contrast ratio: 3000:1;
- Brightness: 500 cd / m<sup>2</sup>;
- Image Aspect Ratio : 16:9;
- Thin 19mm or less Bezel;
- Burn-in resistant technology;
- 24 / 7 Rated Display;
- Viewing angle of  $\pm 80^\circ$  vertical and horizontal;
- Anti-Glare, Anti-Reflective Screen Treatment;
- Standard VESA mounting;
- DVI input.

Manufacturer: The manufacturers shall be Sony, Samsung, NEC or equivalent.

ii. Video Matrix Switcher

A 4 x 4 DVI Video matrix shall be furnished, and shall have, as minimum the following characteristics:

- 4 DVI female input;
- 4 DVI female output;
- 1920x1200 resolution or higher;
- Capable of switching any of the 4 inputs on any of the 4 outputs;
- Must be easily controllable from front-panel pushbuttons and IR remote control.

iii. Operator Workstations (OWS)

Industrials Desktop PC Computers with latest Windows or newer operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Latest Processor;
- Gigabit Ethernet port;
- USB ports;
- IEEE1394 port;
- Serial port;
- Dedicated Video Card with two (2) HDMI and one (1) DVI ports to support 1920x1200 resolution;
- All necessary adapters and software required to connect Control, Metering and Monitoring functions of the local HMI of the Control Boards as well as selected function from systems provided by others and intergrated into the SCADA.

The two (2) HDMI ports on the video card shall be used for dual monitor setup and the DVI port for the Large Monitor (2 x 2 video matrix).

Manufacturer: The manufacturers shall be Hewlett Packard, Dell or equivalent.

#### iv. Engineering Work Station

Industrials Desktop PC Computers with latest operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Latest Processor;
- Gigabit Ethernet port;
- USB ports;
- IEEE1394 port;
- Serial port;
- Dedicated Video Card with two (2) HDMI and one (1) DVI ports to support 1920x1200 resolution;
- All necessary adapters and software required to display Control, Metering and Monitoring functions of the local HMI of the Control Boards as well as selected function from systems provided by others and intergrated into the SCADA.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Access to PLC program functions shall be available from these stations to do maintenance or update of software through a high level password.

Manufacturer: The manufacturers shall be Hewlett Packard, Dell or equivalent.

v. Laptop Engineering Work Station

A Professional grade Heavy Duty Mobile Workstation Laptop Computer with latest Windows or newer operating system and the latest Microsoft Office Basic Edition shall be furnished and shall have, as a minimum, the following characteristics:

- Latest Processor;
    - Gigabit Ethernet port;
    - 17 inches widescreen (1920x1200) (LED) display;
    - USB ports;
    - One (1) IEEE1394 port;
    - One (1) serial port (internal or external);
    - Dedicated 1024MB Video Card with DVI port to support 1920x1200 resolution;
    - Spill Proof Keyboard;
    - Multi-button wireless Bluetooth compatible laser mouse;
    - Titanium Housing;
    - External lockable Docking Station;
  - All necessary adapters and software required to display Control, Metering and Monitoring functions of the local HMI of the Control Boards as well as selected function from systems provided by others and integrated into the SCADA.
- Access to PLC program functions shall be available from these stations to do maintenance or update of software through a high level password.

Manufacturer: The manufacturers shall be Hewlett Packard, Dell or equivalent.

vi. Historian Work Station (HWS):

1. Redundant network storage station shall be provided to be used for configuration back-up and storage of historical data;
2. The storage stations shall be sized to provide storage for 100 revisions of all configuration and programming files for the PCS plus storage capacity for the historian server as specified herein in the Historian Data Management software section plus storage capacity to backup 100 data files for the Protection Server and 100 data files for the Machine Conditioning Server. The storage capacity

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

shall not be less than 1TB (mirror) and shall be hot-swappable hard disk in Raid configuration;

3. The communication with the multipurpose servers shall be done thru a 10 Gbps redundant network;
4. An Industrial Desktop PC Computer Server with latest Windows Server or newer operating system, a redundant 2 hard disks RAID 1 setup and the latest Microsoft Office Basic Edition shall be furnished, and shall have, as minimum

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

the following characteristics:

- Latest Processor or better;
- Gigabit Ethernet port;
- USB ports;
- One (1) IEEE1394 port;
- One (1) serial port;
- Dedicated 1024MB Video Card with HDMI port to support 1920x1200 resolution;
- All necessary adapters and software required to register Control, Metering and Monitoring events of the local HMI of the Control Boards as well as all functions from systems provided by others and integrated into the SCADA;

Manufacturer: The manufacturers shall be Hewlett Packard, Dell or equal.

#### vii. PC Screens

Workstation Monitors as shown on the SCADA SYSTEM ARCHITECTURE drawings shall be furnished, as a minimum, the following characteristics:

- Active matrix – LED, 22-inch screen;
- Minimum pixel pitch of 0.264 mm, and resolution of 1920x1200 at 60 Hz;
- Viewing angle of + / -80° vertical and horizontal;
- Antiglare with hard-coating 3H faceplate coating;
- HDMI input.

Operator Workstations require two (2) monitors per Workstation. Other Workstations shall be supplied with a single monitor.

One external screen shall be provided for the Laptop Engineering Work Station.

Manufacturer: The manufacturers shall be HP, Dell, Samsung or equivalent.

#### viii. Mice

One (1) multi-button UCB Laser Mouse per desktop computer shall be furnished with software for interfacing with the operating system for each Server / Workstation.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

The mouse shall be ergonomically designed for either left or right hand operation.

The mouse shall provide up / down and left / right scrolling.

One extra mouse shall be provided for the Laptop Engineering Work Station.

The mouse shall be Microsoft, Logitech or equivalent.

ix. Keyboards

An ergonomically designed Spill Proof Keyboard per computer shall be furnished for interfacing with the operating system for each Server / Workstation. The keyboard shall be split and sloped to encourage natural hand positioning.

One extra keyboard shall be provided for the Laptop Engineering Work Station.

The keyboard shall be Microsoft, Logitech or equivalent .

x. Keyboard Video Monitor (KVM) Switches

KVM switches shall be provided as required to facilitate optimal control over the servers and workstations.

xi. Printers

a) Multifunctional Black and White Laser Printer / Copier / Scanner / Fax shall be furnished as shown on the SCADA SYSTEM ARCHITECTURE drawings for the main control room. The printers shall be used for printing reports, screens, trend

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

data, etc. The printers shall be high volume rated. The printer shall have, as a minimum, the following features:

- Media size up to A3;
- Print Speed- 35 pages per minute / copy per minute or higher;
- 1200x1200 dpi or higher print / copy;
- 600 dpi optical scan resolution or higher;
- 100 or more-sheet multipurpose tray, 2 x 250 or more-sheet input trays, 500 or more-sheet input tray with cabinet, 50 or more-sheet auto document feeder; 250 or more-sheet output bin;
- Connectivity: 10 / 100 / 1000 Base-T Ethernet print server; 1 Hi-Speed USB 2.0;
- Fax features include 300 dpi, 33.6 kbps, auto fax reduction;
- Memory 256 MB minimum;
- 40 GB Hard disk;
- Media size up to 11.7in x 17.7in;
- Compatible with latest Windows.
- Manufacturer: HP, Canon, Xerox or equivalent.

b) A3 Color Laser Printer shall be furnished as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as a minimum, the following features:

- Colour: up to 26 ppm or more;
- Black: up to 31 ppm or more;
- Memory: 256MB or more;
- Connectivity: 10 / 100 / 1000 Base-T Ethernet print server; 1 Hi-Speed USB 2.0;
- Media size up to A3;
- 500 or more sheet input tray;
- Up to 600 x 600 x 4 dpi resolution or more;
- Compatible with latest Windows;
- Manufacturer: HP, Canon, Samsung or equivalent.

c) Dot Matrix Printer shall be furnished for the main control room. The printer shall have, as a minimum, the following features:

- Print speeds up to 475 cps or more;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- 128KB receive buffer / memory or more;
- Up to 360 x 360 dpi graphics resolution or higher;
- Connectivity: 10 / 100 / 1000 Base-T Ethernet print server; 1 Hi-Speed USB 2.0;
- Rated at 20000-hours MTBF or more;
- 400 million character printhead life or more;
- 7.5 million character ribbon life or more;
- Compatible with latest Windows;
- Manufacturer: Epson, Okidata or equivalent.

#### xii. Routers

Router shall be furnished as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as a minimum, the following features:

- 8 Fast Gigabit ports (10 / 100 / 1000 Base-T Ethernet);
- 1 Hi-Speed USB 2.0;
- DHCP server;
- Heavy Duty Industrial Grade;
- A minimum of two (2) spare RJ45 port shall be provided for each router;
- Manufacturer: RuggedCom, Cisco Linksys or equivalent..

#### xiii. Computer, Server and Controller Requirements:

Each personal computer and controller shall be dual ported to its redundant LAN. Computers connected to more than one LAN shall be dual ported to all networks.

#### xiv. Managed Industrial Ethernet Switches:

- The managed industrial Ethernet switches shall support, store and forward switching mode, 100Mbit/s as a minimum and 1,000Mbit/s or 10,000Mbit/s as required;
- The managed switches shall support Bootstrap Protocol (BootP);
- The managed switches shall support Simple Network Management Protocol (SNMP) Versions 1 through 3 or latest and Remote Monitoring (RMON);
- The switch shall be manageable by the use of a standard Internet browser. If other management software is required, the software shall be supplied at no additional cost;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- SNMP OPC server shall be provided and the data from the switches shall be integrated in the DCS system;
- The managed switches shall support Internet Group Management Protocol (IGMP) snooping and multicast filtering;
- The managed switches shall support Virtual LAN (VLAN) network topology;
- The managed switches shall support Rapid Spanning Tree Protocol 802.1w (RSTP);
- The managed switches shall support industrial ring topology;
- The managed switches shall be provided with auto negotiation and auto crossing RJ45 ports and ST style fiber optic ports as required;
- The switches shall be provided with power indicators and link and activity indicators for each port;
- Spare ports shall be provided for each switch. The number of spare ports shall be 25% of the used ports as minimum and not less than 4 ports;
- The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- Fiber Optic Ethernet Switches shall be Heavy Duty Industrial Grade have enough ports to connect all devices requiring a Fiber Optic connection;
- Spare ports shall be provided for each Ethernet switch. The spare ports shall be 25% minimum and not less than 4 ports;
- Manufacturer:
  - RuggedCom;
  - Belden® Hirschmann;
  - ZIV
  - Or equivalent.

xv. Managed Storage Area Network Switches:

- The managed Storage Area Network switches shall support the communications for the network storage equipment and multipurpose servers;
- The management protocols and integration requirements are equal to the Managed Industrial Ethernet Switches specified above;
- The switches shall be provided with power indicators and link and activity indicators for each port;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- Spare ports shall be provided for each Network switch. The spare ports shall be 25% minimum and not less than 4 ports;
- The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- Manufacturers: The manufacturer and model of the switches shall be part of the approved list of SAN switches from the network storage equipment manufacturer.

xvi. Ethernet Copper to Fiber Optic Media Converters:

- The Ethernet converters shall only be used when it is not possible or practical to use devices or switches with fiber optic ports;
- The function of this module is to convert twisted pair Ethernet to and from a fiber optic segment. The physical and logical interface shall be fully compatible with IEEE 802.3. No additional adapters or transceivers shall be allowed;
- The fiber optic ports (transceivers) shall be matched with the type of the fiber optic cable;
- The Ethernet converters shall be provided with the following indicators: power; electrical link; electrical data; fiber link; fiber data;
- The fiber optic connectors shall be MT-RJ type (or ST or SC);
- The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- Manufacturers:
  - Moxa;
  - RuggedCom;
  - Phoenix Contacts;
  - Belden@Hirschmann;
  - or equivalent.

xvii. RS232 / RS422 / RS485 to Fiber Optic Media Converters:

- The function of this module is to convert the RS232 / RS422 / RS485 communication signal over copper cables to and from a fiber optic segment.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

The physical and logical interface shall be fully compatible with EIA 232 and EIA 422 / 485. No additional adapters or transceivers shall be allowed;

- The fiber optic ports (transceivers) shall be matched with the type of the fiber optic cable;
- The converters shall be provided with the following indicators: power; transmit electrical; receive electrical; transmit fiber; receive fiber;
- The fiber optic connectors shall be MT-RJ type (or ST or SC);
- The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- Manufacturers:
  - RuggedCom;
  - Phoenix Contacts;
  - Moxa;
  - Or equivalent.

#### xviii. Control Boards, Patch Panels and RTU Panels

All Panels shall be multiples of 800x800x2300 mm. They can be wider if needed. They shall be rack mount type with outer glass door complete with lockable hardware. The glass shall be tempered and door shall be easily removable during commissioning. Inner rack frame shall be constructed so as to leave no opening with the back. The rear door shall be provided full height complete with lockable hardware. All doors shall be provided a heavy-duty 3 point lock system. Protection class shall be IP52.

Patch Panels shall be provided at the following locations:

- The powerhouse Main Control Room;
- The powerhouse generator floor between the Units-1 and 2 and at Unit-3;
- Near Control Board ICB;
- Near Control Board PPV;

Manufacturer: The manufacturers shall be Rittal or equivalent.

#### xix. Programmable Logic Controllers (PLCs)

Synchronized redundant PLCs shall be responsible for the control monitoring and metering functions of the units and auxiliary systems and shall interface with the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

HMI. They shall be a rugged industrial design and shall have, as a minimum, the following features:

- Two (2) High-performance 2MHz or higher CPUs in redundant configuration;
- Minimum 32MB. However the same shall be selected based on application requirement;
- Minimum 4096 bytes free mix combination of various I / O types;
- Less than 0.15 ms / kb Scan Time;
- Less than 1 sec response time to operator commands;
- Hot backup redundancy capabilities;
- Two (2) Power Supply Cards;
- Two (2) Synchronizing Modules;
- Optical Fiber Cable for Synchronization;
- Fast Ethernet Ports;
- Field bus (Mod bus / Profibus) External interface compatibility;
- Compliant to IEC 61131 and OPC Lab certified.

Manufacturer: SIEMENS SIMATIC, SCHNEIDER MODICON PREMIUM, GE FANUC, ABB AC800M or equal.

xx. HMIs – Human-Machine Interfaces (HMIs)

HMIs shall be supplied in each Control Board as shown on the SCADA SYSTEM ARCHITECTURE drawings, and shall have, as minimum the following characteristics:

- All HMIs shall be OPC compliant;
- Display: 15 inch TFT display, 64K colors;
- Resolution: 1024 x 768 pixels;
- Control elements: Touchscreen resistive analog;
- User memory: 12 MB, additional 12 MB for options, 256 KB non-volatile memory for Software PLC data;
- Interfaces: 1 x RS485, 1 x RS422, 2 x USB, 2 x RJ 45 Ethernet, 1 x combined SD / Multi Media Card Slot, 1 x CF card slot;
- Degree of protection: IP 65, NEMA 4X front, IP 20 rear;
- Configuration software: WinCC flexible Standard.
- Manufacturer: SIEMENS Simatic, SCHNEIDER Magelis, GE Fanuc, ABB CP400 or equal.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

## xxi. Input / Output (I / O) Modules

### 1. General

- Each CS shall be provided with a system of input-output modules (local or remote), instrumentation bus, and power supplies;
- All input-output modules shall be of “hot-swappable” type, to allow for replacement under power, while the CS is running. The replacement of a module shall not cause downtime for the CPU and the other modules;
- The input-output modules and power supplies shall meet the Surge Withstand Capability standards as defined by IEC and ANSI / IEEE;
- The input-output modules shall be provided with redundant power supplies. Each power supply shall be fed from a different 220 V DC power supply circuit. The loss of a single power supply shall not cause the loss of any input-output module, and shall alarm the operator;
- In the case of the UCB, the Contractor shall provide a minimum of 30% spare capacity of I / O modules for each type used, installed, and wired to be verified when the equipment is approved for shipping after the Factory Acceptance Test. Furthermore 50 % space shall be provided above the provided I / O modules for future addition in the UCB.
- In the case of CCB, ICB and PPVCB the Contractor shall provide the number of I / O modules approximately indicated below with 100% space for future expansion.

Control Board	Digital Input	Digital Output	Analog Input	Analog Output
CCB	550	50	32	4
ICB	100	24	24	2
PPVCB	30	10	8	2

### 2. Digital Input Modules

- The digital input modules shall accept normally open or normally closed dry contacts for status and sequence-of-events inputs. All digital inputs shall include optical isolators and filtering to eliminate contact bounce;
- The digital input module shall accept bi-stable and momentary-change inputs. Circuit breaker status and switch positions are bi-stable inputs.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Equipment alarms and protective relay operations are momentary-change inputs;

- Protective relay operations, including electrical and mechanical protective devices, shall be processed as momentary-change inputs.

### 3. Analog Input Modules

- The analog input modules shall accept and process transducer voltage signals in the range of  $\pm 10V$  DC or current signals in the range of  $\pm 20$  mA DC. All inputs shall be galvanically isolated;
- The analog input processing shall include filtering, scaling, and A / D conversion with a 12-bit 2's complement resolution;
- Accuracy shall be at least  $\pm 1\%$  and linearity  $\pm 1 / 2$  LSB over the full input range and temperature range.

### 4. Resistance Temperature Detector (RTD) Input Modules

- The RTD input modules shall have the capability of interfacing with Platinum or Copper RTDs;
- The RTD input shall have a minimum resolution of 14 bits plus sign.

### 5. Control Output Modules

- The control output modules shall support both maintained and pulse (momentary) outputs;
- All outputs shall use heavy duty interposing relays with three Form-C gold plated contacts.

### 6. Instrumentation Bus

The Instrumentation Bus shall be designed in accordance with industry-standards such as Field bus, MODBUS, Inter-bus or Profibus.

### 7. Communications Media

- The communications media for all external (outside of any cabinet) communication links shall be fiber optics;
- The communications media for internal (inside CS cabinet) communication links may be copper.

### 8. Physical Requirements

The CS shall be housed in a standard electronic equipment cabinet with a



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

window door, as specified herein.

## 9. Power Requirements

The CS shall be suitable for operation from a 220 V DC.

### xxii. Synchronizer, Synchrocheck and Manual Controls and Meters

The synchronizing device shall be housed in a dedicated panel as part of the UCB. An Automatic Synchronization and Paralleling with Power Lines System per unit shall be supplied and shall be model SYNCHROTACT® 5 family from ABB or equivalent.

The system shall be supplied complete with a Synchrocheck ABB model SYN 5200 or equivalent.

Manual synchronization controls and meters shall be provided for manual synchronization such as the ABB model Synchrotact CSS assembly or equivalent.

Manual synchronization controls and meters shall have the following features:

- Double Frequency meter (Generator and Power Line side);
- Double Voltmeter (Generator and Power Line side);
- Synchroscope;
- Speed control (UP / DOWN);
- Voltage control (UP / DOWN);
- Local / Remote switch;
- AUTO / MAN / TEST selector;
- Circuit breaker Control Switch (OPEN / CLOSE);
- Circuit breaker OPEN / CLOSE pilot lamp;
- Mimic of complete power and control single line diagram.

Manufacturer: The synchronizer and synchrocheck shall be ABB Synchrotact or equivalent. Equivalents to the ABB CSS assembly shall be accepted.

### xxiii. Protection, Auxiliary and Interposing Relays

High speed protection relays shall be provided for the opening, closing and tripping of the Unit 220 kV Circuit Breakers. Auxiliary relays shall be provided for Electrical, Protection, for Mechanical Protection and for all 220 V DC circuits. Interposing relays

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

shall be provided for all output signals of the I / O modules controlling external devices including motor starters, coils etc. carrying a thermal load.

The relays shall be Heavy Duty Industrial Grade have a rating compatible with the load. All relays shall be provided with gold plated contacts. Relays shall be mounted in dust tight housing and shall be the plug-in type. The relays must be provided with set screws to secure them to their base. Clips shall not be accepted for Protection and Auxiliary relays under any circumstances. Clips are accepted for interposing relays.

Protection Relays shall be High Speed and specifically designed for tripping of circuit breaker coil. Relay coils shall be supervised using an external Supervisory Relay. They are designated as IEEE function number 86 and 94. Lockout relays shall be of the latching type resettable with an external pushbutton. Remote resetting is not permitted. Relays shall be rated 10 A continuous, 30 A make 5 s at 220 V DC suitable for 100,000 electrical and 1 million mechanical operations. A minimum of 10 convertible form A and B contacts shall be provided. A minimum of 3 spare contacts shall be provided for future use.

Auxiliary and Supervisory Relays shall be Heavy Duty with contacts rated 5 A continuous, 30 A make at 220 V DC suitable for 100,000 electrical and 1 million mechanical operations. A minimum of 4 convertible form A and B contacts shall be provided. A minimum of 2 spare contacts shall be provided for future use.

The Interposing relay contacts shall be rated 10 A continuous, 20 A make at 240 V AC and 24 V DC suitable for 100,000 electrical electrical and 1 million mechanical operations. All relays shall be provided with three form C contacts and LED operation indication.

Relays shall be mounted in the rear section of the I / O module panel and shall be isolated from one another. No mixing of control Voltage is allowed. Metal barriers shall be used to separate Voltage classes. System A, B and Common shall be located in different panels.

#### xxiv. Time Standard System:

- The PCS and the Electrical Protective System system shall be provided with an accurate external time standard. A GPS satellite synchronized clock shall maintain the time reference for all time synchronized devices and systems;
- The clock shall receive and decode time information transmitted by the GPS with

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- an accuracy of  $\pm 100$  nanoseconds or better;
- c. The GPS receiver shall be provided with the antenna, interconnection terminations, cables, and mounting hardware;
  - d. The standard time in day of year, hours, minutes and seconds shall be displayed continuously at the device;
  - e. A separate time slave clock shall be provided at each of the two Control Rooms. In the Main Control Room the clock shall be mounted above the LVS screen. The clocks shall display the date, weekday, year, hours, minutes, and seconds. The time display shall be displayed in characters 80 mm high minimum. Date, weekday and year shall be displayed displayed in characters 40 mm high minimum. Display shall be LCD;
  - f. The time standard shall also display the system frequency, the frequency deviation from standard frequency, and the time deviation between system time and standard time;
  - g. The time standard shall be provided with direct interfaces to the Plant and Unit Control Networks independently;
  - h. Inter-Range Instrumentation Group (IRIG) time synchronization connections to the unit and plant protective relays shall be provided;
  - i. NTP Client / Server hierarchical time distribution is allowed, however no Simple Network Time Protocol (SNTP) clients are acceptable for time synchronization for controllers, HMIs, Workstations, Servers or any other device that provide control, protection, historian or network management functions in the system. NTP Client shall make a transaction with its server over its polling interval. The polling interval shall be dynamically adjusted between 64 to 1024 seconds;
  - j. Clock synchronization shall not have an error greater than  $1 / 10$  of the timestamp resolution;
  - k. No domain time synchronization shall be used for the Windows computers as a primary time synch method;
  - l. The GPS system shall be provided with a master clock and three slave clocks. GPS main and slave clocks shall be provided complete with PPS and IRIG-B configurable output, GPS antenna and surge protection kit or approved

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

equivalent;

#### xxv. Miscellaneous Power Supplies

##### ➤ General Requirements:

The Contractor shall provide all necessary power supplies required to achieve the system's required functionality. The selection of the power supply shall be done considering the modularity / interchangeability criteria for the entire system.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

The output voltage shall not vary more than 5% with voltage input variation between -20% to +10%, and output current variation from 0% to 100%.

➤ Power Supplies:

1. Type: 220 V DC to 24 V DC:

- Input: 220 V DC fused;
- Output: 24 VDC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;
- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

2. Type: 240 V AC to 24 V DC:

- Input: 240 V AC 50 Hz, fused, with harmonic filter (power to be provided by UPS);
- Output: 24 V DC;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- The residual ripple shall be lower than the maximum required by the connected equipment, but never greater than 100mVpp;
- Operating and status indication;
- Type: Primary switched-mode power supply;
- Electrically isolated between input and output side;
- The power supply shall be protected against excessive current and reverse voltage;
- Modular design;
- Mounting type: standard rail mounting or as required.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

### 3. Type: 24 V DC to 24 V DC:

- Input: 10-32V DC fused;
- Output: 24V DC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;
- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

### 4. Type: 240 V AC to 220 V DC

- Input: 240V AC 50 Hz, fused, with harmonic filter (power to be provided by UPS);
- Output: 220V DC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;
- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

### xxvi. Multifunction Meter

#### ➤ General Requirements:

1. The digital multifunction meters shall be of microprocessor based power



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

and energy meter type;

2. The meter shall include onboard non-volatile memory. The amount of memory shall be enough to register a minimum of 16 freely selectable parameters, every 15 minutes for 45 days. The minimum memory shall be 5MB;
3. The meter shall be programmable and shall include logical and mathematical functions to perform calculations over any measured parameter;
4. The meter shall be fully configurable using the local display and / or via a software application;
5. The device shall comply with the following measurement standards:
  - ✓ IEC 62053-22 Class 0.2S;
  - ✓ ANSI C12.20 0.2 Class 10 & 20;
  - ✓ ANSI C37.90.
6. The device shall comply with following power quality and quality of supply standards and network connection requirements:
  - ✓ EN 50160;
  - ✓ IEC 61000-4-30 Class A;
  - ✓ IEC 61000-4-7 harmonics & inter-harmonics;
  - ✓ IEC 61000-4-15 flicker;
  - ✓ IEEE 1159.
7. The device shall be capable to be connected to 4 wire Wye, 3 wire Wye, 3 wire delta, direct delta and single phase systems;
8. The device shall be able to be powered from AC (90-240V) & / or DC (110-300V);
9. The device shall be able to operate in sub tropical environment with a temperature of 20 to 70°C, and humidity of 5-95% non-condensing;
10. The device shall be able to synchronize automatically with the GPS clock directly or through one of the communication ports;
11. The device shall be capable to timestamp the historical data;
12. The device shall have a backlight LED screen with the following minimum characteristics:
  - ✓ High visibility, 320x240 pixels, 3.5" x 4.5", LED backlit with adjustable

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

contrast screen;

- ✓ Capability to display numerical and up to four graphical data simultaneously; the numerical data can include real time, historical time stamped and name plate data. The graphical data can include frequency spectrum and trends logs;
- ✓ Multiple programmable screens: The multifunction meter shall be provided complete, including all the necessary connections, protections (fuses, etc.), software applications, and communications and mounting accessories.

#### ➤ Inputs and Outputs

##### 1. Voltage Inputs:

- ✓ The device shall include four (4) voltage inputs rated to 240 V Line-Neutral / 415 V Line-Line V AC rms;
- ✓ The inputs shall be able to accept an overload of 1500V AC rms continuous;
- ✓ The inputs shall be able to withstand a 2500VAC rms 50 Hz for 1 minute;
- ✓ The minimum impedance shall be 5MΩ per phase.

##### 2. Current Inputs:

- ✓ The device shall include five (5) current inputs rated to 5A, with a maximum voltage of 600V;
- ✓ The current inputs shall have a starting current of 0.005A rms;
- ✓ The current inputs shall be able to accept an overload of 500A rms for 1 second, non-recurring;
- ✓ The current inputs shall be able to withstand a 2500 V AC rms 50 Hz for 1 minute;
- ✓ The burden shall be 0.05 VA @ 5A, and the impedance 0.002W / phase, or less.

##### 3. Analog Inputs:

- ✓ The device shall include four (4) analog DC current inputs, with a

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

selectable range of 0-1mA, 0-20mA and 4-20mA;

- ✓ The input impedance shall be 24  $\Omega$  @ 20mA;
- ✓ The accuracy shall be + / - 0.3% at full scale;
- ✓ The isolation to ground shall be at least of 750V;
- ✓ The channel to channel common mode isolation shall be at least of 400 k $\Omega$ ;

#### 4. Digital Outputs;

- ✓ The device shall include two electromechanical relays form C (NO, Common, NC terminals) rated 250VAC / 3A;
- ✓ The device shall include two solid state outputs rated 30VDC / 50mA for SCADA supervision.

### ➤ Communication Ports

#### 1. RS-232 Port:

- ✓ The device shall include a serial RS-232 port for configuration / maintenance purpose;
- ✓ The port shall be able to connect to 300-115000bps baud rates;
- ✓ The connector shall be standard male DB9;
- ✓ The port shall be fully isolated (optical preferable) from the other connections in the device.

#### 2. RS-485 Port:

- ✓ The device shall include a RS-485 port for parameters reading. The Contractor shall select this port or the Ethernet port to provide connectivity to the PLC;
- ✓ The port shall be able to connect to 300-57600bps baud rates;
- ✓ The connector shall be captured wire type;
- ✓ The port shall be fully isolated (optical preferred) from the other connections in the device.

#### 3. Ethernet Port:

- ✓ The device shall include an IEEE 802.3 Ethernet port for parameters reading. The Contractor shall select this port or the RS-485 port to

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

provide connectivity to the PLC;

- ✓ The port shall be able to connect to 10Mbps or better;
- ✓ The connector shall be RJ45 type;
- ✓ The port shall be fully isolated (optical preferable) from the other connections in the device.

#### 4. Communication Protocols:

The device shall be able to communicate using the following protocols in all the ports:

- ✓ Modbus RTU;
- ✓ DNP 3.0;
- ✓ Modbus TCP (Ethernet Port);
- ✓ Telnet (Ethernet port);
- ✓ Profibus;
- ✓ Other protocols compatible with the PLC.

#### 5. Parameters

The device shall be able to measure the following parameters per phase

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

and three phase average:

- ✓ Frequency;
- ✓ Power Factor;
- ✓ Current rms (A);
- ✓ Voltage rms (kV);
- ✓ Apparent Power rms (MVA);
- ✓ Active Power rms (MW);
- ✓ Reactive Power rms (MVAR);
- ✓ Apparent Energy bidirectional (MVA);
- ✓ Active (Real) Energy bidirectional (MWh);
- ✓ Reactive four-quadrant energy (MVARh).

6. At a minimum, the following calculations shall be implemented:

- ✓ Current: demand, minimum and maximum;
- ✓ Voltage: demand, minimum and maximum;
- ✓ Apparent Power: demand, minimum and maximum;
- ✓ Active Power: demand, minimum and maximum;
- ✓ Reactive Power: demand, minimum and maximum.

xxvii. Optic Fiber network:

- a. The scope if the present specification includes the provision of all multimode Fiber Optic cables and patch cord within the powerhouse. The Monomode cable running from the Powerhouse to the Intake area and valve house area shall also be supplied and laid under this package. The present Contractor shall be responsible for supplying all termination material including converters and routers and for the connection, testing and commissioning of the Monomode cable runs;
- b. The Optic Fiber network shall be comprised of multimode fiber optic cables and patch cords and shall be provided complete with terminal, patch panels and accessories;
- c. Patch Cord shall be factory terminated and their length shall be adjusted to the required length. Any extra length shall be looped and tie- wrapped. Patch cord going from one panel to the other shall be encased in a orange coloured flexible conduit and laid into the Control Cable Trays in a dedicated compartment. Additionnal cable Tray shall be supplied where necessary to reach isolated

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

components;

- d. Fiber Optic Cables shall be loose tube construction type suitable for indoor or outdoor, corrugated steel tape armoured for ruggedness and crush resistance. The Fiber Optic cables shall be run in orange PVC flexible conduit and layed in the Control Cable Trays in a dedicated compartment;

- e. Cable Construction:

Optical fibers shall be placed inside loose buffer tube of nominal diameter 3mm. Buffer tube shall be fitted with a non-hygroscopic, non-nutritive to fungus, electrically non-conductive, homogeneous gel. The gel shall be readily removable with conventional nontoxic solvents. The gel shall be free from dirt and foreign matter.

Each fiber shall be distinguishable by means of color coding in accordance with TIA / EIA 598-B, Optical Fiber cable color coding.

The fibers shall be colored with ultraviolet curable links. In buffer tubes containing multiple fibers colors shall be stable across the specified storage and operating temperature ranges and not subject to fading or smearing into each other or into the gel filling material. Colors shall not cause fibers to stick together.

Buffer tubes containing fibers shall be color coded with distinct and recognizable colors in accordance with TIA / EIA-598-B, "Optical Fiber Cable Color Coding."

A filler may be included in the cable core to lend symmetry to the cable cross-section where needed. The fillers shall be nominally 3.0 mm in outer diameter.

The central member shall consist of a dielectric, glass reinforced plastic (GRP) rod to provide tensile strength and prevent buckling. The central member shall



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

be overcoated with a thermoplastic when required to achieve dimensional sizing to accommodate buffer tubes / filters.

Water blocking performance using swellable polymer technology shall be used

The buffer tubes shall be stranded together with the dielectric central member and a water blocking yarn using the reverse oscillation, or "S-Z," stranding process.

Tensile strength shall be provided by the central member, and dielectric yarn. Dielectric strength yarns shall be applied around the outside of the cable core.

Cables shall contain at least one ripcord under the outer sheath to facilitate its removal.

The armor layer shall be applied directly (no inner jacket) over the dielectric strength members. The armor shall be a corrugated steel tape, plastic-coated on both sides for corrosion resistance. The outer jacket shall be applied over the corrugated steel tape armor. The outer jacket shall be a MDPE with a minimum nominal jacket thickness of 1.3 mm. The polyethylene shall contain carbon black to provide ultraviolet light protection and shall not promote growth of fungus.

The MPDE jacket material shall be defined by ASTM D1248, Type II, Class C and graded J4, E7 and E8.

Cable jackets shall be continuous, free from pinholes, splits, blisters and other imperfections. They shall have a consistent, uniform thickness. Jackets extruded under high pressure are not acceptable. The jacket shall be smooth as is consistent with the best commercial practice.

Jacket shall provide the cable with a tough, flexible, protective coating, able to withstand the stresses expected during normal installation and service.

Cable jackets shall be marked with the manufacturer's name, month and year of manufacture, sequential meter or foot markings, a telecommunication handset symbol as required by Section 350G of the National Electrical Safety Code\*1 (NESC®), fiber count, and fiber type. The actual length of the cable shall be within -0 / +1% of the length markings. The print color shall be white with the exception that cable jackets containing one or more coextruded white

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

stripes shall be printed in light blue. The height of the marking shall be approximately 2.5 mm.

If the initial marking fails to meet the specified requirements (i.e., improper text statement, color, legibility, or print interval), the cable may be remarked using a contrasting alternate color. The numbering sequence shall differ from the previous numbering sequence, and a tag shall be attached to both the outside end of the cable and to the reel to indicate the sequence of remarking. The preferred remarking color shall be yellow, with the secondary choice being blue.

The maximum pulling tension shall be 2700 N (600 lbf) during installation (short term) and 890 N (200 lbf) long term installed.

The storage temperature range for the cable on the original shipping reel shall be - 40 °C to + 70 °C. The installation temperature range for the cable shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- 30 °C to + 70 °C. The operating temperature range for the cable shall be - 40 °C to + 70 °C.

Life of cable - The minimum expected life of the cables shall not be less than 25 years.

f. Quality Insurance Provisions :

All cabled optical fibers > 1000 meters in length shall be 100% attenuation tested. The attenuation of each fiber shall be provided with each cable reel.

g. Optical Cable Specification:

➤ Powerhouse Cable

Fiber type: Multimode mode:

- Total Fiber count: 24;
- Small diameter single tube construction;
- Core / Cladding: Silica;
- Moisture proof;
- Rodent & Termite attack protection & Prevention;
- Nominal weight:  $\leq 152$  Kg. / Km;
- Outside diameter:  $\leq 13.1$  mm;
- Minimum Bend Radius loaded:  $\leq 177$  mm;
- Minimum Bend Radius installed:  $\leq 118$  mm.

➤ Remote Site Cable (Valve house area and Intake area)

Fiber type: Monomode mode:

- Total Fiber count: 24;
- Small diameter single tube construction;
- Core / Cladding: Silica;
- Moisture proof;
- Rodent & Termite attack protection & Prevention;
- Nominal weight:  $\leq 152$  Kg. / Km;
- Outside diameter:  $\leq 13.1$  mm;
- Minimum Bend Radius loaded:  $\leq 177$  mm;
- Minimum Bend Radius installed:  $\leq 118$  mm.

h. Manufacturer: Corning or equivalent

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

xxviii. Control Room Furniture:

- a. The Contractor shall supply and install modular desks, tables, cabinetry and chairs for the main Control Room;
- b. The Main Control Room furniture shall include accommodation for Work Stations and equipment provided herein and by others including: the Operator Work Stations c / w 22" screens (OWS1,2,3), the Historian Work Station (HWS), the SCADA Engineering Work Stations (EWS1,2), the Energy Management Work Station (EMS), the Zoom Processor Vibration Analysis Work Station (ZCS), the closed circuit TV Work Station c / w 22" screens (CCTV), the three desktop printers c / w router, Voice over IP (VoIP) Router Cabinet and filing cabinetry in the location shown on the arrangement drawing;
- c. The GIS equipment furniture shall include accommodation for Work Stations and equipment provided herein and by others including: the Remote Site Optic Fiber Work Station (OWS4), the Protection Operator Work station c / w 2-22" screens (OWS5), the Protection Engineering Work Station (EWS3), the Dispatch Work Station (DWS), Routers, Voice over IP Server Work Station (VoIP WS) Router Cabinet and filing cabinetry in the location shown on the arrangement drawing;
- d. The desks shall be sized to comfortably accommodate the Work Station Monitors, keyboards, and mice. Especially design compartment shall be designed to house the tower Servers and PC beneath the working surface. Space shall also be included for telephones, note taking and log book entries. Furnish storage for miscellaneous office supplies such as pencils, scissors, tape, paper clips, etc.;
- e. Tables shall be sized to accommodate the printers and others table top devices. Shelving shall ne provided below to store paper and ink cartridges.
- f. Cabinetry shall be provided as shown on the drawings. The cabinetry shall be a combination of floor standing cabinets 750 mm high, 600 mm deep and wall mounted cupboard 750 mm high, 300 mm deep. Cabinetry shall be provided with shelving and doors;
- g. Cabinetry shall also include the required cabinet to house the Large Video Screens array. The cabinetry shall neatly recess and support the screen using factory purchased steel hardware. Generous ventilation slots shall be provided to insure natural cooling. The cabinet shall be free standing but secured to the backwall. The cabinet shall be 450 mm deep and have full height. Shelving and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

doors shall be provided in lower part and all cables shall be hidden;

- h. The desks, tables and cabinetry shall be constructed of Medium Density Fiberboard (MDF) with Plastic Laminate Sheet surfaces and metal framing. The Plastic Laminate Sheets shall be High-pressure decorative laminate complying with NEMA LD 3, grade HGS and designated as through-colour plastic laminate. Laminate shall be provided complete with grade BKL backer sheet. Laminate will cover all visible surfaces. Side and rear panel can be made of steel resistant to denting and warping. Metal surfaces shall be cleaned, primed and painted using epoxy powder process. The furniture shall be provided with built-in receptacles to plug all the equipment and designed to hide all wiring;
- i. The chairs shall be ergonomic orthopedic, high grade upholstery fabric, steel framing and 5 wheel roller base. The chairs shall be provided with adjustable armrests, adjustable back rake, adjustable seating angle and adjustable height seat;
- j. The Contractor shall design the arrangement of the Control Room furniture to optimise working surfaces and storage area while maintaining clearances for sitting and circulation;
- k. Control Room furniture submittal shall be provided for review and approval by

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

the Employer and Engineer In-charge;

I. Approved Manufacturers:

- Evans Consoles;
- Or approved equal.

### 7.3.6.2 Man-Machine Interface (MMI) Software System

a. General Requirement:

- MMI includes the HMIs in the control boards and OWS in the control rooms. Those two different types of hardware shall be completely independent (master / slave is not allowed);
- The MMI shall consist of an integrated SCADA PC-based graphic display system to support an interactive dialogue between the operator and the power plant equipment;
- All Software System shall be OPC compliant;
- The operating system for the PC-based MMI shall be with latest Microsoft Windows. The operating system for the PC-based servers shall be latest Windows Server;
- All required service packs, updates and patches for the operating system, MMI software and other applications shall be installed and kept up-to-date throughout the duration of the project and throughout the warranty period;
- The MMI package shall include alarming, reporting, event logging and trending capabilities;
- The software shall provide user-friendly development environment that allows for simple interactive graphics building and application software development. The software shall provide Wizards, Experts, and other productivity tools to support development without having to learn a proprietary language. Advanced development tools such as Visual Basic and scripting shall also be available;
- Real time process monitoring and historical trending shall be included;
- The MMI system shall be capable of seamlessly integrating third party software such as Microsoft's Office products, including Word, Excel, and Access;
- The MMI system shall be designed to allow for future upgrades of the software package without the necessity to reprogram the existing system;
- The database shall be designed to support the following point types:

1. Analog Inputs - Read an analog value either directly from an A / D converter or from a register within an I / O device or intelligent device and automatically

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

convert the raw value to engineering units or use PLC scaled value;

2. Analog Alarms - Alarm capabilities for alarm suspension and remote acknowledge;
3. Analog Outputs - Write an analog value either directly to a D / A converter or to a register within an I / O device, capable of automatically converting the engineering units to raw values;
4. Calculations - Perform arithmetic and logic calculations based on other database points and store them in internal MMI registers;
5. Digital Inputs - Sense logical state of a switch or relay directly from the input module or from a bit in memory of an I / O device including intelligent devices with time tagging;
6. Digital Alarm - Alarm capabilities for alarm suspension and remote acknowledge;
7. Digital Output - Set a logical on / off state in an output relay either directly in the output module or in a bit within the memory of an I / O device.

- Each database point shall include an instrument tag name, hardware device name, address, specific parameters, signal conditioning requirements and point description;
- The database shall be stored as a standard Windows file;
- The database maintenance facilities shall be totally integrated with the graphic display system;
- The database shall make use a high-level data manipulation language, Structured Query Language (SQL);
- The database shall support import and export of individual points, groups and complete database in Comma Separated Value (CSV) file format;
- The MMI system configuration, screen development, and database deletions, additions and changes shall be able to be done offline or online. Online modifications, deletions and additions shall not interrupt the data acquisition.

**b. Security Management**

- The MMI software shall provide a user-based security system. The security system shall allow for the creation of users with certain rights and / or privileges. These



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

rights must include the ability to run any combination or all of the applications in the data acquisition system;

- The ability to allow or disallow user's access to change values, such as set-points and machine-setups, on an individual tag basis shall be supported.

#### 7.3.6.3 Man-Machine Interface (MMI) Application Software

##### a. General Requirements

- MMI includes the HMIs in the control boards and OWS in the control rooms. Those two different types of hardware shall be completely independent (master / slave is not allowed);
- All displays (formats and design) shall be subject to review and approval by the Engineer in charge. The Employer and / or Engineer in-charge reserves the right to participate in the design of the screens as needed;
- A minimum of two MMI software workshops shall be held to coordinate the MMI development;
- The MMI system shall be designed to provide rapid and reliable information to project events and to provide the operator with the ability to monitor and control the plant without objectionable delays in system processing times. The MMI stations shall be able to be configured to perform all or a selected subset of the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

system functions. Control and programming functions shall be password protected;

- The Dot-Matrix printer shall be configurable for automatic alarm and operator action logging;
- The MMI station operator shall be able to use either the keyboard, or mouse to implement monitoring and control commands.

#### b. Security Management

The security management shall be designed to comply with the Employer security requirements.

##### Displays

As a minimum, the Contractor shall be responsible for creating and integrating the following plant common MMI screens:

- Plant Navigation;
- Plant Overview;
- Plant Main One Line;
- Dam Intake, PPV monitoring and instrumentation indications;
- Tailrace level indication, Draft tube level indication, Tail race gate control / Monitoring;
- Single Line Diagrams, including: status, measurements and control for breakers, transformers, etc.;
- Alarm Lists: The alarm lists shall have configurable filters to filter out the alarms not applicable to the particular unit or system. The entries in the alarm lists shall be arranged in chronological order;
- System events summary (one world map): A chronological listing of all system events, i.e.: alarms, status changes and operator-initiated actions;
- Sequence of events list (one list);
- Balance of Plant Navigation;
- Balance of Plant Individual Screens: Arrangement and dynamic information shall be displayed for each BOP system;
- System configuration screens as required;
- Generator and turbine capability curves with real time operating point shown;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- Intelligent devices: All intelligent devices shall be provided with a template display. This display shall include all the signals and tuning parameters provided by the manufacturer. This applies to all the interfaces with intelligent devices;
- Auxiliary Equipment Monitor: The auxiliary equipment monitor function shall monitor the running hours including the lead-lag status of the auxiliary equipment such as governor pressure oil pumps, air compressors, main water supply pumps,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

etc. When the total running hours exceeds the pre-set value, and alarm shall be initiated;

- Hydraulic Conditions: One screen showing by means of a graphic color display, unit flow rates, head and tail-water levels, trash racks differential, silt level in desilting bays, etc.;
- Alarm messages with detailed descriptions shall be displayed automatically for:
  1. All devices connected to the Plant or Unit Network;
  2. PCS components;
  3. Time counts exceeding preset value;
  4. Incomplete sequences.
- Generation and Hydraulic daily (hourly basis) and monthly (daily basis) reports;
- Help screens;
- Operational guidance and help screen for:
  1. Navigation and operation;
  2. Fault restoring operating procedure;
  3. Links to drawings, Acrobat and MS Office documents.
- Status and analog signals from all devices connected to the Plant or Unit network;
- Status of Unit and Plant Network Systems and components including connected fiber-optic lines;
- Status of Controller Stations, Remote I / O's, PLC's, etc.;
- Status of HMI, PC and Servers;
- Display of monitoring signal of systems provided by others and integrated into the SCADA;
- Additional displays shall be as required by other functions included in this Contract.

The Contractor shall be responsible for integrating as a minimum the following displays for each unit and for common systems:

- Unit Screen Navigation Page;
- Unit Control Status;
- Unit Sequence Overview;
- Sequence Monitors:

Each sequence monitor function shall monitor and display the sequential operation of the unit for each step by checking the processing time for each step of the normal start and stop sequences. All permissive, interlock and status shall also be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

displayed. In the event of a sequence interruption in any sequential step, the step and equipment or device shall be listed on the sequence monitor.

- Equipment Lock Out / Tag Out;
- High Pressure Lube Oil System;
- Upper Guide Bearing Lube Oil System;
- Governor;
- Governor Hydraulic Systems;
- Generator Brakes;
- Cooling Water System – Turbine Bay;
- Automatic Voltage Regulator (AVR)
- Excitation;
- Winding Temperatures;
- Bearings Temperatures;
- Generator Temperatures;
- Vibration;
- Single Line Protection and Monitoring;
- Auxiliary AC System;
- Auxiliary DC System;
- UPS system;
- DG sets;
- Fire Fighting systems;
- HVAC.system
- Auxiliary Mechanical System

All units' related screens shall have a clear identification of which unit the screen is related to, and this identification should be presented in the same location for all the screens:

1. All analog and digital signals, including signals provided by intelligent devices shall be displayed on a screen graphically. The screen design shall be representative of the process;
2. The Contractor shall make provisions to design and integrate up to 75 MMI screens before the start of the warranty period. The Contractor shall also make provisions to update and adapt to field changes and modifications the MMI screens and data bases before the start of the warranty period;
3. Faceplates: Standard faceplates shall be provided and shall not be counted as

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

separate screens. The faceplates shall be linked with the software module for

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

the particular piece of equipment or device;

Breaker Faceplates:

- In addition to the opened / tripped status for each breaker, the following information shall also be provided: local / remote status; racked-in status; test position status; racked-out status;
- Breaker disagreement alarm shall be provided. The disagreement alarm shall be active when the actual status differs from the last command sent to the breaker. This alarm shall also activate the alarm horn.

#### 4. Lock-out / Tag-out

- In addition to the Unit and Plant Lock-out / Tag-out screens, each device / equipment faceplate shall have a drop down menu for selection of Lock-out / Tag-out action;
- The Lock-out / Tag-out status shall be shown on each screen or faceplate that the device / equipment appears on;
- The Contractor shall submit the standard lock-out / tag-out system for review and approval by the Employer / Engineer In-charge.

#### 5. Intelligent Devices

- The Contractor shall provide standard templates to display the process information provided by intelligent devices such as protective relays & multifunction meters;
- The Contractor shall submit the standard templates for review and approval by the Employer.

#### 6. Alarm System; Alarm and Event Logs and Sequence of Events:

- The Historian Work Station shall be dedicated to data logging of alarms and events on the servers drives. Alarms and events shall nevertheless be displayed at the MMI;
- A comprehensive alarm system shall be provided. The alarms shall be prioritized and grouped to provide user-friendly operator interface;
- The alarm system shall comprise of process, PCS, network and communication alarms. The alarm system design shall be reviewed and approved by the Employer;
- Alarm and event log shall be provided. The log shall include: all process alarms and events; all operator action events; all PCS alarms and events;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

all network and communication alarms and events of the plants including the systems provided under packages that are integrated into the SCADA with no exception. Each alarm or event shall be logged together with its

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

time stamp. Alarms shall include events generated by the intelligent devices;

- Sequence of Events shall be included for discrete inputs and events generated by the intelligent devices to provide troubleshooting tools for the engineering personnel.

#### 7. Color Standards:

- The color standards mentioned in the following tables are recommended values. The final color scheme shall be coordinated with the Employer during MMI development, and submitted for approval.

#### 8. Equipment or Device Status:

Gate, Damper	Circuit Breaker, Switch	Motor, Pump, Generator, Fan, etc.	Graphic Color
Opened	Closed	Running	Red
In Transition	N / A	In Transition (when applicable)	Flashing Red when Opening / Starting and Flashing Green when Closing / Stopping
Closed	Opened	Stopped / Off	Green
Tagged Out	Tagged Out	Tagged Out	Yellow
Fault	Fault	Fault	Magenta
In Automatic Indication	In Automatic Indication	In Automatic Indication	Amber
In Local or Manual Indication	In Local or Manual Indication	In Local or Manual Indication	Blue
In Alarm Indication	In Alarm Indication	In Alarm Indication	Unacknowledged – Cyan Acknowledged - White

#### 9. Electrical Bus Colors by Voltage

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Voltage	Color	RGB Hex Code
220 kV	Safety Yellow	FDD31D
33 kV	Light Green	C4DA99
11 kV	Dark Blue	023457
415 VAC	White	EDF2F8
220 VDC	Red	CC0000

#### 7.3.6.4 Controller Stations (CS) Software

##### a. Maintenance Facilities

- Each CS shall be provided with maintenance facilities to allow the users to configure the database and program any functions using a portable personal computer or the Engineering Workstation (EWS) connected through:
  - Network;
  - Serial port;
  - Remotely via modem.
- The maintenance facilities shall be password protected and shall contain the option for a dial back security when in dial-up mode.

##### b. Configuration System:

- The CS shall be provided with a Windows-based configuration system, which shall include all the necessary software to configure and program any function in the CS;
- The configuration system shall be installed on the portable laptop and the EWS (Multipurpose Servers);
- The configuration system shall allow downloading and uploading of configuration data files;
- The configuration system shall program, download, debug and store programmable algorithms.

##### c. Programming Package:

- The programming package shall be an industry standard package, IEC 61131 compliant and shall be totally integrated with the PCS software;
- No special database shall be required for the implementation of control programs. The control programs shall use ladder diagrams; function block diagrams,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

sequential function charts, structured text, instruction lists, process control language and C++ based routines. Programs shall be self-documenting;

- The programming package shall support on-line and off-line development, off-line simulation, documentation and reporting capabilities.

d. Naming Conventions:

- All input, output and soft points shall be named consistently in accordance with an approved naming convention;
- The point tag shall include as a minimum: plant; location; system; subsystem; IEEE / ISA component ID (i.e. PT, 52, etc.); point type (analog, discrete, etc.); connection type (software, hardwired, etc.), etc;
- The naming convention shall be approved by the Employer and Engineer In-charge.

e. Functions:

- The algorithms and functions shall reside in the PLC or controllers associated with the equipment or system as indicated (minimum) in the table that follows.

Function									
	Main SCADA	Unit Control Board UCB	Intake Control Board ICB	Penstock Protection Valve Control Board PPVCB	Common Control Board CCB	GIS / Unit Prot. SCADA	Unit Mech Prot & MIV PLC	Unit Exc. & AVR	Unit Gov. Control PLC
Data Acquisition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Discrete Raise / Lower and Set-point Control of MVAR & kV	Yes	Yes	No	No	No	No	No	Yes	No



Discrete Raise / Lower and Set-point Control of MW & Hz	Yes	Yes	No	No	No	No	No	No	Yes
Unit Automatic Start / Stop Control Sequence	Yes	Yes	No	No	No	No	No	No	No
Synchroniz er Control& Monitoring	Yes	Yes	No	No	No	No	No	No	No
Unit Metering Display	Yes	Yes	No	No	No	No	No	No	No
GIS Metering Display	Yes	No	No	No	No	Yes	No	No	No
Auxiliary Metering Display	Yes	No	No	No	Yes	Yes	No	No	No
Governor Control & Monitoring	Yes	Yes	No	No	No	No	No	No	Yes
Excitation & AVR Control & Monitoring	Yes	Yes	No	No	No	No	No	Yes	No
Mechanical Protection Monitoring	Yes	Yes	No	No	No	No	Yes	No	Partia l
GIS and	Yes	Yes	No	No	No	Yes	No	No	No



Elec. Protection Monitoring									
Unit Single Line Display	Yes	Yes	No	No	No	Yes	No	No	No
GIS Single Line Display	Yes	No	No	No	No	Yes	No	No	No
Generator CB Open, Close Control and Monitoring	Yes	Yes	No	No	No	Yes	No	No	No
Line & Bus Coupler CB Open, Close Control	No	No	No	No	No	Yes	No	No	No
Line & Bus Coupler CB Open, Close Monitoring	Yes	No	No	No	No	Yes	No	No	No
Interlocks & Trips	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
MIV Control & Monitoring	Yes	Yes	No	No	No	No	Yes	No	No
Intake Gates and valve house Control &	Yes	Yes	Yes	Yes	No	No	No	No	No



Monitoring									
Desilting Gates Control & Monitoring	Yes	Yes	Yes	Yes	No	No	No	No	No
Power Line Carrier Interface	Yes	Yes	No	No	No	Yes	No	No	No
Transformers RTU Monitoring	Yes	Yes	No	No	No	Yes	No	No	No
Unit Instrumentation Display	Yes	Yes	No	No	No	No	Yes	No	Partial
Dam, Tailrace and Surge Shaft Instrumentation Display	Yes	Yes	Dam only	Dam only	Tailrace only	No	No	No	No
Vibration Monitoring Display	Yes	Yes	No	No	No	No	Yes	No	No
AC Auxiliary Systems	Yes	No	No	No	Yes	No	No	No	No
DC Auxiliary Systems	Yes	No	No	No	Yes	No	No	No	No
UPS System	Yes	No	No	No	Yes	No	No	No	No
DG Set	Yes	No	Yes	Yes	Yes	No	No	No	No



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh					Particular Technical Specifications				
					Volume II Section-II				
					Sub-Sec. 7: Unit Control, SCADA, Automation & Communication				

Control and Monitoring									
HVAC Monitoring	Yes	No	No	No	Yes	No	No	No	No
Fire Fighting Monitoring	Yes	No	No	No	Yes	No	No	No	No
Auxiliary Mechanical Monitoring	Yes	No	No	No	Yes	No	No	No	No
Data Interchange with Intelligent Devices and other Nodes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	No
CCTV and VoIP Interface	Yes	No	Yes	Yes	No	Yes	No	No	No

f. Data Acquisition

The CS shall continuously scan and process the information from the input and output modules, and intelligent devices. The information shall be available system wide and shall be displayed, integrated into the control logic, logged, trended, alarmed, integrated into operator displays:

- Digital status inputs shall be processed for changes from the previous status. All digital input changes shall be collected, correlated and time tagged;
- Analog values shall be read, converted to engineering units, and stored

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

periodically.

g. Controls:

- The CS shall be capable of performing discrete, continuous, and sequential controls;
- The CS shall respond to control commands initiated from the OWS and HMI screen or by control algorithms in the PLC's or local controllers. The control commands shall be open and close; raise and lower; set-point control; and sequential control;
- The open and close control commands shall be used for the direct opening or closing of circuit breakers, switches, valves and other two-position devices;
- The set point controls shall be used as inputs for MW, MVAR and kV control;
- The sequential controls shall be used for the unit automatic start / stop sequences.

h. Discrete Raise and Lower and Set-point Control:

- Discrete raise and lower and set-point control of MW and frequency shall be provided as specified in Governing System;
- Discrete raise and lower controls of MVAR and kV shall be provided as specified in Excitation System;
- Discrete raise and lower and set-point controls shall be manually entered by the Operator at the OWS and HMI screens or automatically generated by the control algorithms as part of a control sequence;
- Set-point control of MW, MVAR and kV shall be manually entered, via interactive templates from the OWS and HMI screens or internally generated by the control algorithms;
- Voltage and Frequency discrete raise and lower controls shall be provided at the Synchronizer Panel of the UCB.

i. Unit Control Sequences:

- The unit PLC's shall perform the automatic starting and stopping of the generating units in conjunction with the excitation and governing system controller and with the start permissive signals;
- The algorithm shall be designed to alarm for any discrepancies between the units's current and expected status at any stage of the sequences;
- The Contractor shall define the exact sequence, pre-start conditions, timers, etc.

j. Governor Control

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

The redundant Governor Control shall be directly interfaced to the redundant Unit Process Control Network.

k. Static Excitation and AVR:

The excitation and redundant AVR shall be directly interfaced to the redundant Unit Process Control Network.

l. 220 kV Substation:

The 220 kV GIS substation shall be provided under separate package. However, all application software and converters required for the protection, monitoring and control of the 220kV Substation shall be developed and implemented in the GIS Substation SCADA and interfaced with the CS under the scope of this bid.

m. Interlocks and Trips:

Electrical protection interlock and trip signals are hardwired to the Unit Control Board (UCB), Unit Protection Boards (UPB), Excitation (ET), Governor Control, Penstock Protection Valve Control Board (PPVCB) and the Intake Control Board (ICB). The redundant Soft interlocks and trips shall be implemented from the ICB and PPVCB to the UCBs. Additional soft interlocks and trip signals shall be provided as required for the safe operation of the turbine-generating units, balance of plant equipment and auxiliary systems soft in addition to the hardwired interlocks and trips.

n. Unit and GIS Electrical Protection:

- Electrical Protection is comprised of Intelligent Multifunctional Relays installed in Protection Boards provided. The Intelligent device are controlled and monitored by

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

application software implemented in the GIS Substation SCADA and interfaced with the CS.

- The Unit and GIS electrical protection is provided and shall be integrated to the GIS SCADA and Main SCADA as shown on SCADA System Architecture drawing.
- Three redundant Unit Protection Boards (UPB-1,2,3) shall be provided on the Generator floor for the protection of the Generators, the Generator Transformers, the Excitation Transformer and the Unit Auxiliary Transformers.
- Two redundant Station Aux. Transformer (SAT UPBs) shall be provided on the Generator floor.
- GIS protection shall comprise the system A & B Line Protection Boards, the Bus Protection Board, the Breaker Failure Protection Board and the Common RTU Board.
- These boards shall be located in the Control Room which shall also house the GIS SCADA.

o. Vibration Monitoring System Interface:

All application software and converters required for displaying the reading of Vibration Monitoring System on the CS shall be provided.

p. Balance of Plant:

All application software and converters required for the monitoring and control of the Electrical Balance of Plant, the Mechanical Balance of Plant and all production related common auxiliary equipment shall be developed and implemented in the Common Control Board (CCB).

Systems which are part of the EBOP include: the 11 kV and 415 V AC Auxiliary Systems, the 220 V DC Auxiliary Systems, the 240 V AC UPS Systems, the Powerhouse DG Sets, the Intake area DG set and miscellaneous building safety systems and auxiliaries.

Systems which are part of the MBOP include: the HVAC systems, the Fire Fighting systems, the Drainage, Dewatering and Domestic Water systems, the Sanitary system and miscellaneous building systems.

q. Intake Gates Control, Main Inlet Valve Control, PPV and Instrumentation:

- Gates and their control and monitoring of Intake area are provided under this package. All application software and converters required for the monitoring and control of the Intake Gates and other gates shall be developed and implemented in

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

the Intake Control Board (ICB). All instrumentation (position, level, flow, etc.) shall be connected to ICB analogical I / O module;

- Control and monitoring of Valve house are provided under this package. All application software and converters required for the monitoring and control of the spillway Gates shall be developed and implemented in the PPVCB. All instrumentation (position, level, flow, etc.) shall be connected to ICB analogical I / O module;
- The Main Inlet Valve Control is provided under this package. All application software and converters required for the monitoring and control of the main inlet valve shall be developed and implemented in the MIV PLC;
- Draft Tube & Tailrace instrumentation (level) & Tailrace gate control / monitoring panels are to be connected to the powerhouse Common Control Board (CCB).

r. Information Interchange with Intelligent Devices and other Nodes:

The information interchange with intelligent devices and the PCS shall be over the Unit Process Control Network and shall use industry standard communication protocols. Access to real time and historical data shall be via standard open access formats such as Open Database Connectivity (ODBC). The intelligent devices shall be configured to transmit time tagging of events such as relay protective function trips.

s. CCTV and VOIP Interface:

These systems shall be integrated to the SCADA LAN network through dedicated Optic Fibers.

- t. SCADA shall have the provisions for implementation of Automatic Generation Control (AGC) as per the requirement notified by the National Load Despatch Centre (NLDC). All the end equipment, integration of the same to the gateway/RTU with necessary

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

firewall required for implementation of Automatic Generation Control (AGC) shall be supplied by the bidder along with their successful commissioning.

#### 7.3.6.5 Historical Data Management (HDM) Software

##### a. General Requirements

- The HDM software shall be provided for collecting, storing, and reporting historical operating data of the power plant system. Data shall be collected at periodic intervals and stored in historical files;
- The historian shall be synchronized with the plant GPS time system.

##### b. Performance

- The data historian shall provide a minimum sustained performance rate of at 20,000 values per second at the largest tag configuration;
- The HDM shall be capable of collecting and storing a minimum of 100,000 tags on a single computer;
- The data historian shall provide 10 millisecond time stamp resolution;
- It shall be possible to archive historical files on removable media or other hard drives for storage, without the need to stop the historian;
- The data management software shall employ data compression to allow optimal data storage without affecting the performance and without distorting the data;
- The historian storage system shall be sized to hold at least 10 years of history for all project points including 30 percent spares;
- The historian shall support redundant configurations and provide high availability. The data collection system shall automatically switch to the best available source

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

should the primary collector fail. Latest Microsoft Cluster Server shall be supported to enable 24 / 7 / 365 data availability for increased uptime.

c. Configuration and Security:

- The system configuration shall be done via web based administration tools;
- All configuration changes including adding new tags must be “on-line” without the need to stop and restart the data historian;
- The system shall automatically import the data type, description, tag name, and other data characteristics from the data source, without a need to retype the tag information;
- Role based security shall be utilized to restrict user access to different administration, system and user functions;
- All configuration changes, user connections, security violations and other system messages shall be logged, and the log shall be available for monitoring by the



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

administrators. The logs shall not be allowed to be modified or deleted by the users or the administrators.

d. Data Collection

- The system shall support tags from multiple data sources utilizing a graphical interface. Data sources include all systems interfaced with the CS;
- The periodicity of data collection and storage shall be configurable for each point type;
- The system shall support input scaling of analog values;
- The systems shall support OPC "Alarms & Events" and collect and store alarms and events from any OPC Alarms & Event server.

e. Calculations and Analysis:

- The historian shall provide a calculation engine for automatic calculations and analysis with incoming and archived data and storing the result in an historian tag;
- The calculation engine shall support installation on remote computers;
- The calculations shall support an unlimited number of trigger tags;
- The calculation engine shall be able to perform mathematical and statistical operations, e.g., interpolation, maximum, minimum, average over a specific time, standard deviation, time weighted total, totalizing, etc;
- The calculation engine shall support data filtering;
- The calculation engine shall support Visual Basic scripting;
- The calculation engine shall support time based, tag based and manual triggers;
- The calculations shall have execution time control and means to disable the calculation if it exceeds a configurable maximum execution time;
- The historian shall be capable of performing downtime analysis for process areas and subsystems.

f. Multiple Server Configuration

- The system shall support multiple server configuration and data forwarding from one historian to a remote historian;
- Tag browse and import shall be possible from the remote historian, without a need to re-configure the tags at the remote historian.

g. Client Interfaces:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

- Interface to Microsoft Excel shall be provided. The interface shall be integrated with the historian package and should utilize drop down menus and toolbars. The interface shall be capable of extracting process, calculations and system data and developing reports using MS Excel. The interface shall provide capabilities for importing and modifying tags, stored data and user comments;
- Interface to OLE DB shall be provided. The interface shall allow process, calculations and system data to be extracted and viewed by applications such as SQL servers and Crystal Reports TM. Modification of historian data through this interface shall not be allowed;
- Interface to Human Machine Interface / SCADA Systems shall be provided for monitoring of the historian's process and calculations data. The interface shall be able to convert Universal Time Co-ordinated (UTC) to standard local and daylight savings time;
- Web based interface to the historian shall be provided to browse, display and chart data.

Manufacturer:

- OSIsoft, PI System;
- Or approved equal.

#### 7.3.6.6 Historical Data Management (HDM) Hardware

The HDM software shall be installed on the Historian Work Station servers. No separate server is required.

#### 7.3.6.7 Historical Data Management (HDM) Application Software:

- a. The HDM software shall be configured so as meet the requirements of this section:
- b. All analog and discrete points shall be logged. The scan times for each analog point shall be submitted with the point list and approved by the Employer.

#### 7.3.6.8 Plant Networks

- a. General Requirements:
  - The Local Area Networks (LANs) shall provide interconnectivity of the Control Boards (PLCs and HMI), the SCADA Work Station and Servers, the Governor Controls, the AVR and Excitations, the Mechanical Protection, the Vibration Monitoring Systems and future Analysis Work Station (ZSC), the Distributed Control Devices, the Electrical Protection relays and GIS SCADA, the Energy

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Management Meters and Work Station (EMS), the Power Line Carrier Dispath Work Station (DWS), the transformer RTUs and the Common RTU specified in other sections. The VoIP and CCTV Networks shall use separate Optic Fibers and implement herein. The LANs shall be seamlessly integrated to meet the system performance requirements specified herein;

- The LAN network shall be as shown on the SCADA System Architecture drawing. The drawings show the general principal and thus not all required components and devices are shown. The Contractor shall provide all additional components and devices required to meet the requirements of the specification;
- One hot redundant Process Control Network (LAN-1 and LAN-2) shall be provided for all PLCs, RTUs, Intelligent Devices, Servers, Work Station Processors, Ethernet Switches, Routers, etc. The Network shall be provided with both redundant hardware and communication links. The Network shall be Ethernet based with a minimum speed of 100Mbps. LAN-1 and LAN-2 networks shall be independent, supplied by different power supplies and physically isolated one from the other;
- All Unit Process Control Networks shall be interconnected to form one redundant common Plant Process Control Network. This network shall be provided with both redundant hardware and communication links. The Plant Process Control Network shall be Ethernet based with a minimum speed of 100 MB/s and shall have 1 GB/s capability;
- One redundant Storage Area Network (SAN) shall be provided to interconnect all the network storage equipment and multipurpose servers;
- The SAN network shall be connected to the Plant Process Control Network via the multipurpose servers;
- The panel mounted HMI workstation shall be connected to the Unit Process Control Network as required to act as backup OPC and I / O servers and provide

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

local control in case of a failure of the multipurpose OPC / HMI servers and / or Plant Process Control network;

- The panel mounted HMI workstations shall be configured to provide backup OPC and I / O server capability;
- Each PCS cabinet shall have two (2) spare RJ45 Ethernet network port for laptop connection.

b. Communication Media

- The communication media for the in-plant networks shall be multimode fiber optic cables. At least 12 spare fibers shall be provided in each cable. Not less than 4 spare fibers shall be provided in each cable for use by others. The cables shall be terminated to a patch panel. Patch cables shall be run from that panel to the devices;
- Category 6 shielded copper cables can be used for short distance runs inside cabinets or as approved by the Engineer In-charge. Standard RJ45 outlets and connectors shall be used as required.

### 7.3.7 Shop Assembly and Tests

1 Factory Acceptance Test (FAT):

- a. The Contractors shall prepare a FAT Plan and shall submit it to the Employer for review and approval;
- b. The FAT Plan shall consist of the following:

a. FAT Overview:

This shall describe the test configuration, the hardware and software simulator, the measurement tools, the complete test schedule, the forms for recording test results, the classification of discrepancies, and the processing of test reports.

b. Test Procedures:

This shall describe the test preconditions and assumptions, the detailed steps

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

to be taken for each test and the verification of results of each step.

## 2 General description; Pre-FAT & FAT Activity

The Test Procedures shall include both hardware and software tests and verification of the Historian System. As a minimum, the step-by step procedures shall include:

- a. Hardware components and assembly are in accordance with the specifications and the latest Employer-approved manufacturer drawings;
- b. Redundancy testing;
- c. Software protocols for all external communication ports between the relays or intelligent devices are functional;
- d. Databases are accurate and contain all of the I / O points identified by the Contractor's latest Employer-approved documents;
- e. Graphical displays are complete and functional;
- f. All Inputs and outputs are functional and properly calibrated;
- g. Software operating logic for the various systems complies with the requirements of the specifications and the latest Employer-approved Contractor documents.
- h. Networks function correctly.

## 3 Pre-FAT activities & FAT

A Pre-FAT shall be performed by the Contractor to verify that the system, as fully integrated, complies with all of the required functional details and that the system satisfies the response and resource utilization requirements. The Pre-FAT shall follow completely the test procedures of the FAT Plan reviewed by the Employer. The Contractor shall notify the Employer for the start date of the Pre-FAT at least four (4)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

weeks before the test. The Employer personnel will have an option to witness the pre-FAT activities:

- a. Contractor shall submit the test procedures for approvals of the Employer;
- b. The Contractor shall eliminate all discrepancies found in the pre-FAT, before the Factory Acceptance Test can be started;
- c. Employer shall witness the actual start of the FAT upon notification by the Contractor that the system is ready for the FAT;
- d. The FAT shall be started with a complete system generation performed by the Contractor. After the completion of the system generation, Contractor shall carry out the FAT test procedures;
- e. The last part of the FAT shall be devoted to the system performance tests using the normal and high-activity loading scenarios;
- f. All discrepancies found in the FAT shall be corrected prior to shipment of the system.

### 7.3.8 Installation and Field Test

#### 1. Availability Demonstration for SCADA system:

- a. The system Availability Demonstration (AD) shall be performed for a period of 1000 hours starting at the end of the Site Acceptance Test (SAT) for each controller and for the entire system once all units are in service after all problems have been corrected. Acceptance of the system shall be contingent upon the successful outcome of the availability demonstration;
- b. The software at the start of the AD shall be assumed to be 100% reliable, i.e., free of all known errors or defects in functionality and performance;
- c. The objective of the AD is to verify that the Average System Availability, A, for a 500 hour period of interest is equal to or better than specified, consistently for two successive time periods.

The Average System Availability, A, shall be calculated as:

$$A = [1 - (\text{Downtime}) / (\text{Period of Interest})] \times 100$$

Where “Downtime” in minutes is defined as the time during which any one or more

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

of the following conditions prevail:

- One Server or Operator station is out of service;
  - One Process LAN out of service;
  - One or more Controllers out of service;
  - HMI functions inoperative at one operator console;
  - System events logging function lost.
- d. The Average System Availability, A, shall be 99.98% or better. This is equivalent to a downtime not exceeding 6 minutes during a 500-hour period of interest;
- e. Within the AD period of 1000 hours, all two values of A for the two 500 hour periods of interest shall satisfy the 99.98% requirement;
- f. The recording and accumulation of downtime shall be subject to the following conditions:
- Restart and fail over times shall be counted;
  - Downtime due to software causes and to repair of software shall not be counted. All software errors and discrepancies found during the AD and during the Warranty Period shall be corrected by the Contractor;
  - Downtime due to Contractor-supplied hardware causes shall be counted and shall be the total time from the occurrence of the failure until the restoration to operation of the function lost;
  - Downtime due to problems in hardware not supplied by the Contractor shall not be counted;
  - Downtime due to undetermined causes shall be counted but will be discounted if later in the demonstration period it can be established as being due to a software problem or a problem in hardware not supplied by the Contractor.
- g. Repeatable or self-recurring failures may cause a suspension of the demonstration period. Only the first downtime shall be counted. The demonstration shall be resumed only after the failure has been corrected;
- h. Downtime caused by personnel action, which is not related to operation functions shall not be counted;
- i. For every downtime that is discounted or excluded, the same amount shall be discounted from the accumulated time of the period of interest;
- j. Rules for restarting the Availability Demonstration;
- k. If at time T, before the adjusted period of interest period has reached 500 hours, the adjusted downtime already exceeds 6 minutes by an amount x, the period of



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

interest may be extended by  $(x / 6) * 500$  hours;

- I. If the calculated extension exceeds 500 hours, or equivalently if x is 6 minutes or more, the availability test for that period of interest shall be restarted;
- m. If the calculated extension is equal to or greater than T, the availability

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

demonstration for that interest period shall be restarted.

## 2. Repair Procedures

- a. Whenever a failure occurs in any hardware or software component, regardless of whether it causes a downtime or not, the Contractor shall analyze the problem and carry out the necessary repairs.
- b. If the Contractor is not successful in locating and / or repairing the problem, the Employer shall be notified immediately. The Contractor shall then undertake the diagnosis & repair.
- c. If the failure had caused a downtime condition, the total repair time (diagnosis time plus actual repair time plus time to place the function back in service) shall be considered as downtime. If the Contractor had not succeeded in locating and repairing the problem, only the repair time of the Contractor shall be counted.

## 3. Loading Scenarios

- a. The normal loading scenario shall be simulated as follows:
  - All analog values updated at the specified scan cycles, processed without exception, and updated on the database;
  - Ten (10) analog alarms occurring every 5 minutes;
  - One (1) Intelligent Electronic Device communicating with the Controller;
  - One (1) status change received and alarmed every five (5) minutes;
  - One (1) display call up every ten (10) seconds on each monitor of all stations, each monitor having four active windows;
  - All periodic programs in execution;
  - Online display maintenance in progress;
  - Trending of four (4) variables in operation;
  - Offline software maintenance in progress.
- b. The high-activity loading scenario shall be simulated as follows:
  - Same as normal loading;
  - Four (4) analog alarms every five (5) per seconds;
  - Six (6) status alarms every two (2) seconds;
  - Fifty (50) DI or fifty (50) AI from each Controller, resulting in 300 DI or AI changing status within the first five (5) seconds of the disturbance. Then, one-

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

hundred (100) DI or AI per second changing status for the duration of the first minute, after which normal load shall be assumed.

- c. The performance tests for the high-activity loading scenario shall be repeated for one process LAN out of service;
- d. CPU Utilization: During the performance test with the high-activity loading scenario, the average CPU loading in any of the station servers shall not exceed 30% for a 1-hour period;
- e. Memory Utilization: Memory utilization for Controllers and PCS shall not exceed 30%. The final application software shall not occupy more than 30% of the Controller Station's memory.

#### 4. Control / SCADA system Performance requirements

##### a. Response Requirements:

The verification of response times for the system shall be made under the following

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

conditions:

- Process LAN; One device out of service or not used.
- High-activity loading scenario in effect.
- All response time requirements shall be wall-clock times.
- The time duration from the instant of a status change at the equipment location symbol is updated on a workstation HMI screen shall not exceed 1.5 sec.
- The overall call up time of any display, from the instant the mouse is clicked until the requested display is on the monitor complete with all dynamic data, shall have an average value not exceeding two (2) sec.
- The overall time for processing an alarm from the time it is generated in the field until it is updated on the alarm list and on the System Events List, the audible sounded, and the logging initiated, shall not exceed two (2) sec.
- Time-of-day displays on the HMIs shall be within two (2) seconds.
- The overall time from the initiation of command at visual display on the operator console to the output terminals of the field controller shall not exceed one (1) sec.

b. Periodicity Requirements and Time Synchronization.

Following periodicity requirements shall be met under normal loading conditions:

- Status-change scan two (2) seconds;
  - All closed loop variables two (2) seconds;
  - All other analog scan as per scan rate;
  - Data update on a window as per scan rate < three (3) s;
  - Time-of-day update on an HMI, as required to maintain two (2) seconds or better.
- c. All digital inputs system wide shall be GPS synchronized at ten (10) ms or better. Then sequence of Event (SoE) / Data logging for Electrical Protection system Alarms shall be time tagged with an accuracy of one (1) ms.
- d. System Overload
- The PCS shall be designed such that it can withstand severe system overloading or any condition worse than those defined for the high-activity loading scenario. No matter what the overload situation might be, HMI screen call up response times shall not be affected. All functions shall be operational

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

although degradation in periodicities within acceptable limits;

- No alarms shall be lost during system overloads;
- The Contractor shall describe the methods which shall be used to guarantee that during a system overload all critical functions will be operational, HMI screen call up response times shall be within the requirements specified, and no alarms shall be lost;

e. The Employer reserves the right to participate and monitor all installation, testing, trouble- shooting and repair activities.

#### **7.4 Optic Fibre Communication System**

a) In this specification, the term “Remote Sites” refers to the following project sites located outside the Powerhouse:

- Intake Area;
- Valve house area
- Heo Power House

b) The purpose of the communication system is to provide a full duplex path of communication between the Powerhouse SCADA and the remote sites for the Control and Monitoring of miscellaneous Gates and the instrumentation for the measurement of gate positions, water levels, water flows, and HPU pressure monitoring. The communication link between Tato-1 and Heo HEPs shall be established for tandem operation of both the power stations. The communication system also serves for the provision of a redundant VoIP and CCTV system;

c) The data to be communicated are water level of the different areas, equipment status and intake gates, other gates position and PPV. Opening and closing commands of gates are also transferred through the communication system. HPU systems at the remote sites are monitored to indicate Oil pressure, Oil level and Nitrogen pressure.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

VoIP and CCTV system shall be transmitted to the Powerhouse via dedicated fibers of the Optic Fiber Network;

- d) The communication converters, ethernet switches, routers, hubs, etc. shall be housed in the Control Board (ICB & PPVCB) and Patch Panels provided under the present Chapter;
- e) The numbers of monomode fibre in proposed ADSS cable / buried optic fiber cable (OFC) shall be 24 (twenty-Four).

#### 7.4.1 Communication System Description

The Contractor shall provide a complete communication system taking into account the limitations of the topology of the area.

The data transfer rate shall be sufficient to ensure that the SCADA system screen and update the data at an interval of two (2) seconds.

##### 7.4.1.1 Available Electrical Power

The electrical power equipment necessary for the communication systems at each site shall be supplied and installed by the Contractor as follows:

Intake & Valve house Area	Input	: 220 V AC, 50 Hz.
	Output	: 24 V DC.

##### 7.4.2 Site Acceptance Testing

The Control and Monitoring of gates and the display of instrumentation readings shall be available at the Fiber Optic Work Stations (OWS4), on the Unit Control Board HMIs and on the Operator Work Stations (OWS1, 2, 3) located in the main control room.

The Contractor shall commission the transmission and reception of VoIP and CCTV signals.

## 7.5 Drawings & Documents Submittals

### a. General Drawings

At minimum, the following outline drawings of the major components, showing the specific features listed here shall be submitted, as well as any additional submittals

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

requested by the Employer.

Controls:

- A system architecture drawing that identifies all boards, panels, controllers and computers that will host the system software modules;
- An overall diagram and subsystem diagrams including major software modules, data structures and data flow, including interfaces with other modules. Location of PLC, HMI, I / O modules, Work Stations, screens, printers and miscellaneous devices for each location shall also be included;
- Front, rear and side views for all cabinets;
- Furniture of the two (2) Control Rooms layout with dimensions and weights.

b. Detailed Drawings

At minimum, the following detailed drawings of the major components, showing the specific features listed here shall be submitted, as well as any additional submittals



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

requested by the Employer.

#### Controls Detail Drawings

- Instruments and control devices details, including location and size;
- Inside view of equipment arrangements, including terminal blocks and cable entrance details for external cables for control cabinets;
- Inside view of equipment arrangements, including terminal blocks and cable entrance details for external cables for protection cabinets;
- Inside view of equipment arrangements, including terminal blocks and cable entrance details for external cables for machine monitoring system cabinets;
- Conduit and cable entrances;
- Schematic diagrams, elementary and three-line diagrams for measuring and protections;
- Wiring diagrams and cable schedules for control protection and machine condition monitoring systems;
- Termination drawings / schedules and external connections diagrams for installation;
- System architecture and network diagrams overall and for each system, network configuration descriptions, managed Ethernet switches configuration, communication devices programming and configuration;
- PID's, loop diagrams, block diagrams and logic diagrams, including ISA Form 20 for all instrumentation;
- Recommended settings for protective and timing relays and instruments, including all alarm / trip points, time constants, gains and timing circuits;
- Logic Schematic drawings of the Auto-sequencer for normal and emergency operations including the interfaces with all external systems and devices including those provided under other packages. Sequence of operations shall be detailed for each possible command and / or event;
- Control and wiring drawings of each Control Board;
- Interface drawings for PLC system and manual control system;
- The Electrical and Mechanical protection logic drawings indicating all start permissive interfaces.

c. Instructions, Procedures and other Drawings and Documents

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

At minimum, the following instructions, procedures and other drawings and documents of the components, showing the specific features listed here shall be submitted, as well as any additional submittals requested by the Employer.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

A. All components as applicable

a) Bills of material:

- A General bill of material listing all major elements of the Unit Control, SCADA and Automation systems;
- Secondary bills of materials detailing the components within a Board shall be submitted with the corresponding drawings, on the drawings.

b) Factory tests and shop inspection schedules, test and inspection procedure, checklists, and data collection sheets;

c) Handling and storage instruction manuals;

d) Storage details for all applicable components including square footage, temperature, and humidity control requirements;

e) Assembly schedule, procedures and checklists;

f) Installation instruction manuals;

g) Site test non-destructive test program schedules, test procedures, checklists, and data collection sheets;

h) Field check out, start-up, testing procedures and manuals;

i) List of instructions for all tests and checks to be performed at each stage including inspections and measurements, assembly, start-up and commissioning, and final signature Test;

j) Data sheets as follows:

- Manufacturer's data sheets for all of the HMI components used in the system including but not limited to: server computers, workstation computers, monitors, printers, software, etc;
- Manufacturer's data sheets for all control and protection switchboard components including but not limited to: control switches, pushbuttons, indicating meters, indicating lights, auxiliary control relays, power supplies, system protective relays, etc;
- Manufacturer's data sheets for instrumentation and other field devices;
- Data sheets and specifications of PLC, I / O modules, Work Stations, Screens, Printers, Ethernet Switches, Routers, etc;
- Catalogue cuts;
- Overall dimensions and layout;
- Nameplates Schedule.

B. Controls Documents

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Technical specifications and interfacing requirements including data format for equipment furnished by others.

Application Software Functional Design, including a functional description of the application software for the unit and plant monitoring and control. Each module shall be described in detail and include the functions of the module and its interface with other modules, field input / outputs and HMI. Application software functional design submittal shall include, but not be limited to:

- Description of the functions to be performed by each software module;
- Detailed description of all interfaces between the system and the operator shall be provided. All related HMI graphics shall be shown;
- Description of the distribution of the modules, loading of controllers and memory requirements;
- Naming convention for the input, output and software points;
- Input, output and software points' database;
- Description of the impact of power failures, system failures, redundancy switch over, normal restarts for all systems and subsystems and application software approach for mitigating issues;
- Description of the original vendor software and programming environment with a list of software licenses provided with the system;
- Controller programming details: The programming shall be fully annotated with sufficient information for determining operation of the system;
- HMI programming details: HMI programming for the servers and workstations and all of the graphic screen configurations, alarm system configuration, short term history configuration, historian configuration, reports configuration, etc;
- Input, output and software database;
- Manufacturer's Information;
- The Manufacturer's information shall be tabulated / located in subfolders based on the usage of the devices and equipment. • Manufacturer's data sheets for all

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

Controller components used in the system including but not limited to: CPUs, power supplies, I / O modules, communication modules, software, etc;

- Manufacturer's data sheets for all network and communication components used in the system including but not limited to: Ethernet switches, cables, connectors, radios, antennas, power supplies, software, etc.

## **7.6 Operation and Maintenance Manuals**

Operations and Maintenance instructions, including descriptive text detailing operation of the new system controllers shall be included. All modes of operation shall be covered including, but not limited to: generator start, stop, synchronizing, loading, unloading, automatic and manual operation, emergency stop, graphics and alarm system utilization, short- and long-term history, reports, etc. The maintenance procedures shall include the weekly, monthly, quarterly, six-monthly and annual maintenance schedules, including the trouble-shooting details.

### **7.6.1 Operation and Maintenance Manuals**

The Contractor shall submit for approval of the Employer, a complete set of Operation and Maintenance Manuals showing the operation of the communication system and the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

maintenance procedures to follow in order to maintain a high degree of availability of the communication system.

The Operation Manual shall show in detail how the system works, the limitations and the explanation of the technology chosen. The Manual shall explain how to put the system back in service upon a failure or after a blackout.

The Maintenance Manual shall explain the operation of the system and present under a flow chart format, how to troubleshoot the system and perform an electronic card or module replacement.

#### 7.6.2 Operation and Maintenance Personnel Training

The Contractor shall arrange a training session for operation and maintenance personnel at site with the real equipment and using the Operation and Maintenance manuals supplied. Drawings and Documents Submittals

The Contractor shall submit the overall communication network diagram, including the major components of the system, RTU and AC / DC auxiliary power supply systems for the approval by the Employer.

#### 7.7 Spare Parts, Consumables & Special Equipment

1. The spare parts mentioned hereunder are meant for use by the Employer for 5 years trouble free operation & shall not be used as erection or commissioning spares required during the works.
2. All spare parts shall be of the same material, workmanship, and manufacturer as the corresponding original parts, completely interchangeable and packaged for long-term storage.
3. If any additional spare parts required for a 5 years trouble free operation period are recommended by Contractor, these shall be listed as "Recommended Spares" and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.
4. All spare parts shall be suitably packed, clearly marked and ready for long term indoor storage.
5. The submittal shall include a separate list of additional spares, consumables and special equipment recommended by the Contractor, together with unit and total cost.
6. The submittal shall include handling and storage instructions for all spare parts, consumables and special equipment.
7. The submittal shall include a list of any specialty software or hardware tools used

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

during project and not listed or provided under other submittals.

8. Minimum spare parts are to include a complete set of antennas transmitter / receiver components as well as a power supply, a router, a hub, a medium converter and an Ethernet Switch of each type.
9. The Contractor shall supply all the special tools and testers necessary for normal and



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

routine maintenance of the communication system

#### 7.7.1 List of “Mandatory Spare” parts

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

S no.	Description	unit	Quantity
1.	<b>Spares for Central Control Room Equipment</b>		
1.1	Operator Work Station PC / Process Server PC comprising, mouse, keyboard, network interface cards	Set	1
1.2	Monitor- Colour, TFT-LED, 22-inch screen, for OWS / Server and EWS PC	No.	1
1.3	<b>Process bus gigabit Ethernet TCP / IP</b>		
a)	Multimode gigabit Ethernet switch; Two (2) nos. of each type	Lot	1
b)	Single-mode gigabit Ethernet switch; Two (2) nos. of each type	Lot	1
c)	Other network component like patch panels, repeaters / hubs [Two numbers of each type]	Lot	1
1.4	<b>Field bus media converter modules</b>		
a)	Multimode Media converter module with connecting hardware [Two numbers of each type]	Lot	1
b)	Field bus connectors [of each type]	No.	2
1.5	Other cards / modules [for GPS based Time synchronizing system- synchronizing pulse distribution, power supply etc.] (each type)	No.	1
1.6	Slave clock for GPS based Time synchronizing system (Large Digital display LED)	No.	1
1.7	a) Multifunctional B / W Laser Printer Ink Cartridges b) Colour Laser Printer Ink Cartridges c) Dot Matrix Printer Ink Ribbon d) B / W Laser Printer Ink Cartridges	No. No. No. No.	10 10 10 10
2.	<b>Spares for Group / Local Control cubicles</b> (Unit Control Board, Common auxiliary and GIS control cubicles)		
2.1	PLC set [complete with redundant power supply cards, CPUs, communication interface cards, 19" mounting rails / racks, synchronizing modules, FO synchronizing cable & connectors, backup batteries, memory card and other accessories]	Set	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

S no.	Description	unit	Quantity
2.2	HMI touch screen, Panel mounted Monitor	Set	1
2.3	Process I / O cards (DI, DO, AI and AO cards) (Four (4) numbers of each type)	Lot	1
2.4	Field isolation (Optical / Electromagnetic) auxiliary relays, front connectors, interface modules, flat intra panel cables and necessary for I / O cards at 2.3 above including, connectors, patch cords and splice boxe. (Four (4) numbers of each type)	Lot	1
2.5	Field-bus Interface module / and connecting pre-fabricated cables, Two (2) numbers of each type	Lot	1
2.6	Ethernet communication processor cards / module (Two (2) numbers of each type)	Lot	1
2.7	Power supply modules / DC-DC converters, 220V to 24V (Two (2) numbers for each type & rating)	Lot	1
2.8	a) Automatic synchronizer b) Synchrocheck relay c) Manual synchronizing devices (pushbuttons, control switches, pilot lamps) and instruments (Voltmeter, Frequencymeter, DV, DF). (One (1) number of each type)	Unit Unit Lot	1 1 1
2.9	a) Protection tripping Relays c / w socket (1 of each type) b) Auxiliary Relays c / w socket (4 of each type) c) Interposing Relays c / w socket (12 of each type)	Lot Lot Lot	1 1 1
2.10	Miscellaneous Indicating lamps, rotary switches, semaphore indicators, push buttons, special relays, indicator and alarm switches; 20% or two (2) no [whichever is higher] each type	Lot	1
2.11	Terminals, ferrules, ac & dc power supply MCBs, auxiliary contacts, diodes for power supply isolation; 20% or two (2) no [whichever is higher] of each type	Lot	1
2.12	Fuses (200%) of each type	Lot	1
2.13	Other cubicle spares and accessories, Door limit switches, space heaters, illuminating lamp, power sockets, cubicle cooling fan etc. (4 of each type)	Lot	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 7: Unit Control, SCADA, Automation & Communication

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.

#### 7.7.2 Special tools and maintenance equipment

1. Contractor shall supply, for hand over to Employer one complete set of special tools and maintenance equipment, recommended by Contractor for complete SCADA and LAN system. The list of these tools shall be approved during detailed engineering.
2. However, it shall include at least the following maintenance equipment for repairs and maintenance with descriptions and quantities of the following: -
  - Standard Electronic Tool kit : Two (2) sets  
[Comprising Digital Multi-meter, loop check / Continuity testers, set of screw drivers, wire-stripper, crimping tool]
  - Optical fibre Splicing kit : One (1) set
  - Optical fibre network testing kit : One (1) set
  - Tag printer : One (1) no.
  - Any other Maintenance & Testing tool recommended by vendor.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

## Volume-II

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### Section II Sub-Section 8 Protection and Metering

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

## **TABLE OF CONTENTS**

<b>8</b>	<b>PROTECTION, METERING, AUTOMATION &amp; COMMUNICATION .....</b>	<b>3</b>
8.1	PROTECTION AND AUTOMATION .....	3
8.1.1	General & Scope .....	3
8.1.2	Standards and Codes .....	20
8.1.3	Design Requirements .....	24
8.1.4	Protection - Design Philosophy .....	31
8.1.5	Equipment Arrangement and Construction: .....	32
8.1.6	Product Description .....	34
8.1.7	Tripping Logic .....	113
8.2	ENERGY MANAGEMENT SYSTEM .....	124
8.2.1	General & Scope .....	124
8.2.2	Reference Standards .....	125
8.2.3	Scope of Requirements .....	127
8.2.4	Operating conditions .....	128
8.2.5	Specification for Energy Management System (EMS) .....	129
8.2.6	Erection .....	131
8.3	SHOP ASSEMBLY AND TESTS .....	132
8.4	REPORTS, STUDIES, DRAWINGS & DOCUMENTS SUBMITTALS .....	141
8.4.1	Short – Circuit and Protective Coordination Study .....	141
8.4.2	Load Flow Study .....	145
8.4.3	Stability Study .....	147
8.4.4	Dimensioning of Current Transformers for Protection Application: .....	149
8.4.5	Drawings .....	150
8.5	OPERATION AND MAINTENANCE MANUALS .....	154
8.6	SPARE PARTS, CONSUMABLES & SPECIAL EQUIPMENT .....	155
8.6.1	List of “Mandatory Spare” parts- .....	155
8.6.2	Special Tools and Maintenance Equipment: .....	158
8.6.3	Relay Test Kit- .....	159

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

## **8 PROTECTION, METERING, AUTOMATION & COMMUNICATION**

### **8.1 Protection and Automation**

#### **8.1.1 General & Scope**

##### **8.1.1.1 General Requirements**

##### **a. General**

This section stipulates the General Technical Requirements under the Contract and will form an integral part of the Technical Specification.

The provisions under this section are intended to supplement general requirements for the materials, equipments and services covered under other sections and is not exclusive. However, in case of conflict between the requirements specified in this section and requirements specified under other sections, the requirements specified under respective sections shall hold good.

##### **b. Instruction to Bidders:**

- i. The bidders shall submit the technical requirements, data and information as per the technical data sheets provided in the bid documents;
- ii. The bidders shall furnish catalogues, engineering data, technical information, design documents, drawings etc. fully in conformity with the technical specification.
- iii. It is recognized that the Contractor may have standardized on the use of certain components, materials, processes or procedures different than those specified herein. Alternate proposals offering similar equipment based on the manufacturer's standard practice will also be considered provided such proposals meet the specified designs, standard and performance requirements and are acceptable to the Purchaser. Unless brought out clearly, the Bidder shall be deemed to conform to this specification scrupulously. All deviations from the specification shall be clearly brought out in the respective schedule of deviations. Any discrepancy between the specification and the catalogues or the bid, if not clearly brought out in the schedule, will not be considered as valid deviation;
- iv. Wherever a material or article is specified or defined by the name of a particular brand, Manufacturer or Vendor, the specific name mentioned shall be understood as establishing type, function and quality and not as limiting competition;
- v. Equipment furnished shall be complete in every respect with all mountings, fittings, fixtures and standard accessories normally provided with such equipment and / or



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

needed for erection, completion and safe operation of the equipment as required by applicable codes though they may not have been specifically detailed in the Technical Specifications unless included in the list of exclusions. Materials and components not specifically stated in the specification but which are necessary for commissioning and satisfactory operation of the switchyard unless specifically excluded shall be deemed to be included in the scope of the specification and shall be supplied without any extra cost. All similar standard components / parts of similar standard equipment provided, shall be inter-changeable with one another;

- vi. The Contractor shall supply type tested equipments and materials. The test reports shall be furnished by the Contractor along with equipment / material drawings. In the event of any discrepancy in the test reports i.e. any test report not acceptable due to any design / manufacturing charges or due to non-compliance with the requirement stipulated in the Technical Specification and / or IEC / IS, same shall be carried out without any additional cost implication to the Purchaser. The Purchaser reserves the right to get any or all type tests conducted / repeated. In case of repetition of the type and special test, if required by the purchaser, these tests fees shall be payable.

c. Standards:

- i. The works covered by the specification shall be designed, engineered, manufactured, built, tested and commissioned in accordance with the Acts, Rules, Laws and Regulations of India;
- ii. The equipment to be furnished under this specification shall conform to latest issue with all amendments of standard specified under respective Chapters of the specification;
- iii. In addition to meeting the specific requirements called for in the respective sections of the Technical Specification, the equipment shall also conform to the general requirement of the relevant standards, which shall form an integral part of the specification;
- iv. The Bidder shall note that standards mentioned in the specification are not mutually exclusive or complete in themselves, but intended to compliment each other;
- v. The Contractor shall also note that list of standards presented in this specification is not complete. Whenever necessary the list of standards shall be considered in conjunction with specific Indian IS and IEC standards;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- vi. When the specific requirements stipulated in the specifications exceed or differ those required by the applicable standards, the stipulation of the specification shall take precedence;
- vii. Other internationally accepted standards which ensure equivalent or better performance than those standards referred shall also be accepted. Copies of such standards shall be submitted by the bidder;
- viii. In case governing standards for the equipment are different from IS or IEC, the salient points of difference shall be clearly pointed out in additional information schedule of Vol III along with English language version of relevant extract of the same standard. The equipment conforming to standards other than IS / IEC shall be subject to Purchaser's approval;
- ix. The bidder shall clearly indicate in his bid the specific standards in accordance with which the works will be carried out.

d. Equipment Performance:

- i. The equipment furnished under this specification shall perform all its functions and operate satisfactorily without showing undue strain under normal operating conditions;
- ii. All equipments shall also perform satisfactorily under various electrical, electro-mechanical and meteorological conditions prevailing at the site of installation.
- iii. All equipment shall be able to withstand all external and internal mechanical, thermal and electromechanical forces due to various factors like temperature variation, humidity, short circuit, etc.;
- iv. The bidder shall design by considering the various forces which the terminal connectors of the equipment shall be subjected;
- v. Operating times of circuit breakers, protective relays, Power Line Carrier and Network Communication equipment have been specified in respective sections.
- vi. The Contractor shall make all the necessary calculations and reports to prove that the provided equipment and systems have been properly selected to operate under the conditions prevailing at site. The Contractor shall provide the calculations and reports for review.

e. Engineering Data:

- i. The submittal of engineering data by the Contractor shall be in accordance with the Schedule for each set of equipment as specified in the Technical Specifications;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- ii. The review of these data by the Purchaser will cover only general conformance of the data to the specifications and documents, interfaces with the equipment provided under the specifications, external connections, and the dimensions which might affect substation layout. This review by the Purchaser may not indicate a thorough review of all dimensions, quantities and details of the equipment, materials, any devices or items indicated or the accuracy of the information submitted. This review and / or approval by the Purchaser shall not be considered by the Contractor, as limiting any of his responsibilities and liabilities for mistakes and deviations from the requirements, specified under these specifications and documents;
  - iii. All engineering data submitted by the Contractor after final process including review and approval by the Purchaser shall form part of the Contract Document and the entire works performed under these specifications shall be performed in strict conformity, unless otherwise expressly requested by the Purchaser in Writing.
- f. List of Documents:
- i. The list of drawings / documents which are to be submitted to the purchaser shall be discussed and finalized by the purchaser at the time of award;
  - ii. The Contractor shall necessarily submit all the drawings / documents unless anything is waived. The Contractor shall also supply calculations, studies, bills of material, Input and Output lists, operating sequences, setting reports, cable schedule, wiring and connection schematics and pre-commissioning test procedures and reports;
  - iii. The Contractor shall submit 6 (Six) sets of drawings / design documents / test reports as may be required for the approval of the Purchaser.

g. Drawings

All drawings submitted by the Contractor including those submitted at the time of bid shall show enough details to indicate the type, size, arrangement, material description, Bill of Materials, weight of each component, break-up for packing and shipment, the external connections, fixing arrangement required, the dimensions required for installation and interconnections with other equipments and materials, clearances and spaces required for installation and interconnections between various portions of equipments and any other information specifically requested in the specifications.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

#### h. Approval Procedure

The scheduled dates for the submission of these as well as for, any data / information to be furnished by the Purchaser shall be discussed and finalised at the time of award. The Contractor shall also submit Six (6) copies of all drawings / design documents / test reports for approval of the Purchaser.

#### 8.1.1.2. Scope of work:

- a. The scope covers the detailed requirements for the design, manufacture, factory testing, transport, delivery, installation, site testing and commissioning of the Protection, Automation, Metering and Communication system (PAMS) covering all the production equipment, 220 kV GIS and GIB equipment and the 220 kV AIS equipment as shown on the drawings and described herein. The protection, control and communication systems are to be hot redundant including all associated equipment and cabling and shall be integrated to the Main Control SCADA furnished by the Turbine-Generator section. The Protection and metering system shall be fully integrated to the Main SCADA without any complex and restrictive conversion devices. This further covers the integration of protection and monitoring data from the Transformers. Spare I / O's are specified for Data Acquisition relating to the electrical BOP and mechanical BOP. The Contractor shall be responsible to map all I / O points provided by others and connected to the Common RTU. The supply shall include all software, parts, devices, accessories and special tools, which though not individually specified, but are necessary to construct, operate and maintain the complete Protection, Metering, Automation and integration to the main LAN-1 and LAN-2 Networks supplied as described hereafter. All hardware and Software shall be 100% compliant to OPC Specifications and shall be OPC Certified;
- b. The work includes all protective device settings (protection study), sizing of the instrument transformers, bay controller units configurations, RTU configurations, communication configurations, the AC and DC schematics and wiring diagrams necessary for the interconnection and interlocking of equipment and associated design briefs, instruction manuals and test reports. The overall protection design shall include the choice of CT and VT accuracy class and rating to provide sufficient sensitivity and speed for the defined 220 kV interconnection;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- c. The complete electrical protection, control and communication system shall include all devices and accessories that, even though not individually specified, are necessary to protect, operate and maintain the complete facility;
- d. The PAMS shall conform to the general SCADA Architecture drawing:
  - Three Unit Protection Boards (UPB-1 to 3) located in the Powerhouse on the Operating floor;
  - Energy Management Work Station (EMS) and Hot Line telephones located in the Main Control Room;
  - Miscellaneous 220 kV GIS protection and metering boards are located in the Control Room. They include the Breaker Failure and Bus Protection Board, the Unit BCU and Metering Board and the Line Metering Board. In addition, the Common RTU, one Operator Work Station (OWS5), one Engineering Work Station (EWS3), one portable engineering work station (laptop) (EWS 4) one Dispatch Work Station are located in this room;
  - Three Transformer RTU Boards located on the Operating floor.
- e. This section specifies the general requirements for the design, manufacture, integration and factory testing of the protection boards, metering boards, control boards, work stations indicated above and their integration to the Optic Fibre LAN-1 and LAN-2 Network to be supplied under this contract complete with all the appurtenances, spare parts, and shop drawings;
- f. The Contractor shall deliver to site all equipment furnished under this Contract and provide the services of a supervising erector and technicians for installation, field testing, and commissioning for the complete Protection and Metering system;
- g. The Contractor shall include all the software, data bases, computers, screens, interfaces and hardware necessary for the control and monitoring of the entire plant and facilities from any of the Human Machine Interfaces (HMI), Operator Work Stations or Engineering Work Stations supplied herein;
- h. The Contractor shall integrate the equipment furnished under this Chapter to the Main SCADA. The Contractor shall also connect and integrate all I / O of the Transformers from their Central Marshalling Box to the RTU boards. Integration of auxiliary system I / O by the EBOP and the MBOP to the Common RTU. The integration of the equipment and systems provided herein and by others shall be as

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

per the overall construction schedule of the project;

- i. All control, metering and monitoring signals of the equipment and systems provided under this contract shall be wired to Input & Output of the Bay Controller Units, the Multifunctional relays and to the common RTU provided within each Protection and Control Board. Interposing control relays shall be supplied as required to interface with external control systems. For Electrical Protection interfaces, Heavy-Duty high-speed lockout, tripping and control relays shall be provided. The interfaces, with the Main SCADA system supplied by others shall be done via a fiber optic links through the LAN Communication Network. The Contractor shall be responsible for the creation, integration and testing of the data base, HMI and PC screens, reports, alarms, diagnostics and other features required ensuring the same overall functionality of the Protection Operator and Engineering Work Stations. The Contractor shall review and insure that hardware and communication interfaces of systems and devices that are being supplied are fully compatible with the Main SCADA and LAN networks.
- j. The interfaces with the Communication LAN Networks shall include:
  - The Protection-A and Protection-B devices including Multifunctional Relays, and Bay Controllers;
  - The common RTU as shown on Tender drawings;
  - The Transformer RTU Boards shall interface the Generator Transformer main marshalling boxes located side by side;
  - The Energy Management System (EMS) including the Energy Meters of the 220 kV GIS, Generator energy meters, whereas other meters associated with the auxiliary services will be provided under the Electrical BOP section and ABT meters;
  - The Power Line Carrier (PLCC) system and Dispatch Work Station specified herein in, including interfaces for tele protection, remote monitoring and control and Voice over IP (VoIP);
  - The microprocessor controlled EPAX Telephone Line Switcher, Work Stations and VoIP routers located in Control rooms as specified herein with the PLCC, and to be interfaced with the Voice over IP (VoIP) telephone network;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- The Common RTU shall interface as required to: the auxiliary AC system, the auxiliary DC system, the fire alarm system, the intrusion alarm system, Control Panels, etc. This Contractor shall provide the necessary number of I / O points for use by the EBOP section and by the MBOP section.
- k. The design and assembly of the Protection, Metering, Automation and Communication systems shall follow the following rules:
- The Protection system is to be totally redundant. To insure the highest level of reliability, protection-A relays and protection-B relays shall be provided by different and independent relay manufacturers according to the table included in this specification. There will be no compromise on this requirement;
  - All protection relays, RTU's and IED's shall operate on the IEC 61850 protocol and software;
  - All protection relays, RTU's and IED's shall be time synchronized and connected by IRIG-B to the GPS clock system;
  - All protection relays, RTU's and IED's shall be networked through Optic Fibre cables only;
  - Protection-A and protection-B shall be totally isolated from one-another and shall consequently be installed in separate panels;
  - Bay Controller Unit are provided in all Protection Boards and are associated with protection-A. The master Unit BCU's are located in Control Room and slave Unit BCU's are located in the respective Unit Protection Boards. The BCU shall do data acquisition; allow control of Isolators and circuit breaker and display mimics associated with the bay;
  - The LAN-1 and LAN-2 communication networks are hot redundant. Patch Panels are provided in all areas of the Power Station and GIS Switchyard by the Contractors and are shown on the drawings. This Contractor shall interface with the networks at these Patch Panels. The Contractor shall provide all the devices and optic cables required for interfacing including Ethernet Switches, converters, hubs, etc.;
  - The protection, metering, automation and communication provided within shall be fully hot redundant. Systems A and B shall be provided throughout;
  - In the common RTU Board, Master PLC-A and Master PLC-B shall be fully synchronized and shall operate simultaneously without interference;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- In the common RTU Board, Master PLC-A shall be interfaced with System-A of other redundant systems including DC and UPS supplies. Master PLC-B in turn shall be interfaced with System-B of other redundant systems including AC, DC and UPS supplies;
- Master PLC A and B shall be totally isolated from one-another and shall consequently be installed in separate panels;
- In each Transformer RTU Board, a non-redundant PLC shall interface both LAN-1 and LAN-2;
- System-A interface relays and System-B interface relays where required shall be isolated from one another and be located in the rear panel section of the relative panel;
- Interface with Unit Control Board for starting, stopping and tripping of units shall be initiated by hard wiring respecting the Protection-A and Protection-B separation;
- No common I / O modules or interface relays shall be installed in the Master PLC-A and Master PLC-B sections;
- Protection Boards, RTU Boards and Metering Board panels shall each measure 800 mm wide by 800 mm deep by 2300 mm high. Width may be increased to accommodate the interface relays if needed;
- The Fibre Optic Network will be designed so that Circuits A and B shall be interfaced to both LAN-1 and LAN-2.

