

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

## Volume-II

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### Section I

### Transformer

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

## TABLE OF CONTENTS

1.	GENERATOR STEP-UP TRANSFORMERS (GTSU)	7
1.1.	Scope of Work (Generator Step-up Transformers)	7
1.2.	Reference Standards	7
1.2.1.	General	7
1.2.2.	International Standards	8
1.2.3.	North American Standards	10
1.2.4.	Indian Standards, CEA Regulations	12
1.3.	General Requirements	14
1.4.	Specific Requirements	15
1.5.	Operational and design requirements	15
1.6.	Technical Main Data, Design and Construction	18
1.6.1.	Technical Main Data	18
1.6.2.	Core Material	22
1.6.3.	Core Construction	22
1.6.4.	Core Oil Ducts	23
1.6.5.	Core Insulation	23
1.6.6.	Core Earthing	24
1.6.7.	Core Flux Density	24
1.7.	Winding Conductor Material	25
1.8.	Winding Clamping and Bracing	26
1.9.	Winding Insulation	26
1.10.	Winding Connections and Neutral Earthing	27
1.11.	Tank Construction	27
1.12.	Pressure Relief Device	29
1.13.	Tank Lifting And Haulage	30
1.14.	Tank Covers	31
1.15.	Earthing of Tank	32
1.16.	Bonding	32
1.17.	HV Bushings for The Generator Transformers	32
1.18.	Bus Duct and Cable Connection	33
1.18.1.	Bus Duct Connections	33
1.18.2.	Cable Connection for Control Cabinet, Marshalling Kiosk and Marshalling Box	34
1.19.	Conservator Vessels and Breather	34
1.19.1.	Conservator Tank	35

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

1.19.2.	Oil Preservation Equipment -----	35
1.19.3.	Dehydrating Filter Breather-----	36
1.20.	Valves and Flanges -----	36
1.21.	Cooling Plant -----	38
1.22.	Oil Circulating Pumps -----	40
1.23.	Temperature Indicating Devices (and Relays) -----	41
1.23.1.	Winding Temperature Indicator (WTI) -----	41
1.23.2.	Optical sensors & temperature measuring unit -----	42
1.23.3.	Oil Temperature Indicator (OTI) -----	42
1.24.	Buchholz Devices-----	43
1.25.	OFF Circuit Tap Changing (OCTC) -----	44
1.25.1.	Tap Position Numbering -----	44
1.26.	Control Cabinets -----	45
1.27.	Painting -----	46
1.28.	Control Wiring -----	47
1.29.	Power Cabling-----	47
1.30.	Insulating Oil -----	48
1.31.	Oil Preservation System -----	48
1.32.	Current Transformers for 11 / (220 / $\sqrt{3}$ ) kV Generator Transformer -----	48
1.33.	Bolts and Nuts -----	49
1.34.	Motors -----	49
1.35.	Labels and Rating Plates: -----	50
1.36.	Transformer Oil Filtration System -----	50
1.36.1.	Performance Requirement-----	50
1.36.2.	Design & Construction-----	51
1.36.3.	Oil Pump (Inlet Side) -----	51
1.36.4.	Instrumentation and Control-----	56
1.36.5.	Electrical System: -----	57
1.37.	Technical specification for oil storage tank -----	58
1.38.	Fittings and Accessories-----	59
1.39.	Packing and Transport-----	61
1.40.	Performance Guarantees-----	62
1.41.	Drawings, Data, Manuals and Guaranteed Particulars -----	63
1.42.	Stage inspection -----	65
1.43.	Testing of Transformer -----	67
1.43.1.	Factory Tests -----	67
1.43.2.	Routine Tests-----	69

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

1.43.3.	Type Tests -----	70
1.43.4.	Tank Tests -----	72
1.44.	Erection, Testing and Commissioning -----	73
1.45.	Inspection and Testing at Site -----	74
1.45.1.	Receipt and Storage Checks:-----	74
1.45.2.	Site Installation Checks:-----	75
1.45.3.	Site Commissioning Checks: -----	75
1.46.	Shop Inspection -----	77
1.47.	Quality Assurance Program -----	77
1.48.	Spare Parts and Tools-----	77
1.48.1.	Mandatory Spares list -----	78
1.48.2.	Tools and Tackles -----	80
1.49.	Completeness of Equipment-----	80
2.	DISTRIBUTION TRANSFORMERS-----	81
2.1.	Scope of Work (Distribution Transformers)-----	81
2.2.	Reference Standards-----	82
2.3.	Oil Type Distribution Transformers-----	82
2.3.1.	Operating Conditions -----	83
2.3.2.	Construction Details -----	87
2.3.2.1.	Core Material -----	87
2.3.2.2.	Core Construction-----	87
2.3.2.3.	Core Oil Ducts -----	88
2.3.2.4.	Core Insulation-----	88
2.3.2.5.	Core Earthing-----	89
2.3.2.6.	Core Flux Density -----	89
2.3.3.	Winding-----	89
2.3.3.1.	Conductor Material -----	89
2.3.3.2.	Winding Clamping and Bracing -----	90
2.3.3.3.	Winding Insulation -----	91
2.3.3.4.	Winding Connections -----	91
2.3.4.	Transformer Tank-----	91
2.3.4.1.	Tank Construction -----	91
2.3.4.2.	Tank Lifting and Haulage -----	92
2.3.4.3.	Tank Covers-----	93
2.3.4.4.	Earthing of Tank -----	94
2.3.4.5.	Bonding -----	94
2.3.5.	Pressure Relief Device -----	94

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

2.3.6.	Bushing Insulators -----	95
2.3.7.	Cable Connection -----	96
2.3.7.1.	Cable Boxes -----	96
2.3.7.2.	Cable Boxes for Marshalling Kiosk -----	96
2.3.8.	Conservator Vessels and Breather -----	96
2.3.8.1.	Vessels -----	96
2.3.8.2.	Breathers -----	97
2.3.9.	Valves and Flanges -----	97
2.3.10.	Cooling System -----	98
2.3.11.	Temperature Indicating Devices (and Relays) -----	99
2.3.11.1.	Winding Temperature Indicator (WTI) -----	99
2.3.11.2.	Oil Temperature Indicator (OTI) -----	100
2.3.12.	Buchholz Devices -----	100
2.3.13.	Tap Changer -----	101
2.3.13.1.	Arrangement (Off-Circuit Tap changer (OCTC)) -----	101
2.3.13.2.	Tap Position Numbering -----	102
2.3.14.	Marshalling Kiosks -----	102
2.3.15.	Insulating Oil -----	104
2.3.16.	Oil Preservation System -----	104
2.3.17.	Current Transformers -----	104
2.3.18.	Fittings and Accessories -----	105
2.4.	Dry Type Distribution Transformers -----	106
2.4.1.	Operating Conditions -----	106
2.4.2.	Technical Description -----	107
2.4.3.	Rating -----	107
2.4.4.	Construction Details -----	112
2.4.4.1.	Enclosure for Dry Type Transformer -----	112
2.4.4.2.	Core and Coils -----	113
2.4.4.3.	Tap Changer -----	113
2.4.4.3.1.	Tapping -----	113
2.4.4.3.2.	Off-Circuit Tap Changer -----	114
2.4.4.4.	Support Insulator -----	114
2.4.4.5.	Marshalling Box -----	114
2.4.4.6.	Fitting and Accessories of Each Transformer: -----	114
2.4.5.	Earthing Details -----	115
2.4.6.	Terminal Arrangement (Cable Connection and Bus Bar) -----	115
2.4.6.1.	33 kV /11 kV XLPE Cable Connection (HT Side) -----	115

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

2.4.6.2.	Bus bar Connections (LT Side)-----	115
2.4.7.	Painting -----	115
2.4.8.	Labels and Plates-----	116
2.4.9.	Bolts and Nuts -----	116
2.4.10.	Control Wiring -----	116
2.4.11.	Packing and Transport-----	117
2.5.	GUARANTEES FOR 1500KVA (SAT), 630KVA (UAT) and 160KVA DISTRIBUTION Transformers: -----	117
2.6.	Guarantees for 5MVA, 220/33kv Station Service Transformer: -----	118
2.7.	Testing-----	119
2.7.1.	Type Tests -----	119
2.7.2.	Routine tests -----	120
2.7.3.	Special tests -----	120
2.7.4.	Tests on associated equipment:-----	121
2.7.5.	Tests at Site:-----	121
2.7.6.	Transformer routine tests shall include tests stated in latest issue of IS: 2026 / IEC 76. These tests shall include but may not be limited to the following: -----	121
2.7.7.	In addition to the routine tests specified above, the following routine tests shall also be made on each transformers :-----	122
2.7.8.	Tests at site: -----	123
2.7.9.	Tests on associated equipment (at works): -----	123
2.7.10.	Test reports:-----	124
2.7.11.	Shop Inspection -----	124
2.8.	Erection, Testing and Commissioning-----	124
2.9.	Drawings, Data, Manuals and Guaranteed Particulars -----	125
2.9.1.	Drawings, data and guaranteed particulars to be furnished with the Bid -----	125
2.9.2.	Drawings, data manuals, etc. and documentation to be furnished by the Supplier after award of contract:-----	126
2.10.	Quality Assurance Program-----	127
2.11.	Spare Parts & Tools-----	128
2.11.1.	A) Tools (Mandatory) -----	128
2.11.2.	B) Spares for each rating- Mandatory spare parts to be included and supplied -----	128
2.12.	Completeness of Equipment-----	129

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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## 1. GENERATOR STEP-UP TRANSFORMERS (GTSU)

### 1.1. Scope of Work

The Scope of works under the contract covers design, manufacture, Quality Assurance, Quality control, shop assembly, shop testing, packing, supply, transportation up to site, including Transit insurance during transportation as well as intermediate storage if necessary, delivery, handling and storage at site, Erection, Testing and Commissioning of Ten (10) numbers single-phase, 35 MVA 11/220kV OFWF Generator Transformers along with their associated auxiliaries, spare parts for 5 years trouble free operation of the transformers, special tools and tackles as per schedule of requirements and as described in Technical specification of the bid documents.

The transformers shall be of core and oil immersed type and suitable in all respects for operation on the system and under the conditions specified in this specification.

The contractor shall coordinate and cooperate fully with Civil Contractor and other contractors involved in carrying other works at the site.

The contractor shall supply all information and details for Civil design of the transformer hall including embedded parts of the equipment foundations as per relevant practice and relevant IS or equivalent codes.

Exclusions:

- i. All kind of civil works like construction of soak pit, cable trenches, rail, firewall, and foundations for transformers are excluded from the scope of the Contract. However, supply of foundation bolts & other embedded parts, foundation drawings and other specification for the finalization of civil drawing where ever required shall be under the scope of contract.
- ii. Laying of earth mat is excluded from this scope of contract. However, earthing connection from the overground riser and providing design details for finalization of Powerhouses earthing system shall be included in the scope of this contract.
- iii. Supply of cable tray is excluded from the scope of contract. However, the contractor shall coordinate with the Powerhouse contractor for their requirement.

### 1.2. Reference Standards

#### 1.2.1.General

The Generator Transformers shall be designed, manufactured, tested and erected in conformance with applicable International, North American and Indian Standards. Many standards may be

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

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.

Transformers, 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.

#### **1.2.2.International Standards**



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

IEC 60034	Rotating Electrical Machines
IEC 60044-1	Instrument Transformers Part 1 : Current Transformers
IEC 60044-1-am 1	Amendment 1
IEC 60044-1-am 2	Amendment 2
IEC 60044-6	Instrument Transformers Part 6: Requirements for Protective Current Transformers for Transient Performance
IEC 60050(421)	International Electrotechnical Vocabulary - Chapter 421: Power transformers and reactors
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 60071-1	Insulation coordination - Part 1: Definitions, principles and rules
IEC 60071-2	Insulation coordination - Part 2: Application guide
IEC 60076-1	Power Transformers - General
IEC 60076-2	Power Transformers – Temperature-rise
IEC 60076-3	Power Transformers - Insulation Levels, Dielectric Tests and External Clearances in Air
IEC 60076-4	Power Transformers - Guide to the Lightning Impulse and Switching Impulse Testing
IEC 60076-5	Power Transformers - Ability to Withstand Short Circuit
Power transformers - Part 7	Loading guide for oil-immersed power transformers
IEC 60076-8	Power Transformers - Application Guide
IEC 60076-10	Power Transformers - Determination of Sound Levels
IEC 60085	Electrical Insulation - Thermal Classification
IEC 60137	Insulated Bushings for Alternating Voltages above 1000 V
IEC 60214-1	Tap-changers - Performance Requirements and Test Methods
IEC 60214-2	Tap-changers - Application Guide
IEC 60270	High Voltage Test Techniques Partial Discharge Measurements
IEC 60354	Loading Guide for Oil-immersed Power Transformers
IEC 60529	Degrees of Protection Provided by Enclosures

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

IEC 60567	Guide for the Sampling of Gases and of Oil from Oil-filled Electrical Equipment and for the Analysis of Free and Dissolved Gases
IEC 61181	Impregnated Insulation Materials - Application of Dissolved Gas Analysis (DGA) to Factory Tests on Electrical Equipment
IEC 61639	Direct Connection between Power Transformers and Gas-insulated Metal-enclosed Switchgear for Rated Voltages 72.5 kV and above
IEC 60296-2003	Fluids for electrotechnical applications - Unused mineral insulating oils for transformers and switchgear

### 1.2.3.North American Standards

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

IEEE-62	Guide for Diagnostic Field Testing of Electric Power Apparatus Part 1: Oil Filled Power Transformers, Regulators, and Reactors
IEEE-1538	Guide for Determination of Maximum Winding Temperature Rise in Liquid-Filled Transformers
ANSI C57.12.00	Standard General Requirements for – Liquid-Immersed Distribution, Power, and Regulating Transformers
ANSI C57.12.70	Standard Terminal Markings and Connections for Distribution and Power Transformers
ANSI C57.12.80	Standard Terminology for Power and Distribution Transformers
ANSI C57.12.90	Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers and IEEE Guide for Short Circuit Testing of Distribution and Power Transformers
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 C57.91	Guide for Loading Mineral-Oil-Immersed Transformers
ANSI C57.91 Cor 1	IEEE Guide for Loading Mineral-oil-immersed Transformers – Corrigendum 1
ANSI C57.91(errata 1)	IEEE Guide for Loading Mineral-oil-immersed Transformers
ANSI C57.93	Guide for Installation of Liquid-Immersed Power Transformers
ANSI C57.98	Guide for Transformer Impulse Tests
ANSI C57.98 (errata 1)	Guide for Transformer Impulse Tests
ANSI C57.106	Guide for Acceptance and Maintenance of Insulating Oil in Equipment

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

ANSI C57.113	Guide for Partial Discharge Measurement in Liquid-Filled Power Transformers and Shunt Reactors
ANSI C57.116	Guide for Transformers Directly Connected to Generators
ANSI C57.120	Loss Evaluation Guide for Power Transformers and Reactors
ANSI C57.123	Guide for Transformer Loss Measurement
ASTM A 193 / A 193 / M	Standard Specification for Alloy-Steel and Stainless Steel Bolting Materials for High-Temperature Service.
ASTM A 194 / A 194 / M	Standard Specification for Carbon and Alloy-Steel Stainless for Bolts for High Pressure or High Temperature Service or Both.
NEMA TR1	Transformers, Regulators and Reactors (for audible sound levels)

#### **1.2.4.Indian Standards, CEA Regulations**

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

IS: 5	Colours for Ready Mixed Paints and Enamels
IS: 104	Ready Mixed Paint, Brushing, Zinc Chrome, Priming
IS: 325	Three-Phase Induction Motors
IS: 325 and IS: 996	Motors
IS: 335	Transformer Oil
IS: 1554 : Part 1:	PVC Insulated (heavy duty) Electric Cables: Part 1 for Working Voltages up to and Including 1100 V
IS: 1822	Motor Starters
IS: 1866	Code of Practice for Electrical Maintenance and Supervision of Mineral Insulating Oil in Equipment
IS: 1885 : Part 38	Electrotechnical Vocabulary – Part 38: Power Transformers and Reactors
IS: 2026 : Part 1	Power Transformers: Part 1 General
IS: 2026 : Part 2	Power Transformers: Part 2 Temperature-rise
IS: 2026 : Part 3	Power Transformers: Part 3 Insulation Level and Dielectric Tests
IS: 2026 : Part 4	Power Transformers: Part 4 Terminal Marking, Tappings and Connections
IS: 2026 : Part 5	Power Transformers: Part 5 Transformer / Reactor Bushings Minimum External Clearance in Air-specification
IS: 2099	Transformers Bushings
IS: 2147	Degree of Protection Provided by Enclosures for Low Voltage Switchgear and Control Gear
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 Specification
IS: 3347	Dimensions for Porcelain Transformer Bushings
IS: 3637	Gas and Oil Operated Relay
IS: 3639	Specification for Fittings and Accessories for Power Transformers
IS: 5120	Oil Pumps
IS: 6088	Heat Exchangers
IS: 6600	Loading Guide for Oil-immersed Transformers

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

IS: 6855	Method of Sampling for Liquid Dielectrics
IS: 10561	Application Guide for Power Transformers
CEA	Standard Specifications and technical Parameters for Transformers and Reactors (66kV & above voltage class)

### 1.3. General Requirements

The scope of works, including the limits of scope, is detailed in Schedule of Requirements.

The transformer together with associated auxiliaries and equipment shall be designed and constructed to facilitate operation, maintenance, repairs and withstand without damage the thermal and dynamic effects of external short circuit. **Thermal stress due to short circuit shall be for a duration of 3 seconds for these Generator Transformers.** The transformer shall be used for bi-directional flow of rated power. 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.

The transformers should be suitable for back charging from HV side.

All control cabinets, marshalling kiosks, marshalling boxes, heat exchangers pumps, and other required auxiliaries, as required are included in this contract. The contractor shall be provided the required 415 V AC supply. The AC supply for the indicating devices and pilot equipment 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 110 V AC for the control and indicating circuits shall be preferred. However, any other voltage level shall be discussed and decided during detailed engineering.

Single phase Generator Transformers are rated to suit the output of the generators rated at **11 kV, 0.85 pf, 35 MVA** as Maximum Continuous Rating, located in the Power House. The Contractor shall check the clearances provided in the enclosed drawings that are required for the transformers as per relevant latest applicable standards and shall clearly indicate the same in the drawings.

The High Voltage side shall be at 220 kV. The Low Voltage side shall be at 11 kV. The LV side of the transformer is connected to the generator through Isolated Phase Bus Ducts. HT side of the transformer shall be connected to the gas insulated switchgear through transformer tube termination. For this purpose, the transformer bushing must be oil tight, gas tight and pressure resistant. Suitable connection for the HV side and LV side shall be the responsibility of the Contractor and the same shall be clearly specified in the Bid Document.

The transformer shall be capable of operating continuously at the rated MVA without danger, at any tapping with voltage variation of  $\pm 10\%$  corresponding to the voltage of that tapping. The

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

generator transformers shall be cooled by using oil forced and water forced (OFWF) and shall be supplied complete with all accessories and auxiliaries as specified in the technical specification including oil for first fill and 10% extra insulating oil supplied in the non-returnable drums. The hotspot temperature in any location of the tank shall not exceed 110 degree Celsius.

The transformer shall be transported without oil but with tanks sealed and filled with, breathable dry air and maintained at a continuous positive pressure. The use of nitrogen is possible but is not preferred on the grounds of safety. The air pressure and dew-point shall be monitored continuously throughout the period immediately after the oil is removed until the transformer is refilled with oil at site. At all times alternative standby means shall be provided to restore any loss of air pressure immediately. The dew point of the dry air shall be measured and recorded to ensure it is below - 50°C. The dew point shall be checked again within 24 hours of the oil having been removed and the transformer dry air filled, the measurements being recorded in the test report and on the shipping tag. If the dew point readings indicate an average moisture level at the surface of the transformer insulation is higher than 0.5%, the manufacturer must dry the transformer.

The maximum acceptable dew point shall also be indicated on the shipping tag. The dew point of the shipping gas shall be recorded along with the pressure and temperature of the shipping gas at the time of the dew point measurement. This information shall be recorded on the test report, the shipping documents and on a tag at the location of the dew point measurement. All tubing, valves, cable connections, and fittings attached to the payload should be adequately protected to minimise risk of damage during loading, transport and unloading.

#### 1.4. Specific Requirements

The following to be enclosed with the Bid-

- 1 For the type tests as specified in IS 2026 or equivalent, the contractor shall submit test certificates of type tests conducted on similar type of transformers (same or higher MVA rating, same voltage class etc.), not older than 7 (Seven) years from the date of bid opening, for acceptance by the purchaser
- 2 For the Short circuit withstand test (special test) as specified in IS 2026 or equivalent, the contractor shall submit test certificates of Short circuit withstand test conducted on similar type of Generator Transformers (same or higher MVA rating, same or higher voltage class etc.), design of which is same as the design of the offered Generator Transformer, for acceptance by the purchaser.

#### 1.5. Operational and design requirements

##### 1 Over Voltage Capability

Transformers shall be capable of withstanding at a voltage approximately 25% above the rated

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

voltage for a period of one (1) minute without damage due to sudden load rejection as well as 40% above the rated voltage for a period of 5 seconds. The transformer shall operate satisfactorily in case of load rejection as per IS: 2026. However, the Contractor shall install an over fluxing protection device.

2 Short Circuit Requirements

Generator Transformers shall be capable of withstanding without damage, the thermal and dynamic (mechanical) stresses caused by symmetrical or asymmetrical faults on any of the windings, i.e. HV or LV for system short circuit apparent power of 20,000 MVA. The transformer shall be designed to withstand the thermal stress due to short circuit for a duration of 3 seconds.

- 3 The bidder shall provide valid Dynamic Short Circuit (DSC) report of a Generator Transformer which will fulfil the similarity criteria, as per latest CEA (Technical Standards for Construction of Electrical Plants and Electric Lines) Regulations, 2022, for a reference transformer to the offered Generator Transformer to the purchaser. In the event bidders don't possess DSC reports, they will have to conduct DSC withstand test on the offered transformer as per IEC 60076-5 and cost of the same shall be included in the price bid.

4 Efficiency and Maximum Losses

Load losses at a reference temperature of 75 °C for the maximum continuous rating and at 75% and 50% of this rated output.

- 5 Transformers shall be capable of operating at full load for 10 minutes after failure of the oil and water circulating pumps without the calculated winding hot-spot temperature exceeding 140 °C. Transformers shall be fitted with two coolers each capable of dissipating 100% of the losses at continuous maximum rating (CMR). One cooler shall work at a time and other shall act as standby;
- 6 The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10% continuous over voltage condition, it does not exceed 1.90 Tesla. Magnetizing current shall be less than 5% of the rated current at the normal rated voltage. Lower flux densities will be preferred if these result in lower noise levels;
- 7 The generator transformers shall work satisfactorily in parallel with each other when connected between high voltage and low voltage. Bus bars shall be interchangeable with each other. The bushings shall be so made so as to enable interchangeability with different makes of bushings;
- 8 Transformers and associated equipment shall be designed in such a manner as to meet the requirements of this section, Technical Specifications and Drawings at ambient conditions of 50°C and cooling water of 30°C at 1100 metres above mean sea level (msl).
- 9 The project is situated in seismic Zone-V as per IS: 1893. The Transformer shall be designed



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

so as to withstand an earthquake without functional impairment. The peak ground acceleration to be considered for designing of the Transformer is 0.27 g in horizontal and 0.18 g in vertical direction based on maximum considered earthquake (MCE).

- 10 Transformers shall meet the latest stage of development reached in design, construction and materials;
- 11 The transformers and all associated facilities (e.g. tap-changer) shall have the ability to withstand the effects of short-circuit currents, defined as symmetrical short circuit current in the Technical Characteristics, when operating on any tapping position according to requirements of IEC 60076-5;
- 12 All metal parts of the transformer with the exception of the individual core laminations, core bolts and associated individual side plates shall be maintained at the same fixed potential. The earthing structure shall be designed to carry, without damage, the maximum possible earth fault current for a duration of at least equal to the short circuit withstand period of the main windings;
- 13 The design and manufacture of the generator transformers shall be such that the noise level is at a minimum and that the level of vibration does not adversely affect any clamping or produce excessive stress in any material. The transformer manufacturer shall supply sufficient information to the civil works contractor to ensure adequate design of the transformer mounting structure;
- 14 If required by Purchaser, the transformers shall be subject to vibration tests;
- 15 Noise measurements shall be made at the Manufacturer's works in the presence of the Purchaser. The average surface noise level of each transformer shall not be greater than that specified in NEMA TR1. Measurements shall be in accordance with IEC 60076-10;
- 16 The transformers shall be designed with particular attention to the suppression of harmonic currents, especially the third and fifth, so as to minimize interference with communications circuits;
- 17 The transformers shall be designed to ensure that leakage flux does not cause overheating in any part of the transformer.
- 18 Transformers shall withstand, without damage, heating due to the combined voltage and frequency fluctuations which produce the following over fluxing conditions:

110 % continuously

125% for 1 minute

140% for 5 seconds

Withstand time for 150% & 170% over fluxing condition shall be indicated. Over fluxing

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

characteristics up to 170% shall be submitted.

- 19 Necessary mechanical withstand capability has to be built into the design without any in-tank temporary bracings / supports / reinforcements and It is required to give information about the peak impacts which will be used in the design of the transformer to withstand transport impacts. These values are requested to be filled in the table below:

Axis	Outside tank	Inside tank	Duration (cont. or msec)	Comments
	Max g-forces used for the design			
Longitudinal				
Vertical				
Lateral				

- 20 Impact recorder: During transport, at least one 3D - accelerometer impact recorder with measurements in X, Y and Z axis (both plus and minus directions) should be used. The impact recorder(s) should have the possibility to measure acceleration events with 3D curve in the range of 1024ms or more. The number of such stored events must be sufficient for the transport. Acceleration range should be adjustable up to 10g with a frequency range of 1-100Hz. In addition, the impact recorder should also be able to register both dynamic inclination curves and time-synchronous inclination events. One impact recorder should also be fixed to the active part during the transportation and one outside the tank. A master-slave connected system shall be of value as events inside and outside the tank will be time synchronized. The Impact recorder measurements shall be downloaded and the reports shall be generated at site in presence of Purchaser.