#### 8.1.1.3. Components Details

The main components comprising the Electrical PAMSS shall include but not limited to the following. The Contractor shall supply all components required to satisfy the requirements for the PAMS of the overall complete project including Generator protection, Transformer protection, GIB protection, Excitation Transformer protection, Unit Auxiliary protection, 220 kV Bus and Breaker Failure protection, 220 kV Line protection, SST protection system, Bay Controller Units, Transformer Control and Data acquisition RTU's, Common Control and Data Acquisition RTU, Operator & Engineer Work Stations, Energy Management system, voice over IP, PLCC interface with Dispatch center and network integration as shown on the SCADA System Architecture drawing and per the present specifications. All components shall be OPC compliant. The PAMS components shall be installed in free

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

standing Rack-Mount panels c / w front glass door. The components shall be provided as follows:

a. Unit Protection Boards (UPB-1, UPB-2 and UPB-3):

- UPB-1 to 3 are located on the Powerhouse Operating floor;
- Panel-1 to include one Protection-A Generator Protection Multifunctional Numerical relay ( ex: GE G60), one Transformer Protection Multifunctional Numerical relay (ex: GE T60), one Isolated Bus Duct Earth Protection relay c / w Bay Controller Display (ex: GE F650), one high speed Lockout relay (86SA-x), one high speed Trip relay (94SAx), one Breaker Trip Switch (52TS-GT-x), CT circuit Test Switches, VT circuit Test Switches, supervision relays, Protection-A Ethernet Switch, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;
- Panel-2 to include one Protection-B Generator Protection Multifunctional Numerical relay ( ex: Siemens 7UM62), one Overall Protection Multifunctional Numerical relay (ex: Siemens 7UT613), one high speed Lockout relay (86SB-x), one high speed Trip relay (94SB-x), CT circuit Test Switches, VT circuit Test Switches, Protection-B Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;
- Panel-3 to include the one Excitation Transformer over-current Numerical relay ( ex: GE F650), Auxiliary over-current Numerical relay (ex: GE F650), CT circuit Test Switches, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, Ethernet switches, etc.;
- The Fibre Optic cable and raceways to interface with the Patch Panels.

b. SST Protection Board (SSTPB-1):

- SSTPB-1 are located on the Powerhouse Operating floor;
- Panel -1 of SSTPB-1 to include one Protection-A Transformer Protection Multifunctional Numerical relay (ex: GE T60), one Isolated Bus Duct Earth Protection relay c / w Bay Controller Display (ex: GE F650), one high speed Lockout relay (86SA-x), one high speed Trip relay (94SAx), one Breaker Trip

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

Switch (52TS-GT-x), CT circuit Test Switches, VT circuit Test Switches, supervision relays, Protection-A Ethernet Switch, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;

- Panel-2 of—SSTPB-1 to include one Protection-B Transformer Protection Multifunctional Numerical relay (ex: Siemens 7UT613), one high speed Lockout relay (86SB-x), one high speed Trip relay (94SB-x), CT circuit Test Switches, VT circuit Test Switches, Protection-B Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;
- The Fibre Optic cable and raceways to interface with the Patch Panels.

c. Breaker Failure / Bus Protection Board (BPB-1):

- BPB-1 is located in the Control Room;
- The bus bar protection scheme shall be centralized or distributed type and shall have provision for future expansion.
- For LBB, separate re-trip and back-trip relays shall be provided for individual bays.
- Panels-1 and 2 to include one Protection-A Breaker Failure and Bus Bar Differential Multifunctional Numerical relay ( ex: GE B90) configured for double bus 07-Feeder Bays and 1-Bus Coupler Bay with provision for 02 future bays, high speed Lockout relays (96SA-1 to 3, 96GLA-1 & 2, 96BA-1, 96ST-1), Bus Coupler Bay Controller Unit (BCU-BC) (ex: GE F650), one Bus Coupler Breaker Control Switch (52CS-BC), one Local-Remote Switch, CT circuit Test Switches, VT circuit Test Switches, Protection-A Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;
- Panels-3 and 4 to include one Protection-B Breaker Failure and Bus Bar Differential Multifunctional Numerical relay ( ex: Siemens 7SS52) configured for double bus 7-Feeder Bays and 1-Bus Coupler Bay with provision for 02 future bays, eleven (11) high speed Lockout relays (96SB-1 to 6, 96GLB-1 & 2, 96BB-

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

1), CT circuit Test Switches, VT circuit Test Switches, Protection-B Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;

- The Fibre Optic cable and raceways to interface with the Patch Panels.

d. Line Protection Boards (LPB-1):

- LPB-1 is located in the Control Room;
- Transmission line protection philosophy shall be in accordance with clauses of the IEGC-2023 notified by the CERC.
- Panel-1 to include Protection-A two Line Differential & Distance Protection Multifunctional Numerical relay (L1A-1 & 2) (ex: GE Relay) , two Line Bay Controller Units (BCU-L1 & L2) (ex: GE F650), two high speed Lockout relays (86LA-1 & 2), two high speed Trip relays (94LA-1 & 2), two Breaker Control Switches (52CS-L1 & 2), two Local-Remote Switches, CT circuit Test Switches, Protection-A Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, Ethernet switches, etc.;
- Panel-2 to include Protection-B two Line Differential & Distance Protection Multifunctional Numerical relay (LB-1 & 2) (ex: Siemens Relay), two high speed Lockout relays (86LB-1 & 2), two high speed Trip relays (94LB-1 & 2), Protection-B Ethernet Switch, supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, etc.;
- The Fibre Optic cable and raceways to interface with the Patch Panels for PLCC interface and network integration.

e. Unit Bay Controller and Metering Board (BMB-1):

- BMB-1 is located in the Control Room;
- Panels-1 and 2 to include three (3) Production Bay Controller Units (BCU-GT1 to GT3) (ex: GE F650), three (3) Bay Production Energy Meters (BEM-1 to 3) (ex. Schneider ION7650), three (3) Breaker Control Switches (52CS-GT1 to3), three (3) Local-Remote Switches, CT circuit Test Switches, VT Test Switches,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

supervision relays, contact multiplication relays, interface relays, miscellaneous accessories and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, Ethernet switches, etc.;

- The Fibre Optic cable and raceways to interface with the Patch Panels Energy Management System interface and network integration.

f. Line Metering Board (LMB-1):

- LMB-1 is located in the Control Room;
- Panels-1 to include two (2) Line Bay Power and Energy Meters (LEM-1A & B, LEM-2A & 2B) (ex. Schneider ION7650) operating in redundancy, CT circuit Test Switches, VT Test Switches and communication interfacing with LAN-1 and LAN-2 Network Patch Panels comprised of patch cords, hubs, Ethernet switches, etc.;
- The Fibre Optic cable and raceways to interface with the Patch Panels Energy Management System interface.

g. Common RTU Board (CRB):

- CRB is located in the Control Room;
- Panel-1 to include Master PLC-A, I / O modules, interface relays relative to Systems-A and LAN-1 Ethernet Switch for Channels A and B. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the internal CRB components;
- Panel-2 to include Master PLC-B, I / O modules, interface relays relative to Systems-B and LAN-2 Ethernet Switch for Channels A and B. Number of I / O modules required is to be defined by Contractor as required for the monitoring of the internal CRB components;
- Panels-3 and 4 to include the Human Machine Interface (HMI), a VoIP telephone and I / O modules and interface relays common to Systems-A and B. These panels shall be provided for Data acquisition relating to common GIS and AIS I / O including Gas Monitoring, GIS alarms, Energy Monitoring & Management, and auxiliary & miscellaneous alarms. In addition, these panels shall be provided with 20% spare additional I / O modules and 20% additional spare space. The additional I / O shall be used by others;
- The Fibre Optic cable and raceways to interface with the Patch Panels Energy

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

#### Monitoring & Management System interface.

##### h. Transformer RTU Boards (TRB-1 to 3):

- TRB-1 to 3 are located on the Operator floor;
- Panel-1 to include Master PLC-A, the Human Machine Interface (HMI), a VoIP telephone, interface devices relative to Systems-A and LAN-1 Ethernet Switch for Channels A and B;
- Panels-2 and 3 to include Master PLC-B, I / O modules, interface devices relative to Systems-B and LAN-2 Ethernet Switch for Channels A and B. Interface relays and I / O modules as required to monitor each phase independently. No. of required I/Os shall be finalized during detail engineering based on system requirement. However, 20% spare I/Os ports shall be provided for future use.;
- The Fibre Optic cable and raceways to interface with the Patch Panels network interface.

##### i. Control Room Equipment:

- One (1) Energy Management Work Station (EMS) c / w Desktop Computers, Keyboard, mouse and 22-inch LED Screen;
- One (1) VoIP router as required for connection of the VoIPS and Control Room hot line telephones;
- Two (2) hot line telephones for direct connection to the dispatch centre;
- Convertors, Routers, Ethernet Switches, etc. to be located as required in the two Patch Panels;
- The Fibre Optic cable and Patch Cords to connect all automation elements.

##### j. Control Room Equipments for GIS:

- One (1) Operator Work Station (OWS5) c / w Desktop Computers, Keyboard, mouse and two (2) 32 inch LED Screens;
- One (1) Engineering Work Station (EWS3) c / w Desktop Computer complete, 22 inch LED Screen, Keyboard and Mouse;
- One (1) Engineering Work Station (EWS4) Laptop c / w Keyboard and Mouse;
- One (1) Dispatch Work Station (DWS) c / w Desktop Computer complete, 22 inch LED Screen, Keyboard and Mouse;
- One (1) PAMS router as required for connection of the portable EWS and extra

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

printer;

- Two (2) hot line telephones for direct connection to the dispatch centre;
- Convertors, Routers, Ethernet Switches, etc. to be located as required in the two Patch Panels;
- The Fibre Optic cable and Patch Cords to connect all system elements.

k. LAN-1 and LAN-2

The integration of all protection relays, PLC's and IED's to the LAN-1 and LAN-2 Optic Fibre cable Networks and to the Main SCADA. The Optic Fibre cables shall be installed in rigid steel conduit throughout. Optic Fibre extension and Patch Cords to interface Control Boards, Protection Boards, Work Stations, RTU, etc. shall be provided and laid in dedicated cable trays or conduits.

8.1.1.4. Copyrights and Software Licenses:

- a. The Employer shall own the copyrights for all documentation and software developed for the project;
- b. All software licenses and vendor support agreements shall be in the name of the Employer;
- c. The programming software, instruction manuals, application software and data files shall become the property of the Employer at completion of the project;
- d. All program documentation shall be reviewed and approved by the Employer prior to implementation. Refer to submittal requirements specified herein;
- e. The Contractor shall submit a full copy of the application software updates once a month until the warranty period expires to the Employer and / or its designee to be kept in case of force major events or bankruptcy of the Contractor.

8.1.1.5. Programming & Application Software:

- a. The senior system programmers shall be experienced in the type of programs and application Software provided and shall have a minimum of 5 years experience in programming similar type systems. The screen graphics shall match as close as possible with the actual device(s) arrangement being controlled;
- b. Review meetings shall be setup between the Contractor, the Employer, and the Engineer In-charge to coordinate the trip logics, the control, monitoring and interface features, the various screen control, monitoring, and arrangement details. The meetings shall be held at the Engineer In-charge's office. As a minimum, the following



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

meetings shall take place:

- i. Pre-design meeting to define the initial scope details for the various screen content and arrangement;
- ii. Review meeting at 50% design;
- iii. Review meeting at 75% design;
- iv. Review meeting at 100% design.

#### 8.1.1.6. Abbreviations

The following are common abbreviations used in this Section:

- UPB: Unit Protection Board
- BPB: Breaker Failure and Bus Protection Board
- GPB: Gas Insulated Bus Protection Board
- LPS: Line Protection Board
- BMB: Unit Bay Controller and Metering Board
- LMB: Line Metering Board
- GCB: GIS Control Board
- CRB: Common RTU Board
- TRB: Transformer RTU Board
- PAMS: Protection, Automation, Metering and Communication System
- PLC: Programmable Logic Controller
- MMI: Man Machine Interface (includes HMI and OWS)
- HMI: Human Machine Interface (in Control Boards)
- OWS: Operator Work Station (in Control Rooms)
- EWS: Engineer Work Station
- VoIPS: VoIP Server
- DWS: Dispatch Work Station
- HWS: Historian Work Station
- EMS: Energy Management Work Station
- CCTV: Closed Circuit TV
- ZCS: Zoom Processor Analysis Work Station
- LVS: Large Video Screen
- LVSW: Large Video Screen Work Station
- FO: Fibre Optic
- LSB: Less Significant Bit

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- MFM: Multifunction Meter. Also referred as Energy Meters or Power Measurement Device
- NTP
- (1) Network Time Protocol (Time Synchronization)
- (2) Notice to Proceed (Submittals)
- OPC
- (1) Open Protocol Compliance (open connectivity, open standards)
- (2) Object-Linking and Embedding (OLE) for Process Control
- OPGW: Optical Ground Wire
- PC: Personal Computer (Desktop Computer)
- DCS: Distributed Control System
- RTU: Remote Terminal Unit
- PMD: Power Measurement Device. Also referred as Energy Meter or Power Meter
- SCADA: Supervisory Control and Data Acquisition
- SNTP: Simple Network Time Protocol
- UTC: Coordinated Universal Time
- VESA: Video Electronics Standards Association
- UCB: Unit Control Board
- CCB: Common Control Board
- ICB: Intake Control Board
- SCB: Spillway Control Board
- GCB: GIS Control Board
- G: Generator
- T: Transformer
- GT: Generator and Transformer
- MVSB: Medium Voltage Switchgear
- EX: Static Excitation
- AVR: Automatic Voltage Regulator
- ET: Excitation Transformer
- UAT: Unit Auxiliary Transformer
- PLCC: Power Line Carrier Communication
- VoIP: Voice over IP
- ODBC: Open Data Base Connectivity
- IRIG: Inter-Range Instrumentation Group

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- LAN: Local Area Network
- IGMP: Internet Group Management Protocol
- RSTP: Rapid Spanning Tree Protocol
- HDM: Historical Data Management
- VLAN: Virtual Local Area Network
- GPS: Global Positioning System
- CPU: Central Processing Unit
- GIS: Gas Insulated Switchgear
- GIB: Gas Insulated Bus
- AIS: Air Insulated Switchyard
- CS: Controller Station
- PCS: Plant Control System (Main SCADA and Control Boards)

#### 8.1.1.7. Manufacturers Past Experience

Protection, Metering, Automation and Communication Contractor shall have designed, manufactured, erected / supervised erection, commissioned / supervised commissioning of at least two (2) nos. of such system for a plant of 50 MW or higher capacity within the last 5 years, which are in successful operation for a period of not less than 2 years as of the date of bid opening.

#### 8.1.2 Standards and Codes

The equipment covered under these specifications shall conform to the latest edition of the following standards:

IEC 60034	Rotating Machines
IEC 60044-1	Instrument Transformers, Part 1: Current Transformers
IEC 60044-2	Instrument Transformers, Part 2: Voltage Transformers
IEC 60255 (All Parts)	Measuring relays and protection equipment. / Electrical relays. Parts 1 to 27
IEC 60909-0	Short-circuit currents in three-phase a.c. systems – Part 0: Calculation of currents
IEC 60947-5-1	Low-voltage switchgear and controlgear – Part 5-1: Control circuit devices and switching elements - Electromechanical control circuit devices
IEC 61850-3	Communication networks and systems in substations - Part 3:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	General requirements
IEC 61850-4	Communication networks and systems in substations - Part 4: System and project management
IEC 61850-5	Communication networks and systems in substations - Part 5: Communication requirements for functions and device models
IEC 61850-6	Communication networks and systems for power utility automation - Part 6: Configuration description language for communication in electrical substations related to IEDs
IEC 61850-7-410	Communication networks and systems for power utility automation - Part 7-410: Hydroelectric power plants - Communication for monitoring and control
IEC 61850-7-1	Communication networks and systems in substations - Part 7-1: Basic communication structure for substation and feeder equipment
IEC 61850-7-2	Communication networks and systems for power utility automation - Part 7-2: Basic information and communication structure - Abstract communication service interface (ACSI)
IEC 61850-7-3	Communication networks and systems for power utility automation - Part 7-3: Basic communication structure - Common data classes
IEC 61850-7-4	Communication networks and systems for power utility automation - Part 7-4: Basic communication structure - Compatible logical node classes and data object classes
IEC 61850-10	Communication networks and systems in substations - Part 10: Conformance testing
IEC 61131-1	Programmable controllers - Part 1: General information
IEC 61131-2	Programmable controllers - Part 2: Equipment requirements and tests
IEC 61131-3	Programmable controllers - Part 3: Programming languages
IEC 61131-5	Programmable controllers - Part 5: Communications
IEC 61131-7	Programmable controllers - Part 7: Fuzzy control programming
IEC 60870-1 series	Telecontrol equipment and systems. Part 1: General considerations. Section One: General principles
IEC 60870-2 series	Telecontrol equipment and systems - Part 2: Operating

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	conditions
IEC 60870-3	Telecontrol equipment and systems. Part 3: Interfaces (electrical characteristics)
IEC 60870-4	Telecontrol equipment and systems. Part 4: Performance requirements
IEC 60870-5 series	Telecontrol equipment and systems. Part 5: Transmission protocols
IEC 60870-6 series	Telecontrol equipment and systems - Part 6: Telecontrol protocols compatible with ISO standards and ITU-T recommendations
IEC 60338	Telemetry for consumption and demand
IEC 60381-1	Analogue signals for process control systems. Part 1: Direct current signals
IEC 60381-2	Analogue signals for process control systems. Part 2: Direct voltage signals
IEC 61000 series	Electromagnetic compatibility (EMC)
IEC 60255-5	Electrical Relays - Part 5: Insulation coordination for measuring relays and protection equipment - Requirements and tests
IEC 60255-22-1	Measuring relays and protection equipment - Part 22-1: Electrical disturbance tests - 1 MHz burst immunity tests
ANSI / IEEE C37.90	Standard for Relays and Relay Systems Associated with Electric Power Apparatus
ANSI / IEEE C37.90.1	Standard Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems and Relay Systems Associated with Electric Power Apparatus
ANSI / IEEE C37.90.2	Standard Withstand Capability of Relay Systems to Radiated Electromagnetic Interference from Transceivers
ANSI / IEEE C37.90.3	Standard Electrostatic Discharge Tests for Protective Relays
ANSI / IEEE C37.91	Guide for Protective Relay Applications to Power Transformers
ANSI / IEEE C37.94	Standard for N times 64 Kilobit Per Second Optical Fibre Interfaces Between Teleprotection and Multiplexer Equipment

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

ANSI / IEEE C37.97	Guide for Protective Relay Applications to Power System Buses
ANSI / IEEE C37.98	Standard for Seismic Testing of Relays
ANSI / IEEE C37.101	Guide for Generator Ground Protection
ANSI / IEEE C37.102	Guide for AC Generator Protection
ANSI / IEEE C37.106	Guide for Abnormal Frequency Protection for Power Generating Plants
ANSI / IEEE C37.109	Guide for the Protection of Shunt Reactors
ANSI / IEEE C37.113	Guide for Protective Relay Applications to Transmission Lines
ANSI / IEEE C37.115	IEEE standard test Method for Use in the Evaluation of Message Communications Between Intelligent electronic Devices in an Integrated substation Protection, control, and Data acquisition System
ANSI / IEEE C37.119	Guide for Breaker Failure Protection of Power Circuit Breakers
ANSI / IEEE C57.13.3	Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases
ANSI / NETA ATS	International Electrical Testing Association Acceptance Testing Specification for Electrical Power Distribution Equipment and Systems
IEEE 242	IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
IEEE 488.1	Standard Digital Interface for Programmable Instrumentation
IEEE 488.2	Standard Codes, Formats, Protocols, and Common Commands for Use with IEEE Std. 488.1-1987, IEEE Standard Digital Interface for Programmable Instrumentation
IEEE 762	Standard Definitions for Use in Reporting Electric Generating Unit Reliability, Availability, and Productivity
IEEE 1010	Guide for Control of Hydroelectric Power Plants
IEEE 1046	Application Guide for Distributed Digital Control and Monitoring for Power Plants
IEEE 1050	Guide for Instrumentation and Control Grounding in Generating Stations
IEEE 1059	Recommended Practice for Monitoring Electric Power Quality
IEEE 1174	Standard Serial Interface for Programmable Instrumentation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

IEEE 1222	IEEE standard for All-Dielectric self-supporting Fibre Optic Cable
IEEE 1249	Guide for Computer-Based Control for Hydroelectric Power Plant Automation
IEEE 1344	Standard for Synchrophasors for Power Systems
IEEE 1346	Recommended Practice for Evaluating Electric Power System Compatibility with Electronic Process Equipment
IEEE 1451.1	Standard for a Smart Transducer Interface for Sensors and Actuators--Network Capable Application Process (NCAP) Information Model
IEEE 1451.2	Standard for a Smart Transducer Interface for Sensors and Actuators - Transducer to Microprocessor Communication Protocols and Transducer Electronic Data Sheet (TEDS) Formats
IEEE1588	Standard for a Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
IEEE 1590	Recommended Practice for the Electrical Protection of Optical Fibre Communication Facilities Serving, or Connected to, Electrical Supply Locations
OPC UA- Parts 1 to 11	Unified Architecture Products Specifications
OPC TEST LAB Parts 1 to 11	OPC Lab Certified Products
BS EN 55011	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific, and medical (ISM) radio-frequency equipment

### 8.1.3 Design Requirements

a. The following minimum output contacts shall be provided per protective relay:

- Two set of breaker trip contacts (one set per trip coil per circuit breaker). Each 220 kV main breakers holds two trip coils designated as A & B;
- One fault recorder start contact
- Two event contacts from the same relay that provides the circuit breaker trip contacts;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Protection signaling send contacts, one for each functionally specified send channel;
  - One direct transfer trip (DTT) send contact where functionally specified;
  - One breaker fail start contact;
  - One alarm contact for each specified operational alarm;
  - One common alarm contact for relay system or relay power supply and / or DC / DC converter failure.
- b. Suitable facilities shall be provided on each measuring relay or system to disconnect trip outputs, short and disconnect the current transformers and to disconnect any voltage transformer, alarm or critical DC circuit, without affecting any other device, prior to removing or testing the relay element. These test facilities, shall enable the measuring relay element to be tested in-situ without affecting the external circuitry;
- c. Target relays, light emitting diodes (LED) or human machine interface (HMI) displays, as appropriate, shall be provided to indicate the operation and stage of each measuring system with means of resetting these targets without removing any covers. If electrically reset, provide a push button;
- d. Repeat relays shall be provided where necessary to provide contacts into the Automation equipment and / or the field controller (PLC or DCS) to provide alarms, indications and sequence of event points as specified;
- e. All relays shall be suitable for use in the ambient and other external environmental factors specified, including the heating effect of other equipment provided under this or other contracts. Setting calibration shall not be affected by temperature or aging;
- f. The design of all relay systems to be immune to malfunction should a DC system ground fault occur on any lead external to the relay panel;
- g. All case mounted static or digital protective measuring relays shall be in front withdrawable, switchboard type, flush / semi-flush, rectangular, dust-tight, back connected cases. These relay cases shall have removable covers or doors with glass windows, and provide means to seal the cover fasteners with wire to prevent tampering with the relay or its settings;
- h. All rack mounted static or digital relays shall be installed in 480 mm (19 inches) modular racks with suitable rack support assemblies. Provide suitably protected power supply units to operate from the DC (nominal) protection supply. Provide these units with supply failure monitor alarm circuits;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- i. All necessary interface and barrier isolation circuits shall be provided for each system to operate as specified in the environment specified and to meet the IEC 60255;
- j. The main and back up protection systems shall be divided into two completely independent groups, where specified, each fed from its own DC circuits and tripping its own breaker trip coil;
- k. All power supply requirements for the protection shall be derived from the DC supply associated with the relay group. Protection-A and Protection-B shall draw power from 2 independent 220 V DC source. The use of small individual batteries as power supplies to the electronic equipment is not permitted except to back up event data records;
- l. Protection Boards, Control Boards, RTU Boards and Metering Boards are divided into individual panels as indicated above. Individual panels are to be electrically separated. Protection-A devices and Protection-B devices shall be totally isolated from one another thus located in separate panels isolated from each other by a full height steel barrier;
- m. The PAMS, core of the system, shall be designed, manufactured, tested and erected in conformance with applicable International, North American, and Indian Standards. Many standards may be similar or redundant from one organization to the other. The Bidders shall conform to International Standards at base. American Standards shall be used for items not covered by the International Standards. Indian Standards shall be considered for regional requirements and when legally binding;
- n. Protection Boards, Control Boards RTU Boards, Metering Boards, accessories, etc., meeting any other authoritative standard, which ensures equal or better quality than the Standards mentioned above, shall be acceptable but subject to prior approval by Employer's authorized Engineer. However, where the equipment offered conforms to any other standards, the salient points of difference between standards adopted and provision of this specification and standards referred above shall be clearly brought out in the bid. Copies of such standards in English language or fair English Translation shall be attached with the bid;
- o. The PAMS shall be designed to be networked redundantly. It shall be provided with its own sub-level SCADA system. All automation, control, metering and data acquisition functions shall be available at each Operator Work Station and Engineer Work Station. Setting of relays will be possible from any Engineering or Operator Work Station and shall have a high security limited access. All settings will be displayed as needed.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- p. An historian shall be built in the Automation System system that will time stamp and register all event within the PAMS. Historian information shall be interfaced with the main Historian Server. The events will be transferred and registered in sequence and in coordination with the main SCADA events;
- q. Control of circuit breakers and isolators switches shall be possible from the relative Bay Controller Unit and from the Operator Work Station;
- r. Interlocks shall be accomplished through the Bay Controller Units in a failsafe manner.
- s. Data acquisition shall be realized using available I / O within the Bay Controller Units, the Multifunctional relay, the Control Board I / O modules and the transformer RTU I / O modules;
- t. The PAMS shall be designed with the Control Room as the central hub;
- u. The PAMS shall be interfaced with the Main SCADA for Data acquisition only. A selected number of monitoring and status points shall be picked up by the Main SCADA;
- v. All Open-close command of circuit breakers from the PAMS shall be realized through hardwiring;
- w. Two way tripping signals between the PAMS and the Unit Control Boards shall be hardwired and redundant;
- x. All START PERMISSIVE signals originating from the PAMS shall be hardwired to the UCB. Any START PERMISSIVE signal required to be sent to all Units shall be interfaced with each UCB independently;
- y. Hardwired interlocks shall be provided to avoid any possibility of closing the line circuit breaker out of synchronization;
- z. Design and Performance Criteria;
  - 1. Availability:
    - The PAMS shall be designed to minimize the consequences of failures by providing sufficient failure detection, and recovery procedures, such that no single device failure shall result in the loss or degradation of any other station in the system;
    - The PAMS shall be designed to minimize the duration of failures by the ability to diagnose and resolve problems quickly and to replace any failed part easily;
    - The Average System Availability of communication system for two consecutive 500-hour periods shall be 99.98% or better;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- The Mean Time before Failure (MTBF) of each individual protection relay shall no less than 70 years.

## 2. Maintainability

The hardware and software elements of the PAMS shall be easy to maintain by Employer using the maintenance facilities, hardware and software tools, and recommended spare parts provided by the Contractor.

All software and components including Multifunction Digital relay shall be guaranteed maintainable for a period of no less than 25 years. The Contractor shall further guarantee a 15-years minimum availability of identical replacements and spare parts. The Contractor shall submit a signed affidavit from each component and software supplier as proof.

## 3. Expandability

The PAMS shall be capable of being expanded by adding more protection and auxiliary relays, stations, controllers, functions, input-output modules, or intelligent devices such as metering modules, etc. The expansion of the data base and components shall not degrade the performance of the specified system;

For ease and flexibility in expanding the PAMS, the Contractor shall conform to the industry standard open architecture concept as described herein;

Space is to be provided in all boards for expansion of I / O modules by 20% minimum or as indicated in the scope;

Lockout, tripping and auxiliary relay racks shall be provided with a minimum 50% expandability.

## 4. Quality and Technology

The hardware and software products shall be of high quality in design, fabrication, and performance;

All multifunction digital relays shall be state of the art device and shall be incorporated the latest technological advancements;

The standard hardware equipment (such as Multifunction Digital, lockout, tripping and auxiliary relays, PLC, HMI, I / O modules, computers, screens, printers, etc) and devices of the PAMS shall be brand-new and shall be the latest design

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

technology. The date of manufacture shall be not more than one year from delivery date. Any hardware exceeding the one year date of manufacture will be removed from site. In order to meet this requirement, the Contractor shall defer the procurement of all standard hardware until one month prior to system integration. The Contractor shall not use project laptops and workstation as development tools during the design and applications engineering phase of project;

The Contractor shall use and provide the latest versions of all the standard software, e.g., the operating system, utilities, language compilers, graphics software, picture editor, networking software, database management system, which are available at the time of system integration, as long as there is full upward compatibility with the PAMS software;

All software shall be standard. Therefore, Contractor's code modification on standard software packages shall not be permitted;

At the end of the project, the Contractor shall upgrade all firmware and software to latest editions. Controller flash memories shall also be updated if required.

#### 5. Setting and Testing Requirements:

1. Setting and testing of the PAMS shall be realized by an experienced team having commissioned at least 2 similar projects within the last 5 years;
2. The Contractor shall prepare a comprehensible and detailed «Protection Setting Report» using the relay manufacturer software. The report shall be approved by the Employer and his authorized Engineer before implementation. The settings shall be implemented following the relay supplier instructions and NETA ATS-2007;
3. The Contractor shall meet the system functional and performance requirements as given in these Documents. The verification of compliance with the requirements shall be done through a series of tests focused primarily on functionality, response, CPU utilization and system availability;
4. The testing sequence of the complete system shall consist of the following:
  - Pre-Factory Acceptance Test (Pre-FAT);
  - Factory Acceptance Test (FAT);
  - Relay Settings and Testing (RST);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Site Acceptance Test (SAT);
- Availability Demonstration (AD);
- Network efficiency Test (NET);
- All system testing shall be made with all the control nodes and stations and the ultimate number of points simulated.

a. Software

All software including operating licenses, manuals, documentation, and electronic files used for developing and implementing the PAMS shall be furnished to and become the property of the Employer.

b. Training and Support:

1. Training shall include sessions and courses in the theory, setting methodology, detailed operation, testing, and maintenance and troubleshooting of the PAMS and as a minimum shall include the following hardware and software training modules: System Overview, System User, Basic System Maintenance, Advance System Maintenance, Engineering Tools, System Configuration, Historian and Specific Applications;
2. The Contractor shall submit a training plan, instructor's background and qualifications, course outline, course material and subject matter. Training course material shall include the use of site-specific Operations and Maintenance Manuals, to the maximum extent possible;
3. The Contractor shall provide off-site and on-site training for the Employer's staff including, but not limited to:
  - Off-site training for minimum of 6 engineers on concept development and design philosophy of protection system.
  - On-site training for a minimum of 3 operators;
  - System overview and hardware maintenance and troubleshooting for maintenance personnel;
  - System overview, application software development, modifications, troubleshooting for engineering personnel;
  - On-the-Job-Training (OJT) for engineering and maintenance personnel.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

4. Continuous on site support shall be provided for the first four weeks after the first unit is in commercial operation, and for two additional non-sequential one week periods selected by the Employer during the duration of the warranty period.

#### 8.1.4 Protection - Design Philosophy

- a. The Contractor shall provide an electrical protection as part of the system with the following features:
  - Electrical Protection in accordance with, and appropriate for the powerhouse single line diagram relaying and metering;
  - Main and back up protections which can operate independently and simultaneously;
  - Provision for independent and simultaneous operation which includes duplicate breaker trip coils, separate DC circuits, and the use of separate CT windings. Separate metering and protection windings are also provided on each VT. The separation between the circuits shall begin at the associated miniature circuit breakers and / or fuses fed from the battery system;
  - Circuit breaker fail protection to directly detect the failure of a circuit breaker to trip on fault following a trip initiation, the information of a 220 kV main breaker fail will be provided by Others;
  - Back up relaying in case of failure of the main measuring schemes. Coordinate this protection to ensure that final tripping is within the short-time thermal rating of the primary equipment;
  - Be stable during system transients and operate correctly during system faults for faults within the protected zones, for the ranges of fault levels, and for the fault current DC time constants relevant to the specified system.
- b. A complete overall design for each protective system shall be provided to include the current and voltage transformers, the measuring relays, tripping relays, lockout relays, auxiliary relays and all wiring necessary for the detection of a fault and the issuing of a trip signal to the circuit breaker including the correct functioning of that circuit breaker. Coordinate this design with the other equipment provided under this contract and by others;
- c. The protective relays will interface with the Automation system at a number of locations throughout the plant for the exchange of alarms, status and commands.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The protective relays shall, however, be capable of autonomous operation and not depend on the Automation system for any of their functions.

#### 8.1.5 Equipment Arrangement and Construction:

- a. The protection relays shall be mounted on the front of the protection boards. Arrangement shall be such as main and back-up protections are installed in separate cubicles insulated from one another;
- b. The panels shall consist of free standing swing rack cabinets with nominal 19 inch wide chassis in sub-panel assemblies as defined in ANSI C37.21; they shall have hinged doors for front and rear access. They shall consist of fabricated steel sections bolted together to form a composite panel. A rear and front access doors shall be supplied. The front access door shall come equipped with a tempered glass or lexan window that shall be gasketed on the whole perimeter. Both doors shall be hinged and shall be easily removable by lifting up, out of the hinges pins. The door interior perimeter shall have a glued neoprene gasket preventing the entry of dust and water. The degree of protection shall be IP 54. Both doors shall have three points latching mechanism and a key lockable door handle;
- c. The panels shall be floor mounted indoor, free standing type. Thickness of the panels shall not be less than 3 mm for weight bearing members of the panels such as base frame, front sheet and door frames and not less than 2 mm for sides, door top and bottom portions. There shall be sufficient reinforcement to provide level surfaces, resistance to vibration and rigidity during transportation and installation;
- d. All joints shall be made flush and all edges shall be bent at right angles and rounded. All structural members shall be bolted or welded together. Necessary arrangements shall be provided for bolting together the adjacent panels as well as for fastening them to the floor. The doors, removable covers and panels shall be gasketed all around with neoprene gaskets. Ventilating louvers, if provided, shall have screws and bolts. The screws shall be made either of brass or steel, which shall be zinc, cadmium or chromium plated. Metal sills in the form of metal channels properly drilled shall be furnished by the manufacturer along with anchor bolts and necessary hardware for mounting the panels;
- e. The panels shall be complete with small wiring, earthing bar, fuses, miniature circuit breakers, lamp test facility, links, and vermin proof joints. Panels shall be equipped with internal lighting arrangement, operated by a door switch, a space heater rated

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

100 W, 240 V AC with a switch, undrilled cable gland plate and 75 mm x 102 mm channel form plinth;

- f. All the relays should be accommodated in the panels complete with necessary indicating instruments, control switches, indicating lamps, wiring, fuse link, terminal block, etc.;
- g. The relay panels shall be delivered with all relays, instrument switches, indicating lamps, etc. duly mounted;
- h. The panels shall be equipped with necessary links and, HRC type fuses of good quality which shall be mounted on sheet steel brackets. Alternatively, the contractor may use heavy duty moulded case circuit breaker having a DC rating of 250 V DC and an interrupting capacity of 10 kA symmetrical. Each shall be identified with a suitable engraved plastic label;
- i. The internal wiring of the panels shall be in the scope of the Contractor of this document. Both ends shall have the numbered plastic ferrules for identification. Panel wiring shall be suitably bunched and clamped to present a neat appearance. All panel wiring should withstand 2 kV AC voltage for 1 min. between each core and earth;
- j. All panel wiring terminations for connecting to external apparatus circuits shall be neatly terminated on terminal blocks. For CT and VT termination links, terminal blocks to be used shall have links for disconnection and plug-in facility for testing purposes. CT terminals should be type NT and equipped with test switch blocks of the make before break type; these switches shall short circuit and ground the leads on the current transformer side before disconnecting and isolating the relays and meters connected to it. Test switch blocks shall be ABB flexitest, type FT. The terminals shall be suitably labelled to readily identify the outgoing / incoming wires. Twenty percent of each type shall be provided as spare terminals in each for future use;
- k. All plug-in contacts shall be silver plated, with arrangements to ensure that any plug-in leads are held in position;
- l. All the equipment on the front side of the panel shall be flush mounted;
- m. The outside surface of the panels shall be synthetic enamel painted. The colour shall be determined at a later date and shall be chosen to match the colours of the Unit Control Boards;
- n. Each relay, auxiliary relay, instrument, lamp, switch, etc. shall be identified, both inside and outside the panel with suitable engraved plastic labels;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- o. The contacts of the protection relays shall not be directly connected to the trip coils of the circuit breaker, unless relay contacts are designed for this application. To achieve fast tripping, auxiliary relay coils can be used, / rated not less than 220 V DC with economizing resistor in series;
- p. Each DC control protection circuit shall be protected by micro circuit breaker (MMCB);
- q. A disconnect link (FT and / or NT) for each circuit breaker trip circuit shall be provided;
- r. An internal wiring shall be of thinned copper with an insulation rated 150°C.
- s. CT/PT spare cores shall be wired up to panel TBs.

#### 8.1.6 Product Description

##### 8.1.6.1. Protection, Automation, Metering and Communication System (PAMS) Hardware

##### a. General Requirements:

1. The PSS shall be redundant; PC based, it shall include a Multifunction Digital relays, Bay Controller Units, PLC, RTU, local panel mounted HMI and software and hardware interfaces with substation controls, Energy Meters, data acquisition, IED devices, protection relays and others as shown on the Architecture drawing;
2. Each panel within a protection or control board shall be a designed to be standalone system to operate independently from other components in the PAMS;
3. Multifunction Digital relay are made redundant by providing 2 independent sets of protections: Protection-A and Protection-B. The Contractor shall provide hot redundant PC's; power supplies and communication processors. No redundancy is required for input-output modules relating to data acquisition;
4. The Programmable Logics Controllers (PLC) of the Control Boards and RTU Boards shall be in redundant configuration. The CPU of system-A shall be synchronized the CPU of system-B to allow seamless and bumpless switchover between the active and the standby CPU. The standby CPU shall allow replacement under power conditions without shutting down the station and without affecting the performance of the CS. Both CPU shall include the following features:
  - The same hardware and accessories;
  - The same application firmware and software;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- The same data blocks;
  - The same image content;
  - The same program and the same memory program;
  - Data updating is event driven and done simultaneously and in synchronism.
5. All CPU's and modules shall be provided with flash memory cards to hold the up-to-date application programming without any need for a module battery backup;
  6. The PAMS shall communicate with all Multifunction Digital relay, Bay Controller Units input-output modules, intelligent electronic devices (IED), Energy Meters etc. All components shall be seamlessly integrated in the PAMS;
  7. The CS shall communicate with the main SCADA and other nodes and systems over the LAN-1 and LAN-2 Networks using industry-standard communication protocol;
  8. All PAMS functions shall be programmed in IEC 61850 compliant language;
  9. The PAMS shall have on-line, self-checking diagnostic routines periodically checking each component in the architecture. Error conditions shall identify the area where the malfunction is located and the specific problem shall be reported to the operator on a dedicated screen;
  10. Software maintenance activities at a PAMS shall not affect the operation of individual protection relays. All compilers, utilities, management software, and storage media required for software maintenance shall be provided;
  11. The PAMS shall be designed to operate normally with one Multifunction Digital relay or Bay Controller Unit out of commission;
  12. The PAMS shall have the necessary processing power, memory, and peripheral facilities to accommodate the software tools and application software as described in this section. The final application software shall not occupy more than 30% of the PLC and PC memory taking into account the expansion provisions;
  13. The CS shall periodically synchronize their clock time using the standard time signal transmitted by the GPS Synchronized System. The plant wide time synchronization error shall not exceed  $\pm 100$  nanoseconds.

b. Product specifications

i. Major Equipment List

Number	Name	Relative	Protection	Location
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EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

		Equipment		
UPB-1	Unit Protection Board No. 1	Generator G-1 / Transformer T-1 Overall GT-1 Excitation ET-1 / Unit Auxiliary Transfo. UAT-1	A & B B/ A A	Powerhouse Operator floor,
UPB-2	Unit Protection Board No. 2	Generator G-2 / Transformer T-2 Overall GT-2 / Excitation ET-2 Unit Auxiliary Transfo. UAT-2	A & B B / A A	Powerhouse Operator floor,
UPB-3	Unit Protection Board No. 3	Generator G-3 / Transformer T-3 Overall GT-3 / Excitation ET-3 Unit Auxiliary Transfo. UAT-3	A & B B / A A	Powerhouse Operator floor,
SSTPB-1	SST Protection Board. 1	SST	A & B	Operator floor,
TRB-1	Transformer RTU Board No. 1	Transformer T-1	NA	Powerhouse Operator floor,
TRB-2	Transformer RTU Board No. 2	Transformer T-2	NA	Powerhouse Operator floor,
TRB-3	Transformer RTU Board No. 3	Transformer T-3	NA	Powerhouse Operator floor,
BMB-1	Unit Bay Controller and	Bay Controller Units BCU- GT1 to BCU- GT3 / Production	NA	Control Room,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	Metering Board No. 1	Bay Meters BEM-1 to BEM-3		
LMB-1	Line Metering Board No. 1	Line Bay Energy Meters Line-1: LEM-1A and 1B Line-2: LEM 2A and 2 B	A & B A & B	Control Room,
BPB-1	Breaker Failure and Bus Protection Board No. 1	GIS Breaker Failure GIS Bus-A and B Differential	A & B A & B	Control Room,
LPB-1	Line Protection Board No. 1	220 kV Transmission Line-1 220 kV Transmission Line-2	A & B A & B	Control Room,
CBB	Common RTU Board	Common Monitoring Controller	NA	Control Room,
PLCC-1	Power Line Carrier System No. 1	Telecommunication Cubicle-1	A	Control Room,
PLCC-2	Power Line Carrier System No. 2	Telecommunication Cubicle-2	B	Control Room,
OWS5	Operator Work Station No. 5	PC, 2-32" Screens, keyboard, Mouse	NA	Control Room,
EWS3	Engineering Work Station No.	PC, 22" Screen, keyboard, Mouse	NA	Control Room,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	3			
EWS4	Engineering Work Station No. 4	Laptop, keyboard, Mouse	NA	Control Room,
EMS	Energy Managemen t Work Station	PC, 22" Screen, keyboard, Mouse	NA	Control Room,
DWS	Dispatch Work Station	PC, 22" Screen, keyboard, Mouse	NA	Control Room,

ii. Accepted Manufacturers of Protection Devices

The PAMS shall be designed using tentatively the products listed in the table below. It is essential that Protection-A and Protection-B relays be of different Make and Brand. Consequently the Contractor shall select relays from 2 columns. The Contractor shall obtain the Purchaser's approval of the vendor prior to selecting the make and model of the protection devices/ relays.

TABLE OF ACCEPTED RELAYS AND TEST SWITCHES					
Protection Device	GE Multilin	Siemens Siprotec	ABB Relion	Alstom GE MiCOM	SEL Schweitzer Engineering Laboratories
Generator Protection	UR G60	7UM62	REG670	P343/P34 5	SEL-700G
Transformer Differential Protection	UR T60	7UT613	RET670	P642/P64 3	SEL-787
Overall Differential Protection	UR T60	7UT613	RET670	P645	SEL487E
Breaker Failure & Bus Differential	UR B90	7SS52	REB670	P746	SEL487B



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Protection					
Transmission Line Distance & Differential Protection	UR L90 + Differential or equivalent combined.	7SA522+ Differential or equivalent combined.	REL670 + Differential or equivalent combined.	P444 + Differential or equivalent combined.	SEL-311C + Differential or equivalent combined.
Bay Controller Unit	F650	7VK61	REC670	P139	SEL-451
Overcurrent Protection	F650	7SJ600	REF610	P141	SEL-751
Lockout relays	NA	NA	Combiflex x RXMVB4	MVAJ	NA
Tripping relays	NA	NA	Combiflex x RXME18	MVAJ	NA
Auxiliary and Supervisory relays	NA	NA	Combiflex x RXMS1	MVAA	NA
Test Switches	NA	NA	Flexitest FT-1 Clear cover, Colour coded	NA	NA

**Important Notes:**

- 1) Some relays listed above are unable to provide 4 steps settings of Undervoltage, Overvoltage, Underfrequency and Overfrequency functions as specified. These functions can be manually programmed into the relay software in most cases. When not possible, the Contractor shall provide external Voltage and Frequency protections. For Protection-A, the Contractor

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

may use the functions available in the Bay Controller Unit. For Protection-B, the Contractor shall add separate external relays such as the GE MIV-II or approved equivalent;

- 2) The protection relays and Bay Controller Units require a large amount of I / O to perform logics and for data acquisition sometimes exceeding the available quantity in the specified IED. The Contractor shall add as required extension I / O modules to satisfy the protection requirements.

### iii. Generator Protection

The protection for the AC Generator shall comprise one Integrated Multifunction Digital Relay for Protection-A of one brand backed up by a second Integrated Multifunction Digital Relay for Protection-B of the same type but provided by a different manufacturer. Although specific functions are specified for the multifunction relay, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The integrated digital protection system shall include protection functions, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

High speed functions such as 87G operate in less than 2 cycles.

The following protection functions shall be included in the system:

- High speed generator stator differential (87G);
- Negative sequence current unbalance (46);
- Phase distance backup (21);
- Reverse Power (32);
- Phase time and instantaneous overcurrent (50 / 51P);
- Ground time and instantaneous overcurrent (50 / 51G);
- Neutral time and instantaneous overcurrent (50 / 51N);
- Phase, neutral and negative sequence directional overcurrent (67 P / N / (2));

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Loss of excitation (40) with two independent zones;
- Accidental Energization (50 / 27) or time overcurrent with voltage restraint (51V);
- Stator ground protection covering 100% of the winding, (64TN & 27TN/59TN); The method of detection shall be through Low Frequency Injection and also 3<sup>rd</sup> Harmonic principle.
- Over-excitation, Volts / Hz (24);
- Loss of Synchronism (78);
- Phase and neutral Overvoltage (59 P / N) with four independent steps;
- Undervoltage phase and 3<sup>rd</sup> harmonic (27 P / TH) with four independent steps;
- Over, under and rate of change frequency (81O / U / R) with four independent steps;
- Fuse failure, voltage balance function (60) with internal block logic.
- Rotor Earth Fault (64R)
- 95% Stator Earth Fault (59N)
- Generator Backup Impedance (21)
- Out of step protection (Pole slip) (78)

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.

The protection system shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Eight configurable spare digital I / O wired to terminals required for interface the TG protection and control;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- One critical self-test alarm;
- One non-critical self-test alarm;
- One VT fuse failure;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The protection system shall include the following user interfaces:

- Individual target LED's for each protection function, with common reset push button on the front panel;
- A keypad to enter settings, access data, and test outputs;
- An MMI display, used with the keypad for the above functions, and the display of event summary information and scrolled present AC values;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- A time synchronization port;
- Test and connection plugs for current and voltage injection testing;
- Facilities for protection function testing;
- Redundant communication facilities through fiber optic cables in compliance with IEC 61850.

The protection system shall use draw-out or plug-in modular construction for ease of maintenance.

External tripping relays (94) and lockout relays (86) shall be provided. Separate relays shall be provided for Protection-A and Protection-B.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

#### iv. Transformer Protection

The protection for the AC Transformer shall comprise one Integrated Multifunction Digital Relay for Protection-A of one brand backed up by a second Integrated Multifunction Digital Relay for Protection-B of the same type but provided by a different manufacturer. The back-up transformer relay Protection-B shall be assumed by the Overall Protection specified below. Although specific functions are specified for the multifunction relay, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The integrated digital protection system shall include protection functions, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay. Additional features to include:

- Two-Winding Current Differential Protection;

Sensitive current differential protection with programmable single- or dual-slope percentage restraint, supervised by a choice of second- and fourth-harmonic blocking or restraint elements, plus fifth-harmonic and dc blocking elements, for secure protection of up to four windings. "Around the clock" phase angle compensation settings and automatic tap calculations simplify settings. Individual Winding Overcurrent Protection

Torque-controllable overcurrent elements provide comprehensive overcurrent protection on each winding input. Combined current feature sums current from two CTs for ring bus and breaker-and-a-half overcurrent applications.

- Protection and Control Logic;

Control Equations with variables, timers, latch bits, and remote control elements for customizing advanced protection and control schemes. Local programmable control elements and programmable text display points for advanced local operator interface.

- Metering and Reporting;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Oscillographic event reports (up to seven 60-cycle reports), Sequential Events Recorder (SER) reporting, and accurate metering eliminate or reduce external recorder and metering requirements. Use through-fault monitor, station battery voltage monitor, and circuit breaker contact wear monitor to provide data for Reliability Centered Maintenance (RCM) programs.

- Settings and Analysis Software;

Software simplifies settings and speeds event analysis. Windows –based menu screens provide error checking and real-time displays to reduce settings and connection errors.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

The Transformer relays shall be provided with 2 Current inputs.

High speed functions such as 87T or 87R operate in less than 2 cycles.

The following protection functions shall be included in the system:

- High speed transformer differential (87T or 87R);
- Restricted earth differential (87G);
- Over-excitation, Volts / Hz (24);
- Phase distance backup (21);
- Phase time and instantaneous overcurrent per input (50 / 51P-1 & 50 / 51P-2);
- Ground time and instantaneous overcurrent per input (50 / 51G-1 & 50 / 51G-2 );
- Neutral time and instantaneous overcurrent per input (50 / 51N-1 & 50 / 51N-2);
- Phase and neutral directional overcurrent (67 P / N);
- Phase and neutral Overvoltage (59 P / N) with four independent steps;
- Phase and neutral Undervoltage (27 P / N) with four independent steps;
- Over and under (81O / U) with four independent steps;
- Fuse failure, voltage balance function (60) with internal block logic.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The following trip signals originating from the Transformer shall be connected to relay digital input. These trip signals are taken from the Common Marshaling Box (CMB):

- High Winding temperature phase-R (49TW);
- High Winding temperature phase-Y (49TW);
- High Winding temperature phase-B (49TW);
- High Gas Pressure phase-R (63T);
- High Gas Pressure phase-Y (63T);
- High Gas Pressure phase-B (63T);
- Low Oil Level, phase-R (71T);
- Low Oil Level, phase-Y (71T);
- Low Oil Level, phase-B (71T);
- Low Water Flow, pump-1 & 2, phase-R (80WT);
- Low Water Flow, pump-1 & 2, phase-Y (80WT);
- Low Water Flow, pump-1 & 2, phase-B (80WT);
- Off Load Tap Changer interlock failure (OCTC).

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.

The protection system shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One VT fuse failure;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The protection system shall include the following user interfaces:

- Individual target LED's for each protection function, with common reset push button on the front panel;
- A keypad to enter settings, access data, and test outputs;
- An MMI display, used with the keypad for the above functions, and the display of event summary information and scrolled present AC values;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- A time synchronization port;
- Test and connection plugs for current and voltage injection testing;
- Facilities for protection function testing;
- Redundant communication facilities through fiber optic cables in compliance with IEC 61850.

The protection system shall use draw-out or plug-in modular construction for ease of maintenance.

The transformer Protection-A shall use the generator protection external tripping relays (94SA-x) and lockout relays (86SA-x).

#### v. Overall Differential Protection

An overall differential protection shall be provided as shown on Drawing. The overall differential protection shall overlap the Generator and Transformer zones and shall act as Protection-B of the Transformer and shall one Integrated Multifunction Digital Relay.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

This relay shall be similar to the transformer protection relay but provided by a different manufacturer. Although specific functions are specified for the multifunction relay, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The integrated digital protection system shall include protection functions, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay. Additional features to include:

- Four-Winding Current Differential Protection;

Sensitive current differential protection with programmable single- or dual-slope percentage restraint, supervised by a choice of second- and fourth-harmonic blocking or restraint elements, plus fifth-harmonic and dc blocking elements, for secure protection of up to four windings. "Around the clock" phase angle compensation settings and automatic tap calculations simplify settings. Individual Winding Overcurrent Protection

Torque-controllable overcurrent elements provide comprehensive overcurrent protection on each winding input. Combined current feature sums current from two CTs for ring bus and breaker-and-a-half overcurrent applications.

- Protection and Control Logic;

Control Equations with variables, timers, latch bits, and remote-control elements for customizing advanced protection and control schemes. Local programmable control elements and programmable text display points for advanced local operator interface.

- Metering and Reporting;

Oscillographic event reports (up to seven 60-cycle reports), Sequential Events Recorder (SER) reporting, and accurate metering eliminate or reduce external recorder and metering requirements. Use through-fault monitor, station battery voltage monitor, and circuit breaker contact wear monitor to provide data for Reliability Centered Maintenance (RCM) programs.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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- Settings and Analysis Software;

Software simplifies settings and speeds event analysis. Windows –based menu screens provide error checking and real-time displays to reduce settings and connection errors.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

The Overall differential relays shall be provided with 4 Current inputs.

High speed functions such as 87GT operate in less than 2 cycles.

The following protection functions shall be included in the system:

- High speed overall differential (87GT);
- Restricted earth differential (87GB);
- Over-excitation, Volts / Hz (24);
- Phase distance backup (21);
- Phase time and instantaneous overcurrent per input (50 / 51T, 50 / 51G, 50 / 51ET & 50 / 51UA);
- Ground time and instantaneous overcurrent (50 / 51G / T-1);
- Neutral time and instantaneous overcurrent (50 / 51N / T);
- Phase and neutral directional overcurrent (67 P / N);
- Phase and neutral Overvoltage (59 P / N) with four independent steps;
- Phase and neutral Undervoltage (27 P / N) with four independent steps;
- Over and under (81O / U) with four independent steps;
- Fuse failure, voltage balance function (60) with internal block logic.

The following trip signals originating from the Transformer shall be connected to relay digital input. These trip signals are taken from the Common Marshaling Box (CMB):

- High Oil temperature phase-R (49T);
- High Oil temperature phase-Y (49T);
- High Oil temperature phase-B (49T);
- Pressure Relief Device, phase-R (63PT);
- Pressure Relief Device, phase-Y (63PT);
- Pressure Relief Device, phase-B (63PT);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Low Oil Flow, phase-R (80OT);
- Low Oil Flow, phase-Y (80OT);
- Low Oil Flow, phase-B (80OT).

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.

The protection system shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One VT fuse failure;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The protection system shall include the following user interfaces:

- Individual target LED's for each protection function, with common reset push button on the front panel;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- A keypad to enter settings, access data, and test outputs;
- An MMI display, used with the keypad for the above functions, and the display of event summary information and scrolled present AC values;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- A time synchronization port;
- Test and connection plugs for current and voltage injection testing;
- Facilities for protection function testing;
- Redundant communication facilities through fiber optic cables in compliance with IEC 61850.

The protection system shall use draw-out or plug-in modular construction for ease of maintenance.

The overall differential Protection-B shall use the generator protection external tripping relays (94SB-x) and lockout relays (86SB-x).

vi. GIS Breaker Failure and Bus Differential Protection

The Breaker Failure protection and Bus protection for the 220 kV GIS circuit breakers and Buses A and B shall be combined and comprise Integrated Multifunction Digital Relays system for Protection-A of one brand backed up by a second Integrated Multifunction Digital Relays system for Protection-B of the same type but provided by a different manufacturer. Although specific functions are specified for the multifunction relay, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted. Separate LBB relays for Re-trip and Back-trip shall be provided for individual bays.

The integrated digital protection system shall include protection functions, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The breaker failure and bus differential relays shall be provided with 12 Current inputs and 96 digital input dedicated for status monitoring of Isolator Switches and Circuit Breakers.

High speed functions such as 87B operate in less than 2 cycles.

The following protection functions shall be included in the system:

- High speed bus differential (87BA);
- High speed bus differential (87BB);
- Unrestrained Bus differential (50 / 87BA);
- Unrestrained Bus differential (50 / 87BB);
- Phase time and instantaneous overcurrent per input (50 / 51P-1 to 50 / 51P-12);
- Neutral time and instantaneous overcurrent per input (50 / 51N-1 to 50 / 51N-12);
- Breaker Failure instantaneous current (50BF-1 to 50 BF-12);
- Bus-A Undervoltage (27A) with four independent steps;
- Bus-B Undervoltage (27B) with four independent steps.

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Isolator discrepancy alarm (ISL);
- DC power supply failure;
- Self-test failure.

The protection system shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The protection system shall include the following user interfaces:

- Individual target LED's for each protection function, with common reset push button on the front panel;
- A keypad to enter settings, access data, and test outputs;
- An MMI display, used with the keypad for the above functions, and the display of event summary information and scrolled present AC values;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- A time synchronization port;
- Test and connection plugs for current and voltage injection testing;
- Facilities for protection function testing;
- Redundant communication facilities through fiber optic cables in compliance with IEC 61850.

The protection system shall use draw-out or plug-in modular construction for ease of maintenance.

External lockout relays (86) shall be provided. Separate relays shall be provided for Protection-A and Protection-B.

#### vii. Transmission Line Distance Protection

The Transmission Line Distance protection shall be comprising one Integrated Multifunction Digital Relay system for Protection-A of one brand backed up by a second Integrated Multifunction Digital Relay system for Protection-B of the same type but provided by a different manufacturer. Although specific functions are specified for the multifunction relay, other arrangements of protection functions



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The integrated digital protection system shall include protection functions, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay. Line voltage and auto-reclose function shall be built in function of Protection-A and Protection-B distance protection relay.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

The following protection functions shall be included in the system:

- Phase Distance, 5 zones, quadrilateral (21L);
- Earth Distance, 5 zones, quadrilateral (21LG);
- Phase time and instantaneous overcurrent (50 / 51L);
- Phase time and instantaneous negative sequence overcurrent (50 / 51L(2));
- Ground time and instantaneous overcurrent (50 / 51LG);
- Neutral time and instantaneous overcurrent (50 / 51LN);
- Phase, neutral and negative sequence directional overcurrent (67 P / N / (2));
- Out of Step Trip (78);
- Power Swing Blocking (68);
- Phase, neutral and negative sequence Overvoltage (59P / N / (2)) with four independent steps;
- Phase Undervoltage (27 P) with four independent steps;
- Over and under frequency (81O / U) with four independent steps;
- Fuse failure, voltage balance function (60) with internal block logic.

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The protection system shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The protection system shall include the following user interfaces:

- Individual target LED's for each protection function, with common reset push button on the front panel;
- A keypad to enter settings, access data, and test outputs;
- An MMI display, used with the keypad for the above functions, and the display of event summary information and scrolled present AC values;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- A time synchronization port;
- Test and connection plugs for current and voltage injection testing;
- Facilities for protection function testing;
- Redundant pilot communication Channels through fiber optic cables for PLCC interface;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Redundant communication facilities through fiber optic cables in compliance with IEC 61850.

The protection system shall use draw-out or plug-in modular construction for ease of maintenance.

External tripping relays (94) and lockout relays (86) shall be provided. Separate relays shall be provided for Protection-A and Protection-B.

Single shot, high speed 1-phase and 3-phase auto reclosing scheme with check synchronizing facility shall be provided.

Auto-reclosing and check synchronism function.

The auto recloser shall allow the automatic reclosure of the circuit breakers after its opening. This reclosure may be dependent on the voltage check or the synchronism check between bus bar and line voltages.

The autorecloser shall have following modes of operation-single phase auto reclosing, three phase auto reclosing and non-auto reclosing.

The system shall have built in synchronism check function to enable operation in following modes:

- Live busbar and dead line.
- Dead busbar and live line.
- Live busbar and live line

#### viii. Bay Controller Unit with Protection Features

The Bay Controller Units (BCU) shall be comprised of one non-redundant Multifunction Digital Protection, Control, Monitoring, Analysis and Energy Metering system, are integrated to Protection-A Panels. The BCU's in the Hydro application are generally used perform operation logics, data acquisition, Bay control and operation of 220 kV GIS related equipment. The BCU's are also used to perform some limited Protection-A functions as shown on the drawings and indicated herein.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The 220 kV GIS substation, for purposes of understanding, will be divided into bays. A bay is composed of circuit breakers, isolator switches, earthing switches, CT and IVT.

Production Bay BCU's are regrouped in the Unit Bay Controller and Metering Board (BMB) along with the Unit Production Energy Meters.

The Unit Protection Board BCU's shall be a slave of the Production Bay BCU.

As part of the Protection, Control and Communications System, a Bay Controller Unit (BCU), shall be included with features such as:

- Conforms to IEC 60255, IEC 60870 and IEC 61850 standards;
- A large HMI display with keypad for displaying the Bay Mimic of the single line and for function and alarm display. HMI to be class 16 X 40 (240X128 pixels) graphical LED display;
- Provided with programmable Buttons and rotary knobs for switchgear control and the display of event summary information and for selecting Menus and Sub-menus;
- Modular card draw-out construction to reduce troubleshooting and maintenance time and costs;
- Digital-based device containing a central processing unit (CPU);
- Signal and command indications;
- Display the position of the switching devices;
- Local / remote switching via key switch;
- Feeder control diagram;
- Measured-value acquisition;
- P, Q, Cos  $\phi$  (power factor) and meter-reading calculation;
- ☐ Event logging;
- A keypad for selecting setting menus and submenus, and test outputs;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- Time synchronization port through an IRIG-B signal;
- Facilities for protection function testing;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Redundant communication facilities through fiber optic cables in compliance with IEC 61850 protocol;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

The BCU shall mainly be dedicated to:

- receiving and sending command signals such as: switching the 220 kV circuit breakers (52), Isolator Switches (89), earthing switches (57) and 15 kV IPB Bus disconnectors (89);
- receiving and sending status, diagnostic, measure, and perturbation signals;
- sending and receiving interlock signals.

The BCU shall be conceived to carry out the aforesaid functions in condition of maximum safety.

The Bay Controller can be a PLC and protection elements type, with control modules that enables the unit configuration (assignment of inputs and outputs) for the implementation of logic circuits, and protection elements such as overcurrent and overvoltage.

At the front panel of the BCU, the operation of opening and closing of the circuit breaker shall be performed directly through ON and OFF keys for switch commands.

An additional CB Control Switch and Local / Remote Selector Switch shall be mounted on the local Control panel in the GIS Hall and shall allow local opening and closing of the circuit breaker.

The control of Circuit Breaker and Isolator Switches shall be carried by discrepancy switches.

At a closing request of a circuit breaker, the BCU logic shall have:

- checked the interlocks;
- checked the condition of synchronism;
- activated the “anti-pumping” function;
- Inhibited the function of Automatic Reclosing.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

In particular the BCU shall be able to manage the interlocks among the different equipment, preventing not allowed operation. An inconsistent request of operation shall be signalized.

It shall be possible to modify the interlock configuration via software.

Although specific functions are specified for the BCU's, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The BCU system shall include protection functions, interlocks, control, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

The following interlock functions shall be performed by the BCU:

- Open position of bay Circuit Breaker (52);
- Close position of bay Circuit Breaker (52);
- Open position of Isolated Phase Bus Disconnecter Switch (Unit 89-1 to 6);
- Close position of Isolated Phase Bus Disconnecter Switch (Unit 89-1 to 6);
- Open position of each line Isolator Switch (89);
- Close position of each line Isolator Switch (89);
- Open position of each earth Isolator Switch (57);
- Close position of each earth Isolator Switch (57).

The following Command functions shall be performed by the BCU:

- Open command of bay Circuit Breaker (52);
- Close command of bay Circuit Breaker (52);
- Open command of Isolated Phase Bus Disconnecter Switch (Unit 89-1 to 6);
- Close command of Isolated Phase Bus Disconnecter Switch (Unit 89-1 to 6);
- Open command of each line Isolator Switch (89);
- Close command of each line Isolator Switch (89);
- Open command of each earth Isolator Switch (57);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Close command of each earth Isolator Switch (57).

The following Instrument Transformer input:

- Bay Current Transformers;
- Bay Voltage Transformers;
- Bus Voltage Transformers.

The following protection functions shall be available in the BCU:

- Phase time and instantaneous overcurrent (50 / 51) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- Ground time and instantaneous overcurrent (50 / 51G) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- Neutral time and instantaneous overcurrent (50 / 51N) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- The broken delta Earth Fault(64B) [for Isolated Insulated Phase Bus];
- Phase, neutral and negative sequence directional overcurrent (67 P / N / (2));
- Synchronous Check (25) (The synchronism and energizing check functions shall be available in the Bay Control Units with features such as
  - Energizing for dead line – live bus, live line- dead bus or dead line – dead bus with no synchro check function.
  - Synchronizing between live line and live bus with synchro check function);
- Bus and Line phase and neutral sequence Overvoltage (59P / N) with three independent steps [additional steps available to complement the protection-A requirements];
- Bus and Line phase Undervoltage (27 P) with three independent steps [additional steps available to complement the protection-A requirements];
- Over and under frequency (81O / U) with three independent steps [additional steps available to complement the protection-A requirements];
- Fuse failure, voltage balance function (60) with internal block logic.

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The BCU shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;
- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

The BCU shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory.

BCU protection function shall use the same tripping relays (94) and lockout relays (86) present in the protection-A panel.

#### ix. Overcurrent Protection

The Overcurrent Protection shall be comprised of one non-redundant Multifunction Digital Protection system similar to the Bay Controller Units but without the unnecessary bay control features. The overcurrent protection shall act as to Protection-A of the Excitation Transformers (ET), Unit Auxiliary Transformers (UAT), Station Auxiliary Transformer (SAT) and Station Service Transformers (SST).

As part of the Protection, Control and Communications System, the Overcurrent Protection shall be included with features such as:

- Conforms to IEC 60255, IEC 60870 and IEC 61850 standards;
- A large HMI display with keypad for displaying the Bay Mimic of the single line and for function and alarm display. HMI to be class 16 X 40 (240X128 pixels) graphical LED display;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Provided with programmable Buttons and rotary knobs for switchgear control and the display of event summary information and for selecting Menus and Sub-menus;
- Modular card draw-out construction to reduce troubleshooting and maintenance time and costs;
- Digital-based device containing a central processing unit (CPU);
- Signal and command indications;
- Display the position of the switching devices;
- Local / remote switching via key switch;
- Feeder control diagram;
- Measured-value acquisition;
- P, Q, Cos  $\phi$  (power factor) and meter-reading calculation;
- ☐ Event logging;
- A keypad for selecting setting menus and submenus, and test outputs;
- Front and rear RS232 serial data ports for local and remote communication, setting, data retrieval;
- Local printer data port;
- Time synchronization port through an IRIG-B signal;
- Facilities for protection function testing;
- Redundant communication facilities through fiber optic cables in compliance with IEC 61850 protocol;
- Metering of currents, voltage, negative sequence current, watts, VAR's, and frequency.

Although specific functions are specified for the BCU's, other arrangements of protection functions would be considered based on the base design offered. No reduction of protection functions shall be permitted.

The Overcurrent Protection shall include protection functions, interlocks, monitoring, diagnostic and communication capabilities. A high degree of reliability and safety shall be provided by extensive self-diagnostic routines and a redundant DC power supply. An alarm output contact shall be made available in case of a self-diagnostic failure from the protection relay.

The protection functions shall operate over the range of at least 31-79 Hz with the same accuracy as at nominal system frequency.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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The following protection functions shall be available in the Overcurrent Protection:

- Phase time and instantaneous overcurrent (50 / 51) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- Ground time and instantaneous overcurrent (50 / 51G) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- Neutral time and instantaneous overcurrent (50 / 51N) [for Excitation transformer and for auxiliary services UAT, SAT and SST];
- The broken delta Earth Fault(64B) [for Isolated Insulated Phase Bus];
- Phase, neutral and negative sequence directional overcurrent (67 P / N / (2));
- Synchronous Check (25);
- Bus and Line phase and neutral sequence Overvoltage (59P / N) with three independent steps [additional steps available to complement the protection-A requirements];
- Bus and Line phase Undervoltage (27 P) with three independent steps [additional steps available to complement the protection-A requirements];
- Over and under frequency (81O / U) with three independent steps[additional steps available to complement the protection-A requirements];
- Fuse failure, voltage balance function (60) with internal block logic.

The following Instrument Transformer input:

- Tap-off Current Transformers;
- Bus Voltage Transformers;

The following alarm functions shall be provided in the system:

- Current Transformer Supervision (CTS);
- Voltage Transformer Supervision (VTS);
- DC power supply failure;
- Self-test failure.

The Overcurrent Protection shall have configurable inputs, configurable output relays and assigned alarm relays which shall include:

- The quantity of I / O as required to execute commands, logics, interlocks and data acquisition;
- Configurable trip relays with two contacts each;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Configurable alarm relays with one contact each;
- One critical self-test alarm;
- One non-critical self-test alarm;
- One alarm for loss of each power supply.

Drawings showing the configuration proposed shall be provided for approval.

The protection system shall have the following monitoring and metering functions:

- The last ten events, time tagged to within one millisecond;
- Fault report for the last three faults;
- User configurable oscillography which capture up to 120 cycles with a waveform sampling rate of at least 12 samples per second and at least two cycles of pre-fault memory.

Overcurrent protection function shall use the same lockout relays (86) present in the protection-A panel.

- x. Tripping relays, Lockout Relays, Auxiliary Relays, Supervisory Relays and Interposing Relays:
  - a. High speed tripping and lockout relays shall be provided for the opening, closing and tripping of the GIS 220 kV Circuit Breakers;
  - b. Auxiliary relays shall be provided for interlocking and for contact multiplication, for Mechanical Protection and for all 220 V DC circuits;
  - c. Interposing relays shall be provided for all output signals of the I / O modules controlling external devices including motor starters, coils etc. carrying a thermal load;
  - d. A tripping relay (94) shall be provided in each protection panel A and B having self reset tripping functions such as overvoltage, undervoltage, over and under frequency, overfluxing etc. as indicated above;
  - e. A lockout relay (86 and 96) shall be provided in each protection panel A and B as indicated above;
  - f. All relays shall be rack mounted for optimum space utilization;
  - g. The relays shall be Heavy Duty Industrial Grade have a rating compatible with the load. All relays shall be provided with gold plated contacts;
  - h. Relays shall be mounted in dust tight housing and shall be the plug-in type. The relays must be provided with set screws to secure them to their base.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Clips shall not be accepted for Protection and Auxiliary relays under any circumstances. Clips are accepted for interposing relays only;

- i. Protection Relays shall be High Speed and specifically designed for tripping of circuit breaker coil. Relay coils shall be supervised using an external Supervisory Relay. They are designated as IEEE function number 86 (and 96) and 94. Lockout relays shall be of the latching type resettable with an external pushbutton. Remote resetting is not permitted. Relays shall be rated 10 A continuous, 30 A make 5 s at 220 V DC suitable for 100,000 electrical and 1 million mechanical operations. A minimum of 10 convertible form A and B contacts shall be provided. A minimum of 3 spare contacts shall be provided for future use;
- j. The main lockout (86 & 96) and self reset (94) relays specified shall have the following performance:
  - High speed trip contacts, 2 ms to 5 ms, light duty trip or electronic contacts shunted by slower speed, heavy duty contacts for current breaking;
  - Making and breaking contacts capable of independently making and carrying the circuit breaker trip circuit current;
  - Heavy duty contacts which allow the light duty contacts to reset first;
  - Tripping relays shall be rack mounted and shall by time delay or current monitor circuits;
  - Lockout relays shall be latching type and shall be using rack mounted. A reset button shall be provided near the relay. Reset can only be performed at the location of the relay;
  - Tripping and lockout relays shall be provided with target operating indicators;
  - The tripping and lockout relays shall be monitored from the local protection relays;
  - Provide three spare tripping and lockout contacts wired to terminal for each Stator relay 86S, 96S and 94S relay for Unit protection and control interface with TG section.

k. Tripping and Lockout Relay Table:

Protection	System	Board	Lockout Relays	Tripping Relays
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EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

System	Number x	Number	Prot. A	Prot. B	Prot. A	Prot. B
Unit (pkg-3)	1 to 3	UCB-x	86GA-x	86GB-x	94GA-x	94GB-x
Generator Field (pkg-3)	1 to 3	EX-x	86FA-x	86FB-x	94FA-x	94FB-x
Generator Stator and Transformer	1 to 3	UPB-x	86SA-x	86SB-x	94SA-x	94SB-x
220 kV Overhead Line	1 and 2	LPB	86LA-x	86LB-x	94LA-x	94LB-x
GIS Breaker Failure & Bus:						
Unit	1 to 3	BPB	96SA-x	96SB-x		
220 kV GIB Line	1 and 2	BPB	96LA-x	96LB-x		
Bus Coupler	1	BPB	96BA	96BB	94BAA 94BBA	94BAB 94BBB
SST	1	BPB	96STA	96STB		

- I. Auxiliary and Supervisory Relays shall be Heavy Duty with contacts rated 5 A continuous, 30 A make at 220 V DC suitable for 100,000 electrical and 1 million mechanical operations. A minimum of 4 convertible form A and B contacts shall be provided. A minimum of 2 spare contacts shall be provided for future use;
- m. Protection Supply Supervision: A combination of undervoltage relay and molded case breaker (MCB) alarm contacts shall be provided to monitor each separately fused or protected 220 V DC supply used for protection. If 220 V DC input modules are available from the DCS system provider, the 220 V DC circuits can be directly wired to the IED relays and BCU inputs for monitoring;
- n. The Interposing relay contacts shall be rated 10 A continuous, 20 A make at 240 V AC and 24 V DC suitable for 100,000 electrical and 1 million

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

mechanical operations. All relays shall be provided with three form C contacts and LED operation indication;

- o. Interposing relays shall be mounted in the rear section of the I / O module panel and shall be isolated from one another. No mixing of control Voltage is allowed. Metal barriers shall be used to separate Voltage classes. System A, B and Common shall be located in different panels;
- p. Manufacturers accepted for interposing relays: Tyco O / E / N type 51D-3 gold or equal.

xi. Test Switches:

- a. Test Switches facilities shall enable the complete isolation of relays individually from the instrument transformer circuits without affecting other devices on the same circuit. Also facilities shall be provided to use test plugs either to inject test supplies into the relay group or to check the actual currents and voltages being supplied from the instrument transformers;
- b. CT Test Switches shall be provided c / w with shorting mechanism for each set of Current Transformer;
- c. VT Test Switches shall be provided for each Voltage Transformer core;
- d. Trip disconnect Test Switches shall be provided for opening the trip circuits of each tripping and lockout relay;
- e. Power sources supplying DC to the relay shall be provided with Test Switches to safely isolate the 220 V DC supply to each Protection relay;
- f. Interlock and interpanel signals shall be provided with Test Switches to safely isolate any power source coming from another source;
- g. Test Switches shall be front mounted and accessible from the front of protection panels;
- h. Test Switches functions (CT, VT, controls, DC sources, interlocks and interpanel signals) shall regrouped in a logical way to optimize the use of space. Different regroupings shall be applied for each relay. CT and VT used in more than one protection panel shall be provided with a Test Switch in each one of them. As an example, test switches would contain 4 potential poles (P) and six (6) current poles (C) arranged as follows: when viewed from the front of the switch PPPP- CC CC CC , (CC designates current shorting);
- i. The Test Switches shall be composed of switch poles that can be operated individually. The switch knobs shall be color code. Each pole shall bear a



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

permanent identification plate. Individual poles shall be of the knife blade type hinged at the bottom with barriers separating each pole. The switches shall be provided with an unbreakable clear cover that can be padlocked with poles in either open or closed position;

- j. The Test Switches shall be a 10-pole rear connection type. The switches shall be for semi flush mounting on the front of the protection panels;
  - k. All measurement and tests shall be performed at the front of the protection panel, without taking any device out of service, and without the need to access wiring at the rear of the devices;
  - l. The test switches and plugs shall have all the features necessary for application involving the safe measurement and isolation of individual currents, voltages, and digital I / O signals to facilitate testing of instrumentation and protection devices;
  - m. The Current Transformer circuits shall be provided with make-before-break current shorting feature allowing test personnel to quickly and safely isolate devices from the CT's;
  - n. Voltage measurement shall be made directly on the test switch without disturbing existing connections. A test clip shall be provided on the top of each pole that allows connection with standard spring clip test leads;
  - o. The Test Switch contacts shall be rated 30 A continuous at 250 V DC or 600 V AC;
  - p. The minimum short-time rating of the switches shall be 500 A for 1 second. Connection diagrams will be supplied by the Customer at the appropriate time;
  - q. The only product accepted is the ABB Flexitest switch.
- xii. Operator Workstation (OWS5)

Industrials Desktop PC Computers with Windows-7™ Professional or newer operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Intel® Xeon® Dual-Core Processor (2.40 GHz, 4 MB cache, 1066 MHz memory) or better;
- 4GB DDR3 SDRAM at 1333MHz;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- 500 GB (7200rpm or faster) SATA hard disk;
- One (1) DVD+ / -RW with Double Layer optical drive;
- Gigabit Ethernet port;
- Four (4) USB ports;
- One (1) IEEE1394 port;
- One (1) serial port;
- One (1) SATA port;
- Dedicated 1024MB Video Card with two (2) HDMI and one (1) DVI ports to support 1920x1200 resolution;
- All necessary adapters and software required to connect Control, Metering and Monitoring functions of the Protection Boards.

The two (2) HDMI ports on the video card shall be used for dual monitor setup and the DVI to interface the Video Matrix.

Manufacturer: The approved manufacturers shall be Hewlett Packard, Dell or equivalent.

#### xiii. Dispatch Work Station (DWS)

Industrials Desktop PC Computers with Windows-7™ Professional or newer operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Intel® Xeon® Dual-Core Processor (2.40 GHz, 4 MB cache, 1066 MHz memory) or better;
- 4GB DDR3 SDRAM at 1333MHz;
- 1000 GB (7200rpm or faster) SATA hard disk;
- One (1) DVD+ / -RW with Double Layer optical drive;
- Gigabit Ethernet port;
- Four (4) USB ports;
- One (1) IEEE1394 port;
- One (1) serial port;
- One (1) SATA port;
- Two Gigabit Ethernet ports (RJ45) for interfacing PLCC-1 and PLCC-2;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Dedicated 1024MB Video Card with two (2) HDMI ports to support 1920x1200 resolution;
- All necessary adapters and software required to connect Control, Metering and Monitoring functions of the Protection Boards;
- Gathering of controls, metering and monitoring signals to be dispatched to the Utility through the PLCC systems. Access to PLCC settings and functions shall be available from this station to do maintenance or update of software through a high level password.

Manufacturer: The approved manufacturers shall be Hewlett Packard, Dell or equivalent.

#### xiv. Engineering Work Station (EWS3)

Industrials Desktop PC Computers with Windows-7™ Professional or newer operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Intel® Xeon® Dual-Core Processor (2.40 GHz, 4 MB cache, 1066 MHz memory) or better;
- 4GB DDR3 SDRAM at 1333MHz;
- 500 GB (7200rpm or faster) SATA hard disk;
- One (1) DVD+ / -RW with Double Layer optical drive;
- Gigabit Ethernet port;
- Four (4) USB ports;
- One (1) IEEE1394 port;
- One (1) serial port;
- One (1) SATA port;
- Dedicated 1024MB Video Card with two (2) HDMI and one (1) DVI ports to support 1920x1200 resolution;
- All necessary adapters and software required to connect Control, Metering and Monitoring functions of the Protection Boards.

Manufacturer: The approved manufacturers shall be Hewlett Packard, Dell or equivalent.

#### xv. Laptop Engineering Work Station (EWS4)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

A Professional grade Heavy Duty Mobile Workstation Laptop Computer with Windows XP™ Professional or newer operating system and the latest Microsoft Office Basic Edition shall be furnished and shall have, as a minimum, the following characteristics:

- Intel® Core i7 processor, with a minimum of 4 MB L2 cache 800 MHz front side bus or better;
- 4 GB DDR3 SDRAM 1333MHz or faster memory;
- 1.0 TB (7200rpm or faster) SATA hard disk;
- One (1) DVD+ / -RW with Double Layer optical drive;
- Gigabit Ethernet port;
- Intel Centrino 802.11a / b / g / n wireless adapter;
- 17 inches widescreen (1920x1200) LED (LED backlit) display;
- Four (4) USB ports;
- One (1) IEEE1394 port ;
- One (1) serial port (internal or external);
- Dedicated 1024MB Video Card with DVI port to support 1920x1200 resolution;
- Integral Bluetooth 2.0 or newer adapter;
- Spill Proof Keyboard;
- Multi-button wireless Bluetooth compatible laser mouse;
- Titanium Housing;
- External lockable Docking Station;
- All necessary adapters and software required to Protection, Automation, Metering & Communication System functions of the local HMI of the Control Boards as well as selected function from systems provided by others and intergrated into the SCADA. Access to PLC program functions shall be available from these stations to do maintenance or update of software through a high level password.

Manufacturer: The approved manufacturers shall be Hewlett Packard, Dell or equivalent.

xvi. Energy Management Work Station (EMS)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Industrials Desktop PC Computers with Windows-7™ Professional or newer operating system and the latest Microsoft Office Basic Edition shall be furnished, as shown on the SCADA SYSTEM ARCHITECTURE drawings and shall have, as minimum the following characteristics:

- Intel® Xeon® Dual-Core Processor (2.40 GHz, 4 MB cache, 1066 MHz memory) or better;
- 4GB DDR3 SDRAM at 1333MHz;
- 1000 GB (7200rpm or faster) SATA hard disk;
- One (1) DVD+ / -RW with Double Layer optical drive;
- Gigabit Ethernet port;
- Four (4) USB ports;
- One (1) IEEE1394 port;
- One (1) serial port;
- One (1) SATA port;
- Two Gigabit Ethernet ports (RJ45) for interfacing PLCC-1 and PLCC-2;
- Dedicated 1024MB Video Card with two (2) HDMI ports to support 1920x1200 resolution;
- All necessary adapters and software required to connect Control, Metering and Monitoring functions of the Protection Boards;
- Gathering of metering data from the Energy Meters as shown on Tender drawing for display, tabulation, storing, analysis trending, etc.

Manufacturer: The approved manufacturers shall be Hewlett Packard, Dell or equivalent.

#### xvii.PC Screens

Workstation Monitors as shown on the SCADA SYSTEM ARCHITECTURE drawings shall be furnished, as a minimum, the following characteristics:

- Active matrix – TFT LED (LED backlit), 22-inch and 32-inch screens;
- Minimum pixel pitch of 0.264 mm, and resolution of 1920x1200 at 60 Hz;
- Viewing angle of + / -80° vertical and horizontal;
- Antiglare with hard-coating 3H faceplate coating;
- HDMI input.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Operator Workstations require two (2) 32-inch screens per Workstation. Other Workstations shall be supplied with a single 22-inch screen.

Manufacturer: The approved manufacturers shall be HP, Dell, Samsung or equivalent.

xviii. Mice

One (1) multi-button UCB Laser Mouse per desktop computer shall be furnished with software for interfacing with the operating system for each Server / Workstation. The mouse shall be ergonomically designed for either left or right hand operation. The mouse shall provide up / down and left / right scrolling.

One mouse shall be provided for each Docking Station for Laptop Work Station.

The mouse shall be Microsoft, Logitech or approved equal.

xix. Keyboards

An ergonomically designed Spill Proof Keyboard per computer shall be furnished for interfacing with the operating system for each Server / Workstation. The keyboard shall be split and sloped to encourage natural hand positioning.

The keyboard shall be Microsoft, Logitech or approved equal.

xx. Routers

Routers shall be furnished as shown on the SCADA SYSTEM ARCHITECTURE drawing and shall have, as a minimum, the following features:

- 8 Fast Gigabit ports (10 / 100 / 1000 Base-T Ethernet);
- 1 Hi-Speed USB 2.0;
- DHCP server;
- Heavy Duty Industrial Grade;
- A minimum of two (2) spare RJ45 port shall be provided for each router;
- Manufacturer: RuggedCom, Cisco Linksys or equal.

xxi. Computer, Server and Controller Requirements:

Each personal computer, IED and processor shall be dual ported to its redundant LAN network.

xxii. Managed Industrial Ethernet Switches:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- a. IED (relays, BCU, etc.) are interfaced with the Automation System through multiport Ethernets Switches as shown on the SCADA SYSTEM ARCHITECTURE drawing;
- b. The managed industrial Ethernet switches shall support, store and forward switching mode, 100Mbit/s as a minimum and 1,000Mbit/s or 10,000Mbit/s as required;
- c. The managed switches shall support Bootstrap Protocol (BootP);
- d. The managed switches shall support Simple Network Management Protocol (SNMP) Versions 1 through 3 or latest and Remote Monitoring (RMON);
- e. The switch shall be manageable by the use of a standard Internet browser. If other management software is required, the software shall be supplied at no additional cost;
- f. SNMP OPC server shall be provided and the data from the switches shall be integrated in the DCS system;
- g. The managed switches shall support Internet Group Management Protocol (IGMP) snooping and multicast filtering;
- h. The managed switches shall support Virtual LAN (VLAN) network topology;
- i. The managed switches shall support Rapid Spanning Tree Protocol 802.1w (RSTP);
- j. The managed switches shall support industrial ring topology;
- k. The managed switches shall be provided with auto negotiation and auto crossing RJ45 ports and ST style fibre optic ports as required;
- l. The switches shall be provided with power indicators and link and activity indicators for each port;
- m. Spare ports shall be provided for each switch. The number of spare ports shall be 25% of the used ports as minimum and not less than 4 ports;
- n. The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- o. Fibre Optic Ethernet Switches shall be Heavy Duty Industrial Grade have enough ports to connect all devices requiring a Fibre Optic connection;
- p. Spare ports shall be provided for each Ethernet switch. The spare ports shall be 25% minimum and not less than 4 ports;
- q. Manufacturer:
  - RuggedCom;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Belden® Hirschmann;
- Or equivalent.

xxiii. Ethernet Copper to Fibre Optic Media Converters:

- a. The Ethernet converters shall only be used when it is not possible or practical to use devices or switches with fibre optic ports;
- b. The function of this module is to convert twisted pair Ethernet to and from a fibre optic segment. The physical and logical interface shall be fully compatible with IEEE 802.3. No additional adapters or transceivers shall be allowed;
- c. The fibre optic ports (transceivers) shall be matched with the type of the fibre optic cable;
- d. The Ethernet converters shall be provided with the following indicators: power; electrical link; electrical data; fibre link; fibre data;
- e. The fibre optic connectors shall be MT-RJ type (or ST or SC);
- f. The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- g. Manufacturers:
  - Moxa;
  - RuggedCom;
  - Phoenix Contacts;
  - Belden®Hirschmann;
  - Or approved equal.

xxiv. RS232 / RS422 / V.11 to RS485:

- a. To be provided as required;
- b. The function of this module is to convert the RS232 / RS422 / V.11 communication signal over copper cables. This is applicable to the PLCC Dispatch Work Station interface. The physical and logical interface shall be fully compatible with EIA 232 and EIA 422 / 485. No additional adapters or transceivers shall be allowed;
- c. The fibre optic ports (transceivers) shall be matched with the type of the fibre optic cable;
- d. The converters shall be provided with the following indicators: power; transmit electrical; receive electrical; transmit; receive;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- e. The copper connectors shall be RJ type (or ST or SC);
- f. The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- g. Manufacturers:
  - RuggedCom;
  - Phoenix Contacts;
  - Moxa;
  - Or approved equal.

xxv. RS232 / RS422 / RS485 / V.11 to Fibre Optic Media Converters:

- a. The function of this module is to convert the RS232 / RS422 / RS485 / V.11 communication signal over copper cables to and from a fibre optic segment. The physical and logical interface shall be fully compatible with EIA 232 and EIA 422 / 485. No additional adapters or transceivers shall be allowed;
- b. The fibre optic ports (transceivers) shall be matched with the type of the fibre optic cable;
- c. The converters shall be provided with the following indicators: power; transmit electrical; receive electrical; transmit fibre; receive fibre;
- d. The fibre optic connectors shall be MT-RJ type (or ST or SC);
- e. The nominal supply voltage shall be 220 V DC. The power supply shall be a Universal range of 88-300VDC;
- f. Manufacturers:
  - RuggedCom;
  - Phoenix Contacts;
  - Moxa;
  - Or approved equal.

xxvi. Common RTU Board and Transformer RTU Boards:

- a. The Common RTU Board (CRB) is provided for the gathering of control, metering, monitoring signals which are common to all units and GIS bays and which are related miscellaneous auxiliary systems of the GIS substation. The Contractor shall connect all I / O's which are related to his scope and shall thus supply are the necessary cables and hardware. Other I / O's are to be used by the Electrical BOP and the Mechanical BOP works. The exact

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

requirements of these Contractors shall be given at a later date. The Common RTU Board shall be provided with the number of I / O point specified which have been estimated sufficient to cover all sections. Contractor shall be responsible for cable and hardware to bring I / O and make connections into the Common RTU Board;

- b. The Transformer RTU Boards are provided for the gathering of metering and monitoring signals of the Generator Transformers (3). All the signals shall be available at the Common Marshalling Box (CMB) located near each RTU Board. Each CMB regroups the metering and monitoring signals originating from the single-phase transformer Marshalling boxes. Contractor shall be responsible for the interconnection between the RTU Boards and CMB and thus provided all necessary cable and hardware;
- c. The Common RTU Board shall be of the same design and construct as the Controls Boards supplied by the Contractor as part of the Main SCADA system. The Transformer RTU Boards shall also be of similar construction except that non-redundant PLC's are sufficient for this application. In addition to interfacing the Automation System, these boards shall also interface the main SCADA system directly according to the following modes:
  - i. Downstream status change information with accurate relation time tagging, real time status change information being transmitted on highest priority;
  - ii. The signals at the measured inputs of the RTU's are read at defined intervals and transmitted to the Automation system upon periodical request;
  - iii. RTU's shall have time tagging and Sequential Event Recording functions.
  - iv. Any status change shall be time-tagged with a selectable time resolution (1 to 10 ms) for transmission to the Automation system and with the same time for local sequential event recording;
  - v. The changes of status are put into a queue, and are transmitted with time of occurrence (1 to 10 ms resolution).
- d. Each single-phase transformer is estimated to provided with the following metering and monitoring signals:
  - Oil temperature indicator (inlet / outlet) 4-20 mA signal;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Water temperature indicator (inlet / outlet) 4-20 mA signal;
- Oil temperature indicator 4-20 mA signal;
- Winding temperature indicator 4-20 mA signal;
- Oil pressure transducer (inlet) 4-20 mA signal;
- Oil temperature transducer (outlet) 4-20 mA signal;
- Oil Flow indicator, pump-1, 4-20 mA signal;
- Oil Flow indicator, pump-2, 4-20 mA signal;
- Auto / Manual selector position;
- High oil temperature alarm (49A);
- High winding temperature alarm (49WA);
- High oil pressure alarm (63A);
- Pressure relief device alarm (63PA);
- Low oil level alarm (71A);
- Oil Pump-1 running signal;
- Oil Pump-1 off signal;
- Oil Pump-1 failure alarm;
- Oil Pump-2 running signal;
- Oil Pump-2 off signal;
- Oil Pump-2 failure alarm;
- High water temperature alarm (49HA);
- Low oil flow alarm (80OA);
- Low water flow alarm (80WA);
- Main AC supply failure alarm (27M);
- Stand-by AC supply failure alarm (27S);
- Off Load Tap Changer discrepancy alarm (OCTC).

xxvii. Panel Construction:

- a. Protection Boards, RTU Boards and Metering Boards are composed of an assembly of free-standing panels;
- b. All Panels shall be multiples of 800x800x2300 mm. The panels shall be built up as a 19" rack-mounted system with the electronic units being contained in a hinged frame, which constitutes the inner front door of the enclosure (opening  $\geq 120^\circ$ ). They shall be provided with an outer glass door complete with lockable hardware. The glass shall be tempered and door shall be easily removable during commissioning. Inner rack frame shall be constructed so as to leave no

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

opening to the back. The rear doors shall be provided full height complete with lockable hardware. All doors shall be provided a heavy-duty 3 point lock system. The panels shall be dust-proof, vermin-proof inner panels. Doors shall be fitted with gaskets; cables enter the cubicle using watertight glands. Degree de protection for panel shall be at least IP 54 and complying with the relevant IEC standards;

- c. Airflow is only possible via a filter loaded with an easily replaceable metallic wool cartridge.;
  - d. Cable access shall be from the bottom only. All panel components shall be mounted fully enclosed;
  - e. Cable connections shall be made at the rear of the cubicle on terminal block strips;
  - f. All the different parts of the equipment shall be accessible without dismantling any door;
  - g. All metallic parts of the cubicle shall be bonded to its main frame by means of flexible copper wires;
  - h. An isolated earthing tinned copper bar mounted on polyamide resin insulators shall be provided and clearly labeled for bonding electronic devices. The earthing bar shall be designed for connection special earthing pit as shown on the earthing drawings. The cross-section of the earthing bar shall be determined so as to withstand the rated short-circuit current of the switchgear in accordance with IEC 62271-200, Clause 5.3;
  - i. In addition to the earthing bar, an additional earthing lug shall be provided for bonding of all non-electronic devices including the panels and various device housings;
  - j. The panel shall be provided with facilities for the lighting, AC receptacles, a telephone jack;
  - k. Manufacturer: The approved manufacturer shall be Rittal or approved equivalent.
- xxviii. Programmable Logic Controllers (PLC):
- a. Programmable Logic Controllers (PLC) are required for Common RTU Board (CRB) and for Transformer RTU Boards (TRB1- to 3);
  - b. Synchronized redundant PLC's shall be provided for the Common RTU Board and a non-redundant PLC shall be provided for the Transformer RTU Boards;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

c. The PLCs shall be responsible for the control monitoring and metering functions of the units and auxiliary systems and shall interface with the HMI. They shall be a rugged industrial design and shall have, as a minimum, the following features:

- Two (2) High-performance 2MHz or higher CPUs in redundant configuration;
- Minimum 32MB. However, the same shall be selected based on application requirement;
- Minimum 4096 bytes free mix combination of various I / O types;
- Less than 0.15 ms / kb Scan Time;
- Less than 1 sec response time to operator commands;
- Hot backup redundancy capabilities;
- Two (2) Power Supply Cards;
- Two (2) Synchronizing Modules;
- Optical Fiber Cable for Synchronization;
- Fast Ethernet Ports;
- Field bus (Mod bus / Profibus) External interface compatibility;
- Compliant to IEC 61131 and OPC Lab certified;
- Power Supply: 220 V DC in Powerhouse and 24 V DC at Remote Sites.

d. Manufacturer: SIEMENS SIMATIC, SCHNEIDER MODICON PREMIUM, GE FANUC, ABB AC800M or approved equal.

xxix. Human-Machine Interfaces (HMI):

- a. Human-Machine Interfaces (HMI) are required for Common RTU Board (CRB) and for Transformer RTU Boards (TRB1- to 3);
- b. HMIs shall be supplied in each Common RTU Board (CRB) and for Transformer RTU Boards (TRB1- to 3) and shall have, as minimum the following characteristics:
  - All HMIs shall be OPC compliant;
  - Display: 15 inch TFT display, 64K colours;
  - Resolution: 1024 x 768 pixels;
  - Control elements: Touchscreen resistive analog;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- User memory: 12 MB, additional 12 MB for options, 256 KB non-volatile memory for Software PLC data;
- Interfaces: 1 x RS485, 1 x RS422, 2 x USB, 2 x RJ 45 Ethernet, 1 x combined SD / Multi Media Card Slot, 1 x CF card slot;
- Degree of protection: IP 65, NEMA 4X front, IP 20 rear;
- Configuration software: WinCC flexible Standard;
- Power Supply: 220 V DC in Powerhouse and 24 V DC at Remote Sites.

c. Manufacturer: SIEMENS Simatic, SCHNEIDER Magelis, GE Fanuc, ABB CP400 or approved equal.

xxx. Input / Output (I / O) Modules

a. General:

- Common RTU Board (CRB) and for Transformer RTU Boards (TRB1- to 3) shall be provided with a system of input-output modules, instrumentation bus, and power supplies;
- All input-output modules shall be of “hot-swappable” type, to allow for replacement under power, while the CS is running. The replacement of a module shall not cause downtime for the CPU and the other modules;
- The input-output modules and power supplies shall meet the Surge Withstand Capability standards as defined by IEC and ANSI / IEEE;
- The input-output modules shall be provided with redundant power supplies. Each power supply shall be fed from a different DC power supply circuit. The loss of a single power supply shall not cause the loss of any input-output module, and shall alarm the operator;
- Common RTU Board (CRB) and for Transformer RTU Boards (TRB1- to 3) shall be provided with the adequate quantity of I / O's. The Contractor shall furthermore provide 20% space for future expansion.

b. Digital Input Modules:

- The digital input modules shall accept normally open or normally closed dry contacts for status and sequence-of-events inputs. All digital inputs shall include optical isolators and filtering to eliminate contact bounce;
- The digital input module shall accept bi-stable and momentary-change inputs. Circuit breaker status and switch positions are bi-stable inputs.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Equipment alarms and protective relay operations are momentary-change inputs;

- Protective relay operations, including electrical and mechanical protective devices, shall be processed as momentary-change inputs.

c. Analog Input Modules:

- The analog input modules shall accept and process transducer voltage signals in the range of  $\pm 10V$  DC or current signals in the range of  $\pm 20$  mA DC. All inputs shall be galvanically isolated;
- The analog input processing shall include filtering, scaling, and A / D conversion with a 12-bit 2's complement resolution;
- Accuracy shall be at least  $\pm 1\%$  and linearity  $\pm 1 / 2$  LSB over the full input range and temperature range.

d. Resistance Temperature Detector (RTD) Input Modules (if later required):

- The RTD input modules shall have the capability of interfacing with Platinum or Copper RTDs;
- The RTD input shall have a minimum resolution of 14 bits plus sign.

e. Control Output Modules:

- The control output modules shall support both maintained and pulse (momentary) outputs;
- All outputs shall use heavy duty interposing relays with three Form-C gold plated contacts as specified article article x above.

f. Instrumentation Bus:

- The Instrumentation Bus shall be designed in accordance with industry-standards such as Field bus, MODBUS, Inter-bus or Profibus.

g. Communications Media:

- The communications media for all external (outside of any cabinet) communication links shall be fibre optics;
- The communications media for internal (inside each board) communication links may be copper.

h. Physical Requirements:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- The Control and RTU boards shall be housed in a standard electronic equipment cabinet with a window door, as specified herein.

i. Power Requirements:

- The Control and RTU boards shall be suitable for operation from a 220 V DC for the Powerhouse Boards and 24 V DC for Remote Sites Boards.

xxxi. Time Standard System:

- a. The GPS clock system is provided (under the TG Section);
- b. The Master Clock is located in the Main Control room;
- c. The Contractor shall provide a Distribution splitter on the Operator floor and provide the necessary cabling to connect it to the GPS Master clock. The Contractor shall connect the local IRIG-B circuits of the Unit protection devices from this splitter;
- d. The Contractor shall provide a Distribution splitter in the Control room and provide the necessary cabling to connect it to the GPS Master clock. The Contractor shall connect the local IRIG-B circuits of the Unit protection devices from this splitter.

xxxii. Miscellaneous Power Supplies (as required)

a. General Requirements

The Contractor shall provide all necessary power supplies required to achieve the system's required functionality. The selection of the power supply shall be done considering the modularity / interchangeability criteria for the entire system. The output voltage shall not vary more than 5% with voltage input variation between -20% to +10%, and output current variation from 0% to 100%.

b. Power Supplies

1. Type: 220V DC to 24V DC:

- Input: 220V DC fused;
- Output: 24VDC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;
- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

2. Type: 240V AC to 24V DC:

- Input: 240V AC 50 Hz, fused, with harmonic filter (power to be provided by UPS);
- Output: 24V DC;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- The residual ripple shall be lower than the maximum required by the connected equipment, but never greater than 100mVpp;
- Operating and status indication;
- Type: Primary switched-mode power supply;
- Electrically isolated between input and output side;
- The power supply shall be protected against excessive current and reverse voltage;
- Modular design;
- Mounting type: standard rail mounting or as required.

3. Type: 48V DC to 24V DC:

- Input: 10-32V DC fused;
- Output: 24V DC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

4. Type: 240V AC to 220V DC:

- Input: 240V AC 50 Hz, fused, with harmonic filter (power to be provided by UPS);
- Output: 220V DC + / -1%;
- Protection: input and output side protected against overload, short circuits, and reverse voltage;
- Nominal output current: minimum 20% greater than the maximum current to be supplied;
- Operating and status indication;
- The residual ripple shall be lower than the maximum required by the connected equipment;
- Primary Switched and electrically isolated between input and output side;
- Modular design;
- Mounting type: standard rail mounting or as required.

xxxiii. Multifunction Energy Meters

a. General Requirements:

1. Three Production Energy Meters shall be provided to meter production of each Unit at the 220 kV GIS level. These Energy Meters are located in the Unit Bay Controller and Metering Board (BMB) located in the Control room;
2. Four Line Energy Meters shall be provided to meter transmission line. The Energy Meters are connected in a redundant arrangement. Two Energy Meters are set-up to read the transmission lines L-1 and L-2 total values;
3. The digital multifunction meters shall be of microprocessor based power

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

and energy meter type;

4. The meter shall include onboard non-volatile memory. The amount of memory shall be enough to register a minimum of 16 freely selectable parameters, every 15 minutes for 45 days. The minimum memory shall be 5MB;
5. The meter shall be programmable and shall include logical and mathematical functions to perform calculations over any measured parameter;
6. The meter shall be fully configurable using the local display and / or via a software application;
7. The device shall comply with the following measurement standards:
  - IEC 62053-22 Class 0.2S;
  - ANSI C12.20 0.2 Class 10 & 20;
  - ANSI C37.90.
8. The device shall comply with following power quality and quality of supply standards and network connection requirements:
  - EN 50160;
  - IEC 61000-4-30 Class A;
  - IEC 61000-4-7 harmonics & inter-harmonics;
  - IEC 61000-4-15 flicker;
  - IEEE 1159.
9. The device shall be capable to be connected to 4 wire Wye, 3 wire Wye, 3 wire delta, direct delta and single-phase systems;
10. The device shall be able to be powered from AC (90-240V) & / or DC (110-300V);
11. All Energy Meters shall be powered at 220 V DC;
12. The device shall be able to operate in sub tropical environment with a temperature of 20°C to 70°C, and humidity of 5-95% non-condensing;
13. The device shall be able to synchronize automatically with the GPS clock directly or through one of the communication ports;
14. The device shall be capable to timestamp the historical data;
15. The device shall have a backlight LED screen with the following minimum characteristics:
  - High visibility, 320x240 pixels, 3.5" x 4.5", LED backlit with adjustable

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

contrast screen;

- Capability to display numerical and up to four graphical data simultaneously; the numerical data can include real time, historical time stamped and name plate data. The graphical data can include frequency spectrum and trends logs;
- Multiple programmable screens: The multifunction meter shall be provided complete, including all the necessary connections, protections (fuses, etc.), software applications, and communications and mounting accessories.

#### b. Inputs and Outputs

##### 1. Voltage Inputs:

- The device shall include four (4) voltage inputs rated to 240 V Line-Neutral / 415 V Line-Line V AC rms;
- The inputs shall be able to accept an overload of 1500V AC rms continuous;
- The inputs shall be able to withstand a 2500VAC rms 50 Hz for 1 minute;
- The minimum impedance shall be 5MΩ per phase.

##### 2. Current Inputs:

- The device shall include five (5) current inputs rated to 5A, with a maximum voltage of 600V;
- The current inputs shall have a starting current of 0.005A rms;
- The current inputs shall be able to accept an overload of 500A rms for 1 second, non-recurring;
- The current inputs shall be able to withstand a 2500 V AC rms 50 Hz for 1 minute;
- The burden shall be 0.05 VA @ 5A, and the impedance 0.002W / phase, or less.

##### 3. Analog Inputs:

- The device shall include four (4) analog DC current inputs, with a selectable range of 0-1mA, 0-20mA and 4-20mA;
- The input impedance shall be 24 Ω @ 20mA;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- The accuracy shall be + / - 0.3% at full scale;
- The isolation to ground shall be at least of 750V;
- The channel to channel common mode isolation shall be at least of 400 kΩ.

#### 4. Digital Outputs:

- The device shall include two electromechanical relays form C (NO, Common, NC terminals) rated 250VAC / 3A;
- The device shall include two solid state outputs rated 30VDC / 50mA for Automation supervision.

#### c. Communication Ports

##### 1. RS-232 Port:

- The device shall include a serial RS-232 port for configuration / maintenance purpose;
- The port shall be able to connect to 300-115000bps baud rates;
- The connector shall be standard male DB9;
- The port shall be fully isolated (optical preferable) from the other connections in the device.

##### 2. RS-485 Port:

- The device shall include a RS-485 port for parameters reading;
- The Contractor shall select this port or the Ethernet port to provide connectivity to the PLC;
- The port shall be able to connect to 300-57600bps baud rates;
- The connector shall be captured wire type;
- The port shall be fully isolated (optical preferred) from the other connections in the device.

##### 3. Ethernet Port

- The device shall include an IEEE 802.3 Ethernet port for parameters reading. The Contractor shall select this port or the RS-485 port to provide connectivity to the PLC;
- The port shall be able to connect to 10Mbps or better;
- The connector shall be RJ45 type;
- The port shall be fully isolated (optical preferable) from the other



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

connections in the device.

#### 4. Communication Protocols:

The device shall be able to communicate using the following protocols in all the ports:

- Modbus RTU;
- DNP 3.0;
- Modbus TCP (Ethernet Port);
- Telnet (Ethernet port);
- Profibus;
- Other protocols compatible with the PLC.

#### 5. Parameters

The device shall be able to measure the following parameters per phase and three phase average:

- Frequency;
- Power Factor;
- Current rms (A);
- Voltage rms (kV);
- Apparent Power rms (MVA);
- Active Power rms (MW);
- Reactive Power rms (MVAR);
- Apparent Energy bidirectional (MVA);
- Active (Real) Energy bidirectional (MWh);
- Reactive four-quadrant energy (MVARh).

#### 6. At a minimum, the following calculations shall be implemented:

- Current: demand, minimum and maximum;
- Voltage: demand, minimum and maximum;
- Apparent Power: demand, minimum and maximum;
- Active Power: demand, minimum and maximum;
- Reactive Power: demand, minimum and maximum.

#### 7. Manufacturers / Models:

- Schneider Power Measurement: Model No. ION 7650 for Units.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

xxxiv. Optic Fibre network and Patch Panels:

- a. The Fibre Optic LAN-1 and LAN-2 networks shall be implemented. The Contractor shall interface these networks at the Patch Panel provided in strategic location throughout the power station. The scope of the supply includes the provision of all multimode Fibre Optic cables complete with terminal, patch panels and accessories within the Powerhouse, from the Powerhouse to the Control room. Main cables are provided with 24 fibers;
- b. The Contractor is to provide all interface devices, optic fibre interconnections, patch cords and accessories that are required for the interface;
- c. Patch Panels (A & B) are provided by the contractor in the following locations:
  - The powerhouse Main Control Room;
  - The powerhouse operator floor between the Units-1 and 2 and between Units-2 and 3 (total: 4).

xxxv. Terminal Blocks and Wiring:

- a. Control and instrument leads from the switchboards or from other equipment will be brought to terminal boxes or control cabinets in conduits. All interphase and external connections to equipment or to control cubicles will be made through terminal blocks;
- b. Terminal blocks shall be 1100 V grade and have continuous rating to carry the maximum expected current on the terminals;
- c. Terminal blocks for current transformer and voltage transformer secondary leads shall be provided with test links and isolating facilities. The current transformer secondary leads shall also be provided with short circuiting and earthing facilities;
- d. The terminals shall be such that maximum contact area is achieved when a cable is terminated. The terminal shall have a locking characteristic to prevent cable from escaping from the terminal clamp unless it is done intentionally.
- e. The conducting part in contact with cable shall preferably be tinned or silver plated however Nickel plated copper or zinc plated steel shall also be acceptable.
- f. The terminal blocks shall be of extensible design;
- g. The terminal blocks shall have locking arrangement to prevent escape from the mounting rails;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- h. The terminal blocks shall be fully enclosed with removable covers of transparent, non-deteriorating type plastic material. Insulating barriers shall be provided between the terminal blocks. These barriers shall not hinder the operator from carrying out the wiring without removing the barriers;
- i. Unless otherwise specified, terminal blocks shall be suitable for connecting the following conductors on each side:
  - a) All circuits except CT circuits      Minimum of two of 4 sq mm copper flexible conductors;
  - b) All CT circuits      1 nos. of 6 sq mm copper flexible conductors.
- j. The arrangements shall be in such a manner so that it is possible to safely connect or disconnect terminals on live circuits and replace fuse links when the cabinet is live;
- k. At least 20 % spare terminals shall be provided on each panel / cubicle / box and these spare terminals shall be uniformly distributed on all terminal rows;
- l. There shall be a minimum clearance of 250 mm between the First / bottom row of terminal block and the associated cable gland plate. Also the clearance between two rows of terminal blocks shall be a minimum of 150 mm;
- m. The Contractor shall furnish all wires, conduits and terminals for the necessary interphase electrical connections (where applicable) as well as between phases and common terminal boxes or control cabinets;
- n. All input and output terminals of each control cubicle shall be tested for surge withstand capability in accordance with the relevant IEC Publications, in both longitudinal and transverse modes. The Contractor shall also provide all necessary filtering, surge protection, interface relays and any other measures necessary to achieve an impulse withstand level at the cable interfaces of the equipment;
- o. All internal protection wiring shall be done using thinned copper with colour coded insulation rated 150°C such as the Dupont™ Tefzel® fluoropolymer resin or approved equivalent;
- p. Wiring size and colour shall be as follows:

Type of circuit	Wire Size	Colour
CT circuits	6 mm <sup>2</sup>	RED

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

VT circuits	4 mm <sup>2</sup>	BLUE
General Wiring	2.5 mm <sup>2</sup>	BLACK or GREY
Communication Wiring	1.5 mm <sup>2</sup>	BLACK
Earthing	4 mm <sup>2</sup>	GREEN

xxxvi. Protection Cables and Cable Schedule:

- The Contractor shall prepare a Cable Schedule covering all protection, control, metering interconnections of the present package;
- All cables shall be laid in Cable Trays, Trenches or Steel Raceway;
- Cable shall be of multiple conductor twisted in pairs and provided with an overall copper shield and outer Fire-resistant PVC jacket. The preferred number of conductors per core shall 2C, 6C, 4C, 8C, 12C and 24C
- The Cable wires shall be provided as follows:

CT circuits	6-mm <sup>2</sup>	screened cable having annealed copper stranded conductors
PT circuits	4-mm <sup>2</sup>	screened cable having annealed copper stranded conductors
Power supply	6-mm <sup>2</sup>	annealed copper stranded conductors
Communication circuit wires	1.5 mm <sup>2</sup>	annealed copper stranded conductors
Minimum size of other wires	2.5 mm <sup>2</sup>	screened cable having annealed copper stranded conductors

While preparing cable schedules for control / protection purpose, following shall be ensured.

- Separate cables shall be used for AC circuits, DC circuits, Main 1 protections & Main 2 protections;
- For different cores of CT and VT separate cable shall be used;
- At least two (2) conductors shall be kept as spare in each copper control cable of 4C, 6C or 8C size where as minimum no. of spare cores shall be two (2) for control cables of 10C size or more.

xxxvii. Synchronization:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- a. The Generator synchronizer and manual synchronization system are located in the Synchronization panels as part of the Unit Control Boards (UCB) located on the Operation floor near the relative UPB as they are shown on the general arrangement drawing;
- b. The Synchronization panels shall be interfaced with the GIS CT's as shown on drawing. The Contractor shall make all provisions which are required to connect the CT's. All required cabling from the CT's to the panels shall be provided by the Contractor;
- c. Synchronizing equipment is used in power stations where a generator needs to be paralleled with a power line and in substations to parallel two synchronous lines;
- d. The Power circuit breakers can only be closed if voltage and frequency are at the proper level and the same is for sequence and phase and if these conditions are not met, a disturbance will occurs in the power network, trip the breaker, shock the generator and unit transformer. In extreme cases, it can damage both;
- e. The purpose of the automatic synchronizing relay is to check that both voltage level and phase on generator side are in synchronism with the line side. To achieve this goal, the relay takes control of the excitation system for voltage matching and it takes control of the governor for frequency or phase matching;
- f. The manual synchronizing relay is used for, as the name implies, for manual synchronization. The operator has to manually act on the raise and lower pushbuttons of the exciter for voltage adjustment and on the speed raise / lower pushbuttons for frequency or phase adjustment. Once in the proper voltage and phase window, the synchrocheck relay permits the closing of the generator and line tie breaker. The manual synchrocheck relay also is connected in series with the automatic synchronizer, this is to increase the safety of operation;
- g. The automatic and manual synchronizing relays are always accompanied by voltage and frequency meters on the line and on the generator side. The synchroscope is used to show the speed or frequency relationship between the generator and the line to be synchronized with.

xxxviii. Standalone Disturbance Recorder (DR)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The Separate high-capacity disturbance recorder (fully digital data recording module) shall be provided and used together with the protection relays.

DR shall have at least 8 Analog and 16 Digital channels with a scan rate of minimum 1000 Hz for recording of disturbances/faults of the plant, including 220 KV GIS & pot-head yard. There shall be a central storage/evaluation unit cum PC located in the Central Control Room for the analysis of disturbances/events recorded in each relay.

xxxix. Control Room Furniture:

- a. The contractor is responsible for the provision of furniture within the control rooms. The furniture includes modular desks, tables, cabinetry and chairs for the main Control Room;
- b. The Control Room furniture for GIS includes accommodation for Work Stations and equipment provided herein and by others including: the Protection Operator Work station c / w 2-32" screens, the Dispatch Work Station (DWS), the Voice over IP Server (VoIP) c / w Routers and filing cabinetry etc. as shown on the arrangement drawing.

8.1.6.2. Automation System MMI Software System

a. General Requirement

The Automation System is comprised of several Man Machine Interfaces (MMI). MMI displays include the BCU displays, the RTU Board HMI, the OWS and EWS. Each display mode shall operate independently using independent hardware and software (master / slave is not allowed);

The MMI shall consist of an integrated IED and PC-based graphic display system to support an interactive dialogue between the operator and the power plant protection devices;

The Automation System shall interface the Main SCADA in a seamless manner. Thus, all software and communication protocols shall be compatible with the main SCADA system.

All Software and Hardware shall be OPC compliant;

The operating system for the PC-based work stations shall be Microsoft Windows-7 Professional or newer;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

All required service packs, updates and patches for the operating system, MMI software and other applications shall be installed and kept up-to-date throughout the duration of the project and throughout the warranty period;

The MMI package shall include alarming, reporting, event logging and trending capabilities;

The software shall provide user-friendly development environment that allows for simple interactive graphics building and application software development. The software shall provide Wizards, Experts, and other productivity tools to support development without having to learn a proprietary language. Advanced development tools such as Visual Basic and scripting shall also be available;

Real time process monitoring and historical trending shall be included;

The work stations and HMI's shall be capable of seamlessly integrating third party software such as Microsoft's Office products, including Word, Excel, and Access;

The MMI system shall be designed to allow for future upgrades of the software package without the necessity to reprogram the existing system or to modify existing relay settings;

The database shall be designed to support the following point types:

1. Analog Inputs - Read an analog value either directly from an A / D converter or from a register within an I / O device or intelligent device and automatically convert the raw value to engineering units or use PLC scaled value;
2. Analog Alarms - Alarm capabilities for alarm suspension and remote acknowledge;
3. Analog Outputs - Write an analog value either directly to a D / A converter or to a register within an I / O device, capable of automatically converting the engineering units to raw values;
4. Calculations - Perform arithmetic and logic calculations based on other database points and store them in internal MMI registers;
5. Digital Inputs - Sense logical state of a switch or relay directly from the input module or from a bit in memory of an I / O device including intelligent devices with time tagging;
6. Digital Alarm - Alarm capabilities for alarm suspension and remote acknowledge;
7. Digital Output - Set a logical on / off state in an output relay either directly in the



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

output module or in a bit within the memory of an I / O device.

Each database point shall include an instrument tag name, hardware device name, address, specific parameters, signal conditioning requirements and point description;

The database shall be stored as a standard Windows file;

The database maintenance facilities shall be totally integrated with the graphic display system;

The database shall make use a high-level data manipulation language, Structured Query Language (SQL);

The database shall support import and export of individual points, groups and complete database in Comma Separated Value (CSV) file format;

The MMI system configuration, screen development, and database deletions, additions and changes shall be able to be done offline or online. Online modifications, deletions and additions shall not interrupt the data acquisition.

The Automation System data shall be made available on the SCADA MMI's though interface of system. Only a selected number of I / O shall be made as indicated below.

#### b. Security Management

The MMI software shall provide a user-based security system. The security system shall allow for the creation of users with certain rights and / or privileges. These rights must include the ability to run any combination or all of the applications in the data acquisition system;

The ability to allow or disallow user's access to change values, such as set-points and protection settings, on an individual tag basis shall be supported.

### 8.1.6.3. Man-Machine Interface (MMI) Application Software

#### a. General Requirements

MMI includes the BCU located in the protection boards, the HMIs located in the control boards and, OWS and EWS located in the control rooms. Those two different types of hardware shall be completely independent (master / slave is not allowed);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

All displays (formats and design) shall be subject to review and approval by the Engineer in charge. The Employer and / or Engineer in-charge reserves the right to participate in the design of the screens as needed;

A minimum of two MMI software workshops shall be held to coordinate the MMI development;

The MMI system shall be designed to provide rapid and reliable information to protection events and to provide the operator with the ability to monitor and control the plant without objectionable delays in system processing times. The MMI stations shall be able to be configured to perform all or a selected subset of the system functions. Control and programming functions shall be password protected;

The MMI station operator shall be able to use either the keyboard, or mouse to implement monitoring and control commands.

b. Security Management:

The security management shall be designed to comply with the Employer security requirements.

c. Displays

As a minimum, the Contractor shall be responsible for mapping, creating and integrating the following plant common MMI screens:

- Plant Navigation;
- Plant Overview;
- Plant Single Line of the Generator-Transformers;
- GIS Substation Single Line;
- The Common RTU (CRB) metering and monitoring;
- The Generator Transformers RTU (TRB-1 to 3) analogue and digital monitoring;
- Bay Single Line Diagrams, including: status, measurements and control of breakers including generator / transformers, bus, GIB, line, etc;
- Protection Trip logic Schematic for each IED relay;
- Alarm Lists: The alarm lists shall have configurable filters to filter out the alarms not applicable to the particular unit or system. The entries in the alarm lists shall be arranged in chronological order;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Alarms are to include the PAMS signals from the multifunction protection relays and the Bay Controller Unit (BCU) through the LAN network. A total of 4000 alarm signals will require interfacing with the Main SCADA;
- System events summary (one world map): A chronological listing of all system events, i.e.: alarms, status changes and operator-initiated actions;
- Sequence of events list (one list);
- System configuration screens as required;
- Intelligent Electronic Devices (IED): All intelligent devices shall be provided with a template display. This display shall include all the protection functions and settings, equipment control, status signals and tuning parameters provided by the manufacturer. This applies to all the interfaces with intelligent devices;
- Alarm messages with detailed descriptions shall be displayed automatically for:
  1. All devices connected to the protection Network;
  2. PAMS components;
  3. Time counts exceeding preset value;
  4. Incomplete sequences.
- Help screens;  
Operational guidance and help screens for:
  1. Navigation and operation;
  2. Fault restoring operating procedure;
  3. Links to drawings, Acrobat and MS Office documents.

Status and analog signals from all devices connected to the protection Network;

Status of Unit and Plant Network Systems and components including connected fibre-optic lines;

Status of IED, Controller Stations, Remote I / O's, PLC's, etc...

Status of BCU, IED, HMI, PC and Servers;

Additional displays shall be as required by other functions included in this Contract.

The Contractor shall be responsible for integrating as a minimum the following displays for each bay and for common systems:

- Bay Screen Navigation Page;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Bay Single Line;
- Bay Control Status;
- Bay Sequence Overview.

All units' related screens shall have a clear identification of which unit the screen is related to, and this identification should be presented in the same location for all the screens.

- All analog and digital signals, including signals provided by IED, BCU, and Energy Meters shall be displayed on a screen graphically. The screen design shall be representative of the process:
  1. The Contractor shall make provisions to design and integrate up to 40 MMI screens before the start of the warranty period. The Contractor shall also make provisions to update and adapt to field changes and modifications the MMI screens and data bases before the start of the warranty period.
  2. Faceplates: Standard faceplates shall be provided and shall not be counted as separate screens. The faceplates shall be linked with the software module for the particular piece of equipment or device.

#### Breaker Faceplates:

In addition to the opened / tripped status for each breaker, the following information shall also be provided: local / remote status; racked-in status; test position status; racked-out status;

Breaker disagreement alarm shall be provided. The disagreement alarm shall be active when the actual status differs from the last command sent to the breaker. This alarm shall also activate the alarm horn.

#### 3. Lock-out / Tag-out

In addition to the Unit and Plant Lock-out / Tag-out screens, each device / equipment faceplate shall have a drop down menu for selection of Lock-out / Tag-out action;

The Lock-out / Tag-out status shall be shown on each screen or faceplate that the device / equipment appears on;

The Contractor shall submit the standard lock-out / tag-out system for review and approval by the Employer / Engineer In-charge.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

#### 4. Intelligent Devices

The Contractor shall provide standard templates to display the process information provided by intelligent devices such as protective relays (IED), BCU & Energy Meters;

The Contractor shall submit the standard templates for review and approval by the Employer.

#### 5. Alarm System; Alarm and Event Logs and Sequence of Events

Protection related Alarm and Event Logs and Sequence of Events shall be logged in Operator Work Station and made available for display at Engineering Work Station.

A comprehensive alarm system shall be provided. The alarms shall be prioritized and grouped to provide user-friendly operator interface;

The alarm system shall comprise of process, PAMS, network and communication alarms. The alarm system design shall be reviewed and approved by the Employer.

Alarm and event log shall be provided. The log shall include: all process alarms and events; all operator action events; all PAMS alarms and events; all network and communication alarms and events relative to the protection system. Each alarm or event shall be logged together with its time stamp. Alarms shall include events generated by the intelligent devices.

Sequence of Events shall be included for discrete inputs and events generated by the intelligent devices to provide troubleshooting tools for the engineering personnel.

The master Historian Work Station is provided as part of the Main SCADA. The Historian Work Station shall be dedicated to data logging of alarms and events on the servers drives including the selected Alarm and Event Logs and Sequence of Events related to the protection system.

#### 6. Colour Standards:

The colour standards mentioned in the following tables are recommended values. The final colour scheme shall be coordinated with the Employer during MMI development, and submitted for approval

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

#### 7. Equipment or Device Status :

Circuit Breaker	Isolator Switch	Earth Switch	Graphic Colour
Closed	Closed	Closed	Red
N / A	In transition	In transition	Flashing Red when Opening / Starting and Flashing Green when Closing / Stopping
Opened	Opened	Opened	Green
Tagged Out	Tagged Out	Tagged Out	Yellow
Fault	Fault	Fault	Magenta
In Automatic Indication	In Automatic Indication	In Automatic Indication	Amber
In Local or Manual Indication	In Local or Manual Indication	In Local or Manual Indication	Blue
In Alarm Indication	In Alarm Indication	In Alarm Indication	Unacknowledged – Cyan Acknowledged - White

#### 8. Electrical Bus Colours by Voltage

Voltage	Colour	RGB Hex Code
220 kV	Safety Yellow	FDD31D
33 kV	Light Green	C4DA99
13.8 kV	Cyan Blue	008B8B
11 kV	Dark Blue	023457
415 / 240	White	EDF2F8
240 V UPS	Orange	F68C00
220 VDC	Red	CC0000

#### 8.1.6.4. Controller Stations (CS) Software

##### a. Maintenance Facilities

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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Each CS shall be provided with maintenance facilities to allow the users to configure the database and program any functions using a portable personal computer or the Engineering Workstation connected through:

- Network;
- Serial port;
- Remotely via modem.

The maintenance facilities shall be password protected and shall contain the option for a dial back security when in dial-up mode.

**b. Configuration System**

The CS shall be provided with a Windows-based configuration system, which shall include all the necessary software to configure and program any function in the CS;

The configuration system shall be installed on Engineering Work Station as well as on OWS for back-up;

The configuration system shall allow downloading and uploading of configuration data files;

The configuration system shall program, download, debug and store programmable algorithms.

**c. Programming Package**

The programming package shall be an industry standard package, IEC 61850 and 61131 compliant and shall be totally integrated with the PAMS software;

No special database shall be required for the implementation of control programs. The control programs shall use ladder diagrams; function block diagrams, sequential function charts, structured text, instruction lists, process control language and C++ based routines. Programs shall be self-documenting;

The programming package shall support on-line and off-line development, off-line simulation, documentation and reporting capabilities.

**d. Naming Conventions**

All input, output and soft points shall be named consistently in accordance with an approved naming convention;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The point tag shall include as a minimum: plant; location; system; subsystem; IEEE / ISA component ID (i.e. PT, 52, etc.); point type (analog, discrete, etc.); connection type (software, hardwired, etc.), etc;

The naming convention shall be approved by the Employer and Engineer In-charge.

e. Functions

The algorithms and functions shall reside in the BCU, IED, PLC or UCB associated with the equipment or system as indicated in the table that follows.

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Data Acquisition	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Unit Metering Display	Yes	Yes	No	No	No	No	No	No
GIS Metering Display	Yes	Yes	Yes Local	Yes Local	Yes Local	Yes Local	No	Yes
Auxiliary Metering Display	Yes All	Yes at EMS	No	No	No	No	No	Yes
Unit, GIS Protection Monitoring	Yes	Yes	Yes Local	Yes Local	No	No	No	No
Bay Single Line Display	Yes	Yes	Yes Local	Yes Local	Yes Local	No	No	No

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Unit Single Line Display	Yes	Yes	No	No	No	No	No	Yes
GIS Single Line Display	Yes	Yes	No	No	No	No	No	Yes
General Single Line Display	Yes	Yes	No	No	No	No	No	No
Generator CB Open, Close Control and Monitoring	Yes	Yes	Yes Local	Yes Local	Yes Local	No	No	No
Line Coupler CB Open, Close Control	No	Yes	No	Yes Local	Yes Local	No	No	No
Bus Coupler CB Open, Close	No	Yes	No	Yes Local	Yes Local	No	No	No

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Control								
Line & Bus Coupler CB Open, Close Monitoring	Yes	Yes	No	Yes Local	Yes	Yes	No	No
Interlocks & Trips	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Transf. RTU Monitoring	Yes	Yes	Yes Local	No	No	No	Yes	No
Common RTU Monitoring	Yes	Yes	No	No	No	No	No	Yes
Power Line Carrier Interface	Yes	Yes	No	No	Yes Tele-protection	No	No	No
Power Line Carrier Monitoring	Yes	Yes	No	No	No	No	No	Yes
VoIP Interface	Yes	Yes	Yes on Board	Yes on Board	Yes on Board	No	Yes on Board	Yes on Board

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Data Interchange with Intelligent Devices and other Nodes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
AC Auxiliary Systems Monitoring	Yes	No	No	No	No	No	No	Yes partial
DC Auxiliary Systems Monitoring	Yes	No	No	No	No	No	No	No
UPS Systems Monitoring	Yes	No	No	No	No	No	No	No
DG Set Control and Monitoring	Yes	No	No	No	No	No	No	No
HVAC Monitoring	Yes	No	No	No	No	No	No	Yes partial
Fire Fighting Monitoring	Yes	No	No	No	No	No	No	Yes partial

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf. RTU Board s TRB	Commo n RTU Board CRB
Auxiliary Mechanical Monitoring	Yes	No	No	No	No	No	No	Yes partial
Discrete Raise / Lower and Set-point Control of MVAR & kV	Yes	No	No	No	No	No	No	No
Discrete Raise / Lower and Set-point Control of MW & Hz	Yes	No	No	No	No	No	No	No
Unit Automatic Start / Stop Control Sequence	Yes	No	No	No	No	No	No	No
Synch. Control & Monitoring	Yes	Yes	Yes	No	No	No	No	No
Governor	Yes	No	No	No	No	No	No	No

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Control & Monitoring								
Excitation & AVR Control & Monitoring	Yes	No	No	No	No	No	No	No
Unit Instrument -ation Display	Yes	No	No	No	No	No	No	No
Mechanic al Protection Interlocks & Trips	Yes	Yes	Yes	No	No	No	No	No
Dam, Tailrace and Main Access Tunnel Instrument -ation Display	Yes	No	No	No	No	No	No	No
Vibration Monitoring Display	Yes	No	No	No	No	No	No	No
MIV	Yes	No	No	No	No	No	No	No

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Function	Controller Stations							
	Main SCADA Work Stations	Auto-mation System Work Stations	Unit Bay Controller Units BCU	Transfo. Bay Controller Units BCU	Line Bay Controller Units BCU	Prot. Relays IED	Transf .RTU Board s TRB	Commo n RTU Board CRB
Control & Monitoring								
Butterfly Valve Control & Monitoring	Yes	No	No	No	No	No	No	No
Intake and Spillway Gates Control & Monitoring	Yes	No	No	No	No	No	No	No
Desilting Gates Control & Monitoring	Yes	No	No	No	No	No	No	No
CCTV Interface	Yes	No	No	No	No	No	No	No

f. Data Acquisition

The CS shall continuously scan and process the information from the input and output modules, and intelligent devices. The information shall be available system wide and shall be displayed, integrated into the control logic, logged, trended, alarmed, integrated into operator displays:

- Digital status inputs shall be processed for changes from the previous status. All digital input changes shall be collected, correlated and time tagged;
- Analog values shall be read, converted to engineering units, and stored periodically.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

g. Controls

The CS shall be capable of performing discrete, continuous, and sequential controls;

The CS shall respond to control commands initiated from the OWS's and BCU's screen or by control algorithms in the BCU's or local controllers. The control commands shall be open and close and sequential control;

The open and close control commands shall be used for the direct opening or closing of circuit breakers and switches.

h. 220 kV Substations:

Application software and converters required for the protection, monitoring and control of the 220 kV Substation shall be developed and implemented in the GIS Substation Automation and interfaced with the PAMS.

i. Interlocks and Trips:

Redundant electrical protection interlock and trip signals are hardwired to the Unit Control Board (UCB), Unit Protection Boards (UPB), Excitation (ET) and Governor Control (GC). Additional soft interlocks and trip signals shall be provided as required for the safe operation of the turbine-generating units, balance of plant equipment and auxiliary systems in addition to the hardwired interlocks and trips.

j. Unit and GIS Electrical Protection:

- i. Electrical Protection is comprised of Intelligent Multifunctional Relays installed in Protection Boards. The Intelligent devices are controlled and monitored by application software implemented in the Automation System and interfaced with the PAMS;
- ii. The PAMS is fully redundant. Protection A and B shall be connected to both LAN-1 and LAN-2 networks;
- iii. The Unit and GIS electrical protection shall be integrated to the Automation System and to the Main SCADA as shown on SCADA System Architecture drawing show the PAMS architecture that is to be integrated to the Main SCADA;
- iv. Three redundant Unit Protection Boards (UPB-1, 2 and 3,) shall be provided on the Generator floor for the protection of the Generators, the Generator Transformers, the Excitation Transformer and the Unit Auxiliary Transformers;
- v. GIS redundant protection shall comprise the Breaker Failure and Bus Protection Board (BPB), Unit Bay Controller & Metering Board (BMB), the Transformer RTU

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Boards (TRB-1 to 3), the Common RTU Board (CRB) and the Line Metering Board (LMB).

k. Information Interchange with Intelligent Devices and other Nodes:

The information interchange with IED, BCU & PLC and, the PAMS shall be over the Unit Process Control Network (LAN-1 & LAN-2) and shall use industry standard communication protocols. Access to real time and historical data shall be via standard open access formats such as Open Database Connectivity (ODBC). The intelligent devices shall be configured to transmit time tagging of events such as relay protective function trips.

l. VoIP Interface:

VoIP system shall be provided under the present package with regards to the EPAX and Control room Routers. This system shall be integrated to the LAN networks through dedicated Optic Fibers.

In addition, the contractor shall provided Dispatch Center direct line telephones (2) in each Control room along with receivers in each Control Board (UCB-1 to 3, CCB) and each Protection Board where indicated.

#### 8.1.6.5. Historical Data Management (HDM) Software

a. General Requirements

The HDM software shall be provided for collecting, storing, and reporting historical operating data of the power plant system. Data shall be collected at periodic intervals and stored in historical files;

The historian shall be synchronized with the plant GPS time system.

b. Performance

The data historian shall provide a minimum sustained performance rate of at 20,000 values per second at the largest tag configuration;

The HDM shall be capable of collecting and storing a minimum of 100,000 tags on a single computer;

The data historian shall provide 10 millisecond time stamp resolution;

It shall be possible to archive historical files on removable media or other hard drives for storage, without the need to stop the historian;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The data management software shall employ data compression to allow optimal data storage without affecting the performance and without distorting the data;

The historian storage system shall be sized to hold at least 10 years of history for all project points including 30 percent spares;

The historian shall support redundant configurations and provide high availability. The data collection system shall automatically switch to the best available source should the primary collector fail. Microsoft Cluster Server 2003 or later shall be supported to enable 24 / 7 / 365 data availability for increased uptime.

c. Configuration and Security

The system configuration shall be done via web based administration tools;

All configuration changes including adding new tags must be “on-line” without the need to stop and restart the data historian;

The system shall automatically import the data type, description, tag name, and other data characteristics from the data source, without a need to retype the tag information;

Role based security shall be utilized to restrict user access to different administration, system and user functions;

All configuration changes, user connections, security violations and other system messages shall be logged, and the log shall be available for monitoring by the administrators. The logs shall not be allowed to be modified or deleted by the users or the administrators.

d. Data Collection

The system shall support tags from multiple data sources utilizing a graphical interface. Data sources include all systems interfaced with the PAMS;

The periodicity of data collection and storage shall be configurable for each point type;

The system shall support input scaling of analog values;

The systems shall support OPC "Alarms & Events" and collect and store alarms and events from any OPC Alarms & Event server.

8.1.6.6. Plant Networks

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

a. General Requirements

The Local Area Networks (LAN-1 and LAN-2) shall be provided. The networks shall provide interconnectivity of the Electrical Protection relays (IED), the Bay Controllers (BCU), the Control Boards (PLCs and HMI), the transformer RTUs (TRB), ~~the Shunt Reactor RTU (RRB)~~, the Power Line Carrier Dispatch Work Station (DWS), the Energy Management Meters and Work Station (EMS), the Metering Boards (BMB & LMB), the Automation System in addition to the main SCADA Work Station and Servers, the Governor Controls, the AVR and Excitations, the Mechanical Protection, the Vibration Monitoring Systems and future Analysis Work Station (ZSC), the Distributed Control Devices, and specified in other sections. The GPS, VoIP and CCTV Networks shall use separate Optic Fibers. The pilot inter connection of the GIB differential shall use dedicated Optic Fibers. The LANs shall be seamlessly integrated to meet the system performance requirements specified herein;

The LAN networks shall be as shown on the SCADA System Architecture drawing. The drawings show the general principal and thus not all required components and devices are shown. The Contractor shall provide all additional components and devices required to meet the requirements to the interface the protection system.

One hot redundant Process Control Network (LAN-1 and LAN-2) shall be provided for all IED, BCU, PLCs, RTUs, Intelligent Devices, Servers, Work Station Processors, Ethernet Switches, Routers, etc. The Network shall be provided with both redundant hardware and communication links. The Network shall be Ethernet based with a minimum speed of 100Mbps. LAN-1 and LAN-2 networks shall be independent, supplied by different power supplies and physically isolated one from the other;

All Unit Process Control Networks shall be interconnected to form one redundant common Plant Process Control Network. This network shall be provided with both redundant hardware and communication links. The Plant Process Control Network shall be Ethernet based with a minimum speed of 100 MB/s and shall have 1 GB/s capability;

Each PAMS Boards shall be provided two (2) spare RJ45 Ethernet network port for laptop connection.

b. Communication Media

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The communication media for the in-plant networks shall be multimode fiber optic cables. The cables shall be terminated to a patch panel. Patch cables shall be run from that panel to the devices;

Category 6 shielded copper cables can be used for short distance runs inside cabinets or as approved by the Engineer In-charge. Standard RJ45 outlets and connectors shall be used as required.

#### 8.1.7 Tripping Logic

##### a. General Requirements

The protection relay tripping logic shall be as indicated in the Logic Tables below and as shown on the drawings. Furthermore, all applicable recommendations of IEEE standard 242 shall be implemented.

##### b. Protection Supply Supervision Relaying

A combination of undervoltage relay and molded case breaker (MCB) alarm contacts shall be provided to monitor each separately protected 220 V DC supply used for protection. The alarm contacts shall be connected to an IED protection relay that is not connected to the same DC circuit.

##### c. Generator Protection-A (located in UPB-1 to 3)

Device No.	Description	Alarm	86SA-x	94SA-x
86FGA-x	Field Fault Lockout (from pkg-5)	X		Note-2
86GA-x	Unit Fault Lockout (from pkg-5)	X		Note-2
87GA	High speed generator stator differential	X	X	
46	Negative sequence Current unbalance	X	X	
21	Phase distance backup	X		X
32	Reverse Power	X		X
50 / 51P	Phase time and instantaneous overcurrent	X	X	
50 / 51G	Ground time and instantaneous overcurrent	X	X	
50 / 51N	Neutral time and instantaneous overcurrent	X	X	
67 P / N / _2	Phase, neutral and negative sequence	X	X	

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	directional overcurrent			
40	Loss of Excitation	X	X	
51V or 50 / 27	Accidental Energization (time overcurrent with voltage restraint)	X		X
64G	Stator ground protection covering 100% of the winding, the method of detection being declared	X	X	
24	Over-excitation, Volts / Hz	X		X
78	Loss of Synchronism	X		X
59 P / N	Phase and neutral Overvoltage	X		X
27P / TH	Undervoltage phase and 3 <sup>rd</sup> harmonic	X		X
81O / U / R	Over, under and rate of change frequency	X		X
60	Fuse failure, voltage balance function	X		X
CTS	Current Transformer Supervision	X		
VTS	Voltage Transformer Supervision	X		
Note-1: x = Unit number (1 to 3)				
Note-2: Trip Generator Circuit Breaker (86 relays located in UCB)				

d. Generator Protection-B (located in UPB-1 to 3)

Device No.	Description	Alarm	86SB-x	94SB-x
86FB-x	Field Fault Lockout (from pkg-5)	X		Note-2
86GB-x	Unit Fault Lockout (from pkg-5)	X		Note-2
94FB-x	Field Fault Tripping (from pkg-5)	X		
94GB-x	Unit Fault Tripping (from pkg-5)	X		
87G	High speed generator stator differential	X	X	
46	Negative sequence Current unbalance	X	X	
21	Phase distance backup	X		X
32	Reverse Power	X		X
50 / 51P	Phase time and instantaneous overcurrent	X	X	
50 / 51G	Ground time and instantaneous overcurrent	X	X	
50 / 51N	Neutral time and instantaneous	X	X	

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	overcurrent			
67 P / N / 2	Phase, neutral and negative sequence directional overcurrent	X	X	
40	Loss of Excitation	X	X	
51V or 50 / 27	Accidental Energization (time overcurrent with voltage restraint)	X		X
64G	Stator ground protection covering 100% of the winding, the method of detection being declared	X	X	
24	Over-excitation, Volts / Hz	X		X
78	Loss of Synchronism	X		X
59 P / N	Phase and neutral Overvoltage	X		X
27P / TH	Undervoltage phase and 3 <sup>rd</sup> harmonic	X		X
81O / U / R	Over, under and rate of change frequency	X		X
60	Fuse failure, voltage balance function	X		X
CTS	Current Transformer Supervision	X		
VTs	Voltage Transformer Supervision	X		
Note-1: x = Unit number (1 to 3)				
Note-2: Trip Generator Circuit Breaker (86 relays located in UCB)				

e. Transformer Protection-A (located in UPB-1 to 3)

Device No.	Description	Alarm	86SA-x	94SA-x
87T	High speed generator stator differential	X	X	
87G	Restricted earth differential	X	X	
24	Over-excitation, Volts / Hz	X		X
21	Phase distance backup	X		X
50 / 51P-1 & 50 / 51P-2	Phase time and instantaneous overcurrent	X	X	
50 / 51G-1 & 50 / 51G-2	Ground time and instantaneous overcurrent	X	X	
50 / 51N-1 & 50 / 51N-2	Neutral time and instantaneous overcurrent	X	X	
67 P / N	Phase and neutral e directional	X	X	



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	overcurrent			
59 P / N	Phase and neutral Overvoltage	X		X
27P / N	Undervoltage phase and neutral	X		X
81O / U	Over and under frequency	X		X
60	Fuse failure, voltage balance function	X		X
CTS	Current Transformer Supervision	X		
VTS	Voltage Transformer Supervision	X		
49TW-R	High Winding temperature phase-R	X	X	
49TW-Y	High Winding temperature phase-Y	X	X	
49TW-B	High Winding temperature phase-B	X	X	
63T-R	High Gas Pressure phase-R	X	X	
63T-Y	High Gas Pressure phase-Y	X	X	
63T-B	High Gas Pressure phase-B	X	X	
71T-R	Low Oil Level, phase-R	X	X	
71T-Y	Low Oil Level, phase-Y	X	X	
71T-B	Low Oil Level, phase-B	X	X	
80WT-R	Low Water Flow, pump-1 & 2, phase-R	X	X	
80WT-Y	Low Water Flow, pump-1 & 2, phase-Y	X	X	
80WT-B	Low Water Flow, pump-1 & 2, phase-B	X	X	
OCTC	Off Load Tap Changer interlock failure	X		X
Note: x = Unit number (1 to 3)				

f. Overall Differential Protection-B (located in UPB-1 to 3)

Device No.	Description	Alarm	86SB-x	94SB-x
87T	High speed generator stator differential	X	X	
87G	Restricted earth differential	X	X	
24	Over-excitation, Volts / Hz	X		X
21	Phase distance backup	X		X
50 / 51T, 50 / 51G, 50 / 51ET, 5051UA	Phase time and instantaneous overcurrent	X	X	
50 / 51G / Tx	Ground time and instantaneous overcurrent	X	X	

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

50 / 51N / Tx	Neutral time and instantaneous overcurrent	X	X	
67 P / N	Phase and neutral e directional overcurrent	X	X	
59 P / N	Phase and neutral Overvoltage	X		X
27P / N	Undervoltage phase and neutral	X		X
81O / U	Over and under frequency	X		X
60	Fuse failure, voltage balance function	X		
CTS	Current Transformer Supervision	X		
VTS	Voltage Transformer Supervision	X		
49TW-R	High Winding temperature phase-R	X	X	
49TW-Y	High Winding temperature phase-Y	X	X	
49TW-B	High Winding temperature phase-B	X	X	
49T-R	High Oil temperature phase-R	X	X	
49T-Y	High Oil temperature phase-Y	X	X	
49T-B	High Oil temperature phase-B	X	X	
63PT-R	Pressure Relief Device, phase-R	X	X	
63PT-Y	Pressure Relief Device, phase-Y	X	X	
63PT-B	Pressure Relief Device, phase-B	X	X	
80OT-R	Low Oil Flow, phase-R	X	X	
80OT-Y	Low Oil Flow, phase-Y	X	X	
80OT-B	Low Oil Flow, phase-B	X	X	
Note: x = Unit number (1 to 3)				

g. Isolated Phase Bus Earth Fault Protection-A (located in UPB-1 to 3)

Device No.	Description	Alarm	86SA-x	94SA-x
64B	Broken DELTA Earth Fault Earth Fault	X	X	
Note: x = Unit number (1 to 3)				

h. Excitation Transformer Protection-A (located in UPB-1 to 3)

Device No.	Description	Alarm	86SA-x	94SA-x
50 / 51P / ET	Phase time and instantaneous overcurrent	X	X	
50 / 51G /	Ground time and instantaneous	X	X	

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

ET	overcurrent			
Note: x = Unit number (1 to 3)				

- i. Unit Auxiliary Protection-A (located in UPB-1 and 3)

Device No.	Description	Alarm	86SA-x	94SA-x
50 / 51P / UA	Phase time and instantaneous overcurrent	X	X	
50 / 51G / UA	Ground time and instantaneous overcurrent	X	X	
Note: x = Unit number (1 to 3)				

- j. Unit Auxiliary Transformer (UAT-1 and 2, SAT, SST) Protection-A

Device No.	Description	Alarm	86-x	94-x
50 / 51P / UA	Phase time and instantaneous overcurrent	X	X	
50 / 51G / UA	Ground time and instantaneous overcurrent	X	X	
64G	Earth Fault on secondary	X	X	
49T	Very High Winding Temperature	X	X	
49H	High Winding Temperature	X		
49A	Cooling Fan Running	X		
Note: x = Transformer number (UAT-1, UAT-2, SAT, SST)				

- k. GIS Breaker Failure and Bus Protection-A (located in BPB)

Device No.	Description	Alarm / Status	96SA-X			96LA-X		96BA
			1	2	3	1	2	
89-xA	Bus-A relative Isolator Switch Closed	X	X	X	X	X	X	X
89-xB	Bus-B relative Isolator Switch Closed	X		X	X	X	X	X
87BA	High speed bus differential	X	X	X	X	X	X	X
87BB	High speed bus differential	X		X	X	X	X	X

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

50 / 87BA	Unrestrained Bus differential	X	X		X		X		X		X		X
50 / 87BB	Unrestrained Bus differential	X		X		X		X		X		X	X
50BF-T1	Breaker Failure instant. overcurrent	X			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-T2	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-T3	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-L1	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	X
50BF-L2	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			X
50BF-AB	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	
50 / 51-T1	P & N time & instant. overcurrent	X	X										
50 / 51-T2	P & N time & instant. overcurrent	X			X								
50 / 51-T3	P & N time & instant. overcurrent	X					X						
50 / 51-L1	P & N time & instant. overcurrent	X							X				
50 / 51-L2	P & N time & instant. overcurrent	X									X		
50 / 51-AB	P & N time & instant. overcurrent	X											X
27A	Undervoltage trip Bus-A	X	<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>
27B	Undervoltage trip Bus-B	X		<u>D</u>		<u>D</u>		<u>D</u>		<u>D</u>		<u>D</u>	<u>D</u>
CTS	Current Transformer Supervision	X											

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

ILS	Isolator discrepancy alarm	X						
<p>Note-1: <u>X</u> = Generator and transformers 1 to 3,</p> <p>Note-2: <u>A</u> = trip and lockout if Bus-A Isolator Switch is closed</p> <p><u>B</u> = trip and lockout if Bus-B Isolator Switch is closed</p> <p><u>C</u> = trip via 94BAA <u>D</u> = trip via 94BBA</p>								

I. GIS Breaker Failure and Bus Protection-B (located in BPB)

Device No.	Description	Alarm / Status	96SB- <u>X</u>						96LB- <u>X</u>				96B B
			1		2		3		1		3		
89-xA	Bus-A relative Isolator Switch Closed	X	X		X		X		X		X		X
89-xB	Bus-B relative Isolator Switch Closed	X		X		X		X		X		X	X
87BA	High speed bus differential	X	X		X		X		X		X		X
87BB	High speed bus differential	X		X		X		X		X		X	X
50 / 87BA	Unrestrained Bus differential	X	X		X		X		X		X		X
50 / 87BB	Unrestrained Bus differential	X		X		X		X		X		X	X
50BF-T1	Breaker Failure instant. overcurrent	X			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-T2	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-T3	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X
50BF-L1	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			<u>A</u>	<u>B</u>	X
50BF-L2	Breaker Failure instant. overcurrent	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>			X
50BF-	Breaker Failure instant.	X	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	<u>A</u>	<u>B</u>	X

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

AB	overcurrent												
50 / 51-T1	P & N time & instant. overcurrent	X	X										
50 / 51-T2	P & N time & instant. overcurrent	X			X								
50 / 51-T3	P & N time & instant. overcurrent	X				X							
50 / 51-L1	P & N time & instant. overcurrent	X						X					
50 / 51-L2	P & N time & instant. overcurrent	X								X			
50 / 51-AB	P & N time & instant. overcurrent	X											X
27A	Undervoltage trip Bus-A	X	<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>		<u>C</u>
27B	Undervoltage trip Bus-B	X		<u>D</u>		<u>D</u>		<u>D</u>		<u>D</u>		<u>D</u>	<u>D</u>
CTS	Current Transformer Supervision	X											
ILS	Isolator discrepancy alarm	X											
Note-1: <u>X</u> = Generator and transformers 1 to 3, Note-2: <u>A</u> = trip and lockout if Bus-A Isolator Switch is closed <u>B</u> = trip and lockout if Bus-B Isolator Switch is closed <u>C</u> = trip via 94BAB <u>D</u> = trip via 94BBB													

m. 220 kV Transmission Line Protection-A (located in LPB)

Device No.	Description	Alarm	86LA-x	94LA-x	PLCC-1	PLCC-2
PLCC-1	Distance Protection carrier send	X			X	X
PLCC-1	Distance Protection carrier receive	X	X			
PLCC-2	Distance Protection carrier send	X			X	X

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

PLCC-2	Distance Protection carrier receive	X	X			
52L-x	Breaker Failure	X			X	X
21L	Phase Distance, 5 zones, quadrilateral	X	X		X	X
21LG	Earth Distance, 5 zones, quadrilateral	X	X		X	X
50 / 51L	Phase time and instantaneous overcurrent	X	X			
50 / 51L_2	Phase time and instantaneous negative sequence overcurrent	X	X			
50 / 51LG	Ground time and instantaneous overcurrent	X	X			
50 / 51LN	Neutral time and instantaneous overcurrent	X	X			
67L	Phase directional overcurrent	X	X			
67LN	Neutral directional overcurrent	X	X			
67L(2)	Negative sequence directional overcurrent	X	X			
78	Out of Step Trip	X		X		
68	Power Swing Blocking	X		X		
59P / N / (2)	Phase, neutral and negative sequence Overvoltage	X		X		
27P	Phase Undervoltage	X		X		



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

81O / U	Over and under frequency	X		X		
60	Fuse failure, voltage balance function	X				
CTS	Current Transformer Supervision	X				
VTs	Voltage Transformer Supervision	X				

Note: x = Line number (1 and 2)

n. 220 kV Transmission Line Protection-B (located in LPB)

Device No.	Description	Alarm	86LB-x	94LB-x	PLCC-1	PLCC-2
PLCC-1	Distance Protection carrier send	X			X	X
PLCC-1	Distance Protection carrier receive	X	X			
PLCC-2	Distance Protection carrier send	X			X	X
PLCC-2	Distance Protection carrier receive	X	X			
52L-x	Breaker Failure	X			X	X
21L	Phase Distance, 5 zones, quadrilateral	X	X		X	X
21LG	Earth Distance, 5 zones, quadrilateral	X	X		X	X
50 / 51L	Phase time and instantaneous overcurrent	X	X			
50 / 51L_2	Phase time and instantaneous negative sequence overcurrent	X	X			
50 / 51LG	Ground time and instantaneous	X	X			

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	overcurrent					
50 / 51LN	Neutral time and instantaneous overcurrent	X	X			
67L	Phase directional overcurrent	X	X			
67LN	Neutral directional overcurrent	X	X			
67L(2)	Negative sequence directional overcurrent	X	X			
78	Out of Step Trip	X		X		
68	Power Swing Blocking	X		X		
59P / N / (2)	Phase, neutral and negative sequence Overvoltage	X		X		
27P	Phase Undervoltage	X		X		
81O / U	Over and under frequency	X		X		
60	Fuse failure, voltage balance function	X				
CTS	Current Transformer Supervision	X				
VTS	Voltage Transformer Supervision	X				
Note: x = Line number (1 and 2)						

Note- In case of LILO, PLCC-1 to PLCC-4 shall be provided for Line 1 & Line 2 to provide redundancy in PLCC.

## 8.2 Energy Management System

### 8.2.1 General & Scope

This section covers the criteria for design, manufacture, supply, transportation up to site, handling and storage at site, erection, testing and commissioning of energy monitoring &

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

management devices as per the schedule of requirements along with their auxiliaries, spare parts for 5 years trouble free operation of the energy management system, special tools and tackles and as described in the specification.

#### 8.2.2 Reference Standards

The energy management system shall be designed, manufactured, tested and erected in conformance with applicable International, North American, and Indian Standards. Many standards may be similar or redundant from one organization to the other. The Bidders shall conform to International Standards at base. American Standards shall be used for items not covered by the International Standards. Indian Standards shall be considered for regional requirements and when legally binding.

Energy management system, accessories, etc., meeting any other authoritative standard, which ensures equal or better quality than the Standards mentioned below, shall also be acceptable. However, where the equipment offered conforms to any other standards, the salient points of difference between standards adopted and provision of this specification and standards referred above shall be clearly brought out in the bid. Copies of such standards in English language or fair English Translation shall be attached with the bid.

#### **International Standards**

IEC 60044 1	Instrument Transformers Part 1: Current Transformers
IEC 60044 6	Instrument Transformers Part 6: Requirements for Protective Current Transformers for Transient Performance
IEC 60060 1	High Voltage Test Techniques Part 1: General Definitions and Test Requirements
IEC 60060 2	High Voltage Test Techniques Part 2: Measuring Systems
IEC 60085	Electrical Insulation - Thermal Classification
IEC 60137	Insulated Bushings for Alternating Voltages above 1000 V
IEC 60270	High Voltage Test Techniques Partial Discharge Measurements Reactors
IEC 60529	Degrees of Protection Provided by Enclosures
IEC 60801-3	Electromagnetic compatibility for industrial- process measurement and control equipment – Radiated electromagnetic field requirements

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

### **North American Standards**

IEEE-C37.1	IEEE Standard definitions, specification, and analysis of systems used for supervisory control, data acquisition, and automatic control
ANSI C57.13	Standard Requirements for Instrument Transformers
ANSI C57.13	Interpretation
ANSI C57.13.1	Guide for Field Testing of Relaying Current Transformers
ANSI C57.13.3	Guide for the Grounding of Instrument Transformer Secondary Circuits and Cases
ANSI C57.13.5	Trial use Standard of Performance and Test Requirements for Instrument Transformers of a Nominal System Voltage of 115 V and above
ANSI C57.19.00	Standard General Requirements and Test Procedures for Outdoor Power Apparatus Bushings
ANSI C57.19.01	Standard Performance Characteristics and Dimensions for Outdoor Apparatus Bushings
ANSI C57.19.100	Guide for Application of Power Apparatus Bushings
ANSI 762	IEEE Standard definition for use in reporting electric generating unit reliability, availability, and productivity

### **Indian Standards**

IS: 5	Colours for Ready Mixed Paints and Enamels
IS: 104	Ready Mixed Paint, Brushing, Zinc Chrome, Priming
IS: 1554: Part 1	PVC Insulated (heavy duty) Electric Cables: Part 1 for Working Voltages up to and Including 1100 V
IS:2705	Current Transformers
IS: 2705: Part 1	Current Transformers: Part 1 General Requirements
IS: 2705: Part 3	Current Transformers: Part 3 Protective Current Transformers
IS:2705: Part 4	Current Transformers: Part 4: Protective Current Transformers for Special Purpose Application
IS:2932	Enamel, Synthetic, Exterior: (a) Undercoating (b) Finishing

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

	Specification
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### 8.2.3 Scope of Requirements

The Energy Management system shall be designed to facilitate operation, maintenance and repairs. All apparatus shall be so designed to ensure satisfactory operation under such sudden variations of load and voltage as may be met with under operating conditions on the system, including those due to short circuit.

All control cabinets, junction boxes and other required auxiliaries, as required are included in this contract. The contractors shall be provided the required 415 V AC supply. The AC supply for the indicating devices and pilot equipments shall be on 110 V AC. 110 V AC supply shall be transformed by the contractor from the 415 V AC with the use of 415 / 110 V Transformer. Use of 415 V and 230 V AC for the control and indicating circuits shall not be acceptable.

The digital power meter instrument base unit shall be flush mountable available as a combined front panel and base unit that can be mounted in switchgear cabinet doors.

The digital power meter instrument shall include a large, backlit integrated LED display with a minimum resolution of 320x240 pixels for ease of viewing from any angle.

The digital power meter instrument shall have five voltage inputs (V1, V2, V3, V4, Vref). The voltage inputs shall be capable of measuring from 0 to 600 Vrms (line-to-line) and shall have provisions for direct connection delta or wye.

The digital power meter instrument shall have five current inputs (I1, I2, I3, I4, I5).

The digital power meter instrument shall support multi-port, multi-protocol communications RS-232 / RS-485 and 10BaseT Ethernet with Ethergate. Make available optional 33.6 kbps internal telephone modem or 10Base-FL fiber optic connectivity. Protocol support must be Modbus RTU, Modbus TCP, ION, DNP3.0, and Telnet.

For ease of set-up the meter must support an internal web page that can be accessed via a standard Internet browser. No other software is required.

Monitor compliance with international standards such as IEC 61000-4-7 (harmonics), and IEC 61000-4-15 (flicker). Or configure the unit for IEEE 519-1992 and IEE 1159 standards.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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I / O: The digital power meter instrument shall include three (3) Form C dry contact relays and four (4) Form A solid state outputs and eight (8) Digital inputs (S1 to S8, SCOM), self-excited dry contact sensing, no external voltage required.

#### 8.2.4 Operating conditions

The meter shall have the capability to read Harmonics up to the 63rd Harmonic.

The digital power meter instrument shall be capable of calculating the following information for any reading at 1-second intervals:

- Sliding Window, Predictive, and Thermal demand calculations for any parameter;
- Maximum and Minimum value for any measured parameter;
- Derived values for any combination of measured or calculated parameter, using arithmetic, trigonometric, and logic functions (equivalent PLC capabilities);
- Nine (9) programmable oscilloscopic waveform recorders with a resolution of 512 or 1024 samples per cycle.

The digital power meter instrument shall provide setpoint control of internal recording mechanisms and all digital output relays, high speed transient detection to detect transients to 17 microseconds.

Minimum event recording response time shall be ½ cycle (8.3ms) for high speed events and 1 second for other events.

The digital power meter instrument shall provide extensive Time of Use (TOU) functionality to store and monitor up to 20 years of seasonal rate schedules. The TOU feature shall allow four seasons, four-day capability.

The digital power meter instrument shall provide setpoint control of internal recording mechanisms and all digital output relays. Consecutive high-speed alarm conditions and triggers shall be supported on a cycle-by-cycle basis with no “dead” time between events (i.e. there shall be no need for a rearming delay time between events).

The digital power meter instrument shall have Power Quality functionality including high-speed voltage transient detection, capture and recording: ITIC (CBEMA), IEEE.

A time-stamped event log with the following features:

- The device shall support at least 500 events;
- The number of records in the log shall be programmable;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Each event record shall record the date and time of the event, the cause and effect of the event, and the priority of the event;
- Time stamps shall have a resolution of 1 millisecond;
- Time stamps shall be able to be synchronized to within 100 ms between devices on the same serial communications medium.

#### 8.2.5 Specification for Energy Management System (EMS)

SCADA shall include standalone Energy Management System (EMS) which shall be capable of calculating deviation of energy exchange data and alert operator.

Metering shall be in the scope of supply. All ABT compliant meters (0.2s class) shall be interfaced with separate PC/laptop and data to be downloaded in single click. Meter data shall be downloaded in DAT file and NPC file format/any other format as per requirement of NERLDC. Meter should capable of recording data in 5- & 15-min time block. Meters shall have facility for automatic GPRS clock sync. A dedicated software for commercial energy management system shall be provided for real-time calculation of following data: Real time Ex-bus in MW, Frequency in Hz, Bus Voltage in KV, Block wise Actual Generation vs schedule, DSM payable/receivable based, Additional DSM payable/receivable, Net DSM payable/receivable, Zero Crossing Violation (ZCV), in frequency and energy rate in Block wise and at the end of day. This should be developed by a third party on taking data from the Purchaser. Software should be capable of capturing Generation schedule from WBES portal and for changing frequency range, energy price, DSM rate etc. by user. Communication shall be established between ABT meter PC/Laptop and SCADA in IEC 61850 protocol and required data shall be reflected in the SCADA.

All the end equipment, integration of the same for implementation of Energy Management System (EMS) shall be supplied by the bidders along with their successful commissioning.

ABT compliant Energy meters and EMS Software shall also be part of Energy Management System.

ABT compliant Energy meters shall be equivalent to the following models:

Schneider Electric ION7400

#### A. Current Transformers (CTs)



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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CTs shall be supplied as required, All CT secondaries shall terminate in CT shorting blocks before being wired to the meter. One CT is required for each phase being metered.

**B. Potential Transformers (PTs)**

PTs shall be supplied as required. PTs shall be wired line-neutral for Wye systems and line-line for delta systems. Meters shall not be powered from the PT secondaries. Voltage inputs shall be fed from a dedicated 15A breaker in distribution panel where practical. Supply and install appropriate 1A fuses.

**C. Meter Enclosures**

The digital meters shall be installed in new switchgear, panelboards or switchboards.

Where meters are not installed in distribution equipment, the meters shall be installed in pre-wired, NEMA 12, CSA approved enclosures. Multiple meters may be installed in the same enclosure. Meters supplied from two different switch-boards or different sources cannot be installed in the same enclosure. Meters shall be wired according to manufacturer's recommended method. Meter control power shall be from a separate source or control power transformer and not from the phase inputs to the meter.

**D. Communications / Networking Components**

RS485 communications for all meters shall be terminated in the enclosure according to manufacturer's recommended practice. To enable the meters to communicate to the central monitoring software, CAT5 – 10BaseT Ethernet shall be run to each meter enclosure. One meter shall have Ethernet connectivity and provide Ethergate network gateway communications to other meters in the same enclosure. Routers or other required networking components shall be provided according to Owner's standard.

**E. Management, Monitoring and Reporting Software**

A real-time power and energy management & monitoring software shall be provided that will perform the following functions:

- Monitor all devices simultaneously with a graphical interface. User screens will be developed in conjunction with the client. Allow for ten (10) customized user screens;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Store all the data in a MS SQL Server database for open connectivity;
- Provide reports to all users based on time-of use or block energy consumption. Reports shall be available using MS Reporting Services. Default reports shall be supplied with the software;
- Be a client-server application that will support multiple clients and web-browser clients so that anyone on the network can view meter data in real-time;
- Require no proprietary network communication hardware;
- Support any combination of the following communication protocols directly to devices ION® ; Modbus RTU; Modbus TCP; Serial or TCP / IP; OPC;
- Provide technical support and the first year of a software assurance contract;
- Provide OPC Client or OPC Server to integrate with other applications such as building automation systems (BAS);
- The software shall be capable of being configured and commissioned by local contractors as well as trained factory personnel;
- Software shall be ION Enterprise or approved equal. Contractor shall supply enough device licenses per the requirements of monitoring application.

#### F. Warranty & Service

The manufacturer warrants the products it supplies for a period of one (1) year from the acceptance date. Warranty Service may be performed by the manufacturer or authorized representative.

### 8.2.6 Erection

#### A. Acceptable Installers

The instrument shall be installed by a qualified control and protection board assemblers at the location shown on the drawings. The manufacturer responsible for the fabrication of the boards shall thus be responsible for the supply, installation, calibration, testing and commissioning of all meters.

#### B. Installation

All power supply and communications wiring connections shall be performed in accordance with the guidelines set out in the product documentation.

All voltage sensing connections to instrumentation shall be made with 2A fuses.

Where practical, the meters voltage inputs shall be from a dedicated breaker.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Appropriately sized current transformers must be installed on each phase and must be installed with CT shorting blocks. All CTs with 5A secondary shall have CT shorting blocks.

Meters must be powered from an auxiliary power supply, and not powered from the PTs.

The installation must be in accordance with the Electrical Code.

All communications networking including hubs, routers, etc. shall be provided by the contractor in accordance with the standards approved by the Owner.

#### C. Configuration

The meters shall be properly configured for the system.

Any power quality settings on the meters shall be configured so the meter's disturbance capture and transient detection is enabled.

Communications networking shall be tested and proved to be working before acceptance by the Owner.

### 8.3 Shop Assembly and Tests

#### a. Factory Acceptance Test (FAT):

- i. The Contractors shall prepare a FAT Plan including Testing Procedures and shall submit them to the Employer for review and approval;
- ii. The FAT Plan shall consist of the following:

- **FAT Overview:**

This shall describe the test configuration, the hardware and software simulator, the measurement tools, the complete test schedule, the forms for recording test results, the classification of discrepancies, and the processing of test reports.

- **Test Procedures:**

This shall describe the test preconditions and assumptions, the detailed steps to be taken for each test and the verification of results of each step. Procedures shall be prepared according to recommendation of the ANSI / NETA standard ATS, latest issue.

#### b. General Description (FAT)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

The Test Procedures shall include both hardware and software tests and verification of all System components comprised in each board. As a minimum, the step-by step procedures shall include:

- i. Hardware components and assembly are in accordance with the specifications and the latest Employer-approved manufacturer drawings;
- ii. Redundancy testing;
- iii. Software protocols for all external communication ports between the relays or intelligent devices are functional;
- iv. Databases are accurate and contain all of the I / O points identified by the Contractor's latest Employer-approved documents;
- v. Graphical displays are complete and functional;
- vi. All Inputs and outputs are functional and properly calibrated;
- vii. Software operating logic for the various systems complies with the requirements of the specifications and the latest Employer-approved Contractor documents;
- viii. Networks function correctly.

c. Pre-FAT & FAT Activities:

- i. A Pre-FAT shall be performed by the Contractor to verify that the system, as fully integrated, complies with all of the required functional details and that the system satisfies the response and resource utilization requirements. The Pre-FAT shall follow completely the test procedures of the FAT Plan reviewed by the Employer. The Contractor shall notify the Employer for the start date of the Pre-FAT at least four (4) weeks before the test. The Employer personnel will have an option to witness the pre-FAT activities;
- ii. Contractor shall submit the test procedures for approvals of the Employer;
- iii. The Contractor shall eliminate all discrepancies found in the pre-FAT, before the Factory Acceptance Test can be started;
- iv. Employer shall witness the actual start of the FAT upon notification by the Contractor that the system is ready for the FAT;
- v. The FAT shall be started with a complete system generation performed by the Contractor. After the completion of the system generation, Contractor shall carry out the FAT test procedures;
- vi. The last part of the FAT shall be devoted to the system performance tests using the normal and high-activity loading scenarios;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- vii. All discrepancies found in the FAT shall be corrected prior to shipment of the system.

d. Factory Tests (FAT)

1. Type Test Certificates

The Contractor shall perform or shall have performed a comprehensive type test on the prototype of the relays offered to confirm the adequacy of its design and the protection techniques. This test shall include all the necessary tests stipulated in IEC Publication 60255 (all applicable sections), ANSI C37.90 and C37.90.1, and other standard tests done by the manufacturer, such as the following: power frequency, impulse, high frequency interference, surge withstand capability, spark test, thermal capability, temperature dependency, temperature rise, static accuracy, power consumption, phase selection, dynamic accuracy, distance measurement, directional measurement, operating characteristics, surge current capability, vibration, shock, environmental, and others.

The Contractor shall submit a copy of the type test results and detailed procedures used to perform these tests. If type test results are already available they shall be submitted for approval in lieu of performing any or all of the specified tests.

2. Functional and Conformance Tests

These tests shall be performed at the factory on all fully assembled protective systems before shipping. Factory tests shall include inspection and routine testing of all relays and devices, insulation testing of devices and wiring and complete control sequence testing, trip logics to the extent feasible in the Contractor's plant. Each Digital and Analogue I / O shall be tested for continuity, insulated and operation. These tests will be witnessed by Employer and Purchaser.

Relay settings shall be loaded on to the IED relays and validated by Voltage and Current injections

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

A copy of all tests done and their results shall be furnished with the delivered relays. The test procedures, which shall include the external circuit tests, as agreed with the Purchaser. The completed protective system shall successfully pass these tests and shall be properly marked and carry the appropriate QA department signatures. Where ISO QA procedures are followed they shall be so identified.

### 3. Type Tests

The Contractor shall perform or shall have performed a comprehensive type test on the prototype of the relays offered to confirm the adequacy of its design and the protection techniques. This test shall include all the necessary tests stipulated in IEC Publication 60255 (all applicable sections), ANSI C37.90 and C37.90.1, and other standard tests done by the manufacturer, such as the following: power frequency, impulse, high frequency interference, surge withstand capability, spark test, thermal capability, temperature dependency, temperature rise, static accuracy, power consumption, phase selection, dynamic accuracy, distance measurement, directional measurement, operating characteristics, surge current capability, vibration, shock, environmental, and others.

The Contractor shall submit a copy of the type test results and detailed procedures used to perform these tests. If type test results are already available they shall be submitted for approval in lieu of performing any or all of the specified tests.

#### e. Installation and Field Test

##### 1 Field Tests

All field testing and verification shall be performed in complete agreement with NETA standard ATS.

On completion of the works at site, prior to commissioning, all equipment shall be tested to the satisfaction of the Purchaser to demonstrate that the plant complies in every respect with the specification and that the equipment is suitable for commercial operation.

Tests shall be performed by a Specialized Firm with at least 10 years experience in the field. The Contractor shall qualify the firm by submitting for approval the Firms past experience. The CV of each test engineer detailing shall be submitted. The list of testing instrument shall also be submitted for approval.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Site tests shall be carried out to the approved test program and procedures and shall include at least the following:

- Visual inspection;
- Insulation and continuity tests of all secondary wiring;
- Testing of all circuit loops;
- Inspection of current at CT secondaries to simulate all fault conditions and verifying all trip sequences;
- Tests to prove correct operation and characteristics of all protection equipment, control sequences, indications and alarm systems;
- Calibration of all instrumentation, protective relays and control devices;
- Magnetization characteristics, measurement of secondary winding resistance, ratio and polarity tests of all current transformers. Ratio and polarity tests of potential transformers;
- Measurement of lead resistances of all protection current circuits;
- Operation of all protective gear systems by primary injection;
- Operation of voltage circuits by primary or secondary injection.

## 2 Availability Demonstration for the Automation System :

- i. The system Availability Demonstration (AD) shall be performed for a period of 1000 hours starting at the end of the Site Acceptance Test (SAT) for each IED, BCU controller, work station and for the entire system once all interfaces with the main SCADA have been completed and tested and once all units are in service after all problems have been corrected. Acceptance of the system shall be contingent upon the successful outcome of the interface compliance and the availability demonstration;
- ii. The software at the start of the AD shall be assumed to be 100% reliable, i.e., free of all known errors or defects in functionality and performance;
- iii. The objective of the AD is to verify that the Average System Availability, A, for a 500 hour period of interest is equal to or better than specified, consistently for two successive time periods.

The Average System Availability, A, shall be calculated as:  

$$A = [1 - (\text{Downtime}) / (\text{Period of Interest})] \times 100;$$

Where "Downtime" in minutes is defined as the time during which any one or



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

more of the following conditions prevail:

- One Server or Operator station is out of service;
  - One Process LAN out of service;
  - One or more Controllers out of service;
  - HMI functions inoperative at one operator console;
  - System events logging function lost.
- iv. The Average System Availability, A, shall be 99.98% or better. This is equivalent to a downtime not exceeding 6 minutes during a 500-hour period of interest;
- v. Within the AD period of 1000 hours, all two values of A for the two 500 hour periods of interest shall satisfy the 99.98% requirement;
- vi. The recording and accumulation of downtime shall be subject to the following conditions:
- Restart and fail over times shall be counted;
  - Downtime due to software causes and to repair of software shall not be counted. All software errors and discrepancies found during the AD and during the Warranty Period shall be corrected by the Contractor;
  - Downtime due to Contractor-supplied hardware causes shall be counted and shall be the total time from the occurrence of the failure until the restoration to operation of the function lost;
  - Downtime due to problems in hardware not supplied by the Contractor shall not be counted;
  - Downtime due to undetermined causes shall be counted but will be discounted if later in the demonstration period it can be established as being due to a software problem or a problem in hardware not supplied by the Contractor.
- vii. Repeatable or self-recurring failures may cause a suspension of the demonstration period. Only the first downtime shall be counted. The demonstration shall be resumed only after the failure has been corrected;
- viii. Downtime caused by personnel action, which is not related to operation functions shall not be counted;
- ix. For every downtime that is discounted or excluded, the same amount shall be discounted from the accumulated time of the period of interest;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- x. Rules for restarting the Availability Demonstration;
- xi. If at time T, before the adjusted period of interest period has reached 500 hours, the adjusted downtime already exceeds 6 minutes by an amount x, the period of interest may be extended by  $(x/6) * 500$  hours;
- xii. If the calculated extension exceeds 500 hours, or equivalently if x is 6 minutes or more, the availability test for that period of interest shall be restarted;
- xiii. If the calculated extension is equal to or greater than T, the availability demonstration for that interest period shall be restarted.

f. Repair Procedures:

- i. Whenever a failure occurs in any hardware or software component, regardless of whether it causes a downtime or not, the Contractor shall analyze the problem and carry out the necessary repairs;
- ii. If the Contractor is not successful in locating and / or repairing the problem, the Employer shall be notified immediately. The Contractor shall then undertake the diagnosis & repair;
- iii. If the failure had caused a downtime condition, the total repair time (diagnosis time plus actual repair time plus time to place the function back in service) shall be considered as downtime. If the Contractor had not succeeded in locating and repairing the problem, only the repair time of the Contractor shall be counted.

g. Loading Scenarios

- i. The normal loading scenario shall be simulated as follows:
  - All analog values updated at the specified scan cycles, processed without exception, and updated on the database;
  - Ten (10) analog alarms occurring every 5 minutes;
  - One (1) Intelligent Electronic Device communicating with the Work Stations;
  - One (1) status change received and alarmed every five (5) minutes;
  - One (1) display call up every ten (10) seconds on each monitor of all stations, each monitor having four active windows;
  - All periodic programs in execution;
  - Online display maintenance in progress;
  - Trending of four (4) variables in operation;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- Offline software maintenance in progress.
- ii. The high-activity loading scenario shall be simulated as follows:
- Same as normal loading;
  - Four (4) analog alarms every five (5) seconds;
  - Six (6) status alarms every two (2) seconds;
  - Fifty (50) DI or fifty (50) AI from each IED, BCU or Controller, resulting in 300 DI or AI changing status within the first five (5) seconds of the disturbance. Then, one-hundred (100) DI or AI per second changing status for the duration of the first minute, after which normal load shall be assumed.
- iii. The performance tests for the high-activity loading scenario shall be repeated for one process LAN out of service;
- iv. CPU Utilization: During the performance test with the high-activity loading scenario, the average CPU loading in any of the station servers shall not exceed 30% for a 1-hour period;
- v. Memory Utilization: Memory utilization for Controllers and PAMS shall not exceed 30%. The final application software shall not occupy more than 30% of the Controller Station's memory.
- h. Control / Automation system Performance requirements
- i. Response Requirements: The verification of response times for the system shall be made under the following conditions:
- Process LAN; One device out of service or not used;
  - High-activity loading scenario in effect;
  - All response time requirements shall be wall-clock times;
  - The time duration from the instant of a status change at the equipment location symbol is updated on a workstation HMI screen shall not exceed 1.5 sec.;
  - The overall call up time of any display, from the instant the mouse is clicked until the requested display is on the monitor complete with all dynamic data, shall have an average value not exceeding two (2) sec.;
  - The overall time for processing an alarm from the time it is generated in the field until it is updated on the alarm list and on the System Events List, the audible sounded, and the logging initiated, shall not exceed

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

two (2) sec;

- Time-of-day displays on the HMIs shall be within two (2) seconds;
- The overall time from the initiation of command at visual display on the operator console to the output terminals of the field controller shall not exceed one (1) sec.

ii. Periodicity Requirements and Time Synchronization

Following periodicity requirements shall be met under normal loading conditions:

- Status-change scan two (2) seconds;
- All closed loop variables two (2) seconds;
- All other analog scan as per scan rate;
- Data update on a window as per scan rate < three (3) s;
- Time-of-day update on a HMI, as required to maintain two (2) seconds or better.

iii. All digital inputs system wide shall be GPS synchronized at ten (10) ms or better. Then sequence of Event (SoE) / Data logging for Electrical PAMS Alarms shall be time tagged with an accuracy of one (1) ms;

iv. System Overload:

- The PAMS shall be designed such that it can withstand severe system overloading or any condition worse than those defined for the high-activity loading scenario. HMI screen call up response times shall not be affected no matter what the overload situation might be. All functions shall be operational although degradation in periodicities within acceptable limits;
- No alarms shall be lost during system overloads;
- The Contractor shall describe the methods which shall be used to guarantee that during a system overload all critical functions will be operational, HMI screen call up response times shall be within the requirements specified, and no alarms shall be lost.

v. The Employer reserves the right to participate and monitor all installation, testing, trouble- shooting and repair activities.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

## 8.4 Reports, Studies, Drawings & Documents Submittals

### 8.4.1 Short – Circuit and Protective Coordination Study

#### A. General Requirements:

- i. The contractor shall carry out a short-circuit calculation and protective device coordination study to be prepared by an approved electric engineer specialized in the field. This study will be the base for the setting of the protection relays;
- ii. The scope of the study shall include all the Medium Voltage equipment including generating units (G1 to G3), the generator transformers (T1 to T3), the unit auxiliary transformers (UATs, SAT & SST), the excitation transformer (ET1 to ET-3), and all the 220 kV equipment of the GIS substation and the 220 kV Transmission Lines as shown on the single line diagram relaying and metering drawings;
- iii. As the auxiliary systems are part of the EBOP section of this package, the Contractor shall extend the Short-Circuit and Protective Coordination Study to include the complete AC auxiliary system including auxiliary transformers, diesel generators, medium Voltage switchgear, Station Service Boards, Unit Auxiliary Boards as shown on tender drawings. The report shall include the setting of all incoming and outgoing circuit breaker within the medium and low voltage switchgears and boards mentioned above;
- iv. The study shall take into account the ANSI C37.90, ANSI C37.91, ANSI C37.101 ANSI C37.90 ANSI C37.102, ANSI C37.102 and the IEC 60909 standards;
- v. The short-circuit and protective device coordination study shall be submitted to the design engineer prior to receiving final approval of the units protection boards (UPBs) and BCU panel shop drawings and / or prior to release of equipment drawings for manufacturing;
- vi. The results of the short-circuit calculations shall be summarized in a final report and shall be used for protective device coordination. No more than five (5) bound copies of the complete final report shall be submitted;
- vii. In addition, a copy of the computer analysis software viewer program is required to accompany the electronic project files, to allow the Owner to review all aspects of the project and print relays settings, one line diagrams, etc.;
- viii. The report of the study shall include the following sections:
  - Executive Summary;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Descriptions, purpose, basis and scope of the study;
- References and software;
- Protective device time versus current coordination curves;
- Fault current calculations;
- One line diagram;
- Conclusions and recommendations.

ix. The studies shall be performed using the latest revision of the SKM Systems Analysis Power\*Tools for Windows (PTW) software program or other software considered equivalent but approved by the engineer.

#### B. Data Collection-

After award of the contract, the Contractor shall gather all data as required to realize the power system studies such as: Utility's transient three-phase and line to ground contribution during a fault , three-phase X / R, line to ground X / R, impedances of the 220 kV overhead lines, electrical characteristics of both generators and transformers, etc.

#### C. Protective Device Coordination Study-

As part of the report, the section regarding the Protective Device Time versus Current Coordination Curves shall include:

- Proposed protective device coordination time-current curves (TCC) shall be displayed on log-log scale graphs;
- Include on each TCC graph, a complete title and one-line diagram with legend identifying the specific portion of the system covered;
- Terminate device characteristic curves at a point reflecting maximum symmetrical or asymmetrical fault current to which the device is exposed;
- Identify the device associated with each curve by manufacturer type, function, and, if applicable, tap, time delay, and instantaneous settings recommended.

Plot the following characteristics on the TCC graphs, where applicable:

- Electric utility's overcurrent protective device;
- Medium voltage equipment overcurrent relays;
- Medium and low voltage fuses including manufacturer's minimum melt, total clearing, tolerance, and damage bands;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Low voltage equipment circuit breaker trip devices, including manufacturer's tolerance bands;
- Transformer full-load current, magnetizing inrush current, and ANSI through-fault protection curves;
- Conductor GIS and GIB damage curves;
- Ground fault protective devices, as applicable;
- Pertinent motor starting characteristics and motor damage points, where applicable;
- Pertinent generator short-circuit decrement curve and generator damage point;
- Provide adequate time margins between device characteristics such that selective operation is provided, while providing proper protection.

#### D. Report Sections-

- i. Input data at each node shall include, but not be limited to the following:
  - Secondary connected resistive burden in ohms;
  - Secondary winding of the current transformer;
  - Fault currents (220 kV Network and Generator contributions);
  - Time constants of proposed current transformers;
  - Burdens of protection relays;
  - Feeder input data including feeder type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic) and conductor material (copper or aluminum);
  - Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, % taps and phase shift;
  - Transmission line parameters;
  - Generation contribution data (Synchronous generators and Utility), including short-circuit reactance ( $X''_d$ ), rated MVA, rated voltage, three-phase and single line-ground contribution (for Utility sources) and  $X / R$  ratio;
  - Motor contribution data (induction motors and synchronous motors), including short-circuit reactance, rated horsepower or kVA, rated voltage, and  $X / R$  ratio.
- ii. Output Data shall include, the characteristics of proposed currents transformers such as:



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Accuracy class;
  - Rated burden;
  - Rated primary current;
  - Rated secondary current;
  - Rated turns ratio;
  - Rated knee point voltage;
  - Maximum exciting rated current at rated knee point voltage;
  - Rated symmetrical short circuit current factor  $K_{ssc}$ ;
  - Time constant of the secondary loop of the current transformer  $T_s$ ;
  - Primary time constant  $T_p$ ;
  - Rated transient dimensioning factor  $K_{td}$ ;
  - Permissible time to accuracy limit ( $t_{al}$ ).
- iii. Short-Circuit Output Data shall include, but not be limited following reports. The Low Voltage Fault Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:
- Voltage;
  - Calculated fault current magnitude and angle;
  - Fault point  $X / R$  ratio;
  - Equivalent impedance.
- iv. Momentary Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:
- Voltage;
  - Calculated fault current magnitude and angle;
  - Fault point  $X / R$  ratio;
  - Equivalent impedance:
    - Based on fault point  $X / R$  ratio;
    - Based on calculated symmetrical value multiplied by 1.6;
    - Based on calculated symmetrical value multiplied by 2.7.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- v. Interrupting Duty Report shall include a section for three-phase and unbalanced fault calculations and shall show the following information for each applicable location:
  - Voltage;
  - Calculated symmetrical fault current magnitude and angle;
  - Fault point X / R ratio;
  - No AC Decrement (NACD) Ratio;
  - Equivalent impedance;
  - Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a symmetrical basis;
  - Multiplying factors for 2, 3, 5 and 8 cycle circuit breakers rated on a total basis.
- vi. Recommended Protective Device Settings:
  - Phase and Ground Relays;
  - Current transformer ratio;
  - Current setting;
  - Time setting;
  - Instantaneous setting;
  - Recommendations on improved relaying systems, if applicable.
- vii. Circuit Breakers:
  - Adjustable pickups and time delays (long time, short time, ground);
  - Adjustable time-current characteristic;
  - Adjustable instantaneous pickup;
  - Recommendations on improved trip systems, if applicable.

#### 8.4.2 Load Flow Study

##### A. Load Flow Study:

- i. The contractor shall carry out a Load Flow Study prepared by an approved electric engineer specialized in the field. This study will assure that all branches and buses are operating between proper voltage levels and that no branches are overloaded;
- ii. The scope of the study shall include all the Medium Voltage equipment including generating units (G1 to G3), the generator transformers (T1 to T3), the unit auxiliary transformers (UATs, SAT & SST), the excitation transformer (ET1 to ET-

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
--	--	--

- 3) and all the 220 kV equipment of the GIS substation and the 220 kV Transmission Lines as shown on the single line diagram relaying and metering Drawings;
- iii. As the auxiliary systems are part of the EBOP section of this package, the Contractor shall extend the Load Flow Study to include the complete AC auxiliary system including auxiliary transformers, diesel generators, Station Service Boards, Unit Auxiliary Boards as shown on tender drawings. The report shall all loads connected to UAB and SSB boards;
  - iv. A copy of the computer analysis software viewer program is required to accompany the electronic project files, to allow the Owner to review all aspects of the project and print bus voltages, drop voltages, load flows, one line diagrams, etc.;
  - v. The report of the study shall include the following sections:
    - Executive Summary;
    - Descriptions, purpose, basis and scope of the study;
    - References and software;
    - Calculations of Bus voltage, voltage angle, and voltage drop at each bus including a definition of terms and guide for interpretation of the computer printout;
    - Calculations of branch voltage drop, power flow in kW, kVAR, kVA, Amps and power factor;
    - One-line diagram along with the flow load results;
    - Conclusions and recommendations.
  - vi. The studies shall be performed using the latest revision of the SKM Systems Analysis Power\*Tools for Windows (PTW) software program or other software considered equivalent but approved by the engineer.

#### B. Data Collection-

After award of the contract, the Contractor must gather all data as required by the power system studies such as: Utility's transient three-phase and line to ground contribution during a fault , three-phase  $X / R$ , line to ground  $X / R$ , impedances of the 220 kV overhead lines, electrical characteristics of both generators and transformers, etc.

#### C. Report Sections-

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Input data shall include, but not be limited to the following:

- Feeder input data including feeder the type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic), conductor material (copper or aluminum), rated continuous Current, short time Current rating and rated maximum Voltage;
- Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, % taps and phase shift;
- 220 kV Transmission Line parameters;
- Generation contribution data (Synchronous generators and Utility), including short-circuit reactance ( $X''_d$ ), rated MVA, rated voltage, three-phase and single line-ground contribution (for Utility sources) and  $X / R$  ratio;
- Motor contribution data (induction motors and synchronous motors), including short-circuit reactance, rated horsepower or kVA, rated voltage, and  $X / R$  ratio.

Load Flow Output Data shall include, but not be limited to the following reports:

- Bus voltage, voltage angle, and voltage drop at each bus;
- Branch voltage drop, power flow in kW, kVAR, kVA, Amps and power factor;
- Branch loss in kW, kVAR, kVA, and total system losses;
- Generation of units in kW, kVAR, kVA.

#### 8.4.3 Stability Study

##### A. General Requirements:

- The contractor shall carry out a Stability Study prepared by an approved electric engineer. This study will allow identifying the problems that can arise during and after transient disturbances such as faults, load changes, switching, motor starting, loss of utility, loss of excitation and blocked governors. Once identifying the problems, the measures required for minimizing the consequences on the Heo Hydroelectric project, must be stated by the contractor;
- The scope of the study shall include all the Medium Voltage equipment including generating units (G1 to G3), the generator transformers (T1 to T3), the unit auxiliary transformers (UATs, SAT & SST), the excitation transformer (ET1 to ET-3) and all the 220 kV equipment of the GIS substation and the 220 kV

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

Transmission Lines as shown on the single line diagram relaying and metering Drawings;

- iii. A copy of the computer analysis software viewer program is required to accompany the electronic project files, to allow the Owner to review all aspects of the project;
- iv. The report of the study shall include the following sections:
  - Executive Summary;
  - Descriptions, purpose, basis and scope of the study;
  - References and software;
  - Plot voltage , speed, frequency, real and reactive power, rotor angle, voltage angle, and torque;
  - One-line diagram;
  - Conclusions and recommendations.

#### B. Data Collection

After award of the contract, the Contractor shall gather all data as required by the power system studies such as: Utility's transient three-phase and line to ground contribution during a fault, three-phase  $X / R$ , line to ground  $X / R$ , impedances of the 220 kV overhead lines, electrical characteristics of both generators and transformers, characteristics of excitation systems, characteristics of governors and turbines, etc.

#### C. Report Sections

- i. Input data shall include, but not be limited to the following:
  - Feeder input data including feeder type (cable or bus), size, length, number per phase, conduit type (magnetic or non-magnetic) and conductor material (copper or aluminum);
  - Transformer input data, including winding connections, secondary neutral-ground connection, primary and secondary voltage ratings, kVA rating, impedance, % taps and phase shift;
  - Transmission line parameters;
  - Excitation system model and associated parameters based on a standard IEEE model;
  - Hydro Turbine system model and associated parameters based on a standard IEEE model;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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- Generation contribution data, (synchronous generators and Utility), including short-circuit reactance ( $X''_d$ ), rated MVA, rated voltage, three-phase and single line-ground contribution (for Utility sources) and  $X / R$  ratio.
- ii. Stability Output Data shall include, but not be limited to the following:
- Plot voltage, current, speed, frequency, real and reactive power, generator rotor angle, voltage angle, torque and impedance;
  - Results of simulations such as:
    - Three phase and line-to-ground fault actions;
    - 220 kV circuit breaker open and close;
    - Generator start-up;
    - Generator input power adjustment;
    - Power grid voltage drop / raise;
    - Isolation from utility;
    - Loss of excitation;
    - Governor fails;
    - Start, trip and reclose of induction motors;
    - motor acceleration / reacceleration.

#### 8.4.4 Dimensioning of Current Transformers for Protection Application:

- a) The contractor shall calculate the characteristics of the current transformers required for protection, taking into account the IEC 60044-1, IEC 60044-6 and IS 2705 standards. These current transformers will be installed along with the generating units (G1 to G3), the generator transformers (T1 to T3), the unit auxiliary transformers, the excitation transformer, SAT, SST and related systems, as they are shown on the relaying and metering drawings;
- b) As the auxiliary systems are part of the EBOP section of this package, the Contractor shall extend CT calculations to include the complete AC auxiliary system;
- c) Note: The ratings of the current transformers shown on the drawings referred above are only for reference. The contractor is responsible for the dimensioning of the current transformers;
- d) The calculation shall be submitted through a report which shall include the following sections:
  - Executive Summary;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- Descriptions, purpose, basis and scope of the calculus;
- References and software if required;
- Fault current calculations;
- Determination of factors required for the current transformers, such as Kssc (rated symmetrical short circuit ), Ktd (transient dimensional factor) and Kr (remanence factor);
- Conclusions and recommendations.

#### 8.4.5 Drawings

##### A. General Drawings

At minimum, the Contractor shall prepare and submit general arrangement drawings showing the location of the major equipment to be supplied and installed by the Contractor or to be interfaced including marshalling boxes, patch panels protection boards, control boards, work stations, etc. The drawings shall show the foot print, safety and maintenance clearances as well as the specific features listed herein shall be submitted, as well as any additional submittals requested by the Employer.

The Contractor shall also prepare large scale erection drawings of each protection board and control board show base preparation and anchoring details.

##### B. Protection and Control Drawings

Protection, control and network drawings shall include the following:

- System architecture and network diagrams overall and for each system, network configuration descriptions, managed Ethernet switches configuration, communication devices programming and configuration;
- The system architecture diagram shall indicate all IED relays, BCU, PLC, controllers (PLC), work stations, Ethernet switches, convertors, modems, etc. that will host the system software modules. The drawings shall also include the Energy Monitoring system and the GPS synchronization IRIG-B schematic;
- PID's, loop diagrams, block diagrams and logic diagrams, including ISA Form 20 for all IED's and instrumentation;
- The details IED relays, BCU, instruments, controller, I / O modules, etc. including location, size and mounting hardware;
- The master Bill of Material indicating all major panels, boards, work stations, screens, printers, accessories, communication devices, etc.;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- vi. The Fiber Optic cable schedule including patch cords as required for integration to the main SCADA;
- vii. The overall I / O List covering all IED relays, BCU's and I / O modules;
- viii. The restricted I / O List indicating the signals and commands to be interfaced with the main SCADA;
- ix. The detailed Single Line diagrams of each bay and of GIS bus assembly;
- x. The detailed Three Line diagrams of each bay and of GIS bus assembly;
- xi. The general arrangement internal and external of each protection panel showing the inside view of equipment arrangements, including terminal blocks and cable entrance details for external cables for control cabinets;
- xii. The panel construction and assembly details;
- xiii. The Bill of Material of each protection panel;
- xiv. The 240 V AC Distribution schematic of each panel;
- xv. The 220 V DC Distribution schematic of each panel;
- xvi. The schematic and elementary diagrams of each IED relay, BCU, PLC and I / O module of each panel;
- xvii. The trip, lockout and auxiliary relay schematic and elementary diagrams of each panel;
- xviii. The interlock schematic and elementary diagrams of each panel;
- xix. The external interconnection schematic and elementary diagrams between panels;
- xx. The wiring diagrams of each panel;
- xxi. The Trip Logic schematic of each bay for protection-A and for protection-B;
- xxii. Terminal block schedule with interconnection identifications;
- xxiii. The Cable Schedule including inter-panel connections;
- xxiv. Recommended settings for protective and timing relays and instruments, including all alarm / trip points, time constants, gains and timing circuits;
- xxv. Unit Start permissive interfaces schematic for each Unit;
- xxvi. Proposed furniture arrangement relative to the PAMS of the Control Rooms.

**C. First Submittals - Technical Data Bulletins and Technical Guides:**

- i. The Contractor shall submit for approval hard copies and soft copies of the Technical Data Bulletins of all major components of the PAMS including IED relays, BCU's, PLC, I / O Modules, Energy Meters, Ethernet Switches, Lockout relays, Tripping relays, auxiliary relay, work stations, screens, terminals, wires,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

lugs, etc. The submittal shall highlight the exact device order number. The hard copy bulletins shall be submitted in 8 copies assembled into a comprehensive manual. The preparation of shop drawings shall not begin before approval;

- ii. The Contractor shall submit for approval softcopies of all applicable Technical Guides. The Technical Guides are to include instructions for installation, configuration, function settings, operation and maintenance. The applicable portion of the Guides shall be highlighted;
- iii. The preparation of shop drawings shall not begin before approval.

**D. Instructions, Procedures and other Drawings and Documents**

At minimum, the following instructions, procedures and other drawings and documents of the components, showing the specific features listed here shall be submitted, as well as any additional submittals requested by the Employer.

a) Bills of material:

- A General bill of material listing all major elements of the PAMS system;
- Secondary bills of materials detailing the components within a Board shall be submitted with the corresponding drawings.

b) Factory tests and shop inspection schedules, test and inspection procedure, checklists, and data collection sheets;

c) Handling and storage instruction manuals;

d) Storage details for all applicable components including square footage, temperature, and humidity control requirements;

e) Assembly schedule, procedures and checklists;

f) Installation instruction manuals;

g) Site test non-destructive test program schedules, test procedures, checklists, and data collection sheets;

h) Field check out, start-up, testing procedures and manuals;

i) List of instructions for all tests and checks to be performed at each stage including inspections and measurements, assembly, start-up and commissioning, and final signature Test;

j) Data sheets as follows:

- i. Manufacturer's data sheets for all of the HMI components used in the system including but not limited to: server computers, workstation

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

computers, monitors, printers, software, etc;

- ii. Manufacturer's data sheets for all control and protection switchboard components including but not limited to: control switches, push buttons, indicating meters, indicating lights, auxiliary control relays, power supplies, system protective relays, etc;
- iii. Manufacturer's data sheets for instrumentation and other field devices;
- iv. Data sheets and specifications of PLC, I / O modules, Work Stations, Screens, Printers, Ethernet Switches, Routers, etc;
- v. Technical data bulletins;
- vi. Overall dimensions and layout;
- vii. Nameplates Schedule

**E. Controls Documents:**

- a. Technical specifications and interfacing requirements including data format for equipment furnished by others;
- b. Application Software Functional Design, including a functional description of the application software for the unit and plant monitoring and control. Each module shall be described in detail and include the functions of the module and its interface with other modules, field input / outputs and HMI. Application software functional design submittal shall include, but not be limited to:
  - i. Description of the functions to be performed by each software module;
  - ii. Detailed description of all interfaces between the PAMS system (IED, BCU, Meters, etc.) and the operator shall be provided. All related Work Station, HMI and BCU graphics shall be shown;
  - iii. Description of the distribution of the modules, loading of controllers and memory requirements;
  - iv. Naming convention for the input, output and software points;
  - v. Input, output and software points' database;
  - vi. Description of the impact of power failures, system failures, redundancy switch over, normal restarts for all systems and subsystems and application software approach for mitigating issues;
  - vii. Description of the original vendor software and programming environment with a list of software licenses provided with the system;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- viii. Controller programming details: The programming shall be fully annotated with sufficient information for determining operation of the system;
  - ix. IED, BCU, PLC programming details: the PAMS programming of devices and workstations and all of the graphic screen configurations, alarm system configuration, short term history configuration, historian configuration, reports configuration, etc;
  - x. Input, output and software database.
- c. Manufacturer's Information:
- i. The Manufacturer's information shall be tabulated / located in subfolders based on the usage of the devices and equipment;
  - ii. Manufacturer's data sheets for all components (, etc.) used in the system including but not limited to: IED, BCU, meters, PLC, I / O modules, power supplies, communication modules, software, etc.;
  - iii. Manufacturer's data sheets for all network and communication components used in the system including but not limited to: Ethernet switches, modem, converters, fiber optic cables and patch cords, communications cables, connectors, antennas, power supplies, software, etc.

## 8.5 Operation and Maintenance Manuals

Operations and Maintenance manuals shall include the following:

- a. Operating instructions including descriptive text detailing operation of the new PAMS system shall be included. All modes of operation shall be covered including, but not limited to: circuit breaker control, Isolator switch control, earth switch control, synchronizing check, Unit start permissives, generator circuit breaker start-stop commands, fault trip and lockout operations, emergency stop, graphics and alarm system utilization, short and long term history, reports, etc.;
- b. The maintenance procedures shall include the weekly, monthly, quarterly, six-monthly and annual maintenance schedules, including the trouble-shooting details;
- c. The «as built» Installation drawings, shop drawings, miscellaneous schematics and diagrams, I / O lists, cable schedules;
- d. The complete list of spare parts;
- e. Original Software programs and licenses;
- f. Software Manual, software configuration, control and operation programming, screen page diagrams, legends, conventions, etc.;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 08 Protection and Metering
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- g. Technical Data Bulletins and Technical Guides of each PAMS device and component;
- h. Factory Test Procedures and Reports covering the complete PAMS;
- i. Site Test Test Procedures and Reports covering the complete PAMS;
- j. Site Commissioning Procedures and Reports covering the complete PAMS;
- k. The «as built» Relay Settings Report.

## 8.6 Spare Parts, Consumables & Special Equipment

### A. General-

- i. The spare parts mentioned hereunder are meant for use by the Employer for 5 years trouble free operation & shall not be used as erection or commissioning spares required during the works;
- ii. All spare parts shall be of the same material, workmanship, and manufacturer as the corresponding original parts, completely interchangeable and packaged for long-term storage;
- iii. If any additional spare parts required for a 5 years trouble free operation period are recommended by Contractor, these shall be listed as “Recommended Spares” and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares;
- iv. All spare parts shall be suitably packed, clearly marked and ready for long term indoor storage;
- v. The submittal shall include a separate list of additional spares, consumables and special equipment recommended by the Contractor, together with unit and total cost;
- vi. The submittal shall include handling and storage instructions for all spare parts, consumables and special equipment;
- vii. The submittal shall include a list of any specialty software or hardware tools used during project and not listed or provided under other submittals.

#### 8.6.1 List of “Mandatory Spare” parts-

S no.	Description	unit	Quantity
<b>1.</b>	<b>Spare Protection Relays</b>		
1.1	Generator Multifunction Digital Relay Protection-A	No.	1
1.2	Generator Multifunction Digital Relay Protection-B	No.	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

S no.	Description	unit	Quantity
1.3	Transformer Multifunction Digital Relay Protection-A	No.	1
1.4	Overall Multifunction Digital Relay Protection-B	No.	1
1.6	Breaker Failure and Multifunction Digital Relay Protection-A; one of each type	Set.	1
1.7	Breaker Failure and Multifunction Digital Relay Protection-B; one of each type	Set.	1
1.8	220 kV Line Distance & Differential Multifunction Digital Relay Protection-A (One of each type)	No.	1
1.9	220 kV Line Distance & Differential Multifunction Digital Relay Protection-B (One of each type)	No.	1
1.10	Multifunction Digital Bay Controller Unit; all BCU shall be identical	No.	2
1.11	Overcurrent Protection Multifunction Digital Relay (One of each type)	No.	1
1.12	Lockout Relay (86 and 96) complete with mounting hardware and casing; all Lockout relays shall be identical	No.	4
1.13	Tripping Relay (94) complete with mounting hardware and casing; all Tripping relays shall be identical	No.	2
1.14	Auxiliary Relay; set of each type	Set	6
1.15	Reset Buttons, resistors, LED, targets, etc.; set of each device	Set	6
1.16	Relay socket assembly on 19" rack bracket for relays above; suitable for 16 auxiliary relays	Set	2
1.17	Interposing relay with socket	Set	12
1.18	Energy Meter	No.	2
<b>2.</b>	<b>Spares for Central Control Room Equipment</b>		
<b>2.1</b>	<b>Process bus gigabit Ethernet TCP / IP</b>		
a)	Multimode gigabit Ethernet switch; Two (2) nos. of each type	Lot	1
b)	Single-mode gigabit Ethernet switch; Two (2) nos. of	Lot	1

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

S no.	Description	unit	Quantity
	each type		
c)	Other network component like patch panels, repeaters / hubs [Two numbers of each type]	Lot	1
2.2	<b>Field bus media converter modules</b>		
a)	Multimode Media converter module with connecting hardware [Two numbers of each type]	Lot	1
b)	Field bus connectors [of each type]	No.	2
2.3	Other cards / modules [for GPS based Time synchronizing system- synchronizing pulse distribution, power supply etc.] (each type)	No.	1
2.4	Colour Laser Printer Ink Cartridges	No.	12
3.	<b>Spares for Control Boards</b>		
3.1	PLC set [complete with redundant power supply cards, CPUs, communication interface cards, 19" mounting rails / racks, synchronizing modules, FO synchronizing cable & connectors, backup batteries, memory card and other accessories]	Set	1
3.2	HMI touch screen, Panel mounted Monitor	Set	1
3.3	Process I / O cards (DI, DO, AI and AO cards) (Eight (8) numbers of each type)	Lot	1
3.4	Field isolation (Optical / Electromagnetic) auxiliary relays, front connectors, interface modules, flat intra panel cables and necessary for I / O cards at 2.3 above including, connectors, patch cords and splice boxes. (Eight (8) numbers of each type)	Lot	1
3.5	Field-bus Interface module / and connecting pre-fabricated cables, Two (2) numbers of each type	Lot	1
3.6	Ethernet communication processor cards / module (Two (2) numbers of each type)	Lot	1
3.7	Power supply modules / DC-DC converters, 220V to 24V (Four (4) numbers for each type & rating)	Lot	1



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

S no.	Description	unit	Quantity
<b>4.</b>	<b>Miscellaneous</b>		
4.1	Miscellaneous Indicating lamps, rotary switches, semaphore indicators, push buttons, special relays, indicator and alarm switches; 20% or six (6) no [whichever is higher] each type	Lot	1
4.2	Terminals, ferrules, AC & DC power supplies, MMCBs, auxiliary contacts, diodes for power supply isolation; 20% or six (6) no [whichever is higher] of each type	Lot	1
4.3	Moulded Case Circuit breakers; of each type and of each rating; 20% or six (6) no [whichever is higher] of each type	Lot	1
4.4	Fuses (200%) of each type	Lot	1
4.5	Other cubicle spares and accessories, Door limit switches, space heaters, illuminating lamp, power sockets, cubicle cooling fan etc. (4 of each type)	Lot	1
4.6	Control and protection wiring; 20 m of each size and colour	Lot	1
4.7	Wiring lugs and terminals; 100 of each type and size	Lot	1

#### 8.6.2 Special Tools and Maintenance Equipment:

- Contractor shall supply, for hand over to Employer one complete set of special tools and maintenance equipment, recommended by Contractor for complete PAMS system. The list of these tools shall be approved during detailed engineering;
- However, it shall include at least the following maintenance equipment for repairs and maintenance with descriptions and quantities of the following:
  - Standard Electronic Tool kit : Two (2) sets;  
[Comprising Digital Multi-meter, loop check / Continuity testers, set of screw drivers, wire-stripper, crimping tool].
  - Optical fibre Splicing kit : One (1) set;
  - Optical fibre network testing kit : One (1) set;
  - Tag printer : One (1) no.
  - Any other Maintenance & Testing tool recommended by vendor

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

### 8.6.3 Relay Test Kit-

One set of relay test kit each comprising the equipment as detailed hereunder shall be supplied by the Contractor as part of the main offer as specified.

1	PC laptop with mouse, 1.44 MB floppy drive & CD Drive with the latest technology available at the time of supply	2 Nos
	Software for the testing & setting of relays	
	Training for the purchaser personnel for relay setting, testing & Easy operation of the system	
2	Relay test kit shall be microprocessor based fully automatic	1 No
3	Necessary Test plugs and clamps for use with testing equipment	1 No
4	Special type test plugs for using with modular type cases	1 No

The Relay Test Kit shall have following features:

- Protection test set and universal calibrator in one device;
- Very powerful current sources for testing even high-burden electromechanical relays;
- High current amplitudes for 5 A relay testing;
- High accuracy and versatility for testing static and numerical relays of all types;
- Testing of all relay generations - electromechanical, static, numerical, IEC 61850;
- Highly accurate test signals. For meter testing: The sources are the reference - no additional reference meters are required;
- Integrated network for testing IEC 61850 IEDs;
- 10-channel analog measurement and transient recording functionalities;
- To test and simulate all types of protection function distance, overcurrent, Earth fault, transformer differential, breaker failure, bus differential. pilot line differential of major manufacturers in automatic as well as manual mode;
- It shall include all the accessories required for making the complete test set up;
- It shall have three phase current output range 0-50 A (rms) and three phase voltage range 0-110 Voltage (Ph-G). Equipment should be capable of giving required voltage and current output at higher zones of Line Protections;
- It shall work on single phase 240V, 50 Hz, +10% variation shall include necessary software and hardware;
- to accept transient fault data recorded by disturbance recorder / Numerical relay from CD / DVD disk and replay these on the relay under test;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 08 Protection and Metering

- To read the relay characteristics;
- It shall be able to carry out the testing at power frequencies between 45-55 Hz;
- The accuracy of relay test kit shall be 1% for voltage and current output and resolution of time measurement of 1 ms or better;
- The relay testing kit shall be similar to the Omicron CMC-356 or approved equivalent.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

## **VOLUME- II**

### **SECTION II SUB-SECTION-09 Pressure Shaft Valve\_HEO**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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## TABLE OF CONTENTS

<b>9</b>	<b>PENSTOCK PROTECTION VALVE (BUTTERFLY VALVE)</b>	<b>4</b>
9.1	SCOPE OF WORK	4
9.2	TYPE AND DESCRIPTION	4
9.2.1	Codes and Standards	4
9.3	BASIC DATA/OTHER DATA FOR BUTTERFLY VALVE DESIGN AND INSTALLATION	6
9.4	BASIC DATA	6
9.5	WATER CONDUCTOR SYSTEM/ PRESSURE SHAFT PARTICULARS	7
9.6	PERFORMANCE REQUIREMENTS	8
9.7	OPERATIONAL REQUIREMENTS	9
9.8	VALVE CONSTRUCTION	9
9.8.1	Valve Body	10
9.8.2	Valve Disc	10
9.8.3	Valve Shaft, Bearing and Shaft Seal	11
9.8.4	Valve Seals	11
9.8.5	Lever Assembly & Counterweights	12
9.8.6	Latch And Trip Mechanism	12
9.8.7	By – Pass Valve Assembly and Drainage System	12
9.8.8	Anti vacuum Breaker Valve & Air Release Valve	13
9.8.9	Transition Section	13
9.8.10	Ultrasonic Flow Meter	14
9.8.11	Penstock rupture detecting device	16
9.9	VALVE OPERATING SEQUENCES	16
9.9.1	Opening of The Valve and Opening Sequence	16
9.9.2	Closing Of The Valve And Closing Sequence	17
9.9.3	Emergency Closing Sequence	17
9.10	ACTUATING SYSTEM	17
9.10.1	Valve Servomotors	17
9.10.2	Actuating Mechanism and Counterweights	18
9.10.3	Command Valves and Hydraulic System for The Servomotors	18
9.10.4	Electro-Hydraulic Control Panel	19
9.11	ELECTRICAL ACCESSORIES AND CONTROL PANEL	19
9.12	ACCESS PLATFORMS	21
9.13	INSPECTION AND TESTS	21
9.13.1	Performance Test	21
9.13.2	Body Hydrostatic Test	21
9.13.3	Disc Strength Test	22
9.13.4	Seal Test	22
9.13.5	Operational Test at Site	22
9.13.6	Test Report	25
9.14	MATERIAL OF CONSTRUCTION STANDARDS & CODES	25
9.15	POWER AND CONTROL SUPPLY	27
9.16	SURFACE PREPARATION & PAINTING	27

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

9.17	INSTALLATION OF THE VALVES .....	28
9.18	DRAWINGS AND CALCULATIONS.....	28
9.19	SAFETY MECHANISMS .....	29
9.20	VIBRATION .....	29
9.21	PACKING AND HANDLING.....	29
9.22	WIRING .....	29
9.23	SPECIAL TOOLS AND MAINTENANCE EQUIPMENT, INCLUDING DISMANTLING & ERECTION.....	29
9.24	DRAWINGS/DOCUMENTS FOR PENSTOCK PROTECTION VALVE.....	30
9.25	MANDATORY SPARE PARTS.....	31
9.26	O & M MANUALS .....	32
9.27	AS-BUILT DRAWINGS.....	32

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

## 9 PENSTOCK PROTECTION VALVE (BUTTERFLY VALVE)

### 9.1 Scope of Work

The scope of work under this section covers the detailed requirements for the design, manufacture, QA, QC, shop assembly and shop testing, packing transportation and delivery at site, storage and preservation, installation, erection, testing and commissioning of one (1) Penstock Protection Valve (PPV) of Butterfly type.

### 9.2 Type and Description

A Penstock Protection Butterfly Valve shall be provided downstream of the Surge-shaft, in order to isolate the penstock from the Head Race Tunnel during maintenance/inspection of the Penstock / High Pressure Tunnel. The Penstock Butterfly Valve shall also be required to (and shall be accordingly designed for) stop water flow in to the penstock / high pressure tunnel during emergency conditions. The Butterfly valve shall be of double seal, self-closing type.

The Valve shall have a nominal diameter of 5750 mm. The arrangement of the valve, the downstream connecting pipe with the dismantling-cum-expansion joint and the upstream transition section are included in the Scope of Works as also indicated in the Tender Drawings. The jointing/holding with U/s Penstock and D/s pipe (distributor) shall be done by the Valve Contractor.

#### 9.2.1 Codes and Standards

The design, manufacture and performance of the equipment along with the accessories shall comply with all currently applicable statutes, regulations, codes and standards in the locality where the equipment will be installed.

However, unless otherwise specified herein, the equipment supplied shall conform to the latest version of the standards/ equivalent international standards listed below.

Standard	Description
IS 732	Code of practice for electrical wiring installation
IS 1271	Thermal evaluation and classification of electrical insulation
IS 1367	Technical supply conditions for threaded steel Fasteners.
IS 1885	Electrotechnical vocabulary: Part 17 Switchgear and controlgear
IS 3043	Code of practice for earthing (First Revision)



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

IS 7326 (I)	Penstock and Turbine Inlet Butterfly Valves for Hydropower Stations and Systems – Criteria for Structural and Hydraulic Design
IS 7326 (II)	Penstock and Turbine Inlet Butterfly Valves for Hydropower Stations and Systems- Guidelines for Design and Selection of Control Equipment
IS 7326 (III)	Penstock and Turbine Inlet Butterfly Valves for Hydropower Stations and Systems- Recommendation for Operation and Maintenance
IS 9409	Classification of electrical and electronic equipment with regard to protection against electrical shock
IS 10422	Requirements and tests for safety of data processing equipment
IS 12065	Permissible limits of noise level for rotating electrical machines
AWWA C-504	American Water Works Association for Butterfly Valve
ASTM A 105	Material Specification for Carbon Steel Flanges.
ASTM A 106	Material Specification for Seamless Carbon Steel Pipes.
ASTM A 193	Dimensions and Thread Pitch for Bolts.
ASTM A 194	Dimensions and Thread Pitch for Nuts
ASTM A 216	Standard Specification for Steel Castings
ASTM A 516	Standard Specification for Pressure Vessel Plates, Carbon Steel, for Moderate- and Lower-Temperature Service
ASTM A 537	Standard Specification for Pressure Vessel Plates, Heat treated, Carbon-Manganese-Silicon Steel
ASTM A743	Specification for Casting, Iron-Chromium, Iron-Chromium-Nickel, Corrosion Resistant for General Application
ASME Section VII Div. I/II	Pressure Vessel Code

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

### 9.3 Basic Data/Other Data for Butterfly Valve Design and Installation.

#### 9.4 Basic Data

The PPV shall be designed and manufactured on the basis of the following parameters:

##### A) Valve size and other data/ requirements:

i)	Diameter /size of valve	5750 mm dia (clear bore)
ii)	Diameter /size of transition piece for connections to steel liner of pressure shaft on U/S and D/S side (if required)	5750 mm dia (clear bore)
iii)	Normal flow through valve equivalent to rated full load discharge of two units at rated head at turbine.	130.25 m <sup>3</sup> /s.
iv)	Maximum static head on valve when all the six generating units are stand still (Normal Design Head).	52.13 m
v)	DESIGN PRESSURE	
	a) Maximum static pressure	7.44 Kg/cm <sup>2</sup>
	b) Design pressure	7.44 Kg/cm <sup>2</sup>
vi)	Pressure for leakage test head	7.44 Kg/cm <sup>2</sup>
vii)	Pressure for hydraulic test head for valve body	11.16 Kg/cm <sup>2</sup>
viii)	Pressure for hydraulic test head for valve disc	11.16 Kg/cm <sup>2</sup>

##### B ) Operation Of Butterfly Valve

i)	Opening	In balanced condition only with practically equal pressure on both sides of disc. The opening time shall not be more than 180 sec. However, in case if different time is offered by the bidder, complete justification for the same may be furnished in the bid.
ii)	Closing	At no flow as well as under penstock rupture conditions against full flow under equal / unbalanced

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

		pressure condition. (Normal as well as emergency closing). The closing time under balanced conditions shall be adjustable between 120sec. to 240sec. Closing time under emergency condition shall be intimated by bidder. In case if different closing time is offered by the bidder, complete justification for the same be furnished in the bid. Closing shall be by means of counter weight.
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## 9.5 Water Conductor System/ Pressure Shaft Particulars

### A) Head Race Tunnel

i)	Type	Circular, concrete lined.
ii)	Size	6.5 m dia
iii)	Length	3550.0 m.
iv)	Design Discharge	130.25 m <sup>3</sup> /sec.

### B) Surge Shaft

i)	Type	Restricted orifice
ii)	Diameter	13 m
iii)	Orifice diameter	3.2 m
iv)	Height	78.5 m
v)	Elevation of centre line of head race tunnel	1347.875 m
vi)	Elevation of center line of pressure shaft in BFV house	1347.875 m
vii)	Elevation of bottom of surge shaft.	1351.50 m
viii)	Max. up surge	1422.28 m
ix)	Minimum down surge	1372.12 m

### C) Pressure Shaft (Steel Lined)

i)	Number	1 No.
ii)	Size	5.75 m dia. circular, steel lined.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

iii)	Length	Underground
a)	Horizontal	112.92m
b)	Length of upper bend	31.42m
c)	Vertical length	117.74m
d)	Length of lower bend	30.08m
iv)	Butterfly valve center line in valve house.	EL 1347.875m.

#### D) Unit Pressure Shaft

i)	Number	3
ii)	Diameter	2750 m
iii)	Length	25 m each (Average)

## 9.6 Performance Requirements

The Contractor shall design the valve, U/s & D/s transition and expansion sections to achieve minimum head losses. Head loss coefficient for the water passage from the inlet end of the upstream transition section to the outlet end of the downstream expansion section shall be quoted based on the normal flow given in the above table and guaranteed by the Contractor.

The valve shall be designed to operate and seal properly under pressure during all operating conditions, including penstock filling. The valve shall be capable of closing by the counterweights and torque due to eccentricity on the disc.

The design pressures shall take into account the overpressures by water hammer.

The valve opening and closing times required are specified in the clause 1.6 below.

The Butterfly Valve shall be designed to open under balanced condition and close against at least double the rated flow in emergency condition.

The Butterfly Valve shall be designed to operate under conditions as given below;

- Normal Condition:** It includes Static Head along with pressure rise due to normal operation or head at transient maximum surge, whichever is higher.
- Emergency Condition:** It includes total rupture of the penstock resulting in 100% pressure difference on the two sides of the valve as well as Slam Shut,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

Malfunctioning of Control Equipment in the most adverse manner resulting in odd situation of extreme loading.