## 1.6. Technical Main Data, Design and Construction

### 1.6.1. Technical Main Data

Rating and Main Data of the Generator Transformer shall be as under:

1	Rated power (forced cooled)	35 MVA (single-phase)
2	Base Power rating (without cooling water and without oil pump operating)	Bidder to specify
3	No. of Transformers	10 (1- $\phi$ )
4	Type of cooling	OFWF
5	No. of phases	1 Phase
6	Frequency	50 Hz
7	No. of Windings	2 (HV and LV)
8	Cooling medium	Mineral oil
9	Rated voltage (H.V. winding)	220 / $\sqrt{3}$ kV
10	Rated voltage (L.V. winding)	11 kV
11	Highest system voltage:	
	HV	245 kV
	LV	12 kV
12	High voltage winding connection of trans. and system of earthing (3- $\phi$ Bank)	Star connected (solidly grounded neutral)
13	Low voltage winding connection of transformer and system of earthing (3- $\phi$ Bank)	Delta connected (Generator neutral earthed through resistor loaded neutral grounding distribution transformer)
14	Connection Details:	
	HV (GIS)	Through a transformer tube termination. Bushing must be oil tight, gas tight and pressure resistant.
	HV (neutral)	Air bushing
	LV	Through isolated phase bus duct from Generator. Outdoor type, top cover mounted porcelain bushing insulator of 17.5 kV* class shall be provided
15	Vector Group	YNd 11

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

16	Temperature rise over an air ambient of 50°C and cooling water temperature of 30°C **::	
	Top oil by thermometer	55°C
	Winding (measured by resistance method)	60°C
17	Class of Insulation	A (HV winding- Graded Insulation, LV Winding- Uniformly insulated)
18	Polarity	Subtractive
19	Duty	Continuous
20	Lightning impulse withstand voltage including chopped wave withstand test	<ul style="list-style-type: none"> <li>• 1050 kVp (HV bushing)</li> <li>• 950 kVp (HV winding)</li> <li>• 170 kVp (HV neutral bushing)</li> <li>• 95 kVp (HV neutral-winding)</li> <li>• 125 kVp (LV bushing)</li> <li>• 75 kVp (LV winding)</li> </ul>
21	Rated switching impulse withstand voltage	<ul style="list-style-type: none"> <li>• N / A (HV bushing)</li> <li>• N / A (HV winding)</li> </ul>
22	Rated power frequency withstand voltage (1 min)	<ul style="list-style-type: none"> <li>• 460 kV (HV bushing)</li> <li>• 395 kV (HV winding)</li> <li>• 38 kV (HV neutral)</li> <li>• 28 kV (LV winding)</li> </ul>
23	Percentage Impedance voltage	12.5 with tolerance as per IS/IEC
24	Tapping	Full capacity (rated MVA) taps shall be provided on HV Winding to give a voltage variation of (+) 5 % to (-) 5 % in equal steps of 2.5% with a constant voltage on 11 kV side.
25	Type of tap changing gear	Off circuit tap changer
26	Installation	Indoor installation (In Transformer Hall- as per layout) at an elevation of 1100 m above msl, ambient air temperature of 40°C and cooling water temperature of 30°C

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

27	Details of Auxiliary supply	220 V DC -15 and + 10%, and 3 phase 415 V $\pm$ 10%, 3-wire		
28	Cooling pumps			
	➤ Oil pumps	2 redundant oil pumps c / w independent starter control panel and 415 V AC power supply		
29	Current transformer			
	➤ HV line side	➤ 1 No. 3 core CT / phase 400 / 1 / 1 / 1 A, CL 5P20/ PS ➤ 1 No. for WTI		
	➤ HV neutral side	2 CT's / bank 400 / 1 / 1 A, CL PS (Vk shall be finalised during Drawing Approval)		
	➤ LV line side	1 no. for WTI		
30	<b>Bushing</b>	HV	LV	HVN
a	Type	RIP/RIS	Porcelain	Porcelain
b	Rated Voltage kV	220 kV	17.5 kV*	33 kV
c	Rated Current A	1250A	6300 A	1250 A
d	Impulse withstand test voltage kV (peak)	1050 kV <sub>p</sub>	95 kV <sub>p</sub>	170 kV <sub>p</sub>
e	One minute power frequency test voltage kV (peak)	460 kV	42 kV*	77 kV
		Rated voltage, creepage distance and other parameters of LV Bushing shall be finalized during detailed engineering to match with the existing bus duct.		
f	Minimum creepage distance mm	31 mm/kV	31 mm/kV	31 mm/kV
g	Short time current rating	50 kA/1Sec	50 kA/1Sec	50 kA/1Sec
h	Dynamic rating kA	125 kA <sub>p</sub>	125 kA <sub>p</sub>	125 kA <sub>p</sub>
i	Maximum Partial discharge level at Um (pC)	As per IEC	As per IEC	As per IEC

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

j	Mounting	Tank cover	Tank cover	Tank cover
		HV Phase Bushing Mounted	LV Phase Bushing Mounted	HV Neutral Bushing Mounted
<p>* Rated voltage, creepage distance and other parameters of LV Bushing shall be finalized during detailed engineering to match with busduct connection.</p> <p>** 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 during detailed engineering</p>				

### 1.6.2. Core Material

All transformer cores shall be fabricated from high grade non-ageing, high permeability, cold-rolled super grain-oriented silicon steel lamination known as HI-B steels of grade M3 or TCH-O or 23ZDKH85 having low-loss (0.9W / kg or less) characteristics and preferably leading to low noise levels. The thickness of the sheet shall be 0.23 mm or less. However, the bidder shall indicate the thickness of the sheet in the Bid Document.

### 1.6.3. Core Construction

The construction is to be of “CORE” type. The magnetic circuit shall be of core construction designed to avoid static discharges and the development of short circuit paths within itself or to the earthed clamping structure and the production of flux component at right angles to the plane of lamination, which may cause local heating. After shearing, the laminations shall be treated to remove all burrs and remove residual stresses so that the laminations are flat and the finally assembled core is free from distortion. Laminations shall be coated with a durable baked enamel insulation coating, which shall be inert to the action of hot transformer oil. Paper and varnish insulation will not be accepted. The nature of insulation shall be stated in the bid. Mitered joints between cores and yokes shall be employed on all sizes of transformers for which this technique is practicable. On no account must ‘butt’ joints be offered.

All parts of the core shall be of robust design which are capable of withstanding mechanical shocks during normal lifting, transportation and handling of the transformer, in hilly terrain and bracing of the core and winding assembly must be adequate to prevent any movement of core and winding relative to the tank during the conditions mentioned above. The clamping structure shall be so constructed that eddy currents are minimized.

Particular care shall be given to the design and construction of the corner joints between columns and yokes to avoid concentration of mechanical and magnetic stresses whilst allowing an easy

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

dismantling of the joint for maintenance at site.

Adequate metallic bridges shall be provided between the core lamination packets in order to keep all portions of the core assembly at the same potential.

All structure members of the assembled cores shall be of steel except where conventional core-bolt clamping is replaced by taping or banded-clamping or epoxy fiber technique.

Adequate fitments, eyes and lugs, shall be provided for lifting the completed core and windings, and suitable accommodation, attached to each transformer, shall be provided for the storage of any removable parts of the lifting gear.

All castings shall be fettled, and structural steel shall be adequately painted before being built into the structure. Any non-magnetic or high-resistance alloy included in the design shall be subject to approval. All painting designed to be under oil or in contact with oil shall be to the Engineers approval.

The supporting framework of the core shall be designed to avoid the presence of pockets which would prevent complete emptying of the tank through the drain valve, cause the trapping of air during filling, or cause the trapping of gases which evolve during in-service faults. All steel sections used for supporting the core shall be thoroughly sand blasted or shot blasted after cutting, drilling and welding.

The hot spot temperature and surface temperatures in the core shall be calculated for over voltage conditions specified in the document and it shall not exceed 125°C and 120°C respectively.

#### **1.6.4. Core Oil Ducts**

Suitable axial oil ducts shall be provided where necessary to ensure adequate cooling by free circulation of oil. The ducts shall be so dimensioned that the maximum temperature at any point remains within the admissible limits. The winding structure and main insulation shall not obstruct the free flow of oil through such ducts. Where the magnetic circuit is separated by more than 0.25 mm by cooling ducts parallel to the plane of the laminations or by insulating material, tinned copper strip bridging pieces shall be inserted to maintain continuity. Alternatively, resistance wire connections may be used if approved by the Engineer where this is part of the manufacturers standard design.

Where oil ducts or insulating barriers parallel to the plane of the laminations divide the magnetic circuit into two or more electrically divided parts, the ducts or barriers shall be bridged as stated previously and the magnetic circuit shall not be regarded as being of sectional construction.

#### **1.6.5. Core Insulation**

Individual laminations shall be insulated with material, which will not deteriorate due to the action

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

of pressure and hot oil.

The magnetic circuit shall be earthed in accordance with respective Clauses of this specification. With the earthing removed, the magnetic circuit shall be insulated from the clamping and supporting structure and all structural parts, and insulation of core to bolts and core to clamp plates shall withstand a test voltage of 2 kV RMS at 50 Hz for one (1) minute.

The class and type of insulation and the method of applying it on the core bolts and under nuts and side plates shall be stated in the Schedules.

#### **1.6.6. Core Earthing**

All metal parts of the transformer except individual core laminations, core bolts and side-clamping plates shall be maintained at earth potential.

Single point core earthing should be ensured to avoid circulating current. Cross section of Core earthing connection shall be of minimum size 80 sq mm copper with exception of the connections inserted between laminations which may be reduced to a cross sectional area of 20 sq mm tinned copper where they are clamped between the laminations.

The magnetic circuit shall be earthed to the clamping structure through one removable core-insulation-test link only, placed in an accessible position beneath the inspection opening in the main-tank cover or the link is brought out on tank cover through insulated bushings. The connection to the link shall be on the same side of the core as the main clamping-structure earth connections to the tank and shall be taken from the extreme edge of the top yoke.

Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section and the arrangement of the connections shall be subject to approval.

Where the magnetic circuit is separated by cooling ducts parallel to the plane of the laminations or by insulating material over 0.25 mm thickness, tinned copper strip bridging pieces shall be inserted to maintain continuity.

All earthing connections with the exception of those from the individual coil clamping rings shall have cross-sectional area of not less than 0.8 cm<sup>2</sup>. Connections inserted between laminations of different sections of core shall have a cross-sectional area of not less than 0.2 cm<sup>2</sup>.

Where clamping ring of coil are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of transformers as the main earth connections.

#### **1.6.7. Core Flux Density**

The maximum flux density in any part of the core and yokes at nominal ratio, frequency and voltage shall not exceed 1.65 Tesla. Lower flux densities will be preferred if these result in lower noise



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

levels. Core placing shall be as magnetically balanced as possible.

The core shall be free from overfluxing liable to cause damage or to cause maloperation of the protection equipment when the transformer is operating under the continuous 10% overvoltage condition specified. Under this steady over voltage condition, the maximum flux density shall not exceed 1.90Tesla, and the magnetizing current shall not exceed 5% of the rated load current at normal rated voltage.

### 1.7. Winding Conductor Material

The conductor windings shall be of high-conductivity electrolytic grade copper free from scale and burns and transposed winding conductors shall be employed where appropriate. Windings of all 245 kV class transformers shall be made in dust proof conditioned atmosphere. Epoxy bonded continuously transposed conductor (CTC) shall be used in main winding for rated current of 400A or more.

The windings shall be designed to reduce to a minimum the out-of-balance electromagnetic forces in the transformer at all voltage ratings / tapings and the voltage between adjacent coils shall be kept as low as consistent with the good design.

The conductors shall be transposed at sufficient intervals to minimize eddy currents and equalize the current and temperature distribution along the winding. Coils shall be constructed to avoid abrasion of the insulation, (e.g. on transposed conductors), allowing for the expansion and contraction set in by the changes of temperature or the vibration encountered during normal operation.

Windings shall be so designed as to obtain an optimal value for series and shunt capacities in order to ensure a favorable distribution of the voltage for full impulse waves and chopped impulse waves.

Leads from winding to bushings shall be adequately supported to prevent damage from vibration and short-circuit forces.

All permanent current carrying joints in the windings and leads shall be brazed. The windings shall be designed to reduce to a minimum the out-of balance forces in the transformer at all ratios and special care shall be given to design and construction of tapped coils and connections.

The construction of the windings shall be such as to ensure uniform voltage and stress distribution on the windings in the event of high frequency impulses applied to the windings and the means adopted for the same shall be stated in the bid.

The windings shall be so designed that all coil assemblies of identical voltage rating shall be interchangeable and field repairs to the windings can be made readily without special equipment. The coils shall be supported between adjacent sections by insulating spacers and barriers. The windings

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

shall be dried by vapor phased system.

### 1.8. Winding Clamping and Bracing

The windings and connections shall be adequately braced to withstand mechanical shocks and electromagnetic impulsive force which may occur during handling, transportation and transient current surges. Bracings and other insulation used in the assembly of the windings shall be arranged to ensure free circulation of the oil and to reduce hot spots in the windings.

The stacks of windings shall receive adequate shrinkage treatment before final assembly so that any further shrinkage during service is not possible. However, adjustable devices shall be provided for taking up any shrinkage of coils in service.

The coil-clamping arrangement and the finished dimensions of any oil ducts shall be such as will not impede the free circulation of oil through the ducts.

Any metal pieces in contact with nonmetallic clamping rings shall be so designed and secured that they do not weaken the electrical or the mechanical properties of the rings.

If the winding is built up of sections or disc coils, separated by spacers, the clamping arrangements shall ensure that equal pressure is applied to all columns of spacers. All such spacers shall be of approved material and shall receive adequate shrinkage treatment before assembly. Either brazing/crimping type of connections are permitted for joints.

### 1.9. Winding Insulation

220 kV windings shall have graded insulation. Use of enamel as a sole conductor insulation is prohibited. The conductor insulation shall be made from high density (at least 0.75 gm/cc) paper having high mechanical strength. Winding paper moisture shall be less than 0.5%

The insulation paper shall be of high quality and the value of degree of polymerization shall not be less than 1200.

The insulation of windings and connections shall be free from insulating composition liable to soften, ooze out, shrink or collapse and be non-catalytic and chemically inert in transformer oil during service.

For oil immersed transformers, the insulating media shall be of Class A material as defined in IEC 60085.

All neutral points of star windings shall be insulated for the voltages specified in the Schedules of Technical Requirements.

The barrier insulation including spacers shall be made from high density pre-compressed press

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

board (1.15 gm/cc minimum for load bearing and 0.95 gm/cc minimum for non-load bearing) to minimize dimensional changes. Kraft insulating paper used on conductor should have density of >0.75 g/cc.

#### 1.10. Winding Connections and Neutral Earthing

The transformers should be connected in accordance with the IEC group of symbols.

The high voltage side of the generator transformer bank shall be solidly grounded wye connection.

The Contractor shall provide all the material and labour to realize the wye connection.

The neutral HV aerial bushing of each transformer of the bank shall be connected to a single point using rigid copper bus mounted on 33 kV, 170 kV BIL porcelain insulators. The copper buses shall be further fully insulated to minimum 17.5 kV on entire length using a non-tracking heat shrink material. Extra and proper insulation shall be applied at locations where crossing near piping or steel framework. The insulation material shall conform and be tested to the following standards:

IEC 60093	Method of test for volume resistivity and surface resistivity of solid electrical insulation material.
IEC 60250	Recommended methods for determination of the permittivity and dielectric dissipation factor of electrical insulation material of power, audio and radio frequencies including meter wave lengths.
IEC 60243-1	Electrical strength of insulating materials Test Methods – Part 1 Test of power frequencies
IEC 60243-2	Electrical strength of insulating materials Test Methods – Part 2 Additional requirements for tests using direct voltage

The Contractor shall extend the neutral insulated bus beyond the single point junction for a length sufficient to install the required zero sequence current transformers

The Contractor shall supply and install two (2) 400 / 1 / 1 A CL PS current transformers per bank.

The neutral point connection and current transformers shall be enclosed within a painted steel box.

The Contractor shall solidly earth the neutral bus to the power house grounding grid located within the transformer gallery.

The neutral bus and ground connection shall be designed to withstand a momentary fault current of 50 kA for 1-second duration without damaging neither the insulation nor the conductors.

#### 1.11. Tank Construction

The tank shall be of proven design of either Bell type with bolted/welded joint or conventional (preferable) with bolted/welded top cover. Bell type tank, if provided, shall have joint as close as

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

possible to the bottom of the tank.

Each oil immersed type transformer shall be enclosed in a suitably stiffened welded steel oil-tight tank of Bell type construction for rated MVA single-phase Transformers. Tanks shall be of welded construction and fabricated from tested quality low carbon steel of adequate thickness. The weld procedure and performance shall be in line with ASME–BPV-IX. The thickness and bracing of the tank shall be such that the tank together with core and oil can be lifted and transported without damage or loss of oil tightness. All seams and those joints, not required to be opened at site, shall be factory welded and wherever possible they shall be double welded. All welding shall be stress relieved.

The base of each tank shall be so designed that it shall be possible to move the complete transformer unit by skidding in any direction without injury when using rollers, plates or rails. The transformer tank shall be suitable for movement in both directions during shipment. The base plate shall have following minimum thickness:

Length of tank (m)	Minimum plate thickness (mm)
Flat bases	
Over 2.5 m but less than 5 m	20
Over 5.0 m but less than 7.5 m	26
Over 7.5 m	32

The main tank body including tap-changing compartment, radiators and coolers shall be capable of withstanding full vacuum.

Aluminum tanks shall not be considered.

Suitable guides shall be provided in the tank for positioning the core and coil assembly. The tanks shall be so designed that with the cores and windings in position there shall be no possibility of formation of pockets where air or gas being trapped when filling the tank with oil, and also water shall not be trapped on the exterior of the tank. Where pockets cannot be avoided, pipes shall be provided to vent the gas into expansion pipe. The tanks shall be fitted with pockets for a thermometer and the bulbs of a winding temperature indicator and an oil-temperature indicator in maximum temperature zone and it shall be possible to remove the bulbs without lowering the oil in the tank. Protection shall be provided as necessary for the capillary tube. Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water. Adequate

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

space shall be provided at the bottom of the tank for collection of sediment. Tanks shall be designed to withstand mechanical shocks during transportation, vacuum filling of oil, and continuous internal pressure of 100.66 kN / m<sup>2</sup> over normal hydrostatic pressure of oil and short circuit force.

The thermometer pockets shall be fitted with a captive screwed cap to prevent the ingress of dirt and water. The pockets shall be located in the position of maximum oil temperature at Maximum Continuous Rating (MCR) and it shall be possible to remove the instrument bulbs.

The tank shields (if provided) shall be such that no magnetic field shall exist outside the tank. They shall be of magnetically permeable material. If required, impermeable shields shall be provided at the coil ends. Tank shield shall not resonate when excited at the natural frequency of the equipment. Bidder shall confirm use of tank shields in the additional information schedule.

Surface and flange temperature around the periphery of the transformers and any other part of the tank or ancillary equipment up to and including 2.6 m above the plinth shall not exceed 60-70°C. At height greater than 2.6 m above the plinth at any part around the periphery of the transformer, the surface and flange temperatures shall not exceed 100°C. Both values shall apply at specified maximum ambient temperature at maximum continuous rating (MCR) on any tapping.

Tank MS plates of thickness >12 mm should undergo Ultrasonic Test (UTI) to check lamination defect, internal impurities in line with ASTM 435 & ASTM 577.

After fabrication of tank and before painting, non destructive test (dye penetration test) is mandatory on the load bearing members such as base plate, joints, jacking pads and lifting devices etc.

The tank cover and bushing turret shall be fixed to the transformer using copper links in such a way that good electrical contact is maintained around the perimeter of the tank and turrets.

All gasketed joints shall preferably be O-ring and designed with gasket-in-groove arrangement. All tank gaskets/O-rings used shall be of NBR (Acrylonitrile Butadiene Rubber) suitable for temperature conditions expected to be encountered during operation.

The oil sampling point for main tank shall have two identical valves put in series.

#### **1.12. Pressure Relief Device**

Each tank shall be fitted with an approved pressure relief device designed to protect the tank from damage, and to control the explosion of oil under internal fault and may result in damage in the equipment. One PRD of 150mm diameter is required for every 30000 litres of oil. However, at least two numbers PRDs shall be provided.

An extension pipe shall be fitted above the device such as to direct the major flow of ejected oil down wards and shall be fitted so as to permit its removal without disturbing the device or its flange

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

fixings. The device shall be so located as not to interfere with the electrical clearances for any overhead connections. The device shall fully reseal after release of excess pressure.

The device shall operate at a static pressure, which shall be less than the hydraulic test pressure of transformer tank. Means shall be provided to prevent ingress of rain water.

One set of electrically insulated contact shall be provided for alarm / tripping. A mechanical indicator, manually resettable type and clearly visible from a long distance shall be provided to indicate that the valve has operated.

For all transformers, the conventional diaphragm type of explosion vent shall also be provided and shall be situated above maximum oil level or according to manufacturer's mounting recommendations. An equalizing pipe shall be connected between explosion vent and conservator.

One number of Sudden pressure Relay/Rapid Pressure Rise Relay with alarm or trip contact (Terminal connection plug & socket type arrangement) shall be provided on tank of transformer. Suitable canopy shall be provided to prevent ingress of rain water.

### **1.13. Tank Lifting And Haulage**

Each tank or enclosure shall be provided with the following handling facilities the first three of which must each be capable of lifting and / or moving the transformer complete and filled with oil.

- Lifting lugs or eyes of ample dimensions designed so that standard lifting shackles can be readily attached. The lifting eyes, lugs or hooks shall have a factor of safety of not less than two (2) to allow for possible unequal lifting forces.
- A minimum of four jacking pads shall be suitably located in accessible positions to make it possible to change the direction of wheels through 90°, when the transformer, complete with oil, is lifted on jacks to permit movement of the transformer both in longitudinal and transverse directions. A convenient track gauge in both longitudinal and transverse direction shall be chosen. Means shall be provided for locking the swivel movements in positions, parallel to and at right angles to the longitudinal axis of the tank. Suitable stoppers for the track wheels shall also be supplied. The pads shall be adequately braced and project a sufficient distance from the transformer side to enable a standard jack to be properly located. The minimum height of the pads above the base shall be 500 mm excluding the under base dimensions, if detachable. The jacking pads shall be so located and designed to balance the complete transformer on three jacks in the event of the failure of the fourth Jack / pad.
- Four anchor points shall be fitted to each transformer tank or frame at not more than 760 mm from the base to enable the transformer complete (and filled with oil) to be slewed or hauled in any direction. Suitable haulage holes shall be provided for transformer wheeling in all four

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

directions.

- d) Lifting handles on the tank-lid or enclosure hand-hold covers where the size and weight of such covers would make manhandling difficult.
- e) The transformer tank shall be supported on a strong structural steel base equipped with forged steel or cast steel single flanged bi-directional wheels suitable for moving the transformer completely filled with oil. The number and the spacing of wheels shall be specified in the Bid. The wheels shall be provided with grease nipples. Arrangement for clamping of the wheels with the rails, capable of being put on and off easily, shall also be provided. The structural steel supporting base shall be so designed that the centre of gravity of the transformer, with or without oil, will not fall outside the base support members for a tilt of the base of 15 degrees from the horizontal.
- f) The Contractor shall provide adequate number of hydraulic jacks for lifting the transformer for changing the plane of rotation of wheels.

#### **1.14. Tank Covers**

At least two adequately sized inspection openings of suitable design, one at each end of the tank, shall be provided on the tank cover. The openings shall be of sufficient size to afford easy access to internal connections of bushings, current transformers winding connections and earth link for testing, etc. The design should be such that water shall not collect near the gasketed joints. Tank covers or enclosure panels shall be so constructed that they can be removed and replaced without sustaining damage. Inspection covers shall also be fitted and these shall not exceed 25 kg in weight.

The tank and cover shall be provided with sufficient and properly spaced bolts and gaskets with metal inserts.

All joint faces shall be machined or ground and arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of air or oil. Oil resisting synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork or similar material. Gaskets, of resilient material which will not deteriorate under the action of hot oil, are to be as thin as possible consistent with the provisions of a good seal and full details of all gasket sealing arrangements shall be shown on the plant drawings.

Enclosure covers and inspection panels shall be accurately fitted and robust to prevent distortion. Countersunk screws may be used for fixing. Gaskets shall be used to deaden vibration where necessary.

The tank cover shall be sloped to prevent retention of rain water and shall not distort when lifted. Bushings, turrets, covers of inspection openings, thermometer pockets, etc. shall be designed to prevent ingress of water into or leakage of from the tank. Turrets and other parts surrounding the



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

conductors of individual phase shall be non-magnetic. Necessary provisions shall be provided to drain out leakage oil / water at the lowest points of the bushing flange wherever required. The same shall be properly sealed with dual stop cock arrangement.

The tank cover shall be fitted with three thermometer pockets (on position of maximum oil temperature at MCR) for bulbs of oil and winding temperature indicators and thermometer. The thermometer pockets shall be fitted with a captive screw top to prevent the ingress of water. It shall be possible to remove these bulbs without lowering the oil in the tank.

#### **1.15. Earthing of Tank**

Two substantial earthing terminals / pads (each complete with two (2) nos holes, M16 bolts, plain and spring washers) suitable for connection to 75x12 mm galvanized steel grounding flat shall be provided each at position close to earth of the two (2) diagonally opposite bottom corners of the tank. The terminals shall be designed to carry this current without damage for a duration at least equal to the short circuit period for which the main windings are designed, in accordance with IEC 60076. These grounding terminals shall be suitable for bolted connection. Two earthing terminals suitable for connection to 75x12 mm galvanized steel flat shall also be provided on each cooler, control panel, marshalling box and any other equipment mounted separately.

The Contractor shall provide the material and labor to bond each earthing terminal to the main grounding grid located within the transformer gallery. Earthing conductors shall be capable of withstanding 40 kA for 3 seconds.

#### **1.16. Bonding**

Substantial bonding-connection studs must be provided to permit the bonding of all transformer ancillary equipment and housings not forming an integral part of the main transformer tank. Bonding studs shall be connected to the grounding grid located within the transformer gallery.

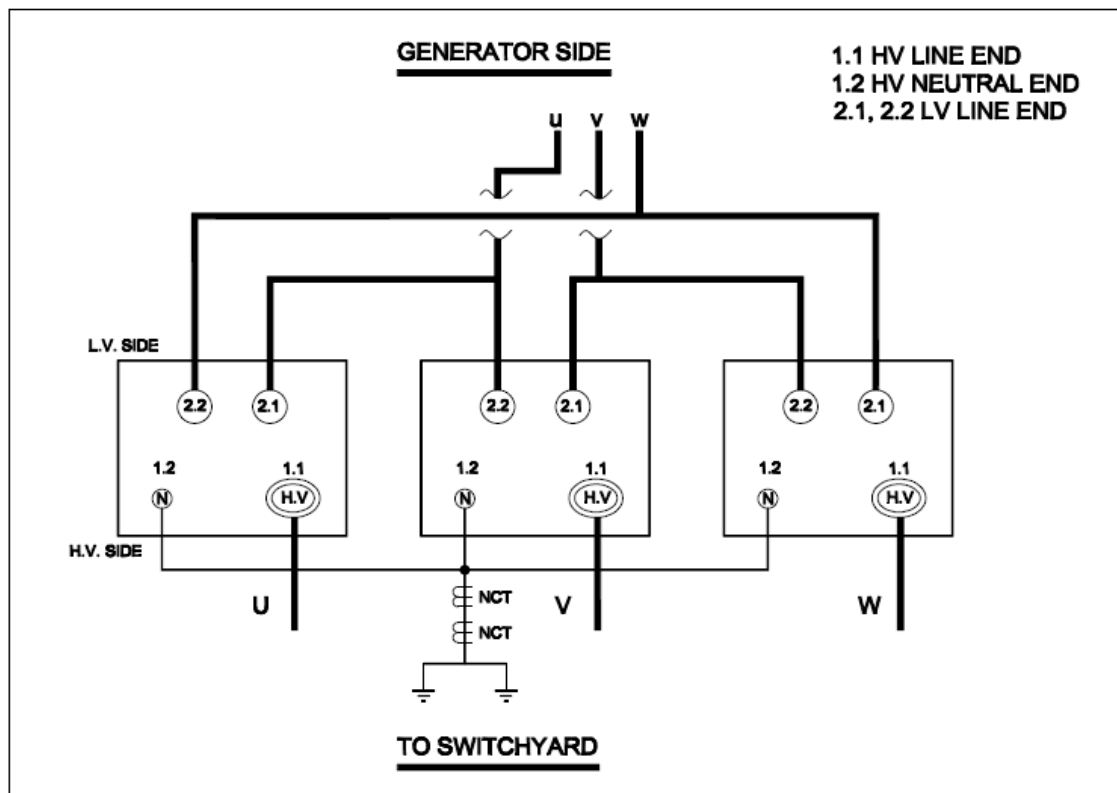
#### **1.17. HV Bushings for The Generator Transformers**

The Generator transformer shall be provided with Oil-SF6 bushing on the 220 kV side. The Transformer bushings on HV line side shall be suitable to connect to the GIS as it is shown on the tender drawings. The orientation of HV phase and Neutral and LV terminals shall be as shown in Figure 1, while respecting the vector group YNd11.

HV neutral side shall be star connected with solidly grounded neutral. The bushing of the transformers shall be of suitable length and shall be supplied with all the accessories which are required for the easy connection and disconnection to the GIS tube. Current Transformers on HV side shall be provided and turret mounted on the oil side of the bushings. The bushings shall be



equipped with a test tap for measuring the power factor.



**Figure 1: Orientation and Connection of Bank of 1-phase Generator Transformers**

Transformer bushings for HV connection shall be Epoxy Resin Impregnated Paper (ERIP)/ RIS for direct connection from transformer (oil) to the gas insulated box (SF6) in accordance with IEC 61639 and IEC 60137. All bushings shall have a minimum current rating of at least 120% the maximum line current in order to accommodate IEC 60354 loading. Routine power frequency test levels on bushings shall be at a test voltage at least 10% higher than the Induced / Applied values applied to the transformer.

The Contractor shall be responsible for coordination and shall supervise and approve all steps relating to the connection between the GIS tube and the HV bushing of the transformer. The Contractor shall be responsible for the sealing, SF6 filling and pressure testing of the connection. Testing of the connections shall be done jointly with the GIS Contractor according to IEC standards 60270, 60137 and 62271-203.

#### **1.18. Bus Duct and Cable Connection**

##### **1.18.1. Bus Duct Connections**

LV windings shall be connected in Delta. An isolated phase bus duct with current carrying of 6300 A shall form the Delta connection and connect LV winding to Generator by isolated phase

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

bus.

The generator transformers bushings shall be mounted on tank top and comply with relevant International and Indian Standards and shall be arranged in such a fashion that the bus duct connections can be made conveniently and safely.

The Contractor shall provide top entrance cylinder shaped throats to allow isolated phase bus duct (IPBD) connections via two connection boxes per transformer. The diameter of the throat and their bolting detail shall be provided later and coordinated with IPBD Contractor.

All connections to the isolated phase bus duct shall be carried out by the bus duct contractor under the supervision and coordination of the Contractor.

#### **1.18.2. Cable Connection for Control Cabinet, Marshalling Kiosk and Marshalling Box**

The power cable and control cable terminations shall be designed to accommodate PVC insulated, single core armored and PVC sheathed cables. The Contractor shall supply a non-magnetic blank gland plate suitable for drilling on site.

The Contractor shall supply, install and connect a marshalling kiosk for each transformer. The marshalling kiosk shall be installed within each transformer vault. A common Marshalling box shall also be provided for each bank and located near partition wall on the operating floor side. The common marshalling box shall regroup all protection, control, monitoring and DC supply of each transformer bank (3 single-phase transformer) via the relevant Marshalling kiosk.

The Common marshalling box(es) shall be provided with normal isolating type terminals for voltage circuits and shorting link type terminals for current circuits. It shall be possible from the box to disconnect all power sources to the transformer bank. The marshalling kiosks, and boxes shall be oil tight and water tight. The Common marshalling box(es) shall be provided with a front glass to view the position of all switches.

Two 415 / 240 V AC supplies will be available near the common marshalling box. Each supply will be terminated in a disconnect switch. The 415 / 240 V AC supplies and disconnect switches shall be supplied and installed by the Contractor.

The Contractor shall supply, install and connect all the control, protection instrumentation and power wiring between the transformer, control cabinets, marshalling kiosks, Common marshalling box(es), disconnect switches, RTU Cabinets (supplied by others and installed) near marshalling boxes.

#### **1.19. Conservator Vessels and Breather**

Main conservator shall have air cell type (Bladder type) constant oil pressure to prevent oxidation and contamination of oil due to contact with moisture, and shall be fitted with magnetic oil level

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

gauge with low oil level electrically insulated alarm contacts. Magnetic oil level gauge shall be type tested. Magnetic oil level gauge and its terminal box(es) shall conform to IP:55 degree of protection. Additionally, a prismatic oil gauge with markings shall also be provided on the conservator tank and oil level shall be visible from ground.

#### **1.19.1. Conservator Tank**

- Conservator tank shall have adequate capacity between highest and lowest visible levels to meet the requirements of expansion of total cold oil volume in the transformer and cooling equipment from minimum ambient temperature to 100°C.
- The conservator shall be fitted in such a position so that it can be removed for cleaning purposes. Suitable provision shall be kept to replace air cell wherever applicable.
- Conservator shall be positioned so as not to obstruct any electrical connection to transformer.
- Contractor shall indicate the arrangement proposed / provided by the Contractor for handling of conservator, bushing, GIS tube etc. in transformer vault.
- Air leakage detector shall be provided in the conservator tank to detect any air ingress into the conservator tank.

#### **1.19.2. Oil Preservation Equipment**

The requirements of air cell type oil sealing system are given below:

- Contact of the oil with atmosphere is prohibited by using a flexible air cell of nitrile rubber reinforced with nylon cloth;
- As the temperature of oil is likely to rise up to 100°C during operation, the air cell used shall be suitable for operating continuously at 100°C;
- Air cell of conservator shall be able to withstand the vacuum during installation / maintenance periods. Otherwise provision shall be kept to isolate the conservator from the main tank when the latter is under vacuum by providing a vacuum sealing valve or other suitable means in the pipe connecting main tank with the conservator;
- The connection of air cell to the top of the reservoir is by air proof seal preventing entrance of air into the conservator.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

### 1.19.3. Dehydrating Filter Breather

Conservators shall be fitted with a delay dropping filter breathing and so designed that:

- Passage of air is through a dust filter and silica gel.
- Maintenance-free regenerating type dehydrating Breather (M Trab or equivalent) with moisture sensor shall be provided.
- Maintenance-free breather shall be equipped with a humidity sensor, a condition-based microprocessor unit and LED status indication and shall have provision for remote indication in control room.
- Breather is mounted not more than 1200 mm above rail top level and enclosed in a stainless-steel enclosure.
- A self-diagnostic system with LED indication and relay for remote signal shall be available.
- The control unit of breather shall have provision for 4 - 20 mA analog output and an RS 485 port for data logging along with an integrated test button for self-check. The device shall be IEC 61850 compliant.
- The type of breather selected shall suit the volume of oil in the transformer tank.
- To minimize the ingress of moisture three breathers (of identical size) for 220 kV and above voltage class transformer and two breathers (of identical size) for below 220 kV class transformer shall be connected in series for main tank conservator.

### 1.20. Valves and Flanges

Valves and flanges shall be in accordance with the relevant Indian / International Standard.

Inside surface of valves shall be clean and valve ends shall be suitably blanked at the time of dispatch. Asbestos / graphite packing material shall not be used for gland packing / gasket material. Valves and flanges shall be of the ball type with brass body and components, and shall be painted from the outside as per relevant codes. Machined and flanged surfaces shall be suitably protected against rusting and transit damage. Valves shall be of the fully sealing full-way type and shall be opened by turning counter-clockwise when facing the hand wheel. They shall be suitable for operation between the minimum ambient and the maximum oil temperatures of 115°C. All valves shall be lockable with appropriate sub-master series padlocks. Padlocks shall be provided for locking all valves in the "open" and "closed" positions. Valves other than filter and drain valves shall be provided with an indicator, readily visible from ground level, to show clearly the position of the valve. Valves located near the bottom shall be provided with lockable covers, fixed to tank body, to prevent unauthorized dismantling of valve bodies from tank.

All valve hand wheels shall be fitted with nameplates that shall be chromium plated brass not less than 3 mm thick with the engraving filed with enamel. All valves shall be fitted with spoke hand

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

wheels, the spokes and rims of which shall be smooth and chromium plated. All valves shall be provided with flanges having machined faces.

Each oil filled transformer shall be fitted with the following valves and plugs / flange with standard screw connection:

- One filter valve located near the top of the tank;
- One filter valve located near the bottom of the tank and diagonally opposite to the valve specified in (a);
- One valve of adequate size together with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained and / or the oil can be sampled;
- One valve in the oil-actuated relay connection;
- One drain valve so arranged on the conservator tank that it can be completely drained of oil as far as practicable. Size of drain valve shall be in accordance with IS: 3689;
- One valve between the transformer and relay and another between the relay and conservator;
- Top and bottom valves for connection to each of the cooler equipment.
- Provision for Online DGA monitoring shall be kept for future.
- Provision for NIFPS shall be provided for implementation of NIFPS system. The Contractor should coordinate with Firefighting contractor for necessary arrangement.
- Provisions in the tank to be kept for fixing of flange mounted UHF sensors for PD measurement.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Type of valves to be used for transformers shall be as per following Table.

Sl No	Description of valve	Type
1	Drain valve	Gate
2	Filter valve	Gate
3	Sampling valve	Globe
4	Radiator Isolation valve	Butterfly
5	Buchholz relay isolation valve	Gate
6	Sudden pressure relay	Gate
7	Valve for vacuum application on Tank	Gate
8	Conservator Drain Valve	Gate
9	Aircell equalising valve	Gate/Globe/Valve
10	Valve for Conservator vacuum (top)	Gate
11	Filter valve for cooler bank (Header)	Gate
12	Cooler bank isolation valve	Butterfly
13	Pump isolation valve	Butterfly
14	Valve for N <sub>2</sub> injection (NIFPS) (If specified)	Gate
15	Valve for NIFPS Drain	Gate
16	Valve for UHF sensors	Gate
17	Valve for Online DGA monitoring	Gate

### 1.21. Cooling Plant

The generator transformers shall be cooled by forced oil and forced water (OFWF). Each transformer shall be furnished with two (2) coolers each of 100 percent cooler capacity, one main and the other standby, equipped with oil-to-water heat exchanger, oil circulating pumps and their driving motors and associated control gear, piping, valves, flow indicators, etc. The coolers shall preferably be mounted on or close to either end of the tanks. The bidder to state the maximum natural cooling capacity of the cooling plant offered in the tender. The cooling water shall be provided by Purchaser in the form of an opened loop system installed in the tailrace. The Bidder shall be required to indicate the minimum quantity of water required for cooling. The Purchaser shall provide flange connection and isolation valve for inlet and outlet cooling water within the transformer enclosure. The piping from this flange to the transformer heat exchanger shall be in the

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

scope of the Transformer Contractor.

Two complete sets of cooling units each of 100% capacity (one shall be standby), both with 20% margin with necessary pipe fittings and valves shall be furnished with each transformer. Cooler tube shall be made of Cu-Ni (90-10%). Double wall type cooler tubes shall be used so that in case of leakage of tube, water is not mixed with oil, and instead get collected in a container. The container shall be equipped with a drain valve and a leakage detector relay. Alarms shall be provided for leakage from the first layer of tube and shall be integrated to SCADA, so that defect is immediately attended.

Cooling fans and oil pump motor winding insulation shall be conventional class B type. Motors shall have hose proof enclosure equivalent to IP:55 as per IS/IEC 60034-5.

Each cooler shall be provided with the following for proper control and functioning of cooler system. A typical drawing for the system is enclosed for information of bidder and indication of the minimum requirement:

- Pressure gauges on oil and water outlet and inlet headers, pressure transmitter on inlet headers (oil and water).4-20 mA output for indication at remote point;
- A differential pressure gauge or other approved device fitted with electrical contacts to given an alarm when the outlet oil pressure does not exceed the inlet water pressure. Alarm contact operates when difference between oil outlet pressure and water inlet pressure is less than 0.2 kg / sq.cm;
- Visual oil and water flow indicators, fitted with electrical contacts, in the pipe work adjacent to the coolers and on the outlet side;
- Inlet and outlet oil and water temperature indicators. Temperature transmitters on water and oil outlets with 4-20 mA output;
- Inlet and outlet valves;
- Air release plug for the water section;
- Oil pump and motor with electrical controls;
- The coolers shall be double tube type in which water shall circulate through the inner tube and oil in between the outer tube and shell. The design of shell and tube assembly shall be such as to facilitate cleaning without any risk of water mixing with the oil. Tubes and tube plates shall be of an approved material and such that corrosion due to galvanic action shall not take place and shall be made of non-ferrous, corrosion resistant metal (cupro-nickel / brass). Means shall be provided to ensure that the pressure of oil in the cooler is at all times greater than that of the

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

water so that any leakage which may take place is oil into water and not the reverse. The rating of the coolers shall be 10% above design capacity to allow for blockages;

- The cooling water for the transformer cooling at reduced pressure shall be arranged by the Contractor from the powerhouse cooling water supply. The Contractor shall include common header for the cooling water system for each transformer bank in their scope. Transformer Contractor / Contractor shall include suitable pressure reducing valves (PRV's) for reducing of inlet pressure (3 to 5 kg / cm<sup>2</sup>) to a constant 0.2 kg / sq.cm (a value less than oil pressure inside the tank). Two redundant PRV's of 100% capacity each (i.e each individually meeting the cooling water requirement of all three single phase transformers) shall be provided for each bank of transformers. A motorized valve for each transformer cooling system (main and standby) shall be provided. The motorized valve shall be closed when the associated oil pump is stopped;
- The Contractor shall include complete piping for the oil system and water system and also the flow relays and indicators, gate valves and terminal flanges required for the entire system;
- Heat Exchanger;
- Flexible connections of water cooler inlet and outlet;
- Piping supports from the transformer Tank.
- A magnetic type oil flow indicator with alarm and trip contacts for outflow of oil from pump shall be provided with each assembly to indicate normal operation and direction of oil flow.

#### **1.22. Oil Circulating Pumps**

Each forced oil cooler shall be provided with an AC motor driven oil pump of adequate capacity. It shall be possible to remove the pump and motor from the oil circuit without having to lower the level of oil in the transformer or coolers and without having to disturb the pump foundation fixing. Oil pump shall be capable of dealing with the maximum output of transformer and total head which may occur in service and with the varying head due to changes in the viscosity of the oil. Each pump assembly shall be furnished with oil flow indicator with alarm contacts to indicate normal pump operation and oil flow. The driving motors shall be suitable for direct starting and for continuous running from 415 volts, three phase, 50 Hz supply. It shall be responsibility of the Contractor to supply all electrical equipment including cables for their connection within and to the transformer. The Purchaser shall provide two (main and standby) only 3-phase supplies, near common marshalling box, terminated in two separate disconnect switches. Switches are to be provided by Contractor. Thereafter all the cabling shall be in the scope of the transformer Contractor.

Once started the cooling shall remain in operation as long as the transformer is in service. When the transformer is switched off the cooling shall continue to run for a further duration of 30 minutes.



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

### 1.23. Temperature Indicating Devices (and Relays)

#### 1.23.1. Winding Temperature Indicator (WTI)

A device for measuring the hot spot temperature of the winding of generator transformers shall be provided. The accuracy class of winding temperature indicator shall be  $\pm 2^{\circ}\text{C}$  or better, and shall be complete with a winding temperature indicator with separate alarm and trip contacts of approved design. They shall be fitted with a dial-type indicator calibrated in degrees Celsius and fitted with a hand-reset pointer to register the highest temperature attained. The tripping contacts of WTI shall be adjustable to close between  $60^{\circ}\text{C}$  and  $120^{\circ}\text{C}$  and alarm contacts to close between  $50^{\circ}\text{C}$  and  $120^{\circ}\text{C}$  and shall reopen when the temperature falls by  $10^{\circ}\text{C}$ .

The winding temperature indicator shall be so mounted in the transformer control cabinet attached to the main tank that the dial is not more than 1500 mm from the ground level, and the cover shall be equipped with a viewing aperture of adequate size, fitted with clear glass. Mechanical protection shall be provided for the capillary tube, and sharp bends avoided.

It shall comprise the following:

- Temperature sensing element;
- Image coil of the bushing current transformer;
- Auxiliary CTs if required to match the image coil, shall be furnished and mounted in the control cabinet;
- 150 mm local indicating instrument with maximum reading pointer mounted in control cabinet. It shall have two adjustable potential free contracts, one for winding temperature high alarm and one for trip, in addition to the contacts required for control of cooling equipment;
- Automatic ambient temperature compensation;
- All contacts shall be adjustable on a scale and suitable for connection in 220 V DC circuit. These shall be accessible on removal of the cover;
- The WTI shall have a full-scale deflection of at least  $240^{\circ}\text{C}$  and shall have linear graduations to read every  $2^{\circ}\text{C}$ ;
- Provisions to transmit the measured temperature to remote points through a 4-20 mA DC current.

The winding temperature indicator shall be energized from a current transformer connected to a heater coil and actuating on to a bulb and capillary tube. Terminals and links shall be provided in the marshalling kiosk for checking the output of the current transformer on load and disconnecting the current transformer from the heater coil to enable the instrument to be used as an oil temperature indicator. A test winding shall be incorporated in the current transformer and the connection brought down to suitable terminals in the control cabinet to enable the operation of the instrument

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

to be checked electrically.

The contacts used to control to cooling plant motors on the above device shall be adjustable to close between 50°C and 100°C and reopen when the temperature falls by any desired amount between 15°C and 30°C.

### **1.23.2. Optical sensors & temperature measuring unit**

Optical temperature sensors shall be fitted on each Transformer unit. 8 number probes for 1-ph unit shall be provided. The optical sensor measuring system shall be of direct measurement non-calibrating type. All sensors shall be brought out to separate optical sensor box or in individual Marshalling Box mounted on transformer tank to facilitate measurement of temperature during service of each unit.

In order to facilitate measurement of temperature from the optical sensors, temperature measuring unit/system having at least 8 channels shall be mounted inside the separate optical sensor box or Transformer Marshalling Box for each transformer unit. The measuring unit shall be capable to retain temperature data for at least 30 days with facility to download these data.

Temperature measuring unit/system shall be suitable for satisfactory operation with ambient condition and IEC 61850 compliant to interface with Employer's SCADA system through FO port.

Location of optical temperature sensors inside the transformer shall be decided during design review.

The installation and commissioning at site shall be done under the supervision of OEM representative or OEM certified representative.

### **1.23.3. Oil Temperature Indicator (OTI)**

The Generator Transformers shall be provided with oil-temperature indicators complete with alarm and trip contacts of approved design and devices in order to transmit the measured temperature to remote points (through a 4-20 mA DC output current). They shall each be fitted with a dial type indicator calibrated in degree Celsius and fitted with a hand-reset pointer to register the highest temperature attained.

The transformer shall be provided with a dial type thermometer of about 150 mm diameter for top oil temperature indication with angular sweep of 270°. The range of temperature should be 0-150°C with accuracy of  $\pm 1.5\%$  (or better) of full-scale deflection.

. The thermometer shall have adjustable, potential free alarm and trip contacts, maximum reading pointer and resetting device and shall be mounted in the control cabinet. A temperature sensing element suitably located in a pocket in the top oil shall be furnished. This shall be connected in the OTI by means of Capillary tubing. Accuracy class of OTI shall be  $\pm 1^\circ\text{C}$  or better. The OTI shall

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

have a full-scale deflection of at least 240°C and shall have linear graduations to read every 2°C.

Each oil-temperature indicator shall be so mounted in the control cabinet that the dial is not more than 1500 mm from the ground level, and the cover shall be equipped with a viewing aperture of adequate size, fitted with clear glass. If the temperature-measuring device makes use of a capillary tube, mechanical protection shall be provided and sharp bends avoided where the tube enters the control cabinet.

All Instruments should meet degree of protection of IP55 as per IS/IEC-60529.

#### **1.24. Buchholz Devices**

A double float reed type Buchholz relay conforming to IS: 3637 shall be provided. All gas evolved in the transformer shall collect in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation. The device shall be provided with two potential free contacts, one for alarm on gas accumulation and the other for tripping on sudden rise of pressure.

A suitable gas collecting device shall also be provided with each transformer which shall be mounted in a conveniently accessible position. The gas collector of the relay shall be connected to gas sampling device with a copper tube accessible from floor. The above should also have a proper arrangement for draining the oil from the relay.

Each oil-containing equipment i.e. transformer tank, connection chamber, etc., shall be fitted with approved vibration-proof gas and oil-actuated relay equipment preferably of the Buchholz type, having alarm and tripping contacts which close following the accumulation of gas, loss of oil or on the occurrence of an oil surge.

An isolating valve shall be mounted either side of the relay so that it can be easily removed for testing purposes.

A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.

A straight run of pipe work shall be provided for a length of five times the internal diameter of the pipe on the tank side of the oil-actuated relay and three times the internal diameter of the pipe on the conservator side of the oil-actuated relay.

The design of the relay mounting arrangements and the associated pipework and the cooling plant shall be such that mal-operation of the relays will not take place under service conditions.

The oil circuit through the relays shall not form a delivery path in parallel with any circulating oil pipe, nor shall it tee into or be connected through the pressure relief vent. There shall be no sharp

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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bends in the pipe work.

The Bidder shall submit full details, including pipe sizes, oil-operating velocities, etc., and the size and run of each proposed relay with his Tender.

### **1.25. OFF Circuit Tap Changing (OCTC)**

Off-circuit tapings shall be provided on the high voltage windings for a variation of no-load primary voltage as specified. The tap changing shall be possible without disturbing the transformer in any way except de-energizing.

The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part which positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to the another shall require that the bolt be withdrawn by hand from its locating socket on the transformer tank against the spring pressure. Provision for communication of operation of tap switch to control room shall be provided for status monitoring / event logging in SCADA. An indicating device shall be provided to show the tap in use. The complete tap changing mechanism shall be built with high electrical, mechanical, and thermal safety factors, and the contacts shall be capable of withstanding the full short-circuit current of the transformer without injury. The tap changing mechanism shall render it impossible to leave a winding open or short-circuited when the operating wheel is placed in a locked position.

The cranking device for manual operation of the off circuit tap changing gear shall be removable and suitable for operation by a man standing on ground level. The mechanism shall be complete with the following:

- A mechanical operation indicator;
- Mechanical tap position indicators which shall be clearly visible from near the transformer;
- Mechanical stops to prevent over cranking of the mechanism beyond the extreme tap position.