## 9.7 Operational Requirements

The time to open the valve from the fully closed position to the fully open position shall preferably be around 60 seconds. The time for the closure of the butterfly valve shall not be more than 60 seconds from the initialization of the closing impulse to the actual closure of the disc. There shall also be provision made to increase the time of closure as well as open up to 120 seconds, if and as necessary after operational tests at site. Normal valve opening shall be preceded by approximate balance of the water pressure at its upstream and downstream side via the by-pass valve. The Valve must be secured in the fully open position before Guide Vanes opening is initiated. All Limit switch (IP 65 or better) with minimum 2NO+2NC contacts shall be provided for fully open, fully closed and creep positions. All limit switches shall be hermetically sealed for any moisture ingress.

Both manual and automatic operation modes shall be provided. The automatic control shall be through powerhouse control room SCADA & UCB and the manual control from the valve local control panel provided near the valve. The Contractor shall provide all equipment, apparatus and devices to achieve the specified methods of local and remote operation, indication and control. The Contractor shall give the termination point in its control panel for further cabling up to Powerhouse Control Room (this cabling shall be in Valve supplier scope). Necessary input/signal for turbine operation shall be also co-ordinated for automatic control of valve from the control room. However, the Contractor shall demonstrate the operation of Valve from UCB-SCADA as well as local control panel.

The Butterfly Valve and its control shall be designed to ensure smooth and stable operation without undue vibration under the specified operating conditions during normal opening, normal closing and emergency cut-off conditions, and without inducing excessive shock loads to cause abnormal fatigue with Valve, Penstock, piping and downstream works.

The design of BFV shall for minimum two (2) closures per day along with the Turbine closure.

Limit switches of weather proof type shall be provided for both bypass and main valve for their open-close status. Limit switches shall also be provided to indicate the status of Butterfly valve rotor in creep operation. These switches must not get damaged due to moisture presence and any variation in temperature conditions.

## 9.8 Valve Construction

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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### 9.8.1 Valve Body

The construction of valve body shall be made in a single/two piece flanged together, reinforced with ribs, brackets and sole plate for anchoring to the foundation. The features of construction shall be as per IS: 7326 (Part I&II)/AWWA C-504. The material for the valve body shall be of carbon steel conforming to ASTM A537 Gr.2 or A516 Grade 70. The fabrication work shall be done so as to fully meet the provisions of ASME Section VIII Division I or equivalent. The interior of the valve body shall be smoothly finished so as to have low resistance and a free & full flow is ensured through the system. A stainless steel ring shall be screwed inside the body near the downstream side of the valve to serve as seating ring for the valve disc when the valve is in the closed position. The Tenderer may propose their own design as an alternative for approval. The valve body shall be flanged at both ends, and the flanges shall be shop-drilled and spot-faced. The valve flanges shall match the flanges for transition and expansion sections.

Foundation Pads to be fabricated from suitable thick carbon steel plates shall be welded to the valve body to support the valve and to transmit all loads to the concrete foundation. The body and transition sections shall be so arranged that no weight or vertical thrust from the valve, transition section or contained water is applied to the penstock steel liner. The support pads shall be of a type to permit adequate movement in the upstream and downstream directions of the inlet valve during opening or closing. Suitable means on the valve of adequate strength for its handling/lifting shall be provided.

A stainless steel nameplate shall be provided and riveted to the valve body at an early visible location with all salient features of the valve etched or stamped on it.

### 9.8.2 Valve Disc

The valve disc shall be of the biplane lattice type to offer minimum head loss in the fully open position and to sustain the full differential pressure across the closed valve. The disc shall be of streamline section to minimize local eddy currents and sudden velocity changes. All surfaces of the disc in contact with water shall be smooth and free from hollows, depressions, cracks or projections that might cause pitting due to cavitation.

The disc shall be cast-fabricated/fabricated in single piece. The material shall be of carbon steel confirming to ASTM A537 class II or A516 Gr. 70, in case of fabricated steel. The disc shall be stress relieved before machining. The centreline of the valve disc shall be slightly off centre to the valve body centre line to provide a hydro-dynamic closing to the valve.

Note:- Regarding Valve Body & Valve Disc-. Materials of different standards such as ASTM, DIN EN, EN, IS can be offered if they are better or at least equivalent in terms

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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of chemical composition, properties etc. A side by side comparison of both the materials shall be carried out during detail engineering.

### 9.8.3 Valve Shaft, Bearing and Shaft Seal

The valve shafts shall be mounted in horizontal positions. The shafts shall have a minimum diameter extending through the valve bearings and into the valve disc to withstand the maximum torque required to operate the valve. The Contractor shall furnish the calculation to show the maximum stresses in the shaft and any keys or dowels, etc, under the operating conditions specified.

The valve shafts shall be of forged carbon steel construction (In case of fabricated disc) with hardened stainless steel sleeves. Self-lubricated bearings, to be housed in both ends of the hubs of the valve body, shall be provided. The friction coefficient of shaft bearings to be taken for calculation, is to be adjusted so that any increase in friction coefficient due to use/aging shall not be a bottleneck in weight as well as closing of valve, against full flow.

The shaft seal at each end shall preferably be of the gland and stuffing box type. The stuffing box shall be easily accessible for adjustment and replacement of packing without disturbing any other part of the valve.

### 9.8.4 Valve Seals

The valve shall be provided with two seals –

- one as service seal located downstream of the valve disc and
- the other as reserve or maintenance seal located upstream of the valve disc.

It should be possible to adjust service seal from downstream side of the valve by applying upstream seal and without dewatering upstream side of the valve. A provision shall also be made for rotation of valve disc to facilitate repair / adjustment of upstream maintenance seal without dewatering upstream of the valve.

Butterfly Valve shall be with eccentricity and 90° rotation.

Both seals shall be mounted on the periphery of the valve disc and be secured in position by means of clamping rings and screws.

The sealing arrangement shall be Stainless Steel seat ring in body and synthetic nitrile rubber seal with retaining ring on the disc. The leakage at the seals shall be zero to achieve water tight enclosure when the valve is pressurized.

The maintenance seal shall be inflatable hose seal type and shall held in position by clamping ring.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

The shape of mating parts (stainless steel ring / profile rubber sealing ring) shall be exactly same on whole circumference. Contact between stainless steel and rubber shall be line contact (i.e. tangent). The design / material of sealing system shall be such that the life of seal shall be not less than 10 years.

Tenderer shall furnish the complete details showing the seal system in the bid submission.

#### **9.8.5 Lever Assembly & Counterweights**

A lever arm shall be assembled to each of the valve disc drive shaft by taper drive key with sleeve assemblies. The lever arm shall be connected to the piston rod of a hydraulic cylinder(s). The lever arm shall carry the cast iron counterweights, preferably on both sides, which provides the necessary force to initially move the valve to the closed position. The lever arms shall incorporate locking pins to be retained by a padlock. The locking pin shall be capable of holding the valve in the closed position against full cylinder force.

The counterweights shall be sized to provide necessary closing torque on the disc under all possible operating & severe conditions including cutting off the maximum turbine flow and shall be fabricated of steel or cast iron. The counterweight, preferably located on upstream side, shall be designed for the worst friction coefficient possible in bearings and seals with a 1.5 safety factor.

A mechanical position indicator shall be provided, mounted on the valve body to show the position of the disc from full open to full closed position.

#### **9.8.6 Latch And Trip Mechanism**

To prevent the valve creeping from the fully open position, over an extended period of time, due to hydraulic oil pressure decay in the hydraulic cylinder, creep sensing device shall be provided to ensure that valve is kept in fully open position.

#### **9.8.7 By – Pass Valve Assembly and Drainage System**

The Butterfly valve shall be provided with a by-pass arrangement of suitable design for balanced opening of the valve. The same shall be suitable for automatic operation in sequential order. The bypass line shall be of minimum 250 mm diameter which shall connect the upstream and downstream companion pipes. The bypass valve shall be sized in such a way that it shall take care of leakages from GUIDE VANES and equalizes the pressure in the preset time. In case this time exceeds, we shall get alarm. The bypass line shall be provided with a manually operated isolating gate valve on upstream side, which shall normally be fully opened all times, and a hydraulic cylinder operated needle valve with auxiliaries on downstream side. The needle of the valve shall be of stainless steel and all piping and valve shall be carbon steel/cast

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

steel construction. The Contractor shall provide one flexible coupling in the by-pass line. The Hydraulic operated By pass needle and Seat rings shall be of stainless steel while body shall be of carbon steel.

The drainage arrangement shall be provided on the upstream side of the valve for drainage of penstock. The drainage pipe of minimum 250 mm diameter with necessary valve, piping, fitting, isolating valve (with locking device), energy dissipater etc. shall be provided.

The calculation for sizing, make and catalogue of the needle valve shall be furnished in the bid submission.

### 9.8.8 Anti vacuum Breaker Valve & Air Release Valve

Anti-Vacuum breaker valve and air valve of suitable size shall be mounted on the downstream companion pipe and shall operate automatically allowing air to enter the penstock to relieve sub-atmospheric pressure which may be induced by closing of Butterfly valve against flow or while the penstock is being de-watered. These valves shall be sized for the penstock rupture in the downstream of pressure shaft valve.

The valves shall be flange-mounted and shall be provided with nitrile rubber seal and metal seal. The nitrile rubber seal shall provide leak tight seal, while metal seal shall take load acting on the seal.

The float shall be Stainless Steel lined with ebonite or rubber and the orifice contact joint with the float shall be a leak-tight joint. The float movement shall be governed by spring actuation and initial clearance shall be given between float and seal, allowing the air to escape during the filling operation. During filling operation, the float shall seal based on buoyant force, overcoming the spring pressure. As the water pressure increases the float shall seat on the seal provided in the body. During the draining operation, the float shall move down assisted by spring pressure.

A separate air release valve shall be provided on top of the downstream pipe, so that during filling, the entire penstock air is released through that air release valve.

The maximum and minimum pressure and temperature shall be considered while sizing the valve. Weather-proof type Limit switches shall be provided for monitoring the open-close status. Details of the sizing, selection, sectional drawings etc shall be submitted along with the bid.

### 9.8.9 Transition Section

#### 9.8.9.1 Upstream Companion pipe

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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The upstream transition pipe shall be flanged for connection to the Butterfly valve body and welded to the steel liner/penstock upstream of the valve. Connections for bypass line, pressure gauge and provision for mounting the differential pressure switches shall be provided at suitable locations on this pipe.

#### 9.8.9.2 Downstream Pipe piece, Dismantling section-cum-expansion joint

The Butterfly valve shall be flanged on the downstream side to a dismantling-cum-expansion joint of telescopic type, for dismantling of the valve during maintenance. The downstream pipe piece shall be of suitable length & shall be site welded/flange bolted to distributor. The connection for by-pass valve, manhole of 600 mm dia, pressure gauge etc., shall be provided in the downstream pipe.

The upstream and downstream pipe pieces shall be of fabricated steel construction of ASTM A537 class II/ A516 Gr. 70 and shall be supplied with a trim allowance of minimum 200 mm for edge preparation and welding. Any alternative material offered must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and material properties. However, the detailed comparison of Chemical composition and material properties must be submitted to the Purchaser for approval during detail engineering stage. The edge preparation & welding of upstream & downstream pipes to steel liner and penstock shall be in the Contractor's scope. All the piping shall be tested to required pressure before installation.

#### 9.8.10 Ultrasonic Flow Meter

A 4 path Ultrasonic Flow Meter shall be installed just downstream of the Pressure Shaft Protection Valve. Details and specifications of the flow meter are described here under:

- Type of Flow Meter

The flow meter shall be of the ultrasonic type with a minimum of 4-path configuration to ensure high accuracy and reliability. It shall be a clamp-on or inline type, as specified in the project requirements.

- Application

The flow meter shall be suitable for continuous flow measurement of water or similar liquids in pipes, used in hydropower applications. The device shall operate effectively under the given environmental and fluid conditions.

- Accuracy

The flow meter shall provide a measurement accuracy of  $\pm 0.5\%$  of the measured value or better, within the specified flow range.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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- Measurement Range

The flow meter shall be capable of measuring flow rates within a range of 0.1 m/s to 200m/s or as per the site-specific requirements.

- Pipe Sizes Supported

The meter shall be compatible with pipe diameters ranging from 50 mm to 6000 mm (or as specified in the project).

- Output Signals

The flow meter shall provide the following outputs for integration with the SCADA/PLC system:

- Analog Output: 4–20 mA.
- Digital Output: RS-485/Modbus or similar communication protocol.
- Pulse Output: Configurable for totalized flow.

- Power Supply

The flow meter shall operate on a standard power supply of 220V AC  $\pm 10\%$ , 50 Hz, or as specified. It shall also include provisions for back-up battery operation for continuous data logging during power outages.

- Enclosure and Protection

- Transmitter: The enclosure shall be IP65 or better for protection against dust and water ingress.
- Sensors/Transducers: The sensors shall be rugged and IP68 rated for submersion in water.
- The device shall be suitable for indoor and outdoor installation in harsh environmental conditions.

- Temperature Range

The flow meter shall operate within a temperature range of:

- Ambient:  $-20^{\circ}\text{C}$  to  $+60^{\circ}\text{C}$ .
- Fluid:  $0^{\circ}\text{C}$  to  $+80^{\circ}\text{C}$  (or as per specific site requirements).

- Standards and Compliance

The flow meter shall comply with international standards such as:

- ISO 4064 for water meters.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

b. EN 61000-6-2 and EN 61000-6-4 for electromagnetic compatibility.

c. CE marking or equivalent certifications.

- Installation Accessories

The supply shall include all necessary installation accessories, including clamps, mounting kits, cables, and connectors, required for proper installation and commissioning.

The flow measured shall be compared with the sum of flow in the MIVs or Turbine Flow Meters to detect any leakage /rupture in penstock and initiate valve closing, if required.

#### 9.8.11 Penstock rupture detecting device

A penstock rupture detecting device shall be provided, which would close the valve under penstock rupture for safe guarding the power house from flooding.

### 9.9 Valve Operating Sequences

The Butterfly valve will be operated from the remote UCB-SCADA and the local control panel.

#### 9.9.1 Opening of The Valve and Opening Sequence

Opening of the valve shall be by hydraulic servomotor. Valve opening sequence is initiated by a push button in the control cabinet or from the remote control cabinet, which shall initiate the open command to the bypass valve. Once the bypass valve is opened and the pressure is approximately balanced in both the upstream and downstream sides of the valve, the opening of Butterfly valve takes place by energizing the solenoid valve provided in the hydraulic circuit. Once the Butterfly valve is fully open, the limit switch shall trip the motor after ensuring that the valve is held in open position by suitable mechanical arrangement (latch mechanism with a trip cylinder). The speed of valve opening shall be controlled by a control valve. The valve shall be kept open by oil trapped in the cylinder.

The servomotor system shall consist of a servo-piston operated by a pump driven with an electrical motor. During opening, oil will be allowed to flow from the sump to operate the piston. The piston movement shall be transmitted properly by a reliable link mechanism to the dead weight mechanism.

The valve's control logic system should be designed in such a way that in case the valve rotor creeps from the open position, then the tendency should be to retain the valve in fully open position, every time it has crept beyond a set point. In case the valve continues to creep, an emergency gets created and the unit must trip. One hand

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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pump with suitable hose pipes, adopters etc. shall be provided to manually open the valve in case of the failure of oil pumping unit during emergency.

### 9.9.2 Closing Of The Valve And Closing Sequence

Closing of the valve shall be by counterweight. The falling dead weight shall be actuated manually or through an electrical solenoid. To close the valve, signal is given to operate a solenoid valve and allow the oil to flow out of the cylinder back to the sump tank. When the valve closes to 80% to 90% closed position (adjustable), another solenoid valve shall actuate to reduce the flow of return oil and slow down the rate of closing the Butterfly valve during the last 20% to 10% of the travel. The tripping mechanism must be actuated hydraulically (oil actuated). Once the Valve reaches the fully closed position, the service (downstream) seal is applied.

A fool-proof mechanical interlock device (locking pin, lever etc.) shall be provided to prevent opening of the valve under unbalanced condition and for safety against accidental opening / closing or accidental energizing of the actuator.

### 9.9.3 Emergency Closing Sequence

Closing of the Valve in the emergency mode shall be initiated from the following conditions:

- i) Emergency closing of TG unit.
- ii) Penstock rupture condition,
- iii) Alarm from level sensors at MIV floor/ Drainage pit under floor flooding conditions.

## 9.10 Actuating System

### 9.10.1 Valve Servomotors

The valve disc shall be actuated by two double-acting oil servomotors with orifice fitting integrated into the servomotor body with counter weights for opening & closing of valve in order to reduce the size of servomotor, which shall be provided. When energized, the servomotors shall move the disk to the open position and keep it in that position against the closing force of the counterweights. For a fail safe provision, the emergency closure has to be without servomotor and with dead weight only.

The servomotors shall be designed to operate adequately with the normal operating pressure range produced by the turbine OPU. They shall be designed to produce the maximum torque that may be produced by the valve and counterweights in any operating condition, and for the full range of friction coefficients that could prevail in

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
---	--	---

the bearings and trunnion seals. A safety factor of 1.5 shall be applied to the friction coefficients, both ways.

During emergency closing, the servomotor oil flow shall ensure that the maximum allowable overpressure is never exceeded. The oil flow out of the servomotors shall be restricted by replaceable orifice fittings integrated into the servomotor body. The orifice fitting design shall be in a way that the piping cannot be installed without the orifice fitting correctly in place.

The servomotor cylinder shall be fabricated from welded plate or seamless pipe. Flanges shall be of forged steel and shall be provided with suitable gaskets or seal rings designed to remain oil tight at maximum pressures. The cylinder bore shall be honed to a polished finish. The piston material shall be steel and shall be supplied with appropriate seals suitable for the maximum design pressure.

The cylinder shall be equipped with a means of purging trapped air with safe plugging.

The servomotors shall be attached in one of two ways:

- Directly onto the valve body, or
- On the same foundation as the valve housing. In this case, all anchor bolts and accessories for the servo motors shall be supplied by the Contractor.

### **9.10.2 Actuating Mechanism and Counterweights**

The actuating mechanism is a series of levers and rods that transmit the forces between the servomotors, the counterweights and the rotor trunnions.

The actuating mechanism articulations shall be equipped with self-lubricating bushings and hardened martensitic stainless steel trunnions.

The closing of the main valve shall be done by counterweights. They shall be designed to close the valve under the most severe conditions, including cutting-off the maximum turbine flow. These counterweights shall be designed for the worst friction coefficient possible in bearings and seals with a 1.5 safety factor.

There shall be appropriate adjustable and lockable stops to ensure that the valve orifice is perfectly aligned with the conduit when in open position, and also to ensure that the seal surfaces on the disk are perfectly aligned with the service and maintenance seal rings when in the closed position.

### **9.10.3 Command Valves and Hydraulic System for The Servomotors**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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The pressurized hydraulic oil for the servomotors shall be provided by the high-pressure pumping unit for the associated TG unit. The pipe sizes shall be chosen so that average oil velocity does not exceed 4 m/s.

The Contractor shall supply all the associated steel piping and steel or bronze accessories necessary to connect all components. Threaded connections shall not be accepted for pressurized piping. All joints shall be welded, and all connections between pipe sections or components shall be flanged.

An electro-hydraulic control panel with provision for housing instruments and controls for safe valve operation including controls for opening, closing and emergency closing of valve with provision for indication / annunciation and alarm shall be provided. Valve closure shall be piloted by a Bosch Rexroth poppet valve with heavy duty solenoid. Required controls shall be provided in the valve control panel for operating the valve by remote commands from the Power House UCB-SCADA. The arrangement of the devices on the panel shall be so that the piping is held to a minimum and the devices could be readily removed from service. All the instruments on the panel shall be of flush mounted type.

The entire piping and valve system shall be designed to ensure total safety for plant personnel. The pressurized piping and components shall be well supported and protected from accidental impacts. The piping shall be arranged as so to avoid any risk of overpressure of any component in case of accidental operation of any valve or combination of valves. All manual valves shall be padlockable in closed and open positions.

#### **9.10.4 Electro-Hydraulic Control Panel**

An electro-hydraulic control panel housing instruments shall provide controls for the valve safe operation including controls for opening, and closing of valve with provision for indication / annunciation and alarm. Requisite controls shall be provided in the valve control panel for operating the valve by remote commands from the Power House UCB-SCADA. The arrangement of the devices on the panel shall be so that the piping is held to a minimum and the devices could be readily removed from service. All the instruments in the panel shall be of flush mounted type.

Name plates shall be provided for each device mounted on the panels and located on or below each device. The name plates shall contain legends which are descriptive of the function performed. Emergency control operations shall be plainly indicated.

#### **9.11 Electrical Accessories and Control Panel**

The local control panel shall house the following:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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- Lockable type local/remote selector switch for valve control selection. The local/remote selector switch position shall be indicated locally and in the remote position, the MIV control will be taken over by the Unit Control Board and Power House SCADA . The change of position shall be recorded as an event. In local mode, no action can be taken on the valve from the UCB or Powerhouse SCADA.
- Lockable push buttons for valve open/close commands. Commands to the valve shall be indicated and recorded as an event at the powerhouse SCADA.
- LED type indicating lamps for display of Butterfly and bypass valve position.
- Oil temperature digital indicator with dual RTD sensor input.
- All digital indicators shall have a 4 to 20 mA repeating output for local controller analog input.
- The local controller shall have the capability to communicate with the UCB- remote SCADA
- Sequence control shall be provided in control circuit, so that valve shall open and close as per defined sequence, once open or close command is given either locally or remotely. When the local/remote selector is in remote mode, it shall be possible to command the Butterfly valve from the Powerhouse Control Room SCADA and also from the HMI located in the Unit Control Boards at the powerhouse operating floor.
- The panel shall be fabricated with instruments installed, wired and tested in manufacturer's work. All the controls and push buttons shall be of flush mounted type. All external connections shall be by way of numbered terminal blocks. Terminals will be provided in the control panel for connecting various incoming and outgoing signals and alarms. 20% spare terminals shall be provided.
- The panel shall be of the free-standing type fabricated from sheet steel with a one piece 3 mm thick steel for front and 2 mm thick steel for sides, back and top. The panel shall be supplied with an integral structural steel framework for supporting purposes and panel bracing. Each panel shall be provided with fully gasketed access doors that provide an IP55 degree of protection. Doors shall be provided with three point latches. Latching mechanism shall be key locking type. The outside and the inside of the panel shall be adequately painted to prevent rust. The control cabinet shall include proper interior lighting controlled by a door switch. A 240 V AC utility receptacle shall also be provided in the cabinet. For more details, refer to General Technical Requirements.
- Limit switches mounted on the butterfly valve shall be enclosed in a weather proof enclosure. Watertight cable connectors shall be used at both ends of the cables. The limit switches shall be redundant.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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- The hydraulic solenoid valves shall be operated from the 24 V DC source.
- Protection, Auxiliary and Interposing Relays: Protection Relays shall be High Speed and specifically designed for tripping of circuit breaker coil. Relay coils shall be supervised using an external Supervisory Relay. Lockout relays shall be of the latching type resettable with an external pushbutton. Remote resetting is not permitted. Auxiliary, supervisory and interposing relays. Relays shall be rated 10 A continuous, 30 A make 5 s at 110 V DC suitable for 100,000 electrical and 1 million mechanical operations and shall be with flag/ LED operation indication. A minimum of 2-3 spare contacts shall be provided for future use.

Manufacturers accepted:

- Protection Relays: ABB Combiflex RXME, RXMS & RXMV or Alstom MVAJ;
- Auxiliary Relays: ABB Combiflex, Alstom PRIMA or equal;
- Interposing Relays: Tyco O/E/N type 51D-3 gold or equal.

## 9.12 Access Platforms

An access steel structure shall be provided by the Contractor for inspection and maintenance of valve by-pass assembly, air release valve and vacuum valve as well as for the purposes of crossing penstock and approaching manholes. The access steel structure shall consist of a platform, ladders and guard rails designed with sufficient strength and rigidity.

## 9.13 Inspection and Tests

The following tests shall be conducted in the shop and witnessed by Employer/Engineer:

### 9.13.1 Performance Test

The valve shall be tested in a fully assembled condition along with hydraulic power pack and control panel. The valve shall be shop operated a minimum of ten (10) times from fully closed to fully open position and ten (10) times vice versa under a no flow condition to demonstrate that the complete assembly is workable. However, if the Employer is not satisfied or would like to test the functioning of the valve even after this, the decision to open and close the valve for more than ten (10) times shall be the Employer's.

### 9.13.2 Body Hydrostatic Test

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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Both ends of the valve shall be blanked off (including upstream & downstream sections) so that the valve is subjected to the full pressure stress in all directions induced by the test pressure. With the valve disc in a slightly open position, the entire valve shall be subjected to at least 1.5 times the specified design pressure including pressure rise or twice the maximum operating pressure whichever is higher for at least 30 minutes. Under this pressure there shall be no leakage through the body or any trunnion seals and no parts shall be plastically deformed.

### **9.13.3 Disc Strength Test**

With one end of the valve open to atmosphere and the disc in the closed position, the valve shall be subjected to 1.5 times the specified design pressure or twice the maximum operating pressure whichever is higher for a period of 30 minutes. The test shall reveal no structural damage at any point. There shall be no permanent deflection in the disc near seal, which shall be demonstrated during its testing.

### **9.13.4 Seal Test**

With one end of the valve open to atmosphere and disc in the closed position and valve shall be subject to maximum design pressure for a period of 30 minutes. The leakage from the seals shall be zero. Low pressure leak test at working pressure shall also be carried out.

### **9.13.5 Operational Test at Site**

After installation at site, the Butterfly valve shall be tested for operation to ensure that the actuator provides sufficient torque for valve opening under approximately balanced water conditions and valve closes by counter-weight in the desired time. Initially, this test will be done by selecting minimum time of 45 sec and 60 sec for closure of Butterfly valve. If required the opening and closing time shall be adjusted at site to meet the system requirements. Further, the valve shall also be tested from the local control panel as well as powerhouse control room SCADA and UCB.

Following tests shall be conducted on accessories;

- Pressure test of all field-installed piping at 1.5 times of maximum design pressure,
- Opening and closing of by-pass valve,
- Operation of all controls/OPU including mechanical locking devices, and
- Other tests as deemed necessary by Engineer.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

Butterfly valve / dismantling joint components shall be subjected to non-destructive testing as per relevant standards. Prior to testing, the test procedures and repair procedure shall be submitted for the Employer/ Engineer's approval. All components subjected to testing shall be fully identified and only those which are successfully tested shall be used for the manufacture of the final product. All test results shall be submitted for the Employer/ Engineer's approval.

The body of the dismantling joint shall be subjected to a hydrostatic pressure which is equal to 1.5 times the design pressure. No leakage shall be permitted.

Inspection and tests on various components of Valve & Accessories

	Type of Test Witness	Mills Test Certificate (Material Traceability Report)
<b>I) Valve and Flanges: Components</b>		
a)	Mechanical and Chemical tests of shafts, seat ring, clamping ring, body, disc, flange and other components	Review of Mills Test certificates and correlation with the material
b)	UT & DP of Shaft, UT of plates for body and fillet welds, UT for disc	Mill Test Certificates
c)	Air seal test (Air Release Valve)	Mill Test Certificates
d)	Hydrostatic test on body, disc and seat	Witness (CHP)
e)	Performance test with actual power pack	Witness (CHP)
<b>II) Oil Pressure Unit</b>		
a)	Performance test	Witness (CHP)
b)	Pressure test at 1.5 times the design pressure for all valves, piping, fittings etc.	Witness (CHP)

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

	Type of Test Witness	Mills Test Certificate (Material Traceability Report)
c)	Functional test for control valves, relief valves, pressure switches, float switch, electrical circuits and other instruments etc.	Witness (CHP)

### III) Tests – Common for all the equipment:

a)	Mechanical and chemical properties	Review of Mills test certificates and correlation with the material
b)	Dimensional check	Witness
c)	100% MPI / DP on all fillet joints	Test Certificates
d)	100% DP test on welded parts	Test Certificates
e)	100% Radiography on welds for flanges fabricated from segments.  100% Ultrasonic testing of weld joints shall also be accepted.	Witness
f)	100% Radiography on all Longitudinal joints as well as all Tee joints of butt welding for Main Valve Body, Disc, Upstream & Downstream Pipes (both for Shop & Site)  100% Ultrasonic testing of weld joints shall also be accepted.	Witness

Notes:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

1. Post weld heat treatment shall be carried out. QAP and testing plan shall be furnished by the Contractor for review/approval by the Employer / Engineer.
2. Prior to dismantling, each assembly shall be permanently and clearly matchmarked in the shop to facilitate site erection. Dismantling shall be done only to the point required for shipping. In particular, there shall be minimum disconnection of electrical wiring.
3. CHP: "Customer Hold Point"

#### 9.13.6 Test Report

After each test, a report shall be produced by the Contractor and transmitted to Employer for approval. Employer reserves the right to demand modifications to the values and a new series of tests without any extra charge.

#### 9.14 Material of Construction Standards & Codes

Valve Component	Material
Valve Body	Carbon Steel confirming to ASTM A537 class II or A516 Gr. 70
Valve Disc	Carbon Steel confirming to ASTM A537 class II or A516 Gr. 70
Valve Shaft	Forged Steel BS 29/EN9
Sleeves for Shaft(as per manufacturer std)	Hardened Stainless Steel ASTM A 743 Gr. 6 NM or CA15
Maintenance Seal	Nitrile rubber of shore hardness 75 <sup>0</sup> A
Service Seal	EDPM rubber of shore hardness 75 <sup>0</sup> A
Seal "O" ring	Nitrile rubber of shore hardness 75 <sup>0</sup> A



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

Seal Retaining ring	SS 410
Retaining Ring (Segments are not permissible)	AISI 316
Body Seat ring	SS 410
Companion Flanges	Carbon Steel confirming to ASTM A537 class II or A516 Gr. 70
U/s. & D/s. Pipe Piece	Carbon Steel confirming to ASTM A537 class II or A516 Gr. 70
Flange Nuts & Bolts for Valve (Body)	High Tensile Steel SS IS: 1367 CL 12/BS:970 817
Nuts & Bolts for (By-pass Piping)	A 193 Grade B7 / 194 Gr 2H
Bypass Gate Valve & Needle Valve	Cast Steel ASTM A 216 Gr. WCB with SS trims
Bypass piping	Seamless Carbon Steel ASTM A 106
Flanges for Bypass piping	Carbon Steel ASTM A 105

Note: Materials of different standards such as ASTM, DIN EN, EN, IS can be offered if they are better or at least equivalent in terms of chemical composition, properties etc. A side by side comparison of both the materials shall be carried out during detailed engineering.

Any alternative material offered must be equivalent or better than the material specified in the Tender specification both in terms of chemical composition and material properties. However, the detailed comparison of Chemical composition and material properties must be submitted to the Purchaser for approval during detail engineering stage.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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### 9.15 Power and Control Supply

The Contractor shall provide the following at the Power House:

- 415/240 V AC distribution board.
- The 230 V AC UPS System along with auxiliaries for essential loads such as the SCADA module racks.
- 24 V DC Battery Charger, Battery and with DC distribution board.
- The lighting, welding and utility receptacles.
- Cables trays, racks, supports and necessary hardware;
- Earthing System.

The Contractor shall provide the following:

- 240 V AC feeder cable between the 230 V AC UPS distribution and the control cabinet.
- 415 V AC feeder cable from the 415 V AC distribution board and the hydraulic motor Starters/MCC.
- All the necessary control cabling between the valve and the associated control cabinet and SCADA I/O Panels.
- Drawing 24 V DC power supply from Employer's Board for feeding of the SCADA input and output modules.
- The 24 V DC distribution shall be through terminal blocks and rail mounted breakers inside of the valve control cabinet.
- Cabling between MCC/Starters to electrical devices and equipment.
- Welding Socket.
- Earthing System for individual components.

### 9.16 Surface Preparation & Painting

All un-machined surfaces of ferrous material shall be thoroughly cleaned to base metal by sand blasting or wire brushes to remove all loose scale, grit ,dust etc. prior to it painting. The painting shall consist of two coats of epoxy primer with a minimum

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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DFT of 80 microns followed by two coats of coal tar epoxy enamel having a minimum DFT of 100microns on the inside water passage surface.

The external surface of the servomotor and the un-machined surface of the Valve shall be cleaned by sand blasting or with wire brushes to base metal to remove all loose scale and then be painted. The surface shall be applied with two coats of epoxy primer followed by at least two coats of epoxy paint.

The surface preparation of steel surface for painting shall conform to IS:9954-1981(Reaffirmed 1995).The epoxy primer shall conform to IS 14506:1998. The surface paint shall be Light grey in colour conforming to paint no.631 of IS 5: 1994. The epoxy enamel shall confirm to IS 14209:1994.

### 9.17 Installation of The Valves

Erection, testing & commissioning of the Butterfly Valve is included in the Contractor's Scope of Supply.

All necessary bolts, studs, nuts, washers and gaskets associated with the upstream and downstream transition sections shall be provided by the Contractor.

### 9.18 Drawings and Calculations

The Contractor shall provide its drawings in conjunction with calculations as well as references, showing the detailed design of butterfly valve and auxiliaries as required by Engineer for review/approval.

In particular, the following calculations/details shall be submitted regarding:

- Analysis of all loading conditions for stresses in the valve components including FEM analysis
- Calculation of the foundation loads.
- Torque Calculation & Shaft sizing
- Sizing of the hydraulic operating system, including servomotor.
- Selection of anti vacuum valve, air release valve, needle valve
- Curves for: opening & closing torque Vs disk angle; head loss Vs disk angle; flow coefficient Vs disk angle

Tenderer shall also furnish the details/write-up/catalogue of expansion cum dismantling joints, seal arrangement, latch mechanism, typical quality assurance program, GA/installation drawings, OPU drawings etc, along with bid.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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All the above information is mandatory, and bids without these shall be rejected. Further, during detail engineering all above drawings/documents shall be approved / reviewed by the Employer.

#### **9.19 Safety Mechanisms**

Safety mechanisms shall be designed to protect personnel engaged in inspection or maintenance work, especially from the hazard of replacing the working seal from downstream side. Type of locking mechanism shall be mechanical toggle latch or approved equivalent.

#### **9.20 Vibration**

Under opening, closure and transient conditions, no detrimental vibrations shall be induced in the equipment and its related mechanisms including the piping. The valve shall be designed to operate under vibrations and noise free conditions.

#### **9.21 Packing and Handling**

Each valve shall be provided with lifting lugs for lifting / handling. Supporting legs with suitable fixing arrangement shall be provided so that it can be conveniently supported.

Piping shall be protected for shipment by wooden protectors on all flanges, screwed caps on threaded ends and wooden plugs in plain ends. The piping shall be shop fabricated to the maximum extent possible consistent with erection, handling and shipping requirements so as to reduce field work to a minimum.

#### **9.22 Wiring**

All internal electrical wiring for the hydraulic control cabinet and valve control panel shall be completed in the shop and shall be neatly arranged and terminated so that all external connections will be made at a terminal box. All wiring shall be color coded, supplied with markers and suitably numbered for identifications. All wiring shall be neatly formed into flat or rectangular wiring groups and shall be properly supported. There shall be no splices in the wire and all connections shall be taken to prevent cutting into conductors where insulators are removed. For more details, refer to General Technical Requirements.

#### **9.23 Special Tools and Maintenance Equipment, including Dismantling & Erection**

The Contractor shall supply one (1) set of special tools and tackles required for maintenance of the Butterfly valve for handing over to the Employer. The list of such tools shall be specified in the bid and the price shall be indicated in the price schedules. These tools and tackles shall not be used during the erection of the valves

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 09 Pressure Shaft Valve
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and the Contractor shall supply a separate set of tools and tackles for erection and commissioning works. The same may be taken back by the Contractor after the erection and commissioning of the equipment. All necessary instrumentation and measuring devices required during erection shall be supplied by the Contractor. For more details, refer to General Technical Requirements.

Special tools and tackles should include Hydraulic Bolt Tensioner.

## 9.24 Drawings/Documents for Penstock Protection Valve

The major drawings/documents to be furnished after award of contract shall include, but not limited to the following:

- i. PPV – GA & Foundation Drawing
- ii. PPV – P & I diagram
- iii. Servomotor - GA & Foundation Drawing
- iv. Inlet Pipe – GA Details
- v. Outlet Pipe – GA Details
- vi. Bypass Piping & Valves - GA Details.
- vii. Operation Procedure.
- viii. Mechanical Design Calculations (FEM) - Valve body, Rotor, and Trunnions, Service Seal & Maintenance Seal.
- ix. Sizing Calculation - Servomotor and Actuating Mechanism.
- x. MIV - Foundation load Calculations.
- xi. Hydraulic Pipe & Connector - Details
- xii. Hydraulic & Control Panel of MIV – GA Details.
- xiii. Hydraulic & Control Panel of MIV – Power & Control wiring diagram.
- xiv. Tools, Tackles and Erection Devices.
- xv. Test Equipment for MIV.
- xvi. Quality Assurance Plan – MIV, OPU, Control Panel etc.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

xvii. Testing & Commissioning Procedures – MIV, OPU, Control Panel etc.

## 9.25 Mandatory Spare Parts

The following spare parts shall be included in the supply:

S. No.	Description	Type/size	Quantity
<b>I</b>	<b>PENSTOCK PROTECTION BUTTERFLY VALVE</b>		
1	Disc Seals of synthetic Nitrile rubber each for Service Seal and Maintenance Seal.		1 set
2	Clamping Ring/Retaining Ring of each type for the Valve Seal (with Ring Bolts)		1 set
3	Trunnion Bearings		1 set
4	All Packing, Seals etc. for Trunnion Bearings		1 set
5	All Packing, Seals etc. for Servomotors		1 set
6	All Packing, Seals etc. for Bypass Valve		1 set
7	Piston Rings and Bushings for Hydraulic Servomotors		1 set
8	'O' Ring (Nitrile rubber) of Shaft Pin		1 no.
9	Seals ('O' Ring) for Gate Valves	each type/size	2 sets
10	Spares for Air Release Valve		1 set
11	Spares for Anti Vacuum Valve		1 set
12	Spares for Needle Valve		1 set

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 09 Pressure Shaft Valve

S. No.	Description	Type/size	Quantity
13	Limit Switch	each type/size	2 nos.
14	Proximity Switch	each type/size	2 nos.
15	Auxiliary Relays/ Contacts (ABB Make)	each type/size	2 nos.
16	Timers	each type/size	2 nos.
17	Power Contactors with Overload Relays		1 Set

The spare parts mentioned here are meant for use by the Employer for 5 years trouble free operation and shall not be used as erection spares required during installation. All the spare parts shall be interchangeable and shall be of the same material and workmanship as corresponding parts of the main equipment.

If any additional spare parts required for a 5-year operation period are recommended by Contractor, these shall be listed and the unit price shall be quoted in the Price Schedule. The Employer reserves the right to order any or all of such spares within 12 months from commissioning.

#### 9.26 O & M Manuals

The Contractor shall furnish to the Employer, 4 (four) sets of operational and maintenance manual (O&M manual) for review/approval. After approval (incorporating the Employer comments) the, Contractor shall submit 12 (twelve) sets of the final O&M manual.

#### 9.27 As-Built Drawings

The contractor shall furnish four (4) sets of MIV Drawings for approval. After approval and after work completion at site, six (6) sets of As-built drawings and one (1) set of electronic version as a CD shall be supplied.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

## Volume-II

### Section II Sub-Section 10

### Medium & Low Voltage Switchgear and Auxiliary Power Supply System\_HEO

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

## **TABLE OF CONTENTS**

10	MV & LV SWITCHGAER 5.....	2
10	MV & LV SWITCHGAER.....	5
10.1	Scope (MV Switchgear) .....	5
10.2	Standards .....	7
10.3	Specific Parameters and Layout Conditions .....	7
10.3.1	Layout and General Arrangement .....	7
10.4	Rating and Functional Characteristics .....	7
10.4.1	Rating.....	7
10.4.2	Current ratings and short circuit capabilities.....	9
10.5	Performance Guarantee.....	9
10.6	Design and Construction.....	9
10.6.1	Bus Bars .....	10
10.6.2	Circuit breaker .....	10
10.6.3	Current transformer .....	11
10.6.4	Potential transformer .....	11
10.6.5	Earthing Trucks .....	11
10.6.6	Control description.....	11
10.6.6.1	General .....	11
10.6.7	Metering and protection .....	12
10.7	Testing .....	12
10.8	Installation and Commissioning.....	13
10.8.1	Commissioning Tests .....	14
10.8.2	Field Tests.....	15
10.9	Drawings and Design Calculations .....	15
10.9.1	Drawings.....	15
10.9.2	Design memorandum .....	15
10.10	Spare Parts & Special Tools .....	16
10.10.1	Mandatory Spares Part .....	17
	LOW VOLTAGE 415 V SWITCHGEAR.....	17

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

<b>10.11</b>	<b>Scope (Low Voltage 415 V Switchgear)</b> .....	<b>17</b>
<b>10.12</b>	<b>415 V Switchgear</b> .....	<b>18</b>
<b>10.13</b>	<b>General Arrangement</b> .....	<b>19</b>
<b>10.14</b>	<b>Applicable Standards and codes</b> .....	<b>19</b>
<b>10.15</b>	<b>General Requirements</b> .....	<b>20</b>
<b>10.16</b>	<b>Design</b> .....	<b>21</b>
<b>10.16.1</b>	<b>Design Methodology / Criteria for 415 V Switchgear (LT Switchboard)</b> .....	<b>21</b>
<b>10.16.2</b>	<b>Construction details</b> .....	<b>22</b>
<b>10.16.3</b>	<b>Space Heaters</b> .....	<b>24</b>
<b>10.16.4</b>	<b>Bus Bar</b> .....	<b>25</b>
<b>10.16.5</b>	<b>Earthing</b> .....	<b>26</b>
<b>10.16.6</b>	<b>Wiring</b> .....	<b>26</b>
<b>10.16.7</b>	<b>Terminal Blocks</b> .....	<b>27</b>
<b>10.16.8</b>	<b>Cable Termination</b> .....	<b>28</b>
<b>10.16.9</b>	<b>Labels</b> .....	<b>28</b>
<b>10.16.10</b>	<b>Painting</b> .....	<b>29</b>
<b>10.16.11</b>	<b>Air Circuit Breakers Panels</b> .....	<b>29</b>
<b>10.16.12</b>	<b>Cable compartment</b> .....	<b>29</b>
<b>10.16.13</b>	<b>Air Circuit Breaker Compartment</b> .....	<b>30</b>
<b>10.17</b>	<b>Outgoing Panels</b> .....	<b>31</b>
<b>10.18</b>	<b>Switchboard Components</b> .....	<b>32</b>
<b>10.18.1</b>	<b>Incoming and Tie Circuit Breakers</b> .....	<b>32</b>
<b>10.18.2</b>	<b>Outgoing Moulded Case Circuit Breakers and cubicle</b> .....	<b>34</b>
<b>10.18.3</b>	<b>Instrument Transformers (CT's / PT's)</b> .....	<b>35</b>
<b>10.18.4</b>	<b>Push Buttons</b> .....	<b>35</b>
<b>10.18.5</b>	<b>Metering, Protection and Control</b> .....	<b>36</b>
<b>10.18.6</b>	<b>Indicating and Metering instruments</b> .....	<b>36</b>
<b>10.18.7</b>	<b>Protection</b> .....	<b>37</b>
<b>10.18.8</b>	<b>Controls</b> .....	<b>38</b>
<b>10.18.9</b>	<b>Other Accessories</b> .....	<b>38</b>
<b>10.19</b>	<b>Inspection and Testing</b> .....	<b>38</b>
<b>10.19.1</b>	<b>Type Tests</b> .....	<b>39</b>
<b>10.19.2</b>	<b>Routine Tests</b> .....	<b>39</b>
<b>10.20</b>	<b>Data Sheet</b> .....	<b>40</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

<b>10.20.1</b>	<b>Site Conditions .....</b>	<b>40</b>
<b>10.20.2</b>	<b>Operating Condition .....</b>	<b>40</b>
<b>10.20.3</b>	<b>Electrical Data.....</b>	<b>40</b>
<b>10.21</b>	<b>Drawings and Documents Submission .....</b>	<b>41</b>
<b>10.22</b>	<b>Spare Parts and Special Tools .....</b>	<b>42</b>
<b>10.22.1</b>	<b>Mandatory Spares Part .....</b>	<b>43</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System
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## 10 MV & LV SWITCHGAER

### 33 kV MEDIUM VOLTAGE INDOOR SWITCHGEAR

#### 10.1 Scope (MV Switchgear)

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, training of Purchaser's personnel, handing over to Purchaser and guaranteeing for five years of trouble free operation of 33 kV switchgear as per the specifications hereunder, complete with all auxiliaries, accessories, spare parts. All ferrous parts shall be suitably pre-treated for removal of rust, dust & grease before application of powder coating.

The scope of work shall be for a complete and comprehensive functional system covering all supply and services including but not limited to following:

- Three (3) incoming supply feeders from 5MVA, 220 /33 kV SST transformer, from Pauk and from Tato- I.
- Two (2) outgoing feeders to 1.5 MVA SAT.
- Two (2) outgoing feeders for feeding local / Colony distribution system.
- Two (2) outgoing for remote sites (such as Barrage, Valve House, Surge Shaft etc)
- One (1) spare
- Bus PT as required for Each Bus Section.

All the above panels shall be complete with free standing cubicles, protection, metering, bus-bar system, cabling, wiring and other accessories, each comprising of following major equipment. The quantities shall be finalised during detailed engineering based on Tender Drawing:-

- 33 kV Vacuum circuit breaker (alternatively SF<sub>6</sub> circuit breaker is also acceptable);
- Required no. of current transformers;
- Required no. of potential transformers for incoming panels only;
- Required no. of ampere meters with selector switches;
- Required no. of voltmeters with selector switches for incoming panels only;
- Required no. of energy meters;
- Potential transformer, voltmeters with selector switches for bus;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

- All necessary AC bus bars;
- One number Earthing switch of suitable rating shall be provided in the incoming 33kV feeder
- All necessary auxiliaries for control and supervisory circuits, local control switches and other relays as required;
- All secondary wiring, terminal blocks, labeling and nameplates, sockets etc.;
- Indicators / Annunciators as required;
- Cubicle lighting including lighting fixtures and power and communication sockets;
- Space heaters;
- All protection relays and systems;
- Coordination and provision of necessary contacts and / or ports for integration with plant SCADA system.

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard(s) / best national / international practices. Corresponding parts of all the equipments and spares shall be of the same material and dimensions, workmanship and finish and shall be interchangeable. All the material and workmanship shall be of suitable commercial quality as have proven successful in their respective uses in similar services and under similar condition.

The selection of the final sub-vendors shall be subjected to purchaser approval and procurement action be stated after getting the approval.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

## 10.2 Standards

Standard	Description
IEC 60044-1	Instrument Transformers - Part 1 : Current Transformers
IEC 60044-2	Instrument Transformers - Part 2 : Inductive voltage Transformers.
IEC 60044-6	Instrument Transformers - Part 6 : Requirement for protective Current Transformers for transient performance.
IEC 62271-100	High-voltage switchgear and control gear - Part 100: High-voltage alternating-current circuit-breakers
IEC 62271-200	High-voltage switchgear and control gear - Part 200: A.C. metal-enclosed switchgear and control gear for rated voltages above 1 kV and up to and including 52 kV.
IEC 60694	Common specifications for high-voltage switchgear and control gear standards.

## 10.3 Specific Parameters and Layout Conditions

### 10.3.1 Layout and General Arrangement

One no. 33 kV breaker shall be used for 33 kV incoming supply from 5000 kVA transformer and six nos. 33 kV CBs for outgoing feeders and spare feeder. Additionally, two 33kV incomer breaker for Tato-I and Pauk Feeder shall be considered.

The 33-kV switchgear shall be suitable for indoor installation with all necessary interlocks to prevent paralleling of different supplies. The installation of the switchgear is proposed inside the power house. The 33 KV switchgear shall be fed from 5000 kVA transformer.

The system offered for the 33-kV switchgear scheme shall be as per Tender drawing enclosed with the specification, including all required provisions for interlocking scheme. All incoming and outgoing feeders of 33 KV Switchgear shall be protected for instantaneous and time delay over current and earth fault (50 / 51) protection. The circuit breakers shall be VCB / SF6 type.

The system shall be compatible with station DAS / SCADA, regarding input and output needed for operation, control and monitoring of 33 kV switchgear and DAS / SCADA.

## 10.4 Rating and Functional Characteristics

### 10.4.1 Rating



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

<b>System Description</b>	
Location & Type	Indoor, Metal clad
No. of bus bar	1
Type of earthing	Solidly earthed
<b>System Requirement</b>	
Rated system voltage, kV, r.m.s	33 $\pm$ 10%
Highest system voltage, kV, r.m.s	36
Rated frequency, Hz	50 $\pm$ 5%
Rated withstand Voltage to earth	
- Power Frequency	70 kV
- Lightning Impulse (peak value)	170 kV
Rated short time withstand current (rms),for 1 Sec	25kA
Rated Peak withstand current	62.5 kA
Rated normal current, A	800
Control voltage DC	220 V $\pm$ 10 %
Auxiliary AC supply, 3 phase	415 V $\pm$ 10 %
<b>Circuit Breaker</b>	
Type of interrupting Medium	Vacuum / SF6
Description	Three phase equipped with group control mechanism
No. of interrupter unit per pole	1
First-pole-to clear factor	1.5
Rated short circuit breaking capacity, kA (rms)	25kA
Rated short circuit making capacity, kA -(peak)	62.5 kA
Rated cable charging breaking current, kA (rms)	25kA
Rated operating sequence	O-3min-CO-3min-CO
Normal voltage for operating mechanism i.e charging motor (DC)	220 V + 10 % / - 10 %
Trip coil Voltage	220 V DC +10%, -20%
Closing coil Voltage	220 V DC, $\pm$ 10 %
<b>Current Transformer</b>	
Current Ratio	
Incoming feeders	125 / 5 A

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

Outgoing feeders	100 / 5 A
<b>Accuracy class</b>	
REF Protection	PS
E/F and O/C protection	20VA, 5P20
Metering	0.2s
<b>Potential Transformer</b>	
Transformation Ratio	33kV / $\sqrt{3}$ / 110V / $\sqrt{3}$
<b>Accuracy class</b>	
Relaying	3P
Metering	0.2
Rated Voltage	1.2 times continuous
<b>Lightning Arresters</b>	36KV

\* Adequate consideration for temperature rise, insulation level as per LOV study clearances at higher altitude (greater than 1000 metres) and ambient temperature to be taken care by the Manufacturer.

#### 10.4.2 Current ratings and short circuit capabilities

The complete 33 kV switchgear shall be designed to be capable of withstanding without damage all stresses due to maximum symmetrical short circuit (peak) currents in the bus bar and in the incoming and outgoing bays.

The complete design and layout shall be subject to approval by the Purchaser.

#### 10.5 Performance Guarantee

The 33 KV switchgear along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of the complete system.

#### 10.6 Design and Construction

The 33 kV Indoor Switchgear shall be of the steel enclosed type vermin proof, dust proof and shall comply with the requirements of latest edition of IEC / IS. The switchgear should be internal arc-tested. Power and Control cable entry shall be from the bottom. The switchgear shall be complete with Vacuum/SF<sub>6</sub> circuit breakers, dry type resin cast instrument transformers, insulators, bus bars, earthing arrangements, instruments and protective relays, labels, cable termination boxes, glands, all necessary wiring and auxiliary devices required to

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

perform its functions.

The switchgear shall be metal clad, compartmentalized, free standing, dead front type. There shall be separate chambers for Busbars, CTs / cable termination, Instrument / Control equipment, CB chamber. The Circuit Breaker (CB) shall be trolley mounted, horizontal drawout type. The finger contacts of CB shall pass through sprouts for making contact with Bus bars / cable connections. The sprouts shall be protected with independently operated automatic shutters to avoid accidental contact with live parts.

Contractor shall ensure availability of spare parts and maintenance support services for offered equipment for a minimum period of 15 years from date of supply. Contractor shall also give at least one year notice to end user before phasing out products / spares to enable end user for placement of order for spares and services.

The cold rolled sheet of the panel shall not be less than 2.5mm thick. The end section of panel shall be provided with blank plates with provisions to facilitate further bus bar extension on either side.

To represent the single line diagram, a mimic diagram shall also be made available on the panel.

The circuit breaker cubicle shall be provided with space heater and door operated illumination lamp.

#### 10.6.1 **Bus Bars**

All the bus bars within the switchgear assembly shall be air insulated, compartmentalized and shall have rated current capacity of minimum 800 A. Bus bars shall have mechanical and thermal capacity of not less than that represented by the short time current rating of circuit breakers. The bus bars shall be hard drawn, high conductivity copper of adequate uniform cross-section conforming to IEC / IS. The Contractor shall furnish calculations establishing adequacy of bus bar sizes for specified current ratings/ fault levels

#### 10.6.2 **Circuit breaker**

The 33 kV circuit breakers shall be vertically trolley mounted, horizontal draw out & isolating type of latest generation of Vacuum/SF<sub>6</sub> breaker, electrically trip free, with anti pumping device and operated by means of motor charged, stored energy type spring mechanism.

Motor operating mechanism shall have provision for closing / opening of breaker manually and an interlock shall be provided between electrical and manually operating modes for either

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

electrical or manual operation. Circuit breaker shall be according to IEC / IS and shall be complete with the proper interlocking. Circuit breaker should not be able to close in service position with door open. The CB shall have distinct position in cubicle viz service, test and Isolated Position with panel door closed.

#### 10.6.3 **Current transformer**

The current transformer shall be of inductive type. It shall be mounted within the cubicles and shall comply with the requirements of relevant IEC / IS. It shall be used for protection and metering.

#### 10.6.4 **Potential transformer**

The potential transformer shall be of inductive type. It shall be mounted within the cubicles and shall comply with the requirements of relevant IEC / IS.

The potential transformers shall be of two cores used for metering and protection. Minimum VA shall be 100 VA for metering & 50 VA for protection core.

#### 10.6.5 **Earthing Trucks**

For earthing of bus & cable side earthing truck shall be provided. Alternatively, suitably interlocked earth switches may be offered. In case of earth truck suitable alarm warning system be provided if the terminals being earthed are live.

#### 10.6.6 **Control description**

##### 10.6.6.1 **General**

Each circuit breaker shall be equipped with facilities for remote operation. Each circuit breaker unit shall be equipped with a manual / auto selection switch, local start-stop push button and an indicator showing the position of the breaker in the control room. The circuit breaker shall be operable with the breaker in test position. Auxiliary contactors with an alarm contact for remote indication of tripped condition shall be provided for protection of control circuits. All circuit breaker shall be equipped with trip circuit supervision device.

Auxiliary contacts for at least the following remote indications of the circuit breakers shall be wired to terminal blocks:

- Main contact position;
- Test and connected / service position;
- Trip condition;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

- Protection relay contacts;
- Trip circuit supervision relays.

#### 10.6.7 Metering and protection

Incoming revenue metering shall be provided as well as individual metering on each feeder circuit breaker.

Incoming feeder containing current transformers and voltage transformers shall have power meter capable to display kWh, current, voltage. Also, an ampere meters and ammeter selector switch, voltmeters and voltmeter selector switches located in the respective feeder compartment doors.

All metering circuit shall be terminated in terminal blocks for remote metering purposes.

#### 10.7 Testing

All the equipment covered under this section shall comply with the requirements of type tests prescribed in the relevant IEC / IS Standards. It shall be certified by the contractor that type test in accordance with the relevant standards have been successfully carried out for all type of equipment being supplied by him.

The 33 KV panel shall be assembled fully at the manufacturer's works with all the instruments, meters etc. connected.

The panel comprising of circuit breaker, current transformer, voltage transformer, etc. shall be subjected to the following routine tests in accordance with the details specified in the relevant IEC / IS as amended from time to time.

##### ➤ **Circuit Breaker:**

- Measurement of resistance of the main circuits (Between Bus and Cable

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

termination;

- Operating mechanism test;
- One-minute power frequency voltage dry withstand test on the main circuit;
- Voltage withstand test on control and auxiliary circuits;
- IR measurement of complete board.

➤ **Voltage Transformer:**

- Verification of terminal markings and polarity;
- Power frequency test on primary and secondary winding separately, measurement of partial discharges;
- Determination of error according to the requirements of the appropriate accuracy class;
- Over voltage inter turn tests;
- IR measurement of windings.

➤ **Current Transformer:**

- Verification of terminal marking and polarity;
- High voltage power frequency test on primary and secondary;
- Determination of error according to the requirement of the appropriate accuracy class;
- IR measurement.

All type tests and routine tests reports shall be submitted and got approved from the Purchaser before despatch of the equipment.

## 10.8 Installation and Commissioning

The contractor shall furnish all labour, supervision, tools, supplies, shims, supports and all other provisions or materials necessary to assemble, erect, install, testing and commissioning of the equipment in a thorough workman like manner following the best modern practices. The equipment and all of its components shall be placed with great care and accuracy and shall be aligned correctly to provide an installation consistent with the close tolerances used in the erection of modern equipment. The proper elevations and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

centrelines to which equipment is to be set shall be established by the contractor.

#### 10.8.1 Commissioning Tests

The following minimum commissioning checks / tests shall be carried out on the equipments at site as per standards.

##### A) Circuit Breaker:

- a) Insulation resistance of each pole of breaker.
- b) Anti pumping operation.
- c) Minimum pick-up volts of closing and tripping coils and operation at the highest permissible voltage.
- d) Contact resistance.
- e) Breaker closing and tripping time.
- f) Functional checking of control circuits, interlocking, tripping through protective relays, local/remote close/trip operation for breakers in service/test position.
- g) Correct operation of spring charging motors and spring charging time.
- h) Insulation resistance of control circuits.
- i) Total operating time and the total time for which the main contact remains closed when the simultaneous close and trip commands are given to the breaker.

##### B) CT's / VT's

- a) Insulation resistance test.
- b) Ratio and polarity.

##### C) Relays

- a) Calibration checking by secondary injection.
- b) Stability and continuity check by primary calibration.

##### D) Bus Bars

- a) Tightness test of bus bar joints.
- b) Inspection of insulators.

E) HV tests DC high voltage test shall be conducted at Site on completely installed switchboards. The high voltage shall be applied to the bus bars and links. All external power connection shall be removed and the test voltage applied with all circuit breaker closed. The Contractor shall furnish complete test procedure, with list of test, test values and test formats for approval during detailed engineering.

The contractor shall furnish a complete outline of the proposed methods and procedures to



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

be followed for the site testing including a list of equipment and instruments to be used, to the Purchaser for review at least 60 days before the schedule testing.

#### 10.8.2 Field Tests

After installation, the switchgear system shall be field tested as per relevant IEC standards, including operational tests and meggar value of insulation. The contractor shall prepare and hand over to Purchaser, details of all test results in a report in a mutually agreed format.

### 10.9 Drawings and Design Calculations

Contractor shall provide its drawings in conjunction with its calculations as well as references, showing the detailed design of 33 kV Switchgear as required by Engineer for its review / approval.

Contractor shall furnish six sets of all the 33 kV Switchgear drawings for approval. After approval and after work completion at site six sets of as built drawings and one set of reproducible print sheets shall be supplied.

#### 10.9.1 Drawings

The Contractor shall submit all the drawings and documents as required by Engineer. These drawings and documents should include at least the following:

- General arrangement, outline and foundation drawings;
- Detailed information and descriptive literature, explaining various safety, protective and regulation features of equipment / components;
- Drawings, showing general arrangement, sections of all major assemblies, sub assemblies and major components;
- Drawing showing mechanical interlocking scheme;
- Control schematic drawings;
- Structure drawings for 33 kV switchgear along with the bill of Material;
- Foundation Drawings;
- Fixing details of structure 33 kV Switchgear;
- Electrical drawings;
- Erection, commissioning, operation and maintenance instructions for 33 kV switchgear and other accessories, etc.

#### 10.9.2 Design memorandum

The contractor shall prepare and submit to the Purchaser a “Design Memorandum” of the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

proposed equipment / system fulfilling the contract specification / requirement given in the section for approval prior to submission of any drawings and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, major technical features, basic arrangement / layout etc.

#### **10.10 Spare Parts & Special Tools**

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

The Contractor shall supply all necessary tools, devices, testing instruments / equipment etc. required for installation, testing, repair and maintenance at site. These shall remain the property of the contractor unless otherwise agreed to be taken over by Purchaser any / all of these at mutually agreed conditions.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall propose the list of special tools including their make and detailed specification as recommended by manufacturer(s), (to be accepted by the Purchaser) for operation and maintenance at site.

Purchaser reserves the right to purchase or not the spare parts and special tools covered in

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

this chapter.

#### 10.10.1 Mandatory Spares Part

Specified spare parts to be supplied under this section are as follows:

S.No.	Description	Quantity
1	33 kV circuit breaker	1 No.
2	Circuit breaker trip and closing coils.	6 Nos. each
3	Fixed and moving finger contacts of type used for each set comprises 6 fixed and 6 moving contacts)	1 set
4	Under voltage relays	1 no.
5	Bus insulator	6 nos.
6	Indicating meter of each type used	1 no. of each used type
7	Over current relays	1 no.
8	Over current and earth fault relay	1 no.
9	Indicating lamps with assembly of each type used	10 nos. of each used type

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Purchaser reserves the right to order any or all of such spares.

### LOW VOLTAGE 415 V SWITCHGEAR

#### 10.11 Scope (Low Voltage 415 V Switchgear)

This specification includes the design, manufacture, testing at manufacturer's works, packing and supply to site, unloading at site, erection & commissioning of 415 V Switchgear Station Service Board (SSB), Unit Auxiliary Boards (UAB-1, UAB-2 & UAB-3), Gas Insulated Switchyard Auxiliary Board (GISAB) and Main distribution Board (MDB) for powerhouse & Remote sites. The feeder list shown in the drawing is tentative and can be modified during detailed engineering based on the equipment supplied.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

## 10.12 415 V Switchgear

3 phase, 50 Hz, 415 V Switchgear systems consisting of following major items:

- One (1) set of Station Service Board (SSB);
- Three (3) sets of unit auxiliary boards (UABs);
- One (1) set of Gas Insulated Switchyard Auxiliary Board (GISAB);
- Two (2) sets of Main distribution boards (MDBs);
- One (1) lot of distribution boards as per requirement complete with cubicles, bus bar system, circuit breakers, instruments transformers, instruments, relays, cabling and wiring and other accessories.

All the above boards shall be of indoor metal enclosed 415 V switchgear type, complete with cubicles, protection, metering, bus-bar system, cabling, wiring and other accessories, each comprising of:

- Draw out type incoming circuit breaker (ACB) for UABs, SSB & MDB;
- Required no. of draw out type ACBs and fixed type MCCB / MPCB;
- Current transformer for protection and all outgoing feeder of motor loads and load more than 25 A. CTs may alternatively be provided in the respective starter panels.
- Required no. of potential transformer;
- Required no. of ampere meters with selector switch;
- Required no. of voltmeters with selector switch;
- Required no. of Energy Meters;
- All necessary AC bus bars (including N-Bus bar);
- Local control switches;
- Indicators as specified;
- All necessary auxiliaries for control and supervisory circuits, and other relays as required;
- Other additional feeder units necessary to fulfill the requirements of the specification and sockets etc.
- All secondary wiring, terminal blocks, labeling and nameplates, sockets etc.
- All protection relays for switchgear as elaborated in Sub-section: Protection System.
- Coordination and provision of necessary contacts and / or ports for integration with SCADA system.

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard (s) / best international practices.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

The selection of the final sub-vendors shall be subjected to purchaser approval and procurement action be stated after getting the approval

#### **10.13 General Arrangement**

The power house is Surface type. The SLD of 415 V AC system is given in Tender Drawing.

#### **10.14 Applicable Standards and codes**

The design, manufacture and testing of the various equipment covered by this specification shall comply with the requirements of latest revision of the following standards issued by BIS (Bureau of Indian Standards).

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

IS 1248	Direct Acting electrical indicating instruments
IS 2705	Current Transformers
IS 2208	HRC cartridge fuse links up to 650V
IS 2824	Method for determining the comparative tracking index of solid insulating materials under moist conditions
IS 3156	Voltage Transformers
IS 3231	Electrical relays for Power System Protection
IS 3618	Phosphate treatment of iron and steel for protection against corrosion
IS 3914	Code of Specification for selection of AC Induction Motor Starter
IS 4047	Heavy duty air break switches and composite units of air break switches and fuses for voltages not exceeding 1000V
IS 4237	General requirements for switchgear and control gear for voltage not exceeding 1000V
IS 5578	Guide for marking of insulated conductor
IS 6005	code of practice of Phosphating of iron steel
IS 8623	Factory built assemblies of switchgear and control gear for voltages up to and including 1000 V AC and 1200 V DC. Part II particulars requirements for busbar trunking systems (bus ways)
IS 11353	Guide for uniform system marking and identification of conductors and apparatus terminals
IS 13703	Low voltage fuses
IS 13947	LV switchgear and control gear (Part 1 to Part 5)

In case of imported equipment standards of the country of origin shall be applicable if these standards are equivalent or stringent than the applicable Indian standards.

In case IS standards are not available for any equipment, standards issued by IEC / IEEE or equivalent agency shall be applicable.

The equipment shall also conform to the provisions of Indian Electricity Rules and other statutory regulations currently in force at the place of installation.

### 10.15 General Requirements

All equipment and components shall be new of excellent quality and reliability for providing secure AC supply to unit auxiliary equipment, controlling systems, lighting system and all other AC equipment in the power plant for safe continuous operation of the plant.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

Components shall be capable to withstand the thermal and dynamic stress resulting from internal and external short circuits and switching operations etc. The design of the equipment shall be such as to minimize the risk of short circuits and shall ensure personal and operational safety.

The contractor shall be responsible for design, engineering and manufacturing of the complete system to fully meet the intent and requirements of this specification and attached data sheet.

Contractor shall ensure availability of spare parts and maintenance support services for the offered equipment for minimum 15 years from the date of supply.

Contractor shall give a notice of at least 1 year to end user before phasing out product / spares to enable end user for placement of order for spares and services.

## 10.16 Design

### 10.16.1 Design Methodology / Criteria for 415 V Switchgear (LT Switchboard)

The SSB, UABs, GISAB & MDBs shall be suitable for installation and satisfactory operation in design ambient temperature of 40°C and altitude 1100 m above MSL.

All Circuit Breakers ACB & MCCB shall be of single break type having 4 Poles and 3 poles respectively. Breaking capacities for all ACBs shall be equal to or higher than the short circuit current of 50 kA and for MCCBs shall be 50 kA.

The switchgear components e.g. Circuit breakers, main horizontal and vertical bus-bars, bus-bar joints, bus-bar supports etc. shall be designed to withstand maximum expected short circuit level of 50 kA for a minimum time of 1 sec.

The switchgear for power house shall be coupled directly to its primary supply transformer (SST, UAT-1, UAT-2, UAT-3 & MDB) through flexible braid connection or cables. Transition cell as required shall be provided to align connection to the transformer connection bus-bars. The switchgear shall have each two incoming cells containing draw-out Air circuit breakers. Each incoming cell shall be capable of taking the entire load of the switchgear. Switchgear for SSB shall be equipped with outgoing and bus tie draw-out Air circuit breakers as per SLD. For Gas Insulated Switchyard auxiliary board (GISAB), minimum two feeders of adequate capacity shall be brought out from the power house to Gas Insulated Switchyard through cables. All ACBs shall be draw out type and all MCCBs shall be fixed type. Bidder shall ensure that all the equipment shall be suitable for operating satisfactorily at an altitude up to 1100 m above MSL.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

#### 10.16.2 Construction details

The switchboard shall be floor mounted compartmentalized, modular type suitable for indoor installation. Switchgear panel shall have degree of protection not less than IP 52 with dust & vermin, drip proof construction for indoor installation and made up of the requisite vertical sections. If louvers are provided, they shall be backed up by fine wire mesh.

The switchboard shall be in single front construction. The switchboard shall be assembled out of vertical panels of uniform height in single line-up. The structure shall contain horizontal busbars running throughout its length and be readily accessible. Each vertical panel structure shall contain a vertical wire / cable alley with provision for suitable cable support. The width of this cable alley shall be sufficient to accommodate all the cables and shall have free access for cable termination. The cable compartment shall have hinged doors.

The switchboard shall be designed to ensure maximum safety during operation, inspection and maintenance. All equipment and hardware require for safe and satisfactory operation shall be provided by contractor even if not specifically mentioned. Means shall be provided to prevent shorting of power and or control terminals due to accidental dropping of maintenance tools etc. inside the switchboard.

The design and construction of each panel shall be such as to allow extension at either end. Ends of bus bars shall be suitably drilled for this purpose. Panels at extreme ends shall have openings which shall be covered with plates screwed to the panel. Details of drilled holes in bus bar and openings in the panels provided for future extension shall be clearly shown in the contractor drawings.

The frame, of individual vertical panels shall be fabricated using pressed and shaped cold rolled sheet steel of adequate thickness or by using mild steel structural sections. The sheet steel shall be minimum 2 mm CRCA. Wherever required, stiffeners shall be provided

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

to increase stiffness of large size doors and covers. Removable undrilled gland plate of 3mm thick shall be provided for incoming and outgoing cables.

The switchboard shall be provided with integral base frame for each vertical panel. The switchboard integral base frame shall be suitable for tack welding to the floor embedded channels.

All openings, covers and doors shall be provided with neoprene gaskets. The panel door should have self-tightening handle / knob so that the door closes properly to prevent ingress of dust. Removable blanking plates shall be provided to cover the openings in the event of withdrawing the feeder modules. Number of blanking plates shall be 20% of each module size with a minimum of one number.

All hardware shall be corrosion resistant. The hinges and the screws shall be made of stainless steel. All joints and connections of the panel members shall be made by cadmium plated high quality steel bolts, nuts and washers, secured against loosening. Star washers shall be used to ensure effective continuity.

Suitable removable lifting hooks and or jacking pads shall be provided on each panel shipping section for ease of lifting of switchboard. These hooks when removed shall not leave any openings in the panels.

All power and controls cables shall be terminated through single compression nickel plated brass cable glands. All cable glands and tinned copper crimping type cable lugs for all power and control cables shall be in contractor's scope of supply. Non magnetic cable glands, plates shall be provided for termination of single core cables.

The layout for components mounting shall be standardized for providing uniformity. The components layout shall be such as to permit easy maintenance / removal. No equipment / switch operating mechanism shall be mounted on the rear side of the board as it is undesirable from maintenance considerations. The panel should have liberal internal spacing for ease of maintenance. Similar rated components / modules shall be fully interchangeable.

The switchboard shall be formed using distinct vertical panels each comprising of following compartments:

- i. A metal enclosed horizontal bus compartment running horizontally;
- ii. Individual feeder modules in multitier mode. Each feeder module shall be provided with front access hinged door of adequate strength and padlocking facility with main

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

power switch handle. Compartment door shall be interlocked mechanically with the switch such that the door cannot be opened unless the switch is in OFF position;

- iii. Vertical bus bars serving all feeder modules in the vertical panel. The vertical bus bars shall be sleeved and provided with anti-tracking barriers as an integral part of bus bar zone;
- iv. Vertical cable alley for cable termination. Power and control terminals in cable alley for each module shall be covered with bolted type sloped hylam or FRP sheet which shall be fixed after termination of power cables. Adequate number of slotted cable support arms shall be provided for cleating the cables.

Perforated sheet steel / insulating material enclosed horizontal auxiliary bus bars for control, interlock, indication and metering wiring running horizontally.

Metal sheets shall be provided between two adjacent vertical panels running up to full useful height of the switchboard. In the cabling chamber shrouds shall be provided on the side of vertical bus bars.

All metering and protection equipment associated with a particular circuit shall be housed in separate and independent compartment earmarked for that particular circuit.

All auxiliary devices for control, indication, measurement and protection such as push buttons, control and selector switches, indicating lamps, Meters and protective relays shall be mounted on the front side of the respective compartment only.

Each shipping section shall be provided with Master Terminal Block (MTB). Number of contacts to be wired up to the MTB and terminal arrangement in MTB shall be indicated in control schematic diagram.

Terminals in the MTB shall be arranged in two groups labeled “1” & “2”, physically separated from each other. Group “1” shall comprise terminals for all outgoing potential free contacts from board. Group “2” shall comprise terminals for all incoming commands / interlocks from remote. Separate removable gland plate shall be provided for each MTB.

The height of the switchboard shall be restricted to 2375 mm including a base channel of 75mm ISMC at the bottom. Operating height shall be around 1800mm from bottom.

#### 10.16.3 Space Heaters

The switchboard panels shall be provided with space heaters to prevent moisture condensation. The space heater with porcelain connectors shall be located at the bottom of each panel and shall be supplied from 240 V AC auxiliary bus for space heater. The

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

space heater shall be provided with a thermostat having variable setting of 30°C-70°C and manually operated switch fuse and link for phase and neutral separately.

#### 10.16.4 Bus Bar

Bus bars shall be air insulated and of high conductivity electrolytic grade supported on insulators made of non-hygroscopic, non-inflammable material with tracking index equal to or more than that specified in IS. The material for bus bars shall be copper (preferable). The current density shall be around 1.5 to 1.8 A / mm<sup>2</sup> for copper. Bus bars shall be of uniform cross section throughout the length rated for continuous and short time current as specified in data sheet.

Removable neutral links shall be provided on feeders to permit isolation of the neutral busbar.

Wherever joints between dissimilar materials are envisaged, silver plated joints shall be provided on the surface. All bus bars and bus bars joints shall be easily accessible for periodic inspection without requirement of dismantling any components like CTs etc.

Separate vertical droppers shall be provided for each vertical panel. Connecting plates for joining bus bars at the shipping sections shall be supplied.

Both horizontal and vertical bus bars, bus joints and supports shall be capable of withstanding dynamic and thermal stresses of the specified short circuit currents for 1 (one) second. Only zinc passivated or cadmium plated high tensile strength steel bolts, nuts and washers shall be used for all bus bar joints and supports. The short circuit capability of the neutral bus bars shall be in line with IS: 13947.

The hot spot temperature of bus bars including joints at design ambient temperature shall not exceed 95°C for normal operating condition.

The main horizontal bus bars shall be located in a separate chamber extending the entire length of the switchgear.

All bus bars shall be insulated with heat shrunk PVC sleeves of 1100 V grade. Red, Yellow and Blue colour shall be used for phase bus bars and black colour shall be used for neutral bus bars. Removable type shrouds shall be provided for joints.

In case units with dry type transformer, the bus bars shall be extended towards dry type transformer side to a transition cell, if required. On the other side cover plate shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

provided with holes for extension. In other cases, switchboard shall be extendable in both directions.

Auxiliary bus bars each of copper shall be provided in switchboard. Exact number of bus bars shall depend on various control, metering and auxiliary power distribution requirement.

Tee-off connectors shall be used for distributing auxiliary supply to each vertical panel. Rubber grommets shall be used for all wires entries to make the entries dust and vermin proof. Isolating links / fish plates shall be provided between two auxiliary bus sections.

Provision to hook up of two external DC control supply shall be provided and located at a convenient location in switchboard.

#### 10.16.5 Earthing

All vertical panel shall be connected to a tinned copper earth busbar of size not less than 50 x 6mm<sup>2</sup> extended throughout the length of the switchgear. It shall be bolted / welded to the frame work of each unit and each breaker earthing contact bar. All doors and movable parts shall be earthed using flexible copper connection to the fixed frame of switchboard. Provision shall be made to connect the earthing busbar to plant earthing grid at two end. All non-current carrying metallic parts of mounted equipment shall be earthed. Minimum 4 nos. 10 mm dia bolts with nuts shall be provided on the earth bus for termination of fourth core of cable per vertical panel.

The size of earth bus shall be sufficient to carry the momentary short circuit and short time fault currents to earth (as specified in specification) without exceeding the allowable temperature rise.

VT secondary neutral point earthing shall be done at one place only on the terminal block. Such earthing shall be made through links so that earthing of one secondary circuit can be removed without disturbing the earthing of other circuit.

#### 10.16.6 Wiring

Inside the switchgear wiring for power, control, signaling, Protection and instrument circuits shall be done with BIS approved FRLS PVC insulated copper conductor. The

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

insulation grade of these wires shall be 1100 volts grade. All control wiring shall be preferably be enclosed in plastic channel or neatly bunched together.

PVC insulated copper conductor for panel control wiring shall be of minimum 2.5 sq.mm cross section and for CT wiring a minimum cross section of 4.0 sq. mm shall be used.

Each wire shall be identified at both ends by PVC ferrules.

Inter panel wiring shall be taken through PVC sleeves or rubber grommets.

#### 10.16.7 Terminal Blocks

All terminal blocks shall be mounted in an accessible position with the spacing between adjacent blocks not less than 100 mm and the space between the bottom blocks and the cable gland plate being a minimum of 200 mm. Sufficient terminals shall be provided to allow for the connection of all incoming and outgoing cables including spare conductors and drain wires. In enclosed cubicles, the terminal blocks shall be inclined towards the door for facilitating terminations.

The terminals shall be of the channel mounting type and shall comprise a system of individual terminals so that terminal blocks can be formed for easy and convenient cabling consistent with the high reliability required of the circuits.

The terminal blocks shall be provided with shorting links and paralleling links where applicable, and mounted identification numbers and / or letters.

The terminal blocks shall conform to the applicable NEMA standard. The smallest size to be used shall be designated for 2.5 sq mm wire and no more than two conductors shall be connected under one terminal clamp.

Terminal identification shall be provided corresponding to wire number of connected leads. Separate terminal blocks shall be used for power, control & signal cables. 415 V AC circuit terminals shall be segregated from other terminals and shall be equipped with non-flammable, transparent covers, to prevent accidental contact with live parts. Warning labels with red lettering shall be mounted thereon in a conspicuous position.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

#### 10.16.8 Cable Termination

The switchgear (SSB, UAB-1, UAB-2, UAB-3, GISAB & MDBs) shall be designed to facilitate PVC insulated and armoured or unarmoured cable entry from top as well as bottom.

Detachable gland plate of adequate thickness shall be provided. Double compression type nickel plated brass cable gland shall be provided for all cable terminations. Crimping type cable lugs shall be used for control and power cables terminations. Lug size shall comply with the drawing details. Suitable shrouds shall be provided to prevent accidental contact with live outgoing termination of other feeders while carrying out maintenance on one feeder.

#### 10.16.9 Labels

A Bluemark label with LT Switchboard (SSB, UAB-1, UAB-2, UAB-3, GISAB & MDBs) designation shall be fixed at top of the central panel. A separate Bluemark label giving detail for feeder compartment of all vertical panel shall be provided. Labels shall be made of Polyamide material with V2 inflammability class as per UL 94, printed with Solvent free plastic ink & with UV technology shall have black letters cured on white back ground shall be provided for each equipment mounted on each switchgear.

Untearable yellow warning label of polyethylene shall be provided on removable covers or doors giving access to cable terminals & busbars. Untearable yellow warning label of polyethylene shall be provided inside switchgear also. Wherever considered necessary identification white colour polyethylene labels shall be provided inside the panels matching with those shown on the circuit diagram. All labels wordings shall be approved by the Engineer / Purchaser.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

#### 10.16.10 Painting

All metal surfaces shall be chemically cleaned, degreased and pickled in acid to produce a smooth clean surface, free of scale, grease and rust.

After cleaning, phosphating and passivation treatment, the surface shall be given two coats of zinc rich epoxy primer and baking in the oven.

After primer, it shall be given two coats of stoving type enamel paint (to be decided during detailed engineering). Alternatively powder coating can be offered.

Sufficient quantity of touch-up paint shall be supplied for application at site.

#### 10.16.11 Air Circuit Breakers Panels

The breaker panel shall have distinct bus bar, breaker and cable compartments. The design of each compartment shall be such as to prevent movement of vermin from a particular circuit breaker compartment to any other portion of the panel. Blanking plates shall be provided for each circuit breaker compartments which would be used after installation, to cover openings in the event of taking out the breaker outside the compartment.

Incoming and outgoing ACBs shall be single tier drawout execution only. The meters and protection relays associated with a particular breaker shall preferably be mounted on the same panel front. Motor starter, switch fuse / MCCB modules accommodated at the front and rear of ACB panels are not acceptable. Also vacant space on ACB panel shall not be used for mounting the Motor starter, switch fuse / MCCB modules. Access to all operating devices shall be from front of the switchboard.

All drawout modules shall be provided with safety shutters, operated automatically by the movement of drawout carriage to cover stationary isolated contacts when the carriage is withdrawn. One adjustable height breaker handling truck shall also be supplied for ease of inspection & maintenance of ACBs.

#### 10.16.12 Cable compartment

Separate compartment totally enclosed from all sides shall be provided for cable termination, on the rear side. Access to cables shall be from the rear side after opening the cable compartment door. The incoming / outgoing cable termination shall be staggered for each circuit and barriers of sheet steel or insulating material shall be provided between termination of two circuits such that maintenance on one circuit could be carried out while

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

the other circuit is live. Suitable clamping arrangements shall be provided for cables and cable termination.

The cable terminations shall be suitably sized for receiving specified number of cables per termination and provision shall be made for terminating each outgoing cable with a separate bolted connection. In case the total number of cables entering a particular panel cannot be accommodated in the cable compartment of panels then an extension panel shall be added to the cabling compartment for accommodating extra cables.

#### 10.16.13 Air Circuit Breaker Compartment

The circuit breaker compartment shall be fully draw out i.e bus side and outgoing power and control connections shall be through draw out contacts. Suitable guides shall be provided to facilitate easy withdrawal of the circuit breaker. All identical feeder compartments shall be interchangeable.

The current transformers for the ammeter / protection circuits shall be mounted on the fixed portion of the compartment. However current transformers associated with built in releases may be mounted on the breaker trolley. All terminals except wiping / sliding type control terminals shall be shrouded with plastic covers to prevent accidental contact. For direct termination clip on shrouded type terminals shall be provided.

There shall be three positions for the draw out trolley but four positions for the circuit breaker follows:

- i. Service **“Service or Fully in” position:** In this position both power and control circuits shall be connected. This shall be the normal operating position of the circuit breaker.
- ii. **“Test” position:** In this position power contacts shall be disconnected but the control circuits shall remain undisturbed. It shall be possible to close and trip the breakers in this position.
- iii. **“Fully out” position:** In this position both power and control circuits shall be disconnected and breaker removed from the cubicle.

The circuit breakers shall be lockable in “Service” and “Test” positions. Safety shutters shall be provided, which shall close when the breaker is in fully out / draw out position.

The earth connection must remain connected in “Test” position. The earth connection shall make before the main power / control contacts make and break after the power / control

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

contacts are disconnected. Earthing connection through a plug and socket connection shall not be acceptable.

Following interlocks shall be provided:

With the circuit breaker in “closed” position it shall not be possible to withdraw its carriage from service position or to plug the carriage into service position. Attempted withdrawal of closed-circuit breaker shall not trip the circuit breaker.

Operation of a circuit breaker shall not be possible unless its carriage is fully in service, test and isolated positions or has been taken out of the panel. Breaker operation shall be prevented in the intermediate positions.

It shall not be possible to open the breaker compartment door when the breaker is in “service” as well as in “test” position. Further, it shall also not be possible to rack in the breaker to “test” or “service” position if the compartment door is not properly closed. However, interlock to defeat this feature shall be provided.

Circuit-breaker/panel shall be provided with safety shutters operated automatically by the movement of circuit-breaker carriage to cover the stationary main contacts as soon as the breaker is withdrawn from service position. It shall, however, be possible to open the shutters intentionally against spring pressure for testing purposes.

The secondary contacts shall be of robust design and fully self-aligning and self-isolating type and the same shall get engaged before the main contacts have done so.

1. Interlock shall be provided for blocking the entry of a carriage equipped with circuit breaker of one rating into a panel having stationary contacts of different rating..

It shall only be possible to insert a circuit breaker of the appropriate rated current.

## 10.17 Outgoing Panels

Each vertical panel shall have a separate cable alley. The width of this cable alley shall be sufficient to accommodate all the cables and shall have free access for cable terminations and in any case shall not be less than 200mm minimum. Cable alley shall be provided with suitable doors. Sheet steel barriers shall be provided between individual compartments and cable alley. This barrier shall be provided with opening for power and control connections and it shall be possible to safely carryout maintenance work on the cable connections to any one circuit in the cable alley with bus bars and adjacent circuits live. Maintenance and connection of cables to any modules shall be possible without having to take out the modules from its position from the panel.

All switch drives other than rotary switches shall be lockable in both ON and OFF position. The switches / MCCBs shall be interlocked with the compartment door to prevent opening

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

of the door when the switch / MCCB is in ON position and to prevent switching on when the door is open. A defeat mechanism for this interlock shall also be provided.

The maximum height of the operating handle and switches shall not exceed 1900mm and the minimum height not below 300 mm.

## 10.18 Switchboard Components

### 10.18.1 Incoming and Tie Circuit Breakers

Circuit breakers shall be air break, draw out type. Circuit breakers shall be 4 pole. The ultimate & service breaking capacity of circuit breakers shall be minimum 50 kA.

The circuit breakers shall be provided with mechanically operated emergency tripping device. This device shall be available on the front of the panel. Mechanically operated “closing” device shall be provided for all breakers. However mechanical closing shall be inhibited for all breakers in service position.

The breakers shall be provided with minimum 4 NO + 4 NC contacts, wired and available for Purchaser’s use. The available spare auxiliary contact shall be multiplied to have 4 NO + 4 NC spare contacts (minimum) if sufficient number of breaker auxiliary contacts are not available.

Circuit breaker position shall be indicated electrically. The following indicating lamps (LED type) shall be used.

BREAKER ‘CLOSED’	: RED
BREAKER ‘OPEN’	: GREEN
BREAKER ‘AUTO TRIP’	: AMBER
BREAKER ‘SPRING CHARGED’	: WHITE
BREAKER ‘TRIP CIRCUIT HEALTHY’	: WHITE

Circuit breaker position (OPEN AND CLOSED), location (SERVICE AND TEST) and charged condition shall also be indicated mechanically.

All circuit breakers in the switchboard shall be provided with electrical power operating mechanism. Control supply voltage shall be 220 V DC with circuit breaker tripping and closing coils designed for DC operation only, of sufficient capacity. All electrical power

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

operating mechanism shall be suitable for remote operation and shall be equipped with following features:

- i. Provided with spring charging motor operable on 240 AC control supplies.
- ii. Provided with emergency manual charging facility. The motor shall be automatically, decoupled (mechanically) once the manual charging handle is inserted.
- iii. Closing operation of circuit breaker shall automatically initiate charging of the spring for the next closing operation without waiting for tripping of circuit breaker.
- iv. Closing operation shall be completed once the closing impulse is given and the first device in the control switch / PB is released provided no counter trip impulse is present.
- v. If circuit breaker is closed on faulty circuit, the circuit breaker shall open and not reclose again, even if the close command is maintained (anti-pumping feature).

Circuit breakers shall be equipped with the following devices and mechanisms:

- i. A set of main draw out contacts
- ii. A set of secondary draw out contacts
- iii. A stored-energy type charging mechanism designed in a way to prevent operation of the breaker before charging is completed.
- iv. A worm gear levering mechanism, self-contained on the circuit breaker draw-out element and operated by a crank permitting maneuvering of circuit breaker between the "Service", "Test" and "Fully out " positions.
- v. Safety device for discharging of spring when the circuit breaker is drawn out.

The breakers shall be trip free and shall be provided with a release to trip the breakers instantaneously if closed on to a fault.

The incoming circuit breakers shall be electrically interlocked and provided with an automatic transfer scheme. The control voltage shall be 220 V DC. Protection lock-out scheme shall be included to prevent switchover under a fault condition.

The incoming and tie circuit breakers shall be equipped with a digital automatic over current tripping system and a earth fault element. This system shall comprise one current sensor per pole, a digital tripping unit and a control mechanism. The sensor rating shall respect the rated values of the current transformers shown on drawings. The digital tripping unit shall be equipped with instantaneous, long and short delay elements, with continuous type setting adjustment, independent from one another. Status of all feeders (in SSB , UAB-1, UAB-2, UAB-3 & GISAB) shall be made available for remote PLC / DCS.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

Spare contacts (potential free) shall be made available for hook up with DCS / PLC of Power House.

#### 10.18.2 Outgoing Moulded Case Circuit Breakers and cubicle

All MPCB's / MCCBs shall be three pole type and shall be mounted in separate compartments and have a rating as shown on drawings. The ultimate & service breaking capacity of circuit breakers shall be minimum 50 kA.

All MPCB's / MCCBs shall be provided with spring assisted quick make / break manually operated trip free mechanism.

All MPCB's / MCCBs shall preferably be provided with adjustable type tripping device with inverse time characteristic for load protection and instantaneous characteristics for short circuit protection.

Each circuit breaker compartment shall have a door and a handle. The door and the circuit breaker shall have a mechanical interlock to ensure that the circuit breaker is opened before access into the compartment is allowed and it shall be possible to padlock the handle in the "Open" position.

'ON', 'OFF' and 'TRIP' position of the operating handle of MCCB shall be displayed and the operating handle shall be mounted on the door of the compartment housing MCCB.

MCCBs shall be provided with auxiliary switches for ON & TRIP indication on compartment front. Control supply for MCCBs ON & TRIP indication shall be 110 V AC. Control Transformer 415 / 110 V AC shall be provided for this purpose. Additionally, Potential free contacts for MCCB ON & TRIP indication shall be provided for Purchaser use / SCADA.

The outgoing circuit breakers in SS B, UAB-1, UAB-2, UAB-3 & MDBs shall be installed in a free-standing motor control center (MCC) type cubicles. MCCBs shall be installed in individual non-draw out compartment. The MCC type cubicle shall be comprised of the number of sections required to house all outgoing MCCBs. 25% unused space shall be provided. Each section will comprise a maximum of 8 MCCBs and 2 unused spaces. Each section shall be provided with a vertical gutter to house outgoing cables. The sections shall be suitable to install combination starters if required. Each section shall be provided with a 1250 A (minimum) vertical tinned copper bus. The MCC cubicle shall be coupled with the incoming breaker sections with a rigid bus connection. Back-to-back assembly

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

may be required in case of space limitations. Back-to-back set-up shall be provided with independent front and rear cubicles. Compartment doors shall be pad-lockable.

MCBs used as outgoing feeder shall be of 4 pole (TPN) with back up HRC fuses as indicated in SLD. R, Y, B indicating lamps shall be provided at outgoing of these backup HRC fuses. These MCBs shall be suitable for heavy start motors application which causes high inrush current when they are switched ON.

These MCBs panel section shall have acrylic sheet on panel front to make the MCBs visible from outside

#### 10.18.3 Instrument Transformers (CT's / PT's)

The current transformers (CT's) shall be resin cast epoxy type. All current transformers shall be provided with shorting links. Current transformers shall conform to IS: 2705 and any special requirement with respect to Numerical relay shall be taken care by the contractor. For general guidance the contractor shall note that the protective current transformers shall have an accuracy class "5" and an accuracy limit factor greater than "10". Contractor shall co-ordinate the knee point voltage, magnetising current for PS class CT's to avoid saturation and mismatching of CT's provided at other end by other contractor.

Current transformers for instruments shall have an accuracy class 0.5 and accuracy limit factor less than 6.0. Current transformer shall be capable of safely withstanding the short circuit stresses corresponding to the fault level indicated. Dynamic rating shall be 2.5 times the symmetrical short circuit rating. Accuracy class, VA burden, ratio, etc. shall be finalized during detailed engineering.

#### 10.18.4 Push Buttons

Push button shall be heavy duty type. Each push button shall have one normally open and one normally closed contact. Push button colors shall be as follows:

Stop / open / emergency	- Red
Start / close	- Green
Reset / test	- Yellow / Black / White



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

#### 10.18.5 Metering, Protection and Control

Each incoming cell shall be provided with a compartment used for metering, protection and control.

#### 10.18.6 Indicating and Metering instruments

All indicating and integrating meters shall be flush mounted on panel front. The instruments shall be of at least 96mm square size with 90-degree scales and shall have an accuracy class of 1.0 or better. The covers and cases of instruments and meters shall provide a dust and vermin proof construction. All instruments shall be compensated for temperature errors and factory calibrated to directly read the primary quantities. Means shall be provided for zero adjustment without removing or dismantling the instruments. All instruments shall have white dials with black numerals and lettering. Black knife-edge pointer with parallel free dials shall be preferred. Power meter shall be of Merlin Gerin "Series 710" or GE "PQM II" or Satec-PM130EH or as approved by Owner. A digital power meter shall be flush mounted on the front door of the incoming cell. Other equipment shall be mounted inside. The energy metering device required is described as under:

- Shall have large LCD display capabilities, at least 15 cm;
- Shall exceed Class 0.2s revenue accuracy;
- Shall be capable to simultaneously display three phase voltage, three phase amperage, frequency and Power Factor;
- Shall be capable to display kW, kWh, kVAR, kVARh, kVA;
- Shall be capable to measure energy: bi-directional, total, import, export, net;
- Shall have Data and Waveform Logs capabilities as described below:
  - Triggered by setpoint, schedule or external signal;
  - Sequence-of-events logs;
  - Min / Max logs for any parameter;
  - Historical logs;
  - Waveform logs;
  - 1 m sec time stamp resolution;
  - GPS time synchronization;
- Shall have communication ports and I / O as described below:
  - RS-485;
  - Ethernet;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

- IRIG-B;
  - DNP 3.0 on Ethernet;
  - Digital status / counter inputs;
  - Digital status / counter outputs;
  - Analog outputs.
- Shall have alarm capabilities.

#### 10.18.7 Protection

The incoming and tie air circuit breakers shall be provided with a numerical tripping system with LSI-G protection units.

This system shall comprise one current sensor per pole, a digital trip unit, a rating plug and shunt release. The calibration of the sensors and the rating plug must be in relation with the current values shown on drawings. The rating plug shall be offered in choices of 25% to 100% of the rated sensor current. However, all the provided rating plugs shall be 100% unless otherwise specified.

The digital trip unit shall be provided with instantaneous elements, with adjustable long and short temporizations, all independent ones from the others and functioning with values of effective current (RMS). The adjustment ranges of the on- and off-delay current shall be as follows:

- Element with long temporization with on-delay 0.4 to 1.0 time the calibration of the sensor and a temporization from 4 to 36 seconds, with six times the calibration of the sensor.
- Element with long temporization with on-delay from two to ten times the calibration of the sensor and a temporization:
  - From 0.1 to 0.5 second:
  - The element can be regulated at definite time or IDMT:
  - A minimum of three curves, which do not overlap, in the range of 100 to 500 ms;
  - The minimal and maximum values of adjustment can be slightly different from those prescribed.

The trip unit shall display the type of tripping detected (L, S, I or G) on a LED display. The indication relative to the type of tripping must be preserved after an automatic tripping. The trip unit shall also be provided with a continuous self-checking circuit and shall provide

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

a visual indication of the correct operation of the internal circuits.

The instantaneous elements must be able to be turned off by a normal adjustments of the relay.

All the energy required for tripping and displaying shall come from current sensors and no distinct power supply unit shall be necessary. If such external power supply is necessary, the Supplier must envisage everything that is required to feed those from the sources available in equipment. Each incoming and tie circuit breaker shall have dry auxiliary contacts, which close on tripping by protection with at least two form “A” contacts and two form “B” contacts for remote indication.

All LT boards shall be provided with Class B type Surge protection device, which shall be single spark gap type, shall have fault indication capability and shall be tested as per IEC 61643-1 to withstand 50 kA 10 / 350  $\mu$ s pulse (L-N) and 100 kA 10 / 350  $\mu$ s pulse (N-PE) with voltage protection level of 1.5 kV and line follow current of 50 kA.

#### 10.18.8 Controls

Suitable interlocking scheme shall be designed to ensure power supply can be fed to any board by avoiding paralleling of two supplies / sources. Typical interlocking scheme is given in attached tender drawing volume. The bidder shall submit suggested interlocking scheme for approval of the Purchaser.

The 415 V switchgear shall be PLC based and all incoming ACBs shall have check synchronizing facility.

#### 10.18.9 Other Accessories

All incoming feeders shall be equipped with an under-voltage relay and its associated voltage transformer, as shown on drawings.

When applicable, control circuits shall be monitored by a DC under voltage relay or “No Volt” coil relay, those relays shall be wired to alarm terminals.

### 10.19 Inspection and Testing

The supplier shall give at least fifteen days advance notice of the date when the tests are to be carried out.

Routine and type test certificates for the board shall be furnished to the Purchaser for prior approval before dispatch of any equipment from the works and the approval in writing from

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

the Purchaser shall be essential to affect the dispatch of the equipment.

#### 10.19.1 Type Tests

Type and routine test certificates of bought out items like CT's, PT's, Relays, Meters, etc. shall be furnished.

Test certificates for the following type tests performed on a typical assembly of a switchboard with bus bars shall be furnished by Contractor.

- i. Test to prove the degree of enclosure protection.
- ii. Short circuit test.
- iii. Heat run test.

In case type test certificates cannot be furnished, the equipment shall be type tested without any extra cost to the Purchaser.

#### 10.19.2 Routine Tests

Following routine tests shall be conducted by the manufacturer at his works and shall be witnessed by Purchaser.

- i. Testing of complete board assembly.
- ii. Operation of air circuit breakers, auxiliary switches, manual devices, etc.
- iii. One minute power frequency withstand insulation (HV) test, on power and control circuits.
- iv. Continuity and polarity tests on all coils, CT's and circuits.
- v. Functional test on all relays and protection schemes.
- vi. Electrical control, interlock and sequential operation tests with PLC and without PLC.
- vii. Insulation resistance test with 1000 V megger, before and after HV test.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

## 10.20 Data Sheet

### 10.20.1 Site Conditions

Ambient Temperature	40°C
Altitude above MSL	1100 m

### 10.20.2 Operating Condition

Voltage	415 V + / - 10%
Frequency	50 Hz+ / - 5%
No of Phase	Three
System fault Level	50 kA (1.0 sec) for SSB , UAB – 1, 2, 3 & GISAB 25 kA (1.0 sec) for MDBs
System Earthing	Solidly Earthed
Auxiliary Supply AC	110 V, 1Phase, 50Hz (Through 415 / 110V, Redundant Control Transformer)
DC	220 V DC
Power supply for spring Charging Motor	240 V AC or 220 V DC

### 10.20.3 Electrical Data

Short Circuit withstand capacity for 1 Sec	50 kA
Busbars	Cu., Heat Shrunk PVC sleeves of 1100 V grade
System Breaking Capacity	50 kA
System Making Capacity	125 kA
Type of Circuit Breaker	ACB at incomer & few outgoings and MCCBs at outgoing feeders
Duty Cycle of Breaker	Continuous
Incoming Power Entry	The switchgears shall be directly coupled to its transformer in case of dry transformers through bus bar at sides and cable entry from top / bottom as per site requirement. In case of oil filled transformers, it shall be cable connection
Cable Entry (Outgoing)	Bottom / Top as per site requirement
Cable Glands and Lugs	Included

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

Colour shade exterior and base channel black	to be decided during detailed engineering
Feeder arrangement	Double front
Floor Fixing	Integral base channel and tack welding to the floor channel
Degree of Protection	IP-52

\* Adequate consideration for temperature rise, insulation level as per LOV study, clearances at higher altitude (greater than 1000 metres) and ambient temperature to be taken care by the Contractor.

Accessories:

- i. Interconnection control & signal cables between the three switchboards required for interlocking scheme.
- ii. All fitting accessories for cables (including Purchaser supplied cables) like cable glands, cable lugs.

## 10.21 Drawings and Documents Submission

The drawings, data and manuals listed hereunder are only the minimum requirements. Any other necessary write up, curves and information required to fully describe the equipment shall be submitted. Nothing in this specification shall be constructed to relieve the contractor of their responsibility for design, manufacture, testing and performance of Switchboard and its accessories.

On award of contract, the contractor shall prepare a Drawing & Documents Schedule in Purchaser's standard format, listing all the drawings and documents which will be submitted during the course of execution of the order.

S.No	Description	Code
1	GA Drawing with transportation dimensions, Foundation detail, Gland plate detail, Weights, loading etc.	B / P
2	Details of coupling between source transformer and switchboards	B / P
3	BOM indicating ratings, quantities, brief specifications and makes.	B / P
4	SLD, schematic and aux. Circuit diagram	P

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

5	Interlock scheme	B / P
6	PLC specs and IO list	B / P
7	Bus bar sizing calculation	B
8	Complete calculations, protection scheme and curves demonstrating the selective co-ordination of the protective elements and recommended settings for the protective devices.	P
9	Terminal block arrangement	P
10	Technical leaflet, commissioning manual of bought out items like ACB's, Relays, Meters, MCCBs PLC etc.	P
11	Routine and Type test certificates including test certificates for bought out items	P
	QA Plan	B
12	List of commissioning spares with brief specs.	B
13	List of panel accessories	B / P

Legend:

B – With Bid                      P – Post Order

## 10.22 Spare Parts and Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

The Contractor shall supply all necessary tools, devices, testing instruments / equipment etc. required for installation, testing, repair and maintenance at site. These shall remain the property of the contractor unless otherwise agreed to be taken over by Purchaser any / all of these at mutually agreed conditions

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall propose the list of special tools including their make and detailed specification as recommended by manufacturer(s), (to be accepted by the Purchaser) for operation and maintenance at site.

Purchaser reserves the right to purchase or not the spare parts and special tools covered in



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

this chapter.

Contractor shall supply one complete set of all special tools required for erection and disassembly of the equipment. A unit price shall be supplied for each of the following special tools:

- One lifting and transfer truck for draw-out circuit breakers;
- One portable test set for test purposes and calibration of the circuit breaker overcurrent tripping devices;
- One device for slow closing;
- One set of templates;
- One set of gauges;
- One set of special keys for contact adjustment.

The above-mentioned tools are bare minimum. Any other special tools as required shall be supplied by contractor.

#### 10.22.1 Mandatory Spares Part

Specified spare parts to be supplied under this section are as follows:

S. No	Description	Quantity
	<b>Air Circuit Breaker</b>	
1	Spring charging universal motor (operable on 240 V AC) for draw-out circuit breakers	2 nos. of each type;
2	Closing Coils for circuit breakers	3 nos of each type
3	Tripping Coils for circuit breakers	3 nos of each type;
4	Main contacts for circuit breakers:	1 Set
5	Secondary contacts for circuit breakers;	2 sets
6	Breaker control switch	1 no of each type;
7	Solid-state overcurrent trip devices without ground fault element;	1 no for each type of CB;
8	Solid-state overcurrent trip devices with ground fault element;	2 nos for each type of CB;
9	Vertical Busbars for distribution centers;	2 sets of each capacity
10	CT & PT :	1 No. of each type

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 10 Medium & Low Voltage Switchgear and Auxiliary Power Supply System

11	Indicating Lamps :	1 No. of Each type
12	Push button :	1 No. of each type
13	MCBs / HRC Fuses :	1 No. of each type
14	Under voltage relay (27).	1 set
	<b>MCCB</b>	
15	MCCB	1 no. of each rating
16	Auxiliary switch / contact	LS
17	Operating knob handle	1 no

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Purchaser reserves the right to order any or all of such spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

## Volume-II

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### Section II Sub-Section 11 DC System and UPS System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

## TABLE OF CONTENTS

<b>11</b>	<b>DC SYSTEM AND UPS SYSTEM .....</b>	<b>4</b>
<b>11.1</b>	<b>Scope.....</b>	<b>4</b>
<b>11.2</b>	<b>General Arrangement .....</b>	<b>4</b>
<b>11.3</b>	<b>Applicable Standards and Codes .....</b>	<b>4</b>
<b>11.4</b>	<b>General Requirements for DC System .....</b>	<b>5</b>
<b>11.5</b>	<b>Battery Charger .....</b>	<b>7</b>
11.5.1	Design basis .....	7
11.5.2	Operation.....	10
<b>11.6</b>	<b>Battery discharge panel (BDP).....</b>	<b>12</b>
<b>11.7</b>	<b>DC Distribution Boards .....</b>	<b>14</b>
11.7.1	Constructional details of battery chargers and DCDB (220 V DC & 48 V DC) .....	15
11.7.2	Wiring .....	16
11.7.3	Terminal blocks .....	16
11.7.4	Earthing .....	17
11.7.5	Labels:.....	17
11.7.6	Tests.....	18
<b>11.8</b>	<b>Battery .....</b>	<b>18</b>
11.8.1	Technical requirements .....	18
11.8.2	Cell construction .....	20
11.8.3	Battery Health monitoring (BHM) system: .....	20
11.8.4	Installation of battery.....	20
11.8.5	Tests.....	21
<b>11.9</b>	<b>220 V DC to 240 V AC Power Inverters.....</b>	<b>22</b>
<b>11.10</b>	<b>240 V AC Distribution Board (ACDB) .....</b>	<b>23</b>
<b>11.11</b>	<b>Data Sheets - DC System .....</b>	<b>23</b>
<b>11.12</b>	<b>UPS (Uninterruptible Power Supply) .....</b>	<b>26</b>
11.12.1	Construction details .....	26
11.12.2	Cooling .....	26
11.12.3	Components .....	26
<b>11.13</b>	<b>UPS Battery .....</b>	<b>32</b>
<b>11.14</b>	<b>UPS Power distribution board .....</b>	<b>35</b>
<b>11.15</b>	<b>240 V AC / 24 V DC Converter &amp; Distribution board .....</b>	<b>36</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

<b>11.16</b>	<b>Technical Specifications of 25 KVA and 6 KVA UPS System .....</b>	<b>36</b>
<b>11.17</b>	<b>Drawings and Design Calculations .....</b>	<b>39</b>
<b>11.18</b>	<b>Name Plate &amp; Labels .....</b>	<b>40</b>
<b>11.19</b>	<b>Packing &amp; Transportation .....</b>	<b>41</b>
<b>11.20</b>	<b>Painting .....</b>	<b>41</b>
<b>11.21</b>	<b>Spare Parts and Special Tools.....</b>	<b>41</b>
11.21.1	Mandatory Spares Parts .....	42

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

## 11 DC SYSTEM AND UPS SYSTEM

### 11.1 Scope

This specification includes the design, manufacture, testing at manufacturer's works, inspection, packing and supply to site, unloading at site, erection and commissioning of Battery Chargers (BC) and DC Distribution panel boards (DCDB), Lead Acid Plante type or Ni- Cd batteries, forming two (2) redundant power supply systems, 220 V DC for DC auxiliary services, protections and the field flashing of the generators. 48 V DC system with Plante/ Ni-Cd type batteries for PLCC and protection system at Powerhouse.

UPS Systems (Uninterrupted Power Supply) for Powerhouse and Remote sites consists of UPS Distribution Board, for power supply to essential auxiliaries, computer and printers.

### 11.2 General Arrangement

The storage battery shall be installed in the battery room, while the battery chargers, the switching and metering panels and the main D.C. distribution boards shall be located separately in the charger room. The Secondary DC Distribution boards shall be installed for feeding switchyard load and transformer marshalling Box loads.

A Key Single Line Diagram of 220 V DC System and UPS systems are enclosed for bidder's guidance.

### 11.3 Applicable Standards and Codes

The DC System shall be designed, manufactured and tested in accordance with the latest applicable IS / IEC standards.

DC System conforming to any other standard which ensures equal or better quality may be accepted. In such case, copies of the English version of the standard adopted shall be submitted along with the bid.

Unless otherwise specified the design, manufacture and performance of DC System provided under this specification shall generally conform to the latest issues of the following standards;

IEC 60947	Low Voltage switchgear and control gear.
IEC 60146	Semiconductor converters.
ASTM D2863	Test method for measuring the minimum oxygen concentration to support candle like combustion of plastics (Oxygen Index).