Tap position numbers corresponding to the tapping switch bolt-locating sockets shall be cast or engraved in a metal indicating plate fixed to the tank, and a keyed metal pointer on the tapping switch operating handle shall show clearly at which tapping number the transformer is pointing.

#### **1.25.1. Tap Position Numbering**

All tap-position indicators shall be marked with one numeral integer for each tap position, beginning at number 1. Adjacent taps shall be numbered consecutively in such a manner, that when moving a tap to a new tapping position which has a higher number, the no-load output voltage of the untapped winding increases. The marking of tapped winding which may be reversed shall be

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

based on that connection which gives the highest effective no. of turns for the winding connected to the tap changer.

The terminal marking and their physical position shall be in accordance with IS: 2026 / International Standards unless specified otherwise.

#### **1.26. Control Cabinets**

- a) A sheet steel weather, vermin and dust proof control cabinet with sloping / domed roof with water tight hinged and pad locked door of a suitable construction with interior and exterior duly painted shall be furnished with each transformer to accommodate:
  - i. Temperature indicators mounted at a height not more than 1600 mm from ground level;
  - ii. Control and protection equipment for the cooler control (if a separate control cabinet is not provided);
  - iii. Terminal boards and gland plates for incoming and outgoing cables;
  - iv. Illumination lamp and 5 A, 240 V 3 pin sockets and switch.
- b) Steel sheet used shall be at least 2.0 mm thick. The cabinet shall be mounted to a specifically designed rack welded to transformer tank structure and base, and have sloping roof. The degree of protection shall be IP:55 in accordance with IS.2147 / International Standards;
- c) The control cabinet shall have a glazed door of suitable size for convenience of temperature indicators reading;
- d) All cables shall enter the cabinet from the bottom and the gland plate shall be not less than 450 mm from the base of the box. The gland plate and the associated compartment shall be sealed in suitable manner to prevent the ingress of moisture, rodents, insects, etc., from the cable trench. Gland plates, cable lugs, cable glands, etc., shall be supplied;
- e) The control cabinet shall be supplied with space heater along with thermostat and cubicle lighting with ON-OFF switches and associated circuit breakers;
- f) It shall be located in such a way that, the front shall not face the transformer. It shall be mounted at least 500 mm above the ground level.

The gland plate shall be made into two detachable halves, for facilitating the termination of other Contractor's cables and contractor's cables separately.

Terminal blocks for control and power wiring shall be rated not less than 600 volts. Terminals shall

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

be provided for the following, as a minimum:

- Leads from alarm contacts on the pressure relief device;
- Leads from the alarm contacts on the magnetic type oil gauge;
- Leads from the alarm / and trip contacts of the dial type oil indicating thermometer;
- Leads from each winding temperature detector;
- Leads from each set of thermal relay contacts;
- Leads from differential pressure relay contacts;
- Leads from oil flow switch contacts;
- Leads from water flow switch contacts;
- Leads from air cell of the conservator;
- Power supply conductors for lighting, receptacle and heater circuits;
- Power supplies conductors for oil - pump motors, etc.;
- Leads from HV current transformers;
- Leads from oil and water pressure gauges.

All terminals provided for current transformer secondary leads should be equipped with devices for shorting the secondary windings. The terminal arrangements shall be subject to the approval of the Purchaser and not less than 20 percent spare terminals shall be provided on each block or group of blocks. Separate blocks shall be provided for power and control wiring with metal barriers between sections.

The control cabinet shall thus be divided into sections to separate different power sources (415 V AC (main and standby), 110 V AC, 220 V DC), controls, protection, as well as current transformer terminals. The control cabinet division can be also obtained by providing separate boxes where necessary.

#### **1.27. Painting**

The internal and external surfaces including oil filled chambers and structural steel work to be painted shall be shot or sand blasted to remove all rust and scale or foreign adhering matter. All steel surfaces in contact with insulating oil shall be painted with two coats of heat resistant, oil insoluble, insulating varnish.

All steel surfaces exposed to weather shall be given a primary coat of zinc chromate, second coat of oil and weather resistant varnish of a color distinct from primary, and final two coats of glossy oil and weather resisting non-fading paint of color light Grey corresponding to shade no. 631 of IS: 5. Primary paint shall be as per IS: 104 International Standards and intermediate and final coats of paint shall be as per IS: 2932 / International Standards. The final touch up shall be applied at site

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

by the Contractor.

All paints shall be carefully selected to withstand heat and extremes of weather. The paint shall not scale off or wrinkle or be removed by abrasion due to normal handling. The total thickness of the paint shall not be less than 50 microns. The quality of paint should be such that its colour does not fade during drying process and shall be able to withstand temperature up to 120°C

#### **1.28. Control Wiring**

All controls, alarms, indicating and relaying devices provided with the transformer shall be wired by the contractor up to the terminal blocks inside the marshalling box. The contractor shall supply and install the required 1.1 kV grade heavy duty PVC insulated, steel wire armored, PVC sheathed, FRLS multi core cables with copper conductors of at least 2.5 sq.mm conforming to IS: 1554 Part 1 / International Standards. The cables shall be properly supported. The cables to be used flexible screened copper HRFR (Heat Resistant and Fire Resistant) cables. All pilot and indicating devices shall operate at 110 V AC. The make of the cables shall be approved by the Purchaser.

All devices and terminal blocks within the control cabinets, marshalling kiosks and marshalling boxes shall be clearly identified by symbols corresponding to those used on applicable schematic or wiring diagrams

Not more than two (2) wires shall be connected to one terminal. At least 20% spare terminals shall be provided. Each terminal shall be suitable for connecting two numbers 2.5 sq. mm stranded copper conductor from each side.

Terminal block for control cable shall be of reputed make. Terminal blocks for CT secondary shall have shorting facility. All cabling from control cabinet to marshalling kiosk and from marshalling kiosk to the marshalling box, to various equipment shall be in the scope of the Contractor. Cables running between devices, cabinets, marshalling kiosks, and marshalling boxes shall be armored and PVC sheathed, FRLS types.

Where apparatus is mounted on panels all metal cases shall be separately earthed by means of copper wire of suitable size. All wiring diagram for control and relay panel shall preferably be drawn as viewed from the back and shall show the terminals boards arranged as in service. All diagrams shall show which view is employed. Terminal board rows should be spaced adequately not less than 100 mm apart.

#### **1.29. Power Cabling**

All cabling between pumps, control cabinet, and disconnect switches shall be carried out by 1.1 kV grade, heavy duty PVC insulated, steel wire armored, PVC sheathed, FRLS, multi core cables conforming to IS: 1554 / International Standards. All the power cabling within the transformer area

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

shall be in the scope of the Contractor.

#### **1.30. Insulating Oil**

The new insulating oil, supplied with the transformer shall conform to the requirement of IS: 335 / International Standards while tested at Contractors' premises. No inhibitors shall be used in oil. Sampling of oil shall be done in accordance with IS: 6855.

#### **1.31. Oil Preservation System**

- a) All transformers shall be provided with air cell type oil sealing in the conservator to prevent oxidation and contamination of oil due to contact with atmospheric air. The Bidder shall describe in detail the sealing arrangement to prohibit contact between transformer oil and atmosphere. A silica gel breather shall be provided in the air side vent line. Prior to filling the oil in the main tank suitable number of samples shall be tested for BDV, moisture content, resistivity at 90°C, tan delta at 90°C and interfacial tension. The oil samples taken from the transformer at site shall conform to the requirements of IS: 1866 / related International Standards.
- b) Ten percent (10%) extra oil shall be supplied for topping up, in non-returnable container suitable for outdoor storage.

#### **1.32. Current Transformers for 11 / (220 / $\sqrt{3}$ ) kV Generator Transformer**

The CTs to be provided in the Phase and Neutral of the transformers shall be in the scope of the transformer Contractor.

The Phase and Neutral CT bushing for the generator transformers shall comply with the requirements of IS: 2705 / IEC: 60044-1 and shall have the following ratings (SLD is enclosed):



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

<b>Neutral CT</b>	<b>Outdoor doughnut type located outside transformer on neutral bus before ground connection</b>
Voltage Class	17.5 kV
CT Ratio	400 / 1 / 1 A
Burden	30 VA
No. of CT's	1 No, 2 core
Purpose	Differential and REF Protection
Accuracy Class	PS
<b>HV Phase CT (CT I to III)</b>	<b>Bushing type, Turret mounted in transformer oil</b>
CT Ratio	400 / 1 / 1 / 1 A
No. of CT's	1 No. 3 core / phase
Class	PS class for each

**Note:** The burdens, ratios, RCT,  $V_K$  and accuracy class of the current transformers will be finalized by the contractor during detailed engineering.

### 1.33. Bolts and Nuts

Bolts and nuts shall conform to ASTM: A193, B-7 and ASTM – A194-2H. Steel bolts and nuts exposed to atmosphere with suitable finishes like cadmium plated or zinc plated passivity shall be used for diameter above 6 mm. All bolts, nuts and washers in contact with non-ferrous parts, which carry current shall be of phosphor bronze, where the transfer of current is through bolts. Suitable spanners shall be provided to reach the bolts where these have been located in inaccessible position.

### 1.34. Motors

The motor shall be of squirrel cage type, totally enclosed, weather proof conforming to IS: 325 and suitable for direct starting and continuous running. The speed of the motor shall be approximately 1500 rpm. Each motor shall be provided with a three pole electrically operated contactor and with control gear of suitable design which includes control switches (with Manual-Auto, Local-Remote, Main Pump-standby pump, cooler-1, cooler-2 position), auxiliary DC relays, timers, etc., to start and stop the motor in conjunction with circuit breakers and unit start relays, winding temperature indicator, etc. Each motor circuit shall be provided with motor protection circuit breaker and thermal overload releases for the protection of motor against short circuit and overload.

All motors shall be capable of continuous operation in service conditions at any frequency within  $\pm 5\%$  of the rated frequency, together with any voltage within  $\pm 10$  percent of the normal value. Motors shall also be capable of continuous operation at 85 percent of the nominal voltage at normal

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

frequency without injurious over-heating.

### 1.35. Labels and Rating Plates:

- Labels shall be provided for all apparatus such as relays, switches, fuses, etc., contained in any control cabinets, marshalling kiosks or marshalling boxes;
- Descriptive labels for mounting indoors or inside cubicles and kiosks shall be of material that will ensure permanence of numbering. A matt or satin finish shall be provided to avoid dazzle from reflected light. Labels mounted on dark background shall have white lettering. Danger notices shall have red letters on white background.

All labels shall be of in corrodible material and shall be attached to the panels with brass screws which have received rust preventive treatment. If required, labels can be stuck to the panels with suitable adhesive also.

Each transformer shall be provided with a rating plate and a valve location plate. The plates shall be made of weather proof material and mounted in a visible position on the transformer tank. The entries on the plates shall be indelibly marked.

### 1.36. Transformer Oil Filtration System

#### 1.36.1. Performance Requirement

The Ultra High Vacuum type oil treatment plant of capacity of 6000 litres per hour shall be mobile and shall be suitable for treatment of new oil and reconditioning of used oil in EHV class transformer, shunt reactor and other oil filled equipment in order to achieve properties of treated oil within specified limits at the rated capacity.

The plant shall be capable of treatment of new oil (as per IEC 296/IS:335) and reconditioning of used oil (as per IS:1865/IEC:422 for oil in-service) at rated capacity on single pass basis as follows:

- i. Removal of moisture from 100 ppm to 3 ppm (max.)
- ii. Removal of dissolved gas content from 10% by Vol. to 0.1% by vol.
- iii. Improvement of dielectric strength break down voltage from 20 KV to 70 KV (min).
- iv. Vacuum level of degassing chamber at rated flow and at final stage :- not more than 0.15 torr (0.2 m bar) max.

Degassing chambers of different degree of vacuum should have sufficient surface areas to achieve the final parameters. A detailed justification as to how end parameters shall be met with detailed calculations and test reports in support of the same shall be submitted along with the offer.

- v. Filtering capacity: Max. particle size less than 0.5 micron in the filtered oil.
- vi. Processing temperature : -40° C to 60°C (Maximum allowed temp. in oil to prevent oxidation (when oil is at atmospheric pressure) :- 60°C)

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

- vii. One Oil storage / filtration tank of capacity to hold maximum oil capacity +10% among all the transformers in the scope of supply

Bidder is to furnish along with the bid detailed calculation to establish the sizing and capability of the vacuum pumping system with respect to moisture and gas removal as above.

Bidder is to submit along with the bid test reports, test methodology to prove the capability of the plant offered.

The plant shall also have two independent vacuum pumping systems one for evacuating the transformer for vacuum filling of oil in transformer and the other for degassing chamber. The blank off vacuum of each pumping system shall be  $10^3$  torr or less. The plant shall be provided with control and indication panel with full automation.

The plant shall be fitted with hoses for connection of oil lines and vacuum lines to transformers and reactors. Hoses shall have leakage rate of  $10^2$  torr-ltr/sec. (max.)

The Ultra High Vacuum Type oil purification plant shall be complete with oil pumps for drawing oil for transformers and reactors, oil heater (max. heating rate =  $2.0\text{W}/\text{cm}^2$ ) of adequate rating, suitable filter or centrifuge as required to ensure oil quality, degasifier complete with vacuum pumps, oil extraction pump etc. of adequate capacity such that throughout from the purification plant is of guaranteed purity.

The plant shall also be suitable for cleaning and degassing of the oil stored in the storage tanks. All equipment required as above shall be mounted on a tow-able road worthy trailer unit with 4 nos. pneumatic tyres. The equipment shall be suitable for outdoor use

### 1.36.2. Design & Construction

The features and construction details of each 6000 litres per hour capacity mobile outdoor type oil filtration & purification plant shall be in accordance with the requirements stated hereunder.

### 1.36.3. Oil Pump (Inlet Side)

Two (2) nos. electrically driven oil pumps with one (1) working and one (1) standby shall be provided. Selection switch is to be provided for selection of either of pumps. The pumps shall be single stage positive displacement gear type. Suitable mechanical seals shall be provided to ensure vacuum tightness. A built-in pressure relief valve to re-circulate the oil to suction side in case of accidental pressure rise shall be provided. Suction lift of the pump shall be at least 5 meters of transformer oil at atmospheric pressure & temperature. A separate by pass valve is provided across the gear pump so that the flow rate through the filter can be adjusted as required.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

The pump should be controlled by frequency drive. This should help to set the flow rating of filter pant from 4000 – 6000 LPH for 6 KLPH machine.

The pumps shall be provided with an interlock with delay such that if there is no oil flow of 30 sec. through the heater, the pump shall trip automatically and also if the pump is not operating the heater will not be energized.

i. Magnetic Strainer

The plant shall be provided with suitable magnetic strainer with wire mesh to filter all particles of sizes above 0.5 mm and all magnetic particles. The strainer shall be installed at the suction of the oil pump described above.

ii. Heater

- a) An oil heater for heating up inlet oil shall be provided at the discharge side of the oil pump.
- b) The oil heater vessel shall be of mild steel welded construction & insulated with glass/mineral wool.
- c) The vessel shall be constructed for ultra-high vacuum & pressure application.
- d) Electric heater shall be provided inside the heater vessel to heat up oil from lowest ambient temperature to temperature required for filtration/degasification operation in single pass. The heater shall also be rated for heating the inlet oil from lowest ambient temperature at 70°C in single pass during filling up of transformers. Two separate temperature settings with thermostatic controllers shall be provided for this purpose.
- e) The heating shall be indirect type and specific heat load shall not exceed 2.0 watt/cm<sup>2</sup> in order to avoid local overheating.
- f) The total heating capacity shall be divided into three independent thermostatically controlled heating stages evenly balancing the three phases of power supply. The control switches and knobs shall be housed on a control panel.
- g) An additional pre-set temper proof safety thermostat set at the highest temperature shall be provided on the heater to put off the heater and give audio and visual alarm to take care of accidental overheating.
- h) The heater body shall be so designed as to allow replacement of heating elements without draining of oil. Suitable pressure relief valve, vent and drain valves & two (2) dial type temperature gauges at inlet & outlet of heater shall be provided.

iii. Filter

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

- a) Cartridge filter as may be required to ensure maximum particle size to less than 0.5 micron in the filtered oil shall be provided.
- b) The filter body shall be fabricated of mild steel & designed for leak tightness at full vacuum & high pressures. The oil will flow from dirty oil chamber to clean oil chamber through filter elements.
- c) Cartridge type element used shall be suitable for transformer oil in service and submicronic filtration, the media shall be non hygroscopic and of high dirt holding capacity.
- d) The filter elements shall be easily removable for replacement when required. Compound gauge to indicate pressure across the filter, vent and drain with valves & other necessary accessories shall be mounted on the filter for each operation.

iv. External Solenoid Operated valves

Two valves should be provided at the inlet and outlet of the plant. The moment inlet and outlet pumps are switched on these valves open thus making way for oil to pass. In case of power failure, oil from the transformer will not enter the plant and vacuum system.

v. Degassing Chamber

- a) The degassing chamber shall be of welded construction and shall be suitable for operation under full vacuum. The fill of ranching rings & trays for distribution shall be designed for efficient distribution of oil over large areas. Incoming transformer oil should be spread over these rings in the form of film and over a longer surface area, thus achieving better degassing and dehumidification.
- b) The degassing chamber shall be multistage (minimum 02 stages) type suitable for ensuring the desired oil properties. Arrangement for condensing back lighter fraction (aromatics) of the insulating oil into the system shall be provided.
- c) The degassing channels shall have adequate height to allow long enough free fall for complete degassing. Design shall be such as to minimize foam formation.
- d) The degassing chambers shall be provided with suitable level monitor for oil or foam level in the chamber and shall trip the inlet gear pump when the level rises above the designed maximum level in order to prevent foam/oil to enter the vacuum pumping system. The oil inlet pump starts again automatically once the oil level in the degassing chamber falls below the preset oil level.
- e) Necessary illuminated sight glass shall be provided through which oil flow through the degasser can be viewed clearly.
- f) The degasser shall be provided with vacuum gauges, vacuum breaking valves, main and auxiliary vacuum connections and other necessary accessories.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

vi. Vacuum Pumping System

- a) The pump shall be provided with a suitable vacuum pumping system for creating adequate high vacuum in the degassing chambers. The pumping system shall consist of suitable combination of Roots Blowers and Rotary vane vacuum pumps with inter-stage condensing units.
- b) The roots blowers shall be of reputed make. Suitable built in labyrinth packing system, slinger rings, oil return chambers shall be provided between bearings and working chambers to prevent penetration of lubricating oil to the working chamber. The pumps motor shall be dynamically balanced. The pumps shall be suitable for starting evacuation from atmospheric pressure and shall be applied with necessary overflow valve.
- c) The rotary vane vacuum pumps shall be installed after the roots blower. An automatic by pass valve across the roots blower shall permit operation of rotary vane pump alone to operate when so required. The rotary vane pumps are provided with gas ballast valve to prevent contamination of vacuum pump oil with moisture. The vacuum pump shall also be provided with suitable non-return valve device such that in the event of power failure the vacuum in the degassing chamber shall be maintained and the vacuum pump oil is not sucked back into the degassing chamber. A high vacuum safety valve (piston type) to prevent back streaming of oil and air intrusion shall be provided. The pump motors shall be having return stop device.

vii. Vacuum Pumping system for Transformer Evacuation

An independent vacuum pumping system shall be provided for evacuating the transformer for oil filling. The vacuum level required for transformer evacuation for oil transfer is about 0.76 torr (1 m bar) for transformer oil heated to 70-80°C. The pumping system shall be identical to that of the degassing vacuum system. The capacity shall be adequate for evacuation of

- (a) 60KL in one hour from 1 atm to 1 mbar (for 6 KLPH Machine)

The vacuum systems for degasser and transformer evacuation shall be inter connected in such a way that it shall be possible to use either or both the systems for any of the purpose. A reinforced hose of 10 mts. length should be provided. The hoses must be for vacuum leakage rate of  $10^2$  torr-litre/sec.

viii. Oil Extraction Pump

Suitable pumping system shall be provided for extracting oil from degasser under vacuum and supplying to transformer/reactor etc., at discharge pressure of 1.5 kg/cm<sup>2</sup> at the outlet hose nozzle of the plant, the pump shall be either glandless centrifugal type with canned motors or a combination of gear pump and centrifugal pump with mechanical seals suitable for extracting

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

oil from high vacuum degassing chamber. The oil extraction pump shall be located at a suitable level below the degasser chamber so as to ensure adequate suction head for the pump. The pump shall be supplied with double check valve assembly and solenoid operated non return valve. In order to stop reverse flow of oil in case of power failure, the pumping system shall preferably be self priming type alternatively priming device with safety interlock to protect pump against dry running shall be provided. Sampling valves shall be provided at the discharge of extraction pump for testing of oil properties. A recirculation line with valves shall be provided to re-circulate a part of the purified oil to the inlet point if necessary during operation. The pump should be controlled by frequency drive. This should help to set the flow rating of filter pant from 4000 – 6000 LPH for 6 KLPH machine.

ix. Hoses for Transformer Oil, Vacuum, Air And Water

- a) Separate reinforced rubber hoses shall be provided for each operation for oil suction, oil discharge, transformer vacuum connection and cooling water supply and return. The hoses shall be at least 15 meter long each and shall be complete with hose quick connect couplers for connection to installations under operation.
- b) Hose pipes for oil service shall be suitable for transformer oil application upto temperature of 100° C, full vacuum and pressure upto 2.5 kg/cm<sup>2</sup>. All oil hoses shall be built up around an earthed core or have built in earthed conductor to avoid static electricity accumulation. Inlet and outlet nozzles of purification plant and corresponding hoses shall be of 50 NB/40 NB size respectively in order to avoid error in connecting.
- c) Vacuum hoses shall be of braided nitrile rubber suitable for full vacuum without collapsing and kinking. Suitable provision/ mechanism should be provided to monitor oil flow in the vacuuming system . Further, in case of accidental oil flow in the vacuum hose, the vacuum process should get stopped automatically.

x. Oil sampling valve: Suitable valve shall be provided for taking sample during filtration.

xi. Material of construction and painting

- a) Oil heater, filter vessel, degasser shall be of mild steel construction. The internal and external surfaces including oil heater, filter vessel, degasifier and structural steel work to be painted shall be shot or sand blasted to remove all rust and scale of foreign adhering matter or grease. All steel surface in contact with insulating oil shall be painted with two coats of heat resistant oil insoluble, insulating varnish.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

- b) All internal paints steel surfaces shall be given a primary coat of zinc chromate, second coat of oil and weather resistant varnish of a color distinct from primary and final two coats of glossy oil and weather resisting paint.
- c) All paints shall be carefully selected to withstand heat and extremes of weather. The paint shall not scale off or crinkle or be removed by abrasion due to normal handling.
- d) Bolts & Nuts: All bolts and nuts exposed to weather shall be hot dip galvanized/cadmium plated and passivated /zinc plated and passivated.
- e) Material of construction for vacuum pumps air compressor, air drying plant, air receiver shall be steel of suitable grade.
- f) All piping and equipment carrying transformer oil shall be insulated with glass wool/mineral wool insulation.

#### **1.36.4. Instrumentation and Control**

- i. Following minimum instruments shall be provided on the oil purification plant:
  - a) Compound gauge at oil pump discharge
  - b) Compound gauge at filter inlet.
  - c) Compound Gauge at filter outlet
  - d) Pressure Gauge at discharge pump outlet
  - e) Pressure Gauge at degassifier
  - f) Vacuum Gauge at transformer evacuation line
  - g) Vacuum Gauge in between roots, vacuum pump and rotary vane vacuum pump.
  - h) Panel mounted vacuum indicators at degasser
  - i) Panel mounted vacuum indicators at transformer evacuating line.
  - j) Separate fine vacuum gauge for measurement of vacuum for transformer evacuation system and oil line degassing chamber evacuation system should be provided. This vacuum gauge should be electronic type having range from 0.01 torr to 20 torr and should be of any of these reputed manufacturers' (Wika/ Hasting/ Edwards) make.
  - k) Oil Filtration Machine should be fitted with on-line moisture in oil-PPM indicator.
  - l) Sight glass at degassifier
  - m) Temperature indicator cum controller at heater inlet
  - n) Temperature indicator cum controller at heater outlet
  - o) Voltmeter
  - p) Oil flow meter (Positive displacement type)
  - q) Ammeter
- ii. Control Panel:



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

A centralized electrical panel with auxiliary step-down transformer, contractors, back up protection fuses, indicating lamps etc. to be provided with following minimum audio and visual alarms:

- a) High temperature at heater outlet
- b) High differential pressure across filters
- c) Oil pump trip
- d) Vacuum pump trip
- e) Loss of vacuum in degassing chamber
- f) Loss of vacuum in transformer evacuation line
- g) No oil flow through heater
- h) High oil level in degasser.

All controls and annunciation equipment should be suitable for 240 V AC.

- iii. Suitable interlock as described against each equipment shall be provided for safe and trouble-free operation.
- iv. All instruments, control hardware and alarms shall be mounted on a suitable control panel. A mimic diagram with indication lamps showing on-off status of various equipment shall be provided on the control panel.
- v. The plant shall be fully equipped with adequate instrumentation having provision of manual operation, if required. All necessary control and indicating panel shall be provided.
- vi. It shall be possible to use the oil transfer pump for the purpose of loading oil to transformers or reactors from tankers and vice versa by by-passing to purification plant, if required.
- vii. There shall be independent vacuum pump for creating and holding the transformer/ reactor winding under vacuum for vacuum drying and filling of winding when required. The vacuum pump shall have capacity to develop and maintain adequate vacuum in the oil space of the 60KL tank for 6KL plant within 1-hour time.

#### **1.36.5. Electrical System:**

- viii. The plant shall be fed with 415V, 3 phase, 50 Hz, 4 wire power supply through flexible cable from the distribution panel located on the plant.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

- ix. Provision for earthing the plant at the operating locations with earthing terminals for safety shall be provided.
- x. The plant shall be suitably illuminated and ventilated for comfort of operator.
- xi. Capacity Demonstration: The supplier has to submit the detailed calculations in support of meeting the desired vacuuming capacity along with their technical offer.
- xii. The adequacy of capacity of Vacuum Pump & Roots Pump to be ensured prior to acceptance of the Plant by demonstration at works/site.

### 1.37. Technical specification for oil storage tank

- i. Oil storage tank shall be of capacity 25,000 Ltr. along with complete accessories. The oil storage tank shall be designed and fabricated as per relevant BIS (BIS 803) and also with other internationally acceptable standards. Transformer oil storage tanks shall be towable on pneumatic tyres and rested on manual screw jacks of adequate quantity & size. The tank shall be cylindrical in shape and mounted horizontally and made of mild steel plate of adequate thickness. Diameter of the tank shall be 2.0 meter approximately. The tank shall be designed for storage of oil at temperature of 100°C.
- ii. **The maximum** height of any part of the complete assembly of the storage tank shall not exceed 4.0 meters above road trip.
- iii. The tank shall have adequate number of jacking pad so that it can be kept on jack while completely filled with oil. The tank shall be provided with suitable saddles so that tank can be rested on ground after removing the pneumatic tyres.
- iv. The tank shall also be fitted with manhole, outside & inside access ladder, silica gel breather assembly, inlet & outlet valve, oil sampling valve with suitable adopter, oil drainage valve, air vent etc. Pulling hook on both ends of the tank shall be provided so that the tank can be pulled from either end while completely filled with oil. The engine capacity in horse power to pull one tank completely filled with oil shall be indicated.
- v. Oil level indicator shall be provided with calibration in terms of litre so that at any time operator can have an idea of oil in the tank.
- vi. Solenoid valve (Electro-mechanically operated) with Centrifugal pump shall be provided at bottom inlet so that pump shall be utilized both ways during oil fill up and draining. Suitable arrangement shall also be provided to relevant overflow and drain from the tank.
- vii. The following accessories shall also from part of supply along with each Oil storage Tank.
  - a) Four number of 50 NB rubber hoses suitable for Transformer oil application up to temperature of 100°C, full vacuum and pressure up to 2.5 Kg/cm<sup>2</sup> with couplers and unions each not less than 10 meter long shall be provided.
  - b) Two numbers of 100 NB rubber hose suitable for full vacuum without collapsing & kinking vacuum hoses with couplers & unions, each not less than 10 meter long, shall be provided.
  - c) One number of digital vacuum gauge with sensor capable of reading up to 0.001 torr, operating on 240 V Hz AC supply shall be supplied. Couplers and unions for

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

sensor should block oil flow in the sensor. Sensor shall be provided with at least 8 meter cable so as to suitably place the vacuum gauge at ground level.

- d) The painting of oil storage tank and its control panel shall be as per Annexure K of *“Standard specification and technical parameters for transformers and reactors (66kV & above voltage class) by CEA”*
- viii. The tank shall contain a self-mounted centrifugal oil pump with inlet and outlet valves, with couplers-suitable for flexible rubber hoses and necessary switchgear for its control. There shall be no rigid connection to the pump. The pump shall be electric motor driven, and shall have a discharge of not less than 6.0 kl/hr with a discharge head of 8.0 m. The pump motor and the control cabinet shall be enclosed in cubicle with IP-55.

### 1.38. Fittings and Accessories

Each transformer shall be provided with accessories but not limited to the following:

- Oil temperature Indicator;
- Winding temperature Indicator;
- One resistance thermometer for remote indication of oil temperature;
- One number magnetic type oil-level gauge with low level alarm contacts and a dial, showing minimum, maximum and normal oil levels. The gauge shall be readable from the transformer base level;
- One oil filling valve (inlet);
- One oil drain valve (outlet);
- One filter valve located at the top of the tank on H.V. side;
- One filter valve located near the bottom of the tank on the L.V. side of the transformer (diagonally opposite to the filter valve at the top);
- Two oil sampling valves at top and bottom of main tank with provision for fixing PVC pipe;
- Pressure relief device of resealing type with alarm and trip contacts to vent out pressure in case the pressure in the tank rises above pre-determined safe limit;
- A buchholz relay mounted in between the conservator and tank;
- Conservator and breather;
- Heat exchangers, complete with pumps and motors along with requisite accessories as specified for OFWF type of cooling and pressure reducing valve;
- Oil preserving equipment complete in all respects;
- Dehydrating air breather with silica gel filling and oil seal;
- Eye bolts and lugs on all parts for ease of handling;
- Two grounding terminals;
- Jacking pads;
- A valve schedule plate showing the location and function of all valves and air releases, cocks

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

or plugs. This plate shall also warn operators to refer to maintenance instructions before applying the vacuum treatment for drying;

- One set of equipment for control, protection, indication and annunciation of each transformer comprising motor contactors, detecting elements or devices, instruments, current transformers, indicating lamps (where necessary), auxiliary relays (including those for remote annunciations and trips), etc., as detailed in the various clauses of the specification;
- Suitable weather proof cubicle with space heater for housing the control equipment, terminal blocks for current transformer secondaries and other cables, etc.;
- A set of devices for lifting / hauling of the various parts of the transformer as also the complete transformer (one set common to all the transformer);
- Terminal connectors;
- Water Flow indicator with alarm contacts;
- Oil flow indicator with alarm contacts and provision of remote indication;
- Off load tap changer;
- L.V. and neutral Bushings;
- Wiring in metallic conduits up to control cabinets with PVC copper cables of 650/1100 volts grade, FRLS type;
- Armored cable wiring between control cabinets, marshalling kiosks and marshalling box;
- Online Gas monitoring device (for minimum H<sub>2</sub>, CO and moisture) along with sensors, analyzers and outputs 4-20 mA for each item sensed for remote indication. It shall be offered as an *optional* item as per details below.

A continuous online monitoring and analyzing system for a minimum of 3 key fault gasses of Generator Transformer viz. Hydrogen (H<sub>2</sub>), Carbon Monoxide (CO) and moisture (H<sub>2</sub>O) shall be offered as an optional item for each transformer. The system should permanently and continuously monitor all the above parameters and additionally shall be equipped with analog outputs (4 – 20 mA DC) for the transfer of Hydrogen (H<sub>2</sub>), Carbon Monoxide (CO) and moisture (H<sub>2</sub>O) measurement to a controller mounted in control room and interfaced with central SCADA system. The system shall be capable to analyze the individual contents of the transformer key fault gases Hydrogen (H<sub>2</sub>, 0 – 2000 ppm), Carbon Monoxide (CO, 0 – 2000 ppm) and moisture (H<sub>2</sub>O, 0 – 100 ppm). The system should give alarms (H & HH) for all quantities and shall be settable both from local and remote location as well as store permanently all data in non-volatile memory (of sufficient capacity) and shall not be affected by short duration of failures of supply to the local unit. The system should contain no external tubes or moving parts, but shall be directly mounted on to the valve on the transformer.

Standard interfaces RS232 & RS 485 ports shall be available in the unit and it should be OPE

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

compliant (IEC 61850) for integration with station SCADA:

- Rating and diagram plate;
- Digital Oil pressure indicator with 4 to 20ma output;
- Digital water flow indicator with 4 to 20 ma output;
- Differential digital pressure indicator with 4 to 20 ma output.

The equipment and accessories furnished with the transformer shall be suitably mounted on the transformer for ease of operation, inspection and maintenance. The mounting details shall be subject to the approval of the Purchaser.

Indication, alarm and trip relay equipment shall have contacts suitable for operation with 220 V DC supply. Any other accessories or appliances recommended by the manufacturer for the satisfactory operation of the transformers together with their prices shall be given in the Bid separately.

### **1.39. Packing and Transport**

The packing may be in accordance with the Contractor's standard practice but he shall give full particulars of packing for the approval of the Purchaser keeping in view the transport limitations. Special arrangement shall be made to facilitate handling and to protect the projecting connections from damage in transit. The conservator, the bushings, the cooling equipment and the wheels shall be removed and packed separately with weather proof wrapping and bags of dehydrating material for the parts which might suffer from moisture during transport. The openings of the mounting flanges of coolers and bushings shall be covered with blind flanges.

The transformer shall be transported duly filled with dry nitrogen gas under low pressure. To provide for any leakage through the temporary covers fitted to the tank, required number of cylinders of nitrogen with appropriate equipment (Pressure Gauges and valves, etc.) shall also be transported along with the transformer so that the tank can be maintained permanently under pressure. The oil shall be supplied in non-returnable standard sealed drums.

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. Paper Moisture calculation after 24 hrs of nitrogen filling shall be carried out prior to dispatch. The acceptable value should be less than 0.5%.

Impact recorders must be attached to the main body of the transformer and parts considered very delicate such as the bushings and others accessories during the transportation to monitor the shock which the transformer and its parts may be subjected to.

It is proposed that the Contractor make his own route survey prior to dispatch of the Goods.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

#### 1.40. Performance Guarantees

The following parameters shall be guaranteed:

- No load losses in kilowatts at rated voltage and rated frequency without +ve tolerance.
- Load losses in kilowatts at rated output, rated voltage and rated frequency without +ve tolerance.
- Maximum power in kW consumed by pumps/ fans (Auxiliary losses) without +ve tolerance.

Penalties shall be separately evaluated for:

- The excess of test figures of the no load losses in kilowatts over the corresponding guaranteed figures.
- The excess of the difference between the test values of the load losses in kilowatts over the corresponding guaranteed values. No tolerance shall be permitted over the test figures of the losses.
- The excess of power consumed by pumps/fans in kW (Auxiliary losses) over the corresponding test values guaranteed by the Bidder.

Following penalties shall be levied on the manufacturer/contractor (as the case may be) if losses measured during routine test are found to be within +2% tolerance of the losses specified in Guaranteed Technical Particular (GTP) by the contractor, beyond which the transformer shall be liable for rejection. No benefit shall be given for supply of transformer/reactor, with losses (measured during routine tests) less than the losses specified in Guaranteed Technical Particular (GTP).

Differential of specified losses vs Measured losses	Rate (in INR per KW) for LD
No load losses	Rs.10,00,000/KW
Load losses	Rs.8,00,000/KW
Auxiliary losses	Rs.8,00,000/KW

The penalties will be applied pro-rata for fraction of a kilowatt.

For the purpose of comparison of bids, the quoted prices shall be equalized for the guaranteed transformer losses. Taking the lowest values of no-load and load losses and other losses indicated by any of the Bidders as the reference, the quoted prices of various Bidders will be loaded for excess losses (difference of guaranteed losses and the reference losses) at the half rate as given above for liquidated damages computation. All losses considered shall be without any +ve tolerance.

For **bid loading** amount will be half of penalty for non-performance.

Differential of specified losses vs Measured losses	Rate (in INR per KW) for loss Capitalization
No load losses	Rs.5,00,000/KW
Load losses	Rs.4,00,000/KW

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

<b>Auxiliary losses</b>	Rs.4,00,000/KW
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➤ **Temperature Rise**

The temperature rise of windings shall be determined by type test. If, according to the results of the tests carried out within the scope of the Contract, the measured temperature rise exceeds the guaranteed value, the price for all transformers shall be reduced as a compensation for decreased life expectancy. The compensation shall be computed as follows:

<b>Temperature Rise over the Admissible Limit (K)</b>	<b>Compensation in Percent of the Total F.O.B. Price of the Transformer</b>
0 – 1.99	0
2 – 2.99	4.5
3 – 3.99	9.0
4 – 5.00	13.5

No additional payment will be payable for measured temperature rise of less than the guaranteed maximum.

- Purchaser may during tests at works, reject a power transformer for the following reasons:
- If any of the losses exceed 25% of the guaranteed values;
  - If the impedance voltage exceed tolerance values specified by IEC of the guaranteed value;
  - If temperature rise exceeds more than 5°K of the prescribed values.

**1.41. Drawings, Data, Manuals and Guaranteed Particulars**

- 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:

- General outline dimensional drawings showing front and side elevation and plan of transformer and all accessories including coolers and external features, spacing of wheels in either direction of motion, net weight and shipping weight, quantity of insulating oil, centre of gravity.

The drawing should indicate location of LV and HV terminals with respect to centre line and ground;

- Detailed dimensioned drawing showing clearances required for the transformer from the Power House wall, fire walls, ground clearance, clearance from Over Head conductor / SF<sub>6</sub>

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

Tube and Ceiling as applicable;

- Assembly drawings and weights of main component parts;
- Shipping drawings showing dimensions and weights of each package. Arrangement for inert gas retention and monitoring and other protective arrangements during transportation;
- Drawings giving the design loads for foundations;
- Tap changing and name plate diagrams;
- Descriptive brochures for all auxiliary equipment;
- Detailed arrangement drawings and specifications of each type of bushings;
- A complete Bill of Material for the equipment;
- Type tests and special test reports conducted on similar transformer;
- Quality Assurance Program and fire fighting scheme as proposed by Bidder;
- Oil-SF<sub>6</sub> transformer bushing for the 220 kV GIS tube.

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.

- Drawings, O & M Manuals, etc., and documentation to be furnished by the Contractor after award of contract

After award of contract, the Contractor shall supply five (5) copies of the following drawings; for approval as per agreed time schedule and shall subsequently provide six (6) complete sets of final as-built drawings, and two (2) set of electronic files in a CD:

- General outline drawing showing front and side elevation and plan of the transformer and all accessories including coolers and extreme features with details of dimensions, spacing of wheels in either direction of motions, net and shipping weights, crane lift for untanking, size of lifting lugs and eyes, bushing lifting dimensions, clearance between HV and LV terminals and ground, quantity of insulating oil, etc.;
- Foundation plan showing loading on each wheel and jacking points with respect to centre line of rail track;
- Details of each type of bushing and terminal connections;
- LV bushing and throat connection interface with the isolated phase bus duct;
- Name plate drawing with terminal marking and connection diagram.
- Wheel locking arrangement;
- Transportation dimension drawing;
- Magnetizing characteristic curves of current transformers;
- Efficiency Curve;
- Inter connection diagram (including wiring between control cabinet, marshalling kiosk and



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Common marshalling box);

- Schematic and control wiring diagram for all accessories and auxiliary equipment;
- Over-fluxing withstand time characteristics of transformer;
- Sectional view showing the general constructional features of the transformers, core, winding, tap changer, etc.;
- Schematic diagram showing the flow of oil and water in the cooling system as well as each limb and winding, longitudinal and cross sectional views showing the duct sizes, cooling pipes, etc., for the transformers / heat exchanger alarm to scale;
- Large-scale drawings of high and low tension windings of the transformers;
- showing the nature and arrangement of insulation and terminal connections;
- Operation and Maintenance Manual of the Generator Transformers;
- Technical sheets and bulletins for all accessories listed in respective Clauses;
- Neutral bus and ground bus layout and detail drawings;
- Neutral current transformer mounting and accessories details;
- HV SF<sub>6</sub> insulated transformer termination details and termination instruction bulletin;
- Transformer oil filtration system drawings, schematics, technical sheets and bulletins;
- SF<sub>6</sub> measuring and handling devices drawings, schematics, technical sheets and bulletins.

Operation & Maintenance and erection manuals four (4 copies) shall be supplied by the manufacturer one month prior to the shipment of the transformer for approval. After approval and incorporating Purchaser's comments, the Contractor shall submit twelve (12) sets of the original O&M Manuals and two (2) set of electronic files in a CD. The manuals shall contain all the drawings and information required for erection, operation and maintenance of the transformers.

Descriptive literature and data on transformers, windings, bushings, heat exchangers, tap changing gear, temperature detector, buchholz relay, instruments and controls, etc., shall also be supplied by the manufacturer along with the instruction manuals.

#### **1.42. Stage inspection**

Stage inspection will be carried out by Purchaser on Core, Winding, core-coil assembly & Tank during the manufacturing stages of the transformer. The manufacturer will have to call for the stage inspection and shall arrange the inspection at manufacturer's premises or manufacturer's sub-supplier's premises, as applicable, free of cost. Stage Inspection shall be witnessed by the purchaser or any third-party inspector engaged by the purchaser.

The manufacturer will offer the core for stage inspection and get approval from purchaser during manufacturing stage. The BIS certified prime core materials are only to be used. The manufacturer has to produce following documents at the time of stage inspection for confirmation of use of prime core materials.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

- a) Invoice of supplier
- b) Mills' approved test certificates
- c) Packing list
- d) Bill of lading
- e) Bill of entry certificate by custom.
- f) Description of material, electrical analysis, physical inspection, certificate for surface defects, chemical composition certificate, thickness and width of the materials.
- g) Place of cutting of core materials

To avoid any possibility of mixing of 'Prime material' with any other second grade/ defective material, the imported packed slit coils of CRGO materials shall be opened in the presence of the Inspector. Only after the inspection and approval from purchaser, the core material will be cut in-house or sent to external agency for cutting individual laminations. In case the core is sent to external agency for cutting, the Inspector will have full access to visit such agency for the inspection of the cutting of core. Core material shall be directly procured either from the manufacturer or through their accredited marketing organisation of repute and not through any agent. Customer inspection shall be carried out for CRGO during Core building and sample to be sent for testing at third party lab/NABL lab for testing of stacking factor, magnetic polarization, specific core loss, Surface insulation resistivity, ductility & aging test etc.

Customer inspection for Paper Insulated Copper Conductor (PICC/CTC) shall be carried out for witnessing conductor finish, dimension of bare conductor, layers of paper covering, resistivity/conductivity etc.

Test certificates of Kraft Insulating paper used for covering PICC & CTC shall also be reviewed for

- Visual check & measurement of thickness.
- Physical check viz. Substance (Grammage), Density, Moisture content, Water absorption, Air permeability etc.
- Mechanical check viz. Tensile index, Tear index, heat stability etc.
- Electrical check (BDV)
- Chemical check viz. Ash content, Conductivity of 5% aqueous extract, PH of 5% aqueous extract etc.

Further, sample of Pre-compressed Pressboard and Unimpregnated wood randomly selected by NEEPCO shall be sent for testing at Third Party lab by the Contractor and documents shall be reviewed by NEEPCO for acceptance. The tentative list of tests shall include –

- Dimension, Thickness, density, compressibility, shrinkage in air, oil absorption, Moisture content, pH value, Ash content
- Tensile strength, Elongation,
- Conductivity of aqueous extract

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

In-process inspection for core & coil assembly shall be carried out for visual check, magnetising current test, core & clamp isolation test, paper moisture content during dry-out etc.

Air Pressure test and Vacuum Test on Tank and complete Radiator assembly shall also be carried out during manufacturing stage.

Exhaustive Manufacturing Quality Plan shall be submitted by bidder along with bid document covering all areas in manufacturing process, where stage inspections are required to be carried out for quality control and details of such tests and inspections. Approval on MQP shall be accorded by purchaser during detail engineering.

In addition to above, Surveillance checks shall also be carried out by NEEPCO as and when deemed necessary. No inspection call to be given for surveillance checks.

### **1.43. Testing of Transformer**

Each transformer shall be completely assembled and tested at the factory and at site. Tests shall be performed in the presence of Purchaser's representative. Tests shall be performed in compliance with latest edition of IS: 2026 / IEC 60076 / IEC 60060 / IEC 60270 / IEEE-48 / IEEE-62 / IEEE-1538 / NEMA TR1 and all other standards listed elsewhere in this specification.

No material shall be shipped until the test reports are duly approved by the Purchaser or his representative. The Contractor shall furnish the type test certificates for the approval of the Purchaser.

#### **1.43.1. Factory Tests**

The manufacturer shall be fully equipped to perform all the required tests as specified. Bidder shall confirm the capabilities of the proposed manufacturing plant in this regard when submitting the bid. Any limitation shall be clearly stated. The contractor shall bear all additional costs related to tests which are not possible to carry out at his own works. The Contractor shall submit a quality assurance and test plan for approval. A typical test plan is indicated below. This is not intended to form a comprehensive programme. It is Contractor's responsibility to draw up and carry out such a programme in the form of detailed quality plan duly approved by Purchaser for necessary implementation.

TEST PLAN TYPICAL				
No	Item	Test Type	1 <sup>st</sup> Unit	Other Units
1	Measurement of winding resistance	Routine	✓	✓
2	Measurement of voltage ratio on each tap and check of voltage vector relationship	Routine	✓	✓ C
3	Measurement of impedance voltage / short circuit impedance (principal tapping and extreme taps) and load loss	Routine	✓	✓
4	Measurement of no-load loss and current, at rated voltage and 110% voltage.	Routine	✓	✓
5	Measurement of no-load current with 415 V, 50 Hz on LV side	Routine	✓	✓
6	Measurement of insulation resistance	Routine	✓	✓
7	Measurement of insulation power factor and capacitance between winding and earth.	Routine	✓	✓
8	Lightning impulse test (at principal and extreme taps)	Routine	✓	✓
9	Switching impulse test	Routine	✓	✓
10	Separate source AC voltage withstand test	Routine	✓	✓
11	Induced over voltage test with partial discharge test	Routine	✓	✓
12	Measurement of harmonic content of No load current	Type	✓ C	N.A
13	Temperature rise test	Type	✓	N.A
14	Measurement of power taken by Oil Pumps	Routine	✓ H / C	✓ C
15	Gas in oil analysis	Routine	✓	✓
16	Appearance, construction and dimension check	Routine	✓	✓
17	Core assembly dielectric and earthing continuity test	Routine	✓	✓
18	Tank vacuum test (to be witnessed)	Routine	✓	✓
19	Tank pressure test (to be witnessed.)	Routine	✓	✓
20	Measurement of acoustic noise level	Type	✓ H / C	N.A
21	Frequency response analysis	Routine	✓	✓

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

22	High voltage withstand test on auxiliary equipment and wiring after assembly	Routine	✓	✓
23	Oil leakage on assembled transformer	Routine	✓	✓
24	Knee point voltage measurement of CT's	Type	✓ C	N.A
25	PF withstand test	Routine	✓	✓
26	Measurement of excitation losses at 90 % and 110 % of rated voltage after impulse test are completed	Routine	✓	✓
27	Tan delta of bushings and windings at variable frequency (Frequency Domain Spectroscopy)	Routine	✓	✓
28	Dry air/ Nitrogen Dew Point measurement prior to dispatch	Routine	✓	✓
29	Paper moisture calculation after 24hrs of dry air/ N2 filling. (Shall be done as per IEEE std. C57.93-2007)	Routine	✓	✓
30	Any other test deemed necessary	Routine	✓	✓
Notes: - H / C- Measured in Cold and Hot state of temperature rise test C- Measured in Cold state				

#### 1.43.2. Routine Tests

All standard routine tests in accordance with IS: 2026 / IEC 60076 with dielectric tests corresponding to Method 2 shall be carried out on each transformer. Complete test report shall be submitted to Purchaser after proper scrutiny and signing on each page by the Test Engineer or Contractor. Six (6) certified copies of each test shall be furnished.

The routine test reports shall also contain the following information:

- Calculated value of regulation at unity, 0.9, 0.8 lagging and 0.95, 0.9 leading power factor;
- Calculated values of positive, negative and zero sequence impedances of three phase bank;
- Calculated values of efficiency of transformer at 50, 75 and 100 percent of rated capacity with 1.0 and 0.9 power factors.

#### ➤ Additional type tests

Following additional routine tests shall also be carried out on each transformer:

##### 1 Magnetic Circuit Test

After assembly each core shall be tested for 1 minute at 2000 Volts between all bolts, side

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

plates and structural steel work;

- 2 Oil leakage test on transformer tank as per details given below under Tank Tests;
- 3 Magnetic balance test;
- 4 Measurement of no-load current with 415 V, 50 Hz ac supply on LV side;
- 5 Frequency response analysis (FRA);
- 6 High voltage withstand test shall, be performed on auxiliary equipment, wiring, and core after complete assembly of core and tank;
- 7 Measurement of excitation current at rated voltage connection at 90,100 and 110 % of rated voltage.

### 1.43.3. Type Tests

Following type tests shall be conducted on one (1) Transformer of each rating. After all tests have been completed, six (6) certified copies of each test report shall be furnished. Each report shall supply the following information:

- Complete identification data including serial number of the transformer / equipment tested. Calibrated oscillographs of impulse test shall form part of the test report;
- Method of application, where applied, duration and interpretation of results for each test. Quantities corrected to 75°C shall be given;
- Temperature and pressure data including ambient temperature and atmospheric pressure:

#### 1 Temp. Rise Test as per IS: 2026 (Part-II)

Gas chromatographic analysis on oil shall also be conducted before and after this test and the values shall be recorded in the test report. The sampling shall be in accordance with IEC 567. For the evaluation of the gas analysis in temperature rise test the procedure shall be as per IS: 9434 (based on IEC: 567) and results will be interpreted as per IS: 10593 (based on IEC -599).

The temperature rise test shall be conducted at a tap for the worst combination of loading on the three windings of the transformer. The Contractor before carrying out such test shall submit detailed calculations showing alternatives possible, on various taps and for the three types of ratings of the transformer and shall recommend the combination that results in highest temperature rise for the test;

- 2 Tank vacuum Test as described in the subsequent paragraph;
- 3 Tank pressure Test as described in the subsequent paragraph;
- 4 Measurement of capacitance and tan delta to determine capacitance between winding and

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

earth;

- 5 Lightning Impulse withstand test on all phases as per IS: 2026 (As type test, only for 220 kV class & below);
  - 6 Measurement of zero Seq. reactance (As per IS: 2026, for 3-phase transformer only).
- Following additional type tests other than type and routine tests shall also be carried out on one unit of each type:
    - 1 Measurement of acoustic noise level;
    - 2 Measurement of power taken by fans and oil pumps;
    - 3 Measurement of harmonic level in no load current.
  - **Type Tests on fittings:**

All the following fittings shall conform to type tests and the type test reports shall be furnished by the contractor along with the drawing of equipment / fittings. The list of fittings and the type test requirement are as follows:

- 1 Bushing (Type Test as per IS: 2099 / IEC: 137);
- 2 Buchholz relay (Type Test as per IS: 3637 and IP-55 Test on terminal box);
- 3 Cooler Control cabinet (IP-55 test);
- 4 Pressure Relief device Test:

The pressure Relief Device of each size shall be subjected to increase in oil pressure. It shall operate before reaching the test pressure specified in transformer tank pressure test below. The operating pressure shall be recorded. The device shall seal off after excess pressure has been released.