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

IEC-896-2	Stationary Lead-Acid Batteries General Requirements and Method of Test Part 2: valve Regulated type.
IEC-68-2	Environmental testing.
IEC-707	Method of test for determination of the flammability of solid electrical insulating materials when exposed to igniting source.
IEC-60068-2	Environmental testing – Part 2: Tests
IEEE Std 142-1991	IEEE Recommended practice for grounding of UPS
NEC[1], 250-26	Grounding Conductor arrangement
IEEE Std 1184-1994	IEEE Guide for the selection and sizing of Batteries for uninterruptible power system
IEC-896-2	Stationary Lead-Acid Batteries General Requirements and Method of Test Part 2: Valve Regulated type
IS 13947	Low voltage switchgear and control gear (Parts-1, 3, 4, 5).
IS 12021	Control transformers for switchgear and control gear for voltages not exceeding 1000 V AC.
IS 7204	Stabilized power supplies DC output (Parts-1 to 4).
IS 6619	Safety code for semiconductor rectifier equipment.
IS 5469	Code of practice for the use of semi-conductor junction devices (Parts-1 to 3).
IS 5001	Guide for preparation of drawings for semi-conductor devices and integrated circuits (Parts-1, 2).
IS 4411	Code of designation of semi-conductor devices.
IS 4411	Rectifier assembly
IS 3715	Letter symbols for semi-conductor devices (Parts-1 to 4).
IS 3700	Essential rating and characteristics of semi-conductor devices. (Parts-1 to 11)
IS 1248	Direct acting indicating analogue electrical measuring instruments and accessories (Parts-1, 2, 8, 9).

#### 11.4 General Requirements for DC System

Bidder shall design, build, assemble factory test, deliver and guarantee the following equipment as per diagram enclosed with tender document.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

<u>220 V DC system</u>
<ul style="list-style-type: none"> <li>➤ Two (2) 220V DC 1000 AH battery bank including seismic proof steel battery racks;</li> <li>➤ Two (2) sets of battery chargers (Main and standby) and accessories (Each Set of Charger shall have one no. Float charger and one no. Float cum Boost charger);</li> <li>➤ Two (2) 220 V DC Distribution Board (DCDB);</li> <li>➤ Two (2) 220 V GIS DC Distribution Board (DCDB);</li> <li>➤ 220 V DC / 240 V AC Inverter;</li> <li>➤ 240 V AC Distribution Board (ACDB).</li> <li>➤ 220V, 100A (min) DC battery discharge panel for 1000AH battery bank</li> <li>➤ Battery health monitoring (BHM) system</li> </ul>
<u>48 V DC system</u>
<ul style="list-style-type: none"> <li>➤ Two (2) 48 V DC 400AH battery bank including seismic proof steel battery racks;</li> <li>➤ Two (2) set of battery charger and accessories (Each Set of Charger shall have one no. Float charger and one no. Float cum Boost charger);</li> <li>➤ Two (2) 48 V DC Distribution Board (DCDB);</li> </ul>
<p>Portable wall mounted vapour condensation type distilled water plant suitable for the batteries shall be offered. The capacity of the distilled water plant shall not be less than 3 liters/hour. The quality of water obtained from the distilled water plant shall meet the requirements of Table-I of IS: 1069. The bidder shall confirm that the capacity of distilled water plant is adequate for topping off all the batteries.</p>

This equipment shall be wired and assembled to form two (2) redundant DC power supply systems for 220 V DC as well as 48 V DC respectively.

The Battery Charger system shall be an integrated system comprising of static rectifiers, isolating and protection devices and all other equipment / accessories required for completeness and satisfactory performance of the system. The Battery Charger equipment shall be properly coordinated with the selected Battery to ensure complete compatibility.

All equipment and components shall be of excellent quality and reliability for providing secure DC power required for vital equipment performance, controlling, monitoring and safeguarding functions in continuously operating power station. Components shall be capable of withstanding the thermal and dynamic stresses resulting from internal and external short circuits and circuit switching operations etc. The design of the equipment shall be such as to minimize the risk of short circuits and shall ensure personnel and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

operational safety.

The Bidder shall be responsible for design, Engineering and manufacturing of the complete system to fully meet the intent and requirements of this specification and attached data sheets.

## **11.5 Battery Charger**

### **11.5.1 Design basis**

There shall be one set of 100% duty dual battery charger per DC power supply. It shall be mounted in a self-ventilated floor mounted sheet steel enclosure.

Each charger of the dual charger shall be located in a different section of the enclosure and shall be complete with all controls relay equipment, charger ammeters, voltmeters, float boost indicators, boost charger warning lamps and fault alarms etc.

Each battery charger shall have provision to work on manual and automatic mode. A manual / automatic selector switch shall be provided.

Each set of chargers shall consist of one float charger and one float-cum-boost charger, as shown in the tender drawings, and shall be capable of performing floating and boosting operations in both manual and automatic modes. A float/boost selector shall be provided accordingly.

The battery charger shall be suitable for installation and satisfactory operation in design ambient temperature of 40°C and altitude approx. +1200 m above MSL.

Battery charger shall be sized to boost recharge its associated battery to approximately 95% of its capacity in a short period so as to prepare it for the next emergency.

Each charger shall have a 3-phase full wave, controlled rectifier bridge with protective devices.

For each charger load current and battery charging current, independent current limits shall be provided. Subsequent to a discharge cycle and after completion of boost charging, when battery is connected to charger under float mode, the battery current shall be monitored, controlled and limited to set value automatically irrespective of the value of load current.

The maximum permissible ripple voltage (rms) without battery shall be less than or equal to 1% of the nominal output voltage. To limit the ripple content at the output filter circuit consisting of smoothing chokes and condensers complete with protection shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

provided.

To prevent back flow from battery into the charger and filters, silicon blocking diodes shall be provided in the charger output circuit. Protection against reverse battery connection and DC earth fault relay for earth leakage protection shall be provided.

Selection, sizing and suitability of all the components used for various applications shall be Bidder's responsibility. All electronic power devices including thyristors, transistors, diodes etc. shall be rated under operating conditions for at least 150% of the maximum current carried by the device. All electrical components such as transformers, reactors, contactors, switches, breakers, busbars etc. shall be rated for at least 125% of the maximum required rating.

Typically, a DC auxiliary power system is designed as an unearthed system. However, a high impedance earth fault relay shall be provided for the protection of battery.

Each charger shall be galvanically isolated from the input power supply by providing a double wound transformer at its input. The transformer shall be continuously rated, natural air cooled, dry type suitable for operation inside the panel. The transformer shall be of class F insulation with temperature rise limited to class B, copper wound, and epoxy resin impregnated with adequate number of taps for voltage adjustment. The rating of transformer shall correspond to the rating of the associated rectifier assembly.

Transient / surge protection devices shall be provided in the input circuit of chargers to protect them against surges and voltage spikes.

The battery chargers shall also be designed to operate satisfactorily while drawing input power from an emergency diesel generator set. Suitable protection shall be provided in the control circuits to guard against the instability of the controlled rectifiers due to electrical oscillations which may be present in the input supply caused by the emergency DG set.

The performance of the battery charger system shall not be affected or degraded by the use of portable radio transmitter receivers in the vicinity of the chargers.

The charger shall be designed to draw power from mains supply at a minimum power factor of 0.8 while sharing the rated load in normal operating condition or configuration.

The charger shall be designed to ensure that the harmonic component in the input supply currents are limited so as not to cause undue harmful effects on other sensitive equipment operating on the same supply bus. Suitable filters / harmonic traps shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

provided as required for this purpose. The input total harmonic distortion (THD) level shall not exceed 5%.for both current and voltage.

All breakers shall be sufficiently rated for the required continuous rating and breaking capacity as applicable. All output isolating devices shall be double pole. All DC contactors must have attested / published DC rating equal to or exceeding the most stringent current carrying and breaking requirements while considering sufficient design margin.

All the thyristors, diodes and other power electronic devices shall be protected with high speed semiconductor fuses. It co-ordination between fuse and semi conducting power devices shall be ensured.

The Battery Chargers shall be specifically designed to limit float and boost charging voltages to the battery within limits as recommended by the battery manufacturer.

Chargers shall be suitable for continuous operation at AC voltage variation of  $\pm 10\%$ , frequency variation of  $\pm 5\%$ , and combined voltage and frequency variation of  $\pm 10\%$ .

The Output voltage shall be regulated at  $+ / - 0.5\%$  on Float mode and  $\pm 1\%$  on boost mode under the above condition with a load variation from 0 to 100%.

Each battery charger circuit shall be provided with its own AC input voltmeter with phase selector switch, DC voltmeter and ammeter, battery DC output ammeter and voltmeter, battery charging current ammeter, control switches, rectifiers, Auto / Manual voltage regulators, load limiting device, DC under voltage and over voltage and AC under voltage protections etc. as required for the successful operation of the DC system. Charger voltmeter shall be able to measure through selector switches, charger output voltage, Battery voltage, tap voltage and load voltage.

Each charger shall have monitoring and test facilities to diagnose and report the condition of the charger and battery locally and provision for the remote control and monitoring system in the sub-station.

The charger shall have facilities to automatically perform the discharge tests on the battery as follows:

On a called for basis

On a pre-selected (programmable) schedule basis.

The charger shall be suitable for parallel operation.

All equipment / components shall be suitable for operation at an altitude approx.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

+1200m above MSL.

### 11.5.2 Operation

Each charger is designed to operate manually and automatically in float mode and boost mode. The charger shall supply battery charging current (boost charging) and load current in boost Mode and float charging and load current in Float Mode.

Facilities shall be provided to automatically isolate a faulty charger and transfer the load to the other charger without loss of supply.

When one charger fails, it is automatically isolated and disconnected from the associated 220 V DC or 48 V DC output bus bar and the DC load is automatically transferred to the second charger. The load transfer shall occur only when a faulty charger is detected or when the battery / charger output voltage falls below a preset level. It shall not occur if the second charger is also on fail condition.

When both bank chargers fail, the DC power is then provided by the last to fail charger battery bank.

Charger shall have a “float / boost” selector switch for selection of battery charging mode. The process of changeover from float to boost charging and reverting from boost charging to float charging is selectable in automatic or manual mode by means of an auto / manual selector switch.

Under normal conditions, the float charger supplies the DC loads apart from the float charging current of the battery. In case the float charging current, which is continuously monitored, exceeds a certain preset value, the charger shall automatically switch over to boost charging mode for charging the battery at a higher rate. When the battery is fully charged the charger switches back automatically to float mode, automatically trickle charges battery again. In automatic control mode during “float” charging, the charger voltage shall remain within  $\pm 0.5\%$  of the rated maximum voltage for input AC voltage and frequency variation of  $\pm 10\%$  and  $\pm 5\%$  respectively, and DC load variation from 0% to 100% load or both occurring simultaneously at any temperature up to the design ambient temperature as specified in the data sheet.

When the auto / manual selector switch is in manual position both changeover from float to boost charging and from Boost to Float charging shall be performed manually through Float / Boost mode selector switch.

When boost charging mode is selected the battery charger shall initially charge the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

battery under constant current mode followed by constant voltage mode or as per the battery manufacturer's recommendation. Changeover from constant current to constant voltage mode shall be fully automatic.

Following control devices shall be included for each battery charger:

- i. ON / OFF control switch for input AC supply;
- ii. Selector switch for float / boost charging mode selection;
- iii. Auto / manual selector switch to select mode of operation;
- iv. Potentiometers in float and boost mode for voltage and current adjustments;
- v. Test, acknowledge and reset push buttons for alarm annunciator.

The above is minimum requirement. Any other controls and switches as required for operation shall be provided by Bidder.

Following metering devices shall also be included:

- i. AC input voltmeter with selector switch for line-line and line-neutral voltage;
- ii. AC input ammeter with selector switch to measure current in each line;
- iii. DC Voltmeter for output voltage of each charger;
- iv. DC Ammeter to measure output current of each charger;
- v. Centre Zero DC milli Ammeter for earth leakage current on each DCDB;
- vi. Centre Zero DC Ammeter for battery charging / discharging current;
- vii. DC Voltmeter (On Main DCDB);
- viii. DC Ammeter (On Main DCDB).

All meters shall be analog type of size 96 sq mm, class 1 accuracy, 90-degree deflection.

Transducers (4-20 mA output self-powered, accuracy class of 0.5 or better) shall be provided for the following, for remote Indication:

- i. Each charger output current and voltage;
- ii. Battery charging / discharging current;
- iii. DC voltage (DCDB).

Following panel signalizations shall be included:

- i. Incoming AC supply ON (one lamp per phase);
- ii. Charger in float mode;
- iii. Charger in boost mode;
- iv. Charger fault.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

All indicating lamps shall be of clustered LED type.

Microprocessor based audio-visual annunciator with annunciation windows, test, acknowledge, reset push buttons and hooter shall be provided on each charger panels for the following fault annunciations. Any additional relays / components as required shall be provided in the charger panel.

- i. AC undervoltage;
- ii. Input AC MCCB trip;
- iii. DC output MCCB trip;
- iv. Battery MCCB trip;
- v. DC over voltage;
- vi. DC undervoltage;
- vii. Charger failure;
- viii. Rectifier fuse fail;
- ix. Output filter fuse fail
- x. Battery on Boost mode;
- xi. Battery earth leakage fault;
- xii. Battery reverse polarity;
- xiii. Load on battery;
- xiv. Battery undervoltage or disconnected during discharge (using zero current sensing);
- xv. Cubicle fan failure / cubicle temperature high (applicable for chargers with forced cooling).

Suitable potential free contacts for above abnormal conditions shall be provided and wired up to separate terminal block in charger panel for remote annunciation.

Potential free contacts for charger in “float” mode, charger in “boost” mode and AC power failure (2 spare contacts) shall also be provided for remote indication.

#### **11.6 Battey discharge panel (BDP)**

The Battery Discharge Panel (BDP) shall be designed for controlled discharge testing of battery banks to verify battery capacity, performance, and health. The BDP shall operate with high efficiency and incorporate advanced monitoring and protection features to ensure safe and accurate discharge operations. It shall have following electrical specifications and protection

Electrical specifications:

- Nominal Voltage: 220V DC



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- Operating Voltage Range: 180V - 260V DC
- Rated Discharge Current: 0 - 100A (adjustable)
- Maximum Discharge Power: Up to 22 kW
- Power Supply for Control Circuitry: 230V AC, 50Hz

Protection Features:

- Overvoltage Protection: Automatic disconnection when voltage exceeds limits
- Overcurrent Protection: Prevents discharge current beyond 100A
- Overtemperature Protection: Shuts down system if components exceed safe temperature
- Reverse Polarity Protection: Ensures safety in case of incorrect connections
- Short Circuit Protection: Prevents system damage during faults

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

## 11.7 DC Distribution Boards

There will be main DCDBs and sub DCDBs for different locations of Power House like GIS Floor, control room, Machine Hall, Turbine floor etc. Similarly, main DCDB and sub DCDBs shall be provided for 48V system as per requirement.

Each DC power supply system shall have one main DC distribution board.

Each DC distribution board shall comprise motor operated molded type circuit breakers, Distribution board shall be designed, constructed and provided according to attached Data sheets and to relevant articles of the present specification.

Each main DC distribution board shall be equipped with one analog 4-20mA transducer for remote bus bar DC voltage indication

A tie Molded Case Circuit Breaker shall be provided between the two DCDB's to allow load switching between the two chargers on specific conditions.

The Measuring units of each charger shall comprise but shall not be limited to:

- One Main DC (220 V DC or 48 V DC) output bus bar
- Required sensors for load transferring
- One incoming feeder comprising one MCCB circuit breaker
- Three outgoing feeders for load supply, battery charging and load transfer. Each feeder comprises of one molded case circuit breaker. Load supply and load transfer molded case circuit breakers shall be equipped with shunt trip, closing coil (motorised), auxiliary contacts, and all necessary wiring. Proper electrical interlocking shall be provided between these two breakers and the load supply breaker of the DCDB-2.
- An automatic / manual transfer selector shall be provided. The transfer selector shall have 3 positions labeled as follow:
  - Load transfer to Battery Bank-1 (Bus-1 / DCDB-1)
  - Automatic (Center position)
  - Load transfer to Battery Bank-2 (Bus-2 / DCDB-2)

Only one transfer push button shall then be required. The transfer push button shall be manually activated to effectively perform the transfer of the load to the selected position. A signal shall light up to confirm the position of the load.

On automatic position, load transfer to Battery Bank-2 shall occur only when Battery Bank-1 is on fail condition or when the voltage level of the DC output bus bar reach a

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

preset low level. The transfer shall not occur if Bus-2 is also on fail condition or if a low output voltage is detected on Bus-2.

When Bus-1 and output bus bar voltage return to normal conditions, the load is automatically switched back to Bus-1. Similar arrangement shall be for Bus-2.

- All instruments, metering and signalisation devices including but not limited to:
  - DC voltmeter
  - DC output ammeter
  - Ground detector
  - Adjustable time delay Under voltage relay

#### 11.7.1 Constructional details of battery chargers and DCDB (220 V DC & 48 V DC)

Each Battery charger and associated DCDB shall be housed in separate free-standing cubicles. The DCDB shall accommodate all outgoing feeders and switching and metering devices associated with it. Each panel shall be provided with LED light of minimum wattage along with door switch for panel interior illumination.

DCDB with MCCB's shall be compartmentalized with each outgoing feeders housed in a separate compartment. Cable alley of minimum 200mm width with suitable supports shall be provided for termination of cables for each vertical arrangement of outgoing feeders in DCDB.

The panels shall be of rigid, self-supporting structure, completely assembled totally enclosed cubicle type constructed out of structural steel members with not less than 2 mm thick sheet steel. The panels shall have hinged front doors with concealed type hinges, locks and latches. The panels shall have adequate ventilation arrangement to avoid any undue rise in temperature. The panels shall have means for easy access to the maintenance of components. Wherever required suitable stiffeners shall be provided. The panel shall be provided with suitable louvers for ventilation backed by wire mesh. Inter panel sheet steel barriers shall be provided.

Equipment and relays mounted on panels shall be easily accessible for repair and replacement without disturbing other equipment and their connected wiring. No special tools shall be needed for this purpose.

The bus bars shall be air insulated and of high conductivity electrolytic grade copper. Bus bars shall be silver plated at joints. Bus bars shall be colour coded and live parts shall be shrouded to ensure complete safety to personnel. All the equipment inside the panel and on the doors shall have suitable name plates and device tag numbers as per

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

the wiring diagram. All wires shall be ferruled and terminals shall be numbered.

All instruments shall be switchboard type and back connected. Standard copper wires 2.5 sq.mm minimum shall be used for secondary wiring. The insulation for all equipment where provided shall be heat resistant, moisture proof and tropicalised. All fuses shall be provided inside the panel. All fuses shall be link type.

For all cabling external to panels, power cables and control cables shall be with FRLS PVC insulated stranded copper conductors. Cable entry shall be from top / bottom. Removable bolted undrilled gland plates of 3mm thick shall be provided along with suitable nickel plated brass cable glands and supports. Clamp type terminals shall be used for connection of wires up to 4 mm<sup>2</sup>. Bolted type terminals suitable for cable lugs shall be provided for wire sizes above this. Separate test terminals shall be provided for measuring and testing the equipment to check performance. All panels shall be supplied complete with crimping type copper cable termination lugs.

Panels shall be provided with sufficient number of panel space heaters with isolating switch and thermostat. These shall also be provided with panel illumination lamps with door switch and three-pin, 15A, 240 V AC sockets with switch for maintenance purpose.

Height of panel should not be more than 2375 mm including base channel.

#### 11.7.2 Wiring

Inside the panel the wiring for power, control, signaling, protection and instrument circuits shall be done with FRLS PVC insulated stranded copper conductor. The insulation grade of these wires shall be 1100 volts grade for control / Power wires. All control wiring shall preferably be enclosed in perforated channel or neatly bunched together.

PVC insulated copper conductor of cross section 2.5 sq.mm

Each wire shall be identified at both ends by PVC ferrules.

Inter panel wiring shall be taken through PVC sleeves or rubber grommets. Unused openings shall be suitably blocked to make enclosures rats and vermin proof.

#### 11.7.3 Terminal blocks

All terminal blocks shall be mounted in an accessible position with the spacing between adjacent blocks not less than 100 mm and the space between the bottom blocks and the cable gland plate being a minimum of 200 mm. Sufficient terminals shall be provided to allow for the connection of all incoming and outgoing cables including spare conductors

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

and drain wires. In enclosed cubicles, the terminal blocks shall be inclined towards the door for facilitating terminations.

The terminals shall be of the DIN RAIL mounting type and shall comprise a system of individual terminals so that terminal blocks can be formed for easy and convenient cabling consistent with the high reliability required of the circuits.

The terminal blocks shall be provided with shorting links and paralleling links where applicable, and mounted identification numbers and / or letters.

The terminal blocks shall conform to the applicable NEMA standard. The smallest size to be used shall be designated for 2.5 sq mm wire and no more than two conductors shall be connected under one terminal clamp.

Clamp type terminals shall be used for connection of wires up to 4 mm<sup>2</sup>. Bolted type terminals suitable for cable lugs shall be provided for wire sizes above this. Separate test terminals shall be provided for measuring and testing the equipment to check performance. All panels shall be supplied complete with crimping type copper cable termination lugs.

Terminal identification shall be provided corresponding to wire number of connected leads. Separate terminal blocks shall be used for power, control and signal cables. 415 V AC circuit terminals shall be segregated from other terminals and shall be equipped with non-inflammable, transparent covers, to prevent accidental contact with live parts. Warning labels with red lettering shall be mounted thereon in a conspicuous position.

#### 11.7.4 Earthing

All panels shall be connected to a tinned copper earth bus bar running throughout the length of panel. All doors and movable parts shall be earthed using flexible copper connection to the fixed frame of panel. Provision shall be made to connect the earthing busbar to plant earthing grid at two ends. All non-current carrying metallic parts of mounted equipment shall be earthed.

#### 11.7.5 Labels:

An identification label as mentioned in the SLD shall be fixed at top of the central panel. A Separate label giving detail for feeder compartment of all vertical panels shall be provided. Label shall be made of embossed plastic having white letters engraved on black back ground shall be provided for each equipment and mounted in each panel. Special warning plate shall be provided on removable covers or doors giving access to

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

cable terminals and bus bars. Special warning labels shall be provided inside the panel also, wherever considered necessary identification tags shall be provided inside the panels matching with those shown on the circuit diagram. All labels wordings shall be as approved by Engineer / Purchaser.

#### 11.7.6 Tests

Each Battery Charger, DCDB shall be tested as per relevant IS/IEC standards. Tests shall be carried out at manufacturer's works under his care and expense.

Following will be the minimum acceptance tests on each Battery charger/ DCDB.

- Insulation Tests;
- Burn –In Test for Printed Circuit Boards (PCB);
- Heat Run Test (Type test);
- Functional Tests;
- Charger Testing at Constant Output Voltage;
- Charger Testing at Constant Output Current Limit;
- Auxiliary Equipment and Control Circuit Tests;
- Parallel operation;
- Charger Efficiency;
- Audible Noise (Type test);
- Site Acceptance Test: Battery chargers, DC distribution board along with battery shall be tested at site as per the Site Acceptance Test (SAT) procedure. Bidder shall furnish SAT procedure for approval from Engineer / Purchaser prior to conducting site tests.

Detailed test schedule and procedures shall be formulated by the Bidder and submitted for Engineer / Purchaser's approval. Bidder shall specify the maximum allowable tolerance against each test parameters in line with applicable standards. All the tests shall be witnessed by Purchaser / Engineer. Necessary modifications or corrections shall be made by the Bidder in case if equipment fails to meet any requirements of the specifications. Test certificates indicating test results shall be submitted to Purchaser / Engineer.

### 11.8 Battery

#### 11.8.1 Technical requirements

- The battery for 220V DC and 48V DC shall be lead acid batteries with Plante positive

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

plate and pasted negative plates / Ni Cd type complete with electrolyte, supporting racks and other accessories. The charge / discharge curves of offered battery shall be suitable for application in a Hydro Power Generating station;

- The rated ampere hour capacity of the cell / battery shall be at reference temperature of 27°C, constant current discharge at 8 hours rate and end cell voltage of 1.85V / cell.
- Type of discharge duty cycle shall be based on the load cycle, duration and end cell voltage. An overall aging factor of 1.25 shall be considered while arriving at ampere hour capacity of battery;
- The numbers of cells and end cell voltage shall be decided on the basis of maximum permissible voltage to the load when batteries are float charged while feeding the load. The system output voltage at the end of design duty cycle shall not be less than 90% of nominal system voltage;
- On float, the cell / battery shall be suitable for being recharged to 90% of ampere hours removed within 24 hours and to 100% within 4 days;
- The component such as containers, lids, covers, and seals used in manufacturing shall meet the fire, flame, and smoke resistance rating as defined in ANSI / UL94 and have an oxygen index of at least 28 in accordance with ASTM D-2863;
- Plante/ Ni-Cd battery shall be designed to withstand the mechanical stress encountered in normal transportation and handling;
- Flame arrestor shall be mounted on the cell so that all the vented gasses diffuse through the arrestor to the outside environment. The construction of arrestor shall be such that the hydrogen burning on the external surface of the arrestor shall not propagate back into the cell to cause explosion;
- The terminal post shall be of nickel-plated steel. The terminal shall be suitable for discharge current and short circuit current without damage to cell as a result of terminal heating;
- The temperature of lead acid cells/ Ni-Cd shall be sufficiently low to prevent thermal runaway (critical condition arising due to constant voltage charging);
- Battery shall be supplied with all necessary accessories including but not limited to the following;
  - i. Mild steel stand pretreated and epoxy painted / PVC coated;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- ii. Inter cell, inter row and interbank connectors and end take offs.
- iii. Cell number plates, fixing pins, lugs for cable terminations as required;
- iv. Other accessories and their quantity as per project data sheet.
- The following information shall be permanently marked on the cell;
  - a. Nominal voltage;
  - b. Name of the manufacturer / model reference;
  - c. Rated capacity in ampere hours (Ah) with end cell voltage;
  - d. Voltage for float operation of 27°C with tolerance of  $\pm 1\%$ ;
  - e. Month and year of manufacture.
- All equipment / components shall be suitable for operation at an altitude approx. +1200m above MSL.

#### 11.8.2 Cell construction

The plates shall be of first-class material and workmanship and shall be free from blow holes, cracks and other imperfections. The separators shall be impervious of the chemical action inside the cell and oxidation resistant;

Electrolyte shall be gelled sulfuric acid of specific gravity varying from 1.160 to 1.180.

#### 11.8.3 Battery Health monitoring (BHM) system:

The Battery Health Monitoring System (BHMS) shall be an advanced diagnostic and monitoring solution designed to assess, monitor, and manage the health and performance of battery systems in real time. It is suitable for providing comprehensive insights into battery condition to optimize performance and extend service life.

#### 11.8.4 Installation of battery

The battery shall be mounted on Steel racks, supported by insulating posts in a battery room. It is proposed to lay the racks in row, single tier fashion. The racks supplied shall be so arranged as to present a neat and aesthetic appearance. The racks shall be robust in construction. As a safeguard against dislocation during earth-quake, the racks shall be rigidly supported and anchored. Each cell as well as its locations shall be numbered for proper record of maintenance operations. Two numbers of Suitably coated copper / lead connector shall be employed for inter cell, and inter row inter tier connectors. Tee off connections shall be made with acid resisting cables of suitable size. A suitable terminal box shall be provided. The connectors shall preferably be of bolted type and the bolts and nuts shall be of similar material as that of connectors and the same shall be provided with corrosion resistant coating. The battery shall be connected to Battery Charger by copper cables. Suitable terminal arrangement with glands shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

provided for this purpose.

#### 11.8.5 Tests

##### Acceptance tests

Each cell and the complete battery shall be subjected to the following acceptance tests in accordance with relevant standards in presence of the Purchaser's representative / inspection agency, if so desired by the Purchaser. The date and place of testing shall be subjected to agreement between the Purchaser and supplier. All test reports shall be submitted and shall be got approved from the Purchaser before dispatch of equipment in case of tests to be carried out in manufacturer's works.

- i. Test for capacities of individual cells and complete battery;
- ii. Dimensional checking of plates;
- iii. Visual inspection;
- iv. Endurance Test.

The acceptance tests shall also be carried out at the discretion of the Purchaser on battery or each cell after installation at site.

##### Type test

The batteries shall have been type tested to meet the performance requirements for design and AH rating of cells as per IEC standard certified copies of the test reports for the following type tests shall be supplied for the approval of the Purchaser.

- i. Test for retention of charge;
- ii. Specific gravity of a charged cell;
- iii. Test for gas emission;
- iv. Test for cycling duty operation (discharge / charge cycle operation);
- v. Test for short circuit current and internal resistance;
- vi. Test for recharge efficiency and time;
- vii. Test for fire resistance (oxygen Index, flammability).

##### Test for thermal runaway

The design integrity of Plante lead acid/ Ni-Cd cells shall be tested for the following tests:

- i. Thermal cycling test;
- ii. Mechanical tests (vibration, Bump and free fall).

In addition to above, the batteries shall have been type tested for service life test on float

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

duty as per ANSI T1 330.

#### Routine tests

Following routine tests shall be carried out as a minimum as part of acceptance tests for each AH rating of cell / battery.

- i. Marking and packing;
- ii. Verification of dimensions;
- iii. Tests for voltages during discharge;
- iv. Test for AH capacity;
- v. Test for charge retention if specified in the data sheet.

Battery duty cycle test to meet the duty cycle shall also be performed at site after installation as part of commissioning by the battery manufacturer.

A discharge test at rated 8-hour current is to be repeated until 8 hour discharge is attained or exceeded and until cell voltages are equalized. (Minimum 2 discharges shall be carried out at the time of commissioning).

### **11.9 220 V DC to 240 V AC Power Inverters**

The power inverters will be used to feed loads that need a reliable power source for Control room SCADA computers, screens and accessories & Printer.

The power inverters shall be installed in the Battery room.

The power inverter shall have the following characteristics:

- Wall mountable or free standing;
- Input voltage of 220 V DC;
- Output voltage of 240 V AC + / - 3%;
- Output power: 1,5 kW;
- Output frequency: 50 Hz +/- 0.1 Hz;
- Pure Sine wave Output;
- Total Harmonic Distortion: < 1.75%;
- Shall operate from 0 to + 40°C;
- Cooling shall be by thermostatically controlled exhaust fan;
- Screw type terminals shall be supplied for input and output cables connection;
- Shall be complete with condition monitoring and status display functions;
- Shall have simple communication capabilities such as dry contacts for status and alarm sending to the switchyard and powerhouse SCADA.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Contractor shall submit the Power inverters sizing calculations, Technical information & mandatory & recommended spare parts & tools.

#### 11.10 240 V AC Distribution Board (ACDB)

The 240 V ACDB shall be wall or floor mounted enclosure with, main breaker and branch moulded case circuit breakers rated to withstand the maximum available short circuit fault currents of 10 kA. Busbars material shall be tinned copper. Space for possible future moulded case circuit breakers to be 20% of space occupied by the branch moulded case circuit breakers and the board to be rated for at least a 20% load increase.

#### 11.11 Data Sheets - DC System

##### Site conditions

Maximum ambient temperature : 40 C;  
Altitude : Approx. +1200 m or more above MSL.

##### Battery:

Type : Plante type battery/ Ni Cd type battery  
AH (Minimum) : 1000 AH for 8 hr for 220 V DC & 400 AH for 48V DC or Actual requirement whichever is higher

Discharge Duty Requirements : Shall be worked out by Bidder for justifying battery capacity selected

Nominal DC System Voltage	Duty Cycle (Typical)			No. of Cells	End Cell Voltage
	First 1 min. (0 to 1min)	Next 58 min (1 to 59 min)	Last 1 min (59 to 60 min)		
220V	Bidder to indicate during DDE			108	1.85V
48V				24	1.85V

Note:

- End cell voltage shall confirm to the values specified;
- Ageing Factor shall be 1.25;
- Design Margin shall be 1.10.

Battery stands formation

: As per specification

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Accessories required with battery set:

- |   |   |         |
|---|---|---------|
| i. Cell testing voltmeter (3-0-3) V complete with leads | : | 1 No    |
| ii. Rubber gloves                                       | : | 4 pairs |
| iii. Rubber Aprons                                      | : | 2 Nos   |
| iv. Spanner   | : | 1 Set   |

Other accessories required shall be as per specification.

Battery charger

System parameters (Incoming Power Supply)

- |                             |   |   |
|-----------------------------|---|---|
| i. Voltage                  | : | 415V $\pm$ 10%  |
| ii. Frequency               | : | 50Hz $\pm$ 5%   |
| iii. No. of phases          | : | 3 Phase, 4 wire   |
| iv. Symmetrical fault level | : | 50 kA (1 sec) for 415 V AC, 35 kA (1 sec) for 220 V DC and 20 kA for 48 V DC* |

(\*) Tentative- Bidder shall furnish actual DC fault level calculation.

DC output supply

Charger

- |                                     |   |                                      |
|-------------------------------------|---|--------------------------------------|
| i. Float Charging voltage range     | : | 2.05 to 2.4                          |
| ii. Boost Charging voltage range    | : | 2.05 to 2.75                         |
| iii. Regulation                     | : | Better than $\pm$ 1% at full voltage |
| iv. Ripple                          | : | Less than 1% RMS                     |
| v. Charger Current Rating (Minimum) | : | Bidder to indicate during DDE (160A) |

Miscellaneous requirements:

- |  |   |   |
|--|---|---|
| i. Mounting                              | : | Free standing floor mounted               |
| ii. Access                               | : | Front                                     |
| iii. Cable entry                         | : | Top / bottom as per requirement.          |
| iv. Earth Bus                            | : | 50 x 6 mm <sup>2</sup> copper (min.)      |
| v. Removable gland plate for Cable entry | : | Required                                  |
| vi. Painting                             | : | to be decided during detailed engineering |

DC bus bar shall be suitable for maximum o / p voltage of the battery charger.

DCDB

- |                          |   |                             |
|--------------------------|---|-----------------------------|
| i. Mounting              | : | Free standing floor mounted |
| ii. Degree of Protection | : | IP54                        |

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- iii. Access : Front
- iv. Cable entry : Top / Bottom as per requirement
- v. Removable gland plate for Cable entry : Required
- vi. Painting : Siemens Grey (RAL7032)

DC bus bar shall be suitable for maximum o / p voltage of the battery charger.

#### Molded case circuit breaker (MCCB)

##### *AC Application*

- Nominal Voltage : 415V
- Duty : Continuous
- Continuous Current Rating : As required
- No. of Poles : 3
- Ultimate and Service Breaking Capacity : 50 kA
- Door operating handle : Required
- Aux. contacts for ON and TRIP : Required  
(2 NO and 2 NC contacts)

##### *DC Application*

- Nominal Voltage : 220 V DC or 48 V DC
- Duty : Continuous
- Continuous Current Rating : As required
- No. of Poles : 2
- Ultimate and Service Breaking Capacity : 35kA for 220 VDC and 20 kA for 48V DC
- Aux. contacts for ON and TRIP : Required  
(2 NO and 2 NC contacts)
- Door operating handle : Required

**Note:** MCCB used for load supply and load transfer between the two chargers, shall be motorized and equipped with all necessary tripping devices. Control voltage for these MCCBs shall be 220 V DC.

#### MCB

##### *DC Application*

- i. Nominal Voltage : 220 V DC
- ii. Duty : Continuous
- iii. Continuous Current Rating : As required

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

iv. No. of Poles :2

## 11.12 UPS (Uninterruptible Power Supply)

### 11.12.1 Construction details

The UPS System of 25 kVA in Powerhouse & 6 kVA at Remote sites comprises of input circuit breakers, isolation transformers, rectifier / charger, inverter, static transfer switch and bypass circuit, manual maintenance bypass switch and metering devices, should be housed in a freestanding steel enclosure with key-lockable doors. Front access only shall be required for expedient servicing, adjustments, and installation. The enclosure will be built to comply with IP20 when the doors are open. The UPS cabinet shall be cleaned, primed, and painted with the manufacturer's standard color. The UPS shall be constructed of replaceable subassemblies. Printed circuit assemblies shall be plug-in. Like assemblies and like components shall be interchangeable.

Some instruments and communication equipment at remote site require a 24 V DC source, in this case the Contractor is responsible to install the 240 V AC / 24 V DC converter and 24 V DC distribution board to ensure a stable and reliable power source to the aforementioned devices.

### 11.12.2 Cooling

Cooling of the UPS shall be natural-air. Temperature will be monitored by thermal sensors.

### 11.12.3 Components

#### 11.12.3.1 Rectifier / Charger

##### A. General

The term rectifier / charger shall denote the solid-state equipment and controls necessary to convert incoming AC power to regulated DC power for input to the inverter and for battery charging. The rectifier / charger shall be full wave thyristor rectifier type with constant voltage / current limiting control circuitry.

##### B. Input Current Walk-In

The rectifier / charger shall contain a timed walk-in circuit that causes the unit to gradually assume the load over a 10-second time interval after input voltage is applied.

##### C. Fuse Failure Protection



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Power semiconductors in the rectifier / charger shall be fused with fast-acting fuses, so that loss of any one-power semiconductor shall not cause cascading failures.

#### D. DC Filter

The rectifier / charger shall have an output filter to minimize ripple voltage into the battery. Under no conditions shall ripple voltage into the battery exceed 1% of nominal voltage. The filter shall be adequate to ensure that the DC output of the rectifier / charger will meet the input requirements of the inverter. The inverter shall be able to operate from the rectifier / charger with the battery disconnected.

#### E. Battery Recharge

In addition to supplying power for the inverter load, the rectifier / charger shall be capable of producing battery-charging current to recharge the battery. After the battery is recharged the rectifier / charger shall maintain the battery at full charge until the next emergency operation. The charging shall be an automatic cycle as per DIN 41772 characteristic I-U (boost to floating charge switching, with current measuring criteria and control during recharge). Both float and recharge voltages shall be adjustable. The charge voltage can also be manually controlled. The use of the inverter is inhibited during manual charging.

The maximum time required for a complete charge of the battery shall not exceed 8 hours.

### 11.12.3.2 Inverter

#### A. General

The term inverter shall denote the solid-state equipment and controls to convert DC power from the rectifier / charger or battery to regulated AC power for supporting the critical load. The inverter shall be an Insulated Gate Bipolar Transistor, phase-controlled, pulse width modulated (PWM) design capable of proving the specified AC output.

#### B. Overload Capability

The inverter shall be capable of supplying current and voltage for overloads exceeding 100% and up to 150% of full load current. A status indicator and audible alarm shall indicate overload operation. The UPS shall transfer load to bypass when overload capacity is exceeded.

#### C. Fault Clearing and Current Limit

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

The inverter shall be capable of supplying an overload current of 150% of its full-load rating for Thirty Seconds. For greater currents or longer time duration, the inverter shall have electronic current-limiting protection to prevent damage to components. The inverter shall be self-protecting against any magnitude of connected output overload. Inverter control logic shall sense and disconnect the inverter from the critical AC load before protective fuses operation.

#### D. Output Frequency

The output frequency of the inverter shall be controlled by an oscillator. The oscillator shall hold the inverter output frequency to  $\pm 0.1\%$  for steady state and transient conditions.

#### E. Output Isolation Transformer

To galvanically isolate the input from the output of the UPS a double wound delta / star or Delta / zigzag transformer shall be included in the output of the inverter. The combination of the inverter and Output isolation transformer shall form a separately derived source. And to make complete isolation in static bypass and Maintenance Bypass mode a Isolation transformer is provided at input of UPS on Bypass / Maintenance circuit.

### 11.12.3.3 Display and Controls

#### A. Monitoring and Control

The UPS shall be provided with a microprocessor-based unit status display and controls section designed for convenient and reliable user operation. A system controls section designed for convenient and reliable user operation. A system power flow diagram, a percentage load and battery time remaining display shall be provided as part of the monitoring and controls sections, which depicts a single-line diagram of the UPS. Illuminated visual indicators shall be of the long-life light-emitting diode (LED) type. All of the operator controls and monitors shall be located on the front of the UPS cabinet. The monitoring functions such as metering, and alarms shall be displayed on an alphanumeric LCD display.

#### B. Metering

The following parameters shall be displayed:

- Battery voltage;
- Battery charge / discharge current;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 11: DC System and UPS System
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- Input voltage;
- Output AC voltage;
- Output AC current;
- Output frequency;
- Active Power (kW) Apparent Power (kVA);
- Temperature - Ambient, battery, inverter assembly module.

#### C. Warning and Alarm Messages

- Normal Operation Input breaker open;
- Bypass circuit input breaker open ;
- Battery breaker open ;
- Manual bypass;
- Bypass absent ;
- Bypass overvoltage;
- Bypass undervoltage;
- Bypass frequency over limit;
- Bypass Phase Reversal;
- Bypass Static Switch fail;
- Bypass inhibit Local;
- Bypass inhibit remote;
- Load on bypass due to over temperature;
- Rectifier off Local;
- Rectifier off remotely;
- Rectifier Block;
- Rectifier overload;
- Rectifier over temperature;
- Rectifier Fuse fail;
- Inverter off local;
- Inverter off remotely;
- Inverter block;
- Inverter overload;
- Inverter overtemp;
- Inverter out of sync;
- Inverter overvoltage;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- Inverter undervoltage;
- Inverter fuse fail;
- DC overvoltage;
- DC undervoltage;
- Inverter no voltage;
- Inverter Peak Volts low;
- Battery under test;
- Battery test fail;
- Discharge battery;
- Battery end of discharge;
- Boost Charge;
- Battery Low;
- Battery Fuse Fail;
- Battery Fast over volt;
- Bypass overuse;
- Cut-off overload;
- Cut-off overtemp;
- Cut-off emergency stop;
- Overload Cut-off;
- max overload.

#### Software Warnings

- All related software warnings shall be displayed.

#### D. Controls

Four pushbuttons shall be located on the operator control panel

- a. Enter;
- b. Escape;
- c. Up;
- d. Down.

The push buttons shall permit the operator either to select options from a menu for display on the LCD window or to change the value of some parameters. One push-button - «alarm silence» switch shall also be provided.

#### E. Power Status Diagram

A mimic panel shall be provided to depict a single line diagram of the UPS.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Indicating lights shall be integrated within the single line diagram to illustrate the status of the UPS. The LEDs shall indicate the following status.

- Bypass voltage OK
- Load on bypass
- Load on inverter

Included in the power status diagram shall be an LED bar graph indicating % load with amber overload indication. Also an LED bar graph indicating % battery time remaining shall be included.

#### F. Ethernet Connectivity Interface Port

An Ethernet Connectivity based interface port shall be provided for remote display of UPS status information on a computer terminal.

### 11.12.3.4 Static Transfer Switch

#### A. General

Static transfers switch and bypass circuit shall be provided as an integral part of the UPS. The static switch shall be naturally commutated high-speed static (SCR-type) device rated to conduct full load current continuously. The UPS shall have a manual bypass switch in the output of the inverter circuit to enable the critical load to be connected to the inverter output or to the bypass / maintenance power source. The static transfer switch control logic shall contain an automatic transfer control circuit that senses the status of the inverter logic signals, and operate an alarm condition. This control circuit shall provide an automatic uninterrupted transfer of the load to an alternate bypass source, without exceeding the transient limits specified herein, when an overload or malfunction occurs within the UPS, or for bypassing the UPS for maintenance.

#### B. Uninterrupted Transfer

The transfer control logic shall automatically turn on the static transfer switch, transferring the critical AC load to the bypass source, after the transfer logic senses any of the following conditions:

- Inverter overload capacity exceeded
- Critical AC load over voltage or under-voltage
- UPS rectifier, inverter, battery or output transformer fault condition.

The transfer control logic shall inhibit and automatically transfer of the critical load to

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

the bypass source if any of the following conditions are present:

- Inverter / bypass voltage difference exceeding pre-set limits
- Bypass frequency out of limits
- Bypass out-of-synchronization range with inverter output.

#### C. Uninterrupted Retransfer

Retransfer of the critical AC load from the bypass source to the inverter output shall be automatically initiated unless inhibited by manual control. The transfer control logic shall inhibit an automatic retransfer of the critical load to the inverter if one of the following conditions exists:

- Bypass out of synchronization range with inverter output
- Inverter / bypass voltage difference exceeding pre-set limits
- Overload condition exists in excess of inverter full load rating
- UPS rectifier, inverter, battery or output transformer fault condition present.

#### 11.12.3.5 Maintenance Bypass Switch

##### A. General

A manually operated maintenance bypass switch shall be incorporated into the UPS cabinet to directly connect the critical load to the input AC power source, bypassing the rectifier / charger, inverter, and static transfer switch.

##### B. Maintenance Capability

With the critical load powered from the maintenance bypass circuit, it shall be possible to check out the operation of the rectifier / charger, inverter, battery, and static transfer switch. A battery disconnect switch shall be provided to isolate the battery from the UPS.

### 11.13 UPS Battery

#### A. Technical Requirements

- The battery shall be suitable for float duty operation at constant voltage permanently applied to its terminals which is sufficient to maintain it in state close to full charge and shall be designed to supply load in event of normal supply failure.
- The rated ampere hour capacity of the cell / battery shall be at reference temperature of 27°C, constant current discharge at 8 hours rate and end cell voltage of 1.85V / cell.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- Ampere hours of battery selected based on operating site temperature and discharge duty cycle based on two (2) hours for full load as given in enclosed data sheet. Type of discharge duty cycle shall be based on the load cycle, duration and end cell voltage. An overall aging factor of 1.25 shall be considered while arriving at ampere hour capacity of battery.
- The numbers of cells and end cell voltage shall be decided on the basis of maximum permissible voltage to the load when batteries are float charged while feeding the load. The system output voltage at the end of design duty cycle shall not be less than 90% of nominal system voltage.
- On float, the cell / battery shall be suitable for being recharge to 90% of ampere hours removed within 24 hours and to 100% within 4 days.
- The component such as containers, lids, covers, and seals used in manufacturing shall meet the fire, flame, and smoke resistance rating as defined in ANSI / UL94 and have an oxygen index of at least 28 in accordance with ASTM D -2863.
- The design of valve regulated cell shall be such that regulating valve shall not allow gas (air) to enter into cell but shall allow the gas to escape from the cell above certain internal pressure which shall not lead to deformation or cause container to crack or cause failure of seals.
- The hydrogen released from valve regulated lead acid cells shall be sufficiently low to make these suitable for use in office, control rooms and equipment environment. The gas leakage rate of cell shall not exceed  $0.05\text{cm}^3 / \text{hr}$  at  $27^\circ\text{C}$  and  $101.3\text{kpa}$ .
- Valve regulated stationary lead acid cells shall be designed to withstand the mechanical stress encountered in normal transportation and handling.
- Flame arrestor shall be mounted on the cell so that all the vented gasses diffuse through the arrestor to the outside environment. The construction of arrestor shall be such that the hydrogen burning on the external surface of the arrestor shall not propagate back into the cell to cause explosion.
- The terminal post shall be of nickel-plated steel. The terminal shall be suitable for discharge current and short circuit current without damage to cell as a result of terminal heating.
- The temperature of the valve regulated lead acid cells shall be sufficiently low to prevent thermal runaway (critical condition arising due to constant voltage charging).



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- Each set of the battery shall be supplied with all necessary accessories including but not limited to the following.
  - i. Mild steel stand pretreated and epoxy painted / PVC coated.
  - ii. Inter cell, inter row and inter bank connectors and end take offs. These shall be of lead plated copper.
  - iii. Cell number plates, fixing pins, lugs for cable terminations as required.
  - iv. Other accessories and their quantity as per project data sheet.
- The following information shall be permanently marked on the cell.
  - i. Nominal voltage
  - ii. Name of the manufacturer / model references
  - iii. Rated capacity in ampere hours(Ah) with end cell voltage
  - iv. Voltage for float operation of 27°C with tolerance of  $\pm 1\%$
  - v. Month and year of manufacturer
- All equipment / components shall be suitable for operation at an altitude approx. 1200m above MSL.

#### B. Cell Construction

- The plates shall be of first class material and workmanship and shall be free from blow holes, cracks and other imperfections. Flat type positive plate shall consist of a suitable bar with spines cast of suitable alloyed lead to give adequate mechanical strength;
- The separators shall be impervious of the chemical action inside the cell and oxidation resistant;
- The containers shall be made from hard rubber. They shall be sufficiently robust and free from flaws and flame retardant;
- Electrolyte shall be gelled sulfuric acid of specific gravity varying from 1.160 to 1.180.

#### C. Installation of Battery

The battery shall be mounted on Steel racks, supported by insulating posts. It is proposed to lay the racks in row, single tier fashion. The racks supplied shall be so arranged as to present a neat and aesthetic appearance. The racks shall be robust in construction. As a safeguard against dislocation during earthquake, the racks shall be rigidly supported and anchored. Each cell as well as its locations shall be numbered for proper record of maintenance operations. Suitably coated copper / lead connector shall be employed for inter cell, and inter row inter tier connectors.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Tee off connections shall be made with acid resisting cables of suitable size. A suitable terminal box shall be provided. The connectors shall preferably be of bolted type and the bolts and nuts shall be of similar material as that of connectors and the same shall be provided with corrosion resistant coating. The battery shall be connected to UPS by extra flexible copper cables. Suitable terminal arrangement with glands shall be provided for this purpose.

#### **11.14 UPS Power distribution board**

##### **A. Construction**

- UPS Power Distribution Board shall be housed in a separate free-standing cubicle. The Distribution Board shall accommodate all outgoing feeders. The panel shall be provided with CFL light of minimum wattage along with door switch for panel interior illumination.
- Other constructional details shall be similar to DCDB.

##### **B. Tests**

Complete tests for UPS system including Battery and Distribution boards before shipment shall be similar to DCDB as per relevant IEC standards.

Following will be the minimum acceptance tests on UPS power distribution board:

- i. Insulation Tests;
- ii. Burn – In Test for Printed Circuit Boards (PCB);
- iii. Heat Run Test;
- iv. Functional Tests;
- v. Auxiliary Equipment and Control Circuit Tests;
- vi. Audible Noise.

##### **Tests for complete UPS System**

The complete UPS system including battery, before shipment includes the following tests.

- i. Functional test and demonstration of all functions, indicators, sensors, and protective devices;
- ii. Full load test;
- iii. Transient-load response test;
- iv. Overload test;
- v. Power failure test.

Efficiency test at 50, 75, and 100 percent loads

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

### 11.15 240 V AC / 24 V DC Converter & Distribution board

The 240 V AC to 24 V DC converters is used for Remote sites monitoring instruments and communication equipment. Feeding 24 V DC to the Digital outputs of the control and monitoring system.

Converter & 24 V DC board shall be mounted in a wall mounted enclosure offering accidental contact protection and sufficient ventilation to prevent air temperature elevation in the vicinity of the converter.

### 11.16 Technical Specifications of 25 KVA and 6 KVA UPS System

UPS Topology True on-line Double conversion PWM IGBT based.

#### A INPUT

1	Input voltage	415V / 240V
2	Input voltage tolerance	+10 %, -15%
3	Input frequency	50 Hz
4	Input frequency tolerance	+ / - 5 %
5	Input current limit	115% (Adjustable between 100 - 125%)
6	Power walk - in period	10 seconds
7	Input circuit	6 pulse minimum fully controlled thyristor bridge rectifier.
8	Inbuilt Input and Bypass Isolator	Required, molded case circuit breakers with padlocking provision

#### B Output

1	Module full load rating KVA / KW	25KVA & 6KVA
2	Rated voltage	415V / 240V
3	Rated current	Vendor to specify
4	Phase Voltage asymmetry (UPS output only)	
	a] Balance load	1%
	b] 100% unbalanced load	2%
5	Output voltage adjustment range	+ / - 5%
6	Output power factor range	0.8 to unity
7	Internal oscillator stability	+ / - 0.2 %

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

8	Mains synchronisation tracking	+ / - 1 Hz (settable to + / -2)
9	Max. rate of change of frequency	1 Hz. Per second
10	Output voltage harmonics	
	a] Linear load	< 1%
	b] Non-linear load ( Crest factor of 3:1)	< 5 %
11	Crest Factor	3 : 1
12	Overload rating	110% for 60 minutes 125% for 10 minutes 150% for 60 seconds
13	Overload trip	10 min at 125% reducing to 60 seconds at 150%
14	Inverter Efficiency	> 92 %
15	Current limit short	Set at 150% of the output power
16	Transient Response	
	a) 100% load change	< + / - 5%
	b) Manual transfer of load from UPS to bypass and vice-versa	< 5 msecs when in sync
	c) Automatic transfer of load form UPS to bypass	< 5 msecs in sync
17	Transient recovery time	Recovery to + / - 3 % in < 4 msec.

**C**     DC characteristics

1	Nominal DC bus voltage	Vendor to specify
2	Battery isolation	Manually closed circuit breaker with under voltage release and over current trip
3	Battery Duty Cycle for full load	Two (2) hours
4	Battery fully discharge voltage	Vendor to specify
5	Allowable voltage drop in battery cables	3 volts at end of discharge voltage.
6	Battery float voltage	Vendor to specify
7	Battery end voltage	Vendor to specify
8	DC Bus voltage ripple	< 1% of nominal voltage

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- |    |                                |                         |
|----|--------------------------------|-------------------------|
| 9  | Battery recharge current limit | Amps, Vendor to specify |
| 10 | No. of cells                   | Vendor to specify       |
| 11 | Battery disconnect switch      | Vendor to specify       |

**D**      UPS Power distribution Board

- |    |                                       |                                    |
|----|---------------------------------------|------------------------------------|
| 1  | Type                                  | Free standing floor mounted        |
| 2  | Rated voltage                         | 415V / 240V                        |
| 3  | Rated frequency                       | 50 Hertz                           |
| 4  | Symmetrical short circuit current     | 25 KA (1 sec.)                     |
| 5  | Rated current Bus bar                 | Vendor to specify with calculation |
| 6  | Degree of protection                  | IP31                               |
| 7  | Access                                | Front                              |
| 8  | Cable entry                           | Top                                |
| 9  | Removable gland plate for Cable entry | Required                           |
| 10 | Painting                              | Siemens Grey (RAL7032)             |

**E**      Controls

Charger input circuit breaker  
Battery circuit breaker  
Inverter output contactor  
Bypass / Maintenance line circuit breaker  
Maintenance Bypass contactor  
Static Switch  
Alarm acknowledge / Reset button  
Inverter On-Off Pushbutton for Manually switching of the Inverter  
Emergency off push button  
Battery disconnect switch (Mounted separately in its own enclosure)

**F**      Measuring Instruments

- |   |   |
|---|---|
| 1 | LCD panel for Measuring Input Voltage, Output voltages, Output currents and Frequency, Battery Voltage and Charging / Discharging current, active power, apparent power, temperature. |
| 2 | LCD panel should display status of the Battery capacity and backup Time in minutes.   |

**G**      Protections

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- 1 RC surge suppressor.
- 2 Sustained undervoltage on input side
- 3 Phase loss on input side.
- 4 Negative sequence on input side
- 5 Semiconductor fuses in the lines for thyristor
- 6 Snubber circuit for device dv / dt protection
- 7 Charger input current limit
- 8 HRC fuses for filter capacitors
- 9 Battery current limit
- 10 DC overvoltage
- 11 Low battery
- 12 Semiconductor fuses at inverter output
- 13 Overload
- 14 Over temperature for the inverter
- 15 HRC fuses in the control circuit

#### H Indications (Alarms)

- 1 Inverter Failure
- 2 Overload (if load exceeds 100%)
- 3 Overload shutdown
- 4 Emergency shutdown
- 5 Equipment over temperature
- 6 Maintenance Bypass ON
- 7 DC over voltage
- 8 Low battery
- 9 Battery circuit breaker open
- 10 Battery on load
- 11 Mains failure
- 12 Rectifier Failed or Off
- 13 Inverter Unsynchronized
- 14 Load on bypass

### 11.17 Drawings and Design Calculations

Supplier shall provide its drawings in conjunction with its calculations as well as references, showing the detailed design of DC System & UPS System required by engineer for its review / approval.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Supplier shall furnish six sets of all the drawings for approval in hard copy as well as one set in soft copy. After approval and after work completion at site six sets of as built drawings and one set of drawings in soft editable format shall be supplied.

### Drawings

The Supplier shall submit the all the drawings and documents as required by Purchaser / Engineer. These drawings and documents should include at least the following:

- Detailed information and descriptive literature, explaining various safety, protective and regulation features of equipment / components;
- Drawings, showing general arrangement, sections of all major assemblies, sub assemblies and major components;
- Control schematic drawings;
- Electrical drawings;
- Erection, commissioning, operation and maintenance instructions;
- Quality assurance plan (QAP);
- Guaranteed Technical particulars (GTPs) of different items.

### Design memorandum

The Supplier shall prepare and submit to the Purchaser a “Design Memorandum” of the proposed equipment / system fulfilling the contract specification / requirement given in the section for approval prior to submission of any drawings and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, major technical features, basic arrangement / layout etc.

## **11.18 Name Plate & Labels**

All the DC System & UPS System shall be provided with a nameplate. It shall be mounted in a position that it shall be visible in the position of normal service and installation. The nameplate shall conform to the requirements of relevant IEC / IS and as per stipulations of General Technical Requirements and shall incorporate the following information:

- Manufacturer’s Name or trade Mark
- Type Designation or Serial Number
- Applicable Rated values



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

- Relevant Standard

- All name plates shall be of non-rusting metal or three (3) ply laminated with white engraved lettering on black back ground, inscription and lettering sizes shall be subjected to Purchaser's approval.
- Caution name plate "Caution Live Terminals" shall be provided at all points where the terminals are likely to remain live and isolation is possible only at remote end.

### 11.19 Packing & Transportation

All the equipment and supporting accessories shall be suitably packed as per the standard practice, while dispatching from the works. Although the method of packing is left to the discretion of the manufacturer, it should be robust enough for rough handling as the equipment shall be moving in hilly region. Manufacturer shall take additional care in packing of material for transportation, so that it does not get damaged during transit due to vibration / jerks / tilting, etc normally encountered during transportation by sea / road / rail in hilly terrain.

All accessories shall be dispatched in suitable boxes or crates. They shall be securely bound with wire and shall have all descriptive marking stamped thereon.

### 11.20 Painting

After fabrication, all surfaces shall be cleaned and pre-treated. A coat of primer (anti-corrosive) shall be applied after the pre-treatment. Two coats of Powder coating of shade (to be decided during detail engineering) shall be applied. Thickness of paint shall be not less than 100 microns.

Protecting peelable film / coating shall be provided on outside finished surface to protect the painted surface during transportation and site handling.

Sufficient quantity of touch-up paint shall be furnished for application at site.

### 11.21 Spare Parts and Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Purchaser reserves the right to purchase or not the spare parts and special tools covered in this chapter.

#### 11.21.1 Mandatory Spares Parts

The following mandatory spare-parts shall be included in the supply for both 220V DC and 48 V DC separately .

Sr. No.	Description	Qty.
<b>A. DC System</b>		
1	Control Cards.	1 no. of each type
2	PCBs of each type used.	--do--
3	Discrete components like SCRs, diodes, capacitors, resistors, potentiometers etc.	--do--
4	Trip indicating fuses, fuses and fuse base (as applicable).	3 Nos. each
5	Power / auxiliary contactors, contactor coils and contact kit.	1 no. of each type
6	MCCB auxiliary switch / contact.	--do--
7	Indicating lights.	--do--
8	Push buttons.	--do--
9	Toggle switches.	--do--
10	CT and Shunt.	--do--
11	Under voltage, over voltage, earth fault relay.	--do--
12	Motorized MCCB	1 no. of each type
<b>B. UPS System</b>		
13	Control Cards	1 no. of each type
14	PCBs of each type used	--do--
15	Discrete components like SCRs, diodes, capacitors, resistors, etc.	--do--

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 11: DC System and UPS System

Sr. No.	Description	Qty.
16	Trip indicating fuses, fuses & fuse base (as applicable)	3 Nos. each
17	Power / auxiliary contactors. Contactor coils and contact kit	1 no. of each type
18	MCCB auxiliary switch / contact	--do--
19	Indicating lights	--do--
20	Push buttons	--do--
21	Toggle switches	--do--
22	CT & Shunt	--do--
23	Undervoltage relay	--do--

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Purchaser reserves the right to order any or all of such spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

## Volume-II

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### Section II Sub-Section 12 Emergency Diesel Generator Sets

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

## **TABLE OF CONTENTS**

<b>12</b>	<b>EMERGENCY DIESEL GENERATOR SETS .....</b>	<b>3</b>
<b>12.1</b>	<b>Scope .....</b>	<b>3</b>
12.1.1	Silent DG sets .....	3
<b>12.2</b>	<b>Specific Parameters and Layout Conditions .....</b>	<b>4</b>
<b>12.3</b>	<b>Applicable Codes and Standards .....</b>	<b>4</b>
<b>12.4</b>	<b>Site Conditions .....</b>	<b>6</b>
<b>12.5</b>	<b>Data Sheet for Emergency Diesel Generator Set .....</b>	<b>6</b>
<b>12.6</b>	<b>DG Set Specification .....</b>	<b>8</b>
12.6.1	Diesel Engine and Accessories.....	8
12.6.2	DG Set Mounting Arrangement.....	16
12.6.3	Automatic Starting .....	16
12.6.4	Alarms / Automatic shut-down .....	17
12.6.5	AMF Panel.....	18
12.6.6	Control.....	19
12.6.7	Enclosure for the Silent DG Set .....	21
12.6.8	Alternator Rating Plate Details .....	22
12.6.9	Engine Rating Plate Details .....	23
<b>12.7</b>	<b>Performance Requirements.....</b>	<b>23</b>
<b>12.8</b>	<b>Performance Guarantee.....</b>	<b>23</b>
<b>12.9</b>	<b>Tests .....</b>	<b>24</b>
12.9.1	Routine Tests .....	24
12.9.2	Type Tests.....	24
12.9.3	Commissioning Tests .....	25
<b>12.10</b>	<b>Drawings and Documents .....</b>	<b>25</b>
<b>12.11</b>	<b>Spare Parts &amp; Special Tools .....</b>	<b>26</b>
12.11.1	Mandatory Spares .....	26

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 12 Emergency Diesel Generator sets
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## 12 EMERGENCY DIESEL GENERATOR SETS

### 12.1 Scope

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, training of Employer's personnel, handing over to Employer and guaranteeing for five years of operation of silent DG set as per the specifications hereunder, complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation. The DG set shall be silent type meeting the statutory requirements of gazette notification of State Pollution Control Board, Ministry of Environment and Forest & CPCB guidelines as on date of issue of this specification.

The scope of work shall be for a complete and comprehensive functional system covering all supply and services including but not limited to following:

#### 12.1.1 Silent DG sets

- Diesel engines coupled with alternators rated capacity as below, complete with fuel system, lubrication system, cooling system, air intake and exhaust system, battery and battery charger, instruments and protection system, annunciations, coupling arrangements etc.;
- DG Sets required are:
  - 800 kVA, 50 Hz alternator with exciter, automatic voltage regulator etc. for installation at Power House.
  - 250 kVA, 50 Hz alternator with exciter, automatic voltage regulator etc. for installation at Barrage site.
- Engine starting system (Automatic Mains Failure Starting System Panel);
- Acoustic housing, domestic silencer and exhaust system meeting the statutory requirements;
- Auto and manual synchronizing Panel (if required).
- Arrangement for neutral earthing, and protection of the generator which shall include REF / differential protection and stator over current earth protection (Numerical);
- Fuel tank (Weekly storage)) and fuel system including fuel transferring pump, piping, valves, and fuel level indication / alarm / trip etc. (at each location);
- External fuel storage tank of 999 litre fuel capacity including fuel transferring pump,

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

pipings, valves, and fuel level indication / alarm / trip etc.;

- Coordination and provision of necessary contacts and / or ports for integration with plant SCADA system.

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standards / best international practices.

## 12.2 Specific Parameters and Layout Conditions

The silent diesel generator set shall be required to provide the necessary emergency supply to 415 V Station Service Board (SAB) installed in power house and Main Distribution Board at Barrage site in case of failure of the power supply to respective bus of switch boards.

In case of failure of power supply on bus of Station Service Board (SSB), DG shall start automatically and feed the power to the board. On reappearance of Power, DG shall automatically disconnect from the associated bus and stop after preset time.

The diesel generator set with all necessary auxiliaries shall be installed outdoor near power house / control room at Barrage site (as applicable).

## 12.3 Applicable Codes and Standards

The design, manufacture and testing of the various equipment covered by this specification shall comply with the requirements of latest revision of the following standards issued by BIS (Bureau of Indian Standards).



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

IS 5	Colour for supply ready mixed paints and enamels.
IS 1239	Mild steel tubes and fittings.
IS 1248	Specification for direct acting indicating instruments and their purposes..
IS 4722 / IEC 60034	Rotating electrical machines.
IEC 60364-3	Electrical Installation of buildings assessment of general characteristics.
DIN 6270	Internal combustion engines, definitions of output.
BS 5000 (Part-III)	Rotating electrical machines of particular type of for particular applications. Generators to be driven by reciprocating internal combustion engine..
BS 5514	Specification for reciprocating internal combustion engine.
IS 10000	Methods of tests for internal combustion engine.
IS 10002	Specification for performance requirements for constant speed compression ignition (diesel) engine for general purposes (above 20 kW).
IS 12075	Mechanical vibration of rotating electrical machines – limits of vibration severity.
IS 4889	Methods for determination of efficiency of rotating electrical machines.
IS 4728	Terminal markings & direction of rotation for rotating electrical machinery.
IS 7132	Guide for testing synchronous machines.
IS 7816	Guide for testing insulation resistance of rotating machines.
IS 8183	Bonded mineral wool.
BS 4999	General requirements for rotating electrical machines
BS 8528 (P 10)	Testing of acoustic enclosure

In case of imported equipment, standards of the country of origin shall be applicable, if these standards are equivalent or stringent than the applicable Indian standards.

In case IS standards are not available for any equipment, standards issued by IEC, then followed by IEEE, or equivalent agency shall be applicable.

The equipment shall also conform to the provisions of Indian Electricity Rules and other

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

statutory regulations currently in force in the country.

#### 12.4 Site Conditions

- Maximum ambient temperature : 40 °C
- Minimum ambient temperature : 5 °C
- Humidity : 90 %
- Altitude : 1100 m – 1405 m above MSL
- Location : Arunachal Pradesh Distt West Siang

#### 12.5 Data Sheet for Emergency Diesel Generator Set

S.No.	Description	Values / Requirements
<b>1.</b>	<b>General</b>	
a.	Diesel generator set type	Auto – On – Mains Failure (AMF)
b.	Number of diesel generator sets	One no- 800 kVA One no- 250 kVA
<b>2.</b>	<b>Engine</b>	
a.	Type	Diesel, Four Stroke, Sound Proof
b.	Power output, continuous rating	To match rated capacity of generator at rated power factor (0.8 lagging)
c.	Overload rating	10% for one hour in any 12 hours of operation without exceeding temperature rise limits specified in IS:4722 / IEC 34 or BS:5000 when corrected to ambient temperature at site.
d.	Speed	1500 rpm (maximum)
e.	Fuel specification	High speed diesel oil
f.	Cooling system	Radiator type
g.	Lubrication system	Forced feed
h.	Fuel supply system	Fuel supply pump
i.	Starting	Electric starter, 24 V DC supplied by its own battery for each DG set.
j.	Power output continuous	To match rated capacity of generator at rated power factor (0.8 lagging)
k.	Governor class	Class-A1(precise standard) governing in

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

S.No.	Description	Values / Requirements
		BS:5514.
I.	Governor type	Woodward type – EGB 10 or equivalent
<b>3.</b>	<b>Generator</b>	
a.	Generator output under site conditions and at output terminals (Exclusive of supply to DG set auxiliaries)	800 kVA and 250 kVA
b.	Nominal voltage	415 $\pm$ 5% V
c.	No. of phases	3 phase & neutral
d.	Frequency	50 $\pm$ 3% Hz
e.	Power factor	0.8 (lagging)
f.	Rotational speed	1500 rpm
g.	Duty	Continuous
h.	Type of insulation	Class-H
i.	Temperature rise of windings	According to IEC 60034-1 (resistance method)
j.	Stator winding connection	Star connection
k.	Excitation system	Brushless
l.	Enclosures	Drip & screen protected IP-23
m.	Method of neutral grounding	Solidly earthed
n.	Manual starting of engine through local / remote push button	Required.
o.	Trip device on main station supply restoration	Required
p.	Paint shade for panels	RAL-7032

The adequate consideration for temperature rise, insulation level as per LOV study, clearances at higher altitude (greater than 1000 metres) and ambient temperature shall be taken care by the Contractor.

The generator shall be capable of delivering continuously at full load rated frequency and power factor and at any voltage between 105% and 95% of rated voltage without any part exceeding the maximum allowable temperature rise. It shall also be capable of operating continuously with 20% unbalanced load. The generator shall be capable of withstanding for

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

not less than 15 seconds a current 50% excess of its rated current after having attained the thermal equilibrium corresponding to the rated load, the voltage being maintained as near the rated values as possible consistent with the maximum capacity of the prime mover i.e. engine. The engine shall be capable of delivering an output of 10% in excess of its rated output at its rated speed for a period of one hour in any period of 12 hours consecutive running, without undue heating of the engine or any other mechanical part.

## 12.6 DG Set Specification

The DG set including daily and weekly tanks, control panels and accessories shall be installed in a shed / open on the surface near the power house. All equipment shall be suitable for operation at an altitude of 1100m above MSL. The DG set shall be enclosed in a containerized type acoustic enclosure suitable for outdoor installation.

The DG set shall be soundproof to the maximum extent possible. The generator shall be brush-less alternator, directly flanged to the engine. The generating sets shall be housed inside a high quality acoustic (suitable for outdoor installation) which shall have features like modular construction along with surface treatment like degreasing, pickling, phosphating, passivation etc.

The voltage regulator shall be electronic type having regulation of 0.5% at all loads between no load to full load and power factor 0.8 lagging to unity suitable for unattended operation. The governor shall be electronic with adjustable speed droop suitable for unattended operation. Suitable lifting lugs shall be provided on diesel generator assembly.

### 12.6.1 Diesel Engine and Accessories

#### 12.6.1.1 Engine

The diesel engine shall be preferably of Cummins, direct injection, four stroke, multi cylinder, air cooled, radiator type cooling system, turbo charged, operating at a normal speed of 1500 RPM and capable of developing requisite BHP at site condition.

The engine and the governing system shall be suitable for standby and AMF duty power generating application and shall conform to BS 5514 / IS 3046. The unit shall be suitable for operation on high speed diesel oil available in Indian Market.

The engine shall be electric start and shall be suitable for battery assisted manual / auto starting. Engine starting system shall have electric motor with suitable lead acid battery and static battery charger.

Diesel engine shall be capable of starting and operating for a few minutes without supply

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

of cooling water at the time of start-up.

A flywheel shall be provided at the power take-off end to smoothen out the variation in engine torque. It shall be rigidly bolted to the crankshaft. The flywheel shall be statically and dynamically balanced, prior to fixing on to the crankshaft. The entire flywheel shall be housed in a flywheel housing to ensure safety of personnel.

Maximum exhaust emission level of the DG set shall be limited to the values as per latest standards recommended by pollution control board. Contractor shall submit maximum exhaust emission level for each DG rating.

The rated output of the unit fitted with all its auxiliaries is defined as the continuous output available at the generator terminals when the diesel engine is operated at normal speed at the specified ambient conditions while using the specific fuel.

The engine shall be capable of satisfactorily driving the alternator at 10% overload at the rated speed for one hour in any period of 12 hours of continuous running.

The contractor shall specify the method used to determine the force of the engine and shall give the engine power curves.

Engine mounted microprocessor based control panel to display the following engine and electrical parameters:

- Lube oil pressure indicator and temperature gauge;
- Tachometer for speed indication with hour meter;
- Battery charging Ammeter;
- Starting switch with key;
- Over speed stop switch with contacts;
- Low lube oil pressure switch;
- High water temperature alarm and trip

The above are minimum requirements.

Wiring harness using temperature resistant insulation and flexible copper conductor wires shall be used. The wiring should be clamped at regular intervals and terminated using lugs and terminals.

The engine supplied with first filling of oil of required quantity as recommended by the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

manufacturers.

#### 12.6.1.2 Fuel Oil System

Diesel oil system shall be complete in all respects but not limited to the following:

- i. A weekly tank of 999 litres for each DG set, complete with instrumentation, fittings, supports, piping and valves and connected to the day tank of the DG shall be provided and installed. The transfer pump, operating through the fuel filter, shall be sufficiently powerful to pump the fuel from weekly tank to day tank. In addition a semi-rotary hand operated fuel transfer pump shall be included in the supply to act as a backup to the electrically driven pump;
- ii. Individual diesel oil day storage tank (day tank) of capacity sufficient to house fuel required for 8 hours of continuous running of DG set at 100% load. Day tank shall be provided with electromechanical oil level indicator, a low oil level switch, a very low oil level switch and a high-level switch with contact output for alarm / annunciation in the plant DCS as well as float control at inlet;
- iii. Engine driven diesel oil booster pump, injectors, filters, hoses etc, for the engine shall be provided. The injection system shall be individual interchangeable pumps with replaceable, calibration free, nozzles. The equipment shall include the necessary valves to empty or purge the injection system whenever air or water has entered the pipes. The fuel system shall have replaceable and easily accessible primary and secondary filters. An automatic bypass to return the excess shall be provided. All the piping required for connecting the fuel tank and engine shall be in the scope of the supply and erection of contractor / supplier of DG set;
- iv. Thermostatically controlled electric heaters for diesel oil if ambient conditions warrant the same;
- v. 1x100% capacity duplex filters or 2x100% capacity simplex individual filters with differential pressure switch across the filter(s);
- vi. The fuel oil system shall be designed to remain primed with diesel oil at all times. If required, AC motor driven priming pump for intermittent operation with timer operated on auto starting facility shall be provided by the contractor;
- vii. Contractor shall ensure that the offered engine (without cold start heaters) can be started at zero degree centigrade using normal HSD and at minus 10 degree centigrade using winter HSD. Further, contractor shall ensure that the offered engines can be started at

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

less than 5 degree centigrade using winter HSD and cold start heater (if applicable).

#### 12.6.1.3 Lube Oil System

Diesel engine lube oil system shall be complete in all respects but not limited to the following:

- Engine driven gear type pump;
- Water cooled lube oil cooler;
- Thermostatically controlled electric heaters for lube oil, if ambient conditions warrant the same;
- A pre-lubricating pump, with adjustable time between lubrications e.g 10-99 hours;
- 1x100% capacity duplex filters or 2x100% capacity simplex filters with differential pressure indicator across filter;
- The lub oil filters shall be suitable for a period of more than 500 hours without the necessity of its replacement or cleaning.
- An AC motor driven intermittent operation priming oil pump shall be provided. The pump, in conjunction with a suitable clock timer shall supply lube oil intermittently to the engine when the engine is not in operation.
- All necessary piping, valves, fittings, instrumentation and supports.

Contractor shall supply first filling of lube oil along with DG set as part of package.

#### 12.6.1.4 Jacket Water System

Totally air-cooled engines are preferable. However, if jacket water cooling system is offered, Diesel engine jacket water system shall be complete with:

- Jacket suitable for closed cooling water system, the coolant shall be mixture of ethylene / propylene glycol and demineralized / clarified water with suitable make-up arrangement as recommended by the engine manufacturer;
- Engine driven pump;
- Thermostatically controlled jacket water preheater to enable quick starting and loading of the engine;
- All necessary piping, valves, fittings, instrumentation and supports.

The cooling system shall be able to cool the engine with an ambient temperature of 40°C and 10% overload. The radiator shall be skid mounted and designed to handle the cooling load of the after-cooler in addition to the above requirements. The engine coupling shall be effected by an air-cooled radiator and a gear driven coolant pump. Fan shall be fabricated and tested in accordance with the AMCA and shall bear its certification seal.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

Fan wheel shall be dynamically and statically balanced. The diesel motor shaft shall drive fan motor with a belt drive. The belt drive system shall be protected with a removable guard including openings facing shaft to permit speed measurements. The cooling system shall be provided with devices to fill and to drain completely the coolant.

#### 12.6.1.5 Governor

Engine speed shall be regulated through an electronic governing system which shall also provide the over speed protection. The governor shall ensure that the speed of the DG set is regulated within 1% of the nominal speed under normal operating conditions.

The governor characteristics shall comply with the requirements of Indian Standards.

#### 12.6.1.6 Diesel Engine Starting System

Starting of diesel engine shall be by electric starting system. In case of total failure of plant AC supply, the DG starting system shall receive an auto start signal from AMF panel.

The electric starting system shall be complete and provided with:

- i. Electric Starter motor;
- ii. 24 V DC starter battery and battery charger;
- iii. Heavy duty flexible copper leads of sufficient length from battery to starter contactor and from starter contactor to starter motor;
- iv. All required power and control cables;
- v. Battery steel supports treated against acid corrosion;
- vi. Any other equipment / accessories required.

The battery shall be rated at 24 V DC. The voltage drop during starting of DG set under various conditions in this specification shall be limited to ensure smooth starting of DG set.

Contractor shall ensure that the control circuitry for the DG set in AMF panel shall be suitable for the battery voltage and voltage variation. The battery and battery charger shall meet the following specific requirements in addition to those listed elsewhere in the specification:

- i. The battery shall be of heavy duty, high performance lead acid type. The number and AH capacity shall be selected to suit the engine and other load requirements.
- ii. The battery shall be suitable for six successive starting attempts each of 10 seconds duration with a gap of 5 seconds between successive attempts.
- iii. Starting battery shall be sufficient for each DG set. If larger capacity is required for six successive attempts at the most unfavorable conditions, larger battery have to be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 12 Emergency Diesel Generator sets
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installed.

- iv. The battery charger shall be capable of boost charging the battery within 8 hours.
- v. The battery shall be supplied complete with electrolyte and accessories. The accessories shall include battery stand, battery leads with terminal ends acrylic top cover and inter battery connectors.
- vi. The battery shall be provided with a charger to charge the battery when the DG set is not running. The charger shall get disconnected while the DG set is running.
- vii. The battery charger shall have a regulator at the output to limit the voltage within safe limits.

#### 12.6.1.7 Air Intake and Exhaust Systems

The air intake and exhaust system shall be provided with the following:

- i. Air intake silencer (if required) and filter;
- ii. Exhaust gas driven turbo charger;
- iii. Charge air cooler;
- iv. Exhaust gas residential type silencer;
- v. Necessary air inlet and exhaust pipe, supports, thermal insulation for the entire exhaust pipe length for personnel safety, flexible piping / expansion joints to avoid transmission of vibrations from the engine to the structures.

#### 12.6.1.8 Alternator

The DG set Alternator shall be preferably of Stamford make suitable for continuous operation with the diesel engine at 1500 RPM, 415V, 0.8 pf (lag), 50Hz horizontal foot mounted, double bearing, self-excited, self-regulated, brushless (rotating diode type), screen protected drip proof, self-air cooled type, continuous duty alternator with class H insulation in IP-23 enclosure incorporating the following:

- i. Continuous damper winding;
- ii. 6 nos RTDs and one anti condensation heater wired to a separate terminal box;
- iii. Pilot exciter;
- iv. Rotating diodes shall be protected by a surge suppressor to chop the transients;
- v. 3 phase sensing AVR with  $\pm 0.5\%$  voltage regulation;
- vi. A neutral CT of adequate ratio and class for REF relay for DG protection;
- vii. Separately mounted adapter box suitable for XLPE cable termination of required size for each phase and for neutral;
- viii. Earthing terminal shall be provided inside the terminal box for earthing neutral point of

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

the winding, directly to the earth grid. Two (2) separate earthing terminals shall be provided for earthing DG set base frame.

The contractor shall provide the torsional analysis of the system. The generator shaft shall have a connecting clamp for coupling to the diesel engine by means of high tensile bolts. Welded steel sheets shall shield the stator frame. All parts of the generator shall be designed to withstand all electrical and mechanical stress which may be experienced during normal operation, including cases of short-circuits, faulty synchronization and over-speed conditions.

Alternator vibration level shall not exceed the values as defined in IS:12075. Alternators in case driven by diesel engine shall be able to withstand vibration level of 9 mm/sec, as per BS 5000 Part-III.

Alternator shall be complete with control and interlocking systems, manual starting / tripping system, control cabinet / panel and all other accessories as per requirements of this specification. Alternator shall be conform to IS 4722 / BS 2613.

The alternator shall be provided with an Auto-Mains Failure (AMF) panel. Time delayed No-Volt relay contact shall be provided to give an impulse for DG set to start. The DG set shall be capable of starting and developing rated voltage and speed automatically without any manual intervention within 10-15 sec after getting the start command.

Alternator shall be provided with an integral speed indicator. Speed transducers shall be provided with output of 4-20mA for remote monitoring of speed.

The DG set shall be capable of five (5) starts in quick succession. A hand reset lockout relay shall be provided with suitably wired contacts such that it prevents starts in excess of five (5) in quick successions. Stopping of DG set for a normal shut down shall be done manually by means of a local push button as well as from remote.

Also, when power supply on 415 V switch board is restored DG set shall stop automatically in auto mode after ensuring stability of restored supply. Provision for remote emergency stop shall be provided.

The line and neutral ends of each phase winding of the alternator shall be brought out on six (6) suitably located terminals. Suitable clamping arrangement shall be provided for connecting the cables to the machine terminals. The terminals shall be suitably enclosed to prevent short circuit by rodents. Suitable cable glands shall be provided on the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

enclosure to facilitate entry of the cables.

240 V single phase space anti-condensation heaters of adequate rating shall be provided in lower part of the stator frame. The kW rating of the space heaters shall be indicated.

The response ratio of the excitation system at rated KVA and rated voltage shall not be less than 0.50p.u./sec.

The excitation system shall be so designed and / or protected, that harmful over-voltage cannot occur at the main exciter commutator due to combined effect of maximum exciter field current and machine over-speed.

The alternator shall further meet the following specifications.

- i. Suitable for 20% over speed for two minutes
- ii. Capable of carrying 50% overload for a duration of one minute
- iii. Capable of carrying 10% overload for one hour in any period of 12 hours running
- iv. The inertia constant shall be 0.26 second or above
- v. The alternator terminal voltage for any load variation should be maintained within  $\pm 5\%$
- vi. The prime mover response should be such that with 100% load thrown ON / OFF for the generator both transient and steady state frequency variation should be within  $\pm 3\%$ . The alternator terminal voltage for this load variation should be maintained within  $\pm 5\%$
- vii. Both ends of each phase winding shall be brought to the terminal box.
- viii. The alternator shall withstand short circuit current at the terminals for a period of 3 seconds
- ix. The total harmonic distortion (THD) shall not exceed 3% and the design shall permit upto 30% unbalance between phase while in operation

#### 12.6.1.9 Excitation System

Each alternator shall be provided with excitation system. The capacity of the exciter shall be adequate to meet the full load and overload ratings of alternator particularly under short circuit conditions. The exciter shall have an automatic demagnetizing arrangement for the field circuit and insertion of field circuit. In the event of an internal fault. Such an arrangement shall be capable of reducing the induced voltage to a safe limit.

#### 12.6.1.10 Automatic Voltage Regulator

The alternator shall be capable of operation over a range of  $\pm 5\%$  of the rated voltage and  $\pm 3\%$  of the rated frequency.

The voltage regulator shall be digital type, supplied complete with cross current

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 12 Emergency Diesel Generator sets
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compensation. The regulator shall be supplied complete with voltage setting device, all accessories and alarm contacts.

#### 12.6.1.11 Timers

A timer with a width of 6.2 mm shall have accurate time setting using a thumb wheel and a function. It should have pre-defined function. A timer with a width of 22.5mm shall be multifunctional. Both shall have switching outputs. The shorting link shall reduce the wiring cost and time. No programming shall be required. Isolation shall be in according with EN50178 & inflammability class according to UL94.

#### 12.6.1.12 Contactors

A three phase solid state contactor with a width of 22.5 mm and performance range upto 4 kW shall have the following features:

1. RIGHT and LEFT Contactor
2. MOTOT protection relay and
3. Emergency STOP contactor

A contactor shall be certified with SIL3 approval, in accordance with IEC 61508-1-ISO13849, EN954-1 standards. Output is single contact type 1 PDT with interlocking circuit as well.

#### 12.6.2 DG Set Mounting Arrangement

The engine and alternator shall be mounted on a common MS fabricated rigid base frame with anti vibration mounting pads to provide at least 98% vibration isolation.

DG set shall be ready-to-use type and shall be supplied in fully assembled condition.

Lifting Lugs shall be provided so that the whole assembly can be lifted without distortion.

DG set shall be enclosed in an acoustic enclosure. With the integral acoustic enclosure the noise level when measured at a distance of 1 meter outside the DG enclosure louvers shall not be more than 75 dB(A) under free field condition.

DG set shall be suitable for outdoor installation.

#### 12.6.3 Automatic Starting

Automatic starting of DG shall be through a starting signal from auxiliary control system

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

after ensuring necessary interlocks in the case of:

- Mains power outage;
- Low mains voltage;
- Loss of one phase in mains.

The unit shall start and build up voltage automatically within 10-15 seconds from getting command to closing of AC supply CB associated with DG set.

#### 12.6.4 Alarms / Automatic shut-down

➤ Following alarm signals shall be provided:

- Circuit Breaker trip;
- Low Fuel Level (day tank) alarm;
- High Fuel Level (day tank) alarm;
- Low Fuel Level (weekly tank) alarm;
- High Fuel Level (weekly tank) alarm;
- High differential pressure across lube oil filter alarm;
- Lubricating oil priming pump in operation alarm;
- Over frequency alarm;
- Over current alarm;
- High engine temperature pre alarm;
- Low oil pressure pre alarm;
- Generator over voltage alarm;
- Generator under voltage alarm;
- Generator under frequency alarm;
- Ground fault alarm;
- High alternator temperature alarm;

➤ Automatic shutdown shall be under following conditions:

- Over-speed of DG set as sensed by over-speed trip device;
- Low frequency;
- Very High engine temperature;
- Very High water temperature;
- Very Low radiator water level;
- Very Low oil pressure;
- High oil temperature;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

- Very low fuel level;
- Over Crank (fail to start);
- DG fail to start in 15 sec, after receiving the first start impulse;
- Excitation failure due to tripping of field breaker or failure to build up voltage;
- AVR fault;
- DG shutdown on electrical fault;
- Ground fault on the system.
- DC control supply failure.

All the sensing devices shall be provided on the DG set and accessory relays on the control section of AMF Panel to achieve the above tripping conditions. These devices shall be suitable for operation on ungrounded DC system.

The tripping / shutdown of diesel engine shall be by means of fuel shut-off solenoid.

Window type annunciations shall be supplied and mounted on control section of AMF Panel to give visual and audible indications for the following conditions. The annunciation lists above are minimum and shall be subject to approval of client / consultant.

Annunciator shall have 20% spare windows.

The annunciation system shall be microprocessor based complete with facilities like 'Acknowledge', 'Test', 'Audible Alarm', etc.

Potential free contacts for tank level & group alarm & trip functions shall be provided and wired up to terminals for remote indication / annunciation.

#### 12.6.5 AMF Panel

AMF panel shall be relay based and made of 2 mm (min.) CRCA sheet and powder coated for a weatherproof, long last finish. The AMF control logic shall be as mentioned elsewhere in this specification. Features of AMF panel can be merged with the incoming feeder CB in the Auxiliary Switchboard.

All bus bars shall be of copper and shall be suitable for short circuit rating of 50 kA/1 sec.

AMF panel should comprise of but not limited to the following:

- One number 1600A (1280A release) four pole ACB drawout type (EDO) with built-in microprocessor based release (LSI+G). ACB shall be 4 pole of Siemens WL with ETU 45B release or Schneider (Merlin-Gerin) NW with micro logic 6.0A trip unit;
- A digital power meter (Schneider PM710 / SATEC PM130E or equivalent) shall be



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

provided and mounted on panel front. The energy metering device required is described as under:

- ❖ Shall have large LCD display capabilities;
  - ❖ Shall have an accuracy of 0.5 or better;
  - ❖ Shall be capable to display three phase voltage, three phase amperage, frequency and Power Factor;
  - ❖ Shall be capable to display kW, kWh, kVAR, KVARh, kVA, kVAh;
  - ❖ Shall be capable to measure demand value: current and power;
  - ❖ Shall have data recording of minimum and maximum of the above-mentioned values;
  - ❖ Shall have communication ports RS 485, Modbus protocol;
  - ❖ Shall have alarming capabilities.
- Ammeter for battery charging current;
  - Voltmeter for DC system;
  - All necessary control and supervisory equipment for the automatic operation of the set;
  - All protection equipment i.e. reverse power relay & reverse kVAR relays with suitable ranges, frequency relay, under voltage relay, frequency relay, instantaneous and IDMT over current relay, generator differential / REF protection, earth fault relay etc. and any other relays to satisfy the clause “Automatic Shutdown” of this section;
  - Running hour meter;
  - Annunciator and associated control systems;
  - Temperature scanner to monitor the temperature of generator stator windings;
  - Generator automatic voltage regulator (AVR);
  - Any other protection as recommended by the generator manufacturer shall be included by contractor.

The above mentioned are bare minimum and any protection and items etc. as required for the completeness of the system shall be included by contractor. Contractor shall submit protection schematics for approval.

All protection relays shall be Numerical.

#### 12.6.6 Control

The diesel generator shall have four different control modes, off, test, manual and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

automatic.

- **Off mode**

In off mode the diesel generator set shall, if running, stop without time delay and remain stopped.

- **Test mode**

In test mode it shall be possible to manually start the diesel generator directly. Then the automatic starting sequence is energized and the generator synchronized and loaded after effecting a changeover from main bus to generator bus. On a manually stop command the generator shall be disconnected, load transferred to the main bus and engines stopped after a cooling period.

- **Manual mode**

In the manual mode, the engine shall be started manually by the operator by pressing the 'start' push button on the generator panel, and the closing of CB shall be done manually with the help of manual synchronizer and check synchronizing relay.

- **Automatic mode**

In automatic mode the diesel generator shall be automatically started in case of starting signal (power failure), and shall be maintained running until auxiliary control circuit detects mains supply.

A red stop push button shall be provided on the generator terminal cubicle for emergency stopping of the diesel generator set.

In automatic mode, the operating procedure in case of power failure shall be as follows:

- The diesel engine shall start if mains power outage is detected on the 415 V switchboard SSB-1 and starting signal has been given by the auxiliaries control system;
- The diesel generator shall supply voltage to the 415 V switchboard/ SSB-1/ The closing of the breaker in the 415 V switchgear connecting the DG set to the electrical network shall be automatic;
- At recovery of mains power, upon receiving a stop signal from the auxiliaries control system, the DG set shall automatically disconnect from the main bus. After adjustable cooling period the engine shall stop;
- With power failure in bus of 415 V Station Service Board (in power house) DG

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

shall run automatically.

#### 12.6.7 Enclosure for the Silent DG Set

The DG set shall be provided with enclosure for reducing the sound level to 75 dB at a distance of 1 meter from the enclosure edge. Construction of the enclosure shall be weatherproof and corrosion resistant. Enclosure shall be fabricated out of 1.6 mm thick CRCA sheet with frame of suitable size. The construction shall be modular type with provision to assemble and dismantle easily as required for maintenance. The frame shall be of sufficient stiffness and rigidity. The enclosure shall be suitable for outdoor duty without any requirement of external shade. The ventilation system shall be of adequate design to ensure no deterioration in the performance of DG.

DG and its enclosure must be winterized meaning that it must be heated and moisture must be controlled.

The sound absorptive layer shall comprise of bonded type mineral wool / rock wool / glass wool of adequate thickness and density to comply the design requirements.

Sound proofing of enclosure shall be done with high quality foam confirming to IS 8183 to suitable thickness and density.

The exposed surface of lining inside the enclosure shall be retained in place by 1.0 mm minimum thick CRCA / aluminum perforated sheet. Absorptive lining shall be provided between the perforated plate and absorbing material. Necessary acoustic sealing shall be done in the panels / modular unit joints.

All hardware Nuts-bolts shall be zinc coated.

The exhaust air from radiator shall be discharged through modular duct duly insulated of adequate size.

The intake air shall be taken from the outside through the intake air duct. The door design shall be generally compatible to the enclosure design. The bonded mineral wool slab of adequate thickness shall be used. The door shall be provided with heavy-duty hinges and handles. The sealing shall be done with neoprene / silicon rubber gasket to avoid leakage of noise. The size of the door shall be as per the functional requirements.

Specially designed sound attenuators shall be provided to control sound at air entry & exit points inside the enclosure.

The construction of duct shall be from 1.6 mm thick CRCA sheet and 1 mm thick CRCA

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

perforated sheet. Other construction details shall be similar to that of the enclosure.

In built fuel tank shall be provided with breather, drain plugs for filling & draining diesel from outside the enclosure. Other accessories as specified elsewhere in this specification shall be included.

A special residential silencer shall be provided to control exhaust noise.

To make the system vibration free, engine and alternator single / double bearing are mounted on specially designed anti-vibration pads mounted on the base frame.

The sheet metal components shall be fourteen tanks pretreated and is polyester based powder coated (inside as well as outside) for long life. The enclosure paint shall be grey RAL 9002.

Cooling air fan with necessary control and protection circuit, if required shall be provided by the DG set contactor.

The acoustic enclosure shall be designed in such a way that there are no hot pockets around engine and it is provided with suitable designed engine radiator / or additional axial flow fan.

The enclosure shall have acrylic plastic window for viewing alternator / engine control panel. Emergency STOP push button shall be provided on exterior of the enclosure. The location of the emergency PB and the engine control panel shall be at the left hand side of the DG set while locking from the alternator end.

Illumination inside the enclosure shall be provided.

#### 12.6.8 Alternator Rating Plate Details

A rating plate stating the following details shall be supplied with the alternator:

- A reference to the designation of the Indian Standard;
- Indication of the name of the manufacturer;
- Manufacturer's number and frame number;
- Type of AC alternator;
- Frequency in cycles per second: 50 Hz;
- Number of phases: 3;
- Rated net output in kVA (after deduction of power for excitation system, battery

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 12 Emergency Diesel Generator sets
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charger and cooling fan) at site conditions;

- Rated voltage and winding connections;
- Current in amperes at rated output;
- Power factor: 0.8 lag;
- Type of duty: Continuous;
- Speed in revolutions per minute;
- Excitation current and voltage at rated output;
- Class of insulation;
- Enclosure type: IP 23.

#### 12.6.9 Engine Rating Plate Details

A rating plate stating the following details shall be supplied with the engine:

- A reference to the designation of the Indian Standard;
- Indication of the name of the manufacturer;
- Manufacturer's number;
- Rated output net in kW at NTP (after deduction of power for Battery charging generator, radiator cooling fan, radiator water pump, fuel injection system and lube oil system from gross power output);
- Speed in revolutions per minute.

#### 12.7 Performance Requirements

The DG set and accessories shall be designed to meet the following performance requirements

The DG shall be capable of starting from cold condition, reaching Synchronous speed and taking up load within the period specified (within 10-15 sec) from the "START" impulse and shall be capable of delivering continuously at the generator terminals rated output, with invisible exhaust.

With the DG running at no-load, rated voltage and speed, the transient voltage drop at its terminals shall not exceed specified percentage of rated voltage, on starting a maximum capacity induction motor direct on-line required to be started during this period.

#### 12.8 Performance Guarantee

The DG set along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

and performance of the individual equipment as well as of the complete system.

## 12.9 Tests

### 12.9.1 Routine Tests

The diesel generating unit and the auxiliaries shall be assembled at the manufacturer's works and the following test shall be performed:

- Measurement of winding resistance for alternator;
- Regulation test (Voltage & Speed);
- Insulation resistance test of wiring and alternator winding;
- Functional test on control panel & checking of phase sequence;
- Measurement of vibration and noise level;
- Four (4) hours at full load followed by a 1 hour continuous load of 110%;
- Engine starting time;
- Fuel consumption test;
- Automatic starting and interlocks test on mains failure;
- Governor responses;
- Operation of DG control panel / AMF panel.

Any other test as mentioned in relevant 'IS' standards to be included. All routine test shall be witnessed by Employer / consultant.

### 12.9.2 Type Tests

Type test reports for the following type tests shall be submitted for Employer / consultant approval:

- Measurement of resistance;
- Phase sequence test;
- Regulation test;
- Measurement of open circuit and short circuit characteristics;
- Efficiency test;
- Temperature Rise test;
- Momentary overload test;
- Over speed test;
- High voltage test;
- Insulation resistance test (both before and after HV test);
- Noise level as per IS: 12065;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

- Vibration as per IS: 12075;
- Degree of protection on control panel IP-52 / IP-54.

### 12.9.3 Commissioning Tests

Following tests shall be conducted on DG set after installation.

Load Test: The engine shall be given test run for a period of at least 6 hours. The set shall be subjected to a maximum available load without exceeding the specified DG set rating. The test shall be conducted at actual power factor of the load available at site.

- Insulation resistance test for alternator;
- Regulation test (Voltage and speed);
- Insulation resistance test of wiring;
- Functional test on control panel;
- Measurement of vibration;
- Measurement of noise level.

Fuel consumptions test shall be carried out and the engine shall be tuned to achieve the fuel consumption close to the values achieve at the engine manufacturer works.

### 12.10 Drawings and Documents

Contractor shall furnish the following documents. “Contractor Documents Requirements” shall be referred for the quantities and time schedule. The drawings, data and manuals listed hereunder are only the minimum requirements. Any other necessary write up, curves and information required to fully describe the equipment shall be submitted. Nothing in this specification shall be constructed to relieve the contractor of their responsibility for design, manufacture, testing and performance of Switchboard and its accessories.

On award of contract, the contractor shall prepare a Drawing & Documents Schedule in Employer’s standard format, listing all the drawings and documents which will be submitted during the course of execution of the order.

#### ❖ **DG set drawings / Manuals / Data sheets along with offer:**

- Single line diagram;
- Layout drawing showing the position and dimensions of DG set with tanks, panels and all other accessories to be installed under DG shed;
- Duly filled in technical particulars;
- Technical literature.

#### ❖ **DG set drawings / Manuals / Data sheets after award:**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

- Design calculation for selection of DG;
- General arrangement of the set and exhaust pipe with minimum clearances and size of the space required (DG set layout with door and window dimensions);
- Principal data for foundation design and detail foundation drawing;
- Technical literature for all equipment including engine, alternator, control panel, battery and battery charger;
- Complete parts list and recommended spares for two years of operation;
- Detailed installation, operation and maintenance manuals for engine, alternator, generator control panel, engine control panel, batteries and battery charger;
- DG set dimensions with and without enclosure;
- GA drawing of the enclosure;
- Quality Assurance Plan (QAP).
- Operation and maintenance manual.

#### 12.11 Spare Parts & Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

A complete set of tools required for the installation, operation and maintenance of DG set shall be supplied as part of the DG set package contractor

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter

##### 12.11.1 Mandatory Spares

The mandatory spares are listed below for one DG set.

Item No.	Description	Qty.
1.	Oil filter	12 nos.
2.	Fuel filter	12 nos.
3.	Nozzle	2 nos.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 12 Emergency Diesel Generator sets

4.	Complete set of belts	3 sets.
5.	Air filter element	4 nos.
6.	Relay	Minimum 1 no. of each type
7.	Pressure switch	Minimum 1 no. of each type
8.	Temperature switch	Minimum 1 no. of each type
9.	Level switch	Minimum 1 no. of each type.
10.	Fuses	5 nos of each type
11.	Indicating lamps	5 nos of each type
12.	Electronic card	Minimum 1 no. of each type.
13.	Sets of gaskets and “O” ring	2 sets for each rating
14.	Fuel injectors	1 set for each rating
15.	AVR	1 no. for each rating (if different)
16.	Trip & closing coil of ACB	1 set for each rating
17.	Rotating diode assembly	1 set for each rating

The above are bare minimum. Any other spares (over and above mandatory list) shall be recommended by contractor along with unit prices for consideration of Employer. Employer reserve his right to order any or all the spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

## Volume-II

### Section II Sub-Section 13

### Power and Control Cables

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 13: Power & Control Cable
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## **TABLE OF CONTENTS**

<b>13</b>	<b>POWER AND CONTROL CABLES .....</b>	<b>3</b>
13.1	Scope .....	3
13.2	Codes and Standards .....	4
13.3	Power and Control Cables .....	6
13.3.1	General.....	6
13.3.2	PVC Cables .....	6
13.3.3	XLPE Cables .....	7
13.3.4	Continuous withstand temperature and short circuit withstand temperature.....	8
13.3.5	Instrumentation and signal cables.....	8
13.3.6	Computer and data transmission cables .....	9
13.3.7	Cable accessories .....	10
13.4	Testing and Inspection.....	10
13.4.1	General.....	10
13.4.2	PVC and XLPE cables .....	11
13.4.3	Cable accessories .....	11
13.5	Packing and marking .....	12
13.6	Marking on the length of cable .....	12
13.7	Information required with tender .....	13
13.8	Spare Parts & Special Tools .....	13
13.8.1	Mandatory spares .....	13

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

## 13 POWER AND CONTROL CABLES

### 13.1 Scope

The scope of work under this section covers the detailed requirements for the design, manufacture, QA, QC, shop testing, packing, transportation and delivery to the site, site storage and preservation, installation, laying, termination, testing and commissioning of the Power, Control and instrumentation Cables in Powerhouse including GIS, Transformer & Pothead yard and Remote sites covered under the scope of this package. Special cables such as Computer and Data Transmission Cables are included in the scope as well.

All cables from Powerhouse to Marshalling box/ LCC of respective equipment of Pothead yard, GIS and Transformer yard shall be in the scope of bidder. For preparation of cable schedules, the bidder has to coordinate with respective package contractors for termination details.

The scope of bidder shall include all cables required for interconnection between various equipment and system covered in this package. All the required accessories, component and items whether specified herein or not shall also be in the scope of the bidder.

The quantity of various sizes of cable to be supplied shall be as determined during detailed engineering plus mandatory spares.

#### ➤ HT Cable

11 kV, if required, stranded Aluminum Conductor, XLPE insulated, FRLS cables,

33 kV, of required size, stranded Aluminum Conductor, XLPE insulated, FRLS cables,

#### ➤ LT Cable

All cables XLPE, FRLS type of different sizes required for including intermediate equipment (from source to utilization) of 415 – 240 V ac system and 220 V DC & 48 V DC. These cables of different sizes shall have stranded copper conductor for size up to 16 sq. mm and stranded Aluminum conductor for size above 16 sq. mm and rated for 1100 V grade. The DC cables of all sizes shall have stranded copper conductor only. The sizes and quantity shall be estimated by the bidder at his end.

#### ➤ Control, Instrumentation and Communication Cable:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

These shall include all cables required for control, protection, instrumentation, alarm and communication system of Power House. These cables shall have copper conductor only. Minimum one (1) spare core shall be provided for cables with core upto 7 cores, two (2) cores shall be provided for cables having cores between 10 to 20 cores and three (3) cores for cables having cores higher than 20 cores.

The maximum size of cables for instrument transformer shall be as follows: -

- Cable for PT connection shall not be less than 4 Sq. mm Copper Cable (1100 volts grade);
- Cable for CT connection shall not be less than 6 Sq. mm Copper Cable (1100 volts grade);
- All control cabling for operation and interlocks shall not be less than 2.5 Sq mm. (1100 V grade) copper cables.

Sizes of cable shall be so selected that the voltage drop in DC cable and AC cable shall not be more than 3% and 5% of applied voltage respectively.

The scope includes the preparation, and submission for approval, the cable schedules, interconnecting cable diagrams / schematics, cable lists and cable ratings etc.

The bidder shall also be responsible for erection/laying of cables and associated accessories/structures within all the areas under scope of this work package as per the approved scheme.

### 13.2 Codes and Standards

The cables shall be designed, manufactured and tested in accordance with the latest applicable IEC& IS and other applicable statutory provisions, rules and regulations except where modified and / or supplemented by this specification. In absence of applicable IEC standards shall prevail.

Cables conforming to any other standard which ensures equal or better quality may be accepted. In such case, copies of the English version of the standard adopted shall be submitted along with the bid.

Unless otherwise specified the design, manufacture and performance of all the cables provided under this specification shall generally conform to the latest issues of the following standards:

IEC 61034 series	Measurement of smoke density of cables burning under defined conditions
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EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

IEC 61540 series	Test methods for insulations and sheaths of electric cables and cords (elastomeric and thermoplastic compounds)
IEC 60502 series	Power cables with extruded insulation and their accessories for rated voltages from 1 kV (Um = 1,2 kV) up to 30 kV (Um = 36 kV)
IEC 60331 series	Tests for electric cables under fire conditions - Circuit integrity
IEC 60332 series	Tests on electric and optical fibre cables under fire conditions
IEC 60840	Power cables with extruded insulation and their accessories for rated voltages above 30 kV (Um = 36 kV) up to 150 kV (Um = 170 kV) - Test methods and requirements
IEC 60811 series	Common test methods for insulating and sheathing materials of electric cables - Part 1: Methods for general application
IEC 60885 Series	Electrical test methods for electric cables
IEC 60754	Test on gases evolved during combustion of electric cables
IEC 62444	Cable glands for electrical installations
IEC 61138	Compression and mechanical connectors for power cables for rated voltages up to 30 kV (Um = 36 kV)
BS 5308-1 and 2	Design Guideline
BS 6360	Conductor
BS1442	Specification for Galvanized mild steel wire for Armouring Cables
BS : 2782 Part - I	Methods 141 A, British Standard methods of testing Plastics - Part-I thermal properties.
ASTM-D-2863	Standard method of test for flammability of plastics using oxygen index method.
ASTM-D-2843	Standard test method for density of smoke from the burning or decomposition of plastics
IS : 1554 (Part I)	PVC insulated (heavy duty) electric cables - Part I for working voltages up to and including 1100 V.
IS : 7098 (Part I&II)	Cross-linked Polyethylene insulated PVC sheathed cables: Part I & II.
IS : 8130	Conductors for insulated electric cables and flexible cords.
IS : 5831	PVC insulation and sheath of electric cables.
IS : 3975	Mild steel wires, strips and tapes for armoring of cables.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

IS 10418	Drums for electric cable
IS : 10810 (Part 41)	Methods of test for cables
IS: 613	Copper Rods & bars for electrical purposes-Specification
IS : 4905	Methods for random sampling
IS:13573	Joints and terminations for polymeric cables for Working voltages from 6.6 kV up to and including 33 kV
IS :10462	Fictitious calculations method for determination of dimension of protective covering of cables Part-1 Elastomeric and thermoplastic insulated cables
IS : 2633	Methods of testing weight, thickness and uniformity of coating on hot dipped galvanized articles.
IS : 209	Specification for Zinc.
IS : 3961 (Part II)	Recommended current ratings for cables: Part-II PVC insulated and PVC sheathed heavy duty cables.
IS : 1753	Aluminum conductors for insulated cables.
IS: 10810 (Part-61)	Flame retardant test
IS: 10810 (Part 62)	Fire resistance test for bunched cables.
IS : 9968 (Part-I)	Elastomer insulated cables - for working voltage up to and including 1100 V
IS:10810(Part 58)	Standard method for measuring the minimum oxygen concentration to support candle like combustion of plastics.

### 13.3 Power and Control Cables

#### 13.3.1 General

The cables shall be brand new and of best quality and class most suitable for working under the site conditions including variation of temperature without disturbance or deterioration or the setting up of undue stress in any part. These shall be suitable for laying in trays, trenches, ducts, conduits and underground buried installation with uncontrolled back-filled and possibility of flooding by water. The terminating and straight through joint kits for the cables shall be suitable for the type of cables offered and for storage without deterioration up to 40°C ambient temperature.

#### 13.3.2 PVC Cables

Low voltage power cables and control cables shall be of copper. All conductor cable shall be of Stranded construction.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

All power / control cables for use on low voltage systems shall be heavy duty type, 1100 V grade, XLPE, inner & outer sheathed, unarmored and overall PVC sheathed & FRLS type.

The construction of the conductors shall be stranded for copper / Aluminum cables. Conductors of nominal area less than 25 sq. mm shall be circular only. Conductors of nominal area 25 sq. mm and above may be circular or shaped.

The core insulation shall be with PVC compound applied over the conductor by extrusion / XLPE and shall conform to the requirements of applicable IEC standards. Control cables having 6 cores and above shall be identified with prominent and indelible core nos. on the outer surface of the insulation. Color of the numbers shall be white with a spacing of maximum 500 mm between two consecutive numbers.

The inner sheath shall be applied over the laid-up cores by extrusion and shall be of PVC conforming to the requirements of applicable IEC standards. The extruded inner sheath shall be of uniform thickness of size not less than 0.5 mm up to 16 sq. mm, 0.8 mm from 25 sq. mm up to 120 sq. mm and 1.0 mm above 120 sq. mm conductor size. Taped inner sheath is not acceptable.