The terminal box / boxes of PRD should conform to degree of protection as per IP-55 of IS: 13947;

- 5 Regenerative breather;
- 6 Magnetic Oil Level gauge & Terminal Box for IP-55 degree of protection;
- 7 Air Cell (Flexible air separator) - Oil side coating, Air side under Coating, Air side outer coating and coated fabric as per IS: 3400 / BS 903 / IS: 7016;
- 8 OTI & WTI- Switch setting & operation, Switch differential, Switch rating;
- 9 Oil pump - Vacuum Test at 250 torr maximum, oil pressure test at 1 kg / cm<sup>2</sup> for 24 hrs.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

Temperature rise test by resistance method, IP-55 degree of protection for terminal box;

#### 10 Motors:

Each motor shall be subjected to the following tests where applicable:

- Measurement of winding resistance (cold);
- No load test at rated voltage for determination of fixed losses;
- An over voltage test at 1.5 times rated voltage applied with the machine running at no load, for a period of 3 minutes, to test interturn insulation;
- High voltage in accordance with IEC 60034-1.

#### 11 All tests on CT's as per IS: 2705.

### 1.43.4. Tank Tests

#### Routine Tests

##### ➤ Oil Leakage Test

All tanks and oil filled compartments shall be tested for oil tightness by being completely filled with air or oil of a viscosity not greater than that of insulating oil conforming to IS: 335 at the ambient temperature and applying a pressure equal to the normal pressure plus 35 kN / Sq.m (5 psi) measured at the base of the tank. The pressure shall be maintained for a period of not less than 12 hours for oil and one hour for air during which time no leak shall occur.

#### Type Tests

##### ➤ Vacuum Test

One transformer tank of each size shall be subjected to the specified vacuum. The tank designed for full vacuum shall be tested at an internal pressure of 3.33 kN / Sq.m absolute 25 torr for one hour. The permanent deflection of flat plate after the vacuum has been released shall not



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

exceed the values specified below:

Horizontal Length of flat plate (in mm)	Permanent deflection (in mm)
Up to and including 750	5.0
751 to 1250	6.5
1251 to 1750	8.0
1751 to 2000	9.5
2001 to 2250	11.0
2251 to 2500	12.5
2501 to 3000	16.0
Above 3000	19.0

➤ Pressure Test

One transformer tank of each size having radiator, conservator / cooler vessel and other fittings together or separately shall be subjected to a pressure corresponding to twice the normal head of oil or to the normal pressure plus 35 kN / m<sup>2</sup> whichever is lower measured at the base of the tank and maintained for one hour. The permanent deflection of flat plates after the excess pressure has been released shall not exceed the figure specified above for vacuum test.

Pre-Shipment Checks at Manufacturer's works:

- 1 Check for interchangeability of components of similar transformers for mounting dimensions;
- 2 Check for proper packing and preservation of accessories like radiators, bushings, dehydrating breather, rollers, buchholz relay, fans, control cubicle, connecting pipes, conservator etc.;
- 3 Check for proper provision for bracing to arrest the movement of core and winding assembly inside the tank;
- 4 Gas tightness test to confirm tightness;
- 5 Derivation of leakage rate and ensure the adequate reserve gas capacity;
- 6 The transformers will be dispatched only after they are given dispatch clearance from Purchaser.

#### 1.44. Erection, Testing and Commissioning

The transformers are to be installed inside the transformer hall at the location as shown in the drawings. The installation of the transformers includes but not limited to the following:

- Transport and unloading of the transformers from the trailer to the respective locations of the transformers.
- The Purchaser shall provide the transformer foundation based on the foundation drawings,

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

foundation bolts & other embedded parts provided by the Supplier.

- Welding, jointing and clamping, soldering, brazing as per drawings and as per engineering practices and Quality Assurance Plan;
- Installation of control cabinet;
- Installation of transformer components, pumps, coolers and other accessories
- Earthing connection
- Dry out of transformer
- Treatment of oil and oil filling;
- Field tests comprising Commissioning, operational or other tests as per technical provisions and / or applicable standards, whether specifically mentioned or not;
- Performance / Final acceptance tests as applicable in accordance with provisions of technical specifications;
- Corrections (if any) in erection or during assembly for the transformers shall be done as per approved drawings;
- Any other activities / services not specially mentioned in technical provisions but necessary for completeness of the Equipment, its commissioning, performance testing or sustained operation / maintenance;
- Implementation of quality assurance plan and control of quality.

The Contractor shall be responsible to arrange all the tools and tackles necessary for the erection, testing and commissioning of the transformer. The Contractor shall submit the foundation design for the same to the Purchaser for approval.

The Contractor shall maintain at his site office up-to-date copies of all drawings. He shall also maintain continuous record of all stages of erection, test data and changes made in the drawings and supply one corrected copy to Purchaser.

#### **1.45. Inspection and Testing at Site**

The Contractor shall carry out a detailed inspection and testing programme for field activities covering areas right from the receipt of material stage upto commissioning stage. An indicative programme of inspection as envisaged by the Purchaser is given below. However, it is contractor's responsibility to draw up and carry out such a programme duly approved by the Purchaser. Testing of oil sample at site shall be carried out as per relevant standards.

##### **1.45.1. Receipt and Storage Checks:**

- 1 Check and record condition of each package, visible parts of the transformer etc. for any

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

damage;

- 2 Check and record the gas pressure in the transformer tank as well as in the gas cylinder;
- 3 Visual check for wedging of core and coils before filling up with oil and also check conditions of core and winding in general;
- 4 Check and record reading of impact recorder at receipt and verify the allowable limits as per manufacturer's recommendations. Downloading & analysis of Impact recorder data to be done at site in presence of Purchaser.
- 5 N2/Dry air Dew Point measurement and Paper Moisture Calculation shall be done after receipt at site.

#### **1.45.2. Site Installation Checks:**

- 1 Inspection and performance testing of accessories like tap changers, cooling fans, oil pumps self-regenerative breather etc.;
- 2 (i) Check the direction of rotation of fans and pumps;  
(ii) Check the bearing lubrication;
- 3 Check whole assembly for tightness, general appearance etc.;
- 4 Oil leakage test;
- 5 Capacitance and tan delta measurement of bushing before fixing / connecting to the winding, contractor shall furnish these values for site reference;
- 6 Leakage test on bushing before erection;
- 7 Measure and record the dew point of nitrogen in the main tank before assembly;
- 8 Check the correct connections to the earthing system.

#### **1.45.3. Site Commissioning Checks:**

- 1 Check for cleanliness of the transformer and the surroundings;
- 2 Check the colour of silica gel in silica gel breather or healthiness of self-regenerative breather;
- 3 Check the oil level in the breather housing, conservator tanks, cooling system, condenser bushing etc.;
- 4 Check the bushing for conformity of connection to the lines etc.;
- 5 Check for correct operation of all protection devices and alarms:
  - Buchholz relay;
  - Excessive winding temperature;
  - Excessive oil temperature;
  - Low oil flow;
  - Low oil level indication;
  - Pump failure protection;

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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- Low / high pressure of oil at cooler inlet;
  - High temperature of oil at cooler outlet;
  - Differential oil and water pressure gauge operation;
  - Low / high cooling water pressure;
  - Low water flow in coolers;
  - High inlet cooling water Temperature;
  - Low cooling water outlet Temperature;
  - Low cooling water outlet pressure.
- 6 Check for the adequate protection on the electric circuit supplying the accessories;
  - 7 Frequency response analysis (FRA);
  - 8 Measure Insulation resistance measurement for the following:
    - Control wiring;
    - Cooling system motor and control;
    - Main windings;
  - 9 Ratio test on all taps;
  - 10 Magnetizing current test;
  - 11 Check winding resistance on all taps.
  - 12 Capacitance and Tan delta measurement of winding and bushing;
  - 13 Capacitance and Tan delta measurement of bushing at variable frequency;
  - 14 Phase out and vector group test
  - 15 Dielectric test of oil, moisture content and dissolved gas analysis;
  - 16 DGA of oil just before commissioning and after 24 hours energization at site;
  - 17 Coolers-Pressure tests and operational tests (Alarm, Trip);
  - 18 Gradually put the transformer on load, check and measure increase in temperature in relation to the load and check the operation with respect to temperature rise and noise level etc.;
  - 19 Continuously observe the transformer operation at no load for 24 hours;
  - 20 Contractor shall prepare a comprehensive commissioning report including all commissioning test results and submit to Purchaser for future record;
  - 21 Energization tests (From the Grid);
  - 22 Bushing PF withstand test;
  - 23 **The Purchaser** and / or his representative including a third party inspection agency appointed by the **Purchaser** shall have the right to witness any or all tests;
  - 24 **The Purchaser** reserves the right to reject the transformer, if losses exceed the declared losses beyond tolerance limits as per IS / IEC or temperature rise in oil and of winding exceed the

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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value specified.

#### **1.46. Shop Inspection**

No equipment or material shall be dispatched to the site prior to its inspection at manufacturer's works by the **Purchaser** or his authorized representative. The **Purchaser's** representative shall have access and facilities for un-restricted inspection of manufacturer's works.

#### **1.47. Quality Assurance Program**

A quality assurance program detailing specific control procedure proposed to be adopted for controlling the quality characteristics relevant to each item of equipment shall be furnished. This shall include, but not be limited to the following table to ensure conformance of equipment specification and relevant Codes / Standards:

- Inspection of incoming raw materials;
- Tests to Verify chemical and physical properties of all materials including test certificates of bought-out items like motors, contactors, circuit breakers, instruments / gauges, etc., as per relevant Indian Standards;
- Tests during manufacture / assembly of transformer, its fittings and accessories including customer hold points, etc.;
- Testing on complete transformer and final inspection before dispatch.

Other tests as part of manufacturer's standard quality assurance plan. The Contractor shall submit the Quality Assurance Plan for the approval of the Purchaser.

#### **1.48. Spare Parts and Tools**

The spare parts mentioned hereunder are meant for use by the Purchaser for 5 years 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 Purchaser reserves the right to order any or all of such spares.

All spare parts shall be protected against corrosion and shall be marked with identification labels in the English Language. The identification shall be in accordance with the agreed Works Identification System.

All spare parts, tools and materials shall be delivered in marked boxes of sufficient sturdy construction to withstand long term storage. Material that is subjected to long term storage shall be

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

stored in a dry, ventilated room with low humidity.

Acceptance of any spare parts will not take place before the Contractor has submitted the complete final list of all spare parts and tools. They shall be replaceable without cutting or destruction of adjacent components. Before issue of the Completion Certificate, the spare parts shall be checked at the Site by the Contractor in presence of the Engineer / Purchaser.

#### **1.48.1. Mandatory Spares list**

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 Transformer (1-phase):

Item No	Description	Qty.
1	H.V bushing complete with gaskets etc.	3 set
2	L.V bushing & terminal suitable for connecting bus duct of 11 kV or as specified in technical specifications.	3 set
3	H.V neutral bushing and gaskets.	3 set
4	Gaskets for all openings with tank requiring gaskets	6 set
5	Oil and winding temperature indicators	3 set
6	Oil pump with motor	3 set
7	Silica gel drying agent / required for one filling of 3 Nos. transformers (Single-Phase)	1 Lot
8	Oil / water flow indicator with alarm contacts	3 set
9	Diaphragm and spares for conservator tank	3 set
10	Oil level indicator	3 set
11	Buchholz relay	3 set
12	Air dryer / silica gel breather – Self regenerating type	1 set
13	Oil / water cooler	2 set
14	Neutral C.T. (No. of cores & specifications as required for one Bank of 3-phase)	1 Nos
15	Phase C.T. (No. of cores & specifications as required for one phase)	2 set
16	Safety valve / Pressure relief valve	3 set
17	Pressure reducer / pressure regulator for cooling water	2 Nos
18	Motorized gate valve	3 set
19	Spares of off-circuit Tap Changer	2 set
20	Cooling water flexible and expansion joint (complete replacement for one transformer)	3 set
21	Magnetic oil level gauge	3 set
22	Set of valves	3 set
23	Fuses, MCCB and MCB's, Terminal Block	3 set
24	Indication Lamps	9 set
25	Starters, contactors, switches and relays for electrical control panel	3 set
26	Indicating Lamps with holders and Lens	3 set
27	Panel wiring rolls (100 m) of different sizes used for Marshalling Boxes.	6 Rolls

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

28	Air Cell	1 No.
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#### 1.48.2. Tools and Tackles

Item No.	Description	Qty.
<b>Mandatory Tools and Tackles</b>		
1	Oil filtration system complete with hoses, accessories etc. as per technical specification	2 set
2	Jacks required for lifting of Generator Transformer (1 phase)	3 Lot
3	Oil Sampling bottle of stainless steel having 1-liter capacity each along with impermeable oil proof, transparent plastic or rubber tube of 5 mm diameter (of sufficient length) along with suitable connectors to fit the tube on to the oil sampling valve of the transformer and the oil collecting bottles respectively. The bottles shall be capable of being sealed gas tight and shall be fitted with cocks on both ends.	10 set
4	Set of chain pulley block of suitable capacity required for handling of items in transformer vault along with required sling etc.	3 Lot
5	Winches of required capacity required for movement of GT on Track along with required accessories.	1 Lot
6	Spanners including D ring and box type of all sizes	3 set
7	Set of all types and sizes of eye bolts	3 Lot
8	Torque wrenches of each size	3 set
9	Racks for storage of Tools and Tackles	3 set

Any additional tools / special devices specifically required for assembly / erection, dismantling and maintenance of the Generator Transformer shall be listed and included in offer by the Contractor.

#### 1.49. Completeness of Equipment

All fittings and accessories of the transformers and associated equipment though may not have been specifically mentioned in the specification but are usually necessary for the completeness of the above equipment shall be deemed to be covered by the specification and shall be indicated and furnished by the contractor without any extra charges.



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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## 2. DISTRIBUTION TRANSFORMERS

### 2.1. Scope of Work

The Scope of works under the Contract covers design, manufacture, supply, transportation up to site, handling and storage at site, erection, testing and commissioning of following Distribution Transformers (Oil & Dry Type) complete with associated accessories and fittings, as specified and suitable for indoor mounting, spare parts for 5 years trouble free operation, special tools and tackles as per the Schedule of Requirements and the Technical Specification of the Bid Documents.

1. 5000 kVA 220/33 kV, 3 phase Station Service Transformer (SST)- 1 no. (Oil Type)
2. 160 kVA 33/0.433 kV, 3 phase Auxiliary Transformers (AT)- 2 no. (Oil Type)
3. 630 KVA, 11 kV/ 0.433 kV Unit Auxiliary Transformers (UAT)- 3 nos. (Dry Type)
4. 1500 kVA 33/0.433 kV, 3 phase Station Auxiliary Transformer (SAT) – 2 no. (Dry Type)

The transformers shall be designed, manufactured and tested in conformity with the latest issue of IS 2026 / IEC 76 and / or BS 171 and with this Specification where it differs from IEC 76. Tap changers shall be tested to IEC 214. The transformer and associated auxiliaries and equipment 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. 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.

Marshalling Box and other auxiliaries, as required also form part of the scope / offer.

Exclusion:

1. All kind of civil works like construction of soak pit, cable trenches, rail, firewall, and foundations for transformers are excluded from the scope of the Contract. However, supply of foundation bolts & other embedded parts, foundation drawings and other specification for the finalization of civil drawing where ever required shall be under the scope of contract.
2. Laying of earth mat is excluded from this scope of contract. However, earthing connection from the overground riser and providing design details for finalization of Powerhouses earthing system shall be included in the scope of this contract.
3. Supply of cable tray is excluded from the scope of contract. However, the contractor shall coordinate with the Powerhouse contractor for their requirement.

The Distribution Transformers supplied under the Contract shall be designed & manufactured either by the Contractor himself or the Contractor may outsource from other reputed transformer

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

manufacturers. In case of outsourcing by the Contractor, the selected vendor shall possess adequate experience in the design, manufacturer, supply, erection, testing and commissioning of transformers of similar class and rating. The Contractor shall submit the vendor's credentials and shall obtain prior approval from the Purchaser before engaging such vendor.

## 2.2. Reference Standards

The equipment and materials covered by this specification shall conform to the latest edition of following Indian Standards or equivalent IEC standards except where specified otherwise in this specification:

The offered equipment shall also confirm to the provisions of electricity rules and other statutory regulations currently in force at the place of installation.

IS: 2026 (Part I to IV) / IEC 76	Power Transformer
IS: 2099 / IEC 137	Transformer bushings
IS: 2705 / IEC 185	Current transformers
IS 1180	Outdoor Type Oil Immersed Distribution transformer
IS: 335	Transformer oil
IS: 3637	Gas and oil operated relay
IS: 325 and IS: 996	Motors
IS: 5120	Oil pumps
IS: 1822	Motor starters
IS: 3639	Fittings and accessories for power transformer
IS: 6088	Heat exchangers
IS: 3347	Dimensions for porcelain transformer bushings
IS: 6600 / IEC 354	Loading guide for oil-immersed transformers
IEC 270	Partial Discharge Measurement
IS: 3070	Lightning Arresters

## 2.3. Oil Type Distribution Transformers

The transformer shall be of core type, suitable in every way for operation on the system and under the conditions specified in this specification.

- One No. 5000 kVA; 220 kV / 33 kV, YNyn0 3 phase, 50 Hz., Oil type, Station Service Transformer (SST);
- One No. 160 kVA; 33 kV / 0.433 kV, Dyn11, 3 phase, 50 Hz., Oil type, HRT Intake Auxiliary

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Transformer (IAT).

- One No. 160 kVA; 33 kV / 0.433 kV, Dyn11, 3 phase, 50 Hz., Oil type, Valve House Auxiliary Transformer (VAT).

The Station Service Transformer (SST), HRT Intake Auxiliary Transformer (IAT) and Valve House Auxiliary Transformers (VAT) shall be rated to suit the requirement and located as shown in the drawings. The transformers shall be plinth mounted (SST) & Two Pole mounted (IAT & VAT) as per standard practice. The Bidder shall check the clearances that are required for the transformers as per relevant latest IS Codes / IEC / BS Codes and shall clearly indicate the same in the drawings.

The voltage ratio shall be as specified in salient data sheets. The transformers shall be skid / wheel mounted, along with bus duct /cable flange on HV side and / cable flange connection on LV side to suit the requirement indicated in Data Sheet. The transformers shall be (ONAN) cooled and shall be supplied complete with all accessories and auxiliaries as specified in the technical specification including oil for first fill and 10% extra insulating oil.

The transformers shall be transported with / without oil. In case transported without oil the tanks shall be sealed and filled with nitrogen gas under pressure and complete with pressure relief device for replenishing gas pressure.

### **2.3.1. Operating Conditions**

The maximum flux density in any part of the core and yoke at the rated MVA, voltage and frequency shall be such that under 10% continuous over voltage condition, it does not exceed 1.80 Tesla. Lower flux densities will be preferred if these result in lower noise levels.

The average sound level due to operation of the transformers and accessories shall not exceed the applicable limits specified in NEMA Standard Publication TR-1. The transformers shall be free from undue or harmful vibration of the transformer or accessories or any vibration which will cause avoidable noise.

Transformers shall be capable of operating at a voltage approximately 25% above the rated voltage for a period of one minute and 40% above the rated voltage for a period of 5 seconds.

Transformers shall be capable of withstanding without damage, the thermal and mechanical stresses caused by symmetrical or asymmetrical faults on any of the windings, i.e. HV or LV for system short circuit apparent power specified in Data sheets.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

### Technical Description

**Station Service Transformer (SST) is as under:**

Rated Power	5000 KVA (3 Phase)
Voltage Ratio	220kV/33kV
Type of cooling	ONAN
No. of phases	3-phase
Frequency	50 Hz
No. of Windings	02 (Primary and Secondary)
Cooling medium	Mineral oil
Rated System voltage (Primary winding)	220 kV
Rated System voltage (Secondary winding)	33 kV
Highest system voltage	245 kV / 36 kV
Primary winding connection of transformer & system of earthing	Star connected with neutral, solidly earthed.
Secondary winding connection of transformer and system of earthing	Star connected with neutral, solidly earthed.
Connection Details	GIB connection on HV side
Vector Group	YNyn0
Temperature rise over designed ambient of 40°C a) Top oil by thermometer b) Winding (Measured by resistance method)	45°C 50°C
Class of Insulation	A
Altitude	1100 m above msl.
Duty	Continuous
Insulation level	
➤ Lightning impulse withstand voltage	<ul style="list-style-type: none"> <li>• 1050 kV (HV)</li> <li>• 170 kV (LV)</li> </ul>
➤ Rated power frequency withstand voltage (1 min)	<ul style="list-style-type: none"> <li>• 460 kV (HV)</li> <li>• 70 kV (LV)</li> </ul>
Percentage Impedance voltage	7

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Tapping	Full capacity (rated MVA) taps shall be provided on Primary Winding to give a voltage variation of (+)5% to (-) 5% in equal steps of 2.5%.
Type of tap changing gear on primary side	Off circuit changing gear
Installation	Outdoor installation
Details of Auxiliary supply	220 V DC. -15 & + 10%, and 3 phase 415 V $\pm$ 10%
Maximum / limiting losses for transformer (without any positive tolerance) <ul style="list-style-type: none"> <li>➤ No load losses</li> <li>➤ Load losses at 75°C</li> <li>➤ Current density</li> </ul>	to be given by bidder (Please refer clause no. 2. 6)
Flux density (Tesla) at rated voltage and rated frequency	Less than 1.65
Type of rollers	Dismantlable flat / flanged bi-directional rollers
Type of Terminations	GIB at one end/Cable box at other end
Minimum phase to phase and phase to earth clearance in air	Not less than 2127 mm.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Description and Rating of the Intake and Valve House Auxiliary Transformer (IAT&VAT) is as under:	
Rated Power	160 KVA (3 Phase)
Voltage Ratio	33 kV / 433 V
Type of cooling	ONAN
No. of phases	3-phase
Frequency	50 Hz
No. of Windings	02 (HV and LV)
Cooling medium	Mineral oil
Rated System voltage (Primary winding)	33 kV
Rated System voltage (Secondary winding)	415 V
Highest system voltage	36 kV (HV)
Primary winding connection of transformer & system of earthing	delta connected (un-grounded)
Secondary winding connection of transformer and system of earthing	Star connected with neutral solidly earthed.
Connection Details	HV:- Through a transformer bushing termination in Air LV: - 415 V Termination through Low voltage cable.
Vector Group	Dyn11
Temperature rise over designed ambient of 40°C c) Top oil by thermometer d) Winding (Measured by resistance method)	45°C 50°C
Class of Insulation	A
Altitude	1100 m above msl.
Duty	Continuous
Insulation level	
➤ Lightning impulse withstand voltage	• 170 kV
➤ LV	• N/A
➤ Rated power frequency withstand voltage	• 70 kV
➤ LV	• 3.0 kV
Percentage Impedance voltage	4%

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Short circuit level for 33 kV System (Primary Delta Wdg.)	25 kA
Tapping	Full capacity (rated MVA) taps shall be provided on HV Winding to give a voltage variation of (+)5% to (-) 5% in equal steps of 2.5%.
Type of tap changing gear on primary side	Off circuit tap changing gear.
Installation	Outdoor installation on two pole structure
Details of Auxiliary supply	3 phase 415 V $\pm$ 10%
Maximum / limiting losses for transformer (without any positive tolerance) <ul style="list-style-type: none"> <li>➤ No load losses</li> <li>➤ Load losses at 75°C</li> <li>➤ Current density</li> </ul>	As specified at Guarantee Clause 2.5

### 2.3.2. Construction Details

#### 2.3.2.1. Core Material

All transformer cores shall be fabricated from high grade non-ageing, high permeability, cold-rolled super grain-oriented silicon steel lamination known as HI-B steels trade name or other approved steel having low-loss characteristics and preferably leading to low noise levels. The thickness of the sheet shall be 0.23 mm or less. However, the Bidder shall indicate the thickness of the sheet in the Bid Document.

#### 2.3.2.2. Core Construction

The magnetic circuit shall be of core construction designed to avoid static discharges and the development of short circuit paths within itself or to the earthed clamping structure and the production of flux component at right angles to the plane of lamination which may cause local heating. After shearing, the laminations shall be treated to remove all burrs and remove residual stresses so that the laminations are flat and the finally assembled core is free from distortion. Laminations shall be coated with a durable baked enamel insulation coating, which shall be inert to the action of hot transformer oil. Paper and varnish insulation will not be accepted. The nature of insulation shall be stated in the Bid. Mitered joints between cores and yokes shall be employed on all sizes of transformers for which this technique is practicable. The mitered joints in the core shall be interleaved. On no account must 'butt' joints be offered.

All parts of the core shall be of robust design which are capable of withstanding mechanical shocks during normal lifting, transportation and handling of the transformer, and bracing of the core and

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

winding assembly must be adequate to prevent any movement of core and winding relative to the tank during the conditions mentioned above. The clamping structure shall be so constructed that eddy currents are minimum.

All structure members of the assembled cores shall be of steel except where conventional core-bolt clamping is replaced by taping or banded-clamping or epoxy fiber technique.