All cables used for electronic circuit shall be of 1.5 mm<sup>2</sup> copper screened cables. The screening shall be of copper foil with drain wire. The 1.5 mm<sup>2</sup> conductor shall be stranded.

The outer sheath for the cable shall be applied by extrusion and shall be PVC compound conforming to the requirements of applicable IEC standards. To protect the cables against rodent and termite attack, suitable chemicals shall be added into the PVC compound of the outer sheath.

### 13.3.3 XLPE Cables

Power cables for 33 kV system shall be with Aluminum Conductor, XLPE insulated, screened, sheathed, armored and overall PVC sheathed & FRLS type single core as detailed below. Insulation level of the medium voltage cables shall be 33 kV suitable for a high resistance grounding system and continuous ground fault condition. Conductor sizing shall take into account the maximum available short circuit. Medium voltage cables shall have a one second withstand at the maximum available RMS short circuit.

The construction of the conductors shall be stranded and compacted circular for all cables.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

All cables rated 33 kV and above shall be provided with both conductor shield and insulation screening. The conductors shall be provided with non-metallic extruded semi-conducting shielding.

The core insulation shall be with cross-linked polyethylene unfilled insulating compound. It shall be free from void and shall withstand all mechanical and thermal stresses under steady state and transient operating conditions.

The insulation shielding shall consist of non-metallic extruded semi-conducting compound in combination with a non-magnetic metallic screening of copper. The insulation screen shall be strippable without application of heat. The copper screen shall be capable of carrying the single line to ground fault for duration of 1 second.

The conductor screen XLPE insulation and insulation screen shall all be extruded in one operation by 'Triple Extrusion' process to ensure perfect bonding between the layers. The core identification shall be colored strips or by printed numerals.

The inner sheath shall be applied over the laid up cores by extrusion and shall conform to the requirements of applicable IEC standards. The extruded inner sheath shall be of uniform thickness of size not less than 0.7 mm for all sizes of cables.

The outer sheath for the cables shall be supplied by extrusion over the armoring and shall be of PVC compound conforming to the requirements of applicable IEC standards. To protect cable against rodent and termite attack, suitable chemicals shall be added into the PVC compound of the outer sheath

#### 13.3.4 Continuous withstand temperature and short circuit withstand temperature.

The continuous withstand temperature shall be 90°C and 70°C for XLPE and PVC cables respectively.

The short circuit withstand temperature shall be 250°C and 160°C for XLPE and PVC cables respectively

#### 13.3.5 Instrumentation and signal cables

##### Instrumentation cables

All instrumentation cables shall be suitable for outdoor / indoor operation in a sub-tropical climate. All instrumentation cables shall be oil, moisture and UV resistant, anti-termite, anti-vermin and flame retardant and shall be suitable for at least 25 years service life.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

### Signal cables

Cables for low level 4-20 mA signals to / from field transmitters, control valve positions, mV level signals from proximity and vibration sensors, electronic level binary status signals for general field instrumentation including inter panel signals, shall be as per detailed specification below.

Cables for instrumentation 24 V signals, control relays, etc. shall be of core sizes 1.5 mm<sup>2</sup> to 6.0 mm<sup>2</sup>, as required to minimize voltage drop to less than 3% of nominal applied voltage over long cable runs.

Detailed specification shall be as below:

Voltage Grade	600 V
Nos. of Core	As per requirement.
Conductors	Stranded Electrolytic annealed tinned copper conductor
Insulation	Extruded PVC type C
Pairs	Twisted
Individual screen	Tinned annealed copper mesh over metallised tape, in a close woven braid.
Overall shielding	Special aluminum foil to provide 100% shield coverage for optimum protection against radiated interference and ingress of audio and radio frequencies. It shall have shorting fold for metal to metal contact and isolation fold to prevent adjacent shields from shorting to one another, so as to improve the voltage breakdown characteristics. The drain wire shall be of standard tinned copper wire of 0.518 mm <sup>2</sup> . (20AWG) cross section, and shall be effectively bonded to overall screen.
Armour	As per applicable standards
Outer Sheath	FRLS thermoplastic compound, rodent proof
Spare Cores	20% spare cores but not less than 2 spares shall be provided in all the multi core cables.
Core Identification	Number Black / White for pairs. Number Black / White / Red for triples. / As per applicable standards

#### 13.3.6 Computer and data transmission cables

Cables for digital data transmission between Computers / Electronic systems for outdoor or hazardous area service shall be flame retardant as per IEC 60332 Part 3 and fire

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 13: Power & Control Cable

resistant as per IEC 60331. The data transmission cables shall have minimum armour and cable over-sheath requirement as below:

Armour	Interlocked Aluminum Armour
Sheath	FR thermoplastic compound

The details of computer and data transmission cables shall be submitted by the Contractor during detailed design phase for approval by the Employer / Engineer.

### 13.3.7 Cable accessories

The termination for use on medium voltage system shall be suitable for the type of cables offered as per this specification. The termination shall be supplied in kit form. The kit shall include all insulating and sealing materials apart from conductor fitting and consumable items. An installation instruction shall also be included in each kit. Makes of kits other than those specified may be considered by Employer if type test certificates accompany the offer. These kits are to be provided as back-up tools and are not to be used by Contractor. Joints are not permitted under any circumstances.

#### Termination kit

The terminating kits shall be suitable for termination of the cable in indoor switchgear or in a weather proof cable box of an outdoor mounted transformer / motor. The terminating kits shall preferably be one of the following types:

- “TAPEX” type using non-linear resistance material for stress grading.
- “PUSH-ON” type using factory moulded silicon rubber insulators.
- Heat - Shrink sleeve type.

For outdoor terminations, whether shields / sealing ends and any other accessories required shall also form part of the kit.

## 13.4 Testing and Inspection

### 13.4.1 General

The cables shall be tested and examined at the manufacturer's works. All the materials employed in the manufacturing of the cable shall be subjected, both before and after manufacture of the cable to examination, testing and approval by Employer. Manufacturer shall furnish all necessary information concerning the supply to Employer's inspectors. The inspector shall have free access to the manufacturer's works for the purpose of inspecting the process of manufacture in all its stages and he will have the

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 13: Power & Control Cable
---	--	---

power to reject any wire or other material which appears to him to be of unsuitable description or of unsatisfactory quality.

#### 13.4.2 PVC and XLPE cables

After completion of manufacture of cables and prior to dispatch, cables shall be subjected to type, routine, acceptance and special tests as detailed below. Employer reserves the right to witness all tests with sufficient advance notice from bidder. The test reports for all cables shall be submitted for approval by the Employer before dispatch of the cables.

All routine tests, acceptance tests, type tests as well shall be carried out on cables (as applicable IEC / IS standard).

In addition to above, the following special tests shall also be performed on the cables.

Accelerated water absorption test for insulation as per NEMA-WE-3.11.

Dielectric retention Test: The dielectric strength of the cable insulation tested in accordance with Cl. 6.7.4 of NEMA WE-5 at  $75 \pm 1^\circ\text{C}$  shall not be less than 60% of the original dielectric strength.

Oxygen Index Test: The test shall be carried out as per ASTM D 2863 - 1974 and the minimum oxygen index number should be 30.

Test for rodent and termite repulsion property: Bidder shall furnish the test details to analyze the property to chemical method.

Medium voltage cables shall be subjected to hi-pot testing after installation and after completion of termination. First a 5 kV AC "MEGGER" test shall be done to establish cable soundness and note insulation resistance. Then a DC hi-pot test shall be conducted at a level of about 45 kV DC. Voltage shall be applied progressively in 10 steps with a 60-second wait at least in between. Test report shall be provided for approval by Employer.

#### 13.4.3 Cable accessories

Type tests shall have to be carried out to prove the general qualities and design of a given type of termination / jointing system. The type test shall include the following tests conforming to the latest IEC 60502-2, 466 and VDE 0278 specifications. The type test certificates shall be submitted along with the offer.

- AC Voltage withstand dry test for 1 minute.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 13: Power & Control Cable
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- Partial discharge test - Discharge magnitude shall be less than 20%.
- Impulse voltage withstand test with 10 impulses of each polarity.
- AC high voltage test following load cycling test with conductor temperature at 90 °C.
- Thermal short circuit test at 250°C for 1 second.
- DC Voltage withstand test for 30 minutes.
- Humidity test.
- Dynamic short circuit test.
- Salt fog test.
- Impact test.
- Site testing of joints.
- Megger testing of 1100V cables.
- HIPOT and Megger testing of 33 kV cables

### 13.5 Packing and marking

Cable shall be dispatched in wooden drum of suitable barrel diameter, securely battened, with the take-off end fully protected against mechanical damage. The wood used for construction of the drum shall be properly seasoned, sound and free from defects. Wood preservatives shall be applied to the entire drum.

On flange of the drum, necessary information such as manufacturer's name, type, size, voltage, grade of cable, length of cable in meters, drum No., cable code, ISI Certification mark, gross weight, etc. shall be printed. An arrow shall be printed on the drum with suitable instruction to show the direction of rotation of the drum.

Cables shall be supplied in drum lengths as follows:

Medium voltage power cables up to and including 6 sq. mm - 1000 M.

Medium voltage power cables from 10 sq. mm up to and including 300 sq. mm - 500 M.

Control cables up to and including 27 cores - 1000 M.

33 kV XLPE Cables - 500 M.

### 13.6 Marking on the length of cable

The cable manufacturer shall be identified at every metre of the length of the cable by manufacture name or trade mark, voltage grade, cumulative length of cable and year of manufacture Embossed (Protruded) on the cable. The embossing shall be done on outer sheath of the cable.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 13: Power & Control Cable
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### 13.7 Information required with tender

Catalogue and brochure giving technical and physical details of the cable, e.g. current rating, derating factors etc.

“Type Test” certificates and “Special Test” results for cables offered.

Shelf life of cable accessories for the ambient temperature specified in the Schedule of guaranteed Performance Particulars attached.

### 13.8 Spare Parts & Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter.

#### 13.8.1 Mandatory spares

Sl. No	Item	Quantity
1	Spare cable lengths of each type and size of power, control & instrumentation cables used	5% of the total cable length but at least one length equal to the longest cable length used in the plant.
2	Termination kits for each type and size of cable	5% of the total scope of each accessory but not less than 2 pcs. of each item
3	Pre-fabricated straight through joints for each type and size of cables	---do---

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

## Volume-II

---

### Section II Sub-Section 14 Cable Trays

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

## **TABLE OF CONTENTS**

<b>14.1</b>	<b>SCOPE</b> -----	<b>3</b>
<b>14.2</b>	<b>STANDARDS</b> -----	<b>3</b>
<b>14.3</b>	<b>EQUIPMENT DESCRIPTION</b> -----	<b>4</b>
14.3.1	Metallic Cable Trays, Fittings, Accessories & Support System -----	4
14.3.2	Support System for Cable Trays-----	5
14.3.3	Trefoil Clamps-----	6
14.3.4	Pipes, Fittings & Accessories-----	7
<b>14.4</b>	<b>INSTALLATION - CABLE TRAYS AND SUPPORT SYSTEM</b> -----	<b>7</b>
<b>14.5</b>	<b>CABLE GLANDS</b> -----	<b>8</b>
<b>14.6</b>	<b>CABLE LUGS/FERRULES</b> -----	<b>9</b>
<b>14.7</b>	<b>CABLE LAYING IN TRAYS:</b> -----	<b>9</b>
<b>14.8</b>	<b>TESTING</b> -----	<b>10</b>
<b>14.9</b>	<b>SPARE PARTS &amp; SPECIAL TOOLS</b> -----	<b>11</b>
<b>14.10</b>	<b>MANDATORY SPARES</b> -----	<b>11</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

## 14 CABLE TRAYS

### 14.1 Scope

The scope of work under this section covers detailed requirements for the design, manufacture, QA, QC, shop testing, packing, transportation, delivery at site and installation of cable trays, fittings, accessories & support system for laying of all cables covered under the scope of this package. The cable tray system layout shall be submitted by the contractor for Employer's approval. All cable trays in generator transformer yard, GIS, Pothead Yard, Remote sites etc. are covered in this package.

### 14.2 Standards

Cable troughs and fittings shall confirm to the latest edition of the applicable IEC standards. All standards, specifications and codes of practice referred to herein shall be the latest editions including all applicable official amendments and revisions as on date of opening of bid. In case of conflict between this specification and those (IS, IEC standards, etc.) referred to herein, the most strict requirement shall prevail. All work shall be carried out as per the following standards/codes as applicable.

IEC 61537	Cable Management- Cable trays system & Cable ladder system
IEC 61084	Cable trunking and ducting system for electrical installations
IEC 60423	Conduit systems for cable management - Outside diameters of conduits for electrical installations and threads for conduits and fittings
IEC 60981	Extra heavy-duty electrical rigid steel conduits
IEC 62444	Cable glands for electrical installations
IEC 61238	Compression and mechanical connectors for power cables for rated voltages up to 30 kV ( $U_m = 36$ kV)
IS: 1239	Mild steel tubes, tubular and other wrought steel fittings
IS: 1255	Code of practice for installation and maintenance of power cables upto and including 33 kV rating
IS: 1367	Technical supply conditions for threaded Steel fasteners (Hot dipPart-13 galvanized coatings on threaded fasteners)
IS: 2629	Recommended practice for hot dip galvanizing of iron & steel

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

IS: 2633	Method for testing uniformity of coating on zinc coated articles
IS: 3063	Fasteners single coil rectangular section spring washers
IS: 6745	Methods for determination of mass of zinc coating on zinc coated iron & steel articles
IS: 9537	Conduits for electrical installation
IS: 316	Code of practice for use of metal arc welding for general construction in mild steel
IS: 277	Galvanized sheet steel
BS: 476	Fire tests on building materials and structures

### 14.3 Equipment Description

#### 14.3.1 Metallic Cable Trays, Fittings, Accessories & Support System

Cable trays shall be ladder/perforated type as specified complete with matching fittings (like brackets, elbows, bends, reducers, tees, crosses, etc.) accessories (like side coupler plates, etc. and hardware (like bolts, nuts, washers, G.I. strap, hook etc.) as required. Cable tray shall be ladder type for power cable and perforated type for control & instrumentation cable.

Cable trays, fittings and accessories shall be fabricated out of rolled mild steel sheets free from flaws such as laminations, rolling marks, pitting etc. These (including hardware) shall be hot dip galvanized after fabrication as per relevant IEC and IS standards. Cable trays shall have standard width of 300 mm, 600 mm & 750 mm and standard lengths of 3.0 meter. Minimum thickness of mild steel sheets used for fabrication of cable trays and fittings shall be 2 mm. The thickness of side coupler plates shall be minimum 3 mm. Ladder type trays shall have a rung spacing of 300 mm for power cable application and 150 mm for control and communication cables.

Cable troughs shall be required for branching out few cables from main cable route. These shall be U-shaped, fabricated of mild steel sheets of minimum thickness 2 mm and shall be hot dip galvanized after fabrication as per relevant IS. Troughs shall be standard width of 50 mm & 75 mm with depth of 25 mm.

Cable trays shall be designed and manufactured in accordance with the NEMA standards Publication No. VE 1-1979. The trays shall be hot dip galvanized after

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

fabrication in accordance with ASTM A 386.

Filling of cable trays shall be in accordance with Indian regulations, the North American National Codes (CSA Standard C 22.1) or NEC ANSI/NFPA-70-1981.

The cable trays shall have the following design characteristics:

Width	Design Support	Design Load
300 mm	1.5 m	67 kg/m
600 mm	1.5 m	67 kg/m
750 mm	1.5 m	112 kg/m

The table above is based on tray sections of 3 meters long that are supported every 1.5 meters. Shorter sections requirement more supports. Each section no matter its length must have at least one support.

All ladder and perforated tray bends, T's and crosses shall have a 600 mm inner radius.

#### 14.3.2 Support System for Cable Trays

Cable tray support system shall be pre-fabricated galvanized steel U shaped channels and hardware similar or equivalent to «Unistrut» brand.

Support system for cable trays shall essentially comprise of the two components i.e. main support channel and cantilever arms. The cable tray support shall be designed to support twice the rated weight of the cable tray. As an example, a 600 mm tray with supports spaced 1500 mm can carry 200 kg (67kg × 3m); thus the support must be designed to support 400 kg. The main support channel shall be of two types:

- C1:- having provision of supporting cable trays on one side and
- C2:- having provision of supporting cable trays on both sides. The support system shall be the type described hereunder.
  - a) Cable supporting steel work for cable racks/cables shall comprise of various channel sections, cantilever arms, various brackets, clamps, floor plates, all hardware such as lock washers, hexagon nuts, hexagon head bolt, support hooks, stud nuts, hexagon head screw, channel nut, channel spring nuts,, fixing studs, etc.
  - b) The system shall be designed such that it allows easy assembly at site by using

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

bolting. All cable supporting steel work, hardware fittings and accessories shall be prefabricated factory galvanized.

- c) The main support and cantilever arms shall be fixed at site using necessary brackets, clamps, fittings, bolts, nuts and other hardware etc. to form various arrangements required to support the cable trays. Welding of the components shall not be allowed. However, welding of the bracket (to which the main support channel is bolted) to the overhead beams, structural steel, insert plates or reinforcement bars will be permitted. Any cutting or welding of the galvanized surface shall be brushed and red lead primer, oil primer & aluminum paint shall be applied
- d) All steel components, accessories, fittings and hardware shall be hot dip galvanized after completing welding, cutting, drilling and other machining operation
- e) The main Support channel and cantilever arms shall be fabricated out of minimum 2.5mm thick rolled steel sheet conforming to IEC and IS.
- f) Cantilever arms as required shall be provided. The arm portion shall be suitable for assembling the complete arm assembly on to component constructed of standard channel section. The back plate shall allow sufficient clearance for fixing bolt to be tightened with tray in position.

The size of structural steel members or thickness of sheet steel of main support channel and cantilever arms and other accessories as indicated above or in the enclosed drawings are indicative only. Nevertheless, the support system shall be designed by the Tenderer to fully meet the requirements of type tests as specified. In case the system fails in the tests, the components design modification shall be done by the Tenderer without any additional cost to the Employer. The tenderer shall submit the detailed typical drawings of the system offered by him along with the bid.

#### 14.3.3 Trefoil Clamps

Trefoil clamps shall be supplied suitable for single core 33kV Grade XLPE cables of suitable size.

Trefoil clamps for single core cables shall be of aluminum alloy and shall include necessary fixing GI nuts, bolts, washer etc. These are required at every 2 meter of cable



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

runs

#### 14.3.4 Pipes, Fittings & Accessories

Pipes offered shall be complete with fittings and accessories (like tees, elbows, bends, check nuts, bushings, reducers, enlargers, coupling caps, nipples etc.) The size of the pipe shall be selected on the basis of maximum 40% fill criteria. GI Pipes shall be of heavy duty as per IEC and IS standards. Duct Banks shall be provided with GI pipes encased in PCC (10% spare of each size, subject to minimum one) with suitable water-proof termination boxes.

#### 14.4 Installation - Cable Trays and Support System

Cables shall run in cable trays mounted horizontally or vertically on cable tray support system which in turn shall be supported from floor, ceiling, overhead structures, trestles, pipe racks, trenches or other building structures. Cable trays shall be installed in a way to allow access for cable laying. An access of not less than 750 mm must be provided on one side of each cable tray run.

Horizontally running cable trays shall be clamped by bolting to cantilever arms at an interval of 1500 mm or less. Vertically running cable trays shall be bolted to main support channel by suitable bracket/clamps on both top and bottom side rails at an interval of 1000 mm. For vertical cable risers/shafts cable trays shall be supported at an interval of 1000mm. Fixing of cable trays to cantilever arms or main support channel by welding shall not be accepted. Cable tray installation shall generally be carried out as per the approved drawings.

Where the cables leave cable trays to enter equipment or to pass through floor or wall openings or where it is not possible to support cables by means of tray, the cables shall be adequately supported by means of suitable racks and clamps, subject to approval by the Employer/ Engineer.

The cantilever arms shall be positioned on the main support channel with a minimum vertical spacing of 300 mm unless otherwise indicated in the relevant tray layout drawings.

The contractor shall fix the brackets, Clamps, insert plates using anchor fasteners. Minimum size of anchor fasteners shall be M 8 X 50 and material shall be stainless steel

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

grade 316 or better. Anchor fastener shall be fixed as recommended by manufacturer and as approved by site engineer. For brick wall, suitable anchor fasteners shall be used as per the recommendations of manufacturer. Make of anchor fasteners shall be subjected to QA approval.

All cable way sections shall have identification, designations as per cable way layout drawings and painted/stenciled at each end of cable way and where there is a branch connection to another cable way. Minimum height of letter shall be not less than 75 mm. For long lengths of trays, the identification shall be painted at every 10 meter. Risers shall additionally be stencil painted with identification numbers at every floor.

In certain cases, it may be necessary to site fabricate some of the portions of trays, supports and other non standard bends where the normal prefabricated trays, supports and accessories may not be suitable. In such cases the Contractor shall fabricate at site, suitable sections of trays, supports and accessories to make the installation complete for the specific purpose after obtaining employer's prior approval, which shall be neat in appearance and shall match with the prefabricated sections in the dimensions. They shall be applied with one coat of red lead primer, one coat of oil primer followed by two finishing coats of aluminum paint.

All steelwork supports shall be designed with a factor of safety not less than four.

The installed cable tray systems shall be rigid and have all components firmly bolted and in good electrical contact with the earthing grid.

The contractor shall supply and install galvanized steel cable tray covers, as directed by the Employer/Engineer, where cables are liable to mechanical damage or the effect of wind, rain and sun.

Pre-fabricated galvanized steel barriers shall be supplied and installed, if deemed necessary and/or as directed by the Employer/ Engineer.

Where single conductor cables are installed to form a 3-phase feeder, they shall be secured in place by means of non-magnetic cable clamps as per standards.

#### **14.5 Cable Glands**

Cable shall be terminated using double compression type cable glands. Cable glands shall conform to IEC and be of robust construction capable of clamping cable and cable

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

armor (for armored cables) firmly without injury to insulation. Cable glands shall be made of heavy duty brass machine finished and nickel chrome plated. Thickness of plating shall not be less than 10 micron. All washers and hardware shall also be made of brass with nickel chrome plating. Rubber components shall be of neoprene and of tested quality.

#### **14.6 Cable lugs/Ferrules**

Cable lugs for power cables shall be Tinned Copper solder-less crimping type conforming to IEC and IS standards suitable for aluminum/ copper compacted conductor cables. Cable lugs and ferrules for control cables shall be tinned copper conforming to IEC and IS standards. The lugs for control cables shall be provided with insulating sleeve and shall suit the type of terminals provided on the equipment. Cables lugs shall be compressed using compression tools and dye approved by the lug manufacturer. The contractor must choose the right dye for each type and size of lug.

#### **14.7 Cable Laying in Trays:**

- The following provisions shall be made during the laying of cables in the trays  
Identification tags for cables

Indelible tags to be provided at all terminations, on both sides of wall or floor crossing, on each conduit/duct/pipe entry/exit, and at every 20 m in cable trench/tray or buried run.

- Cable tray numbering and marking

To be provided at every 10 m and at each end of cable way and branch connection.

- Joints

Joints for less than 250 Meters run of cable shall not be permitted. Joint marker shall be provided. Extra length shall be provided for one joint for LT and two joints for HT at a later stage.

- Buried cable protection

With concrete slabs for HT and bricks for LT. Route markers at every 20 Meters along the route and at every bend.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

- Road crossings

Cables to pass through buried high density PE pipes encased in PCC.

- Separation

At least 300mm between HT power & LT power cables, LT power and LT control/ instrumentation cables. Spacing between cables of same voltage grade shall be in accordance with the derating criteria adapted for cable sizing.

- Segregation

All cables associated with the unit shall be segregated from cables of other units.

Interplant cables of station auxiliaries and unit critical drives shall be segregated in such a way that not more than half of the drives are lost in case of single incident of fire. Power and control cables for AC drives and corresponding emergency AC or DC drives shall be laid in segregated routes. Cable routes for one set of auxiliaries of same unit shall be segregated from the other set. Segregation means physical isolation to prevent fire jumping or minimum one hour fire rating.

In switchyard control cables of each bay shall be laid on separate racks/trays.

- Cable clamping

All cables laid on trays shall be neatly dressed up & suitable clamped/ tied to the tray. For cables in trefoil formation, trefoil clamps shall be provided.

- Cable fire protection

Wherever the cables pass through walls/floors, fire proof cable penetration seals rated for one hour shall be provided. This shall be by suitable block system using individual blocks with suitable framework or by silicon RTV foaming system. In case foaming system is offered, damming board, if used, shall not be considered for fire rating criteria. Any of the system offered shall be of proven type as per BS:476 (Part-20) or equivalent standard.

## 14.8 Testing

A sample of cable trays shall be subjected to the Preece test detailed in ASTM A239

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 14 Cable Trays

standard.

#### **14.9 Spare Parts & Special Tools**

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter.

#### **14.10 Mandatory spares**

5% of the total cable tray length of each type including accessories.

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

## Volume-II

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### Section II Sub-Section 15 Communication System & CCTV System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

## TABLE OF CONTENTS

<b>15</b>	<b>COMMUNICATION SYSTEM &amp; CCTV SYSTEM .....</b>	<b>3</b>
<b>15.1</b>	<b>Scope of Work.....</b>	<b>3</b>
15.1.1	Public address (PA) system .....	3
15.1.2	Microprocessor based (digital) EPABX system.....	3
15.1.3	CCTV system.....	3
<b>15.2</b>	<b>Specific parameters and layout conditions .....</b>	<b>4</b>
<b>15.3</b>	<b>Standards .....</b>	<b>4</b>
<b>15.4</b>	<b>Communication System.....</b>	<b>5</b>
15.4.1	Rating and functional characteristics .....	5
15.4.2	Performance guarantee .....	5
15.4.3	Design and construction .....	6
<b>15.5</b>	<b>CCTV System .....</b>	<b>9</b>
15.5.1	General.....	9
15.5.2	System requirements.....	9
15.5.3	Equipment details .....	10
<b>15.6</b>	<b>Junction boxes.....</b>	<b>18</b>
<b>15.7</b>	<b>Cables .....</b>	<b>19</b>
<b>15.8</b>	<b>Drawings, Documents and Design Calculations .....</b>	<b>19</b>
<b>15.9</b>	<b>Packing &amp; Transportation .....</b>	<b>20</b>
<b>15.10</b>	<b>Name Plate &amp; Labels .....</b>	<b>20</b>
<b>15.11</b>	<b>Spare Parts and Special Tools .....</b>	<b>20</b>
15.11.1	Mandatory Spares .....	20



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

## **15 COMMUNICATION SYSTEM & CCTV SYSTEM**

### **15.1 Scope of Work**

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, training of Employer's personnel, handing over to Employer for trouble free operation at least for five years of communication and surveillance system (CCTV).

The scope of work shall be a comprehensive functional system covering all supply and services including but not be limited to following.

#### **15.1.1 Public address (PA) system**

- Master Control Station (MCS) including microphone and all accessories required for the system;
- Central control equipment consisting of Central-switching system (CSS); Central paging control and amplifier rack, preamplifier, power amplifiers and all required accessories;
- Field handset stations consisting telephone set with wall / column / structure mounting arrangements etc.;
- Loud speakers / Hooters with wall / column / structure mounting arrangements;
- Head microphones.

#### **15.1.2 Microprocessor based (digital) EPABX system**

- 128 lines EPABX;
- Telephone sets;
- Sockets / telephone jacks for the telephone wiring network;
- The telephone cabling system.

#### **15.1.3 CCTV system**

- Fixed colored cameras with vari focal length lenses;
- Camera mounting platforms / structures;
- Receiver Driver unit;
- Matrix switcher;
- Key board unit;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

- Digital video recorder;
- Control console;
- Color video monitors;
- Interconnecting power, video and control cables;
- Video distribution amplifiers / Video cable equalizers, as per requirement;
- Alarm annunciator;
- All other auxiliary equipment, connectors, erection accessories etc. as required.

## 15.2 Specific parameters and layout conditions

(A) The major areas covered are as follows:

- Power House Block (all floors);
- All floors of control block (including priority distribution in rooms on different floors);
- Pothead Yard;
- Staircases lift well and other utility areas;
- Remote Sites (Intake Control Room & Valve House)
- Entrance gate and facilities.

(B) Available Power Supplies:

- 240V, 50Hz, 1 Phase UPS supply (redundant);
- 48 V (+15%-10%), DC supply (redundant).

## 15.3 Standards

The system and equipment shall be designed, built, tested and installed to the latest revisions of the following applicable-standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose

Standards	Description
IEC 60065	Audio, video and similar electronic apparatus-Safety requirements
IEC 60326	Printed Boards
IEC 60446	Basic and safety principles for man-machine interface, marking and identification, identification of conductors by colours or numerals
IEC 60478	Stabilized power supplies, DC output

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

IEC 60870-5	Tele-control equipment and systems
IS 10426	Specification for public address amplifier
IS 1881	Code of practice for indoor installation of public address system
IS 1882	Code of practice for outdoor installation of public address system
IS 9302	Characteristics and method of measurement for sound systems equipment

#### 15.4 Communication System

The communication system shall consist of zones, sub-zones and exchanges to interface all the zones among themselves and with Employer's existing telephone exchange (If any).

The communication system shall cover all operational areas of Power house complex, Pothead yard and tail race outlet area.

The entire system shall comprise of following:

- Public Address system;
- EPABX system.

The main panel of the public address system shall be located in the control room of the powerhouse. The loud speakers, Hooters, the head microphones, the call station connecting points and the other telephone connecting points shall be located at various points.

The system shall be adequately protected from signal and power line noise and meet the surge withstand capability requirements of ANSI C37.90 A / IEEE standard 472-1989 equivalent.

##### 15.4.1 Rating and functional characteristics

Capacity and bandwidth ( $\pm 3\text{dB}$ ) for outdoor wall / column mounted horn type loudspeakers shall be at least 4W (rms) and 100 -7000 Hz respectively.

Capacity and bandwidth ( $\pm 3\text{dB}$ ) for indoor wall / column mounted cone type loudspeakers shall be at least 4W (rms) and 100 -7000 Hz respectively.

##### 15.4.2 Performance guarantee

The communication along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of the complete

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

system

#### 15.4.3 Design and construction

##### 15.4.3.1 Public address system

Public address system shall be a microprocessor controlled software programmable, centralized amplifier based system.

System shall be comprised of two main channels:

i. Page channel:

This provides loud speaking facility and is used to broadcast / announce messages, instructions and to locate field people in the plant. The loudspeakers can be arranged indifferent groups and the announcements can be made either to individual groups or all groups together.

ii. Party channel:

It shall be used for carrying prolonged conversations in private mode, which shall not be heard over the loudspeakers. The system possesses multiple party channels i.e. one dedicated channel for each field handset station

#### (A) Master Control Station (MCS)

Master Control Station shall be microprocessor based and of modular design. It shall be desktop type construction and installed in the control room.

The MCS shall comprise of at least the following-

- Two (2) dynamic microphones;
- All zone / Individual zone selection switches;
- Field paging 'ON' indication;
- Press to talk switch;
- Digital display for identification of calling station number and area name;
- Dial key pad;
- Function keys (programmable for different features of the system like call answer, call transfer, call release, call end, call hold, call wait, memory dialing, Redial etc.);
- Hands free dialing;
- Monitor the functionality and status of individual field handset stations;
- Automatic fire alarm tone generation.

It shall be possible that during an emergency control room operator can

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

broadcast siren / alarm tone in selected or all zones.

Control room operator shall have page priority over the paging from field.

(B) Central control equipment

Following Central control equipment shall be located in the control room,

i. Central switching system (CSS)

CSS shall be in non-blocking architecture and based on TDM / PCM technology or state of art technology which shall have improved speech quality and the noise interference and the distortion is reduced to minimum.

ii. Central paging control and amplifier rack

The racks shall be designed for free floor standing. The system shall have high reliability amplifiers with built in protection circuitry. The system shall be provided with standby amplifier with changeover circuitry to ensure continuous operation at all times. The system shall have provision in the amplifier for further expansions to meet the requirements. The rack shall have preamplifier with built in MIC and AUX input, Control panel, Power supply unit, Individual / all zone selection switch, Chime module, siren access, Priority matrix, etc.

Central paging control and amplifier rack shall have solid state, class-B, Push-pull type Power amplifiers fully conforming to international standard.

Total harmonic distortion shall be less than 1 % at rated output at 1 KHz, Signal / Noise ratio shall be 60 dB.

All the heat generating devices shall be operated well within their rated limits to minimize the thermal stresses. The temperature sensors shall be provided on the heat sinks to monitor the temperature. The Amplifier shall comprise of at least following minimum features:

- Mains power supply;
- Mix and match capabilities;
- Adjustable sensitivity as volume control with facility for coarse and fine setting;
- Bass and treble control;
- Electronic protection.

(C) Field handset stations

The field handset station shall be weatherproof and located / installed at

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

multiple locations in the indoor and outdoor field locations. These shall be wall / column / structure mounted.

The handset stations in the noisy areas shall be housed in acoustic hoods. The design noise level within the hood shall be limited to a maximum of 60 db SIL.

Handset transmitter / microphone shall be noise cancelling type for effective communication from noisy areas. The handset shall consist of push button type keys, handset cord protected in SS metallic tubing and external canopy in fibre for extra protection. Handset transmitter / microphone shall have filters to protect from dust.

The weatherproof station for outdoor areas shall, be made of corrosion resistance aluminum alloy.

#### (D) Loudspeaker / Hooters

The loudspeaker and Hooters shall be weatherproof and located / installed at multiple locations in the indoor and outdoor field locations. These shall be wall / column / structure mounted.

Loudspeaker shall have control switch to vary the loudspeaker output. Its cabinet shall be treated with acoustic under-coats to prevent resonance.

#### 15.4.3.2 EPABX system

The EPABX system shall be fully automatic microprocessor based, stand alone modular system with one touch line / feature selection and flexible user friendly programmable push buttons. The system shall support full duplex voice and data transmission on a twisted pair line. The system shall have at least 128 subscriber ports with future expandability of another 128 ports and 8 line ports and ISDN port. The system shall be integrated with public address system. Control rooms, offices, facilities, utilities, cabinets, cubicles and rooms containing equipment requiring maintenance shall be equipped with sockets for the telephone network.

The type and standard shall be submitted to the Employer for review and approval. The number of points shall be according to the following:

- At least one telephone outlet for every five meter in office area and fifteen meter in other areas;
- One outlet in each cabinet and cubicle;
- Two outlets in each office room.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

EPABX system shall also have features based on suitable technology for mobile connectivity with project area.

EPABX system shall also be capable for VOIP transmission. At least following features shall be provided:

- P and T line connectivity, Call transfer, Call back, Call forwarding, Account code, Group calling, Conference facility, Messages wait lamps etc;
- Sixty four (64) telephone sets with at least following features shall be provided:
  - Redialing, Adequate memory for storage of minimum 10-15 numbers, hands free answer and dialing.

## 15.5 CCTV System

### 15.5.1 General

The Closed Circuit Video Monitoring System will be provided for comprehensive round the clock surveillance for control and supervision of technological processes at points which are difficult to be observed directly or which require monitoring from a remote control center by operational people as well as access monitoring. The system consists of colour cameras (CCD type) with fixed lens, weather proof housing, 22" TFT color monitor, monitor console, Receiver Driver unit, matrix switcher, Digital Video recorder, camera mounting platforms / structures, control console with control units for complete control of the cameras. Inter connecting video and control cables, Video distribution amplifiers / Video cable equalizers (if required), and all other auxiliary equipment, connectors and erection accessories etc. as required for completeness of the system.

### 15.5.2 System requirements.

The cameras will be of Charge Coupled Device (CCD) type and these will be mounted in such a manner as to provide continuous monitoring of the critical processes / operation of the shop floor as required.

The system will provide clear and sharp picture on monitors in industrial lighting conditions at any time of the day or night

The complete CCVM Systems will work on 240 V  $\pm$  10%, 50Hz  $\pm$  2 Hz, single phase AC supply. In case any other power source is required, the same will be arranged from the above available source. The CCVM system will be provided power from an uninterrupted power supply system for feeding stabilized and continuous



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

power supply to all equipment.

All equipment for C.C.V.M systems covered in this specification will comply with the IEEE / IEC standards.

All control functions related to the CCVM Systems comprising Cameras and Monitors of the weatherproof housing will be effected from the control units, which are to be installed in the control rooms of the shop.

All the CCTV Cameras shall be multiplexed to suitable number of monitors. The CCTV Cameras along with multiplexing and control shall be interfaced to the operator stations.

### 15.5.3 Equipment details

#### (A) Camera

The cameras will be compact, of rugged design and suitable for industrial continuous monitoring applications.

These will be specially designed and tested to provide continuous good quality video output throughout wide variations in environment conditions like temperature, humidity, shock and vibrations and varying light condition prevalent in the hydro power plant.

The cameras will use 1 / 3" format interline transfer CCD imager and have virtually zero lag, no image burns and no geometric distortion. These will be of latest state of art technology ensuring high operational reliability.

The cameras shall deliver well defined, clear, high resolution colored picture, with sufficient contrast to allow for good object recognition even in poor light conditions. A highly sensitive automatic light compensation circuit will ensure constant video signal independent of wide variations in light levels.

The cameras will have long life and require virtually zero maintenance in adverse environmental conditions prevalent in the hydro plant.

The Cameras will also possess the following features:

- High resolution;
- Low power consumption;
- Phase adjustable line lock facility;
- All controls like back focus, lens select, phase adjustment, power ON / OFF

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

etc,

- The camera unit will be complete with all electronic circuitry, devices, components, control switches, standard mount for lenses, mounting assemblies etc. The mounting assemblies of the cameras will be individually selected depending upon the special requirements as per actual site conditions.

Color cameras of 1 / 3" or 1 / 4th format with iris lenses are envisaged to suit different requirements of site. The camera shall be color CCD type, high resolution of minimum 450 TV lines. All outdoor cameras shall be provided with sun shield.

It will also possess the following features:

- Pick-up device- 1 / 3rd inch or 1 / 4th inch format, interline transfer, CCD image sensor;
- Minimum illumination- 0.5 lux at f 1.2;
- Signal to noise ratio- 46dB minimum;
- Electronic Shutter- Automatic, On / off selectable;
- Video outputs- Composite video - 1.0 V p-p, 75 ohm;
- AGC- On / Off selectable;
- Aperture Correction- Horizontal and Vertical;
- Synchronization- Line lock- for roll-free vertical interval Switching- Crystal lock;
- Connectors- Video out: BNC, Video / DC-Iris connector: 4-pinEIAJ;
- Operating Temperature- as per location indicated;
- EMC- CE and UL certification.

#### (B) Camera lens

The camera lens will be suitable for the camera on which it is to be mounted. The lenses chosen will be Auto iris, vari focal lens so as to meet the operational requirements. The choice of lenses, their focal length and viewing angle will be judiciously done for effective monitoring suited to the specific application requirements.

#### (C) Camera mounting platform

The camera mounting platform will be suitable for mounting the camera assembly on walls / column / structures as per the actual requirements at site and keeping

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

in view the area to be covered by the individual camera. The mounting will be with adjustable support so as to have flexibility to move the camera assembly as and when required. Wherever necessary, structures / vertical poles to mount the cameras shall be fabricated.

**(D) Receiver Driver Unit**

The receiver shall be able to receive command signals from the operators keyboard through the CPU / Matrix and execute them. The unit shall generate the power for the enclosure, camera, lens etc.

Receiver driver unit shall comply min IP65 for outdoor. The equipment shall be CE / UL certified.

The receiver driver unit shall withstand the temperature indicated for the corresponding area.

**(E) Microprocessor based Matrix Switcher**

To control the C.C.V.M system microprocessor based matrix switchers are envisaged. The system shall have matrix switchers at control rooms.

At control rooms matrix switchers of suitable inputs and outputs and alarm interface units are provided for switcher to handle the alarm events.

The switcher system shall provide minimum the following basic features

- Full matrix switching;
- Synchronized video switching;
- A logging printer port which provides a hardcopy printout of either the system status changes or system Tables and Sequences;
- Keyboard log-on / log-off with password protection;
- 16 character camera titling;
- Accommodation of alarm points;
- CE / UL certification.

The matrix switcher must be modular in construction i.e. should have Main base having CPU, power supply and main bay, and required number of input and output cards must be put in the bay for configuring a solution. The system should allow multiple number of keyboards to be directly connected to it in star configuration. It should allow prioritizing the keyboards as per the requirement.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

It will also possess the following features:

- Video Inputs - as per requirement;
- Video outputs - as per requirement;
- RS-232 Ports - 1 each for PC, printer and alarm signals;
- Input voltage level - 0.5 V p-p to 2.0 V p-p, Composite Negative Sync;
- Gain - Unity (75 ohm terminated);
- Switching - Cross point Matrix;
- Features - Full matrix switching, any camera to any monitor;
  - Programmable switching sequences;
  - Salvo switching capability;
  - min 40 character on screen display for time- date, camera number, camera ID, monitor or status information and 16 character alarm titling
  - With the keyboard,
- Operating Temperature - as per locations indicated
- Humidity - as per locations indicated, non-condensing.
- EMC - CE / UL certified

An additional alarm interface unit shall be also supplied along with the above switcher. The unit shall have the ability to automatically display video under alarm conditions. It shall accept up to 32 contact closures or logic level inputs from remote sensing devices. The unit shall also provide 8 relay closure outputs upon alarm conditions.

(F) Key Board for matrix switcher

Keyboard is envisaged for full function, for system control and programming at control rooms.

It will also possess the following features:

- Control of Matrix switcher;
- Soft backlit keys with user friendly menu and easy to read display;
- Shall be interfaced to Matrix switcher for control of Camera selection;
- LCD display of complete menu for selection of various functions;
- CE / UL certification;
- RJ11 connector for matrix switcher (power / data);
- Aux. power, for extended distances;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

- RS-232 port for remote programming;
- Other standard connectors.

(G) Digital Color Multiplexer Cum Recorder

This multiplexer and integrated digital recorder provides multi-camera recording and playback with the added capability of multiscreen viewing. Programming is easily accomplished via front panel control keys and on-screen displays menus.

The duplex multiplexer / recorder can encode up to 8 / 16 color video inputs on its internal hard drive while simultaneously displaying video in the full screen or any of the multi-screen modes.

The multiplexer specified shall be designed to record (encode) and playback (decode) up to 8 / 16 color cameras. The unit shall also have the added capability of multiscreen viewing.

In playback (DECODE mode), the multiplexer shall provide a full screen display of any of the sixteen previously recorded cameras or it can display a selection of any of the cameras in various multi-screen modes.

The multiplexer / recording shall allow instant access to critical recordings by alarm, time, date, and camera searches.

The multiplexer / recorder, in addition to camera video, shall provide the time and date, camera number, and a user programmable 16 character camera title, which is recorded.

The multiplexer / recorder shall provide, but not be limited to, the additional following features:

- On-screen menu programming;
- Sequencing of cameras;
- Video loss with on-screen indication;
- Freeze function;
- Action / Alarm output relay contacts;
- Password access protection;

The multiplexer / recorder shall use good compression technology for high quality video, and shall include a minimum hard drive capacity for storing data for 24hrs X 15 days. The multiplexer / recorder shall include a SCSI-2 / USB port for archiving video to external media.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

A 22" color monitor shall also be supplied along with above for viewing multiplexed / recorded video.

The multiplexer / recorder shall be designed for use as a desk top unit or may rack mounted using an optional rack mount kit.

It will also possess the following features:

- Video Standard - PAL, 625 line, 50 Hz;
- AGC - Automatic or manually adjust for each video input;
- Inputs - Camera: 8 /16inputs; 16 / 32 BNC connectors. Automatic
- looping termination;
- Outputs - min 2 composite monitor outputs;
- Recording - extremely high quality video recording for 15 days storing
- Capacity;
- Digital Memory
- Recording modes - Selectable from 0.1 IPS to real time recording, max
- recording speed 50 IPS for 16 cameras (max);
- Resolution of recording - High, medium and low quality;
- Input voltage level - 0.5 V p-p to 2.0 V p-p, Composite Video signal;
- Display Modes - On monitor A - Full, quad and various combinations of multi-screen viewing;
- Features - controls with keyboard
  - Motion detection with direction sensing
  - Programming via included software
  - Sequencing of cameras
  - Video loss with on-screen indication
  - Instant access to critical recording by alarm, time, date and camera searches
  - Display of time, date, camera number and user programmable 16 character camera title for viewing and recorded information;
- Ethernet port (RJ-45) -- For network video access, shall be provided. Remote viewer software to allow simultaneous access shall be also provided;
- EMC - CE / UL certified.

#### (H) CCVM Monitors

The CCVM monitors will be suitable for industrial applications and compatible for

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

the cameras. These will be of fully solid state type, modular in design, have low radiation and provide a bright, clear, well defined and high resolution picture display on the Screen.

All controls for power supply on / off, brightness, contrast, color, vertical hold, horizontal hold, etc. will be provided on the front panel behind the flip open protective cover for readily adjusting the video signal. The input and output video connectors for coupling the video input / output to other equipment, DC restoration switch and power supply connections will be provided on the rear panel. The monitor will have easy access for servicing and other adjustments.

The monitors will be housed in a dust-proof metal enclosure with anti-dazzling light shield. It will be suitable for rack mounting / mounting on control console / ceiling hang type as per the site requirement at a convenient viewing angle.

(I) Control Console

The control console shall house matrix switcher, Keyboard, Multiplexer and recorder and other control equipment, interfacing modules required for control of complete system. The console shall be of industrial usage, dust and vermin proof. It shall be located in control room. The console shall be of pre-wired ready for installation and commissioning.

Required protections and cooling arrangements shall be incorporated. The equipment shall meet IP54. Control of temperature indication of camera and audio visual alarm indication in case the temperature violates the desired limits shall also be housed.

(J) Video cable equalizers

The video cable equalizers will be used to compensate for high frequency losses due to long runs of coaxial cable used between the camera and video monitor.

(K) Surge Protection

Surge protection for video, power and control signals shall be given for cameras and associated equipment at both ends. The equipment shall protect cameras and associated equipment in case of surge. It shall be as per IEEE / IEC standards.

Required junction boxes and associated equipment shall be supplied to complete the installation in all respects.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

Surge capability shall be of min 10kA and UL / CE listed.

#### (L) Cables

For connecting the control room equipment with field equipment following cables are envisaged. Co-axial cable for video signal transmission, twisted pair shielded cable for controlling cameras are envisaged.

- Co-axial cables are envisaged for video signal transmission for cameras which are up to 300mts distance. Beyond 300 mts post equalizing amplifier shall be used;
- Independent control and video cables are envisaged for these cameras.
- Independent power cable for each camera to be provided;
- Booster amplifier shall be used wherever video signal is weak;
- The following criteria shall be used for selection of cables-  
Power supply cable : min 2.5 sq.mm  
Control cable : min 2.5 sq.mm

While designing cable layout and selection of multi core cable the following criteria must be satisfied.

- Minimum 20% of pairs shall be considered as spare subject to min one pair;
- All cables shall be of FRLS type.

#### Video Cable:

The specifications shall be as under:

- Center conductor size - 7 / 0.4 mm Annealed Tinned Copper (ATC);
- Di-electric material. - Polyethylene (PE), White color;
- Shield material - Copper braided;
- Jacket material - FRLS PVC BLUE;
- Armour - 1.4 mm GI wire round;
- Outer jacket thickness - 1.2 mm FRLS;
- Outer jacket - FRLS PVC BLUE;
- Nominal impedance. - 75 ohms.

#### Power Supply Cable:

The specifications shall be as under:

- No of cores - min 3 (three);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

- Conductor size - min 2.5 sq mm, 7 / 0.68 multi strand with standard
- Annealed electrolytic copper conductor;
- Primary insulation - PVC insulated of 85° C PVC;
- Thickness of PVC insulation - 0.8 mm;
- Color code - Red, Black and Green;
- Inner and Outer Jacket - Extruded Flame retardant and 90° C PVC;
- Armoring -- Galvanised Steel Wire / flat

The above cables shall also have the following:

- a. Fire retardant shall be as per standard IEC 332 part III Cat A.
- b. The insulation grade shall be 600 V / 1100 V as a minimum and shall meet insulation resistance, voltage and spark test requirement.
- c. Armour over inner jacket shall be of galvanized steel wire / flat.

#### Twisted Pair Cable

The specifications shall be as under:

- No of pairs - as required;
- Conductor size - 2.5 sq mm standard annealed electrolytic copper.

Conductor;

- Primary insulation - Low density polyethylene (LDPE) / PE;
- Thickness of insulation - 0.5 mm;
- Pair shielding - Aluminum backed by mylar / polyester;
- Drain wire - 0.5 sq mm multistrand bare tinned;
- Inner and Outer jacket -- Extruded flame retardant and 90° C PVC;
- The cable shall be as per IEC / IEEE standard.

### **15.6 Junction boxes**

Junction boxes shall be used for connecting field handset stations, loudspeakers, etc from central equipment. The Junction box shall be constructed with suitable locking arrangement.

All junction boxes shall have minimum 20% spare terminals for future requirements.

Junction box shall be of 4-way type having opening on each side. The degree of protection shall be minimum IP65. Disconnecting (sliding) cage clamp type terminal

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

blocks shall be provided, to facilitate testing and maintenance without disconnecting the cables

## 15.7 Cables

Cables for use in communication shall be of FRLS PVC sheathed cables and shall conform to latest edition of international standards. Cables shall be suitable for installation as follows:

- Above ground in open air location (tray / ducts) in tropical, humid and corrosive atmosphere prevalent in power plant;
- Direct buried in underground Frenches conduits with uncontrolled back fill and possibility of flooding by water and chemicals;
- Laid underground in RCC lined cable trenches with possibility of flooding by water.

Cabling shall be done at various important location of the powerhouse to ensure the portable camera connection wherever needed.

Redundant single mode underground optical fibre link, complete in all respects, shall be used for public addressing between power house and dam.

## 15.8 Drawings, Documents and Design Calculations

### Drawings and documents

The list of drawings / documents which are to be submitted to the Employer shall be discussed and finalised by the Employer at the time of award.

The Contractor shall necessarily submit all the drawings / documents unless anything is waived. The Contractor shall also supply calculations, studies, bills of material, Input and Output lists, operating sequences, setting reports, cable schedule, wiring and connection schematics and pre commissioning test procedures and reports.

### Design calculations

The Contractor shall submit the design calculation covering at least the following, for review / acceptance.

- Calculation for echo sound generated in the powerhouse;
- Design calculation for selecting number of loudspeaker with power output,

The Contractor shall also provide other calculations as required by the Engineer for

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

his approval of the Contractor's design.

## 15.9 Packing & Transportation

All the equipment and supporting accessories shall be suitably packed as per the standard practice, while dispatching from the works. Although the method of packing is left to the discretion of the manufacturer, it should be robust enough for rough handling as the equipment shall be moving in hilly region. Manufacturer shall take additional care in packing of material for transportation, so that it does not get damaged during transit due to vibration / jerks / tilting etc normally encountered during transportation by sea / road / rail in hilly terrain.

All accessories shall be dispatched in suitable boxes or crates. They shall be securely bound with wire and shall have all descriptive marking stamped thereon.

## 15.10 Name Plate & Labels

All the Communication System shall be provided with a nameplate. It shall be mounted in a position that it shall be visible in the position of normal service and installation. The nameplate shall conform to the requirements of relevant IEC / IS and as per stipulations of General Technical Requirements and shall incorporate the following information:

All name plates shall be of nonrusting metal or three (3) ply laminated with white engraved lettering on black back ground, inscription and lettering sizes shall be subjected to Employer's approval.

## 15.11 Spare Parts and Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter

### 15.11.1 Mandatory Spares

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 15 Communication system & CCTV system

S.No	Description	Quantity
1	Each type of loud speakers with wall mounting arrangements	10% of installed quantity
2	Telephone sets with wall / column / structure mounting arrangements	10% of installed quantity
3	Head microphones	10% of installed quantity
4	Power supply cards used in the amplifier system	4nos
5	Electronic cards of each type used in the system	4nos
6	Cables of all type	10% of installed quantity
7	CCTV system equipment	1 Lot

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

## Volume-II

### Section II Sub-Section 16

#### Earthing System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

## **TABLE OF CONTENTS**

<b>17</b>	<b>EARTHING SYSTEM .....</b>	<b>3</b>
17.1	SCOPE .....	3
17.2	SYSTEM REQUIREMENTS .....	3
17.3	DESCRIPTION .....	4
17.4	STANDARDS .....	5
17.5	DESIGN .....	5
17.6	SIZE OF THE CONDUCTOR .....	6
17.7	LAYOUT OF THE EARTHING MAT .....	6
17.8	EQUIPMENT AND STRUCTURE EARTHING .....	7
17.9	JOINTING .....	9
17.10	SPECIFIC REQUIREMENT FOR EARTHING SYSTEMS .....	10
17.11	EARTH MAT RESISTANCE .....	10
17.12	LIGHTNING PROTECTION .....	10
17.13	DRAWING & DATA TO BE FURNISHED BY THE BIDDER .....	11
17.14	INSTALLATION .....	11



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

## 17 EARTHING SYSTEM

### 17.1 Scope

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, training of Employer's personnel, handing over to Employer and guarantee for five years of the complete Earthing system for power house, Transformer area, GIS building, Intake area, valve house and pothead yard with extension bays including interconnection as per the specifications hereunder, each complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation.

The scope of complete earthing at pothead yard area, GIS floor and Transformer yard has been included in this bid.

The scope of work shall be a comprehensive functional system complete in every respect including but not limited to following:

### 17.2 System Requirements

The intent of scope is to supply, install complete earthing system for Power House, Transformer area, Pothead yard area, Intake area and control room at Intake, valve house and adjoining functional areas. The erection of earthing system shall have to be done with respect to the actual progress of work by civil contractors and slippage on this account shall not be acceptable.

#### i) Underground earthing network

The underground earthing network shall consist of underground earth mat in power house, transformer area, tailrace, pothead yard area and adjoining functional areas. The purpose of this underground earthing network is to lower the overall grid resistance to a value less than 1  $\Omega$ .

#### ii) Over-ground earthing network

The over-ground earthing network shall consist of suitably spaced meshed grid embedded in transformer area, all floors of power house, GIS floor, Control room etc.

#### iii) Embedded grounding points connected to over-ground meshed grid at required

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

locations for earthing of equipment.

- iv) Connections of all steel structures and metal parts to embedded earthing network.
- v) An interconnected above ground / above floor main earthing network of galvanized iron flats at the power house, generator floor, transformer area, pothead yard, GIS floor and to the other places wherever needed for earthing of machinery, equipment and the other parts.
- vi) Galvanized mild steel flats or strips shall be used for connection of ground points of equipment and the other parts. Additionally, copper braided connections shall also be provided as per the requirement.
- vii) Clamps, sheaths, terminals and other miscellaneous items for making ground connections.

Any other items not mentioned specifically, but necessary for satisfactory completion of scope of work defined above, as per accepted standard (s)/ best international practices.

### 17.3 Description

The work includes all the buried and surface work. The description of earthing equipment supplied and installed by Contractor, mainly include the following articles:

- Mild steel rods
- 75 x 8 GI Flat
- Connectors : for strip to cable tray, strip to strip, strip to plate, strip to pipe/rod;
- Lugs;
- Hardware such as bolts, nuts and lock-washers;
- The welded and bolted joints.

The material to be supplied shall be new and of first quality.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

#### 17.4 Standards

The grounding system shall conform to the requirement of following standards:

IEEE: 80 - 1986	Guide for safety in AC Substation Grounding
CBIP Publication: 223	Design of Earthing Mat for High Voltage substation
IS: 3043	Code of Practice for Earthing Indian Electricity Rules
IEC 61936-1	For power installations exceeding 1 kV AC

#### 17.5 Design

Neutral points of the systems of different voltages, metallic enclosures and frame works associated with electric system shall be connected to a double earthing system unless stipulated otherwise.

Earthing and lightning protection system installation shall be in strict accordance with the latest editions of Indian Electricity Rules, relevant Indian Standards and Codes of practice and Regulations existing in the locality where the system is installed.

A number of ground rods (40 mm dia – 3000/7000 mm long) shall be added to the earth mat to obtain consistently lower resistance under all weather conditions.

All non-current carrying metal parts of electrical equipment and apparatus shall be earthed through two separate diametrically/diagonally opposite connectors.

The apparatus shall include:

- The neutral point of each system through its own independent earth
- Equipment frame work and other non-current carrying parts
- All extraneous metallic frame work not associated with equipment
- The earth point of lightning arrestors, voltage transformers, and lightning conductors through their permanent independent earth electrodes
- Boundary fence of pothead yard shall be earthed at the spacing of every 3 meter and earthing mesh shall be extended upto a distance of 2 meter all around .
- Shielding of cables and electrical wiring conduits
- Metallic structures of switch gear, cable racks, casing of cable boxes
- Pothead yard and equipment structures

The conductor shall be of adequate cross-section to safely withstand the system fault

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

current for time duration of fault clearance by the remotest/back up protective system Also sufficient allowance need be provided for corrosion of the embedded conductor on account of chemicals properties of soil and also due to galvanic action with other embedded systems.

The bidder shall have to measure the soil resistivity on his own and design the earthing system subsequent to the Employer's approval.

#### **17.6 Size of the Conductor**

The embedded earthing system of power house, transformer yard, pothead yard, Intake and valve house area shall consist of interconnected earthing grid formed by MS rods. The earth mat shall be of MS rods of diameter 40 mm minimum and fault current shall be decided during detailed engineering. However it shall be designed for Minimum fault current of 50 kA for 1 second. 25% extra margin shall be considered in calculation of earthing rod to take care of corrosion. During detailed engineering calculation for size of rod shall be made considering above factors. If it is required to increase the diameter of MS rod during DDE, same shall be done without extra cost to the owner. All connections of the embedded earthing conductors shall be thermo welded. The connections between buried conductors or conductors inside concrete are made by welding process. Above-ground accessible grounding conductor connections are either bolted or made by welding process.

Above ground connection to equipment would be through 75x8 mm. GS flat.

#### **17.7 Layout of the Earthing Mat**

The earth mat shall be laid on the excavated surface of power house. Separate earth pit shall be provided for neutral earthing.

The pothead yard mat shall be designed to obtain safe touch/mesh and step potentials as applicable and contractor shall furnish detailed calculations for personnel safety compliance. Touch and step voltages and transferred potential shall be calculated in accordance with IEEE80/76. Considering requirements of risers, laying of the mat over an uneven area due to excavation profile, and also to account for wastage actual requirement of the conductor over the calculated length shall be nearly 25 % extra.

The contractor shall make a detailed design of the earthmat based on soil resistivity recorded at various places of the power station and pothead yard area, which shall also

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

be within the scope of the Contractor, so as to ensure the availability of safe touch/mesh potential, safe Step potential & low ground mat resistance of less than 1  $\Omega$  (Ohm). soil resistivity tests shall be carried out using the Wenner method.

Wherever earthing conductor crosses cable trenches, underground service ducts, pipes, tunnels, railway tracks etc, it shall be laid minimum 300 mm below them and shall be re-routed in case it fouls with equipment/structure foundations.

Tap-connections from the earthing grid to the equipment structure to be earthed shall be terminated on the earthing terminals of the equipment/structure as per relevant standards/practice, if equipment is available at the time of laying the grid. Otherwise, “earth insert” with temporary wooden cover or “earth riser” shall be provided near the equipment foundation/pedestal for future connections to the equipment earthing terminals.

Earthing conductors or leads along their run on cable trench ladder columns, beams, walls etc. shall be supported by suitable welding/cleating at intervals of 750 mm. Wherever it passes through walls, floors etc, galvanized iron sleeves shall be provided for the passage of the conductor and both ends of the sleeve shall be sealed to prevent the passage of water through the sleeves.

In outdoor areas, tap connections shall be brought 300 mm above ground level for making connections in future, in case equipment is not available at the time of grid installation.

Earthing conductors crossing the road shall be laid 300 mm below road or at greater depth to suit the site conditions.

Earthing conductors embedded in the concrete shall have approximately 50 mm concrete cover.

After placing the earth mat conductors, the trenches and electrode pits shall be back filled with bentonite clay.

## **17.8 Equipment and Structure Earthing**

Earthing pads shall be provided for the apparatus/equipment at accessible position. The connection between earthing pads and the earthing grid shall be made by two short earthing leads (one direct and another through the support structure) free from kinks and splices. In case earthing pads are not provided on the item to be earthed, same shall be

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

provided in consultation with Employer.

Dedicated earth pits along with earth electrodes shall be provided for electronic equipment earthing. The connection between electronic earth point in the panel to the earth pit shall be with insulated cable.

Steel/RCC columns, metallic stairs etc. shall be connected to the nearby earthing grid conductor by two earthing leads. Electrical continuity shall be ensured by bonding different sections of hand-rails and metallic stairs.

Metallic pipes, conduits and cable tray sections for cable installation shall be bonded to ensure electrical continuity and connected to earthing conductors at regular interval. Apart from intermediate connections, beginning points shall also be connected to earthing system. Metallic conduits shall not be used as earth continuity conductor.

A separate earthing conductor shall be provided for earthing lighting fixtures, receptacles, switches, junction boxes, lighting conduit etc. Wherever earthing conductor crosses or runs along metallic structures such as gas, water, steam, conduits, etc. and steel reinforcement in concrete it shall be bonded to the same.

Light poles, junction boxes on the poles, cable and cable boxes/glands, lockout switches etc. shall be connected to the earthing conductor running along with the supply cable which in turn shall be connected to earthing grid conductor at a minimum two points whether specifically shown or not.

Rail tracks within pothead yard area shall be earthed at a spacing of 30 m and also at both ends. All the gates and every alternate post of the fence shall be connected to earthing grid. Flexible earthing connectors shall be provided for moving parts.

All lighting panels, junction boxes, control cabinets, Bay Marshalling kiosks etc. shall be grounded in compliance with the provision of Indian Electricity Rules.

75 mmx 8 mm GS flat shall run on the top tier and all along the cable trenches and the same shall be welded to each of the racks. Further this flat shall be earthed at both ends and at an interval of 30 mtrs.

Each penstock shall be considered to be an auxiliary mat and shall be connected to the main Mat so as to effectively reduce the grid resistance. Two MS rods in parallel on either

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

side of penstock shall connect the each penstock with the main earth mat.

## 17.9 Jointing

Earthing connections with equipment earthing pads shall be bolted type. Contact surfaces shall be free from scale, paint, enamel, grease, rust or dirt, Two bolts shall be provided for making each connection. Equipment bolted connections, after being checked and tested, shall be painted with anticorrosive paint/compound. All underground connections shall be exothermic welding to minimize resistance and improve durability.

Connection between risers and main earthing conductors of the grid shall be welded type. For rust protections, the welds should be treated with red lead and afterwards coated with two layers bitumen compound/cathodic protection to prevent corrosion.

The M.S. rods shall be welded to the earth mat at all peripheral joints, at and around riser junctions and other strategic locations for equipment connections.

Steel to copper connections shall be brazed type and shall be treated to prevent moisture ingress. For protection against rusting, the welds shall be treated with Barium Welded surface shall then be painted with red lead and Aluminum paint and afterwards coated with bituminous paint. If joints are not brazed, bimetallic washers must be used as separators at all joints of dissimilar metals to prevent electrochemical corrosion of the joint.

For end connections of Earthing of indoor LT Panels, Control panels, out door Junction Boxes, Control Cabinets, Lighting Panels, Motors etc. with G.S. flat, Copper Braided Wire along with Copper lugs as per IS: 2121 at both ends shall be used.

Resistance of the joint shall not be more than the resistance of the equivalent length of the conductor.

All ground connections shall be made by electric arc welding. All welded joints shall be allowed to cool down gradually to atmospheric temperature before putting any load on it. Artificial cooling shall not be allowed.

Bending of earthing rod shall be done preferably by gas heating. All arc welding with large dia. conductors shall be done with low hydrogen content electrodes.

The 75mmx8mm GS flat shall be clamped with the equipment support structures at

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

1000mm interval.

#### 17.10 Specific Requirement for Earthing Systems

Each earthing lead from the neutral of the power transformer & lightning arrester shall be directly connected to pipe electrodes in treated earth pit separately (as per IS) which in turn, shall be buried in Cement Concrete pit with a cast iron cover hinged to a cast iron frame to have an access to the joints. All accessories associated with transformer like cooling banks, radiators etc. shall be connected to the earthing grid at minimum two points.

Earthing terminal of each capacitor voltage transformer shall be directly connected to rod earth electrode, which in turn, shall be connected to station earthing grid. Earth mat shall be placed at a depth of 600mm from the gravel level to ensure stability and resistance to external disturbances like soil erosion

Auxiliary earthing mat comprising of closely spaced (300mmx300mm) conductors may be provided at depth of 300mm from ground level if the design of earth mat so requires.

#### 17.11 Earthmat Resistance

The earth mat shall be so designed & constructed that with the measured soil resistivity at power house site, the mat resistance is less than 1.0 Ohm. While targeting to achieve the mat resistance, 1) bentonite backfill or similar conductive materials or 2) increasing grid size or adding vertical electrode shall be used. Measurement of the earth mat resistance of the power house mat and the pothead yard mat after these have been laid shall be a part of the bid. Also the potential rise of the mat during passage of fault current shall remain within the tolerable limits. To limit the potential rise within safe limits, with the object of reducing the effective resistance, the main mat may be connected to each penstock, which can be considered as separate mat for this purpose. Also to maintain the earth mat resistance of power house within safe limits, the later shall be extended to the pothead yard mat to obtain composite resistance of both the mats within permissible limits.

#### 17.12 Lightning Protection –

The contractor shall provide a comprehensive lightning protection system for the powerhouse building. The system shall be designed and installed in accordance with relevant international standards, such as IEC 62305 or equivalent, to ensure effective protection against lightning strikes. Upon completion, the entire system shall undergo testing and verification to confirm compliance with the specified standards and operational



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

reliability.

### 17.13 Drawing & Data to be Furnished by the Bidder

The following drawings & data shall be submitted by the Bidder along with the bid

- A general arrangement drawing indicating the layout, size and any notable features of the proposed earthing grid.

The Manufacturer shall submit to the Engineer/Employer, for review and approval, 6 copies of the following drawings:

- Calculations for Conductor Size
- Calculations for conductor length and no. of Rods
- Calculations for determination of Earth mat Resistance
- Calculations for safe and calculated values of touch & step potentials.
- Calculations for safe & calculated values of ground potential rise touch & step potentials.
- Drawing for earth mat showing disposition of the mat along-with proposed grid arrangement, of conductor with ground rods, welding arrangement of risers with the mat etc. location of terminals for measurement of mat resistance, details of junction boxes etc.
- Any special measures proposed by the tenderer to limit the potential rise within the safe values.

### 17.14 Installation

Contractor shall install the earthing equipment in accordance with the requirements of this Specification and as required by the Engineer.

All surface to receive earthing connections shall be cleaned. Painted or varnished surfaces shall be cleaned to bare metal in order to insure a good electric contact.

Equipment supplied by the Contractor shall include earthing lugs. Contractor shall also supply earthing lugs for motors supplied by him.

The end of an embedded conduit not connected to equipment shall be connected by the Contractor to the earthing grid at one point.

All conduits terminated close to a cable tray or any other equipment shall be earthed by

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 16: Earthing System

means of an earthing ring or bushing and by a mild steel strips.

The installation of earthing material covered in this section includes, without being limited to, earthing of motors, switchgears, lighting and distribution panels, lighting poles, control panels, cubicles, DC equipment, transformers, disconnect switches, air handling units, heaters and steel plates supporting electrical equipment.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

## Volume-II

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### Section II Sub-Section 17 Illumination System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

## TABLE OF CONTENTS

<b>17</b>	<b>ILLUMINATION SYSTEM</b>	<b>4</b>
<b>17.1</b>	<b>GENERAL</b>	<b>4</b>
<b>17.1.1</b>	<b>SCOPE</b>	<b>4</b>
<b>17.1.2</b>	<b>ELECTRICAL DATA</b>	<b>5</b>
<b>17.2</b>	<b>CODES AND STANDARDS</b>	<b>5</b>
<b>17.3</b>	<b>ILLUMINATION SYSTEM</b>	<b>6</b>
<b>17.3.1</b>	Lighting level, fittings and lamps	8
<b>17.3.2</b>	Lighting fixtures and accessories	9
<b>17.3.3</b>	Lamps	11
<b>17.3.4</b>	Lamp holders for LED lamps	11
<b>17.3.5</b>	Emergency lighting	11
<b>17.4</b>	<b>EQUIPMENT SPECIFICATION</b>	<b>11</b>
<b>17.4.1</b>	Lighting distribution boards / lighting panels	12
<b>17.4.2</b>	Lighting transformer	14
<b>17.4.3</b>	Receptacles	15
<b>17.4.4</b>	Switches	15
<b>17.4.5</b>	Decorative switches and sockets	16
<b>17.4.6</b>	Switch board / box	16
<b>17.4.7</b>	Junction boxes	16
<b>17.4.8</b>	Outlet boxes	17
<b>17.4.9</b>	Lighting poles	17
<b>17.4.10</b>	Junction boxes for lighting poles	18
<b>17.4.11</b>	Earthing of lighting poles	18
<b>17.4.12</b>	Lighting mast (if required)	18
<b>17.4.13</b>	Lighting wires	19
<b>17.4.14</b>	Conduits and accessories	20
<b>17.4.15</b>	Cabling	20
<b>17.4.16</b>	Cable glands	20
<b>17.4.17</b>	Cable lugs	21
<b>17.4.18</b>	MCCB (Moulded Case Circuit Breaker)	21
<b>17.4.19</b>	MCB (Miniature circuit breaker)	21
<b>17.5</b>	<b>TESTS</b>	<b>22</b>
<b>17.5.1</b>	Shop tests	22
<b>17.5.2</b>	Testing and commissioning	22

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

<b>17.6</b>	<b>LIST OF DRAWINGS / DOCUMENTS-----</b>	<b>23</b>
<b>17.7</b>	<b>SPARE PARTS &amp; SPECIAL TOOLS -----</b>	<b>23</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

## 17 ILLUMINATION SYSTEM

### 17.1 General

Contractor shall perform all necessary work for the design, supply of material / equipment, installation, testing and commissioning of the Lighting system for Power House area, GIS Building, outdoor areas around powerhouse, Pothead yard area, approach road near power house, Valve House, Intake area and its approach roads etc. as per relevant standards and as specified hereafter.

#### 17.1.1 Scope

The technical specification of the lighting equipment / system to be supplied, installed and connected by Contractor is briefly defined as under.

Contractor shall design, build, guarantee, deliver, perform the factory and commissioning tests, install and connect the following lighting equipment:

- Different type of Lighting fixtures including lamps for illumination of different areas;
- Critical lighting fixtures connected to 220 V DC system including lamps;
- Main lighting distribution board (MLDB) with isolation transformer resin encapsulated dry type, 415 / 415 V, 100 KVA (tentative – exact capacity to be decided during detailed engineering), Main Essential lighting distribution board (MELDB) with isolation transformer resin encapsulated dry type, 415 / 415 V, 100 KVA (tentative – exact capacity to be decided during detailed engineering) lighting distribution boards (LDB), MCB boxes, switch boards, 220 V DC Emergency Lighting Distribution Board (ELDB) etc. The capacities indicated are minimum for isolation transformers. The contractor shall supply a higher capacity, if considered necessary based on actual estimates during detailed engineering;
- Lighting poles including fixture, lamps and accessories;
- Flood lighting fixture including lamps and accessories;
- Lighting switches including the appropriate boxes and wall plates;
- Power cables, Conduits, wires, connectors, junction boxes, supports, material for earthing and any other items required to complete the work;
- The 240 V AC receptacles including the appropriate boxes and wall plates etc.;
- 415 V Power outlets 63A (4 nos) /125A (50 nos) along with cables to be connected between Power Sockets and LT Distribution boards / Station Service Board;
- Lighting distribution (LDB-I & LDB-2) at remote sites along with isolation transformer at respective location (Intake & Valve House);

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

- 48 V hand lamps socket outlets having inbuilt 230 V / 48 V transformer of adequate rating in control room, generator floor, turbine floor, service bay and near Power Transformers, switchgear area.

#### 17.1.2 Electrical data

	AC	DC
Voltage	415 V + / - 10% (ph – ph)	220V
	240 V + / - 10% (ph – N)	
Frequency	50 Hz+ / - 5%	
No of Phase	3 ph + N	
System fault Level	50 kA (1.0 sec)	20 kA
System Earthing	Solidly Earthed	

Note: The adequate consideration for temperature rise, insulation level as per LOV study, clearances at higher altitude (greater than 1000 metres) and ambient temperature shall be taken care by the manufacturer.

## 17.2 Codes and Standards

The system and equipment under the scope shall be designed, built, tested and installed to the latest revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

Standards	Description
IEC 60598	Luminaries
IEC 60309	Plugs, socket outlets and couplers for industrial requirements
IEC 60811	Common test methods for insulating and sheathing materials of electric cables and optical cables
IEC 60050-461 1984	Electric cables
IEC 60439	Low-voltage switchgear and control gear assemblies – Part 1: Type-tested and partially type-tested assemblies
IEC 695-2-1	Cable trunking and ducting systems for electrical installations – Part 2-1: Particular requirements – Cable trunking and ducting systems intended for mounting on walls or ceilings

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

IEC 60839	Alarm and electronic security systems - Part 11-1: Electronic access control systems - System and components requirements
IEC 60851	Winding wires - Test methods - Part 6: Thermal properties
IEC 62676	Video surveillance systems for use in security applications - Part 4: Application guidelines
IEC 60529	Degrees of protection provided by enclosures (IP Code)
EN 60598-2-22	Luminaries - Part 2-22: Particular requirements - Luminaires for emergency lighting
EN 13032	Lighting calculation
BS 5266	Guide to the design and provision of emergency lighting to reduce the risks from hazards in the event of failure of the normal lighting supply
BS 4343	Specification for industrial plugs, socket-outlets and couplers for a.c. and d.c. supplies
IS 6665	Code of practice for industrial lighting
IS 10322	Specification for Luminaries
IS 3646	Code of practice for interior illumination

The installation shall generally be carried out in conformity with the latest IEC Standards.

### 17.3 Illumination System

Lighting System shall comprise of normal and essential and Critical lighting. Normal and essential lighting shall be fed by AC supply (415 / 240 V, 3 phase 4 wire) system from Main Lighting Distribution Board (MLDB) and Main essential Lighting Distribution Boards (MELDB).

During normal operation, both normal and essential lighting circuits shall be fed by normal power source. On failure of normal supply, essential lighting load shall be fed from to essential source after the start of DG set. Minimum 40% to 50% of the total lighting fixtures shall be fed from AC essential supply board (MELDB).

Critical lighting fixtures shall be connected to 220 V DC board fed from 220 V batteries through DC Emergency Lighting board (ELDB). It will be normally energized from AC supply and on failure of AC supply, this board will be supplied from DC source. The 220 V DC fixtures shall be used at entrance, exit points and other areas requiring critical lighting for escape purpose as well as to illuminate the signages.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

Unless otherwise specified, maintenance factor of 0.6 and 0.8 has to be considered for outdoor and indoor lighting respectively.

Maximum load on any individual lighting circuit shall not exceed 1000 W. For total load calculations a diversity factor of 0.3 may be considered for receptacle circuits.

The co-ordination of light fittings to the circuits shall be done so as to distribute the loads uniformly on all circuits. In control rooms the power distribution to every alternate fixture in a row / column shall be through a different phase.

For lighting and socket circuits, the cross section of cables / wires will be adopted to limit the permissible voltage drop to normally less than total 3% of the nominal system voltage.

Wires shall be laid in GI conduits / metal channels. Aesthetic look and operational convenience shall be the prime consideration while arriving at the lighting layouts. However, the suitability of the conductor size with reference to the type of fixture shall be checked by the Contractor.

The lighting layout shall cover circuiting details, type of fixtures and fixing details used and quantities as per the requirement of that particular building / area.

For indoor lighting, LED tube light fixtures shall be used in areas having ceiling height not greater than 5 meters. For high bay area's (greater than 5 meters), high bay LED fixtures shall be used. LED Tube Light fixtures shall be recessed, suspended or surface mounted according to the types of ceiling / wall.

All circuits shall be switched ON and OFF manually through suitable installed lighting panels, switch boxes or switches.

Outdoor area lighting shall be provided with wall / column / pole mounted LED lamp to illuminate approach / work area etc..

All outdoor area lighting is generally controlled by synchronous timer with manual override switch for bypassing timer contact.

Lighting system shall consist of isolating (lighting) transformers for reduction of fault level, Main lighting distribution boards (MLDB or MELDB), lighting distribution boards (LDB or ELDB), fixtures, junction boxes etc.

Lighting Distribution Board (LDB) shall be fed from Main lighting distribution board (MLDB or MELDB) through 415 / 415V, Dyn11, dry type isolating transformer having taps up to  $\pm 5\%$ . These LDB / ELDBs shall be provided with MCCB as incomer and

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

Miniature Circuits Breakers (MCB's) for outgoing feeders for control and protection of lighting circuits. MCB's shall not be loaded beyond 80% of rated capacity. A minimum of 25% of MCB's of each board shall be left as spares. Normally about 8-10 fixtures shall be wired in each circuit, while limiting the load to 1000 watt. The domestic socket outlets shall be fed through single pole Earth leakage circuit breakers (ELCBs) of LDBs. Not more than 4 power sockets shall be supplied from one circuit.

Battery room shall have fixtures mounted on wall in order to facilitate easy replacement of fused lamps. Switches controlling the lighting fixtures in battery room shall be installed outside the battery room. Intrinsically safe fixtures shall be mounted inside battery room.

Locally mounted lighting fixtures on platforms, walkways, stairs shall be installed in such a way that relamping can be done without the use of ladders.

Wiring for lighting and convenience outlets in outdoor areas shall be carried out with PVC cables run along the column / platforms and structures. The cable shall enter lighting fixture / JB through double compression weather proof cable glands of nickel plated brass. Where required, suitable mechanical protection shall be provided for lighting fixtures (e.g. wire guard). All wires and cables shall be copper conductor (FRLS type cables / wires to be used for indoor areas).

#### 17.3.1 Lighting level, fittings and lamps

The Lighting Levels, type of fittings and lamps as proposed for each area shall be as below. The system shall be designed in accordance with these stipulations:

<b>A. Power House</b>			
<b>S No</b>	<b>Location</b>	<b>LUX (Normal)</b>	<b>Lighting Fixtures type</b>
1.	Turbine floor	250	Low Bay LED Fixtures with reflector
2.	Machine Hall / Generator floor	300	High Bay LED Fixtures with reflector
3.	Service bay / Maintenance areas	300	High Bay LED Fixtures
4.	Electrical and Mechanical Equipment area	300	High Bay LED Fixtures

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

5.	Control room / Remote sites (Control Room)	500	Recessed type decorative luminaries with heavy gauge steel housing, stove enameled white opal acrylic diffuser, suitable for flush mounting with false ceiling or pendant mounting with LED lamps
6.	Offices (If any)	500	Recessed type decorative luminaries with heavy gauge steel housing, stove enameled white opal acrylic diffuser, suitable for flush mounting with false ceiling or pendant mounting with LED lamps
7.	Staircase	200	LED Fixtures / Incandescent lamps
8.	Toilet	200	LED light
9.	Battery Room	150	Corrosion proof luminaries, cast aluminum housing with specially designed Vapour proof lamp holder with LED lamps
10.	Critical area / Escape lighting	As required	LED lamps fixtures with inbuilt battery backup
<b>B. Outdoor Areas</b>			
1.	Pothead yard / Transformer area / outdoor areas adjoining power house / Remote sites	50	Flood light fixture with LED lamp with IP 55 enclosure protection mounted on Pothead Yard structure / wall
2.	Approach Road	20	LED fixture suitable for street lighting

The Contractor is required to design and submit the complete lighting system indicating the quantities of fittings of each type as required, conduit / cables layouts, Location of MLDB / MELDB / ELDB / LDBs/ Switchboard / Power boards etc. The design and layout of Lighting System shall be subject to approval of Employer / Engineer.

Contractor can recommend suitable lighting fixtures for above areas. All lighting fixtures shall be selected after approval of Employer / Engineer.

### 17.3.2 Lighting fixtures and accessories

All lighting fixtures and accessories shall be designed for continuous operation for its lifetime under environmental conditions existing at site.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

All light fittings and accessories shall be designed for an operating voltage  $240\text{ V} \pm 10\%$  and frequency  $50\text{ Hz} \pm 5\%$  and combined voltage and frequency variation of absolute sum of 10%.

All lighting fixtures shall be complete with lamps, lamp holders, terminal blocks, clamps, locking arrangements, fixing brackets etc.. All the fixtures, except for bulkhead fixtures, shall be fully wired up to terminal block. The internal wiring of the fixtures shall be done with insulated copper conductor wires of suitable size and type. However, the minimum cross section of conductor shall not be less than 2.5 sq.mm. The wiring shall be capable of withstanding the maximum temperature to which it will be subjected under specified service conditions without deterioration and affecting the safety of the luminaire when installed and connected to the supply.

All fixing / locking screws, washers, nuts, brackets, studs etc. shall be zinc plated and passivated.

All lighting fixtures shall be provided with an external, brass / GI earthing terminal suitable for connecting 14 SWG, GI earthing wire. Alternatively, PVC insulated 2.5 sq.mm copper wire may be used for earthing. All metal or metal enclosed parts of the housing and accessories shall be bonded and connected to the earthing terminal so as to ensure satisfactory earthing continuity throughout the fixture.

The lighting fixtures shall be designed for minimum glare. The finish of the fixtures shall be such that no bright spots are produced either by direct light source or by reflection.

Generally, all lighting fixtures (except the street light and post top lantern type fixture) shall be provided with 20 mm diameter conduit knock-out for connection to the incoming supply.

The diffusers / louvers used in fixtures shall be made of impact resistant polystyrene sheet and shall have no yellowing property over a prolonged period.

High bay fixtures shall be suitable for pendant mounting and provided with safety chains in case the glass cover is present. Hook mounted bay fixtures are not acceptable. Flood lights shall have suitable base plate / frame for mounting on structural steel members.

If required, brackets and supports shall be provided. These shall be hot dip galvanized after fabrication. The brackets shall be bolted or welded to the structure.

The reflectors shall be manufactured from CRCA sheet steel or aluminum as specified. The aluminum reflectors shall be made of high purity aluminum sheet, polished electrochemically brightened and anodized.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

Lamp holders for LED tubes shall be of spring loaded, low contact resistance, bi-pin rotor type, resistant to wear and suitable for holding the lamp in normal position under condition of shock and vibration. Live parts of the lamp holder shall not be exposed during insertion or removal of the lamp or after the lamp has been taken out.

The stove enamel / epoxy / vitreous enamel colour shade shall be light grey.

### 17.3.3 Lamps

LED lamps shall be provided with screwed (G.E.S) type caps.

The lamps shall be capable of withstanding small vibrations and the connections at lead-in wires and filaments / electrodes shall not break under such circumstances.

LED lamps shall be of 'clear' type unless otherwise specified.

### 17.3.4 Lamp holders for LED lamps

The holders shall be made of high quality thermo setting material for optimum utility and shall be suitable for use with LED lamps of 150 to 1000 W. The holders shall be provided with spring lock so that the lamp does not get unscrewed due to vibration. The center contact of the lamp holders shall be of chromium plated brass strip supported by stainless steel spring, which can withstand temperature rise up to 300°C.

'Phase' and 'Neutral' marking shall be provided on the lamp holder.

Street lighting fixtures, post top lanterns, flood light fixtures, control gear housing of integral type high / medium bay lighting fixtures, Bulk head fixtures and well glass fixtures shall be provided with neoprene / synthetic rubber gaskets suitable to achieve specified degree of protection.

Flood light fixtures, shall be provided with graduated disc facilities for aiming angle of luminaire and separately mounted gear box.

### 17.3.5 Emergency lighting

The emergency / escape DC lighting will be provided in addition to the normal / essential lighting. The DC emergency lighting shall be fed by 220 V DC emergency lighting DB which in turn will be fed from 220 V DC battery system / AC system.

The emergency lighting fixture will be of incandescent/LED type suitable for both AC and DC supply and shall be provided in critical areas, exit and entrances.

## 17.4 Equipment Specification

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

#### 17.4.1 Lighting distribution boards / lighting panels

All equipment and accessories shall be designed for continuous operation under site conditions without exceeding permissible temperature rise as stipulated in relevant standards.

The lighting distribution system shall generally comprise a Main lighting distribution board (MLDB or MELDB) and adequate number of lighting panels (LP) / Sub lighting distribution boards (SLDB) fed from MLDB. A lighting transformer to reduce the fault level at LPs shall be included in MLDB / MELDB. The MLDB shall consist of a lighting distribution transformer with MCCB on incoming circuit, Voltmeter with selector switch, Ammeter with selector switch and MCBs / MCCBs on outgoing feeders. All MCCBs and MCBs on MLDB shall be TPN. Sub lighting distribution board (SLDB) as required shall be provided. This SLDB shall be fed from MLDB (through MCCB) which in turn will feed SLDBs. SLDB shall have MCCB on incoming circuit.

If outgoing feeder from the Lighting Distribution Board shall have MCCB then proper discrimination between outgoing MCCB of Lighting Distribution Board and downstream MCB of Lighting Panel / LDB should be ensured.

MCCBs, Switches, fuses, Miniature Circuit Breakers (MCB), busbars shall be fully rated for short circuit level at the point of application. All equipment and accessories shall have proper enclosure to suit the site conditions.

Sub Lighting Distribution Boards / Lighting Panels shall be metal-enclosed, cabinet type, fabricated from CRCA sheet steel minimum 2 mm thick, suitable for column mounting on brackets. Removable glands plates shall be provided for top / bottom entry of cables / conduits. However outdoor type lighting panels shall have bottom cable entry only.

Indoor Lighting Distribution Boards and Lighting Panels shall be dust and vermin-proof, IP52 or better; outdoor panels shall be IP55 weather protected and shall also preferably have integral canopy for additional weather protection. The canopy shall be made of 2mm thick galvanized sheet steel or FRP where these are separate from equipment. The cubicle housing for lighting transformer shall be minimum IP42.

Lighting Distribution Boards and Lighting Panels shall be so constructed as to permit free access to the terminal connections and easy replacement of parts without coming in direct access to the live busbars / connection. The front access doors shall be hinged and have padlocking arrangements.

Two external earthing studs with M10 G.I bolts and nuts shall be provided on each

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

Lighting Distribution Board / Lighting Panel for connection to the plant earthing grid. Further a separate earth bus of copper of adequate cross section for earthing shall be provided throughout the length of MLDB / LPs for connecting to external plant earth grid.

Each Lighting Distribution Boards shall be complete with designation and caution notice plates fixed on front cover and a directory plate fixed on inside of the front cover. This directory plate shall contain details of the Lighting Panels being fed from the Distribution Board including their designation, location, loading etc. Equipment mounted inside the panel shall be provided with individuals labels with equipment designation and rating. Labels shall be made of 3 ply lamicaid / engraved PVC having white letters on black background.

Nameplates for the lighting distribution boards shall be installed at top of lighting distribution boards and shall be made of anodized aluminum.

A circuit diagram indicating incomer details and outgoing details e.g circuit number, circuit rating, load connected and details of load shall be pasted inside the panel. Also, a laminated copy of the diagram shall be provided inside the lighting distribution board / panel in a suitably designed pocket.

Lighting panels shall comprise of one number TPN MCB as incomer of adequate rating, suitable for continuous duty, 415V, 3 phase 4 wire system. Required number of outgoing feeders shall have 240V, SP MCB feeders of rating. MCB knob shall be marked with ON / OFF indication. Terminals shall be shrouded to avoid accidental contact. MCB shall be suitable for manual closing and opening and also automatic trip on overload and short circuit. A minimum of 25% of MCBs of each board shall be left as spares. The domestic socket outlets shall be fed through single pole Earth leakage circuit breakers (ELCBs) of lighting panels. Not more than 4 power sockets shall be supplied from one circuit.

Bus bar shall be of aluminium, colour coded for easy identification and designed for a maximum temperature of 90°C. Busbars shall be sized to carry the rated current continuously as well as the fault current for 1 sec without exceeding the temperature rise limits. The minimum size shall be 25 x 6 mm.

Board / Panel shall be fitted with phase barriers such that it is not readily possible for personnel to touch the phase busbars. Insulation barriers shall preferably be fitted around the MCB such that only the surface and the toggle of the MCB is available on the front.

Incoming and outgoing circuits shall be terminated in suitable terminal blocks. The size



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

of terminal blocks shall be suitable for incoming cable of multicore 35 or 70 Sq.mm or higher size stranded copper conductor cable and outgoing circuit of required size. All the terminals of terminal block shall be preferably shrouded, numbered and provided with identification strips for the feeders.

Board / Panel access door shall be interlocked with incoming switch such that the door can be opened only when the switch is in OFF position. Means shall be provided to defeat this interlock.

MCB's shall be current limiting type with magnetic and thermal release suitable for manual closing and automatic tripping under fault condition.

For area lighting and street lighting synchronous timer of 24 hours range with contactor in incomer with ON-OFF time setting facility shall be provided which shall ensure respective ON-OFF operation in every 24 hours cycle. The timer operated switching arrangement shall be suitable for operation on 240 V AC supply for controlling street lights and outdoor lighting.

Contactors shall be triple / four pole, air break, electromagnetic type, suitable for 415 V AC provided with minimum 2 NO and 2 NC auxiliary contacts. The coil shall be suitable for 240 V AC supply.

#### 17.4.2 Lighting transformer

Type	: Cast Resin Dry Type
KVA rating	: As required
Voltage rating	: 415 V / 415 V
Cooling	: AN
p.u.Impedance	: $0.04 \pm 10\%$
Voltage control	: Off load tap switch / link with range of $\pm 5\%$ in step of 2.5% tapping full capacity
Vector Group	: Dyn11
Class of Insulation	: F (155°C)
Maximum Temperature rise over 40°C ambient in winding by Resistance method	: 70°C
Neutral	: Solidly grounded

The equipment shall also conform to the provisions of IEC guidelines, IS and other



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

statutory regulations currently in force in the country.

The transformer shall be mounted inside sheet steel enclosure which shall be an integral part of Main Lighting Distribution Board (MLDB or EMLDB) or it can be separately mounted.

The secondary neutral of the transformer shall be brought out for getting a grounded 4 wire supply. Each transformer shall be routine tested.

Audible noise level for lighting transformers shall be as per relevant IEC/IS standard.

The Transformer shall be liable for rejection if the tolerance on the quoted values of losses, impedance, temperature rise, etc. exceeds the specified values of relevant standard.

Each transformer shall be equipped with fittings and accessories as listed below :

- Handling and lifting lugs both for enclosure and core-coil assembly.
- Inspection covers for cable end box.
- Door handle operated safety limit switch with 1 NO + 1NC contact.
- Ground bus.
- IP-54 junction box.
- Rating and terminal marking plates.

#### 17.4.3 Receptacles

Three pin type 5A / 15A receptacles shall be used for non hazardous area. The receptacles and the controlling MCB shall be mounted in the same enclosure box but these shall be in separate units to facilitate replacement by parts. The enclosure box shall be of galvanized sheet steel with provision of conduit / cable entry. Flush mounting type receptacles shall be used in areas where concealed wiring has been adopted and surface type shall be used in other areas.

In buildings such as sub-station, D.G. shed, Workshop, maintenance shop etc. industrial type metal clad socket outlets and plugs shall be provided. These sockets shall be supplied complete with plugs.

#### 17.4.4 Switches

Switches shall be used for non hazardous areas. Switches in areas where concealed wiring has been adopted, shall be flush mounting piano type unless otherwise specified. For surface conduit wiring, piano type switches in surface mounted box shall be provided. Industrial Type switches (Weather protected) shall be used for outdoor

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

areas.

#### 17.4.5 Decorative switches and sockets

Decorative lighting switches and sockets in Control room, Administrative Building, Office Rooms, Conference Rooms etc. shall be modular in design. All these items shall fit into the same frame with overall standard dimensions. Frames shall be suitable for surface and flush mounting in brick / concrete wall. The frames shall be suitable for conduit entry from all the sides. Switches and sockets shall match colors of the frame and cover plates to obtain a combination which shall match decor of the interiors of Control Room, Administrative buildings, offices rooms, Conference rooms etc.

#### 17.4.6 Switch board / box

All switch boards / boxes shall be of bent steel construction, fabricated of 1.6 mm MS sheet with 3 mm thick bakelite cover with brass fixing screws. Switchboard shall be hot dip galvanised provided with earthing terminal, mounting holes and screws.

Switch boards / boxes located in control room and office areas shall be flush mounted type on brick wall with only the switch knob projecting outside. It shall be provided with universal type 5 / 15A, 3 pin 240 V AC socket with 15A switch.

Switch boards / boxes shall have conduit knock outs on the sides. Adequate provision shall be made for ventilation of these boxes.

Flush type receptacles where provided shall be so located that only the plug projects outside.

Switches shall be piano key type single pole quick-make and quick-break mechanism suitable for operation on 240 V AC supply

Switch boxes shall be adequately sized to accommodate switches / fan regulators / sockets and terminal blocks. Terminal blocks shall be suitable for loop in - loop out of stranded copper wire.

#### 17.4.7 Junction boxes

Junction boxes shall be of made of min. 1.6 mm thick CRCA sheet steel hot-dip galvanised, dust and damp proof, generally conforming to IP-55 and those for hazardous location shall be flame proof type (unless otherwise specified).

Junction boxes shall be complete with gasketed inspection cover, conduit knock out / threaded hub and terminal blocks. The junction boxes shall be suitable for surface / flush mounting on wall / ceiling / structure and for bottom entry of the cables. A earthing stud

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

shall be provided in the junction box for earthing purpose. For outdoor installations the Junction boxes shall be provided with a canopy.

The junction boxes shall be hinged and bolted with captive nuts and bolts.

Terminal blocks shall be provided for loop in loop out arrangement. The terminals shall be shrouded and numbered.

#### 17.4.8 Outlet boxes

The outlet boxes used as point outlets shall be prefabricated type 65mm deep junction boxes. Outlet boxes custom fabricated for sockets, switches, fixtures and fan regulators etc. shall be made of M.S. Sheet having minimum thickness of 1.6mm. Outlet boxes shall be galvanized after fabrication. These shall be complete with terminal block suitable for connection of wires up to 4 sq. mm. Front cover plate shall be of 3mm thick bakelite / PE sheet. The colour shall suit the shade of the walls or shall be white if the shade of the walls is not finalised. The sheet shall extend at least 2 cm on all sides of outlet box. Cover plate shall be fixed by cadmium plated brass screws and cup washers. Outlet boxes shall be provided with adequate number of knock outs on all the sides for ease of wiring either with conduits or without conduits.

#### 17.4.9 Lighting poles

Lighting poles (Octagonal Poles) shall be fabricated from ERW steel tubular pipes of specified section, with joints, swaged together when hot and beveled on outside edges. Poles shall be coated with bituminous preservative solution on the ground portion of the outside surface. Remainder of the outside surface shall be given one coat of red oxide primer and finished with two coats of aluminum paint. The poles shall be used either with street lighting fixtures, post top lanterns or with flood lighting fixtures. The type of application, height of the pole and the overhang projection shall be given with the typical installation diagram. Poles shall be complete with base plates and taper plugs, and necessary pipe reducer / fixing brackets for fixing the lighting fixture, inner threaded nipple for bringing inside wire, along with gaskets and junction box, 2 numbers of 50 diameter GI conduit per pole shall be supplied.

The poles for street lighting shall be single or double bracket arm type. The bracket arm shall be securely welded to the top cover. Top cover shall be suitably threaded to lower the arm and provision shall also be made to bolt to the same lighting pole. It shall be possible to convert the single arm pole to double arm pole at site for which suitable arrangement shall be made. The nipple provided at the end of arm shall be suitably

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

designed to take care of the weight of street lighting fixture. The pole shall have, a junction box near the bottom to contain HRC fuses, a neutral link, an earth stud and terminal block. All internal wiring shall be done with minimum 2.5 sq.mm copper stranded wire. Red, black, Green color-coded wires shall be used for this purpose.

#### 17.4.10 Junction boxes for lighting poles

The junction box shall be located 1.0 metre above the FFL / FGL. It is proposed that armoured cable of either 4C x 16 sq. mm or 4C x 10 sq.mm copper, 1.1 kV grade cable will be used for feeding various lighting pole marshalling box. The cable will be buried and connected to junction box through loop in - loop out method. Two (2) Nos 50mm diameter GI pipe from 600mm below FFL / FGL and up to junction box shall be provided. Suitable glands, lugs, fuse, terminal blocks and other accessories shall be supplied with the junction box. The junction box shall be fabricated out of 2.0 mm thick MS sheet with suitable bracket to mount on the poles. The Junction box shall be with IP: 55 protection with provision for terminating internal wire from lighting fixture. Junction Boxes shall be provided with 2 Nos. earth stud of 12 mm diameter. The bottom of the pole shall be provided with suitably sized base plate of MS and welded to pole.

#### 17.4.11 Earthing of lighting poles

The lighting pole will be earthed at two (2) points. The junction box shall be also earthed at two points by suitable size of ground wire. Suitable earthing pad to connect to the ground shall be provided on the pole. The junction box shall be provided with two numbers of earthing studs with locknuts, spring washer and other hardware.

#### 17.4.12 Lighting mast (if required)

Height of lighting mast shall be approx 18m from FGL. They shall be complete with 2 nos. MS flats provided at the base plate for connection to the plant earthing grid. A ladder, platform, handrail, a weather protected TPN switch (at 1500mm from ground level) and a weather protected distribution board fabricated out of sheet steel shall be provided at the top of mast. The TPN Switch and the distribution board shall also have a canopy for additional weather protection. The TPN switch shall be suitable for looping one more lighting mast from the same incoming power supply. The distribution board shall have TPN busbars of 30 Amps, rating and 12 Nos. outgoing circuits each with a 6A single pole MCB. The distribution board shall have cable entries from bottom. Necessary space provision and suitable mounting arrangement shall be made on top of the tower for mounting of the lighting fixtures. The masts shall be given one coat of red oxide

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

primer and two coats of aluminum paint. Distribution board shall be fabricated out of 2mm thick sheet steel and shall be painted with two coats of enamel over a base coat of red oxide.

#### 17.4.13 Lighting wires

The wiring used for lighting shall be standard products of reputed manufacturers. The wires shall be of 1100 V grade, PVC insulated FRLS. The conductor sizes used for point wiring beyond lighting panel shall be single core, stranded, 2.5 sq mm or 4 sq mm, copper wire. 16 Gauge Copper Wire shall be used as Earthwire. The wires used for connection of a lighting fixture from a nearest junction box or for loop-in loop-out connection between two LED fixtures shall be single core copper stranded conductor, 1100 V grade flexible PVC insulated cords, unsheathed, with nominal conductor cross sectional areas of 2.5 sq.mm.

The wires shall be color coded as follows:

Red	R-phase
Yellow	Y-phase
Blue	B-phase
Black	Neutral

Green wire shall be used for earthing, if applicable. Size of earth wire shall be same as neutral.

Wiring shall be generally carried out by PVC wires in conduits. All wires in a conduit shall be drawn simultaneously. No subsequent drawings of wires are permissible.

Wires shall not be pulled through more than two equivalents 90°C bends in a single conduit run. Where require, suitable junction boxes shall be used.

Wiring shall be spliced only at junction boxes with approved type terminal strip.

For lighting fixtures, connection shall be teed off through suitable round conduit or junction box, so that the connection can be attended without taking down the fixture.

For vertical run of wires in conduit, wires shall be suitably supported by means of wooden / hard rubber plugs at each pull / junction box.

No joints shall be made at intermediate point the run of cables, unless the length of final sub-circuit or sub main or main is more than the length of the standard cable coil.

Power and heating sub -circuit shall be kept separate and distinct from lighting sub circuits. All types of wiring whether concealed or unconcealed shall be capable of easy

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

inspection.

#### 17.4.14 Conduits and accessories

Conduits offered shall be complete with all fittings and accessories (like tees, elbows, bends, check nuts, bushings, reducers, enlargers, coupling caps, nipples etc.). Conduits shall be rigid steel, hot-dip galvanised. However, for corrosive areas conduits and accessories and fittings shall have additional epoxy painting.

Required number of pull boxes shall be used at intervals to facilitate easy drawing of wires. Separate conduit shall be run for lighting and power circuits. Further, conduits for Normal lighting / Emergency lighting shall be separate. All exposed run of conduits on surface, shall be vertical or horizontal.

Conduits up to and including 25 mm shall be of 16 SWG and conduits above 25 mm shall be of 14 SWG. Minimum size of conduits shall be 20 mm.

Each piece of conduit shall be straight. The inside and outside surfaces of conduits shall be reasonably smooth and free from blister and other defects and covered with capped bushings at both ends.

Flexible conduits shall be of 20 mm diameter made with bright, cold rolled annealed and electro-galvanised mild steel strips and coated with PVC.

The conduits required shall be either of 20mm, 25mm, 32mm and 40 mm.

#### 17.4.15 Cabling

All cables shall be copper conductor PVC insulated FRLS.

In outdoor areas, main runs from lighting panels shall be by means of copper armoured cables, directly buried in ground or laid in trenches for the underground portion and through conduit for the overground portion.

Buried cables shall be laid and covered with sand / riddled earth, and protected from damage by bricks at sides and precast concrete slab at top. Buried cables shall have cable markers at 50M interval and projecting 150mm above ground. At cable bends and joints markers shall be provided.

When buried cables cross road / railway track, additional protection to be provided in form of Hume pipe / G.I. pipe.

#### 17.4.16 Cable glands

The cable glands shall be of Double compression or single compression type (as

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

required) with Nickel-Plated brass. All washers and hardware shall be made of Brass with Nickel / Chrome plating. Rubber components used in cable glands shall be neoprene and tested quality. The cable glands shall also be duly tested for dust proof and weather proof terminations. Cable glands shall be of robust construction capable of clamping cable and cable armour (for armoured cable) firmly without injury to insulation.

#### 17.4.17 Cable lugs

Cable Lugs for power cables shall be copper solder less crimping type and suitable for power cables and control cables. The lugs shall be of tinned copper. The lugs for control cables shall be provided with insulating sleeve.

#### 17.4.18 MCCB (Moulded Case Circuit Breaker)

All MCCBs shall be three pole type and shall be mounted in separate compartments. The rating of MCCB shall be so chosen as to get complete protection under all normal / abnormal conditions such as full load, overload, short circuit etc. MCCBs shall be provide with spring assisted quick make / break manually operated trip free mechanism.

The MCCB shall be rated for full fault level

MCCBs shall preferably be provided with adjustable type tripping device with inverse time characteristic for load protection and instantaneous characteristics for short circuit protection.

Each circuit breaker compartment shall have a door and a handle. The door and the circuit breaker shall have a mechanical interlock to ensure that the circuit breaker is opened before access into the compartment is allowed and it shall be possible to padlock the handle in the “Open” position.

‘ON’, ‘OFF’ and ‘TRIP’ position of the operating handle of MCCB shall be displayed and the operating handle shall be mounted on the door of the compartment housing MCCB.

#### 17.4.19 MCB (Miniature circuit breaker)

The miniature circuit breakers shall be suitable for manual closing, opening, automatic tripping under overload and short circuit. The MCB shall also be trip free.

Single pole as well as three pole versions shall be furnished as required in the Schedule of Lighting Panels. The MCB shall be rated for full fault level.

The MCB shall be suitable for housing in the lighting panels and shall be suitable for connection with stranded copper wire connection at both the incoming and outgoing side by copper lugs or for bus bar connection on the incoming side.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

The terminals of the MCB, and the 'open' 'close' and 'trip' conditions shall be clearly and indelibly marked.

The Contractor shall check and co-ordinate the ratings of MCB with respect to starting characteristics of discharge lamps. The Contractor has to furnish overload and short circuit curve of MCB as well as starting characteristics curves of lamps.

## 17.5 Tests

Typical type test reports for the various tests on lighting fixtures, lamps and other accessories offered shall be submitted, by Contractor for approval. Routine tests shall be conducted as per approved QA Plan and relevant standards.

### 17.5.1 Shop tests

All equipment shall be completely assembled, wired, adjusted and routine tested as per relevant IEC Standards at manufacturer's works.

Tests on lighting Distribution Boards / Panels shall include:

- Wiring continuity tests;
- High voltage and insulation tests;
- Operational tests.

### 17.5.2 Testing and commissioning

Lighting installation shall be tested and commissioned by the Contractor. Pre-commissioning checks and tests, shall include but not be limited to the following:

- i) The insulation resistance of each circuit without the lamps (load) being in place shall be measured and it should not be less than 500,000 ohms. (Between phases, phases to neutral, phase / neutral to Earth);
- ii) Current and voltage of all the phases shall be measured at the lighting panel busbars with all the circuits switched on with lamps. If required load shall be balanced on the three phases;
- iii) The earth continuity for all socket outlets shall be checked. A fixed relative position of the phase and neutral connections inside the socket shall be established for all sockets;
- iv) After inserting all the lamps and switching on all the circuits, minimum and maximum Lighting level shall be measured in the area and recorded;
- v) It shall be ensured that switch provided for ON / OFF control of point (light / fan / socket) is only on LIVE side;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

vi) Operation of ELCB's shall be checked.

Contractor shall duly fill in all the above test results and submit the test reports to Engineer-in-Charge.

All lighting layout drawings shall be marked by Contractor for “As Built Status” and “As built drawings” in required sets shall be submitted to Employer / Engineer.

## 17.6 List of Drawings / Documents

### ➤ Along with Bid

- i) Lighting calculations, curves, for arriving at the number of lighting fixtures for different areas and rooms;
- ii) Catalogues, leaflets and other details of Lighting fixtures;
- iii) Complete BOQs area and room wise.

### ➤ During detailed Engineering stage

The following drawings shall be submitted by the Contractor for approval of Employer:

- i) Key distribution Scheme for AC Lighting system (Normal, Essential and DC system);
- ii) Lighting calculations for arriving at the number of lighting fixtures for different areas and rooms;
- iii) Lighting fixtures layout drawings showing location of fittings, location of distribution, sub distribution and switchboards, Lighting panels, conduit / cable routing etc.;
- iv) Catalogues, leaflets and other details of Lighting fixtures, with data on reflection factors and room index etc.;
- v) General description, schematic and dimensional details of lamp etc.;
- vi) Dimensional drawings of each type of switch box, junction box, receptacles etc.
- vii) General Arrangement and schematic diagram for each type of MLDB and sub LDB etc.
- viii) Technical particulars of Lighting transformers, conduits, Cable glands, Cables, Wires etc.;
- ix) MQP (Manufacturing Quality Plan) and FQP (Field Quality Plan).

## 17.7 Spare Parts & Special Tools

Contractor shall supply separately the price of additional spare parts and special recommended tools. Each item shall be clearly described.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

All spare parts shall be identical electrically and mechanically to corresponding parts of the equipment supplied and shall be suitably packed and clearly marked, ready for long term indoor storage.

If dismantling of certain parts requires the use of special tools, Contractor shall supply them with the equipment. Each tool shall be described and its unit price indicated in the Tender.