Adequate fitments, eyes and lugs, shall be provided for lifting the completed core and windings, and suitable accommodation, attached to each transformer, shall be provided for the storage of any removable parts of the lifting gear.

All castings shall be fettled, and structural steel shall be adequately painted before being built into the structure. Any non-magnetic or high-resistance alloy included in the design shall be subject to approval. All painting designed to be under oil or in contact with oil shall be to the Engineers approval.

The supporting framework of the core shall be designed to avoid the presence of pockets which would prevent complete emptying of the tank through the drain valve, cause the trapping of air during filling, or cause the tripping due to gases which evolve during in-service faults. All steel sections used for supporting the core shall be thoroughly sand blasted or shot blasted after cutting, drilling and welding.

#### **2.3.2.3. Core Oil Ducts**

Suitable axial oil ducts shall be provided where necessary to ensure adequate cooling by free circulation of oil. The winding structure and main insulation shall not obstruct the free flow of oil through such ducts. Where the magnetic circuit is divided into pockets separated by more than 0.25 mm by cooling ducts parallel to the plane of the laminations or by insulating material, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between the pockets. Alternatively, resistance wire connections may be used if approved by the Engineer where this is part of the manufacturers standard design.

Where oil ducts or insulating barriers parallel to the plane of the laminations divide the magnetic circuit into two or more electrically divided part, the ducts or barriers shall be bridged as stated previously and the magnetic circuit shall not be regarded as being of sectional construction.

#### **2.3.2.4. Core Insulation**

Individual laminations shall be insulated with material, which will not deteriorate due to the action of pressure and hot oil.

The magnetic circuit shall be earthed. With the earthing removed, the magnetic circuit shall be insulated from the clamping and supporting structure and all structural parts, and insulation of core



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

to bolts and core to clamp plates shall withstand a test voltage of 2 kV RMS at 50 Hz for one minute.

The class and type of insulation and the method of applying it on the core bolts and under nuts and side plates shall be stated.

#### **2.3.2.5. Core Earthing**

All metal parts of the transformer except individual core laminations, core bolts and side-clamping plates shall be maintained at earth potential.

The magnetic circuit shall be earthed to the clamping structure through one removable core-insulation-test link only, placed in an accessible position beneath the inspection opening in the main-tank cover. The connection to the link shall be on the same side of the core as the main clamping-structure earth connections to the tank and shall be taken from the extreme edge of the top yoke.

Magnetic circuits having an insulated sectional construction shall be provided with a separate link for each individual section and the arrangement of the connections shall be subject to approval.

Where the magnetic circuit is divided into pockets by cooling ducts parallel to the plane of the laminations or by insulating material over 0.25 mm thickness, tinned copper strip bridging pieces shall be inserted to maintain electrical continuity between pockets.

All earthing connections with the exception of those from the individual coil clamping rings shall have cross-sectional area of not less than 0.8 cm<sup>2</sup>. Connections inserted between laminations of different sections of core shall have a cross-sectional area of not less than 0.2 cm<sup>2</sup>.

Where clamping ring of coil are of metal at earth potential, each ring shall be connected to the adjacent core clamping structure on the same side of transformers the main earth connections.

#### **2.3.2.6. Core Flux Density**

The maximum flux density in any part of the core and yokes at nominal ratio, frequency and voltage shall not exceed 1.65 Tesla. Lower flux densities will be preferred if these result in lower noise levels. Core placing shall be as magnetically balanced as possible. The Bidder shall clearly indicate additional cost, if any, if low flux density is adopted.

### **2.3.3. Winding**

#### **2.3.3.1. Conductor Material**

The conductor windings shall be of high-conductivity electrolytic grade copper free from scale and burns and transposed winding conductors shall be employed where appropriate. Windings of

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

transformers shall preferably be made in dust proof conditioned atmosphere.

The windings shall be designed to reduce to a minimum the out-of-balance electromagnetic forces in the transformer at all voltage ratings / tapping and the voltage between adjacent coils shall be kept as low as consistent with the good design.

All permanent current carrying joints in the windings and leads shall be brazed. The windings shall be designed to reduce to a minimum the out of balance forces in the transformer at all ratios and special care shall be given to design and construction of tapped coils and connections.

The construction of the windings shall be such as to ensure uniform voltage and stress distribution on the windings in the event of high frequency impulses applied to the windings and the means adopted for the same shall be stated in the Bid.

The windings shall be so designed that all coil assemblies of identical voltage rating shall be interchangeable and field repairs to the windings can be made readily without special equipment. The coils shall be supported between adjacent sections by insulating spacers and barriers. The windings shall be dried by vapour phased system.

#### **2.3.3.2. Winding Clamping and Bracing**

The windings and connections shall be adequately braced to withstand mechanical shocks and electromagnetic impulsive force which may occur during handling, transportation and transient current surges. Bracings and other insulation used in the assembly of the windings shall be arranged to ensure free circulation of the oil and to reduce hot spots in the windings.

The stacks of windings shall receive adequate shrinkage treatment before final assembly so that any further shrinkage during service is not possible. However, adjustable devices shall be provided for taking up any shrinkage of coils in service.

The coil-clamping arrangement and the finished dimensions of any oil ducts shall be such as will not impede the free circulation of oil through the ducts.

Coil-clamping rings shall be of approved material (preferably steel) but axially laminated material other than bakelised paper shall not be used. Where such bakelised paper rings are used it will only be approved as major insulation between the windings and earth if the creepage-voltage stress obtained by dividing the line voltage by the creepage distance to earth does not exceed 200 kV per meter. Metal clamping rings will be earthed. Clamping assemblies shall be arranged to prevent deterioration of the core characteristic.

Any metal pieces in contact with nonmetallic clamping rings shall be so designed and secured that they do not weaken the electrical or the mechanical properties of the rings.

If the winding is built up of sections or disc coils, separated by spacers, the clamping arrangements

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

shall ensure that equal pressure is applied to all columns of spacers. All such spacers shall be of approved material and shall receive adequate shrinkage treatment before assembly.

#### **2.3.3.3. Winding Insulation**

All windings for system voltages above 33 kV shall have graded insulation. Use of enamel as a sole conductor insulation is prohibited.

The insulation of windings and connections shall be free from insulating composition liable to soften, ooze out, shrink or collapse and be non-catalytic and chemically inert in transformer oil during service.

For oil immersed transformers the insulating media shall be of Class A material as defined in IEC 85.

All neutral points of star windings shall be insulated for the voltages specified.

#### **2.3.3.4. Winding Connections**

The transformers should be connected in accordance with the IEC.

### **2.3.4. Transformer Tank**

#### **2.3.4.1. Tank Construction**

Each oil immersed type transformer shall be enclosed in a suitably stiffened welded steel oil-tight tank construction. Tanks shall be of welded construction and fabricated from tested qualify low carbon steel of adequate thickness. The weld procedure & performance shall be in line with ASME – BPV - IX. The thickness and bracing of the tank shall be such that the tank together with core and oil can be lifted and transported without damage or loss of oil tightness. All seams and those joints, not required to be opened at site, shall be factory welded and wherever possible they shall be double welded. All welding shall preferably be stress relieved.

The base of each tank shall be so designed that it shall be possible to move the complete transformer unit by skidding in any direction without injury when using rollers, plates or rails. The transformer tank shall be suitable for movement in both directions during shipment.

The main tank body including tap-changing compartment, radiators and coolers shall be capable of withstanding full vacuum.

Aluminum tanks shall not be considered.

Suitable guides shall be provided in the tank for positioning the core and coil assembly. The tanks shall be so designed that with the cores and windings in position there shall be no possibility of formation of pockets where air or gas being trapped when filling the tank with oil, and also water shall not be trapped on the exterior of the tank. Where pockets cannot be avoided, pipes shall be

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

provided to vent the gas into expansion pipe. The tanks shall be fitted with pockets for a thermometer and the bulbs of a winding temperature indicator and an oil-temperature indicator in maximum temperature zone at MCR (Maximum Continuous Rating) and it shall be possible to remove the bulbs without lowering the oil in the tank. The thermometer pockets shall be fitted with a captive screwed cap to prevent the ingress of dirt and water. Protection shall be provided as necessary for the capillary tube. Tank stiffeners shall be provided for general rigidity and these shall be designed to prevent retention of water. Adequate space shall be provided at the bottom of the tank for collection of sediment. Tanks shall be designed to withstand mechanical shocks during transportation, vacuum filling of oil, continuous internal pressure of 100.66 KN /m<sup>2</sup> over normal hydrostatic pressure of oil and short circuit force.

The tank shields (if provided) shall be such that no magnetic field shall exist outside the tank. They shall be of magnetically permeable material. If required, impermeable shields shall be provided at the coil ends. Tank shield shall not resonate when excited at the natural frequency of the equipment. Bidder shall confirm use of tank shields.

#### **2.3.4.2. Tank Lifting and Haulage**

Each tank or enclosure shall be provided with the following handling facilities the first three of which must each be capable of lifting and / or moving the transformer complete and filled with oil.

Lifting lugs or eyes of ample dimensions designed so that standard lifting shackles can be readily attached. The lifting eyes, lugs or hooks shall have a factor of safety of not less than 2 (two) to allow for possible unequal lifting forces.

A minimum of four jacking pads shall be suitably located in accessible positions to make it possible to change the direction of wheels through 90°, when the transformer, complete with oil, is lifted on jacks to permit movement of the transformer both in longitudinal and transverse directions. A convenient track gauge in both longitudinal and transverse direction shall be chosen. Means shall be provided for locking the swivel movements in positions, parallel to and at right angles to the longitudinal axis of the tank. Suitable stoppers for the track wheels shall also be supplied. The pads shall be adequately braced and project a sufficient distance from the transformer side to enable a standard jack to be properly located. The minimum height of the lugs above the base shall be 500 mm excluding the under base dimensions, if detachable.

Four anchor points shall be fitted to each transformer tank or frame at not more than 760 mm from the base to enable the transformer complete (and filled with oil) to be slewed or hauled in any direction. Suitable haulage holes shall be provided for transformer wheeling in all four directions.

Lifting handles on the tank-lid or enclosure hand-hold covers be provided where the size and weight

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

of such covers would make manhandling difficult.

The transformer tank shall be supported on a strong structural steel base equipped with forged steel or cast steel single flanged / flat wheels suitable for moving the transformer completely filled with oil. The number and the spacing of wheels shall be specified in the Bid. The wheels shall be provided with grease nipples. Arrangement for clamping of the wheels with the rails, capable of being put on and off easily, shall also be provided. The structural steel supporting base shall be so designed that the centre of gravity of the transformer, with or without oil, will not fall outside the base support members for a tilt of the base of 15 degrees from the horizontal.

The Supplier shall provide / supply adequate number of hydraulic jacks for lifting the transformer for changing the plane of rotation of wheels.

#### **2.3.4.3. Tank Covers**

Adequately sized inspection openings of suitable design, one at each end of the tank, shall be provided on the tank cover. The openings shall be of sufficient size to afford easy access to internal connections of bushings, current transformers winding connections and earth link for testing, etc. The design should be such that water shall not collect near the gasketed joints. Tank covers or enclosure panels shall be so constructed that they can be removed and replaced without sustaining damage. Inspection covers shall also be fitted and these shall not exceed 25 kg in weight.

The tank and cover shall be provided with sufficient and properly spaced bolts and gaskets with metal inserts.

All joint faces shall be machined or ground and arranged to prevent the ingress of water or leakage of oil with a minimum of gasket surface exposed to the action of air or oil. Oil resisting synthetic rubber gaskets are not permissible except where the synthetic rubber is used as a bonding medium for cork or similar material. Gaskets, of resilient material which will not deteriorate under the action of hot oil, are to be as thin as possible consistent with the provisions of a good seal and full details of all gasket sealing arrangements shall be shown on the plant drawings.

Enclosure covers and inspection panels shall be accurately fitted and robust to prevent distortion. Countersunk screws may be used for fixing. Gaskets shall be used to deaden vibration where necessary.

The tank cover shall be sloped to prevent retention of rain water and shall not distort when lifted. Bushings, turrets, covers of inspection openings, thermometer pockets etc. shall be designed to prevent ingress of water into or leakage of from the tank. Turrets and other parts surrounding the conductors of individual phase shall be non-magnetic. Necessary provisions shall be provided to drain out leakage oil / water at the lowest points of the bushing flange wherever required. The same

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

shall be properly sealed with dual stop cock arrangement.

The tank cover shall be fitted with thermometer pockets (on position of maximum oil temperature at MCR) for thermometer and bulbs of oil and winding temperature indicators. The thermometer pockets shall be filled with a captive screw top to ingress of water. It shall be possible to remove these bulbs without lowering the oil in the tank.

#### **2.3.4.4. Earthing of Tank**

Two substantial earthing terminals / pads suitable for connecting 50x8 mm mild steel flat capable of carrying the maximum possible earth-fault current shall be provided at positions close to the two diagonally opposite bottom corners of tank. The terminals shall be designed to carry this current without damage for a duration at least equal to the short circuit period for which the main windings are designed, in accordance with IEC 76. These grounding terminals shall be suitable for bolted connection. Two earthing terminals shall also be provided each on cooler, marshalling box and any other equipment mounted separately.

#### **2.3.4.5. Bonding**

Substantial bonding-connection studs must be provided to permit the bonding of all transformer ancillary equipment and housings not forming an integral part of the main transformer tank.

#### **2.3.5. Pressure Relief Device**

Each tank shall be fitted with an approved pressure relief device designed to protect the tank from damage, and to control the explosion of oil under internal fault and may result in damage to the equipment. An extension pipe shall be fitted above the device such as to direct the major flow of ejected oil down wards and shall be fitted so as to permit its removal without disturbing the device or its flange fixings. The device shall be so located as not to interfere with the electrical clearances for any overhead connections. The device shall fully reseal after release of excess pressure.

The device shall operate at a static pressure, which shall be less than the hydraulic test pressure of transformer tank. Means shall be provided to prevent ingress of rain water.

One set of electrically insulated contact shall be provided for alarm / tripping. A mechanical indicator, manually resettable type and clearly visible from a long distance shall be provided to indicate that the valve has operated.

For all transformers, the conventional diaphragm type of explosion vent shall also be provided and shall be situated above maximum oil level. An equaliser pipe shall be connected to pressure relief

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

device from the conservator.

### **2.3.6. Bushing Insulators**

All bushings shall have the current rating, voltage rating, basic insulation level, creepage distance etc. as indicated in the Schedule / IS: 2099 / IEC 37. The standard dimensions shall be kept in view so that transformer can accept any bushing of parameter and dimensions. The bushings shall be subject to snowfall (if applicable). Proper care of the increase in weight due to snow shall be taken care of while designing the bushings. Any change in ratings due to the same shall be intimated by the Bidder in the Bid document.

A flexible pull-through lead suitably sweated to the end of the windings is to be continuous to the connector which is housed in the helmet of the bushings.

All porcelain is to be sound, free from defects and thoroughly vitrified. The glaze must not be depended upon for insulation. The glaze is to be smooth, hard, of a uniform shade of brown and shall cover completely all exposed parts of the insulator. Outdoor insulators and fittings are to be unaffected by the specified atmospheric conditions.

The porcelain must not engage directly with hard metal and, where necessary, gaskets are to be interposed between the porcelain and the fittings. All porcelain clamping surfaces in contact with gaskets are to be accurately ground and free from glaze. All porcelain insulators are to be designed to facilitate cleaning. Bushing shall also be provided with oil level indicator, suitably placed.

All fixing material used is to be of suitable quality and properly applied and must not enter into chemical action with the metal parts or cause fracture by expansion in service. Cement thicknesses are to be as small and even as possible and proper care is to be taken to centre and locate the individual parts correctly during cementing.

Each porcelain bushing or insulator is to have marked upon it the manufacturer's identification mark. Each porcelain part is, in addition, to be marked to indicate the date of firing. These marks are to be clearly legible and visible after assembly of fittings and are to be imprinted and not impressed. For porcelain parts the marks are to be imprinted before firing and for paper bushings before varnishing.

When a batch of insulators bearing a certain identification mark has been rejected, no further insulators bearing this mark are to be submitted and the contractor is to satisfy the Engineer that adequate steps will be taken to mark or segregate the insulators constituting the rejected batch in such a way that there can be no possibility of the insulators of the insulators being re-submitted for test or supplied for the use of the Purchaser.

Bushing insulators are to be mounted on the tank in a manner such that the external connections



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

can be taken away clear of all obstacles. Neutral bushings are to be mounted in a position from which a connection may be taken if required to a neutral current transformer mounted on a bracket secured to the transformer tank.

The clearances from phase to earth must not be less than those stated in the Schedules.

The bushing flanges must not be of the re-entrant shape which may trap air.

### **2.3.7.Cable Connection**

#### **2.3.7.1. Cable Boxes**

HV cable box, if specified, shall be suitable for 3 core or 3X1 core HV cable of size specified. The gland plate shall be non-magnetic / Aluminum in case of termination 3X1C HV cables. The box shall be weather proof as well.

#### **2.3.7.2. Cable Boxes for Marshalling Kiosk**

The power cable and control cable shall be designed to accommodate PVC insulated, single / multi core armored and PVC sheathed cables. The marshalling box shall be with minimum IP-54 enclosure, weather proof & with canopy.

### **2.3.8.Conservator Vessels and Breather**

#### **2.3.8.1. Vessels**

A conservator shall be mounted above the highest point of the oil-circulating system of the transformer. Tanks shall be formed of substantial steel plate. Connections between the main tank and the conservator shall be such that air or gas is not entrapped and Buchholz relays can be correctly installed. Conservator shall be provided in such a position so as not to obstruct the electrical connections to the transformer. Conservator shall be complete with sump and drain valve. The oil connection from transformer to the conservator shall be arranged at a rising angle of 3 to 9 degree to the horizontal and to the Buchholz relay.

The oil pipe from the base of the conservator tank shall project into the conservator for a distance of not less than 50 mm so as to form a water trap. Conservator shall be designed so that it can be completely drained by means of the drain valve provided, when mounted as in service.

One end of the conservator shall be fixed by bolts so that it can be removed to enable the tank to be cleaned.

The capacity of each conservator tank shall be adequate to accommodate the oil preservation system and volumetric expansion and contraction of oil in the whole system, over the extreme range possible in operation, i.e. equipment unenergised in an ambient temperature of -5°C, to the



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

condition corresponding to maximum oil temperature.

Each conservator shall be fitted with:

- a. One magnetic oil-level indicator and a gauge of direct reading prismatic glass type visible from ground level and indicating oil levels over the range specified above. The oil-level indicator shall be marked to indicate the correct oil level with the oil at a temperature of 15°C, 30°C and 90°C;
- b. Filling orifice with an air-tight captive-screwed cap;
- c. Low oil level alarm initiating device;
- d. Air bag inside main conservator tank, shall be fitted with a silica-gel filter breather as described elsewhere in the specification;
- e. A valve shall be provided at the conservator to cut-off the oil supply to the transformer, after providing a straight run of pipe on the tank side of the gas and oil actuated relay and at least three times the internal diameter of the pipe on the conservator side of the gas and oil actuated relay.

#### **2.3.8.2. Breathers**

The Transformers shall be provided with silica-gel breather of an approved type complete with oil-seal, oil-seal oil-level indication window and a sight glass for inspection of the silica-gel. A visual indication of the extent to which the drying agent has absorbed moisture is preferred, showing how much active material remains effective. The unit must allow simple cleaning and replacement of the desiccator and sealing oil without the use of tools, by using wing-nuts or similar forms of corrosion-resistant hand-tightening devices. The breather should be mounted at approximately 1,000 mm from ground level and must, together with its connecting pipe, be firmly fixed to the main tank by means of substantial brackets. One spare charge of silica-gel shall be provided with each transformer.

Breather shall be designed so that passage of air is through silica-gel and external air is not in contact with silica-gel.

#### **2.3.9. Valves and Flanges**

Valves and flanges shall be in accordance with the relevant Indian / International Standard / Manuals.

Inside surface of valves shall be clean and valve ends shall be suitably blanked at the time of dispatch. Asbestos / graphite packing material shall not be used for gland packing / gasket material. Valves and flanges shall be painted from inside and outside as per relevant IS codes. Machined and flanged surfaces shall be suitably protected against rusting and transit damage. All hardware used

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

shall be cadmium plated / electro-galvanised.

Each oil filled transformer shall be fitted with the following valves and plugs / flange with standard screw connection (as minimum):

- a. One filter valve located near the top of the tank;
- b. One filter valve located near the bottom of the tank and diagonally opposite to the valve specified in (a);
- c. One valve of adequate size together with such arrangements as may be necessary inside the tank to ensure that the tank can be completely drained and / or the oil can be sampled;
- d. One valve in the oil-actuated relay connection;
- e. One drain valve so arranged on the conservator tank that it can be completely drained of oil as far as practicable. Size of drain valve shall be in accordance with IS: 3689;
- f. One valve between the transformer and relay and another between the relay and conservator.

All valves in oil line shall be suitable for operation with transformer insulating oil at 100°C. Every valve shall be provided with an indicator to show clearly the position of the valve. All valves shall be provided with flanges having machined faces. Means shall be provided for pad locking the valves in the open and closed position.

### **2.3.10. Cooling System**

The transformer shall be ONAN cooled. Detachable radiators shall be fitted on the main tank with machined flanged outlet and inlet. Each radiator shall be provided with drain plug at Bottom and air release plug at the top. Valves shall be provided on the tank at each point of connection to radiators.

In case separate cooler banks are used, they shall be suitable for mounting on a flat concrete base. These shall be provided with a valve at each point of connection to the transformer tank, removable blanking plates to blank off main oil connections to each cooler. Thermometer pockets with captive screwed cap at inlet and outlet of each separate cooler filter valve at top and bottom and air release plug.

### **Motors**

The motor shall be squirrel cage totally enclosed weather proof type suitable for direct starting and for continuous running from 415-240 volts, three phase / single phase 50 Hz supply. The motors shall comply with IS as applicable for continuous rated machine.

All motors shall be capable of continuous operation at frequency 50Hz with variation of  $\pm 5\%$  and 415 / 240 V AC  $\pm 10\%$  variation of the normal voltage without injurious overheating.

All motors shall have ball or roller bearing with hexagonal nipples for greasing. In case of vertical

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

spindle, motor shall have bearing capable of withstanding thrust, due to weight of the moving parts.

Varnished cambric or glass insulator shall be used for connections from stator winding to the terminal suitable for external wiring. The motor terminals shall be of stud type and totally enclosed.

### **2.3.11. Temperature Indicating Devices (and Relays)**

#### **2.3.11.1. Winding Temperature Indicator (WTI)**

A device for measuring the hot spot temperature of the winding of transformer shall be provided. The accuracy class of winding temperature indicator shall be  $\pm 2^{\circ}\text{C}$  or better complete with a winding temperature indicator with separate alarm and trip contacts of approved design. They shall be fitted with a dial-type indicator calibrated in degrees Celsius and fitted with a hand-reset pointer to register the highest temperature attained. The tripping contacts of WTI shall be adjustable to close between  $60^{\circ}\text{C}$  and  $120^{\circ}\text{C}$  and alarm contacts to close between  $50^{\circ}\text{C}$  and  $120^{\circ}\text{C}$  and shall reopen when the temperature falls by  $10^{\circ}\text{C}$  (Adjustable).

The winding temperature indicator shall be so mounted in the transformer marshalling kiosk attached to the main tank that the dial is not more than 1500 mm from the ground level, and the cover shall be equipped with a viewing aperture of adequate size, fitted with clear glass. Mechanical protection shall be provided for the capillary tube, and sharp bends avoided.

It shall comprise the following:

- Temperature sensing element;
- Image coil with bushing current transformer;
- Auxiliary CTs if required to match the image coil, shall be furnished and mounted in the marshalling box;
- 150 mm local indicating instrument with maximum reading pointer mounted in marshalling box. It shall have two adjustable potential free contracts, one for winding temperature high alarm and one for trip, in addition to the contacts required for control of cooling equipment;
- Automatic ambient temperature compensation;
- All contacts shall be adjustable on a scale and suitable for connection to 220 V DC Circuit. These shall be accessible on removal of the cover;
- The WTI shall have a full-scale deflection of at least  $240^{\circ}\text{C}$  and shall have linear graduations to read every  $3^{\circ}\text{C}$ .

The winding temperature indicator shall be energised from a current transformer connected to a heater coil and actuating on to a bulb and capillary tube. Terminals and links shall be provided in the marshalling box for checking the output of the current transformer on load and disconnecting the current transformer from the heater coil to enable the instrument to be used as an oil temperature indicator. A test winding shall be incorporated in the current transformer and the connection

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

brought down to suitable terminals in the marshalling box to enable the operation of the instrument to be checked electrically.

The contacts used to control cooling plant motors on the above device shall be adjustable to close between 50°C and 100°C and reopen when the temperature falls by any desired amount between 15°C and 30°C.

#### **2.3.11.2. Oil Temperature Indicator (OTI)**

The Transformers shall be provided with oil-temperature indicators complete with alarm and trip contacts of approved design. They shall each be fitted with a dial type indicator calibrated in degree Celsius and fitted with a hand-reset pointer to register the highest temperature attained.

All transformers shall be provided with a 150 mm dial type thermometer for top oil temperature indication. The thermometer shall have adjustable, potential free alarm and trip contacts, maximum reading pointer and resetting device and shall be mounted in the Marshalling Box. A temperature sensing element suitably located in a pocket in the top oil shall be furnished. This shall be connected to the OTI by means of Capillary tubing. Accuracy class of OTI shall be  $\pm 2^{\circ}\text{C}$  or better. The OTI shall have a full scale deflection of at least 240°C and shall have linear graduations to read every 3°C. In case an RTCC Panel is supplied with transformer, a remote repeater dial indicating oil temperature shall be provide on RTCC Panel and OTI shall be suitable for the purpose.