Employer reserves the right to purchase or not the spare parts and special tools covered in this chapter

#### 17.7.1 Mandatory Spares

S.No	Description	Qty
1.	Lighting Boards / Panels	
a.	Each rating of isolator	2 Nos.
b.	Each rating of HRC fuse	12 Nos.
c.	Each rating of MCBs	25 Nos.
d.	Each rating of contactor	3 Nos.
e.	Each rating of push button	5 Nos.
f.	Synchronous Timers	1 No
2.	Lighting Fixtures	
a.	Each type of fixtures complete with accessories without lamps	5% of total quantity with minimum 1 of each type.
b.	Lamps	5 % of each type and rating with minimum of one of each type and ratings.
3.	Receptacles	
a.	Each type of receptacle	5% of total quantity
b.	Lighting switch boards	3 Nos. of each type
c.	Junction boxes (each type)	5 % of total quantity
d.	Trunking / conduits	2 % of total quantity of each type / size

If any additional spare-parts required for trouble free operation are recommended by

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 17 Illumination System

bidder, these shall be listed and the unit price shall be quoted in the price schedule. The Employer reserves the right to order any or all of such spares.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

## Volume-II

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### Section II Sub-Section 18 Electrical Workshop

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 18 Electrical Workshop
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## **TABLE OF CONTENTS**

<b>18</b>	<b>ELECTRICAL WORKSHOP-----</b>	<b>3</b>
<b>18.1</b>	<b>Scope of Work -----</b>	<b>3</b>
<b>18.2</b>	<b>Electrical Workshop-----</b>	<b>3</b>
<b>18.3</b>	<b>Specific Parameters and Layout Conditions-----</b>	<b>3</b>
<b>18.4</b>	<b>Rating and Functional Characteristics-----</b>	<b>4</b>
<b>18.4.1</b>	<b>Rating -----</b>	<b>4</b>
<b>18.5</b>	<b>Training to O&amp;M personnel-----</b>	<b>15</b>
	<b>On-site hands on training to the O&amp;M personnel shall be provided for at least five days to acclimatize the operators with the testing equipment supplied under this bid. -----</b>	<b>15</b>
<b>18.6</b>	<b>Performance Guarantee -----</b>	<b>15</b>
<b>18.7</b>	<b>Design and Construction -----</b>	<b>15</b>
<b>18.6.1</b>	<b>Standards-----</b>	<b>15</b>
<b>18.8</b>	<b>Drawings, Documents and Design Calculations -----</b>	<b>16</b>
<b>18.7.1</b>	<b>Drawings and documents-----</b>	<b>16</b>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 18 Electrical Workshop
---	--	--

## **18 ELECTRICAL WORKSHOP**

### **18.1 Scope of Work**

Scope of work under this section covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, training of Employer's personnel, handing over to Employer and guarantee for two years of electrical workshop equipment as per the specifications hereunder, each complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation.

The scope of work shall be a comprehensive functional system complete in every respect including but not be limited to following:

### **18.2 Electrical Workshop**

- I. Measuring devices;  
Measuring devices as defined in later clauses "Measuring devices" of this section.
- II. Testing devices;  
Testing devices as defined in later clauses "Testing devices" of this section.
- III. Transformer oil testing devices;  
Transformer oil testing devices as defined in later clauses "Transformer oil testing devices" of this section.
- IV. Tools and devices;  
Tools and devices as defined in later clauses "Tools and Devices" of this section.
- V. Lockers;  
lockers as defined in later clauses "Workbenches, lockers and instruments" of this section.

### **18.3 Specific Parameters and Layout Conditions**

An electrical workshop is to be located in the power house to meet the requirements of powerhouse O&M works. This workshop shall be equipped with all general, measuring, testing, calibrating tools and devices as elaborated below. However, this list is indicative only and final list shall be approved during detailed engineering.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

## 18.4 Rating and Functional Characteristics

### 18.4.1 Rating

#### 18.4.1.1 Measuring devices

Following items shall be supplied with all accessories, carrying cases, connecting leads, power supply unit / cells etc. necessary for operation.

I. One (1) no. 5KV Digital Insulation Resistance tester:

Sr. No.	Description	Specifications
1.	Functional Requirement	<ul style="list-style-type: none"> <li>The instrument should be suitable for measuring insulation resistance and PI, in live switchyard up to 400 kV level, as per applicable standard.</li> <li>The test results should have repeatability, consistency &amp; immunity to electromagnetic interference in live switchyard upto 400 kV levels.</li> <li>The instrument should automatically discharge the energy transferred to test specimen at the end of test.</li> <li>The instrument should have Guard Terminal to eliminate the effect of surface leakages etc.</li> </ul>
2.	Mode of test available	IR, Polarization Index, Dielectric Absorption Ratio, & Polarisation- Depolarisation Test
3.	Insulation test voltage	5 KV in steps of 250, 500, 1000, 2500, 5000 V DC
4.	Accuracy	<ul style="list-style-type: none"> <li>IR: <math>\pm 0.5\%</math> of reading</li> <li>Voltage: <math>\pm 0.5\%</math> of reading</li> </ul>
5.	Short Circuit Current	6 mA minimum
6.	Range of Measurement Noise interference	0 -15 T Ohm 8 mA
7.	Power Supply	It shall work on single phase 230 Volts $\pm 10\%$ , 50 Hz $\pm 5\%$ supply with standard socket/ Internal rechargeable Battery.
8.	Operating Temperature	0 to +50 deg C
9.	Relative humidity	Max. 90% non-condensing

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

Sr. No.	Description	Specifications
10.	Batteries Battery life	Rechargeable 6 hr. (typical) continuous Testing at 5 KV with a 100Mohm load) The kit should operate without battery also (if battery is removed the kit should operate up to 5 kV with main input supply)
11.	Test leads and Accessories	Two complete set of screened cables, each of 3m and 15m with suitable clamps & connectors, compatible with the instruments should be provided for successfully carrying out the test in live switchyard. Additionally all the required accessories should be provided for the smooth functioning of kit. Further hard carrying case (which should be robust/ rugged enough) for ensuring proper safety of the kit during transportation shall have to be provided.
12.	Display	Colour LCD Display
13.	Protection/ Control	Against short circuit, over voltage, improper ground connection over load & transient surges, the kit should have alarm/cut-off features to protect the instrument.
14.	Weight	It should be easily portable.
15.	Environmental and statutory requirement	Shall conform EMI/EMC and environmental protection requirement as per IEC. Copy indicating conformation shall be enclosed.
16.	Guard termination	The instrument should have Guard Terminal to eliminate the effect of surface leakages etc.
17.	Calibration Certificate	Calibration certificate from/traceable to, NABL accredited lab or internationally reputed lab, shall be submitted. Date of calibration shall not be older than one month from the date of supply of Kit.

II. Two (2) AC motorized insulation testers (Make- Megger) with:

- Accuracy:  $\pm 2\%$ ;
- Range 1 M $\Omega$  to 100 G $\Omega$  at 1 kV, 2.5 kV and 5 kV;
- Battery.

All meggers shall be suitable for manual as well as motorized operation.

III. One (1) portable universal bridge with:

- Accuracy class: 1;
- Built in capability for storing, printing and downloading test results;
- Ranges;
  - Resistance: 100 m  $\Omega$ ...10 M $\Omega$ ;



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

- Inductivity: 1...100 H;
- Capacity. 10 pF...1  $\mu$ F;
- $\tan\delta$ : 0...1 in several steps;
- Frequency range: 15...1000 Hz.

IV. Five (5) digital multimeters for AC and DC with:

- Accuracy;
  - DC:  $\pm 1\%$ ;
  - AC:  $\pm 1.5\%$ ;
  - Ohm:  $\pm 1\%$ .
- Ranges;
  - voltage: 60 mV... 1000 V in several steps;
  - current :1.5 mA...30 A in several steps;
  - Resistance: 0...50 k Ohm.
- Continuity audible test;
- Diode test, capacitance measurement, frequency measurement;
- Hold display features;
- Overload protection.

V. Two (2) analog multimeters for AC and DC with:

- Accuracy;
  - DC:  $\pm 1\%$ ;
  - AC:  $\pm 1.5\%$ ;
  - Ohm:  $\pm 1\%$ .
- Ranges;
  - voltage : 60 mV... 1000 V in several steps;
  - current: 1.5 mA...30 A In several steps;
  - resistance: 0...50 k Ohm.

VI. Laboratory connection leads, suitable for all specified instruments, with vulcanized banana plugs on ends, 1.5 mm<sup>2</sup> copper, high-flexible, insulator voltage 1000 V with:

- Twenty (20) leads of each colour namely yellow, black, green, red, blue length 0.5 m;
- Twenty (20) leads of each colour namely yellow, black, green, red, blue length 1.5 m;
- One (1) ring (100 m) laboratory cable;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

- Fifty (50) banana plugs;
- Fifty (50) test clips fitting to banana plugs.

VII. One (1) single phase toroidal transformers with:

- Primary voltage: 230 V;
- Secondary voltage: 0 ... 230 V stepless adjustable;
- Rated power: 2500 VA.

VIII. Three (3) phase-sequence indicators with:

- Voltage :100...500 V;
- Terminals marked with L1, L2, L3;
- Frequency 15...1000 Hz.

IX. Two (2) portable digital frequency meters with:

- Accuracy class:0.5;
- Rated voltages:110/230/440V;
- Ranges: 40..60 Hz.

X. Two (2) contact type portable temperature measuring instrument with sensor and batteries:

- Accuracy:  $\pm 0.5$  % reading;
- Range: -50°C to +210°C in several steps;
- Setting time: maximum 3 second.

XI. Two (2) digital mechanical revolution counters with:

- Range: 0... 15000 rpm in several steps.

XII. Three (3) stop-watches with:

- Three (3) separate scales.

XIII. Two (2) Clamp-on volt-ammeters with:

- Accuracy class: 1.5;
- Ranges: 1.2...60 A and 60...600 V in several steps;
- For round conductors up to 30 mm diameter;
- For flat conductors up to 30 x 45 mm;

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

- All accessories.

XIV. One {1} portable earth resistance measuring device with:

- Accuracy class: 1;
- Digital indication;
- Measuring ranges: 0.....20  $\Omega$  in steps of .01  $\Omega$   
0.....200  $\Omega$  in steps of .1  $\Omega$   
0.....2000  $\Omega$  in steps of 1.0  $\Omega$

Measuring case completely equipped with all accessories required for a proper measurement of the protective earthing resistance according to the relevant IEC/VDE recommendations or relevant Indian or International Standards for measuring of the earthing resistance of switchgears, of lightning system etc. and the specific soil resistance.

XV. One (1) Primary current injection kit for injecting current 10 A to 7000 A in steps of 10 A-100 A-500 A-2500 A-5000 A- 7000 A, suitable for 230V, 50 HZ supply.

XVI. One set of decade resistors with rotary switches for DC and AC current.

XVII. One set of precision multiple resistors with rotary switches for DC and AC current with maximum frequency 10 KHz.

#### 18.4.1.2 Testing devices

I. Fully Automatic Capacitance & Tan Delta Measurement kit – 1 (one) set

Sl No	Parameters	Specifications
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EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

1	Functional Requirement	<ul style="list-style-type: none"> <li>The instrument should be suitable for automatic offline measurement of C &amp; Tan <math>\delta</math> of the switchyard equipment as well as excitation current of transformers/reactors, in live switchyard up to 400 kV level, as per applicable standards and testing procedure.</li> <li>The test results should have repeatability, consistency &amp; immunity to electromagnetic interference in live switchyard up to 400kV levels.</li> <li>Automatic Interference Suppression.</li> <li>The measurement of ambient temperature &amp; relative humidity with inbuilt/external arrangement.</li> <li>The set shall be capable of measuring Power Factor, C &amp; Tan Delta (DF) of each winding of transformers and bushings using different test circuits in UST, GST-G and GST modes without changing connection.</li> </ul>
2	Display	In-built LCD Display
3	Memory	More than 2000 Results through inbuilt memory
4	Test	It shall execute all test modes automatically
5	Voltage Setting	Fully Automatic through inbuilt control display
6	Software	The software should be suitable for automatic testing & report generation and trend analysis. The kit should have facility to store and communicate with windows based computer for exporting the test data.
7	Input Power	230V $\pm$ 10% Single Phase AC or better at 50 $\pm$ 5% Hz
8	Output Voltage	0 - 12KV (continuously adjustable)
9	Output Current	100mA (Minimum) continuous. 300 mA (Minimum) intermittently.
10	Test Frequency	15 Hz to 500 Hz, Resolution: 0.1Hz, Accuracy 1% of Reading. Voltage output could change with respect to output frequency.
11	Measurement Range	
a)	Capacitance	Range: 0- 5 $\mu$ F (Minimum) or better Resolution: 0.1pF or better maximum resolution. Accuracy: $\pm$ 0.5% of the reading $\pm$ 0.1pF

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

b)	Tan Delta (DF)	Range: 0-100% Resolution: 0.01% Accuracy: $\pm 0.5\%$ of the reading $\pm 0.05\%$ .
c)	Voltage Measurement	Range: Up to 12 KV Resolution: 1V Accuracy: $\pm 0.5\%$
d)	Current Measurement	Range: 0-5 Amps Resolution: 1mA Accuracy: $\pm 0.5\%$
e)	Power Factor	Range: 0 to 100% (0-1) Resolution: 0.01% Accuracy: $\pm 0.5\%$ of the reading $\pm 0.05\%$
12	Environment features	The test kit shall be compatible for EMI/EMC/safety environment requirement as per IEC.
13	Applicable Standards	Electromagnetic Compatibility: EN61326-1:2013
14	Essential Accessories	<ul style="list-style-type: none"> <li>• Cables: 1 No. HV Cable-20Meter with clamps, 2 Nos. LV Cable-20Meter with clamps, Ground Cable with clamps, Interconnecting cables &amp; .</li> <li>• other cables and accessories required for carrying out</li> <li>• measurement.</li> <li>• Software: Data analysis software in windows XP/Vista/latest version with the features of Storing and downloading of files in data base for further analysis in PC.</li> <li>• Carrying Cases: Foam Padded Carrying Cases for Bridge &amp; Power supply, Carry Bag for Cables</li> <li>• Windows based software</li> <li>• Operational Manual</li> </ul>
15	Type Testing	The test kit shall be type tested for Environmental Tests, EMI-EMC & Safety Tests as per relevant IEC Standard. The type test report should be submitted along with the offer.
16	Calibration certificate	Unit shall be duly calibrated before supply and the date of calibration shall not be older than two months from the date of supply of kit.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

#### 18.4.1.3 Transformer oil testing devices

- I. One (1) no. high voltage insulation oil testing device, which shall be an automatic testing device, freely programmable, for execution of test specifications according to IEC / VDE or Indian or other International test standards, complete with all accessories, suitable for:

S.No	Description	Specification
1	Functional Requirement	The instrument should be suitable for Automatic Measurement of Electrical Breakdown Strength of transformer oil as per relevant standards.  The test results should have repeatability, consistency in laboratory condition.
2	Test Output	0-100 kV rms (Rate of rise: 0.5 to 5 kV/ Sec)
3	Accuracy	$\pm 1$ kV
4	Resolution	0.1 KV
5	Switch off Time	$\leq 1$ ms
6	Display/Control	LCD/Keypads.
7	Printer	Inbuilt/External
8	Measurement Program	Fully Automatic Pre-programmed/User programmed Test Sequences including as per latest IEC & other national/ international standards.
9	Test Lead/ Accessories	One complete set of electrodes with gauge etc. compatible with the instruments should be provided for successfully carrying out the test at site. Additionally all the required accessories, tools, drawing, documents should be provided for the smooth functioning of kit. Further hard carrying case (which should be robust/ rugged enough) for ensuring proper safety of the kit during transportation shall have to be provided. Additionally, one spare set of electrodes and one spare oil vessel shall also be provided.
10	Design/Engg.	The complete equipment along with complete accessories must be designed/ engineered by Original Equipment Manufacturer.
11	Power Supply	It shall work on input supply variations, V: $230 \pm 10$ %, f: 50 Hz $\pm 5$ % on standard sockets.
12	Operating Temperature	0 to +50 deg C
13	Relative humidity	Max. 90% non-condensing.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

14	Protection/ Control	Against short circuit, over load, transient surges etc. Also the instrument should have facility of stopping automatically on power failure. Also, the kit should have facility of HV chamber interlocking as well as zero start interlocking.
15	Display/Control	LCD/keypads.
16	Environment	The test kit shall be compatible for EMI/EMC/ Safety environment requirement as per IEC.
17	Calibration Certificate	Unit shall be duly calibrated before supply and the date of calibration shall not be older than two month from the date of supply of Kit.
18	Training	Supplier shall have to ensure that the instrument is made user friendly. Apart from the detailed demonstration at site, the supplier shall also have to arrange necessary training to engineers.
19	Commissioning, handing over the Instrument	Successful bidder will have to commission the instrument to the satisfaction of purchaser. The instrument failed during the demonstration shall be rejected and no repairs are allowed.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

## II. Dissolved Gas Analyser (Portable) – 1 (one) set.

SI No	Parameters	Specifications			
1	Functional Requirement	The portable dissolved gas analysis kit should extract, detect, analyse and display the dissolved gases in transformer oil based on as specified in relevant IEEE/IEC.			
2	Construction	The unit shall be compact and rugged. The unit shall be provided with built in carrying case with all its accessories			
3	Detection Gases	Concentration of all the fault gases ie H2, CH4, C2H2,C2H4, C2H6, CO & CO2 shall be individually measured and displayed. It is preferable that instrument also displays N2 and O2 individually. The minimum detection limits of the instrument shall be strictly met the requirement of IEC-60567-2011- Page No.47 - Clause 9.2, table-5.			
4	Moisture Analysis	The unit should also be capable of measuring moisture in transformer oil and the readings should be expressed in ppm or relative saturation.			
5	Extraction of Gases	Gases shall be extracted from insulating oil by either of the mercury free extraction method. <ul style="list-style-type: none"><li>• Shake test method as described in IEC-60567-2005 Annexure C.</li><li>• Head space method</li><li>• Partial Degassing toepler pump method</li></ul>			
6	Ability to test Gas Samples from Buchholz Relays	The kit should have Ability to test gas samples from Bucholtz relay			
7	Performance Parameter	Gases	Minimum Detection Limits in ppm	Working Range in ppm	Accuracy
		Hydrogen-H2	5	0-5000	+/- 2 ppm or +/- 5% whichever is greater and +/-3 ppm for moisture
		HydrocarbonsCH4, C2H2, C2H4, C2H6	1	0-10000	
		Carbon Monoxide-CO	25	0-10000	
		Carbon dioxide-CO2	25	0-50000	
8	Consumable gases	The kit should require no calibration or carrier gas.			
9	DGA Diagnostic features	The Kit should have built in DGA diagnostic software features using various IEEE/IEC approved interpretation rules.			
10	Settable limits	The kit shall have the facility to preset limits for "Caution" and "Warning" thresholds for all gases.			
11	Display	The kit should have built in LCD display with touch screen facility.			



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

12	Temperature Range	0-50 degree C
13	Software	The instrument should have built in control for all the functions, data acquisitions and data storage based on latest Window based software. The internal diagnostic software should be capable of translating the measured data into valuable information by employing standard DGA interpretation rules.
14	Interface	It should have the facility for communication with PC/Laptop for downloading the data from the instrument via USB port. Licensed copy of the software required to download data to computer shall be provided.
15	Internal memory	The internal memory should be capable to storing minimum 1000 records
16	Inbuilt printer	The kit should have built in Thermal Printe
17	Accessories	The kit shall be supplied with the oil sample accessories. The accessory box shall contain all tools to extract sample from source. The kit should accompany hard copy and soft copy of manuals, original software, carrying case from OEM etc.
17	Humidity	Up to 95%
19	Power Supply	It shall be operated with AC single phase, 50 Hz +/-5%, 230 V +/-10% supply. All power cable and necessary adaptors shall be provided by supplier.
20	Calibration	Unit shall be duly calibrated at NABL accredited laboratory before supply and the date of calibration shall not be older than two months from the date of supply of the kit.
21	Instrument control and Data handling, Internal Memory	<p>a) In case laptop is essential for operating the instrument, it shall be of latest specification along with licensed preloaded OS and software as well as software for interpreting DGA results accordance with IEEE C 57-104-1991 and IEC 60559-1999 along with laptop with carrying case included.</p> <p>b) In case instrument is having in built control for all the functions. Data acquisitions and data storage, it shall have a facility for communication with computer for downloading the data from instrument via USB port. Licensed copy of the software required to download data to computer shall be provided.</p> <p>c). Internal Memory can capable of store 1000 records, if inbuilt functions</p>

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

#### 18.4.1.4 Tools and devices

- I. One (1) hydraulic crimping tool for crimping of cables of sizes up to 630 sq. mm
- II. One (1) crimping tool suitable for manual operation for crimping of cables of sizes up to 50 sq. mm
- III. Four (4) short filled nylon headed mallets;
- IV. One (1) silica gel drying oven of stainless steel, with" minimum clear size of 500 mm x 500 mm x 500 mm, temperature range 60...240°C;
- V. One (1) motor winding drying oven for drying the windings of the motors having ratings up to 100kW;
- VI. Two (2) vacuum cleaners of 1000 W;
- VII. Two (2) sets of electric nut tighteners;
- VIII. Two (2) sets of portable type silt measuring instruments;
- IX. Four (4) hot air blowers having:
  - Power input: 1500 W;
  - Temperature control :150 / 560°C;
  - Airflow: 400 / 450 litre / min.
- X. Ten (10) nos. transformer oil stainless steel sampling bottles.

#### 18.4.1.5 Lockers

Three (3) tool lockers of appropriate size.

### 18.5 Training to O&M personnel

On-site hands on training to the O&M personnel shall be provided for at least five days to acclimatize the operators with the testing equipment supplied under this bid.

### 18.6 Performance Guarantee

The electrical workshop equipment along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Bidder shall guarantee the reliability and performance of the individual equipment as well as of the complete system

### 18.7 Design and Construction

#### 18.6.1 Standards

The system and equipment shall be designed, built, tested and installed to the latest

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 18 Electrical Workshop

revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

The equipment of electrical workshop shall be such designed and constructed to suit the requirement of the powerhouse.

## **18.8 Drawings, Documents and Design Calculations**

### **18.7.1 Drawings and documents**

The list of drawings / documents which are to be submitted to the Employer shall be discussed and finalised by the Employer at the time of award.

The Bidder shall necessarily submit all the drawings / documents unless anything is waived. The Bidder shall also supply calculations, studies, bills of material, Input and Output lists, operating sequences, setting reports, cable schedule, wiring and connection schematics and pre commissioning test procedures and reports.

The Bidder shall submit 6 (Six) sets of drawings / design documents / test reports as may be required for the approval of the Employer.

All drawings submitted by the Bidder including those submitted at the time of bid shall show enough details to indicate the type, size, arrangement, material description, Bill of Materials, weight of each component, break-up for packing and shipment, the external connections, fixing arrangement required, the dimensions required for installation and interconnections with other equipment and materials, clearances and spaces required for installation and interconnections between various portions of equipment and any other information specifically requested in the specifications.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## **VOLUME- II**

---

### **SECTION II SUB-SECTION 19 EOT Cranes**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## TABLE OF CONTENTS

<b>19</b>	<b>EOT CRANES .....</b>	<b>4</b>
19.1	SCOPE .....	4
19.2	REQUIREMENTS: .....	5
19.2.1	<i>General Requirements: .....</i>	5
19.2.2	<i>Design Requirements:.....</i>	5
19.2.3	<i>Conforming Standards and Codes: .....</i>	5
19.2.4	<i>Material requirements and workmanship: .....</i>	6
19.2.5	<i>Safety requirements: .....</i>	7
19.3	TYPE, PARAMETERS AND PERFORMANCE REQUIREMENTS: .....	7
19.3.1	<i>Power House EOT Crane:.....</i>	7
19.3.2	<i>Butterfly Valve House Crane : .....</i>	8
19.3.3	<i>GIS Hall Crane: .....</i>	10
19.4	CRANE DETAILS (COMMON TO ALL THE CRANES): .....	11
19.4.1	<i>General: .....</i>	11
19.4.2	<i>Structures:.....</i>	11
19.4.3	<i>Mechanical Details: .....</i>	17
19.5	ELECTRICAL EQUIPMENT: .....	22
19.5.1	<i>General: .....</i>	22
19.5.2	<i>Motors: .....</i>	22
19.5.3	<i>Brakes:.....</i>	25
19.5.4	<i>Limit Switches: .....</i>	26
19.5.5	<i>Load Cell System: .....</i>	27
19.6	ELECTRICAL CONTROL & PROTECTION FOR OPERATION OF CRANES:.....	28
19.6.1	<i>General: .....</i>	28
19.6.2	<i>Drive control: .....</i>	28
19.6.3	<i>Control levers &amp; Push Buttons:.....</i>	29
19.6.4	<i>Remote Radio Control: .....</i>	29
19.6.5	<i>Electrical Interlocks: .....</i>	33
19.6.6	<i>Miscellaneous Features:.....</i>	34
19.6.7	<i>Power Supply: .....</i>	35
19.6.8	<i>Cross Wires:.....</i>	36
19.6.9	<i>Power and Control Cables:.....</i>	36
19.6.10	<i>Trolley Conductors:.....</i>	36
19.6.11	<i>Down Shop Lead Arrangement (Long travel current collecting system): .....</i>	36
19.6.12	<i>Circuit Arrangement: .....</i>	37
19.6.13	<i>Lighting and Convenience Outlets: .....</i>	38
19.7	EARTHING: .....	38
19.8	CLEANING AND PAINTING: .....	39
19.9	INSPECTION, SHOP ASSEMBLY AND MATCH MARKINGS:.....	39
19.10	TESTS:.....	40
19.10.1	<i>Test at Manufacturer's Works: .....</i>	40
19.10.2	<i>Tests at Site:.....</i>	40

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

19.11 MANDATORY SPARES: .....42

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## 19 EOT CRANES

### 19.1 Scope

This Section of the contract specification covers the design, engineering, manufacture, testing at works, dispatch and delivery of:

- One (1) No., EOT crane for Power House with the requisite capacity of Main hoist and Auxiliary hoist, suitable to operate as and when required, complete in all respects including monorail hoist of 5 ton capacity, all accessories and slings etc.;
- One (1) No. EOT crane for Butterfly Valve House with the requisite capacity of Main hoist and Auxiliary hoist, suitable to operate as and when required complete with all accessories and slings.;
- One (1) No. EOT crane for GIS hall of 10 Ton capacity or higher as may be required, suitable to operate as and when required, complete with all accessories and slings.
- One (1) set each of the required spares, special tools, consumables etc. as specified herein for all types of cranes.
- Power, control cables & special cables, cable racks, cable glands, lugs, terminals, connectors termination etc. for cabling between equipment & devices covered in this contract.
- Rung ladders.

Weight of the lifting beam shall also be considered for selection of capacity of the crane in addition to the above stated weight.

#### **Note:**

The capacity of the cranes may be finalized with the Electro-Mechanical Equipment Manufacturer and should be in accordance with the maximum load to be lifted. The Bidder shall indicate the weight of the heaviest package that can be lifted by crane when operated justifying the capacity of the cranes proposed by the Bidder. Cranes should meet all the requirements of erection and commissioning of T.G. Equipment including the MIV, GIS Equipment & Butterfly Valves. The capacity of crane can be altered by contractor in consultation with Turbine & Generator supplier.

In addition to the above the contractor shall provide following services:

- Loading, unloading, storage and preservation at site till installation and commissioning.
- Complete assembly, erection, testing and commissioning at site.
- All other works incidental to and connected with the above services from delivery up to handing over the equipment after successful commissioning.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## 19.2 Requirements:

### 19.2.1 General Requirements:

The general arrangement of the crane shall be in accordance with the Powerhouse layout drawings enclosed and as described in the specification at various places. The EOT crane is required to handle major assemblies and sub-assemblies of generating units, power transformers and other power house equipment during loading, unloading, erection, repair, assembly, reassembly and maintenance. Performance requirements:

The crane shall be capable of raising, lowering, holding and transporting its rated load without any damage to or excessive deflection of any crane component.

The following tolerances shall be maintained in the operation of the crane:

- i) The motor speed not to exceed 105% of the synchronous speed while lowering the rated load.
- ii) The vertical deflection of the main girders caused by the rated load plus all dead loads not to exceed 1/1000 of the crane span.

### 19.2.2 Design Requirements:

All parts of the crane and runway rails shall be designed to sustain the loads and the combinations of loads as per IS: 3177 or relevant international standards.

### 19.2.3 Conforming Standards and Codes:

The cranes and their components shall be manufactured and tested in accordance with applicable Indian standards or equivalent international standard. List of some of the relevant major standards is given below. Latest version of these standards shall be applicable.

1. IS - 3177/BS: 466 - Code of Practice for Electric overhead travelling cranes and gantry cranes other than steel work crane.
2. IS - 807/BS: 2573 - Code of practice for design, manufacture, erection and testing (Structural portion) of cranes and hoists.
3. IS-5749/BS: 3017 - Forged Ramshorn hooks.
4. IS-2266/BS: 302 - Specifications for steel wire ropes for general engineering purposes.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

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|-----|---------------------------------|--|
| 5.  | IS - 6938                       | - Code of Practice for design of rope drum and chain hoists for hydraulic gates. |
| 6.  | IS - 325/BS: 2960               | - Three phase induction motors.  |
| 7.  | IS-13947(Part4/sec1)            | - Contactors and motor starters - Electromechanical contactors & motor starter.  |
| 8.  | IS - 2062                       | -Steel for general structural purposes.  |
| 9.  | IS – 3815                       | - Point hooks with shanks for general engineering purpose.                       |
| 10. | IS-1030                         | - Carbon steel castings for general engineering purposes.                        |
| 11. | IS-1875                         | - Carbon steel billets, bloom, slabs and bars for forgings.                      |
| 12. | IS - 210                        | - Grey Iron castings.  |
| 13. | IS - 1363 (Part 1, 2, 3) grade- | -Hexagon head bolts, screws & nuts of product C.                                 |
| 14. | IS-1364(Part1, 2, 3, 4, 5)      | -Hexagon head bolts, screws & nuts of product grade A & B.                       |
| 15. | IS - 4460 (Part 1, 2, 3)        | - Gears - spur & helical gears - calculation of load capacity.                   |
| 16. | IS - 800                        | - Code of practice for general construction in steel.                            |
| 17. | IS – 276                        | - Wire rope slings and sling legs.   |
| 18. | Other equipment                 | - Applicable ISS or equivalent standards.  |

#### **19.2.4 Material requirements and workmanship:**

Materials and workmanship shall conform to and comply with the latest edition of internationally accepted standards such as BIS, CMAA, DIN, FEM, ASTM, IEC, British Standards, etc. and are subject to acceptance by the Owner. The Contractor shall indicate in the Tender, the standards to which the materials, components, workmanship etc. would conform.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

Bronze and stainless-steel bolts and nuts shall be used in all cases where component parts are subject to frequent adjustments or removal, such as stuffing box, adjustment bolts, adjustable bearings etc.

#### **19.2.5 Safety requirements:**

In the design of crane all safety regulations as applicable with factory acts, Indian Electricity Rules etc. shall be taken into consideration and provided for.

Buffers - Buffers shall be provided for stopping the crane & trolley.

#### **19.3 Type, parameters and performance requirements:**

The cranes shall be of indoor, electrically driven, cage (for Powerhouse and Valve House only) as well as radio remote operated, single trolley, double girder (for Powerhouse and Valve House only), overhead travelling type. The hoists shall be mounted on a trolley which shall facilitate cross travel of hooks & hoists. The cranes shall run on runway rails along the entire length of the power house/unloading bay. The bridge of the crane shall be carried on adequate number of wheels, mounted in trucks designed to distribute the load equally on the truck beams and wheels and also to allow the wheels to adjust themselves to irregularities of the rails. Power shall be supplied from conductors mounted at a convenient height along the run of power house.

Suitable platforms shall be provided for access to bridge trucks and a walkway of ample width shall be attached to the outside of each bridge girder.

Cranes shall conform to the following requirements (subject to confirmation of the required capacity of the main hook of machine hall EOT crane): The bidder may note that the requirements given below are tentative and while finalizing these, the bidder shall be required to coordinate between the designer/manufacturer of Generator, Penstock Protection Valve & GIS Equipments and the EOT Crane manufacturer to ensure compatibility and workability of the Cranes, and the dimensional requirements shall be finalized during detail design.

#### **19.3.1 Power House EOT Crane:**

The general arrangement of the crane shall be in accordance with the Powerhouse layout drawings enclosed and as described in the specification at various places. The EOT crane is required to handle major assemblies and sub-assemblies of generating units, power transformers and other power house equipment during loading, unloading, erection, repair, assembly, reassembly and maintenance.

The Power House EOT crane shall be designed for the following Clause meters/duties

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

A.	Capacity (in Tonnes)			
i)	Main	As per Requirement		
ii)	Auxiliary	As per Requirement		
iii)	Monorail	5 T or higher		
B.	Span (s)	As per requirement; 18,000 mm (approx.)		
C.	Normal speeds with full loads, in m/minute			
a)	Main hoist			
i)	Hoisting & lowering speed	0-1.0 m/min		
b)	Aux. hoist			
i)	Hoisting & lowering speed	0-5.0 m/min		
c)	Trolley Travel	10.0 m/min		
d)	Bridge Travel (long travel)	0-25.0 m/min		
D	Max. acceleration / deceleration of bridge travel & trolley travel.	0.2 m/sec <sup>2</sup>		
E	Crane hook vertical travel reach	Main Hook	Aux. Hook	
i)	From top most level of hooks below crane grader	Upto MIV	Upto MIV	
F.	Position of Hook from rail C/L (mm)	Main Hook	Aux. Hook	Mono Rail
i)	On U/s side	1600	3250	1600
ii)	On D/s side	3150	1500	1600
G	Position of C/L of hook from end wall	Main Hook	Aux. Hook	
i)	From service bay end wall	4500	4500	
ii)	From unit 3 side end wall	4500	4500	
H	Runway level and Travel lengths			
i)	Crane beam top level	As per Civil Design		
ii)	Length of run way	≥ 76,000 mm		
iii)	Trolley travel length	Max. Feasible for specified crane span and hook reaches.		
I.	Monorail Hoist {Attached under Crane Girder}			
i)	Capacity	5 ton or higher as per requirement		
ii)	Hoist speed with full load	12 m/min		
iii)	Cross Travel speed with full load (along the bridge)	12 m/min.		
J	Means for Micro speed for Inching Motion for lifting hooks.	step less, frequency converter speed control system		
K.	Factors of safety & Deflections:			
a)	Minimum Factors of safety for Design			
i)	For structural members based on ultimate tensile strength	5		
ii)	For ropes & slings, based on ultimate tensile strength	6		
b)	Deflection limit of girder under safe working load plus dead loads.	As per IS:807 & IS:3177		

### 19.3.2 Butterfly Valve House Crane :

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications	
		Volume II Section-II	
		Sub-Sec. 19 EOT Cranes	

The general arrangement of the crane shall be in accordance with the BF Valve House layout drawings enclosed and as described in the specification at various places. The EOT crane is required to handle major assemblies and sub-assemblies of the Penstock Protection Valve and other associated equipment during loading, unloading, erection, repair, assembly, reassembly and maintenance.

The Valve House EOT crane shall be designed for the following Clause meters/duties:

A.	Capacity (in Tonnes)		
i)	Main	As per Requirement	
ii)	Auxiliary	As per Requirement	
B.	Span (s)	10000 mm (approx.)	
C.	Normal speeds with full loads, in m/minute		
a)	Main hoist		
i)	Hoisting & lowering speed	0-1.0 m/min	
b)	Auxiliary hoist		
i)	Hoisting & lowering speed	0-6.0 m/min	
c)	Trolley Travel	0-12 m/min	
d)	Bridge Travel (long travel)	0-25 m/min	
D	Max. acceleration/ deceleration of bridge travel & trolley travel.	0.2 m/sec <sup>2</sup>	
E.	Crane hook vertical travel reach between Butterfly valve cavern floor level (viz service bay floor to upper most position)	Main Hook From top most position of hook below girder to lowest floor level	Aux Hook From top most position of hook below girder to lowest floor level
F.	Required hook approach limit from Rail C/L	Main Hook	Aux. Hook
i)	On Upstream	≤ 1,600 mm	≤ 3,200 mm
ii)	On Down stream	≤ 31,50 mm	≤ 1,500 mm
G.	Position of Hook from End walls	≤ 4,500 mm	≤ 4,500 mm
H.	Runway; Travel lengths		
i)	Crane beam top level	as per Civil Design	
ii)	Length of run way	20,000 mm ( approx..)	
iii)	Trolley travel length	Max. Feasible for specified crane span and shall ensure hook reaches.	
J.	Means for Micro speed for Inching Motion for main lifting hooks.	step less, frequency converter speed control system	
K.	Factors of safety & Deflections:		
a)	Minimum Factors of safety for Design		
i)	For structural members based on ultimate tensile strength	5	
ii)	For ropes & slings, based on ultimate tensile strength	6	

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

b)	Deflection limit of girder under rated load plus dead loads.	As per IS807 & IS:3177
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### 19.3.3 GIS Hall Crane:

The general arrangement of the crane shall be in accordance with the GIS Hall layout drawings enclosed and as described in the specification at various places. The EOT crane is required to handle major assemblies and sub-assemblies of the Gas Insulated Substation and other associated equipment during loading, unloading, erection, repair, assembly, reassembly and maintenance.

The GIS Hall EOT crane shall be designed for the following Clause meters/duties

A.	Capacity (in Tonnes)	10 T or higher, as per requirement
B.	Span (s)	13500 mm (approx.)
C.	Normal speeds & with full loads	
i)	Hoisting speed for hook hoist	5 m/min
	Reduced speed for hook hoist	0.5 m/min
ii)	Trolley Travel (Cross)	15.0m/min
iii)	Bridge Travel (long travel)	30.0 m/min
D	Max. acceleration / deceleration of bridge travel & trolley travel.	0.2 m/sec <sup>2</sup>
E.	Crane hook vertical travel reach from transformer floor	From topmost position of hook below crane girder to transformer hall floor level
F.	Required hook approach limit from Rail centre line	
i)	On Upstream	≤ 1400 mm
ii)	On Down stream	≤1200 mm
G.	Hook reach from the left & right side walls of GIS Hall end stops on side walls	≤1500 mm ≤1500 mm
H.	Runway; Travel lengths	
i)	Crane beam top level	EL- 1210.8 m
ii)	Length of run way	63000 mm (approx.)
iii)	Trolley travel length	Max. Feasible for specified crane span shall ensure hook reaches
I.	Factors of safety & Deflections:	
a)	Minimum Factors of safety for Design	
i)	For structural members based on ultimate tensile strength	The factor of safety and stress level shall be as per IS-807-1976 or the latest
ii)	For ropes & slings, based on ultimate tensile strength	6
b)	Deflection limit of girder under rated load plus dead loads.	As per IS:807 & IS:3177
J.	Means for Micro speed for Inching Motion for main lifting hooks.	step less, frequency converter speed control system

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- \*) The approach distance shall be coordinated by the Contractor with the MIV & PPV design to allow vertical lifting of the valves during installation and disassembly.

The limits of travel of main and auxiliary hoists of crane shall be coordinated as per enclosed relevant drawings. These dimensions & parameters are tentative and the manufacturers are free to improve upon these limits to provide a better command for the crane. Minimum clearance of 300 mm shall be made available between the extreme point on the crane & side walls and the top of crane and nearest over-head obstruction.

## **19.4 Crane Details (Common to all the cranes):**

### **19.4.1 General:**

All mechanical equipment and structural shall be simple and substantial in design and shall enable easy erection, inspection, adjustment, painting and disassembly. All fastenings shall be adequate to hold the parts in place under all conditions of service. All shaft loads shall be transmitted by keys, splines or pins. The transmission of loads by press fits only shall not be accepted.

Wherever practicable, machinery shall be mounted on self-contained frames or bed plates or on rigid structural steel supports. In the design of all affected parts, suitable allowance shall be made for forces arising out of collision between bumpers and track stops.

### **19.4.2 Structures:**

#### **19.4.2.1 Bridge:**

The crane bridge, made of two (2) girders as box type construction, reinforced with stiffening ribs, supported on end trucks, shall be designed to safely carry the full rated load without undue vertical or lateral deflection or vibration. The design shall ensure that girder vibrations are quickly dampened to within 1 mm in 4 seconds.

The bridge shall be designed taking into consideration the specified transport and handling limits in regard to size and weight of packages. Accordingly the bridge shall be sectionalised into suitable but minimum number of sections within the transport constraints and also of need of field erection & handling.

The joints between the sections shall be spliced and shall be made by most appropriate method. Most appropriate design shall be adopted for the spliced joints between the sections.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The bridge shall have the following provisions:

- i. Welded end-stop of steel to act as stoppers for trolley / crane.
- ii. Heavy rails for trolley consisting of preferably 125 mm square bar of manganese alloyed steel, continuously welded to one corner at each main girder.
- iii. Large gusset and skew plates with interference fit bolts at girder ends to connect to the end trucks to maintain a square rigid structure secure against shock & skewing of crane on the track.
- iv. Suitable number of guide rollers for guiding trolley wheels on rail track.

#### 19.4.2.2 Trolley:

The trolley shall be made as a welded frame of structural steel and shall be designed and fabricated in accordance with the following;

- a) Provision of adequate bracing to withstand vertical, lateral and torsional strains.
- b) Properly machined to receive the drum, wheels, axles and motors for hoisting and cross travel.
- c) Provision of heavy duty roller bearings, for trolley wheels & winding drum, with bearing caps and fittings for pressure lubrication.
- d) Double end resilient or spring buffers at bottom of trolley frame on each side to engage stops at each end of the bridge.
- e) A provision to fit / receive a device to lift the heaviest parts of the trolley viz. the drum and motors for maintenance without any external place for anchoring the hooks or need for any other device.

#### 19.4.2.3 End carriages (Trucks):

The trucks of box type construction with openings at each end for receiving the truck wheels shall be either cast or weld fabricated or bolted or riveted structure of steel and shall have adequate strength and stiffness.

The ends of the trucks shall be shaped to form a hood over the truck wheels extending beyond them to receive the track (rail) sweeps and bumpers. The trucks shall be arranged so that wear may be compensated in order to maintain the drive gear in proper mesh. The size of the journals shall be ample to carry the rated

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

capacity load at specified speed without excessive heating during continuous operation.

Wheel assembly shall be mounted on L-type bracket and shall be so arranged that replacement of any wheel can be achieved from the side without undue difficulties. The wheel base shall not be less than 1/5<sup>th</sup> (one fifth) of span, as reckoned between the centres of outer wheels. The end trucks shall be designed to contact end stops.

Each truck shall have:

- i) Suitable numbers of double flanged rail wheels with bearings running on suitable axles, wheels, fracture props, buffer etc. for easy maintenance.
- ii) Suitable track sweeps at each end of trucks, effective in both directions of travel.
- iii) Guide rollers extending below the top of rail on both sides to prevent the trucks from leaving the rails.
- iv) Lugs to prevent a drop of not more than 25 mm in case of axle getting broken.
- v) Resilient bumpers or spring buffers on contact faces of end stops.
- vi) End stops at each end of runway rails, designed in such a way that they make contact with the face of the end truck and not the wheel.
- vii) Suitable pads on each truck for all wheels for jacking of the crane for changing truck wheels and bearings, to be so designed as not to interfere with the replacement of the truck wheels.
- viii) Lifting jib arrangement along with a lifting jack. Jack need not be of built-in type.
- ix) Hand holes with removable covers, in each closed compartment of end trucks to facilitate painting of the interior with a spray gun without major disassembly.

Arrangement for jacking the cross-traverse wheels shall be provided. The supplier shall furnish the technical details of jacks to be supplied.

#### **19.4.2.4 Lifting beam**

The lifting beam shall be supplied by the crane supplier for Powerhouse crane.

The weight and dimensions of the lifting beam shall be within the transportation limitations. It shall have a rated capacity to handle the highest weighted assembled part of generator rotor and generator stator. Suitable number of detachable wheel shall be provided with the lifting beam for easy movements on the assembly bay.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

All connections between the lifting beam and lifting devices / attachments for the generator rotor / stator etc. shall be so arranged that when the lifting beam is attached to the main hoists of the crane, the generator rotor/ stator with the shaft shall remain in a vertical position and shall be free to turn upon its vertical axis. The horizontality of the beam shall be maintained when it is lowered or raised. Suitable roller type bearings shall be provided for the load support. The final lifting arrangement for the components requiring use of lifting beam etc. shall however be finalized in consultation with the generator manufacturer. The lifting beam shall be provided with suitable arrangements (such as mercury limit switch) to check the horizontality of the beam when it is attached to the crane. For this, balance indicator is to be provided on the lifting beam to show that the beam is horizontal at all times.

The lifting beam with pins / slings shall be adequately designed for handling the rotor weight. The spacing of the lifting trunnions shall be finalized in consultation with the generator supplier. The total length of the lifting beam shall be determined taking into consideration the shortest distance available between the two main hooks of the cranes when operating in tandem.

Necessary drawings for lifting arrangement for stator and rotor along with attachments for lifting these items shall be supplied by the generator supplier.

#### 19.4.2.5 Wheels and Axles & bearings:

##### A) Wheels:

The bridge shall be carried on at least 16 (sixteen) wheels, 8 (eight) on each side, for Powerhouse and Valve House cranes and 4 (four) wheels, 2 (two) on each side for GIS Hall crane, suitably mounted on trucks and designed so as to distribute the load equally on truck beams & wheels. The wheels shall meet the following requirements:

- i) Double flanged type with treads machined and ground to size.
- ii) Turned, bored and ground to true and uniform diameters concentrically.
- iii) Made of cast steel or forged steel and heat treated. Cast iron wheels are not acceptable.
- iv) Equalized in pairs or individually as necessary.
- v) Flanges tapered to prevent rubbing on the rails & fillets of suitable radius to be provided.
- vi) Tread width to have proper clearance, and to be of sufficient size to withstand maximum static and moving / rolling loads. The BHN of hardness of wheels shall be at least 50 points more than the BHN of rails.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- vii) Bridge wheels shall be identified for interchangeability. Similarly trolley wheels shall be identified for interchangeability.

The design of the wheel truck assembly shall be such as would allow the wheels to adjust themselves to irregularities of the runaway within allowable limits.

#### B) Wheel Axles:

The wheel axles shall be in accordance with following:

- Made of forged carbon or alloy steel.
- Accurately turned ground and polished at the positions fitting into wheels.
- Suitable interference fit with the wheels.
- Driving wheel axles to be keyed, in addition to interference fit.

#### C) Wheel Axle Bearings:

The wheel bearings shall be interchangeable, easily removable type & shall comprise the following:

- Bearing housings / journals fitted into truck bodies.
- Anti friction roller bearings with high pressure grease lubrication.

#### 19.4.2.6 Runaway Rails:

One (1) set each of runway rails suitable for the crane complete with sole plates, anchor bolts, clamps etc. for the bridge travel shall be designed and supplied by the supplier. The rails shall extend for the:

- Power House length of 80m (approx.) covering the generating units and service bay.
- Valve House length of 20m (approx.)
- GIS Hall Length of 91m (approx.)

These dimensions are tentative, exact dimensions to be furnished during detailed engineering.

- The runway rails shall preferably be CR-100 type, as per IS: 3443 for machine hall crane. The faces of the rail lengths shall be inclined at an angle

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

of forty five ( $45^{\circ}$ ) degrees to the length to provide oblique gaps between rail lengths.

- b) The rails for bridge travel shall be laid on and fixed to the crane beam by means of anchor bolts etc. The supplier shall supply all the materials including embedded parts for fixing the bridge rails on the crane beam.

#### 19.4.2.7 Operator's Cage:

In respect of the operator cages / cabins of the crane for the Power House, it shall be fitted on the downstream side. This arrangement is necessary as it will ensure that while operating the crane, the lifting beam shall not interfere with cage even when it is moved to extreme upstream sides. Operator's cage for the Valve House crane shall also be place on the downstream side.

The operator's cages shall be structural steel frame and shall be of the open type fire proof and suitable for indoor service. The cage shall be suspended from the outside girders of the crane and braced to the crane so as not to sway, swing or shake. The cage shall have ample space for containing the control equipment and for performing all crane operations and maintenance.

The cage shall be so designed that it shall afford the driver an unrestricted view of the working area. The floor of the cage shall be made of steel plate connected securely to the frame and covered with rubber matting. Suitable rising shall be provided for all open sides. A foot operated rotary alarm gong at least 300 mm in diameter shall be provided in the cage. The cage shall have Railing on all open sides, a ladder for access to the crane bridge walkway, a CO<sub>2</sub> portable fire extinguisher & a cut-off switch near the cabin for disconnecting the incoming power supply before entering or leaving the cabin, for operator safety.

#### 19.4.2.8 Walkways and Ladders:

Ladders, platforms, walkways, hand holds, etc. necessary to give safe access to and movement in the cage, bridge drive and trolley drive mechanisms and all other components of the crane needing inspection, maintenance and repair shall be provided. The walkways shall be of steel chequered plate with minimum width of 750 mm extending to the entire length of the bridge preferably at the same elevation as the bridge and attached to the outside of each girder. The steel ladders and stairs shall have nonslip treads not less than 600 mm wide between the sides and shall preferably slope forward. 1100 mm high hand rails with an intermediate rail shall be provided for completely enclosing walkways, platforms, stairs/ladders etc. Two plates on each side edge for a height of about 100 mm shall be provided for all open edges of walkway.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

#### 19.4.2.9 Slings:

The contractor shall furnish and deliver suitable length of wire rope slings in pairs having a safety factor of not less than 6 (six) for lifting specified load. A minimum of 5 (five) pairs shall be provided for different loads up to the rated capacity of the main hoist of each crane. The slings shall be for use with main and auxiliary hoist. Each sling shall have a ring at one end and a ring or a hard eye at the other with matching shackle for the hard eye. Sling rings shall be suitably proportioned to fit on the crane hook. A wall chart shall be provided showing the maximum safe lift of the slings individually and in pairs at various angles.

#### 19.4.2.10 Safety Guards:

Appropriate and effective safety guards, encasements, and covers shall be provided for various rotating components, and for live electrical conductors of the crane as below:

- i. For gears, chain drives: Encasements.
- ii. For revolving shafts & couplings: Guards for full lengths.
- iii. For sheaves of hook block and rope: Guards to prevent trapping of hand and to prevent rope from dismounting from sheave grooves even if rope slackening develops.
- iv. For openings in foot walk floorings and other inspection platforms: Covers of lockable type.

Suitable safety lugs shall be provided to contain the movement of the crane during an earthquake. Clamps to keep the crane in locked condition while not in operation shall also be provided.

### 19.4.3 Mechanical Details:

#### 19.4.3.1 Bridge Travel Mechanism:

For the Powerhouse and Valve House crane, the mechanism shall comprise of four (4) electric motors and totally enclosed speed reduction helical gear units, two (2) for each end of the bridge, to drive the four (4) bridge wheels and shall ensure equal speed. For GIS crane, the mechanism shall comprise of two electric motors.

The gear motors shall be keyed directly to the extended wheel shafts.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The bridge motion shall be free from vibrations and rocking under all conditions of operations and the crane structure shall not have any tendency to get out of line.

The coupling for the shafts of the motors, gear units and wheels shall be of safety flange type accurately faced and turned and shrunk into place with taper flush keys.

#### 19.4.3.2 Trolley Travel Mechanism:

This mechanism shall comprise of two (2) electric motors for Powerhouse and Valve House crane and totally enclosed speed reduction gear units, one (1) for each end of the trolley to drive two (2) trolley wheels, designed to ensure equal speed and steady motion, free from vibrations and rocking. For the GIS Hall crane, motors can be two (2) or less and control drive system as mentioned in bridge travel mechanism can also be adopted.

#### 19.4.3.3 Hoisting Machinery:

The hoisting mechanism provided and mounted on the crane trolley shall comprise of motors, speed reduction gear units for normal speed, drums, brakes, lifting tackles and hooks, hoisting rope and slings as below:

##### Hoist Drive for Normal Speed:

The hoist shall be driven by a motor through speed reduction gear units for normal speed of the hoist and shall be complete with brakes and retarding devices.

##### Hoist Drive for Micro Speed (Inching):

Gradual and very slow, accurate and controlled operation will be required to place the generator rotor and other heavy equipment very gently. The hoist shall have such provision by means of stepless, frequency converter speed control system, enabling control of the vertical motion of the hoist within 1 mm.

In respect of machine hall cranes, the inching operation shall work for both individual as well as for tandem operation of the two cranes.

The hoist machinery and lifting tackle for both hoists shall be arranged so that the centre of lift does not shift in any direction throughout the full lift of the hoists.

##### Winding Drum:

The winding drum shall have machined grooves to receive the full hoisting rope without overlapping. The drum shall be of such size that there will be no more than one layer of rope on the drum when the rope is in fully wound position and its length shall be such that each lead of rope has a minimum of two & half (2.5) full turns on the drum left when the hook is in its lowest position and one spare groove for each

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

rope lead off the drum when the hook is at its highest position. The drums shall be designed to withstand the maximum compressive stresses and local bending stresses in the drum at the grooves when the rope is wound on.

#### Lifting Tackles & Hooks:

The lifting tackles shall consist of a safety type lower pulley block, hook, necessary sheaves and flexible steel wire rope. The lower block shall be a heavy steel housing to support the sheaves and hook.

Sheaves shall be made of cast steel and shall be machine grooved to a depth of not less than one and a half (1.5) times the diameter of the rope. The groove shall be finished smooth and shall be free from surface defects likely to injure the rope. The sheaves shall be provided with guards to retain the rope in grooves and other requirements of sheaves shall be as per approved relevant standards.

The swivelling hook shall be of forged steel and mounted on ball thrust bearings and protective skirt shall be provided to enclose the bearings.

The main hook shall be of the Ramshorn type conforming to approved relevant standards (IS: 5749) and the auxiliary hook shall be of shank type conforming to IS: 3815.

#### Hoisting Ropes:

The hoisting rope shall be as per relevant approved standards. The factor of safety for the hoisting ropes shall be not less than six (6). The rope system shall be equalised and arrangements entailing reverse bends shall be avoided as far as possible.

#### 19.4.3.4 Shaft:

All shafts shall be designed and made in accordance with the following:

- Material - High tensile rolled steel or forged steel.
- Shaft diameter to take into account the provision of key slot & splines. Slot bottom shall have proper radius.
- Where needed, designed with suitable shoulders / step-up diameter for carrying and fitting of gears, pinions and similar parts.
- Provision of fillets of ample radius at all diametral changes in sections.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- e) Designed to limit shaft deflection to within  $1/3000^{\text{th}}$  of the span between bearings.

#### 19.4.3.5 Gears:

All gears in power operated motion shall be machined out conforming to internationally accepted standards. The gear trains shall be in totally enclosed oil tight gear cases with welded seams. An inspection cover on the top of the gear case shall be provided for quick and easy inspection of gears and for adding oil in the case. Adequate breathing and drainage facilities shall be provided on all gear cases. Means for clear and correct indication of the oil level in gear cases shall be provided. All gears not enclosed in gear case shall be properly guarded. The pitch line shall be described on all the gears and pinions to facilitate erection. All gears shall be of cast or wrought steel and shall be designed for the specified crane duty.

Only spur and helical gears shall be used for speed reduction gearing. The tooth profiles are to be carefully designed and machined.

- a) The gears having speeds higher than 500 rpm shall be of helical teeth type with active contact area hardened to a depth of 0.2 to 0.3 mm.
- b) Shall be made of cast steel or forged steel and designed as per IS: 4460 for the specified crane duty.
- c) Shall be totally enclosed in oil tight gear cases of welded fabricated steel.
- d) Shall have Inspection covers on the top of the gear case for quick and easy inspection of gears and for adding oil in the gear case.
- e) Adequate breathing and drainage facilities on all gear cases.
- f) An oil level indicator.
- g) Proper guards for uncased gears.
- h) Markings of pitch line on all gears for facilitating erection.

#### 19.4.3.6 Bearings:

The bearings shall be of the roller, ball sleeve type with removable bronze linings preferably flanged at both ends. The shaft bearings shall be placed as close as possible to the points of loading. Unless otherwise specified herein, bearings on revolving shaft shall be of the divided type so that each shaft may be removed from the crane with its pinions and gears in position. In all cases where divided bronze bearings are used, the bearing caps shall be dowelled or secured with not less than



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

two turned bolts, the holes for which shall be reamed to a close fit unless the caps are recessed into the base. Cap screws shall not be used for this purpose. This requirement will not apply where roller or ball bearings are involved. All bearings shall be designed so as to be replaceable easily. Bushings at the ends of shafts shall be sealed by an approved method so as to be drip proof if oil lubrication is used. In case of grease lubrication, open ends of bushings shall be sealed with approved grease retainers.

#### 19.4.3.7 Lubrication:

Provision shall be made for lubricating all bearings including ball and roller bearings by a pressure gun. All lubrication nipples shall be readily accessible. Ball and roller bearings shall be packed with grease during initial assembly. Where access to a bearing (e.g. end carriage wheels) for lubricating purpose is difficult, provision shall be made for remote lubrication through copper or brass piping of ample size. Gear trains, sleeve bearings etc. shall be provided with oil lubrication. Gear trains shall be run in oil baths. High pressure grease guns shall be supplied with the crane. The crane shall be handed over completely lubricated with approved oils and grease in the presence of Employer's maintenance crew. The contractor shall furnish details of the lubricants such as the quantities and specifications etc. to enable Employer to procure the lubricants for stock. The contractor shall supply a lubricating chart indicating points to be lubricated and frequency of lubrication.

#### 19.4.3.8 Drip Pan and Covers:

All bearings and gear cases shall be made oil tight. Suitable drip pans shall be provided to collect oil and grease, which may drip from bearings, gear cases and other components of the crane in case drip proof arrangement is not possible. Means for cleaning the drip pans shall be available. Dust covers shall be provided where necessary to protect sliding and rotating pairs and to prevent dust from mixing with the lubricant.

#### 19.4.3.9 Bumpers:

Spring bumpers shall be attached to the bridge trucks and the trolley. The bridge shall have four bumpers one at each corner arranged to meet the crane stops squarely. The trolley shall have two spring bumpers on each side placed to meet the track stops squarely at the end of the stops. The bumpers shall consist of suitable springs, steel cylinders, rams, etc. and shall be fastened to the trucks and the trolley and shall be capable of bringing the crane and the trolley to a gradual stop when travelling at rated speed in either direction, when the power supply is off and thus eliminate excessive stresses and damage to any part of the crane.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

#### 19.4.3.10 Holding Clamps:

As a safeguard against movement of the crane off the rail during an earthquake, suitable provision to contain the movement of crane shall be made. Clamps to keep the crane in a locked condition while not in operation shall be supplied.

### 19.5 Electrical Equipment:

#### 19.5.1 General:

Electrical requirements for motors, controllers, inverter, rectifier, braking, limit switches, protective equipment, isolating switches, cable, wiring, earthing and other conductors, etc. shall be in accordance with IS 3177-1999. The power supply for the electrical system shall be 415 V, 3-phase, 4 wire, 50 Hz AC. The supply for crane control and lighting system shall be 240 V AC, 50 Hz and shall be obtained through individual 415/240 V transformers. All electrical equipment shall be suitably designed and constructed for operation under tropical conditions. Allowable temperature rise of the equipment shall be as prescribed in the Indian Standards or the corresponding International Standards and shall be based on ambient temperature of 40°C. The Tenderer shall state in his Tender the make and type of electrical equipment which he proposes to furnish so that this could be confirmed by the Employer. Controllers, levers and other operating mechanism shall be marked plainly and permanently. The location of all operating mechanism and electrical devices shall be subject to the approval of the Owner.

#### 19.5.2 Motors:

All the cranes shall be provided with motors for normal as well as creep speed for all motions except unloading bay crane where motors for creep speed for bridge & trolley travel shall not be required to be provided.

All the motors shall be of ample capacity for the duties and speeds specified and shall conform to IS: 325 (latest) or equivalent. The motors shall also meet the requirements as specified in IS: 3177 (latest) or equivalent. Motors shall be suitable for reversing, frequent accelerating and electro-hydraulic/DC braking. The rating of motors for all motions shall be 40% CDF with minimum 150 (one hundred & fifty) starts and stops per hour. All motors shall be suitable for operation at 415 V, 50 Hz, 3 phase, 3 wire system.

The bearings shall have ample strength to withstand the heavy shocks and variations to which they will be subjected. Full technical particulars of each motor including the value of the locked motor current, breakdown torque etc. shall be given in the Tender. All electrical works shall conform to Indian Electricity Act 1910 and Indian Electricity Rules 1956, wherever applicable.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

#### Motor for Various Motions:

- |   |   |
|---|---|
| i) Motor Standards                          | As per IS: 325 and IS: 3177   |
| ii) Capacity                                | Of ample capacity to suit respective duties.<br>Full load torque of motors shall be higher than the maximum load torque.  |
| iii) Type and Enclosures                    | All motors will be of squirrel cage type to suit 415 V, AC, 3 phase, 50 Hz, four wire power supply, totally enclosed. The motors shall be suitable for direct on line starting any hoisting / lowering rated load, even in event of frequency control system being out of order. Protection IP 54 with fan cooling arrangement. |
| iv) Variation of supply Voltage & Frequency | Voltage: $\pm 10\%$ ,<br>Frequency: $\pm 3\%$ ,<br>Any combination values of voltage and frequency variations within the above limits.  |
| v) Pull out torque (2.25)                   | Not less than Two point two five times the full load torque of motors at rated voltage and frequency.   |
| vi) Insulation                              | Class - F   |
| vii) Time rating                            | One (1) hour for all motors   |
| viii) Temperature rating                    | Temperature rise not to exceed the limits in Table-1 of IS: 325. Max. temperature rise at full load measured by resistance method shall not exceed 60 deg. C over the maximum ambient temp. of 40 deg. C.   |
| ix) Rated synchronous speed                 | To suit duty for various motions.   |
| x) Over speed withstand capacity            | Two point five (2.5) times rated speed or 2000 rpm whichever is less.   |

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- |       |   |  |
|-------|---|--|
| xi)   | Space heaters capacity is   | To be provided in case motor capacity is $\geq 20$ KW (To suit 240 V, AC supply).  |
| xii)  | Motor bearings grease leakage<br>Shall be of ample strength to withstand heavy shocks and vibration to which subjected under all conditions of operation. | Roller type. Sealed to prevent and entry of dust.  |
| xiii) | Tests   | Type & routine tests as per IS: 325.<br>Copies of test reports to be furnished by the supplier   |
| xiv)  | Temperature rise  | By resistance method measurement.  |
| xv)   | Climate   | Shall be located indoor in tropical climate.<br>Protection against fungus, vermin, and corrosion shall be provided                       |
| xvi)  | Terminal  | Shall be arranged such that terminals are easily accessible for inspection and maintenance. Natural ventilation shall not be restricted. |
| xvii) | General requirements  | Sturdy and strong to withstand operational shocks and vibrations.  |

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

### 19.5.3 Brakes:

The brakes for various motion drives shall be as per the IS: 3177 or other international standard. The following type of brakes shall be provided for the various crane drives:

- a) Bridge Travel
  - i) Main Braking by means of frequency speed control of motors down to zero (0) (regenerative braking).
  - ii) Automatic DC electro-magnetic brake for each motor drive.
  - iii) Foot actuated hydraulically operated brakes for wheels on both sides of bridge of double (2) brake discs.

- b) Trolley Travel
  - i) Main braking by means of frequency speed control of motors down to zero (0) (regenerative braking).
  - ii) Automatic DC electro-magnetic brake for each motor drive.
  - iii) Automatic Electro-Hydraulic thruster brakes.

#### c) Hoisting Motion

#### For Main Hoist:

- i) Main braking by means of frequency speed control of motors down to zero (0) (regenerative braking).
- ii) Automatic DC electro-magnetic brake for each motor drive.
- iii) Automatic electro hydraulic thruster brake

#### For Auxiliary Hoist:

- i) Main braking by means of frequency speed control of motors down to zero (0) (regenerative braking).
- ii) Automatic DC electro-magnetic brake for each motor drive.
- iii) Automatic electro hydraulic thruster brake or double brake discs.

The electromagnetic brakes shall be of DC type complete with rectifier equipment to convert the available AC 230 V, 50 Hz supply. The electro-hydraulic thruster brakes be of AC type.

The operating solenoids of the DC Electro-magnetic brakes shall release the brakes on energisation and shall automatically apply all the brakes immediately in the event of stoppage, interruption or failure of electrical power supply. The brakes shall also

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

apply immediately on operating the emergency stop push button or switch irrespective of controller position.

The DC Electro-magnetic brakes shall be of spring set shoe type equally effective in both directions of rotation. The springs for the Electro-magnetic brakes shall be of compression type and shall have adequate factor of safety.

The brake system shall have the following provisions:

- a) Locking device in the brake lever.
- b) Means for adjustment to compensate for wear of the shoes / discs.
- c) Emergency stop push buttons.

The wearing surfaces of all brake drums shall be machined and shall be cylindrically smooth and free from defects. The brake lining shall be effectively and permanently secured to the brake shoes during the effective life of the lining and shall be protected from water, grease, oil and other adverse effects. The brake pedals in case of foot operated brakes shall have non-slip surfaces and it shall be possible to apply the foot brakes with a force not exceeding 25 kgs.

All the brakes shall have adequate capacity. The brakes for hoisting when applied shall arrest the motion and sustain the load up to the test load at any position of the lift. Provision shall be made to control with safety the lowering of any load up to the test load.

Brakes in other motions shall be capable of bringing the relevant motions of the fully loaded crane safely to rest in the shortest possible time with least possible shock and shall arrest the motion under all other service conditions.

The various brakes shall be designed to exert, the torque equal to 1.5 times the full load torque of motors.

The brake torques may be increased if considered necessary by the supplier in order to ensure proper and safe application of the brakes. All Electro-magnetic brake coils shall have continuous rating.

Each brake of the travel motions shall be equipped with a manual disconnect lever which will allow the brakes to be released without electrical power.

#### **19.5.4 Limit Switches:**

All limit switches shall have a minimum contact rating of 5A at 240 V AC and shall include the following:

Self-reset rotary type limit switch of gear or cam design for the hook block.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

1 (one) each for main & auxiliary “Hoist” motions.

1 (one) each for main & auxiliary “Lowering” motions.

Hand reset gravity type back up unit switch to operate in the event of failure of main unit switch (s) 1 (one) each for main & auxiliary hoist motions.

Self-reset type lever operated limit switches with closed contacts shall be provided to operate at the extremities of travel motions as given below or as required.

2 (two) for bridge travel motions.

2 (two) for trolley travel motions.

All limit switches shall be capable of reset by reversing the controller.

The Contractor shall ensure that spring failure within the limit switches do not make them inoperative.

All limit switches shall be of IP-55 enclosures.

#### **19.5.5 Load Cell System:**

The main & auxiliary hoists of all cranes shall be equipped with a load cell system capable of measuring the loads on their hooks. The load cell system shall measure loads from 0 to 130% of the hoists rated capacity with a precision of +/- 5% or better, between the effective & indicated loads, for all loads between 0 to 130% of the rated load of the hoists.

The load cell shall be of corrosion-resistant steel construction and shall be designed with a factor of safety of not less than four (4) at 130% of the rated capacity, relative to the ultimate strength of the material.

The load cell system shall operate from the crane’s AC power supply and shall display the load on the hooks in tons through a 3-digit display or meter located in the operator’s cage.

The load cell system shall incorporate a capacity limiting feature which will prevent the crane from handling a load which exceeds a set point by stopping all crane motions. This point shall be adjustable for any load between 90% and 120% of the hoists rated capacity. Whenever this feature stop the crane, a flashing red light, visible from the floor beneath the crane, shall be energised, to indicate that the crane is overloaded. An override switch shall be provided in the radio control transmitter to allow for overload tests. The response of this capacity limiting features shall be suitable delayed to compensate for the momentary, dynamic loading when the hoist’s motors are started.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## **19.6 Electrical control & protection for operation of cranes:**

### **19.6.1 General:**

The cranes for Powerhouse and Valve House shall normally be controlled from the floor by radio control. The cranes shall also be controllable from a stand-by control station located in the operator's cage. This stand-by station shall be equipped with a complete set of lever type controls for temporary crane operation and shall provide reasonable visibility for the operator to permit safe temporary operation. The cranes shall be provided with a control scheme selector switch located in the operator's cage. This switch shall select between the radio control and the standby control scheme. Modes of operation shall be controllable by the radio control scheme. The radio control system shall provide all crane motions with separate control levers.

The GIS Hall crane shall be controlled & operated only from the floor by radio control.

All crane motions (hoist, trolley, and bridge) shall be regulated by adjusting either the voltage and / or frequency of the motor electrical supply with a variable frequency drive device.

Each crane shall be provided with control panel / desk located in the operator's cabin. The controls shall provide for:

Individual independent control of cranes for all motions and various speeds up to normal speeds.

### **19.6.2 Drive control:**

All the drives (Main hoist, Auxiliary hoist, Bridge & Trolley travels) of each crane shall be supplied with variable voltage variable frequency (VVVF) for fine speed control of the drives.

#### **19.6.2.1 Description:**

Equipment for controlling this drive shall be a multi drive system, with inverters in one cabinet. Each cabinet consists of one common rectifier with a common DC-bus, with inverters connected. This system will, in case braking energy is being supplied from one motor, supply the energy to the next motor connected to the DC-bus. If the braking energy exceeds the energy used by the other inverters, a braking chopper will open, and supply the energy to a braking resistor.

All frequency converters shall be connected to application process controller (APC), where all controls on the frequency converters shall be done. The APC shall program the application to fit the required specifications.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The APC shall also be provided with communication controllers of other systems. In tandem drive applications communication shall be done through these serial communication channels, in order to obtain exact common speed for the two systems.

The control shall be closed loop vector control system.

#### 19.6.2.2 Functional Description:

Each movement of the crane motors is controlled by joysticks in the crane control cabin. Motors are controlled by the APC in the frequency converter cubicle. The APC gets the direction / speed signals from the joystick. The APC calculates the speed and torque, in order to secure correct speed.

When stopping the operation of hoisting or lowering, the APC performs commands to the frequency converter, for lowering the speed to zero, and keeping it at zero speed before giving order to turn on the brake. When starting the operation of lowering or hoisting, the APC controls the frequency converter with a certain torque before releasing the brake, in order to avoid any drop.

If the braking energy exceeds the energy of all the frequency converters, the braking chopper will open and use the braking resistor.

When in "position Mode", the joystick signal is disabled and only joystick movement signal is used.

When the crane operator moves the joystick forward, the crane will move only over a predefined distance, and stop. To move an additional step he will have to move the joystick once more etc.

#### 19.6.3 Control levers & Push Buttons:

For individual independent control (start, stop and motor speed selection) of each crane, suitable joysticks/control levers/push buttons shall be provided as described in this specifications.

The controls shall provide for torque and precise speed control of the various motors in adequate numbers of steps (within the range of stepless speed control) in both directions of motions.

#### 19.6.4 Remote Radio Control:

##### 19.6.4.1 General:



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The operation of Powerhouse EOT crane from service bay shall be made by remote radio control system. However, provision for control of the crane from the floors immediately below it, available during the progressive construction of the power house (including the lower most floor) when subsequent floors have not been casted, shall also be possible by the above remote radio control system. For Valve House and GIS Hall cranes, the operation shall be carried out by a remote radio system from their respective floors.

The equipment furnished shall provide for the complete radio control of all crane functions specified in following paragraphs:

Each radio controlled crane shall be equipped with a 100W amber indicator lamp located beneath the centre of one of the bridge girders. This light shall be energised whenever the crane is in the radio control mode and the crane's master contactor has been energized.

Reliability, dependability and ease of maintenance shall be prime considerations in the design and construction of all components and parts of the equipment to ensure positive operation of the system under all conditions of dust, moisture, temperature, vibration and electrical interference. Reduced maintenance requirements and long service shall be achieved through simplicity and use of conservatively rated, heavy-duty industrial type parts. The design of the equipment circuitry and application of components shall represent the state of the art.

Wherever practicable, replaceable modules with reliable plug-in connections shall be used.

The system shall be designed so that no field tuning adjustments will be required when replacing a faulty module and permit a field change of the operating frequency by replacement of plug-in type components with minimum adjustment.

The radio control equipment shall be type accepted by and shall conform to all applicable Government rules and regulations. The frequency of operation shall be in the requisite frequency band. However, the remote radio control of the cranes shall operate at different operating frequencies within the requisite frequency band. The supplier shall perform a frequency search and shall file operating license on behalf of the Owner.

Radio crane control equipment shall be of reputed make.

#### 19.6.4.2 Operation:

The following functions shall be radio controlled:

- Forward and reverse speed control of the bridge travel motion.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- Right and left speed control of each trolley travel motion.
- Up and down speed control of each hoist motions.
- On and off control of the lights on the underside of the crane bridge.
- On and off control for the crane's master contactor
- On and off control for the crane's alarm gong.

The speed control of each motion shall provide for the direct radio stepless control specified for that motion. Stepless radio control shall be accompanied with a speed set point telemetering system utilizing pulse rate, pulse width, or other similar systems. The speed of a motion shall be a direct function of the control lever's position and shall preferably utilize a logarithmic scale for greater control of the slower speed. A "jogging" system of controlling a motorised potentiometer or any other system, in which the control lever's position corresponds to acceleration rather than a speed, is unacceptable.

Control information shall be transmitted using digitally coded information. The radio control system shall allow simultaneous transmission of all crane functions. A means of checking and detecting error in the digital data stream shall be provided to prevent a mis-operation of the crane. Radio interference signal shall not cause operation of any of the crane functions.

The power supply to the radio receiver shall be obtained from a branch circuit in the power distribution panel.

When a "control hand-over" feature is specified for a crane, there shall be 2 radio control units, each equipped all crane functions and tuned to operate on different radio frequencies. Interlocking circuitry in the receiver shall permit only 1 of the 2 control units to be effective at a time. There shall be no crane motion when one of the units takes control, and all crane drives must be stopped when a unit releases control.

#### 19.6.4.3 Safety:

The complete control systems shall be designed to provide maximum safety for personnel, crane equipment, adjacent structures, plant equipment and materials being conveyed. The equipment shall comply with all laid down safety requirements applicable to this class of equipment.

Control signal combinations shall be designed for safe operation so that uncommand operation of any crane cannot result from stray or transient control signals or from extraneous natural or man-made sources of radio frequency interference.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The system shall be designed “fail safe”. Failure of electronic component or normal aging beyond specific limits shall result in stopping all crane motions. Crane motions shall also stop when any crane receiver is out of the range of its transmitter.

A “dead man” feature, consisting of self-centring control levers and safety cut-off switches, shall be built into the control transmitters to cause all crane motions to stop if the operator releases pressure on the corresponding control lever or if he accidentally trips, or fall or drop the transmitter.

Shock conditions or vibration encountered on the cranes shall not defeat the safe operation of the receiver units. The crane control system shall be designed to provide nearly instantaneous operation of all crane motions and functions in response to master control settings.

Operating frequencies shall be selected to be free from interference from other radio frequencies used in the vicinity. It shall also be ensured that remote radio control of one crane cannot operate other crane.

#### 19.6.4.4 Transmitters:

The transmitter shall be of light weight construction not exceeding 3 kg in weight (including battery) and shall be equipped with a belt or shoulder harness.

Transmitter control levers shall be furnished for all multi-speed crane motions and shall be spring return and guarded against false operation.

The transmitters shall be operated by compact, nickel-cadmium batteries capable of 8 hr. of operation without recharging.

Battery chargers suitable for charging 2 sets of transmitter batteries simultaneously shall be furnished for either wall or shelf mounting. The battery chargers shall operate on 230V, 50 Hz AC supply. Batteries and battery chargers shall be supplied in an amount as required to permit 24 hours per day, 7 days per week operation of the radio controllers.

Radio control units designed and adjusted for use with one crane shall not be capable of controlling any other cranes at the site unless specifically readjusted for the purpose of controlling a different crane.

Transmitters shall be completely solid state.

All control functions shall use crystal controlled radio frequency signals.

#### 19.6.4.5 Receivers:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

Receivers shall be designed to respond only to signals from the transmitter control unit designed and adjusted for operating that specific receiver.

Receivers shall be chock proof to resist vibration.

Receiving antennas shall be rugged construction, corrosion proof and shall be mounted under the crane bridge.

The receivers shall be completely solid state. All semi-conductors shall be silicon to the extent practicable.

Failure of any electronic component shall result in "fail safe" operation bringing all crane motions to a halt. Uncommand motions shall not be possible. Digital coding shall be designed to prevent inadvertent control actions.

#### 19.6.4.6 Intermediate Relays:

Intermediate relays shall be heavy-duty with 10A continuously rated contacts and shall be capable of withstanding inductive transient voltages resulting from crane control contactor operation. Surge suppression shall also be provided to protect receiver component from inductive transient voltages.

Intermediate relay panels shall be separately fused and provided with disconnect devices.

#### 19.6.4.7 Alarm gong operation:

The crane shall have a radio control function to sound the alarm gong wherever the operator elects.

#### 19.6.4.8 Operating distances:

The Powerhouse, Valve House and GIS cranes shall be operable by radio control system from a minimum horizontal distance of 80m, 20m and 91m respectively.

### 19.6.5 Electrical Interlocks:

The main circuit breaker (CB) for power supply to the crane shall have interlock providing CB to be able to be closed only when all the control lever switches for the various motors are in "Off" positions. The interlock shall be so arranged that if the contactors for various motors / drives have failed to open even though the control lever switches have been brought to the "Off" positions, the CB will not close.

The master controller shall be provided with a thumb operated auxiliary switch so as to ensure the safety of personnel and equipment in case of loss of attention or

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

chance death of the operator during operation of any crane. The control circuit of the master controller shall be so arranged that all the controls during starting and subsequent operations shall be de-energised unless the thumb operated switch is kept in pressed position. During the operation also if the operator fails to keep it pressed, the power supply to the controls shall be disconnected.

The inter locking arrangement shall be such that during tandem operation of power house cranes, if the main circuit breaker of one crane trips, the circuit breaker of other crane shall also trip automatically.

An isolator fitted on the crane bridge which cannot be operated from the floor, shall be provided to prevent inadvertent operation of the crane from the floor from Radio Remote Control system while maintenance work is being carried out on the crane.

T.P. isolators with indicating lamps shall be provided by the contractor so that it can be operated from ground and power supply can be cut off immediately in case of any emergency condition.

#### **19.6.6 Miscellaneous Features:**

19.6.6.1 The controls shall have following provisions:

- a) 3 pole 415 V AC, ACB with rupture current not less than 50 KA.
- b) A master push button for complete emergency stop in the cabin at a convenient location.
- c) A key operated electrical switch for the control circuit to prevent unauthorized operation and for the safety of maintenance and operating personnel.
- d) Indicating lamp to show that the control circuit is healthy.
- e) Indicating lamp for the main circuit breaker position (OFF, ON or AUTO TRIP).
- f) Radio Remote Control system with proper indication.
- g) All control panels shall be of minimum 14 SWG, CRCA sheet steel.

19.6.6.2 Automatic Electrical Protection:

The electrical equipment and circuitry shall be provided with automatic protection, as detailed below against various faults and mal-operation of the equipment.

- a) Protective relays for protection against instantaneous over-current, over-load, single phasing and under voltage for all motors. The OC relay shall be adjustable between two (2) to three (3) times the full load motor current.
- b) Protective relays of motors to trip the main power supply circuit breaker in case of their operation due to fault.
- c) MCCB's for control and protection of all motor circuits.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

- d) Air circuit breaker located in operator cabin, of 3 pole, 415 V, A.C, totally enclosed type for power supply tapping from the main collectors, with interrupting capacity not less than 50 KA, equipped with short circuit, overload and under-voltage trip devices and one shunt trip coil and prevention against single phasing, three (3), timer relays and other necessary devices / items.
- e) Protection against over speed of the hoist motors which shall cut-off the power supply and apply the brakes in case any hoist motor speed increases to 105% of the rated synchronous speed.
- f) Operation of any protective relays of motors shall trip the motor supply circuits by opening the primary contactors of the motors.

#### 19.6.6.3 Circuit Breaker / Controllers:

Each main supply circuit breaker or contactor shall have an interrupting capacity of not less than 50KA symmetrical at 415 volts. All switches, contactors, primary relays and primary circuits on the controller shall have a thermal capacity corresponding to 50KA for one second without injury and shall have a rating of at least 660 volts and capacity ratings in accordance with the British Standards or those of the National Electrical Manufacturer's Association (NEMA) standards. Allowable temperature rises shall be as prescribed in the Indian Standards or other equivalent standard and based on an ambient temperature of 40 deg. C.

All switchgear control and protective equipment viz. breakers, contactors, controller, control switches, HRC fuses, relays, meters etc. shall be housed suitably in a cabinet placed in a manner convenient for operation and maintenance in the cabins / travelling girders of the cranes. For wiring adequate number of terminal blocks ready for making external connections shall be provided.

#### 19.6.6.4 Alarm Gong:

An electrically operated alarm gong or buzzer which will sound while the crane is in motion shall be furnished with each crane. The alarm gong shall also be operable from a conveniently located switch when the crane is not in motion. Control switch shall be provided to silence the alarm gong, if required.

#### 19.6.7 Power Supply:

The power to the crane shall be supplied through a fully shielded conductor and collector system installed at appropriate elevation of the machine hall/unloading bay. The conductor system shall be of sufficiently low impedance and suitable current

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

carrying capacity to permit full operation of the crane at the most distant point from the power infeed.

The Contractor shall furnish the voltage drop calculations to establish satisfactory operation of the crane operating at rated load.

Red warning light shall be provided at both ends of the runway to indicate that power supply leads are alive.

Metal enclosed isolating switch fuse units shall be provided by the Contractor at 1.5 m above the operating floor level for isolating the power supply leads. All cabling from these isolating switch fuse units onwards shall be in the Contractor's scope.

#### **19.6.8 Cross Wires:**

Flexible copper wire PVC insulated trailing cables arranged in festoon configuration shall be provided on the bridge & cross wires. The cable shall be suspended on bearings operating on I-beam of suitable size just outside on the bridge girder.

#### **19.6.9 Power and Control Cables:**

All electrical wiring shall conform to latest version of IS: 1554 (part I) "PVC insulated (heavy duty) electric cables, for working voltage upto and including 1100 volts". All conductors for primary power, lighting and control circuits shall be insulated for not less than 1100 volts and shall have standard moisture resisting double braid coverings. All conductors between the secondaries of the motor contactors and resistors shall have sufficient current carrying capacity in accordance with the standard specifications and shall be insulated with 1100 volts class asbestos, high temperature type tropical insulation with moisture resisting impregnation. The primary conductors to the motor shall have standard, continuous current carrying capacity of not less than 120% of the rated full load primary current of the motors. All control and lighting conductors shall be of copper of suitable sizes. All the wiring shall be subject to approval of the purchaser. All wiring shall be laid in hot dip galvanised metal conduits. Alternately armoured cables can be used. Conductor having nominal equivalent copper area of cross section less than 2.5 mm shall not be used for wiring.

#### **19.6.10 Trolley Conductors:**

The conductors shall be of rigid type. Bare copper wire shall not be acceptable. The minimum clearance between live parts and ground shall be 80 mm. sufficient safety guards shall be provided to avoid any accidental touch with these conductors.

#### **19.6.11 Down Shop Lead Arrangement (Long travel current collecting system):**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

A safe, robust and compact approved down shop leads (DSL) power supply system with suitable collector using latest technology shall be provided for the Powerhouse & Valve House cranes on the upstream side. It shall consists of substantial Shrouded Copper Bus Bar of adequate capacity with end brackets and insulators, straining bolts, intermediate brackets and insulators etc. to suit power house buildings. One end of each conductor shall be fitted with a terminal log to enable power and earth wires to be connected. Safety guards shall be provided to avoid the possibility of any accidental touch with these conductors. The supply to D.S.L. shall be controlled by L.T. breakers installed at each end at a convenient place so as to receive the supply from L.T. Switchgear.

Down shop lead conductor system shall have ratings and characteristics as follows:

- |                               |     |
|-------------------------------|-----|
| • Normal operating voltage, V | 415 |
| • Maximum design voltage, V   | 600 |
| • Number of poles             | 3   |

These conductors shall have a continuous current rating as necessary to supply the maximum demand during crane operation, as determined by the greater of the following two (2) operating conditions:

- Load current for the simultaneous operation of main hoist motors and all bridge travel motors and
- Load current for the simultaneous operation of main hoist motors and all trolley travel motors.

The Down shop lead system, when assembled in place, shall permit independent longitudinal movement of the housings and conductors to allow for unequal thermal expansion and contraction. All conductors wherever required shall be housed in a common enclosure made of sheet steel not less than 16 gauge thick. Conductors shall be capable of carrying the rated current per pole continuously without overheating. Pickup trolleys shall have wheels equipped with sealed ball bearings and contacts of sufficient size to maintain full current carrying capacity without overheating. Contacts shall maintain constant contact pressure and alignment with the conductors.

The supplier shall furnish all necessary supports, wall brackets, mounting bolts and accessories, anchor bolts, concrete inserts, and conduit and cable connections for the power supply to the feed box. The supplier shall verify and satisfy himself about the adequacy of levelling, grouting etc.

#### **19.6.12 Circuit Arrangement:**



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The leads from the down shop collector shall be connected to a master manual magnetic contactor which shall be controlled by "on" and "off" pushbuttons and / or radio-controlled relays as specified for each crane. A control transformer shall be provided to activate the contactor and the radio receiver. The master contactor shall be connected to two (2) circuit breakers, each of appropriate carrying and interrupting capacity. One circuit breaker shall be connected to a 415 V/ 230 V, 3-phase, dry-type transformer of the rating required to supply power for all lights, controls, heaters, and convenience outlets on the crane. The second circuit breaker shall supply the main feed for the bridge, trolley, and hoist motors.

A 240 V, distribution panel equipped with branch circuit breakers as required, shall be provided to distribute power to the lights, heaters, and receptacles.

Interlocking circuits shall permit energization of the contactor only when all motion controllers are in the "off" position. Other interlocking features, as specified for the individual cranes, shall also be furnished.

#### **19.6.13 Lighting and Convenience Outlets:**

The permanent AC illumination system on the crane shall consist of four 1000 watts high bay beamed flood lighting units for the service bay crane to illuminate uniformly the area under each crane. Two 100 watts lighting units and two convenience outlets shall be provided in operator's cabin. A convenient outlet at each end of the bridge shall also be provided. The system shall be supplied from 415 V. AC crane power system through 415 V circuit breaker. For lighting and convenience outlets, 4 branch circuits shall be taken; one connected to two 100 watts lights in the operator's cage, another two branch circuits each connected to two 1000 watts high bay lights and fourth branch circuit connected to four convenience outlets. The wiring shall be done in accordance with latest Indian Electricity Rules. The 415 V circuit breaker shall be provided with an overload tripping element for each pole. The flood lighting units shall be suitable for control by both on-off push-buttons and radio control.

A portable hand lamp with plug and 25 m long wiring shall also be supplied for each of the crane by the supplier for use during maintenance.

#### **19.7 Earthing:**

The crane structure, motor frames and metal cases of all electrical equipment including metal conduit or cable armouring shall be efficiently bonded to facilitate earthing as per Indian Electricity Rules 1956 and IS 3043.

The supplier shall provide an earthing system to which all equipment under his scope of supply shall be interconnected. This system will in turn be connected by the contractor to the power house earth mat.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

## 19.8 Cleaning and Painting:

After fabrication, all structural steel and unfinished surface of castings shall be cleaned thoroughly of all mills or foundry scale, rust, dirt, oil, grease and other foreign substances. The cleaning shall be done by metal brush scrapers, chisels or hammers or by sand blasting. Oil and grease shall be removed by wiping with gasoline or benzene.

After cleaning the surfaces shall be given two priming coats of approved rust resistant paint. Surface which will not be accessible after the parts are assembled or erected shall be given additional shop coat. Immediately after cleaning all machined finished parts and surfaces including bolts and nuts shall be well coated with a suitable rust preventive compound. In addition, one coat of finishing paint of approved colour shall be applied over two coats of primer in the shop. All paintings shall be performed in workman like manner and the resulting paint film shall be uniformly thin without runs, or partially covered areas. All joints and crevices will be coated thoroughly. No paint shall be applied on damp or framed surfaces, and material painted under cover in damp or cold weather shall remain under cover until dry. In painting machinery, special care shall be taken that no paint is applied to finished surfaces. The material shall not be loaded for shipment until the paint is thoroughly dry. At no time after the application of paint shall any material be laid on ground. In handling painted material, care shall be taken to avoid scraping or breaking the painted surface. Sufficient quantity totally of paint for giving one coat to equipment after erection at site shall be supplied.

## 19.9 Inspection, Shop Assembly and Match Markings:

Shop tests (to be inspected) shall include chemical and physical tests on castings, X-ray tests on welds and general inspection of all important casting. Test certificates for motors, contactors, circuit breakers, hoist ropes, hooks, etc. shall be required to be furnished.

The cranes shall be completely assembled and operated and load tested in the shop by the motors and controls. The parts of cranes shall be delivered assembled in as large units as practicable for field erection and handling. Field connections shall be fitted in the shop and match marked suitably to facilitate field erection. All such match marks shall be clearly legible after the crane is painted. On painted surfaces the match marks shall be placed after the painting is completed. Six copies of all diagrams of such marks for field connections shall be furnished with the crane.

The Employer or his authorised representatives shall have access to the manufacturer's works at all reasonable times for the purpose of witnessing the manufacture, inspection and testing for all components or complete crane.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

Any work found defective or which is not in accordance with the approved drawing, standard or contract may be rejected by the inspector.

The particulars of the proposed tests and the procedures for the tests shall be submitted in detail in the proposal clearly indicating the tests offered for witnessing by the Owner. All materials, castings and forging shall be of tested quality. Besides other tests certificates, crane hook and wire rope tests certificates shall be made available. The certified reports on all these tests shall be submitted to the Owner for review. All materials can be despatched only after test certificate are approved. The approval of the Test Certificates shall be given only if the corresponding drawings and technical particulars of the equipment have been approved by the Owner.

The crane bridge shall have permanent inscription in English on each side readily legible from operating floor stating manufacturer's name, serial number, the year of manufacture and the safe working load.

## **19.10 Tests:**

### **19.10.1 Test at Manufacturer's Works:**

All electrical and mechanical equipment shall be tested in accordance with appropriate International or Indian Standard Specification at either the crane maker's or equipment manufacturer's works and test certificates shall be furnished.

The crane shall be tested under load on hoisting and cross traverse motions. Travelling gear may be run light to check shaft and gear alignments.

The Contractor shall clearly list the test that can be performed at his works.

### **19.10.2 Tests at Site:**

#### **19.10.2.1 Insulation tests:**

After erection but before crane is connected to the supply, insulation of electrical equipment shall be tested by suitable instrument and any defects revealed shall be rectified by the Contractor. The supply voltage required for the insulation resistance test shall be DC with voltage not less than twice the rated voltage.

#### **19.10.2.2 Motions and Approach Distances:**

The basic parameters like crane clearance shall be verified and the height of lift shall be measured.

#### **19.10.2.3 Speeds:**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The speed load characteristics of the various motions of the crane as offered by the manufacturer shall be verified by the Employer at his premises by actual loading such as no load, half load, full load at all notches. Any deviation shall be corrected by the manufacturer.

#### 19.10.2.4 Tests for operation:

After the supply has commenced and before the complete crane installation is put into commercial service, tests shall be carried out to prove the following:

- i) Satisfactory operations of each controller, tandem operation, switch contractor, relay and other control devices and in particular the correct operations of all limit switches under the most unfavourable conditions.
- ii) The correctness of all circuits and interlocks and sequence of operation.
- iii) The satisfactory operation of all protective devices.
- iv) The satisfactory operation of each motion of the crane.
- v) The compliance of the crane with the specified performance requirements and
- vi) The tolerance of specified speed at full load shall be within  $\pm 10\%$ .
- vii) The satisfactory operation of cranes by radio remote control individually & in tandem operation of above operations.

#### 19.10.2.5 Deflection Tests:

The test shall be carried out with the working load at rest and with the trolley in a central position. The measurement shall not be taken at the first application of the load. The datum line for measuring the deflection should be obtained by placing the crab on the extreme end of the crane span with smaller hook approach. The vertical deflection caused by the safe working load and weight of the crab/lifting beam in central position (without taking into account the impact factor) shall not exceed 1/1000 of the span.

#### 19.10.2.6 Overload Tests:

After tests but before the crane is put into service, it shall, with overload relays appropriately set, be tested to lift and sustain a minimum test load of 125 percent of the working load when the load is located at the centre of the span.

During the overload test each motion including bridge travel, in turn, shall be manoeuvred in both directions and crane shall sustain the load under full control.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 19 EOT Cranes

The test loads and necessary lifting arrangements shall be arranged by the Contractor.

#### 19.11 Mandatory Spares:

The Mandatory Spares shall comprise of the following:

Sl. No.	Item of Spare	Quantity
1.	<u>Bearings for :</u> - i) Truck wheels ii) Trolley wheels. iii) Long Travel Motor. iv) Cross Traverse Motor. v) Main hoist Motor. vi) Auxiliary Hoist Motor. vii) Creep speed motor for main & auxiliary hoist, cross travel & long travel. viii) Rope drums. ix) Pulleys for main hoist. x) Pulleys for auxiliary hoist.	4 Nos. 2 Nos. 4 Sets. 2 Sets. 2 Sets. 2 Sets. 2 Sets each. 1 Set. 1 Set. 1 Set.
2.	<u>Brake coil for E.M. Brakes for :</u> i) Long Travel Motion. ii) Cross Traverse Motion. iii) Main Hoist. iv) Auxiliary Hoist.	1 Set. 1 Set. 1 Set. 1 Set.
3.	<u>Brake lining with rivets for Electro Magnetic brake for :</u> i) Long Travel Motion. ii) Cross Traverse Motion. iii) Main Hoist. iv) Auxiliary Hoist.	2 Sets. 2 Sets. 2 Sets. 2 Sets.
4.	<u>Brake spring for electromagnetic brake for :</u> i) Main Hoist. ii) Auxiliary Hoist. iii) Cross Traverse. iv) Long Travel.	1 Set. 1 Set. 1 Set. 1 Set.
5.	<u>Brake lining with rivets for thrustor operated brakes for :</u> i) Main Hoist ii) Auxiliary Hoist.	2 Sets. 2 Sets.
6.	<u>Brake lining with rivets for Foot operated hydraulic brake for :</u> i) Long Travel Motion.	2 Sets.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

## **VOLUME- II**

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### **SECTION II SUB-SECTION 20 Electric Lifts & Elevators**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 20 Electric Lifts & Elevators
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## TABLE OF CONTENTS

<b>21</b>	<b>ELECTRIC LIFTS &amp; ELEVATORS.....</b>	<b>3</b>
21.1	GENERAL .....	3
21.1.1	Scope of Works .....	3
21.1.2	Design Data .....	4
21.1.3	Operating Conditions.....	4
21.2	SPECIAL CONDITIONS.....	4
21.2.1	Tender Drawings.....	4
21.2.2	Submission of Documents.....	5
21.2.3	Subcontract Orders.....	5
21.3	MATERIALS AND WORKMANSHIP.....	5
21.3.1	General.....	5
21.3.2	Erection.....	6
21.3.3	Painting and Protection.....	6
21.4	PARTICULAR REQUIREMENTS .....	6
21.4.1	Hoisting Machine.....	6
21.4.2	Landing Doors.....	7
21.4.3	Car, Counterweight, Safety Gear and Buffers .....	7
21.4.4	Suspension, Over speed Governor and Final Limit Switches .....	9
21.4.5	Guides.....	10
21.4.6	Power Supply, Controller, Electric Installation and Appliances.....	10
21.4.7	Emergency Operation.....	12
21.4.8	Spare Parts .....	12
21.4.9	Maintenance.....	13
21.4.10	Training and Instruction of Corporation's Personnel .....	13
21.5	INSPECTION AND TESTS .....	13
21.5.1	Technical Dossier and Certificates.....	13
21.5.2	Site Tests.....	15

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

## 21 ELECTRIC LIFTS & ELEVATORS

### 21.1 General

The Powerhouse shall be equipped with an elevator – for transport of persons and material. The elevator shall be located as shown in the Tender Drawings.

#### 21.1.1 Scope of Works

Scope of work under this chapter covers the provision of labour, tools, plants, materials and performance of work necessary for the detailed Design, Engineering, manufacture, quality assurance, quality control, shop assembly, shop testing, transportation, insurance till commissioning, delivery at site, site storage & preservation, erection, testing and commissioning, Safety certification from concerned authority, performance testing, field acceptance, training of Employers personnel, handing over to Employer and guarantee for two years of elevator with all auxiliaries, accessories and spare parts for making the system complete and for a trouble free and safe operation for HEO H.E. Project (3x80MW) in Arunachal Pradesh.

This Scope of work shall be as comprehensive functional system complete in every respect covering all supply and services including but not be limited to following:

- i) One (01) No. Sixteen (16) Passenger, 1088 kg Weight Elevator for Power House complete with control and accessories.
- ii) All Embedded parts, scaffolding, fire service switch, sound reducing systems, safety devices, pit ladder, indicators, facia and alarms etc.
- iii) Spare parts in accordance with relevant clause of the Contract Document
- iv) Tools and instruments in accordance with relevant clause of the Contract Document.

The Works shall also include the following items:

- Hoisting machine with provision for hand operation
- Landing doors and thresholds
- Car, counterweight, safety gear and buffers
- Suspension, overspeed governor and final limit switches
- Guides
- Power Supply, Electric Installation and Appliances
- First lubricant fill plus 10% reserve



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

- Special tools
- Submission of documents

Training and instruction of Corporation's personnel

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of work defined above, as per accepted standard(s) best international practices shall be provided by contractor at their own cost.

### 21.1.2 Design Data

1.	Type of service	-	Passengers
2.	No. of the passengers/load capacity of the lift	-	16 passengers (1088kg)
3.	Rated speed	-	1.0-1.5 m/sec.
4.	Total length of travel for serving the floors	-	Operating between Service bay & GIS Hall
5.	Method of control	-	Variable voltage and variable frequency (VVVF) control system.
6.	Position of machine room	-	As per layout feasibility

### 21.1.3 Operating Conditions

The elevator shall be driven by an electric hoisting machine of the traction type complete with motor, brake, gearing, drive sheave and driving shaft, all mounted in proper alignment on a steel bed plate. The motor shall be comply with the requirements of BS 5655 part 6, and be designed to operate on a duty cycle of 240 starts per hour.

Lift-car and well landing doors shall be of automatic sliding type for access to elevator car from one facial side. Smooth, however, rapid acceleration of the car, accurate floor landing/levelling without jerking and jumping shall assured. The elevator shall be designed for continuous operation as well as high stat/stop frequency as given above without overheating of hoisting machine.

## 21.2 Special Conditions

### 21.2.1 Tender Drawings

In addition to the request addressed in Volume 2, Part I, the Contractor shall submit the following drawings:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

- Arrangement of the elevator with particular reference to main dimensions of the elevator well and car, counterweight and guides and landing doors.
- Car emergency exit.
- Hoisting machine and safety brake.
- Access, assembly and maintenance spaces for lifting machine in the machine room.

### 21.2.2 Submission of Documents

Specific requirements with regard to the submission of documents are outlined in Part I, Volume 2.

In addition to the documents requested in Part I, the Contractor shall submit the following documents:

- Technical dossier as stated in Appendix C of the Standard EN 81, Part 1, 1985, consisting of
  - Name and address of the lift maker
  - Address of the installation premises
  - All necessary technical details and plans
  - Electric schematic diagrams
  - Certificates
- Draft operation and maintenance manual at least three months before beginning of site tests.

### 21.2.3 Subcontract Orders

Should some parts of the equipment be supplied by a subcontractor, the Contractor shall provide the engineer with references of the subcontractor on similar works.

## 21.3 Materials and Workmanship

### 21.3.1 General

The requirements outlined in Volume 2, Part I are likewise applicable for the elevator and appliances.

With regard to storage and erection of the equipment, the following requirements are also applicable:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

The Contractor shall be responsible for ensuring that all items of equipment be adequately protected from damage and deterioration at all times, including the period of storage and erection at Site. During the storage and erection of the equipment at Site, the Contractor shall be wholly responsible for its care and maintenance as well as operation until the tests have been satisfactorily carried out and the equipment formally taken over by the Corporation all as described in the Conditions of Contract.

During storage and erection at the Site, all equipment shall be kept clean and free of dirt and debris and water shall not be allowed to remain in any pockets of the equipment.

The Contractor shall be responsible for ensuring that the erection of the equipment is carried out in accordance with the Contract requirements and to the satisfaction of the Engineer so that the equipment, when fully completed and erected, will completed and erected, will comply with all the specified requirements.

When the site work is completed the Contractor shall remove all his constructional equipment, temporary works, building and other things and leave the whole area of the Site used by him in a clean and tidy condition to the Satisfaction of the Engineer.

### **21.3.2 Erection**

The elevator and associated equipment shall be assembled and installed in accordance with the drawings and erection procedures approved by the Engineer. It will be the Contractor's responsibility to establish the shop tolerances necessary to meet site installation requirements. After assembly and installation but before starting the site tests, the entire equipment shall be thoroughly cleaned. Alignments shall be recorded as outlined in the erection procedures.

### **21.3.3 Painting and Protection**

Reference is made to Part I, Volume 2. Car lining and door colours shall be to the approval of the Corporation.

## **21.4 Particular Requirements**

### **21.4.1 Hoisting Machine**

The hoisting machine, its associated equipment and pulleys shall be placed in the machine room above the elevator well. The machine room shall be ventilated and the maximum ambient temperature shall not exceed +45°C. One or more metal supports or hooks, as appropriate, shall be provided in the machine room ceiling, conveniently positioned to permit hoisting of heavy equipment during erection.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

The hoisting machine shall be equipped with a worm gear. All bearings shall be self lubricated ball-bearings. The braking device shall be provided with an amply dimensioned drum brake, automatically closing by pressure springs. In case of emergency, e.g. electric power failure, the car shall be lifted or lowered to the next landing level by a hand-operated device.

A stop switch, allowing the elevator to be stopped and kept stopped, shall be arranged so that there is no risk of mistaking the stop position.

#### **21.4.2 Landing Doors**

Automatic sliding landing doors shall be imperforated and shall be made of metal in such a way that they will not become deformed in the course of time. The landing doors shall be of a model which has undergone a fire test following the procedure described in Appendix F.2 of EN 81, Part 1, and satisfied the criteria laid down therein. The landing doors shall be guided top and bottom.

The landing doors shall be suitably interlocked with the car position. The doors shall open only if the car has reached the respective floor level. The car shall come to rest within 5mm of the level of the selected floor irrespective of the load. In case that the landing door is not closed, the operation of the elevator shall be prevented. In normal service, automatically operated landing doors shall be closed after the necessary period of time, which shall be adjustable between 5 to 30 seconds, in absence of a signal for the movement of the car. When a landing push button has been operated to call the lift, and the lift doors and landing doors are closed then the control of the elevator shall remain with the lift car for a period of not less than five seconds. After this delay, the lift car can be controlled by other landing push buttons. A floor switch or interlock for retaining control with the lift is not permitted. A protective device shall automatically initiate re-opening if the door in the event of a person being struck (or about to be struck) by the door in crossing the entrance during the closing movement

Each landing door shall be provided with a locking device which shall be protected against deliberate misuse. Further, each of the landing doors shall be capable of being unlocked from the outside with the aid of a triangle key.

The panels at the landing doors shall be provided with:

- electronic sensor touch plates as landing level switches marked with each floor name.
- direction and floor level indicator,
- gong signal indicating arrival of car.

#### **21.4.3 Car, Counterweight, Safety Gear and Buffers**

The car shall be completely enclosed by walls, floor and roof, the only permissible openings being as follows:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

- entrance door
- emergency exit cover
- ventilation apertures.

The walls, floor and roof shall have sufficient mechanical strength to resist the forces which will be applied in normal operation, in safety gear operation or impact the car on its buffers. The floor shall have a robust non-skid surface. The walls and sliding imperforate entrance doors shall be of brushed stainless steel.

The car doors shall be designed in such a way as to minimise the harmful consequences of jamming a part of a person, clothing or other object. A sensitive protective device shall automatically initiate re-opening of the doors in the event of a person being struck (or about to be struck) by the doors in crossing the entrance during closing movement.

The car roof shall be provided with a 600 mm x 600 mm emergency exit with cover of flap type. A telescope ladder shall be mounted to the cover to allow easy access from the car bottom to the roof.

The elevator car shall be sufficiently ventilated and lighted. The electrical lighting shall ensure a permanent illumination of a light intensity of at least 50 lux at floor level and on the control devices. There shall be an automatically rechargeable emergency supply which is capable of feeding at least a 1 W lamp for 1 hour in case of an interruption of the normal lighting supply. The emergency lighting shall come on automatically upon failure of the normal lighting supply.

The counterweight shall balance the weight of the elevator car weight plus 50% of the loading capacity. The counterweight shall incorporate filler weights; necessary measures shall be taken to prevent their displacement.

The car shall be provided with a safety gear capable of operating only in the downward direction and capable of stopping a car carrying the rated load, at the tripping speed of the over speed governor, even if the suspension devices break, by gripping the guides, and holding the car there. The car safety gear shall be preferably of the progressive type but can be also of the instantaneous type with buffered effect. The safety gear of the counterweight may be tripped by the failure of the suspension gear or by a safety rope. The release of the safety gear on the car (or on the counterweight) shall be only possible by raising the car (or the counterweight).

The car and counterweight shall be provided with appropriate buffer for the bottom limit of travel for car and counterweight. In addition, buffers on the car top shall be provided to function at the upper limit of travel. These upper buffers shall not function until the counterweight buffers are fully compressed. The energy dissipation type buffers shall be preferred, but the energy accumulation type buffers may be used.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

The car and counterweight shall be guided by four (4) rigid guides made of drawn steel with machined rubbing surfaces.

A storage cabinet for two battery lamps and a 5 kg fire-extinguisher shall be arranged in the car.

The car control panel shall be equipped with:

- electronic sensor touch plates as,
  - 1) Landing level switches marked with each floor name.
  - 2) Non sustaining switch to hold the doors open.
  - 3) Alarm switch connected to bells audible outside the lift well at all levels.
- floor indicator,
- safety switch for emergency stop and acoustic alarm at all levels and in the central control room ,
- key locked switch for manual control of car position.
- car overloaded indicator lamp

A wall type telephone inside the car shall be provided to connect with the station PABX supplied under Volume-2, Part-B, Section-17.

#### **21.4.4 Suspension, Over speed Governor and Final Limit Switches**

The car and counterweight shall be suspended from two (2) ropes. The safety factor of the suspension ropes shall be at least 16. The ration between the pitch diameter of sheaves or pulleys or drums and the nominal diameter of the suspension ropes shall be at least 40.

The over speed governors shall be completely accessible in all circumstances. If located in the well it shall be accessible from outside. Tripping of the over speed governor for the car safety gear shall occur at a speed at least equal to 115% of the rated speed and less than 1.5 m/s. The tripping speed of the over speed governor for the counterweight safety gear shall be higher than for the car safety gear, not, however, exceeding it by more than 10%.

The over speed governors shall be driven by very flexible wire ropes. The ratio between the pitch diameter of the over speed governor pulley and the nominal rope diameter shall be at least 30.

The final limit switches shall be provided and shall be set to function as close as possible to the terminal floors. They shall operate the car comes into contact with

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

buffers. The action of the final limit switches shall be maintained whilst the buffers are compressed. Separate control devices shall be used for normal terminal stopping and final limit switches.

#### **21.4.5 Guides**

The strength of the guides, their attachments and joints shall be sufficient to withstand the forces imposed due to the operation of the safety gear and deflection due to uneven loading of the car. The deflections shall be limited to values that will not affect the normal operation of the elevator.

The fixing of the guides to their brackets and to the building shall permit compensation of effects due to normal setting of the building or shrinkage of concrete.

The clearances specified in the Standard EN 81, Part 1, shall be maintained not only during the examination and tests before the elevator is put into service, but also throughout the life of the elevator.

#### **21.4.6 Power Supply, Controller, Electric Installation and Appliances**

Power supply shall be 415/240 V, 50 Hz. The electric equipment used shall conform to specific guide lines are outlined in Volume 2, Part I. Further, the stipulation specified in the Standard EN 81, Part 1, 1985, Chapters 13, 14 and 15 regarding electric installation and appliances, controls, priorities, protection against electric faults, and operating instructions shall be observed accordingly. Insulation of all wiring and cabling shall be of fire resistant type.

The controller shall be of the floor mounted, totally enclosed cubicle type, of robust steel cabinet construction. The controller shall be designed for 'frequent duty' in accordance with BS 587. It shall be designed to start, accelerate, stop and reverse the lift car when the appropriate push button is pressed. Means shall be provided to prevent the motor from being energised against phase failure and/or phase reversal.

All operating mechanisms fixed in the lift shaft or to the lift car shall be arranged so that positive contact and action is assured irrespective of the floating movement of the car from side to side in the guides and under all conditions of operation of operation of the lift.

Where gravity and/or spring opening contactors having metal to metal contacts are employed to open a main circuit to stop the lift machine, such devices shall have at least two independent breaks.

Neither the operation of a spring nor the completion of another electrical circuit shall be depended upon to open a circuit to stop the lift at terminal floors.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 20 Electric Lifts & Elevators
---	--	---

No control system shall depend upon the completion or maintenance of an electrical circuit for:

- 1) The interruption of the power supply to the motor and the application of the brake to stop the lift car at terminal floors.
- 2) The interruption of the power supply to the motor and the application of the brake to stop the lift car when the emergency stop push-button or switch is operated.
- 3) The operation of the safety gear, dynamic braking and speed control excepted.

A reverse phase relay shall be incorporated in the controller.

The installation of capacitors will not be permitted, unless it can be shown that their mal-operation or failure will not create an unsafe condition.

Control circuits shall be so arranged that an earth fault or open circuit shall not create an unsafe condition.

Mechanical or electrical timing or time delay mechanisms only shall be used. Oil dash-pot timers will not be permitted.

Resistances shall be of tubular grooved ceramic construction, mounted vertically in a separate and ventilated compartment within the main control cubicle or within a separate cubicle.

The machine room shall contain a main switch capable of breaking the power supply for the elevator interrupting the highest current involved in normal conditions of use of the elevator.

The switch shall not cut the circuits feeding:

- car lighting or ventilation
- socket outlet on the car roof
- lighting of the machine room
- socket outlet in the machine room
- lighting of the elevator well
- alarm device.

The main switch shall have stable open and closed positions.

#### Fire Protection :

The Contractor shall supply and fix a thermostatic device which upon detecting a temperature of 70°C on the outer surface of the landing doors or 40°C in the machine room, lift well or pit, shall send a signal to terminals in the machine room.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 20 Electric Lifts & Elevators
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#### 21.4.7 Emergency Operation

- Automatic Emergency Movement to Nearest Floor:

The elevator shall be equipped with an emergency operation system that automatically moves the lift to the nearest floor and opens the doors under the following emergency conditions:

- a. Failure of the primary power supply.
- b. Detection of a fire hazard or activation of fire alarms.
- c. Activation of the emergency stop button by a user inside the elevator.

- Back-Up Battery Supply

To ensure functionality during emergencies, the elevator shall be equipped with a back-up battery supply. The battery system shall provide sufficient power to enable the emergency movement to the nearest floor, the opening of doors, and illumination of the elevator cabin for at least 30 minutes.

- Safety and Compliance

The emergency operation and back-up power system shall comply with all relevant safety standards, including (mention applicable standards, e.g., EN 81-20, ASME A17.1, or local standards).

Testing and Certification

#### 21.4.8 Spare Parts

The Contractor shall supply two (2) sets of Wear and Tear items and one (1) set of customary spare parts for “Identical Assemblies” as outlined in Part I ,Volume 2. In addition, the following spare parts shall be provided:

- Suspension ropes of the total length for erection of the car and counterweight
- Complete set of ropes for over speed governors
- One set of brake parts, flexible coupling subject to wear
- Two sets of limit switches, of each type
- One set of centrifugal switch, of each type
- Two sets of relays, of each type
- Two sets of all lamps, of each type
- Two sets of protectors of fuses, of each type

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

- Bolts, nuts, painting material, etc. shall be supplied as outlined in Part I, Volume 2.

The Contractor shall price the above parts I the Price Schedule for Specified Spare Parts.

The Contractor shall also identify and price parts not specified above, but recommended for a five (5) years operation period I the Price Schedule for Recommended Spare Parts.

#### **21.4.9 Maintenance**

A control point for maintenance operation shall be located on top of the lift car in compliance with BS 5655. The control point shall consist of:

- a) A changeover switch labelled “NORMAL”; “STOP”, “INSPECTION”. In the “NORMAL” position, the control of the lift shall be from inside the lift car and landings. In the “INSPECTION” position, the control of the lift car shall be from the control point on top of the lift car only. In order to reach the control point in safety, the lift must be taken out of service.
- b) Two non-sustaining push buttons labelled “UP” AND “DOWN” shall be provided at the control point on top of the lift car.
- c) A notice shall be provided on top of the lift car as follows:-

#### **ACCIDENT PREVENTION!**

#### **TRAVEL IN DOWNWARD DIRECTION ONLY!**

#### **21.4.10 Training and Instruction of Corporation’s Personnel**

The Contractor shall hold training session to familiarise the Corporation’s Personnel with all aspects of operation and maintenance of the equipment before the beginning of the site tests. The technical documentation used in the training session shall include the Contractor’s draft operation and maintenance manuals and test procedure descriptions approved by the Engineer.

### **21.5 Inspection and Tests**

#### **21.5.1 Technical Dossier and Certificates**

The Contractor shall submit with the Documents stated in Clause 21.2.2 above also all necessary certificates.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

The type examination and tests certificates shall be provided in triplicate to the Engineer. The type examination and tests certificates are required for (but not limited to) car, locking devices, landing doors, over speed governors, safety gear, buffers, ropes, etc.

When the equipment is approved by the Engineer, he will confirm that it is satisfactory, and can be packed for shipment.

The contractor shall ensure proper testing of the emergency operation system and back-up battery during commissioning. A certificate of compliance with the specified safety standards shall be submitted prior to final acceptance.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 20 Electric Lifts & Elevators

### 21.5.2 Site Tests

The Contractor shall conduct the following commissioning tests to ensure that the equipment has been correctly installed, all necessary adjustments and settings been made, and that it is in sound condition to operate.

Before the elevator will be put into service the examination and commissioning tests shall be performed according to the Appendix D of the above Standard EN 81, Part 1.

After successful completion of examination and all commissioning tests, the goods passenger elevator and the associated equipment shall be subject to a Test Service Period. The Test Service Period operation shall be carried out under supervision and responsibility of the Contractor.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

## VOLUME- II

### SECTION II SUB-SECTION 21 Fire Fighting System

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 21 Fire Fighting System
---	---	---

## Table of Contents

21.1	SCOPE OF WORK.....	3
21.2	DETAILED SCOPE OF SUPPLY .....	3
21.3	SPECIFIC DESIGN AND LAYOUT CONDITIONS .....	5
	<i>Design considerations</i> .....	7
21.4	BASIC DIMENSIONS AND RATINGS .....	7
	<i>Pumps</i> .....	7
	<i>Fire pumps</i> .....	7
	<i>Headers and piping</i> .....	8
	PERFORMANCE CRITERIA AND GUARANTEE .....	8
21.5	DESIGN AND CONSTRUCTION.....	8
	<i>Standards</i> .....	8
	<i>Overhead fire tank</i> .....	9
	<i>Piping, valves and appurtenances</i> .....	9
21.6	FIRE DETECTION DEVICES.....	9
	<i>Notification devices</i> .....	11
21.7	FIRE SUPPRESSION SYSTEM .....	11
	<i>Hydrant systems and hose reels</i> .....	11
21.8	FIRE ALARM, SUPERVISION AND SIGNALING SYSTEM .....	14
21.9	FIRE WORK STATION AND VIDEO DISPLAY UNIT .....	16
	<i>Fire barriers, assemblies and interior finish</i> .....	17
	<i>Cable and wires</i> .....	17
21.10	DRAWINGS, DOCUMENTS AND DESIGN CALCULATIONS .....	17
	<i>Design memorandum</i> .....	17
	<i>Drawings and documents</i> .....	17
	<i>Design calculation</i> .....	18
	<i>Shop Tests</i> .....	18
21.11	INSTALLATION AND COMMISSIONING .....	18
21.12	FIELD TEST .....	19
21.13	SPARE PARTS .....	20
	<i>General Spare Parts</i> .....	20
	<i>Recommended Spare Parts</i> .....	20
	<i>Specified Spare Parts</i> .....	20
	SPECIAL TOOLS .....	21

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

## **21. FIRE FIGHTING SYSTEM**

### **21.1 Scope of Work**

Scope of work under this chapter covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, insurance till commissioning, delivery at site, site storage and preservation, installation, commissioning, performance testing, acceptance testing, obtaining approval of TAC / concerned Govt. Authority, training of Employer's personnel, handing over to Employer and guarantee for two years of firefighting system, as per the specifications hereunder, complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation. The scope of work shall be a comprehensive functional system covering all supply and services including but not be limited to following:

### **21.2 Detailed Scope of Supply**

#### **Fire protection system**

- i) Two (2) nos. horizontal centrifugal pumps (Fire Water Pumps) of suitable type, along with, local control panel, instrumentation and associated accessories for filling of overhead water tank from Cooling Water Header.
- ii) In case there arises a need for booster pumps for developing the requisite water pressure in the hydrant system, such pumps shall be provided with 100% redundancy, the redundant pumps being diesel engine driven.
- iii) Ten (10) nos. HVWS system for fire protection of GSU transformers, Station Service Transformer.
- iv) Three (3) nos. of HVWS system for fire protection of governor oil pumping units,
- v) Three (3) nos. of HVWS system for fire protection of main inlet valve oil pumping units.
- vi) Nitrogen Injection Fire Protection and Extinguishing system (NIFPES) for GSU transformers, Station Service Transformer.
- vii) Suitable system for firefighting of power & control cables/trays/GIB and trenches/gallery as per approved drawings and bill of materials
- viii) Wet sprinkler system for offices, conferences room/ meeting rooms/ stores/DG room/other equipment rooms, cable spreading room area, cable trays in power house etc. as per approved drawings
- ix) Automatic inert gas clean agent fire extinguishing system complete with clean agent cylinders, manifolds, directional valves, pipes, discharge nozzles bracket supports, hangers and such other fittings as necessary for the complete installation of the system.
- x) Firefighting hose cabinets along with hydrant valve and hose reels as per approved layout
- xi) Portable fire extinguishers as per approved layout
- xii) Insulation for firefighting pipes, wherever required.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

- xiii) All piping including embedded and exposed piping, pressure reducer station, valves, fittings, instrumentation and associated accessories necessary for the system including separate filling pipe from filling pumps to fire tank and pipe from fire tank to main fire header.

#### **Fire detection system**

- i) Intelligent, analogue, addressable type sensors/ detectors such as multi-sensors (smoke and heat), photo-electric detectors, optical beam detectors and thermal sensors/ detectors complete with necessary cabling distributed throughout the plant GIS and switchyard area, for detection of fire,
- ii) Digital linear heat sensing cable (LHS) along with associated accessories for detection of fire in the cable/ cable trays throughout the plant as per approved drawings,
- iii) Aspirator type smoke detection system complete with ancillary devices and remote display for generator, excitation cubicle, main control room, office and conference room.
- iv) Manual pull stations and notification devices such as fire horns/ alarms/ hooters/ bells, light or text display etc. distributed strategically throughout the plant GIS and switchyard area for manual intervention and audible and visual alarm as per approved drawings,

#### **Alarm panels and misc. items for the firefighting system including:**

- i) Local alarm panels as required distributed throughout the plant including Pothead yard area,
- ii) One (1) microprocessor based addressable analogue, intelligent type main fire alarm panel with minimum five loop panel located in control room,
- iii) Five (5) repeater panels, one located at main entrance, second in the service bay, third in control Block, Fourth in Transformer area and Fifth in M/c Hall
- iv) One (1) fire work station and LED monitor
- v) Two (2) video display units with LED monitors along with necessary graphic software & associated accessories which shall be suitable for interface with the DCS system of the plant. One number shall be located in the control room and other shall be in machine hall floor.
- vi) One (1) fire alarm printing device to be located in the control room,
- vii) One (1) set of microprocessor based digital EPABX system for fire alarm system along with minimum 30 nos. individual stations distributed strategically throughout the plant.

#### **Miscellaneous items**

- i) Fire rated penetration seals, fire barriers, fire dampers etc, as per approved drawings,
- ii) Signal and evacuation signs installed in the plant areas in accordance with the specification and the codes,
- iii) Six (6) sets of fireman suit and self-contained breathing apparatus and other safety/rescue equipment,
- iv) Necessary pressure indicating devices for fire water headers and level sensing/ indicating and remote monitoring devices for fire tank.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

- v) Coordination and provision of necessary contacts and/or ports for integration with plant SCADA system.
- vi) Spare parts in accordance to clause 22.13 "Spare Parts" of this chapter.
- vii) Tools and instruments in accordance to clause 22.13 "Special tools" of this chapter.

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of work defined above, as per accepted standard(s) best international practices.

## 21.3 Specific Design and Layout Conditions

### Layout and General Arrangement

The water for firefighting system will be drawn by gravity from the over ground Fire & Service Water Tank located outside the Power House. The Fire Water Tank is filled through Fire Water pumps, of which one will be main Fire Water Pump and the other stand by, from the header of cooling water system, which in turn draws water from Tail race.

The concrete over ground fire water tank (compartmentalized in two parts), will be having capacity of at least two (2) hrs supply to meet the largest fixed fire suppression demand plus the maximum hose stream demand of not less than 1890 lpm.

There shall be two headers, one installed in the powerhouse spanning the length of the Power house and other in the control/transformer hall block spanning the length of complete building (including the Station Transformer) and drawing water from the tank. Sub-headers in Power house, Control block, transformer bay, GIS Building, Pothead yard area shall be laid to distribute the fire water at various floors/area. To prevent excessive pressure in any of the headers/pipe network due to elevation difference etc. Suitable pressure reducers/ orifices shall be provided and have a capacity of at least two (2) hours supply to meet the largest fixed fire suppression demand plus the maximum hose stream demand of not less than 1890 LPM meeting the NFPA standard shall be provided. The capacity of the overhead tank shall take into consideration the basic requirement of firefighting water. Further, a separate overhead tank of suitable capacity for shaft seal water requirement during emergency condition shall also be provided. Inlet filling header from pump to main tank and outlet pipeline header from tank shall be separate. The tank shall have level switches for automatic starting and stopping of fire pumps.

The type of firefighting arrangement for various equipment with sensing devices is given below.

S.No	Equipment/ Area	Fire sensing Devices	Fire fighting arrangement
1	Oil pressure units of governor, Main Inlet Valve	Temperature sensing bulbs	High velocity Water (HVWS) spray system
2	Generator	Smoke and heat Detectors, Aspirator	Automatic CO <sub>2</sub> Flooding

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

		Type smoke detectors, Manual pull station	
3	Excitation Cubicle	Aspirator Type smoke detectors	Portable fire extinguishers and Fire hydrants
4	Generator Transformers Area	Temperature sensing bulbs. Manual pull station	High velocity Water (HVWS) spray system and NIFPES.
5	Cable spreading area	Multi sensors (heat and smoke detector), digital linear heat sensing cable Manual pull stations	i) MVWS/ Water Sprinkler System ii) Portable fire extinguishes
6	Control, computer & communication Room, Offices	Multi sensors (heat and smoke detector), Aspirator Smoke detectors Manual pull station	Inert Gas clean Agent System, Fire hydrants, Portable fire extinguishers
7	Conference room, pantry etc.	Multi sensors (heat and smoke detector), Aspirator type smoke detection system/ photoelectric detector Manual pull stations	Portable fire extinguishers Water Sprinkler System and Fire Hydrants
8	Control block floor Mechanical and Electrical Utility Areas	Multi sensors and/or photoelectric detector, Manual pull stations	Water Sprinkler system, Portable fire extinguishers and Fire hydrants
9	Power house floors	Multi sensors or Beam detectors Manual pull stations	Portable fire extinguishers and Fire hydrants
10	Pothead yard area	Manual pull station	Portable Fire Extinguishers, Fire hydrants and Water sprinkler and spray systems
11	DG room	Beam detectors and /or heat detectors Manual pull stations	Portable fire extinguishers and Fire hydrants
12	GIS Building including control & Panel room	Multi sensors Beam detectors Manual pull stations	Portable fire extinguishers and Fire hydrants
13	Other miscellaneous areas	Photo-electric detectors and/or heat detectors Manual pull stations	Portable fire extinguishers and Fire hydrants
14	Battery Room	Multi sensors Beam detectors	Portable fire extinguishers and Fire hydrants

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

15	Switch gear Room	Multi sensors Beam detectors	Portable fire extinguishers
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It is the responsibility of the Contractor to complete the system in all respects. Any item/ equipment not covered above but which are necessary for safe working of the entire power plant, shall be furnished by the Contractor. However, the same shall further be finalized during detailed engineering.

Suitable means or arrangements shall be ensured for isolation of fire and smoke in the power plant.

### Design considerations

- i) A looped conduit system shall be provided so that if the conduit and all the conductors get severed at any point, the initiating device circuit, signal line circuit and notification appliance circuit shall remain functional,
- ii) The implementation of the communication technology for fire signaling system shall be such to compensate for any failure to communicate a signal by eliminating the risk of missing even a single fire alarm signal,
- iii) Addressable system in the control panel shall be advanced microcomputer-based system,
- iv) The time delay between the activation of an initiating device and the automatic activation of a local fire safety function shall not exceed ten (10) seconds,
- v) Detectors shall be located at strategic position and arranged in zones to facilitate proper indication of fire location, transmission of audio-visual signals to fire control panels and actuation of the appropriate firefighting system,
- vi) Detectors installed in concealed areas shall have suitable visual indication in a visibly located area.
- vii) Necessary fire barriers of suitable resistance rating and smoke control barriers shall be provided to prevent transmission of the fire and smoke from one area to another in accordance with relevant standards.
- viii) Contractor shall give due consideration to ensure aesthetic of the powerhouse areas. Necessary coordination with the architectural work contractor shall be made while finalising the system.
- ix) Necessary smoke and heat venting shall be planned for areas identified by fire risk evaluation, carried out by the Contractor, where either the heat or smoke or both shall be vented from its place of origin directly to the outdoors. The Contractor shall ensure the necessary co-ordination with the ventilation contractor for the same to ensure proper functioning in emergency situations.

## 21.4 Basic Dimensions and Ratings

### Pumps

#### Fire pumps

Each pump shall have 100 % capacity to meet the flow requirement of largest deluge system or sprinkler and hydrant system combined whichever is higher at

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 21 Fire Fighting System
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required pressure but in any case, shall not be less than the capacity to fill the tank within four (4) hours. The Contractor shall coordinate with generator, transformer and turbine shaft seal manufacturer to assess the water requirement for deluges/sprinkler and incorporate the same while finalizing the pump capacity. The design head for pumps shall be sufficient to fill the fire tank. The fire pump-motor set shall be suitable for fire application and shall meet the applicable design standards/NFPA The pumps shall be of horizontal centrifugal type complete with continuous duty electric motors with class F insulation (temperature rise limited to class B), Protection IP 54/55, control panels, cables, anchor bolts and other mounting materials. The motor shall be suitably sized to drive the pump continuously over the specified characteristics without getting overloaded. Pump shall be capable of furnishing not less than 150% of rated capacity at a head of not less than 65% of the rated head. The shutoff head shall not exceed 120% of rated head. The motor rating shall be at least equivalent to the horse power required to drive the pump at 150% of its rated discharge.

### Headers and piping

The fire header and piping shall be looped and of sufficient size to supply the flow requirements at any point in the loop considering the most direct path to be out of service. Fluid velocity in the main headers shall normally not exceed 3.0 m/s. Pipe sizes shall also be designed to accommodate any future expansion/ water demands.

### Performance Criteria and Guarantee

The firefighting system along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of the complete system.

## 21.5 Design and Construction

### Standards

The system and equipment shall be designed, built, tested and installed to the latest revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

S.No.	Standards	Description
1	NFPA 10	Standard for Portable Fire Extinguishers
2	NFPA 11	Standard for Low, Medium, and High-Expansion Foam
3	NFPA 13	Standard For the Installation of Sprinkler Systems
4	NFPA 14	Standard for the Installation of Standpipe, Private Hydrants, and Hose Systems
5	NFPA 15	Standard for Water Spray Fixed Systems For Fire Protection

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

6	NFPA 20	Standard for the Installation Of Stationary Fire Pumps For Fire Protection
7	NFPA 22	Standard for water tanks for Private Fire Protection
8	NFPA 72	National Fire Alarm and Signaling Code
9	NFPA 75	Standard for the Protection of Information Technology Equipment
10	NFPA 851	Recommended Practice for Fire Protection for Hydroelectric Generating Plants
11	NFPA 1221	Standard for the Installation, Maintenance, and Use of Emergency Services Communications Systems

### Overhead fire tank

The fire tank shall have suitable type of level switches in the control panel for automatic starting and stopping of the fire pumps and remote level indication. The capacity of the tank shall also take into consideration the requirement of all units of shaft seal water for continuous running of 3 hours under emergency conditions only, in addition to the basic requirement of firefighting water as specified earlier in this specification. Requirement (calculations and other details) of capacity of water tank along with other requirement shall be provided by the Contractor. The tank shall be of reinforced concrete or other suitable arrangement and the civil works of tank shall be done by the other Contractor. The tank shall be suitably compartmentalized along with its level switches, level transducers and level indication for inspection, cleaning or repair maintaining 50% of design capacity. The tank "status" shall be properly annunciated in the main control room.

### Piping, valves and appurtenances

All required pipes, flanges, fittings, supports, fasteners, valves and other related material necessary for completion of the system shall be supplied as a part of this contract. All embedded and exposed water pipes size 25mm and above shall be made of carbon steel of minimum schedule 40. Pipe size less than 25mm shall be of minimum schedule 80. Gravity drain pipes shall be of minimum schedule 20. The outdoor pipe line shall be preferably Ductile iron type conforming to latest IS/ISO standard. Heavy duty gate valves suitable in fire application shall be used in fire fighting system for isolation and control. Pipes crossing roads, trenches etc. shall be provided with mild steel sleeves. Water pipes shall be insulated against condensation wherever required with approved type insulation and be provided with vapour proof cover.

Mechanical groove type coupling shall be provided for ease of dismantling of pipe & fittings which shall be finalized during detailed engineering.

## 21.6 Fire detection devices

### Automatic fire detectors

The detectors spacing and rating shall be in accordance with the applicable standards/codes and shall have Underwriter Laboratories (UL) approval. The

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

smoke detectors shall be designed with minimised effect of environmental conditions like air velocity, altitude, humidity, temperature, colour of smoke, electrical and mechanical influences like abnormal pressure or vibration and the influence of aerosols and any particulate matter. It shall be plug-in type with detector base containing terminals for making connections. The detectors shall be assembled and engineered for flush or surface ceiling mounting with a standard outlet box. Provision of visual indication of detector's alarm condition shall be visible from a distance of six (6) m and visually different from indications of other conditions. The openings of the smoke entry shall be at least thirty (30) mm below the ceiling level assumed to be smooth and flat.

- A. Thermal detectors  
Thermal/ heat detectors shall be designed to operate when the rate of temperature rise at the detectors exceeds a predetermined value irrespective of the actual temperature. It shall be possible to reset detectors after attending the alarm.
- B. Multi sensors  
Multi sensors shall be state of the art and operate on sensing of smoke and heat both. The selected sensors model shall be suitable for the different type of smoke. The spacing shall be in accordance to the relevant standard.
- C. Digital linear heat sensing cable  
Heat sensing cable shall permits early detection of fire or overheating. The cable shall be digital type and set to give an alarm signal in the range of 79 to 90 deg. C.
- D. Optical beam detectors  
Beam detectors shall be reflector type linear optical beam smoke detectors operate on principle of light obscuration utilizing infrared beam. The beam type detectors are envisaged to used in ceiling height 10m or above for detection of fire/ smoke.
- E. Photo-electric detectors  
Photo-electric detectors shall be self-compensating type and shall have an obscuration rate in accordance with suitable standards. Detectors shall not initiate alarm during failure of its LED light source. Any other suitable type detectors required can be acceptable subject to acceptance during detailed engineering.

### **Manual pull stations**

The manual pull station shall be intelligent addressable type suitable for surface mounting. The manual pull stations shall preferably be located at access ways within a distance of 1.5 m from the exit doorway opening at each exit on each floor and distance to the nearest pull station measured horizontally on the same floor shall normally not to exceed 50m.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

The coded manual pull station shall produce at least three (3) repetitions of the coded signal, with each repetition to consist of at least three impulses.

The lever of the manual pull stations shall get locked after manual activation till it is reset. The front colour of the station shall be fire red with white inscription as per relevant standards.

### **Aspirator smoke detectors**

Generators, Excitation cubicles and control & communication room shall be provided with aspirator type smoke detection system for earliest warning of a potential fire in incipient stage. Suitable pipe work for drawing the sample air continuously from the generator housing/ other protection area shall be laid and the Contractor shall critically study the configuration of the area and the associated problems for designing and installing the smoke detection system.

Aspirator type smoke detection system with display unit based on laser technology shall be provided. Suitable interfaces shall be provided for supervision of the real time data through plant SCADA. Provision for multiple alarm levels at least three levels with programmable relays shall be made.

### **Notification devices**

If an alarm in a fire zone occurs, electric hooters/bells/horns/ speakers, light or text displays providing audible, tactile, or visible outputs or any combination thereof shall be actuated. The number of these items shall be sufficient to alert the complete zone. These devices shall have separate screw terminal for each conductor and the sounders/audible appliances shall generate sound in the range of 500-1000Hz different from the equipment and other devices provided in the area and in the building.

A minimum sound level of either 5dB (A) above any other noise likely to persist for a period longer than 30 seconds or 65dB (A), whichever is greater but not exceeding 120dB (A) shall be produced by the sounders at any point which can be occupied in the building. Audible notification appliances shall be so selected and placed that they are sufficiently intelligible with adequate audibility and clarity minimizing any kinds of distortion in an electro acoustic system. Visual notification appliances shall conform to the applicable standards and shall be surface mounted.

## **21.7 Fire suppression system**

### **Hydrant systems and hose reels**

Fire hydrants and its components shall be designed and installed in conformity to relevant code/standards. Hose reels with shut-off nozzle shall preferably be installed in recesses so that they do not form obstruction on a route of escape and shall be located in accessible positions at each floor level adjacent to exits in corridors on exit routes.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

The spacing of hydrants shall be in accordance to the relevant national/ international standards. The space requirement, location, maximum overall size, component case, water supply for hose reels, materials, appliances etc. shall be in accordance with relevant standards. The hose stations shall be so positioned so that two streams can be directed to any location.

### **High Velocity Water spray systems**

Each of the high velocity water spray system shall consist of a deluge valve, pressure switches, distribution piping, nozzles, thermal/heat detectors and a deluge panel. The deluge panel shall provide a connection point from the deluge system to the powerhouse annunciation and detection system, as well as transferring the signal from the heat detectors to the electrically operated deluge valve. Deluge valves for Generator Transformers shall be capable of electrically operation from Buchholz relay, PRV and GT Differential relay (in UCB).

Each deluge system shall consist of an electrically monitored isolating valve; normal dry/wet distribution piping, flow/ pressure switch and bulb type monitoring system which automatically gets activated at a rated temperature.

The Contractor shall coordinate the system design with all oil filled transformers manufacturer(s) to assure complete transformer protection system and to design the water requirement. Contractor shall coordinate for interfaces if any with Generator transformer vendor.

### **Water Sprinkler systems**

Each sprinkler system shall consist of an electrically monitored isolating valve; normal wet distribution piping flow/ pressure switch and glass type sprinklers which automatically get activated at a rated temperature.

All automatic sprinklers shall have temperature-sensitive sealing. The type, size and design of each sprinkler installation used in the system shall be appropriate to the hazards covered by the installation.

### **Nitrogen Injection Fire Protection and Extinguishing System**

Nitrogen Injection Fire Prevention and Extinguishing System (NIFPES) provided by the manufacturer/ vendor shall be complete in all respects. The scope shall cover design, supply, installation, connections, testing, commissioning and after-sales service of the system all associated items specified in these specifications.

All other components meant for activation and successful operation of the NIFPES shall be provided by the manufacturer.

NIFPES system shall work on the principle of 'drain and stir' method of transformer oil. On activation of NIFPES, it shall isolate conservator tank oil from the oil in the main transformer tank, drain a pre-determined quantity of oil from the tank top through drain valve to reduce the tank pressure, and inject nitrogen gas from the bottom side of the tank through the inlet valves to create stirring action and reduce the temperature of oil to prevent/ mitigate the fire. On the operation of NIFPES, the quantity of oil removed from the tank shall be such that adequate amount of



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

oil shall remain in the transformer to cover the active part of the transformer i.e. the 'core-coil' assembly. The NIFPES shall be designed in such a way that in case of external fire, the NIFPES may be operated manually, after electrically isolating the transformers from all sides. During operation of NIFPES, the oil flow pumps should also be tripped in case of OFAF/OFWF cooling of transformers in line with discussion with the end user / utilities.

All exposed metalwork in systems shall be efficiently earthed to prevent the metalwork becoming electrically charged. The temperature rating of a sprinkler shall not be less than 30°C greater than the highest expected ambient temperature of the location. Sprinklers shall be made of preferably Stainless steel or suitably coated with corrosion-resistant material.

The system design and equipment shall be in accordance with relevant standards. All sprinklers etc. shall be UL or equivalent approved make.

### **Inert Gas Clean Agent System**

Electrically actuated automatic inert gas clean agent fire extinguishing system complete with clean agent cylinders, manifolds, directional valves, pipes, discharge nozzles bracket supports, hangers and such other fittings as necessary for the complete installation of the system.

- i. The supplier shall design, provide, install, test and place into full operating condition of total flooding Inert Gas Inergen clean Agent System for Fire Protection of Control room and PLCC room as a primary equipment, whereas water sprinkler and spray systems shall be provided as back-up equipment.
- ii. The work shall include electrically actuated automatic Inert Gas Clean Agent fire extinguishing system complete with Clean Agent cylinders, manifolds, pressure reducing device, cylinder valves, directional valves, pipes, discharge nozzles, bracket supports, hangers and such other fittings as necessary for complete installation of the system. The system shall also comprise of both automatic and Manual firing, canceling facility etc. with necessary control panel.
- iii. The Clean Agent fire suppression system shall include an automatic detection sub system, agent storage and automatic actuation/releasing sub-system.
- iv. The Inert Gas system shall be provided to meet the requirement of NFPA-2001 (1996). Hence anything specified as mandatory in NFPA-2001, although not mentioned in this specification shall form part of total specification/scope of the work for the job to be executed.

### **Portable fire extinguishers**

The type and number of portable fire extinguishers shall be determined on the basis of classification of fires anticipated in the area, the construction and occupancy of the individual property, ambient temperature conditions etc. Portable fire extinguishers shall preferable be dry chemical (DCP), CO<sub>2</sub> type, foam type etc. and free from agents which are non eco-friendly such as Halon. Necessary

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

provision of hand appliances like fire buckets shall also be made. Fire buckets shall be of mild steel and shall conform to relevant standards.

## **21.8 Fire alarm, supervision and signaling system**

### **Fire detection, alarm and supervision**

The fire alarm and detection system shall be a completely supervised fire alarm reporting system, which shall be activated into the alarm mode by the activation of any of the alarm initiating devices in the event of fire. The system shall remain in the alarm mode until the initiating device is reset and the fire alarm control panel is reset and restored to normal. All alarms coming from the detectors shall be line wise transmitted to the main fire alarm panel. The alarms of the system shall be transferred first to the respective panels for activating the fire suppression systems. In parallel, each line shall be printed out on a fire alarm printer and indicated at video display units (VDU).

### **Power supplies**

Fire alarm systems shall be provided with at least two independent and reliable power supplies, one primary and one secondary (standby), each of which shall be of adequate capacity for the application and performance of the fire alarm system. The Contractor shall coordinate with the plant DC system manufacturer in designing and supplying the necessary cables, connections, interfaces etc. for the secondary power supply of the fire alarm panel. A secondary supply shall be supplied from rechargeable sealed-type storage batteries of adequate capacity to operate the fire alarm system for 24 hrs. which together with the battery charger, protection, metering and supervision, as per relevant standards, shall be permanently identified in the fire alarm control panel. Battery charger shall be completely automatic, with 24V DC high/low charging rate, capable of restoring the batteries from fully discharged condition (18V DC) to fully charged condition within 48 hrs. The Contractor shall fully ensure that the changeover from primary supply to secondary supply and vice-versa shall be fully automatic without affecting the transmission of signal via the fire reporting system upon operation of the initiating devices.

### **Fire alarm control panels**

The automatic addressable and intelligent fire alarm system is to be built with modern, redundant system structure and microprocessor-controlled detectors. All control unit elements of the fire alarm system, i.e. CPU, Loop card, Networking card, Panel mounted relay cards shall be designed to be fully 100% redundant. If any faults occur in the control unit or peripheral devices, all detectors and functions remain intact and all controls continue to be active.

The main and repeater fire alarm control panels shall provide automatic, supervised, multi zone detection and alarm system. Each fire alarm panel shall be of modular type, installed in a mounted steel cabinet with hinged door and cylindrical lock. The panels shall be clean, uncluttered and orderly assembled containing all necessary operating and supervising elements/ components, using

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

a solid state technique. The start-up shall be automatic after restoration of power either primary or secondary. Signals and LEDs/LCDs together with visual annunciation shall be provided to indicate by zone any alarm, supervisory or trouble condition on the system as an integral part of the control panel with suitable identification.

The operational features of the modules shall have at least the following. Other additional features required to make the system fully functional shall also be incorporated in accordance with relevant standards.

- i) Monitoring electrical supervision of different circuits viz. initiating device circuits, circuits used for supervisory signal services viz. sprinkler water-flow, water level indicators etc.
- ii) Monitoring electrical supervision of power supply, transmitter tripping circuit integrity etc.,
- iii) Trouble buzzer and trouble LEDs/LCDs against any fault due to loss of power supply, single break, open, or ground fault condition, panel fault and panel door open etc. impeding the normal functioning of the system,
- iv) Evacuation alarm signal switch and transmitter disconnect switch,
- v) Confirmation or verification of all smoke and heat detectors,
- vi) Provision of supervised addressable relay for HVAC shut-down which shall not be overridden at the HVAC panel,
- vii) Monitoring and control of fire sprinkler system, release of deluge system and other fire extinguishing system,
- viii) Control panels and field panels shall have suitable software programme enabling expansion and modification of the system without replacement of hardware or firmware viz. addition or deletion of zones etc.

An alarm condition in the circuit which shall automatically annunciate in the mimic and shall have at least the following functions to make the system fully functional. These alarms shall also be printed out.

- a) Transmission of signals to the plant SCADA system,
- b) Transmission of signal to the station security and surveillance system,
- c) Visual indication of the alarm device on the fire panel control panel display,
- d) Continuous operation and sounding of alarm notification appliances as per the applicable standards,
- e) Operation of smoke control system and de-activation of air handling units in the alarmed area,
- f) Automatic discharge of the respective fire suppression system with maximum 15 seconds delay for deluge system and 30 seconds for wet pipe system.

Provision of necessary contacts/ports for control, monitoring, supervision and alarm functions shall be made in the fire alarm control panels for duplicating these functions in plant SCADA system. Unacknowledged alarm signals shall not be interrupted if a fault on a fire detector circuit or a signaling line circuit occurs while there is an alarm condition on that circuit.

All major devices installed in the panel shall have 10% spare capacity. Fire alarms, supervisory signals and trouble signals shall be distinctively and descriptively annunciated.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

## 21.9 Fire Work Station and Video display unit

The video display unit shall show the plant appearance with fire zones with the alarm indication. The fire work stations provided in the main control room shall have 26" LED flat screen colour monitor, processor CPU, minimum 16GB RAM, DVD-ROM drive, key board, mouse etc.

The video display unit for machine hall and control room shall be at least 42" large screen LED display or better along with graphic display including all standard accessories. If an alarm, fault or release occurs, the pertaining graphics shall be activated. After acknowledgement the horn shall be silent and the light shall remain steady and go off after resetting.

At least following information shall be included in the graphics:

- i) Alarms,
- ii) Release signals,
- iii) Air conditioning and ventilation fire dampers and plant stops,
- iv) Release commands,
- v) Evacuation signal release for sections,
- vi) General plant evacuation release.

### Signs and evacuation signals

For deluge areas, the warning signs and releasing signs according to applicable codes may be installed. Laser type exit and evacuation route signs shall be installed throughout the plant as to be finalized during detailed engineering.

### Fire alarm printing

Fire alarms printing shall be printed in the alarm printer installed in the central control room. The printers shall have a memory, which enables the printing system to print out the alarms and events in the sequence they occur.

### Fire alarm bus interface

Signals going to the alarm printer shall also be transferred to the main data logger via a bus coupler system in the sequence they occur. The signals shall be stored in the main data logger for at least one year, shall be retrievable via the bus system from the fire work station and be printed out through alarm/ event printer on request.

### Fire telephone

An emergency EPABX fire telephone system shall be installed throughout the plant based on a two-way communication system connecting the individual locations with the central control room. The priority features shall be assigned to fire telephone stations in the main control room and GIS building.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

### **Name plates and external indicators**

For an easy identification, each detector and manual pull station shall be equipped with a nameplate showing at least line number, detector identification number and fire zone number.

### **Fire barriers, assemblies and interior finish**

All fire barriers shall have fire resistant classification for minimum 4-hour exposure rating or as specified in applicable codes. Openings in such barriers should be provided with fire door assemblies, fire dampers, penetration seals (fire stops), or other approved means having a fire protection rating consistent with the designated fire resistance rating of the barrier. Penetration seals provided for any electrical and piping openings should meet the requirements of suitable rating in accordance with applicable ASTM or other International Standards. Cellular or foam plastic materials shall not be used as interior finishing material for subsurface structures and in areas critical to fire. Material shall be suitably tested as per International Standards prior to their usage for interior finish.

### **Cable and wires**

The cable, wires and conduit/ raceways shall be in accordance with relevant standard. All the power, control and loop cable used in fire protection system shall be fire survival cable designed to withstand 950 deg.C fire for at least three hours.

## **21.10 Drawings, Documents and Design Calculations**

### **Design memorandum**

The contractor shall prepare and submit to the engineer Of-Contract as "Design Memorandum" of the proposed equipment/system fulfilling the contract specification/requirements for approval prior to submission of drawing and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, measure technical features, basic arrangement/layout etc.

### **Drawings and documents**

The contractor shall submit all the drawings and documents in accordance with requirements stipulated in relevant clause of Technical Specifications. These drawings and documents shall include at least the following:

- Applicable codes, standards and other design criteria to which the system is required to comply.
- Annunciator locations and type of fire alarm system with type of initiating devices, notification appliances etc. to be provided.
- Complete list of detection, evacuation, signaling and annunciator zones/areas.
- Complete list of fire safety control functions with complete sequence of operations detailing all inputs and outputs in the form of input/output matrix.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

- A completion certificate stating compliance of the system with the applicable standards referred to with details of departure and recommendations, if any.
- Complete set of operating instructions and as-installed drawings with proper identifications.

### Design calculation

The Contractor shall submit the design calculation in accordance to relevant Clause of “General Technical Specification (GTS)” covering at least the following, for review / acceptance.

- Pipe sizing and pressure drop calculation, Sizing of piping for distribution manifold.
- Selecting the pump capacity and working head for pumps,
- Size of the fire tank,
- HVWS system pressure drop calculation for transformers, generators, cables, OPU's system etc.,
- Selection of numbers and type of automatic fire detectors, manual pull stations including types and quantities of notification appliances like bells, horns, speakers, flashlights etc.
- Capacity and number of the rechargeable storage batteries.
- Calculations for secondary supply and voltage drop calculations
- Calculations for Inert Gas System
- Calculation for NIFPES
- Calculation for capacity of Overhead water tank for fire fighting and Emergency Shaft seal tank

### Shop Tests

The pump, pipes, valves, Deluge system, sprinkler system, automatic detectors etc. to be supplied shall be routine tested as per relevant IEC/IS/NFPA at the work's of Contractor in presence of the Employer. The Contractor is required to submit type test certificates and routine test reports of equipment.

## 21.11 Installation and Commissioning

The contractor shall furnish all labour, supervision, tools, supplies, suitable bracing, spiders, shims and supports and all other provisions or materials necessary to assemble, erect, install, test and commission the equipment in a thorough workman like manner following the best modern practices and standards available.

The equipment and all its components shall be corrosion resistant and shall be placed with great care and accuracy. They shall be aligned correctly to provide an installation consistent with the close tolerances used in the erection of modern equipment. The proper elevations and centrelines to which equipment is to be set shall be established by the contractor. Moreover, devices and appliances shall be located and mounted so that accidental operation or failure is not caused by vibration or jarring. Circuits and equipment shall be properly protected against the possibility of induced transients.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

The power supply shall be equipped with locking mechanism and marked in red with proper identification.

Detectors shall be located at strategic positions and arranged in zones to facilitate proper indication of fire location, transmission of audiovisual signals to fire control panels and actuation of the appropriate fire fighting system. Detectors installed in concealed areas shall have suitable visual indication in a visibly located area. Smoke detectors shall not be installed until construction is essentially complete and the building thoroughly cleaned.

All types of pipe and fixtures used in this fire protection system shall be spaced according to accepted standards and with due allowances made for thermal expansion and contraction and shall not be subjected to mechanical, chemical or other damage. Before installation all system components shall be checked for cleanliness and after installation, the systems shall be effectively flushed out with clean water and filled up for testing before the nozzles and discharge horns are fitted.

The power plant fire alarm system must be in any case, ready for operation prior to the commissioning of the first generating unit, the control block fire alarm prior to the main control building finish date.

## 21.12 Field Test

After installation, the fire fighting system with all its equipment and devices shall be field tested for performance/operational tests etc. as per General Technical Specifications in accordance with, but shall not be limited to, relevant NFPA codes. If the system shall be tested in sections, the same applies for each section.

The tests at site should at least include the following:

- Hydrostatic pressure tests of the whole piping system
- Pump output test
- Leakage test
- Test for megger value of insulation as per relevant IEC
- Test for sensitivity range of sensors/detectors
- The tests for the piping system shall be completed prior to installation of the equipment in the pipes.

All test equipment and instruments necessary to complete the tests in all respect shall be furnished by the contractor except otherwise specified and shall remain the contractor's property after the fulfilment of all field tests. All necessary materials and labour for performing all the above tests shall be provided by the contractor. Any defects or leaks disclosed in the tests shall be duly mended/ repaired to meet the desired function.

The contractor shall prepare and hand over to the Employer details of all test results in a report in a mutually agreed format.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

## 21.13 Spare Parts

### General Spare Parts

The Contractor shall supply the general spare parts as per as per relevant clause of Contract Document. The supply of this spares shall be as per the approved list of spares for each component / equipment / item during detail engineering.

### Recommended Spare Parts

The Contractor shall furnish the list of recommended spare parts as per relevant clause of Contract Document.

### Specified Spare Parts

The following specified spare parts, as defined in relevant clause of Contract Document, which shall comprise the total requirement of Firefighting System under this Contract, shall be supplied:

S.No.	Description of Items	Quantity
1	Complete Fire pump with motor	1 no.
3	Filter element for filter of each type	1 no.
4	Multi sensors, photoelectric detector and heat detectors	5 no. of each type
5	Electric plug-in cards for the main and repeater panels	1 no. of each type
6	Electric plug-in cards for the sub panels/local panels	1 no. of each type
7	Aspirator type detector module	2 no. of each type
8	LED installed in the system	10 nos. of each colour (Red, Green, Yellow, Blue, Amber etc.)
9	Intelligence interface unit for pressure switch	5 no. of each type
10	Digital LHS cables	500 m
11	Nozzles for HVW and MVW water spray system.	5 nos. of each type and size
12	Deluge valves	2 no. of each type & size
13	Sprinkler valve	2 nos. of each type & size
14	Manual pull station	10 nos. of each type
15	Hydrant valve	5 nos. of each size and type
16	Pressure gauges	2 nos. of each type and size
17	Pressure switches	2 nos. of each type and size
18	Under voltage relays	2 nos.
19	Over current and earth fault relays	2 nos.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 21 Fire Fighting System

20	Fuses	10 nos. of each type
21	MCCB and MCB	1 nos. of each type
22	Valves of size DN 80 and above	2 nos. of each type
23	Control Valve (Alarm valve)	3 nos. of each type
24	Butterfly Valve	3 nos. of each type
25	Gate Valve	3 nos. of each type
26	Non return valve (NRV)	3 nos. of each type
27	Solenoid Valve	3 nos. of each type

### Special tools

In addition to the tools listed in general technical specification the Contractor shall provide one set of software, connecting cables, proprietary equipment, other necessary special tools necessary for maintenance, testing and reprogramming of the equipment of the firefighting system as recommended by the manufacturer. A list of such tool shall be approved during detailed engineering.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

## **VOLUME- II**

---

### **SECTION II SUB-SECTION 22**

### **Air Conditioning System and Ventilation**

### **System**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

<b>7</b>	<b>HEATING, VENTILATION AND AIR CONDITIONING SYSTEM.....</b>	<b>4</b>
7.1	SCOPE.....	4
7.1.1	Air Handling Units:.....	4
7.1.2	Exhaust Air Fans:.....	4
7.1.3	Cooling Water Circuit (if required):.....	4
7.1.4	Auxiliary System and Miscellaneous Items:.....	5
7.2	SPECIAL DESIGN AND LAYOUT CONDITIONS:.....	5
7.2.1	Layout and General Arrangement:.....	5
7.2.2	Fire Safety:.....	6
7.3	BASIC DIMENSIONS AND RATINGS:.....	6
7.3.1	Design Condition:.....	6
7.3.2	Air Changes per hour:.....	6
7.3.3	Noise Levels:.....	6
7.3.4	Air velocities:.....	7
7.3.5	Performance Criteria and Guarantee:.....	7
7.4	DESIGN AND CONSTRUCTION:.....	7
7.4.1	Standards:.....	7
7.4.2	Air Handling Units:.....	8
7.4.3	Split Type Air Conditioners:.....	10
7.4.4	Piping and Valves:.....	10
7.4.5	Cooling Water System (If required):.....	10
7.4.6	Ducts:.....	11
7.4.7	Insulations:.....	11
7.4.8	Grills and Diffusers:.....	11
7.4.9	Outside Air Louvers:.....	11
7.4.10	Louver Dampers:.....	11
7.4.11	Air Filter:.....	12
7.4.12	Exhaust Air Fans:.....	12
7.5	CONTROLS AND ELECTRICAL EQUIPMENT:.....	12
7.5.1	Automatic Control and Regulation:.....	12
7.5.2	Manual Mode:.....	13
7.6	QUALITY ASSURANCE AND TESTING:.....	13
7.7	DRAWINGS, DOCUMENTS AND DESIGN CALCULATIONS:.....	13
7.7.1	Design Memorandum:.....	13
7.7.2	Drawings and Documents:.....	13
7.7.3	Design Calculations:.....	13
7.8	INSTALLATION, TESTING AND COMMISSIONING:.....	13
7.8.1	Shop Tests:.....	13
7.8.2	Installation and Commissioning:.....	14
7.8.3	Field Tests:.....	14
7.9	SPARE PARTS:.....	14
7.9.1	General Spare Parts:.....	14
7.9.2	Recommended Spare Parts:.....	14

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

7.9.3	<i>Specified Spare Parts:</i> .....	14
7.10	SPECIAL TOOLS:.....	15
7.11	SCHEDULE OF REQUIREMENT: .....	15
7.11.1	<i>Main Equipment &amp; Accessories:</i> .....	16
7.11.2	<i>Tools, Tackles and Spares:</i> .....	17
7.11.3	<i>Services:</i> .....	17

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

## 7 HEATING, VENTILATION AND AIR CONDITIONING SYSTEM

### 7.1 SCOPE

Scope of work under this chapter covers the provision of labour, tools, plants, materials and performance of work necessary for the detailed Design, Engineering, manufacture, quality assurance, quality control, shop assembly, shop testing, transportation, insurance till commissioning, delivery at site, site storage & preservation, erection, testing and commissioning, performance testing, field acceptance, training of Employers personnel, handing over to Employer and guarantee for two years of Heating, Ventilation And Air Conditioning System (HVAC) with all auxiliaries, accessories and spare parts for making the system complete and for a trouble free and safe operation for HEO HEP (3x80MW).

HVAC System for BF Valve House shall be within the scope of the bidder. Dry Type Ventilation System is envisaged for the BF Valve House. Supply, Exhaust, Rate of air change per hour and other design parameters shall be as per system requirements and relevant IS/ IEC Codes.

The scope of work shall be a comprehensive functional system covering all supply and services including but not be limited to following.

#### 7.1.1 Air Handling Units:

- i) Three (3), sets of Air handling units (AHU's), each of them be of 50 % of the required capacity, one unit serves as standby, for Power house floors, Transformer area, Service bay, drainage gallery etc. If required, additional fresh air blowers of the required capacity / rating against each AHU shall be provided.
- ii) Required no. of Split type Air Conditioners of the required capacity for Power house Control room, relay/panel rooms, PLCC room areas, staff room, Conference Room, Office Rooms etc. The no. of the Split type air conditioning units provided in each closed space shall be (N+1), where N is the number of air conditioning units of equal rating/capacity required for the said closed space. If required, additional dehumidifiers shall be placed at the Control Room and Panel Rooms for maintaining the relative humidity at desired level.
- iii) Any other boosters/blowers/ AHU's /Fan coil units etc. required to ensure a well-ventilated/air-conditioned system in the Power house to maintain a positive draft under all circumstances of operation.

#### 7.1.2 Exhaust Air Fans:

- i) Required nos. of exhaust air fans for exhaust of air from the Power house with 100% stand by capacity.
- ii) Required nos. of exhaust air fans for exhaust of air from the toilets, kitchen, battery rooms and mechanical work, each of 100% of required capacity with separate exhaust duct.

#### 7.1.3 Cooling Water Circuit (if required):

- i) Two (2) nos. raw water pumps for primary cooling water circuit along with local control panel, instrumentation and associated accessories etc. each with 100% of required capacity.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

- ii) Two (2) nos. raw water automatic self - cleaning wedge wire fine filters, along with local control panel, instrumentation and associated accessories for cooling water circuit.

#### 7.1.4 Auxiliary System and Miscellaneous Items:

- i) Air duct distribution system for supply and return air of all HVAC systems, with necessary galvanized sheet metal ducts (for battery room exhaust air system, special rust, acid and corrosion proof ducts etc.), elbows, tees, supports, fixations, including all necessary grills, louvers, outside air louvers, adjusting duct dampers, motorized air dampers, heating and cooling insulations, etc.
- ii) Central computerized control panel for HVAC system complete with all wiring, instrumentation and associated accessories etc.
- iii) Any additional AHU's pumps, fans, FCU (fan coil unit) and other items/equipment felt necessary during detailed engineering.
- iv) Local control panels for air handling units, circulation/cooling water pumps & automatic filters (If required), supply fans, exhaust fans, FCU etc.
- v) Insulation with vapour proof cladding for exposed pipes, wherever applicable.
- vi) Cooling water distribution system (if required) along with necessary insulation, valves, fittings, piping, filters, regulating orifices, all type of consumables and other materials.
- vii) Necessary instrumentation pressure gauges, pressure switches, temperature gauges, temperature switches, flows indicator, flow relay/transmitter and humidity sensing devices/instruments etc.
- viii) Provision of necessary contacts and/or ports for integration with plant SCADA system and fire fighting system.
- ix) Spare parts in accordance to clause "Spare Parts" of this chapter.
- x) Tools and instruments in accordance to clause "Special Tools" of this chapter.
- xi) Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard(s) / best international practices.

## 7.2 SPECIAL DESIGN AND LAYOUT CONDITIONS:

All equipment items shall be designed to operate at the rated characteristics of the installation in continuous mode. The system shall allow maintenance of various system elements without affecting service continuity. The ambient conditions, moisture, temperature and seismicity shall be taken in to account for the design, operation and installation of the equipment.

### 7.2.1 Layout and General Arrangement:

The Power House building will be divided into individual areas for the sake of convenience of operation and maintainability of temperature and humidity. The design of Fire Fighting System will be coordinated with the designing of the Ventilation System in order to provide necessary means to stop the supply of the air to the fire affected area and to evacuate smoke & toxic air from the place of origin to outdoor in a manner that it does not interfere with the other areas of the plant.

All air-conditioned areas will be maintained at  $24 \pm 1$  deg C and RH  $55 \pm 5\%$  with split/ window type air-cooled air conditioners. All ventilation and air-conditioned areas will be designed to maintain a positive pressure. Air changes in accordance to IS-4720, applicable for Surface Hydrel Stations, will also be applicable for this Power House.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

The Power House floors, Erection bay, Transformer area & GIS area shall be divided into suitable areas for heating, ventilation and air conditioning. Type of Ventilation & Air-Conditioning for various areas will be as under:

Operating Floor	:	Forced Supply and Forced Exhaust Air Ventilation
Floors below Operating Floor	:	Forced Supply Air Ventilation
Electrical Room	:	Forced Supply Air Ventilation
Battery Room,	:	Exhaust Ventilation
Control Room and Panel Rooms	:	Air-conditioning with Temperature & Humidity control
Office Rooms & Conference Room	:	Air-conditioning with Temperature control only
Toilets, Kitchen etc.	:	Exhaust Ventilation

The cooling water for the raw water circuit shall be tapped-off from the header of drawn water from the Tail pool by pumps with automatic self-cleaning filters at suction side and cyclone separator & cooling coil of AHU at outlet side. The water after passing through cooling coils shall be discharged to collection chamber. The contractor has to lay all necessary pipes, valves, instrumentation etc. to make the system complete. The Cooling water header for HVAC System shall be interconnected with the Generator & GSU Transformers Cooling Water header through a gate valve.

#### 7.2.2 Fire Safety:

The Contractor shall design the ventilation and air conditioning system providing necessary means and pressure to stop the supply of air to the affected area and to evacuate smoke and toxic particles from the place of origin to the outdoors in a manner that it does not interfere with the operation of plant and to allow for emergency access and egress. In addition to above, manual option for activation of exhaust/smoke evacuation shall also be provided.

### 7.3 BASIC DIMENSIONS AND RATINGS:

The system design shall be based on but not limited to criteria, factors, and details outlined herein.

#### 7.3.1 Design Condition:

The maximum and minimum ambient temperature and relative humidity for the design of the HVAC system in summer and winter shall tentatively considered as follows:

Summer: 40° C & 100% max. Relative Humidity

Winter: 1° C & 39% min. Relative Humidity

The temperature of Ventilated area shall be maintained at max. 5 degree C above ambient.

The maximum and minimum river water temperatures during the year shall tentatively be considered as 20° C and 8°C respectively.

#### 7.3.2 Air Changes per hour:

For all ventilated and air-conditioned rooms, the air changes shall be as per relevant ASHRAE / IEC / IS to provide the desired heat relief and maintain a minimum level of fresh air in the powerhouse. All ventilated and air-conditioned area shall be designed to maintain a positive pressure within the powerhouse.

#### 7.3.3 Noise Levels:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

The noise level when measured at (one) 1 m from source, caused by operation of the HVAC systems shall not exceed:

- i) 45 dB (A) in rooms as in the control rooms, offices, conference rooms, record room, library and reception room and 60dB (A) in other areas,
- ii) 70 dB (A) for all diffusers grills and 85 dB (A) for motors, fans, etc,

Silencer, as required, shall be provided to guarantee the above sound levels.

#### 7.3.4 **Air velocities:**

The air velocities in ducts shall be as specified in IS:4720. The range of Air velocities in ducts should be within the range given below;

In main ducts -	: 370-670 m/min
In branch ducts-	: 250-550 m/min
In occupied room zones -	: 120 m/min

#### 7.3.5 **Performance Criteria and Guarantee:**

The heating, Ventilation and air conditioning system along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. The Contractor shall guarantee the reliability and performance of the individual equipment as well as of complete system.

### 7.4 **DESIGN AND CONSTRUCTION:**

#### 7.4.1 **Standards:**

The system and equipment shall be designed, built, tested and installed to the latest revisions of the following applicable standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose.

Sl. No	Standard	Description
1	-	ASHRAE Handbook, data and guidebook
2	IS 4720	Code for practice for ventilation of surface hydel power stations
3	IS 3103	Code of practice for industrial ventilation
4	ANSI/ ASHRAE St. 62	Ventilation for acceptable indoor air quality
5	IS 655	Specification for metal air duct
6	IS 277	Galvanized steel sheets specification
7	IS: 4894	Centrifugal fans
8	IS : 7613	Air filters
9	IS : 325	Three phase induction motors
10	Electricity Act	Indian Electricity Rules
11	BS: 2831	Methods of test for air filters used in air conditioning and general ventilation
12	IS: 737	Specification for Wrought Aluminum or Aluminum Alloys Sheet and Strip
13	IS: 226	Structural Steel
14	IS: 1239	M.S Tubes, Tubular and other wrought Steel fittings
15	IS: 3589	Seamless or Electrically welded steel pipes
16	IS: 3588	Specification for electrical axial flow fans
17	IS: 659	Safety code for Air Conditioning.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

Sl. No	Standard	Description
18	IS: 996	Single phase small AC and universal electric motors
19	IS: 2062	Steel for general structural purposes specification

#### 7.4.2 Air Handling Units:

##### 7.4.2.1 General Description:

Unit shall be central station air handler. It shall consist of a fan with the following factory-installed components as indicated on the equipment schedule, as per applicability:

- i) Cooling section with water coils
- ii) Access and plenum section
- iii) Filter section
- iv) Mixing box section:
- v) Face and bypass damper sections for:
  - a) Multi zone damper section.
  - b) Air mixer section.
  - c) Return fan section.
  - d) Exhaust section.

Units shall ship in the number of sections necessary to meet project requirements. All sections shall be flanged and gasketed to allow easy assembly and disassembly. In case, heating and cooling cannot be met from one unit, separate coils shall be provided for each duty.

##### 7.4.2.2 Casing:

###### Construction:

The AHUs shall be double skinned free floor mounted type, constructed as a stable compact galvanized steel casing, factory assembled, divided in several cubicles for easier installation.

- i) Casing panels shall be removable for easy access to unit. All panels shall be gasketed to ensure a tight seal.
- ii) The construction of the AHU shall allow for easy maintenance/replacement of faulty components without dismantling the whole assembly.
- iii) Access sections shall have a double-wall hinged access door on both sides of component.

###### Insulation:

Each section shall be factory insulated. Insulation shall have full coverage Insulation shall meet the erosion requirements of UL 181. Insulation and insulation adhesive shall comply with NFPA 90A requirements for flame spread and smoke generation.

###### Drain Pans:

Drain pans shall be constructed of insulated double wall stainless steel. The pan shall be sloped toward the drain fitting.

##### 7.4.2.3 Fans:

The bidder may opt for supplying centrifugal (forward/backward curve) or Axial Flow fans. The selection of fans shall be made based on the efficiency at the operational pressure range, wear & tear during operation and other relevant parameters.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

Centrifugal fans shall be of Double Inlet Double Width (DIDW) type and designed to operate satisfactorily over a range of rated speed. They shall be constructed of heavy gauge galvanized steel. They shall conform to IS:4894.

#### **Airfoil Fan Section:**

Airfoil fan sections shall have one DWDI airfoil fan wheel and scroll. Airfoil blades shall be double thickness design. They shall be painted with zinc chromate primer and enamel paint.

#### **Plenum fan section**

Plenum fan sections shall have one single width single inlet (SWSI) airfoil fan wheel. Airfoil blades shall be double thickness design. Wheels shall be painted with zinc chromate primer and enamel paint. They shall be designed for continuous operation at the maximum rated fan speed and motor horsepower.

#### **Fan Bearings**

All fans bearings shall have a minimum life of 40,000 hours. Fan shafts shall be solid steel, turned, ground, polished and coated with rust preventative oil. All fan motors shall have minimum service factor of 1.15.

#### **Fan wheels**

Fan wheels shall be keyed to the shaft and shall be designed for continuous operation at maximum rated fan speed and motor horsepower. Fan wheels and shafts shall be selected with a maximum operating speed 25% below the first critical, and shall be statically and dynamically balanced as an assembly.

#### **Fan shafts**

Fan shafts shall be solid steel, turned, ground, polished and coated with rust preventative oil.

#### **Fan motor**

Fan motor shall be mounted within the fan section casing on slide rails equipped with two adjusting screws. Motor shall be of high efficiency, open drip-proof or totally enclosed fan cooled Premium efficiency motors shall be available. Motor shall be mounted on a horizontal flat surface and shall not be supported by the fan or its structural members. All motors shall have a  $\pm 10\%$  voltage utilization range and a 1.15 minimum service factor.

#### **Dampers**

Mixing boxes, filter-mixing boxes, and exhaust boxes shall have parallel blades and interconnecting outside-air and return-air dampers. Damper blades shall be constructed of galvanized steel with a double-skin airfoil design.

#### **Air mixer**

Air mixer shall be constructed of welded aluminum framing and turbulators. The mixer shall have no moving parts. It shall contain a primary set of direction-changing vanes, a secondary set of turbulator vanes, and a cone design for mixing of air streams.

#### **7.4.2.4**

#### **Coils:**

##### **General Fabrication:**

All water cooling coils shall have 12.5 mm OD seamless copper tubes mechanically expanded into fins to ensure high thermal performance with lower total flow and pumping requirements. Minimum tube wall thickness shall be at least 0.6mm.

Copper plate fin type with belled collars. Copper-finned coils shall be supplied with stainless steel casing and tube sheets

##### **Water Coils:**

Headers shall be non-ferrous with steel MPT connections.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

#### **7.4.2.5 Blowers / Boosters:**

Blowers/boosters shall consist of fans, casings, air filters and dampers with enclosures. The fans, casings, air filters and dampers shall be as per relevant sub – clauses of Air handling unit of this chapter.

#### **7.4.3 Split Type Air Conditioners:**

The air conditioner units shall be provided as independent and standard package. It shall include the noise absorption element inside. Each unit shall consist of condenser and compressor in one section and another section comprise of fan, cooling and heating coils/sections. The condenser and compressor section shall be located outside of Power House Control room, GIS/DG building or any other suitable location.

#### **7.4.4 Piping and Valves:**

The supply shall include the necessary fittings, valves (manually and motor operated valves, return valves etc.), flow control meters, pressure gauges, thermostats, insulations and fixations. All embedded and exposed pipes size 25mm and above shall be galvanized and insulated of minimum schedule 40. Pipes sizes less than 25mm shall be minimum schedule 80. Gravity drain pipes shall be of minimum schedule 20. The piping and valves shall be in accordance with relevant clauses of Technical Specification. Valve body of all type of valves shall preferable be of cast steel except smaller valves (50 mm and lower) for which the material shall be stainless steel.

#### **7.4.5 Cooling Water System (If required):**

##### **7.4.5.1 Cooling Water Pump:**

The cooling water pumps shall be horizontal centrifugal type. The material of the pump impeller shall preferably be high grade duplex stainless steel (AISI 329 or better). The selected impeller material shall have excellent abrasion and corrosion resistant properties. Shaft and casing material shall be stainless steel (AISI 410 or better) and grey cast iron respectively. Mechanical seal made of preferably tungsten cemented carbide material shall be provided in the pump.

The pumps shall be complete with continuous duty electric motors with class F insulation (temperature rise limited to class B), control panels, cables, anchor bolts and other mounting materials complying with suitable Indian and International Standards. The motor shall be suitably sized to drive the pump continuously over the specified characteristics without getting overloaded. The pumps shall be suitable for 415V  $\pm$  10%, 50Hz  $\pm$  5% with contacts for remote operation / indication. The speed of pumps shall preferably be not more than 1450/1500 rpm.

Shut-off valves and check valves shall be provided to allow disconnection and switching of each pump without emptying pipes.

##### **7.4.5.2 Automatic Self-cleaning Filters:**

The automatic self-cleaning wedge wire candle type filters shall be of sufficient capacity to match the capacity of the cooling water pumps. The equipment must have proven performance in treating water with high abrasive silt content. The automatic self-cleaning filter shall be heavy duty preferably wedge wire candle type to arrest debris, tree leaves, pebbles, coarse sand etc. The filter shall comprise of stainless steel candles and shall have cast steel body. Automatic filters shall be capable of removing all the material of 600 microns and above size. The design shall have proven performance for continuous operation without clogging. The pressure drop across the filters shall be less than approximately 0.2 bars.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

Differential pressure gauges and differential pressure switches across the each filter shall be provided with visual indication for alarm purpose. The silt flushing operation shall be controlled/ initiated by both pressure difference and preset time.

#### 7.4.6 **Ducts:**

All ducts for the ventilating systems shall be of high quality galvanized sheet metal. The exhaust air ducts of the battery room shall be corrosion, rust and acid resistant material. Ducts passing through the machine hall and service bay shall maintain the aesthetic of the floors and shall be finalised during detailed engineering.

The sheet thickness shall not be less than the thickness indicated in IS 655.

All ducts shall be airtight with opening at suitable locations. If necessary, the rectangular elbows shall be equipped with aerodynamically formed guiding vanes.

All take-off branches shall be equipped with an adjustable volume extractor, which assists in balancing by directing a regulated amount of air for supply outlets from the main duct. Volume dampers shall be two gauges heavier than gauge of the large duct and shall be rigid in construction to the passage of air.

Ducts shall be supported by structural angles, hanging in rods with adjustable nuts, anchored to the ceiling or walls by concrete fastener bolts or anchors. The material for all support, hanger, rods, angle etc. shall be hot dip galvanized. Maximum allowable distance between duct supports shall be 1500mm as per as per IS 655 whichever is lesser.

#### 7.4.7 **Insulations:**

The cooled down supply air ducts shall be insulated to prevent condensation on the duct surfaces. The insulation material (thickness to be as per detailed design) shall be non-hygroscopic, rot-proof, preferably foamed nitrile rubber. The insulation mats or plates shall be fastened on the duct and wrapped with aluminum foils. The insulation material shall also be sufficient to obtain the acoustical guarantee. The cooling water piping shall be properly insulated. The mentioned insulations shall be included in the supply.

#### 7.4.8 **Grills and Diffusers:**

The supply air grills shall be used for correct air distribution by horizontal and vertical adjustable bars of sidewall installations. The return air grills shall be suitable for adjustment from outside and shall be equipped with 45° horizontal fixed fins.

The grills / diffusers in the control rooms / offices and other areas where false sealing have been provided shall be decorative type and in accordance to the architecture of the control room and conference room and aesthetic of the area. Material of construction, type colour etc. shall be decided during detailed engineering.

The design has to fit the architectural false ceiling and lighting schemes and the grills be made of extruded aluminium powder coated with high surface finish and the sizes have to correspond to the fixed noise criteria.

Grills for the battery room shall be of acid corrosion and rust resistant material.

#### 7.4.9 **Outside Air Louvers:**

Outside air louvers of each of the fresh air and exhaust air systems shall prevent the entrance of rain, insects, birds and trash into the ducts. They shall be stamped and pressed out of one piece of aluminum sheet of at least 2 mm thickness. The frames shall also be made of extruded aluminum.

#### 7.4.10 **Louver Dampers:**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

Double acting louvers shall be fabricated with a welded frame of rolled section. Bearings shall be of the oil retaining porous bronze type and shall be fixed into the frame. The louver dampers as well as the steel frames shall be hot-dip galvanized after fabrication. Louvers and dampers shall be equipped with related limit switches to be used in control and interlocking system.

The fire /smoke dampers shall be provided wherever required. The damper shall be multi blade motorized operated type. The blades shall be minimum 1.6 mm thick aluminum. The frame shall be minimum 2 mm thickness.

#### 7.4.11 **Air Filter:**

The air filter media shall have layers of HDPE (High density Polyethylene) supported by Aluminum wire mesh with water as the mode of cleaning medium. The frame structure of the panel cells shall be made of aluminum sections.

A properly positioned pressure gauge of the inclined tube type shall give an indication of the degree of dust loading on the filters for establishing the periods between services.

#### 7.4.12 **Exhaust Air Fans:**

Exhaust air fans shall be adjustable axial flow fans. Axial air fans shall be of the multi blade vane type. The vanes shall be adjustable individually at standstill. The hub of the impeller shall be directly coupled to the motor shaft and its diameter adapted to the motor frame. The impeller shall be statically and dynamically balanced.

However, fans to be installed in small area like toilets, pantry room, DG room etc. shall be of propeller type.

All bearings shall be pre-lubricated, self-aligning and selected for a minimum of 40000 hour's average life at the maximum design rating. If, however, frequent lubrication is required, this should be possible from the outside of the fan casing without disturbing the fan duct assembly. Bearing supports shall be specially designed for trouble-free bearing service. All fan shafts and wheels shall be designed to operate at their maximum rated speed, which is below the first critical speed.

All motor bases shall be adjustable and V-belt drives selected for 120 percent of motor power. The casing of the air fans shall be made of hot dip galvanized steel or aluminum. Where the impeller is accessible in operation, guards shall prevent injuries to maintenance personnel. Ant vibration mountings shall be provided for each fan.

### 7.5 **CONTROLS AND ELECTRICAL EQUIPMENT:**

The HVAC system shall be equipped with operation on fully automatic mode and manual mode. All the necessary cabling between the control panels and the field HVAC components (as fans, sensors, pumps, valves, air dampers, etc.) shall be included in the supply.

Each of the control systems shall be equipped with the necessary control, interlocking and security devices. Any failure or breakdown in the control system shall be indicated by a signal on the respective control panel, as well as remotely in the main control room. Potential free contacts and terminals for remote indication of the alarms shall be provided in the panels. All necessary protection viz. single phasing, IDMT and Instantaneous over current relays, under voltage relays etc. shall be provided.

Pumps shall be provided with electric motors, anchor bolts and other mounting materials. The pumps shall be with starting unit suitable for  $415V \pm 10\%$ ,  $50Hz \pm 5\%$  with contacts for remote operation / indication.

#### 7.5.1 **Automatic Control and Regulation:**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

The HVAC system shall be equipped with a fully independent computerized automatic control system for efficient operation, which shall be included in the supply. It should automatically stop the supply of fresh/recirculated air to the affected zone immediately in case of fire detection and initiate smoke extraction.

All sensors and instruments (temperature, pressure, humidity, etc.), limit switches, etc. required for automatic regulation and monitoring of proper service of the systems shall be included in the supply.

#### **7.5.2 Manual Mode:**

Individual starting and stopping of equipment by push buttons.

### **7.6 QUALITY ASSURANCE AND TESTING:**

The contractor shall follow the quality assurance and testing requirements specified in the relevant guidelines.

### **7.7 DRAWINGS, DOCUMENTS AND DESIGN CALCULATIONS:**

#### **7.7.1 Design Memorandum:**

The contractor shall prepare and submit to the Engineer of Contract a “Design Memorandum” of the proposed equipment/system fulfilling the contract specification/requirements for approval prior to submission of drawing and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, measure technical features, basic arrangement/layout etc.

#### **7.7.2 Drawings and Documents:**

The contractor shall submit all the drawings and documents in accordance with requirements stipulated in relevant clause of General and Particular Technical Specifications.

#### **7.7.3 Design Calculations:**

The Contractor shall submit the design calculation as per standard practice for approval.

- i) Sizing of ducts for air distribution,
- ii) Calculation for selecting the Blowers, AHUs and other fans capacity,
- iii) Calculation for selecting the air-cooled packaged Air conditioner capacity,
- iv) Cooling loads, Heating loads, air flow rate and temperature and humidity conditions at all locations/areas,
- v) Calculation for selection of raw water pumps and motors.

The Contractor shall also provide other calculations as required by the Employer for his approval of the Contractor's design.

### **7.8 INSTALLATION, TESTING AND COMMISSIONING:**

#### **7.8.1 Shop Tests:**

The HVAC system shall be type and routine tested as per relevant IEC/ IS / Standards. The Contractor is required to carry out all type tests on air cooled chiller



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

units and other equipment of one-unit and routine tests on all units and submit the reports to the Employer. At the discretion of the Employer, type test certificates can be accepted in place of type tests.

#### **7.8.2 Installation and Commissioning:**

The Contractor shall furnish all labour, supervision, tools, supplies, bracing, spiders, shims and supports and all other provisions or materials necessary to assemble, erect, install, test and commission of the equipment in a thorough workman like manner following the best modern practices.

The equipment and all its components shall be placed with great care and accuracy and shall be aligned correctly to provide an installation consistent with the close tolerances used in the erection of modern equipment. The proper elevations and centrelines to which equipment is to be set shall be established by the Contractor.

All necessary materials and labour for performing all the above tests shall be provided by the Contractor. All test equipment and instruments shall be furnished by the Contractor and will remain the Contractor's property after the fulfilment of all field tests.

All civil work required for foundation shall be provided by the Employer. The Contractor is required to submit all foundation drawings and supporting steels well in advance.

#### **7.8.3 Field Tests:**

After installation, the HVAC system shall be field tested for operational tests, visual inspection of complete installations, main air flow rates, performance of heaters, electrical consumption of electrical components, room conditions in all rooms, control system, hydrostatical tests of whole piping systems, air tightness, vibration and noise due to turbulence in the duct assembly etc. The Contractor shall prepare and hand over to Employer details of all test results in a report in a mutually agreed format.

### **7.9 SPARE PARTS:**

The spare parts mentioned here under are meant for use by the Employer during operation and maintenance stage and shall not be used as erection spares required during installation

#### **7.9.1 General Spare Parts:**

The Contractor shall supply the general spare parts as per as per relevant clause of Bid Document. The supply of this spares shall be as per the approved list of spares for each component / equipment / item during detail engineering.

#### **7.9.2 Recommended Spare Parts:**

The Contractor shall furnish the list of recommended spare parts as per relevant clause of Contract Document.

#### **7.9.3 Specified Spare Parts:**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

The following specified spare parts, as defined in relevant clause of Contract Document, which shall comprise the total requirement of Firefighting System under this Contract, shall be supplied:

Sl. No.	Description of Items	Quantity
1	Air Filter Bank Set	1 no. of each type and size
2	V- belts set	2 nos. of each type and size
3	Cooling Water Pump	
	a) Complete pump-motor sets	1 no.
	b) Impellers	1 nos.
	c) Stators	1 no.
	d) Shafts	1 no.
	e) Pump mechanical seals	2 nos. of each type
	f) Set of seals, gasket and O-rings	2 nos. of each type
	g) Pump bearings each size & type	2 nos. of each type
	h) Motor bearings each size & type	2 nos. of each type
4	Automatic Self-cleaning Filters	
	a) Set of complete element assembly consisting of multiple candles, as per design for primary cooling circuit	1 no.
	b) Pneumatic and motorised valve of each type	2 nos.
	c) Motor for automatic filter of each type	1 no.
	d) Solenoid valve of each type	2 nos.
5	Air handling fan-motor set	1 no. of each type and size
6	Blowers fan-motor set	1 no. of each type and size
7	Cooling coils set	2 nos. of each type and size
8	MCCB , MCB & Contactors	1 no. each type
9	Fuses	5 nos. of each type and rating
10	Indicating lamps (LED)	10 nos. of each colour (red, blue, yellow, green, amber)
11	Push buttons	5 nos. of each type
12	Motorised valve along with motor panel and associated accessories	2 nos. of each size and type
13	Pressure gauges and pressure switches	2 nos. of each size and type
14	Temperature gauge, temperature switches/transmitter	2 nos. of each size and type
15	Valves of DN 80 and above	2 nos. of each size and type

#### 7.10 SPECIAL TOOLS:

In addition to the tools listed in general technical specification the Contractor shall provide one set of software, connecting cables, proprietary equipment, other necessary special tools necessary for maintenance, testing and reprogramming of the equipment of the firefighting system as recommended by the manufacturer. A list of such tool shall be approved during detailed engineering.

#### 7.11 SCHEDULE OF REQUIREMENT:



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

#### 7.11.1 Main Equipment & Accessories:

1	Three Sets	(3)	Air handling units (AHU's), each of them be of 50 % of the required capacity, one unit serves as standby, for Power house floors, Transformer area, Service bay, drainage gallery etc. with additional fresh air blowers of the required capacity / rating against each AHU if required.
2	Lot		Required no. of Split type Air Conditioners of the required capacity for Power house Control room, relay/panel rooms, PLCC room areas, staff room, Conference Room, Office Rooms etc.
3	Lot		Required no. of Dehumidifiers of the required capacity for Power house Control room, relay/panel rooms, and other areas wherever necessary.
4	Lot		Exhaust Air fans as detailed in the technical specifications
5	Lot		Cooling Water Circuit (if required) having raw water pumps, raw water automatic self - cleaning wedge wire fine filters, local control panels, instrumentation and associated accessories as detailed in the technical specifications
6	Lot		Cooling water distribution system (if required) along with necessary insulation, valves, fittings, piping, filters, regulating orifices, all type of consumables and other materials
7	Lot		Air duct distribution system for supply and return air of all HVAC systems, with necessary galvanized sheet metal ducts (for battery room exhaust air system, special rust, acid and corrosion proof ducts etc.), elbows, tees, supports, fixations, including all necessary grills, louvers, outside air louvers, adjusting duct dampers, motorized air dampers, heating and cooling insulations, etc.
8	Lot		Central computerized control panel for HVAC system complete with all wiring, instrumentation and associated accessories etc
9	Lot		Local control panels for air handling units, Air cooled packaged Air conditioner units, circulation/cooling water pumps & automatic filters (If required), supply fans, exhaust fans, FCU etc
10	Lot		Insulation with vapour proof cladding for exposed pipes, wherever applicable
11	Lot		Necessary instrumentation pressure gauges, pressure switches, temperature gauges, temperature switches, flows indicator, flow relay/transmitter and humidity sensing devices/instruments etc
12	Lot		Provision of necessary contacts and/or ports for integration with plant SCADA system and fire fighting system

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 22 Air Conditioning System & Ventilation System

13	Lot	Any additional Boosters, Blowers, Pumps, Fans, FCU (fan coil unit) and other items/equipment felt necessary during detailed engineering to ensure a well-ventilated/air-conditioned system in the Power house to maintain a positive draft under all circumstances of operation.
14	Lot	Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard(s) / best international practices

#### 7.11.2 Tools, Tackles and Spares:

a)	One (1) set	Spares as per the Technical Specifications
b)	One (1) set	Tools as per the Technical Specifications

#### 7.11.3 Services:

a)	Lot	Insurance during transit, handling, storage, erection, testing & commissioning and up to the defect liability period.
b)	Lot	Storage & preservation at site until erection & commissioning.
c)	Lot	Site assembly, erection, testing and commissioning.
d)	Lot	All other items implied as per the contents of the specification or otherwise required for completion of the equipment/work even though not explicitly mentioned.
e)	Lot	Training

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipement

## **VOLUME- II**

### **SECTION II SUB-SECTION 23 Oil Handling Equipment**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipement

## TABLE OF CONTENTS

<b>23 OIL HANDLING EQUIPMENT .....</b>	<b>3</b>
23.1 GENERAL .....	3
23.1.1 <i>Scope of Works</i> .....	3
23.1.2 <i>Design and Operating Conditions</i> .....	3
23.1.3 <i>Guarantees</i> .....	4
23.2 SPECIAL CONDITIONS.....	6
23.2.1 <i>Tender Drawings</i> .....	6
23.2.2 <i>Submission of Documents</i> .....	6
23.3 MATERIALS AND WORKMANSHIP .....	6
23.3.1 <i>Painting and Protection</i> .....	6
23.4 PARTICULARS REQUIREMENTS .....	6
23.4.1 <i>Oil Treatment Unit</i> .....	6
23.4.2 <i>Oil Transfer Pumps</i> .....	7
23.4.3 <i>Control and Safety Devices</i> .....	7
23.5 INSPECTION AND TESTS .....	8
23.5.1 <i>Shop Tests</i> .....	8
23.5.2 <i>Site Tests</i> .....	8

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 23 Oil Handling Equipement
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## 23 OIL HANDLING EQUIPMENT

### 23.1 General

One mobile oil treatment unit shall be provided for purification & dehumidification of lubricating & control oil of the - Main Inlet Valve Hydraulic System, Turbine Governor Hydraulic System, Turbine/Generator Bearing but not for the Transformer Oil.

Further, two portable oil transfer pumps shall be supplied for oil transfer between the respective oil sumps of bearings, oil pressure units, etc., and oil drums when no purification will be required. Normally, oil will be transported in oil drums up to the place of oil filling or of emptying.

#### 23.1.1 Scope of Works

The Works shall consist of the following items:

- One mobile pneumatic tyred oil purifier, dehumidifier and degasser for governor and lubrication oil.
- One portable clean oil transfer pump.
- One portable dirty oil transfer pump.
- Two self-priming barrel pumps.
- Tools and devices
- Spare parts.
- Submission of documents.
- Training and instructions of Corporation's Personnel.

Accessories not specifically outlined in the Section 23 but necessary for the effective operation of the oil treatment plant and oil treatment plant and oil pumps shall be included in the Scope of Works.

#### 23.1.2 Design and Operating Conditions

A vacuum-pump of the mobile oil treatment unit shall draw in the dirty oil and convey it to the vacuum chamber, from where it shall be conveyed through filtering elements. A thermostat-controlled heating system shall provide dehumidification and degassing.

Design Data :

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipment

One mobile pneumatic type, oil treatment unit including the purifier, dehumidifier and degasser for governor and lubrication oil of:

- Capacity : 1500 litre/hour
- Pumping head : As per requirement
- Power supply / socket outlet : 415/240V, 50 Hz.
- Including vacuum pump, vacuum tank with heating equipment, pressure pump, filter compartment and necessary drives and controls.
- Filter elements shall remove all particles of size greater than 10 microns. They shall be designed for easy removal and re-fitting. It shall be possible to clean the filters without dismantling and the normal service life shall be at least ten years.
- All inlet and outlet connections (positively sealing hose couplings) shall be provided and shall include fine gauge filters of an easily removable type for cleaning.
- An incorporated control board shall comprise all necessary instrumentation and shall be lockable. A reel-mounted power cable of sufficient length shall form part of purifier and dehumidifier equipment.
- The carrying trolley shall be of sturdy construction.
- All necessary steel-armoured hoses including connections of sufficient length shall be provided to purify all oil sumps at site.

Two electrically driven portable oil pumps of screw type for oil transfer from oil drums to oil sumps and vice versa, each one of the following data :

- Pump capacity : 1500 litre/hour
- Pumping head : As per requirement
- Max. operating speed : 1450 rpm
- Power supply / socket outlet : 415/240V, 50 Hz.

Two self-priming barrel pumps with electric motor of pumping head as per requirement and capacity of approximately 75 L/min.

### 23.1.3 Guarantees

- Minimum size of removed particles 10 microns.
- Water content of treated oil 10 ppm from a 50 ppm initial content.
- Minimum capacity in L/hr. as specified above.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipement

- Sufficient sludge capacity of the filter separator.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipement

## **23.2 Special Conditions**

### **23.2.1 Tender Drawings**

The Tender shall also provide a brief description of the oil treatment plant and portable oil pumps (documentation, catalogue sheets).

### **23.2.2 Submission of Documents**

In addition to the documents requested in Part I, the Contractor shall submit the following documents.

- Piping and Instrumentation Diagram (P & ID) for the oil treatment unit and portable oil transfer pumps.
- Component lists for each equipment.
- Sequence chart of control functions.
- Operation & maintenance manual at least three months before beginning of site tests.

## **23.3 Materials and Workmanship**

### **23.3.1 Painting and Protection**

The painting requirements are outlined in Part I of the Technical Specifications.

## **23.4 Particulars Requirements**

### **23.4.1 Oil Treatment Unit**

A vacuum type oil purifier, suitable for carrying out the degassing, dewatering, filtering and drying of the lubricating and governor oil. The rated capacity of the oil treatment equipment shall be 1500 L/h. The oil purifier shall be arranged on a pneumatic type trolley of a sturdy construction.

All necessary components, including coarse oil-filter, oil pump, oil drying apparatus and continuous flow oil heaters, filter presses, ceramic filter, vacuum pump, switchboard, piping and valves shall be provided. The equipment shall be locally operable.

Hose connections shall be provided with quick-disconnect couplers, and with shut-off and dust caps. The necessary steel-armoured hoses shall be included in the supply.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 23 Oil Handling Equipement

Alternative to this, Electrostatic Liquid Cleaning (ELC) system can be offered for particulate and water removal from Oil. The ELC system uses the principle of electrostatics to collect fluid contaminants. As the fluid flows freely through the system, ELC removes contaminants submicron particles even smaller than 0.01 micron, dust, dirt and products of oxidation such as tars or sludge and varnishes. ELC also removes particles such as paper, wood, plastic and rubber. The Contractor shall supply the electrostatic oil cleaning machine along with the Low vacuum dehydration and de-gasification (LVDH) machine.

#### **23.4.2 Oil Transfer Pumps**

The portable clean oil and dirty oil transfer pumps shall be electric motor driven. The pump head shall be as per requirement. The capacity of each pump shall be 1500 L/h. Each portable oil pump shall be mounted on a conveniently manoeuvrable trolley.

The pumps shall be equipped with all necessary accessories including non-return valve, filter, throttling valves, safety valves, shut-off valve, pressure switch and pressure gauge. The pump sets shall be furnished with attached control switches for local control. If backflow from the unit oil reservoirs is detected, the clean oil transfer pump shall be shut off.

Hose connections shall be provided with quick-disconnect couplers, and with shut-off and dust caps. The necessary steel-armoured hoses shall be included in the supply.

#### **23.4.3 Control and Safety Devices**

All items supplied shall have flow indicator switches. The dirty oil, clean oil and purifier pumps shall be locally controlled. The oil treatment unit shall include all necessary solenoid valves, flow indicators, pressure switches, etc. for local control from the incorporated control switchboard.

The control switchboard shall be designed as outlined in Part I (volume-2), and for protection class IP 65. The switchboard shall accommodate the control equipment, rectifier, a set of terminals with 20% spare arranged on a terminal strip, electric switchboard heating, vapour-tight type lighting inside of the switchboard to facilitate maintenance work, and a 240 V, 50 Hz socket outlet.

The control equipment shall include the following components:

- Push buttons “ON” and “OFF”.
- Control relays.
- Indication lamps “ON” and “Failure”.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 23 Oil Handling Equipement
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## **23.5 Inspection and Tests**

### **23.5.1 Shop Tests**

The Contractor shall prepare a table, listing all components to be tested and the tests to be performed. The Engineer reserves the right to request additional tests if necessary.

Test certificates for materials and equipment shall be provided in triplicate to the Engineer. Shop tests shall include the following.

- Hydraulic pressure tests on all components under internal pressure. The test pressure shall be 2 times the design pressure.
- Routine tests on purchased equipment.
- Insulation tests, operating tests, heating tests, load tests, etc. on electric motors, starters, and other electrical and mechanical components.

When the equipment has passed the tests to the Engineer's satisfaction, he will confirm that it is satisfactory, and it can be painted and packed for shipment.

### **23.5.2 Site Tests**

The Contractor shall conduct the following commissioning tests to ensure that the plant has been correctly installed, all necessary adjustments and settings have been made, and that it is in sound condition to operate.

- Electrical check of correct wiring and cabling.
- Testing and setting of all relays, pressure switches, etc.
- Measuring of insulation level on electrical equipment with Megger.
- Performance test of pump sets.

After successful completion of all commissioning tests, the oil treatment unit and the associated equipment shall be subject to a Test Service Period. Test Service Period operation shall be carried out under the supervision and responsibility of the Contractor.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

## VOLUME- II

### SECTION II SUB-SECTION 24 Mechanical Workshop

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

## TABLE OF CONTENTS

<b>24. WORKSHOP EQUIPMENT .....</b>	<b>3</b>
24.1 SCOPE OF WORK.....	3
24.2 SPECIAL CONDITIONS.....	3
24.2.1 Tender Drawings.....	3
24.2.2 Submission of Documents.....	3
24.3 MATERIALS AND WORKMANSHIP .....	3
24.3.1 General.....	4
24.4 MECHANICAL EQUIPMENT .....	4
24.4.1 Table Drilling Machine.....	5
24.4.2 Double-Wheel Round-Grinding Machine.....	6
24.4.3 Tool-Grinding Machine.....	6
24.4.4 Electric Welding Machine.....	6
24.4.5 Gas-Welding Equipment.....	7
24.4.6 Anvil.....	7
24.4.7 Water Container .....	7
24.4.8 Welding Table.....	7
24.4.9 Work Bench.....	7
24.4.10 Tool Cabinets .....	8
24.4.11 Universal Racks .....	8
24.4.12 Stool.....	8
24.4.13 Tube Vice with Stand .....	8
24.4.14 Tube Stand .....	8
24.4.15 Folding Ladder .....	8
24.4.16 Small Mechanical Tools for Workshop .....	8
24.4.17 Mechanical Measuring Instruments .....	12
24.4.18 Chain Blocks with Monorails for Work Shop.....	13
24.4.19 Lighting Appliances.....	13
24.4.20 Lathe Machine.....	13
24.4.21 Shaper Machine.....	14
24.4.22 Power Hacksaw.....	15
24.4.23 Universal Milling Machine.....	15
24.5 GENERAL .....	16

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

## **24. WORKSHOP EQUIPMENT**

### **24.1 Scope of Work**

This section of the specification covers the requirement of design, manufacture, shop testing, delivery, erection, testing and commissioning, handing to NEEPCO and guarantee for two years of machine tools, hand tools, measuring devices, testing devices and accessories, equipments and tools necessary for normal maintenance and repair of electromechanical equipment of the Powerhouse, for the workshop provided in the Powerhouse at EL. 1027.22m.

The Contractor shall submit a proposal on the allocation of equipment and tools to be put in workshop room in powerhouse and also submit arrangement drawings with his tender to provide information on the equipment layout in the workshop. The operations to be performed in the workshop shall also include turning, drilling, grinding, welding etc.

The equipments specified under the section shall also include mobile equipment and hoisting blocks that may also be assigned to other facilities of the Power Plant.

For the storage of the tools, testing devices and equipment a suitable number of lockers, racks, shelves and dust proof instrument boards shall be delivered and installed.

### **24.2 Special Conditions**

#### **24.2.1 Tender Drawings**

Tenderer shall submit arrangement drawings for the workshop, showing the equipment arrangement for an effective working environment. They shall also show the location of monorails, terminal boxes, switchboards and the required location of socket outlets.

#### **24.2.2 Submission of Documents**

In addition to the documents requested in Part I, the Contractor shall submit the following documents:

- Component lists for the workshop
- Operation and maintenance manuals of all equipment at least three months before beginning of commissioning.

### **24.3 Materials and Workmanship**

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 24 Mechanical Workshop
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### 24.3.1 General

Hand tools shall be made of quality chromium – vanadium steel.

The painting requirements are outlined in Part I, General Technical Specification.

### 24.4 Mechanical Equipment

The equipment shall consist of the following main components

#### Mechanical Equipment for Workshop

- 1 table drilling machine with supporting bench
- 1 double-wheel rough grinding machine
- 1 tool grinding machine
- 1 work bench with vice
- 2 sets of universal racks
- 1 tube vice with stand
- 1 tube stand
- 2 tool cabinets
- 2 stools
- Tools for workshop
- Mechanical measuring instruments
- 1 one ton chain block with monorails
- 2 electrical hand drilling machine
- 1 radial drilling machine
- 1 long lathe machine
- 1 Shaper machine
- 1 Universal Milling machine
- 1 Power Hacksaw
- Pipe Bending Machines

In addition to these, 1 lot of hand tools & testing instruments shall also be provided.

#### Equipment for Welding Section:

- 1 electric-welding equipment
- 2 gas-welding sets and other welding equipment

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- 1 anvil
- 1 welding table
- 1 water container
- 1 Rectifier Type Welding Machine
- 1 no. electrode storage oven & 1 no. Portable electrode drying oven.

**Mobile Equipment:**

- 1 tool trolley
- 2 handle operated monkey winches of 0.5-ton capacity
- 2 lighting appliances
- 1 folding ladder

Any other item (s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard(s) / best international practices.

#### **24.4.1 Table Drilling Machine**

The table-drilling machine shall be supplied complete with electric motor, spindle head, working table (height adjustable) and base plate suitable to be used a working table.

The drilling machine shall have the following main data:

- |   |                      |
|---|----------------------|
| – drilling capacity (in steel)                          | 40 mm                |
| – spindle speeds  | normal range         |
| – size of working table                                 | approx. 200 x 200 mm |
| – size of base plate                                    | approx. 250 x 250 mm |
| – max. distance between drilling spindle and base plate | approx. 450 mm       |

The drilling machine shall be equipped with all normal accessories and shall be furnished with the following additional special accessories and tools.

**Additional Special Accessories**

- lighting equipment
- parallel vice
- steel parallel to mount the work pieces (assorted sizes)
- V- blocks for supporting round work pieces (assorted sizes)
- U- traps for clamping the work pieces (assorted sizes)
- Greasing gun

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 24 Mechanical Workshop
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### Tools

Two sets of drills 1 to 15 mm diameter in step of 0.25 mm

#### **24.4.2 Double-Wheel Round-Grinding Machine**

To be supplied complete with electric motor, mounted on a high stand with one grinding wheel mounted on each side of the motor shaft. The machine shall be provided with the necessary protection shields and adjustable work-piece support and shall have the following main data:

- diameter of grinding wheels                      250 mm
- width of grinding wheels                          40 mm
- grinding disc speeds                                1,400 and 2,800 rpm

All accessories, 4 spare grinding wheels (2 of each type), 2 wheel dressers and 6 pairs of grinder's glasses shall be furnished with the machine.

#### **24.4.3 Tool-Grinding Machine**

Base mounted universal grinder for the sharpening of cutting tools and drills. Design and accessories similar to the rough-grinding machine but with a grinding disc width of approximately 20 mm.

#### **24.4.4 Electric Welding Machine**

The electric welding machine shall be of the converter type with electric motor generator and stepless adjustment of current with hand wheel. The welding machine shall be capable for both SMAW and TIG welding.

The machine shall be transportable on two wheels and shall be provided with all necessary controls, indicating instruments, cables and accessories to guarantee maximum efficiency.

The generator shall be supplied for a range of 35 – 500 A, and shall be supplied with all necessary accessories for both SMAW and TIG welding, such as 2 x 10 m welding cables with electrode holders, 2 x 10 m earthing cables with clamps, Argon cylinder with 10 m length of hose, gas flow meter, protection shield, brush, welding hammer, welding gloves, etc.

Argon cylinder shall be mounted on a carriage and the electric holders shall be equipped with stepless current controllers.

Furthermore, the Contractor shall furnish suitable number and types of welding electrodes.



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

#### **24.4.5 Gas-Welding Equipment**

The gas welding equipment shall be supplied complete with acetylene and oxygen bottle, bottle carriage, pressure-reducing and safety valves, hoses miming valve, 1 set of suitable nozzles, glasses, etc.

The tool cabinet shall contain the following:

Torch holder, one set of 10 torches for sheets of 0.5 to 200 mm, combines cutting heads and guide for oxygen cutting of plate 50 to 200 mm in thickness, safety goggles etc.

One set of spare parts including the following:

Cylinders, pressure reducing valves, pipes, double clips, snap-on high-speed connectors, clamps, spanners etc.

Furthermore, the Contractor shall furnish a suitable number of welding wires of various diameters.

#### **24.4.6 Anvil**

The anvil shall be suitable in size and the material adequate for the work to be performed. Approx. dimensions shall be as follows:

- length 500 mm
- width 220 mm

#### **24.4.7 Water Container**

A quenching tank if welded steel plate, galvanised approx. dimensions 700 x 700 x 200 mm

#### **24.4.8 Welding Table**

The welding table shall be supplied complete with plate, supports, drawers, vice and all necessary accessories for welding operations.

Table size approx. 1,000 x 1,200 mm

#### **24.4.9 Work Bench**

The work benches shall have a height of 850 mm and shall be supplied complete with plate, supports, chest of drawers for tools, vice etc.

The sizes shall be as follows:

Work benches with vice approx. 800 x 2,000 mm.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

#### **24.4.10 Tool Cabinets**

The tool cabinet elements shall have a height of 1,000 mm approx. and a width of 750 mm approx. All elements shall be of steel construction with various types of drawers for the storage of all kinds of tools.

#### **24.4.11 Universal Racks**

The universal racks shall be made of steel profiles with all necessary metal of wooden trays and shall be designed as a series of modular parts which can be used to build free-standing racks of multibay racking. The height of all racks shall be approx. 2.20 m to 2.30 m and the width 0.8 m.

##### For the Workshop

Total length approx. 2.0 m (multiple sections)

##### For the Welding Section

Total length approx 2.0 m (multiple sections)

#### **24.4.12 Stool**

With 3-legged steel base; with plastic covered circular seat, adjustable in height.

#### **24.4.13 Tube Vice with Stand**

Adjustable, to suit all required pipe diameters.

#### **24.4.14 Tube Stand**

To suit tubes maximum 2,000 mm long.

#### **24.4.15 Folding Ladder**

Aluminium, minimum height 2,500 mm in folded position.

#### **24.4.16 Small Mechanical Tools for Workshop**

The Contractor shall supply a complete set of heavy duty tools for the workshop, to be located in the tool cabinets and on the universal racks of the workshop.

The tools shall consist but not be limited to the following:

- (one) portable electric hand grinding machines 230V/50Hz.  
The supply shall include 6 spare grinding wheels.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- 1 (one) set each of Portable Angle Grinder, Portable Flexible Shaft Grinder and Portable Sanders/ Polish.
- portable electric 2 – speed percussion drilling machine 230V/50 Hz. Drilling capacity in steel 25 mm  
Drilling capacity in rock 20/10 mm  
The supply shall include two sets of carbide drills and a set of rock frill
- portable pneumatic drilling machine; 32 mm drilling capacity. The supply shall include for each machine a complete set of drills.
- portable pneumatic worm drive nut runner suitable for up to 12 mm diameter bolts.
- portable pneumatic straight grinder suitable for 75 x 25 mm wheel.
- pneumatic pistol grip drill with chuck capacity 12 mm.
- pneumatic chipping hammer 15 mm bore with selection of chisels.
- spray gun suitable for low and medium viscosity fluids.
- industrial vacuum cleaner, compressed air driven complete with connectors and compressed air hoses 10 meter in length.

Suction capacity	1,800 – 4,500 mm w.g.
Dust capacity	30 liters
Required air pressure	4 – 12 bar
Air consumption	0.4 m <sup>3</sup> /min
Weight	approx. 10 kg

- 2 hand operated pulley blocks; one (1) ton
- 2 oil-cans
- 3 adjustable nozzles air hoses
- 10 compressed air hoses complete with connections suitable for instantaneous connection with compressed air tapping.
  - \* length each 10 m
  - \* operating pressure 8 bar
- 1 bastard file, flat 250 mm
- 1 bastard file, three-cornered 250 mm
- 1 bastard file, half-found 250 mm
- 1 bastard file, round 250 mm

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

– 1 flat file, smooth	200 mm
– 1 three –cornered file, smooth	200 mm
– 1 half-round file, smooth	200 mm
– 1 round file. Smooth	200 mm
– 1 four-cornered file, smooth	200 mm
– 15 wooden file handles	
– 2 bearing scrapers	
– 2 triangular scraper	
– bench hammers (260 g – kg, set of 4)	
– rivet hammer	
– nylon hammer	
– lead hammers	
– flat chisels	
– 1 set of punches	
– centre punches 10 x 20	
– 2 angular scribing needles	190 mm
– 2 piercer awls	80 mm
– 2 dividers	250 mm
– sets screwdrivers, of 1 – 8 size	
– 1 sets screwdrivers	4 size
– 1 wire cutter	
– 2 hacksaw + spare blades	
– 1 power saw	
– keyhole metal saw	
– 1 plumb with 40 m string	
– 1 set machine tap drills M3 – M10	
– 1 sheet metal shear	2-12 mm
– 1 hexagonal key set	15 mm
– 1 sliding wrench	25 mm
– 1 sliding wrench	50 mm
– 1 tape measure	30 mm
– 1 tape measure	10 mm
– 1 pipe cutter	150 mm
– 1 pipe wrench	200 mm
– 1 pipe wrench	350 mm
– 1 pipe vice	
– 1 set pipe thread cutter	10-50 mm

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- 1 scissors
- 6 hollow punches for gasket rings
- 1 combination pliers 190 mm
- grip pliers 250 mm
- 1 nose plier 6 inch
- 1 round nose plier 50 mm
- 1 cutting plier 8 inch
- 2 sets spiral drills 1-20 mm in dia.;  
one millimetre increment between each diameter
- 2 sets spiral drills 20-30 mm in dia.;  
two millimetre increment between each drill
- 1 set of reamers
- 1 thread cutter set M3-24, including tap drill and cutter with holder and tap wrench
- 1 set open ended spanners size 6-32 mm
- 1 set of open ended spanners size 36-72 mm
- 1 set of shifting spanners, range 13 to 40 mm
- 1 set of double bent ring spanners, size 6-36 mm
- 1 set of socket wrenches, including complete set of ratchets size 6-36 mm
- 1 set of internal Allen key wrenches size 3-20 mm
- 1 contact screwdriver set No. 1 to No. 4 size
- 1 Universal pliers 500 V 160 mm
- 3 portable lamps, cable length 5 m, extension cable 20 m, with plug and adapter, and insulator transformer
- 1 precision screwdriver set with 4 blades
- 1 manual hydraulic pipe bending device with standard accessories and additional bending tools.

#### Radius

0/900

5/900 10/1800

8/900

10/900

15/900

20/900

- 4 sets hand gloves

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- 1 set hook stick
- helmets
- 1 set of steel figures and letters
- 1 set of consumable articles such as oil, grease, cotton waste, 10 liters cutting lubricant etc.

#### **24.4.17 Mechanical Measuring Instruments**

The Contractor shall include in his supply all mechanical measuring instruments, as mentioned hereafter. All instruments shall be enclosed in rigid wooden protection cases for proper storage.

##### Sliding Gauges

- 2 slide gauges, combined for inside and outside measurements, measuring range  
0 – 200 mm, accuracy 1/50 mm
- 1 slide gauge for outside, measurement, measuring range 0 – 40 mm, accuracy 1/50 mm
- 1 slide gauges for measuring depth, measuring depth, measuring range 0 – 250 mm, accuracy 1/50 mm

##### Micrometers

- 1 outside micrometer, measuring range 0 – 25 mm, accuracy 1/100 mm
- 1 outside micrometer, measuring range 25 – 50 mm, accuracy 1/100 mm
- 1 pair of inside micrometer heads with the necessary control rings, elongations and adjusting wrenches

##### Other Measuring Instruments

- 2 sets of precision rules of various types and lengths
- 1 adjustable precision universal angle measuring equipment.
- 1 spirit precision frame level, accuracy: 1 division – 0.05 mm per meter
- 2 short type and 2 long type feeler gauges with feelers of various thicknesses varying from 0.05 to 1.0 mm
- 1 ISO thread gauge M3 – M36, including tube threads
- 1 radius gauge concave and convex for radii 1 – 7 mm

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- 1 divider
- 1 outside calliper
- 1 inside calliper
- 1 straight edge, 1 m in length
- 2 angular scribing needle 150 mm
- 1 precision mechanical revolution counter
- 12 dial gauges with magnetic base, accuracy of measurements 1/100 mm
- 1 stopwatch accuracy of measurement 1/5/ second
- 1 thermometer, 0 – 100°C
  
- 1 electronic vibration meter and analyzer of hand held type with pickups for measuring acceleration, velocity, amplitude of vibrations.
  
- 2 sets filter gauge, accuracy of measurement 0.01 mm to 1 mm
  
- 2 steel scales 1 metre
  
- 2 steel scales 300 mm

#### **24.4.18 Chain Blocks with Monorails for Work Shop**

Hoisting Capacity 1 ton

Standard chain blocks designed for travel along monorail beams and therefore equipped with hoist and travelling rollers. Designed for manual operation. The design shall include load chain, hand chain load dependent pressure broke, steel hook and spring-loaded safety catch. The chain block weight shall allow easy displacement from one monorail beam to another. Lifting ropes with rope slings shall be included in the supply.

Two monorail beams of sufficient length shall be supplied, including fixing anchor bolts and clamps, to be temporarily attached to foundation plates provided in the ceiling of various rooms such as workshop, welding section, cooling equipment room etc., to allow handling of heavier equipment.

#### **24.4.19 Lighting Appliances**

Two portable rechargeable lighting appliances – 160 lumen; self contained units including Ni-Cd battery with built-in charger, drop out switch, cable with plug for connection to main supply, carry handle.

#### **24.4.20 Lathe Machine**

Long lathe – 1 No. mentioned above shall have the following specifications:

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications Volume II Section-II Sub-Sec. 24 Mechanical Workshop
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The long Lathe shall be centre lathe, all geared, heavy duty type. The contractor shall recommend and supply the lathe machine in accordance of the machining requirement of not less than 2.0m job length along with travelling and fixed steadies and following tools & accessories.

- i) One (1) set Taper turning attachment,
- ii) One (1) no. each 3 jaw self centering chuck (20") and 4 jaw independent chucks (20"),
- iii) Two (2) nos. corresponding dead centre
- iv) Two (2) nos. drive dogs
- v) Two (2) nos. each driving plate, face plates (24" and 30")
- vi) One (1) set Quick change tool
- vii) One (1) set machine lamp
- viii) One (1) set tool post,
- ix) Four (4) sets each of HSS and high carbon tool bits with tool base
- x) Four (4) sets tool kit consisting of turning tools, parting tools, external threading tool with a set of corresponding inserts,
- xi) Two (2) drum of lube oil for gear box,
- xii) One (1) set coolant pump complete with coolant tank & swarf tray,
- xiii) One (1) set of reduction sleeves, various sizes of sleeves to accommodate turning of different dear taps
- xiv) One (1) set dog plate each of 24 inch and 30 inch,
- xv) One (1) set each of revolving centre (MT-5) , centre adaptor, along with standard tools & accessories,
- xvi) One (1) set of copying attachment

#### **24.4.21 Shaper Machine**

Shaper Machine- 1 No. mentioned above shall have the following specifications:

The shaper machine should be capable of withstanding the operation of heavy loads with no noise, should have heavy duty ribbed sturdy structure and erosion resistant. The machine shall have automatic lubrication system.

- i) Maximum stroke – 650 mm
- ii) Maximum distance table to ram – 450 to 550 mm



EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- iii) Minimum distance table – 40 to 60 mm (approx.)
- iv) Length of Cross slide – 900 to 1000 mm (approx.)
- v) Travel of tool slide – upto 200 mm
- vi) Table feed – Suitable table feed for above specification

#### 24.4.22 Power Hacksaw

Power hacksaw shall be suitable for operation with 415V $\pm$ 10%, 50Hz (-5% to +3%) power supply with following particulars:

Cutting capacity:

- i) Round section (mm) 300
- ii) Rectangular section (mm) 250x250
- iii) Stroke per minute 60 to 100

The following standard accessories shall be provided with the hacksaw:

- a) One (1), coolant tank (with chips separator),
- b) One (1) set of electrically driven coolant Pump with motor and coolant piping and nozzle
- c) Fifty (50) power blades extra
- d) One (1) adjustable bar rest,
- e) One (1) V shape vice jaws to cut material in bundle,
- f) Emergency stop push button

#### 24.4.23 Universal Milling Machine

The Universal Milling Machine shall have the following specifications or better:

- i) Table Size: Range from 800x200 mm to 2000x500 mm.
- ii) Longitudinal Travel (X): From 500 mm to 1500 mm, depending on the machine size.
- iii) Cross Travel (Y): From 200 mm to 800 mm, depending on the table width.
- iv) Vertical Travel (Z): From 300 mm to 600 mm, depending on machine type and size.

EPC execution of Power House Electro-Mechanical Works of Heo Hydro Electric Project (240MW) Arunachal Pradesh		Particular Technical Specifications
		Volume II Section-II
		Sub-Sec. 24 Mechanical Workshop

- v) Spindle Speed: Variable speed ranging from 40 to 3000 RPM.
- vi) Spindle Taper : ISO 40, ISO 50, NT40, or NT50.
- vii) Power Feed: Automated feed for X, Y, Z axes; speeds may range from 15–2000 mm/min.
- viii) Table Load Capacity: from 200 kg to 400 kg.
- ix) Swivel Angle: swivel up to  $\pm 45^\circ$  or  $\pm 90^\circ$  for angular machining.

## 24.5 General

The tenderer may suggest/recommend any additional mechanical or electric equipments, alongwith their capacities, required for the workshop, for approval of the purchaser.