Each oil-temperature indicator shall be so mounted in the marshalling box that the dial is not more than 1500 mm from the ground level, and the cover shall be equipped with a viewing aperture of adequate size, fitted with clear glass. If the temperature-measuring device makes use of a capillary tube, mechanical protection shall be provided and sharp bends avoided where the tube enters the marshalling box.

#### **2.3.12. Buchholz Devices**

A double float type Buchholz relay conforming to IS: 3637 shall be provided. All gas evolved in the transformer shall collect in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation. The device shall be provided with two potential free contacts, one for alarm on gas accumulation and the other for tripping on sudden rise of pressure.

A suitable gas collecting device shall also be provided with each transformer which shall be mounted in a conveniently accessible position. The gas collector of the relay shall be connected to gas sampling device with a copper tube. The above should also have a proper arrangement for draining the oil from the relay.

Each oil-containing equipment i.e. transformer tank, tap changer tank, connection chamber etc.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

shall be fitted with approved vibration-proof gas and oil-actuated relay equipment preferably of the Buchholz type, having alarm and tripping contacts which close following the accumulation of gas, loss of oil or on the occurrence of an oil surge.

An isolating valve shall be mounted on either side of the relay so that it can be easily removed for testing purposes.

A machined surface shall be provided on the top of each relay to facilitate the setting of the relays and to check the mounting angle in the expansion pipe and the cross level of the relay.

A straight run of pipework shall be provided for a length of five times the internal diameter of the pipe on the tank side of the oil-actuated relay and three times the internal diameter of the pipe on the conservator side of the oil-actuated relay.

The design of the relay mounting arrangements and the associated pipework and the cooling plant shall be such that mal-operation of the relays will not take place under service conditions.

The oil circuit through the relays shall not form a delivery path in parallel with any circulating oil pipe, nor shall it be into or be connected through the pressure relief vent. There shall be no sharp bends in the pipework.

The Bidder shall submit full details, including pipe sizes, oil-operating velocities, etc., and the size and run of each proposed relay with his Tender.

### **2.3.13. Tap Changer**

#### **2.3.13.1. Arrangement (Off-Circuit Tap changer (OCTC))**

Off-circuit tapping shall be provided on the high voltage windings for a variation of no-load primary voltage as specified. The tap changing shall be possible without disturbing the transformer in any way except de-energizing.

Off-circuit tap-changing for the Transformers shall be carried out by means of a single, external, hand- operated tapping switch mounted on the side of the enclosure for simultaneous switching of similar taps on the three phases by operating an external handwheel.

The tapping switch shall have a spring-loaded captive bolt or other approved means on the moving part which positively locates the switch correctly at each tapping position. This bolt must be lockable at each tapping position and shall be provided with a suitable padlock and keys. Moving the switch from one tapping position to the another shall require that the bolt be withdrawn by hand from its locating socket on the transformer tank against the spring pressure. An indicating device shall be provided to show the tap in use. The complete tap changing mechanism shall be built with high electrical, mechanical, and thermal safety factors, and the contacts shall be capable of withstanding the full short-circuit current of the transformer without injury. The tap changing

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

mechanism shall render it impossible to leave a winding open or short-circuited when the operating wheel is placed in a locked position.

The cranking device for manual operation of the off circuit tap changing gear shall be removable and suitable for operation by a man standing on ground level. The mechanism shall be complete with the following:

- a. A mechanical operation indicator;
- b. Mechanical tap position indicator which shall be clearly visible from near the transformer;
- c. Mechanical stops to prevent over cranking of the mechanism beyond the extreme tap position.

Tap position numbers corresponding to the tapping switch bolt-locating sockets shall be cast or engraved in a metal indicating plate fixed to the tank, and a keyed metal pointer on the tapping switch operating handle shall show clearly at which tapping number the transformer is pointing.

Wherever OLTC has been specified in place of off-circuit tap changer, the bidder shall include the same along with RTCC panel and automatic voltage correction relay of reputed make / numerical type.

#### **2.3.13.2. Tap Position Numbering**

All tap-position indicators shall be marked with one numeral integer for each tap position, beginning at number 1. Adjacent taps shall be numbered consecutively in such a manner, that when moving a tap to a new tapping position which has a higher number, the no-load output voltage of the untapped winding increases. The marking of tapped winding which may be reversed shall be based on that connection which gives the highest effective no. of turns for the winding connected to the tap changer.

The terminal marking and their physical position shall be in accordance with IS: 2026 / International Standards unless specified otherwise.

#### **2.3.14. Marshalling Kiosks**

- a. A sheet steel weather, vermin and dust proof marshalling box with sloping / domed roof with water tight hinged and pad locked door of a suitable construction with interior and exterior duly painted shall be furnished with each transformer to accommodate:
  - i Temperature indicators mounted at a height not more than 1600 mm from ground level;
  - ii Control and protection equipment for the electrical control of tap changer;
  - iii Control and protection equipment for the cooler control if a separate control cabinet is not

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

provided;

- iv Terminal boards and gland plates for incoming and outgoing cables;
  - v Illumination lamp and 5 A, 240 V 3 pin sockets and switch.
- b. The sheet steel used shall be at least 2.0 mm thick. The box shall be free standing, tank mounted / floor mounted type and have sloping roof. The degree of protection shall be IP:55 in accordance with IS.2147 / International Standards;
  - c. The marshalling box shall have a glazed door of suitable size for convenience of temperature indicators reading;
  - d. All cables shall enter the kiosk from the bottom and the gland plate shall be not less than 450 mm from the base of the tank. The gland plate and the associated compartment shall be sealed in suitable manner to prevent the ingress of moisture, rodents, insects etc. from the cable trench. Gland plates, cable lugs, cable glands, etc. shall be supplied along with Marshalling box;
  - e. The marshalling box shall be supplied with space heater and cubicle lighting with ON-OFF switches and associated fuses;
  - f. It shall be located in such a way that, the front shall not face the transformer. It shall be mounted at least 500 mm above the ground level.

The gland plate shall be made into two detachable halves, for facilitating the termination of other supplier's cables and contractor's cables separately.

Terminal blocks for control and power wiring shall be rated not less than 600 volts. Terminals shall be provided for the following, as a minimum:

- a. Leads from alarm contacts on the pressure relief device;
- b. Leads from the alarm contacts on the magnetic type oil gauge;
- c. Leads from the alarm contacts of the dial type indicating thermometer;
- d. Leads from each winding temperature detector;
- e. Leads from each set of thermal relay contacts;
- f. Leads from differential pressure relay contacts;
- g. Leads from Current transformers;
- h. Leads from air cell of the conservator;
- i. Power supply conductors for lighting, receptacle and heater circuits.

All terminals provided for current transformer secondary leads should be equipped with devices for short-circuiting the secondary windings. The terminal arrangements shall be subject to the approval of the Purchaser / Engineer and not less than 20 percent spare terminals shall be provided on each block or group of blocks. Separate blocks shall be provided for power and control wiring

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

with metal barriers between section.

### 2.3.15. Insulating Oil

The new insulating oil, supplied with the transformer shall conform to the requirement of IS: 335 / International Standards while tested at suppliers' premises. No inhibitors shall be used in oil. Sampling of oil shall be done in accordance with IS: 6855.

### 2.3.16. Oil Preservation System

All transformers shall be provided with air cell type oil sealing in the conservator to prevent oxidation and contamination of oil due to contact with atmospheric air. The Bidder shall describe in detail the sealing arrangement to prohibit contact between transformer oil and atmosphere. A silica gel breather shall be provided in the air side vent line. Prior to filling the oil in the main tank suitable number of samples shall be tested for BDV, moisture content, resistivity at 90°C, tan delta at 90°C and interfacial tension. The oil samples taken from the transformer at site shall conform to the requirements of IS: 1866 / International Standards.

Ten percent (10%) extra oil shall be supplied for topping up, in non-returnable container suitable for outdoor storage.

It shall be designed to take care of the following:

Air bag shall be suitably sized to accommodate total changes in oil volume from minimum ambient temperature to 100°C.

Air bag shall withstand full vacuum during installation / maintenance. Alternatively, Bidder shall bring out that how any damage to air bag is prevented when vacuum filling of oil is done. The complete details of the same shall be clearly Includes in the instruction manual.

### 2.3.17. Current Transformers

The CTs to be provided in the bushing and neutral of the HV / LV winding of the transformers shall be in the scope of the transformer Supplier.

The neutral CTs shall comply with the requirements of IS: 2705 / IEC: 185 and shall have the following ratings (indicative). Actual ratio to be finalised during detailed engineering.

CT Ratio for 5 MVA	SST	:	400 / 1/1/1A - HV Bushing
CT Ratio for 5 MVA	SST	:	400/1/1A – HV Neutral
CT Ratio for 5 MVA	SST	:	200/1/1A – LV Neutral
CT Ratio for 1.5 MVA	SAT	:	2500/5/5A – LV Neutral
Purpose		:	Protection
Accuracy Class		:	PS, 5P20



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Min. Knee Point Voltage : 60 V

In case of LV (433 V) winding, the neutral CT (NCT) shall be mounted before bifurcation of neutral for connection to the two neutral bushings.

### 2.3.18. Fittings and Accessories

Each transformer shall be provided with accessories but not limited to the following:

- a. Oil temperature Indicator as described elsewhere;
- b. Winding temperature Indicator as described elsewhere;
- c. One number magnetic type oil-level gauge with low level alarm contacts and a dial, showing minimum, maximum and normal oil levels. The gauge shall be readable from the transformer base level;
- d. One oil filling valve (inlet);
- e. One oil drain valve (outlet);
- f. One filter valve located at the top of the tank on H.V. side;
- g. One filter valve located near the bottom of the tank on the L.V. side of the transformer (diagonally opposite to the filter valve at the top);
- h. Two oil sampling valves at top and bottom of main tank with provision for fixing PVC pipe;
- i. Pressure relief device of resealing type with alarm and trip contacts to vent out pressure in case the pressure in the tank rises above pre-determined safe limit as described elsewhere;
- j. A buchholz relay mounted in between the conservator and tank as described elsewhere;
- k. Conservator and breather as described elsewhere;
- l. Oil preserving equipment complete in all respects;
- m. Dehydrating air breather with silica gel filling and oil seal;
- n. Eye bolts and lugs on all parts for ease of handling as described elsewhere;
- o. Two grounding terminals;
- p. Jacking pads as described elsewhere;
- q. A valve schedule plate showing the location and function of all valves and air releases, cocks or plugs. This plate shall also warn operators to refer to maintenance instructions before applying the vacuum treatment for drying;
- r. One set of equipment for control, protection, indication and annunciation of cooling system of each transformer comprising motor contactors, detecting elements or devices, instruments, current transformers, indicating lamps (where necessary), auxiliary relays (including those for remote annunciations and trips) etc. as detailed in the various clauses of the specification;
- s. Suitable weather proof cubicle with space heater for housing the control equipment, terminal blocks for current transformer secondaries and other cables, etc.;
- t. A set of devices for lifting the various parts of the transformer as also the complete

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

transformer (one set common to all the transformer);

- u. Terminal connectors;
- v. Off circuit tap changer / OLTC as described elsewhere;
- w. H.V., L.V. and neutral Bushings as described elsewhere;
- x. Wiring in metallic conduits up to marshalling box with PVC copper cables of 1100 volts grade;
- y. The equipment and accessories furnished with the transformer shall be suitably mounted on the transformer for ease of operation, inspection and maintenance. The mounting details shall be subject to the approval of the Purchaser / Engineer;
- z. Indication, alarm and trip relay equipment shall have contacts suitable for operation with 220 V DC supply. Any other accessories or appliances recommended by the manufacturer for the satisfactory operation of the transformers together with their prices shall be given in the Bid separately.

#### 2.4. Dry Type Distribution Transformers

- Three (3) Nos., 630 KVA; 11 kV / 0.433 kV, Dyn11, 3 phase, 50 Hz., Dry type Unit Auxiliary Transformer (UATs) with "off-circuit" taps in steps of 2.5% from +5% to -5% of the rated voltage on H.V. side, complete with accessories and fittings, as specified and suitable for indoor installation.
- Two (2) No., 1500 kVA, 33/0.433kV, three phase, cast resin, Dry type Station Auxiliary Transformers (SAT) with "off-circuit" taps in steps of 2.5% (2 steps for each direction, +5 to -5 range) of the rated voltage on H.V. side, complete with accessories and fittings as specified and suitable for indoor mounting.

##### 2.4.1. Operating Conditions

Transformers UAT and SAT are proposed to be installed on inside the Power House where ambient temperature will be 40°C.

- 1 The Transformer shall be capable of operating continuously at rated output at all the taps under following conditions:
  - Voltage variation at particular tap : +/- 5 % at rated voltage
  - Frequency variation :  $\pm 5$  % nominal frequency
  - Combined voltage and frequency variations :  $\pm 10$  %
- 2 The Transformer shall be capable of withstanding the short circuit stress (mechanical and thermal) due to a terminal fault on any one winding with full voltage maintained on the other winding for minimum period of (3) seconds;

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

- 3 The dry type of transformer shall be completely encapsulated cast resin type; naturally cooled (AN) non-inflammable and moisture proof. The flux density of all transformer shall not be more than 1.55 Weber / Sq.m at the rated voltage and frequency. Current density of HV and LV winding of all transformers shall be free from annoying hum or vibration. The design shall be such as not to cause any undesirable interference with radio and communication circuit;
- 4 Transformer secondary is to be directly connected through bus to respective LT panel to avoid cabling and space;
- 5 Altitude of Transformers installation is 1100m above msl;
- 6 Transformers shall be capable of operating at a voltage of 125% for a period of 60 seconds and voltage of 140% for a period of 5 seconds.

#### 2.4.2. Technical Description

The rating and electrical characteristics of the **Unit Auxiliary Transformer** and **Station Auxiliary Transformer** shall be as follows:

- |  |                                    |
|--|------------------------------------|
| i. Service                                     | : UAT, SAT                         |
| ii. Installation                               | : Indoor                           |
| iii. 3 Phase Unit / Single Phase               | : Three Phase                      |
| iv. Cooling                                    | : Natural Cooling (AN)             |
| v. Quantity                                    | : Three                            |
| vi. Ambient Temp                               | : 40 deg C                         |
| vii. Temperature rise by resistance of winding | : 75 deg C                         |
| viii. Insulation Class                         | : H (with temp. rise Limited to B) |

#### 2.4.3. Rating

1.	KVA Rating	630
2.	No Load Voltages i) HV winding ii) LV Winding	11kV 0.433KV
3.	Frequency	50Hz
4.	Ambient Temp	40°C
5.	Temperature rise by resistance of winding	75°C
6.	Winding Connection and material i) High Voltage ii) Low Voltage	Copper Delta Star
7.	Type	Dry Cast Resin encapsulated mounted inside enclosure with Louvers for

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

		ventilation Suitable for indoor installation
8.	Vector Group Reference	Dyn11
9.	Protection class	IP31
10.	Approximate Overall dimension	Vender to specify
11.	Approximate Weight	Vender to specify
12.	System Voltage i) HV Nominal / Highest ii) LT Nominal / Highest	11 / 12 kV 0.415 kV / 1.1 kV
13.	System Neutral Earthing HV side LV side	UE Neutral Solidly Earthed
14.	Current Density both HV and LV winding Indicative / Typical Maximum Losses (Inclusive of all tolerance)  - No Load current at rated voltage & frequency -	2.2A / mm <sup>2</sup> (max.)   2% of full load current
15.	Maximum Losses (Inclusive of all tolerance) :  - No load losses at rated voltage : - Load Losses at principal tap rated capacity : - Total losses	As specified at Guarantee Clause no. 2.5
16.	Excitation current At 100% of rated voltage At 120 % of rated voltage	less than 1.5% of rated full load current less than 3 % of rated full load current
17.	Voltage drop at maximum capacity At 100% of Power factor At 80% of Power factor, lagging At 80% of Power factor, leading	To be indicated by Bidder To be indicated by Bidder To be indicated by Bidder
18.	Basic impulse level (withstand value) i) HV	75kVp

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

	ii) Winding iii) Support Insulator (HV) iv) LV	75kVp 95kVp N / A
19.	Power Frequency withstand voltage i) HV ii) Winding iii) Support Insulator iv) LV	38kV 38kV 38kV 3.0kV
20.	Impedance voltage at 75 deg C temperature rise ➤ Off circuit tap link at position +5% ➤ Off circuit tap link at Rated position ➤ Off circuit tap link at position -5%	To be indicated by Bidder 4% for 630KVA To be indicated by Bidder
21.	Inrush Current	7 to 8 times of rated current
22.	Noise level (Full load transformer noise level at 1 m from transformer)	As per NEMA TR1
23.	Tap Changer i) Tapping on winding HV / LV ii) Weather ON load / Off load circuit iii) Total taping range iv) Step v) Capacity (Full / Reduced) vi) Type of Control	HV Off circuit  +5%, -5% 2.5% Full Manual
24.	Current Transformer Electrical Detail i) Type ii) Turn ratio iii) Protection Accuracy iv) Number of secondary winding v) Rated Primary Current vi) Rated Secondary Current vii) Location of Installation	Resin cast CT / Window Type for neutral CT For 1000 / 5 / 5A (Neutral CT) PS Two 100A 5A Between Neutral and Terminal connected to Ground pit
25.	Terminal Arrangement i) High Voltage (Primary)	

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

	ii) Low Voltage (Secondary)	Segregated Cable Box / Terminals as required Bus Duct / Flexible cable connection single core
26.	Alarm and tripping	Winding Temperature Indicator to be provided which should have potential free contacts for alarm and trip.
27.	Temperature Rise <ul style="list-style-type: none"> <li>• One hundred fifty percent of full load for fifteen minutes, or</li> <li>• Two hundred percent of full load for fifteen minutes.</li> </ul>	To be given by Bidder
28.	Fault level on 33 kV side terminals	65 kA
29.	Over load capacity of Transformer while Transformer is in operation continuously on full load at 40°C ambient temperature, the transformer shall be capable of delivering twice every twenty four hours either <ul style="list-style-type: none"> <li>• One hundred fifty percent of full load for fifteen minutes, or</li> <li>• Two hundred percent of full load for five minutes</li> <li>• Two hundred fifty percent of full load for two and half minute.</li> </ul>	

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Station Auxiliary Transformer (SAT) is as under:	
Rated Power	1500 KVA (3 Phase)
Voltage Ratio	33/0.433 kV
Type of cooling	ONAN
No. of phases	3-phase
Frequency	50 Hz
No. of Windings	02 (Primary and Secondary)
Cooling medium	Mineral oil
Rated System voltage (Primary winding)	33 kV
Rated System voltage (Secondary winding)	0.433 kV
Highest system voltage	36 kV / 1.1 kV
Primary winding connection of transformer & system of earthing	Delta and neutral isolated from earth
Secondary winding connection of transformer and system of earthing	Star connected with neutral, solidly earthed.
Connection Details	cable connection on HV side
Vector Group	Dyn11
Temperature rise over designed ambient of 40°C e) Top oil by thermometer f) Winding (Measured by resistance method)	45°C 50°C
Class of Insulation	A
Altitude	1100 m above msl.
Duty	Continuous
Insulation level	
➤ Lightning impulse withstand voltage ➤ LV	• 170 kV • N/A
➤ Rated power frequency withstand voltage ➤ LV	• 70 kV • 3.0 kV
Percentage Impedance voltage	6%

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

Tapping	Full capacity (rated MVA) taps shall be provided on Primary Winding to give a voltage variation of (+)5% to (-) 5% in equal steps of 2.5%.
Type of tap changing gear on primary side	Off circuit changing gear
Installation	Outdoor installation
Details of Auxiliary supply	220 V DC. -15 & + 10%, and 3 phase 415 V $\pm$ 10%
Maximum / limiting losses for transformer (without any positive tolerance) <ul style="list-style-type: none"> <li>➤ No load losses</li> <li>➤ Load losses at 75°C</li> <li>➤ Current density</li> </ul>	As specified at Guarantee Clause no. 2.5
Flux density (Tesla) at rated voltage and rated frequency	Less than 1.65
Type of rollers	Dismantable flat / flanged bi-directional rollers
Type of Terminations	Cable box at both ends
Minimum phase to phase and phase to earth clearance in air	As per Standard IS / IEC

#### 2.4.4. Construction Details

##### 2.4.4.1. Enclosure for Dry Type Transformer

The transformer shall be housed in IP31 enclosure fabricated from sheet steel of minimum 2 mm thickness and shall be suitable for indoor installation. The Louvers shall be screen protected. The screen shall be perforated sheet steel or wire mesh type. The enclosure shall be adequately reinforced to ensure rigidity so as to permit transportation of transformer within enclosure. Louvers shall be designed for natural ventilation and thermal class K10 and shall be screen protected to guard against vermin's and reptiles.

Double leaf access doors shall be provided with concealed hinges and neoprene gaskets for easy access to HV links and also for withdrawal of core and coil assembly, if required. Enclosure shall be provided with lifting lugs and grounding terminals; and the enclosure door shall have provision of pad locking in door close position.

Transformer shall be provided with suitable mounting and fixing arrangement (nut bolt assembly). Jacking Pads, lifting eyes and pulling lugs shall be provided to facilitate movement of the



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

transformer. All heavy removable Parts shall be provided with eye bolts for ease of handling.

The incoming HV cable shall be terminated in the HV Cable box and associated LT switchboard shall be connected to the LV terminals of the transformer. Ph to Ph and Ph to E clearance air shall be minimum 127 mm on the HV side of the transformer.

#### **2.4.4.2. Core and Coils**

The transformer shall be of either core type or shell type. The core shall be built up with high grade, non-ageing, low loss, high permeability grain oriented cold-rolled silicon steel laminations especially suitable for core material. The laminations shall also be free of all burrs and sharp projection.

The coils shall be manufactured from electrolytic grade copper conductor and fully insulated for rated voltage. Both HV and LV windings shall be completely encapsulated. Epoxy insulation shall be treated against fungus and vermin.

Insulating material shall be of proven design. Coils shall be so insulated that impulse and power frequency voltage stresses are minimum and withstand even extreme of temperature fluctuations. The insulating material shall be glass fibre reinforced with epoxy resin conforming to class 'H'. Separate encapsulation for HV and LV winding shall be provided and winding temperature rise is restricted to class B (75 deg C).

All leads from the windings to the terminal board and supporting insulator shall be rigidly supported to prevent injury from vibration or short circuit stresses. Guide tube shall be used where practicable.

The core and coil assembly shall be securely fixed in position so that no shifting or deformation occurs during movement of transformer or under short circuit stresses. Core coil assembly shall be provided with locking arrangements, lifting lugs, and earthing terminals.

The insulating structure for the core to bolts, core to clamp plates and core to structural steel works shall be such as to withstand a voltage of 2 kV A.C for one minute. No strip conductor wound on edge shall have a width exceeding six times its thickness. Winding shall not contain sharp bends which might damage insulation and produce high dielectric stresses.

#### **2.4.4.3. Tap Changer**

##### **2.4.4.3.1. Tapping**

Off-circuit taps with steps of 2.5% (2 steps for each direction) shall be provided on the high voltage winding. The transformer shall be capable of operation at its rated KVA on any tap provided the voltage does not vary by more than + / - 5% of the rated voltage corresponding to the tap. The winding

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

including the tapping arrangement shall be designed to maintain electromagnetic balance between HV and LV windings at all voltage ratios.

#### **2.4.4.3.2. Off-Circuit Tap Changer**

The off-circuit tap changing shall be affected (on 3-phases) by change of links for dry type transformers. All contacts shall be silver plated and held in position under strong contact pressure to ensure low contact drop and avoid pitting. The design of tap changing link shall be such as to ensure that same tap is set on all the three phases at a time.

#### **2.4.4.4. Support Insulator**

Support insulator shall be resin moulded type of appropriate voltage class.

#### **2.4.4.5. Marshalling Box**

A sheet steel, weatherproof, IP55, marshalling box shall be provided containing all auxiliary devices such as winding temperature indicators etc.

All terminal blocks for connection shall be located in this box. The terminal blocks shall be 10sq.mm. The marshalling box shall be provided with cubicle lamp with door switch, space heater of 240 volt (AC) with thermostat & switches and removable cable gland plate. For isolation of incoming supply, switch / MCCB shall be provided.

#### **2.4.4.6. Fitting and Accessories of Each Transformer:**

The transformer shall be equipped with fittings and accessories as listed below:

- i) Maximum winding temp. monitoring device with electrically separate sets of contacts for trip and alarm along with temperature sensing element embedded in L.V. winding of all three phases.(two per phase);
- ii) Jacking pad for core coil assembly;
- iii) IP 55 marshalling box;
- iv) Ground bus;
- v) Door handle with safety limit switch 1NO+1NC contact and padlocking arrangement;
- vi) Inspection Cover for cable end box;
- vii) Handling and lifting lugs for core coil assembly;
- viii) Rating and terminal marking plates, danger plates;
- ix) Bus / Flexible cable connection between transformer LV Terminal and associated LT SWBD;
- x) A door operated illumination lamp shall be provided for the transformer enclosure;
- xi) Phase segregated HV cable box for termination of 3RX1CX630 sq. mm XLPE cable.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

#### **2.4.5. Earthing Details**

A ground bus of 75 x 8 mm G.I. flat shall be run all along the transformer enclosure. Grounding pad shall have clean buffed surface with two tapped holes, M10 G.S. bolts and spring washers for connection to 75 x 8 mm G.S. flats.

The core coil assembly shall be directly connected to this ground bus by removable bolted link for effective grounding. Ground terminals shall also be provided on cable end box and marshalling box to ensure its effective earthing.

#### **2.4.6. Terminal Arrangement (Cable Connection and Bus Bar)**

##### **2.4.6.1. 33 kV /11 kV XLPE Cable Connection (HT Side)**

HT side of transformer shall have provision for connecting the suitable no. of XLPE cable connections as or mentioned below. The cable box shall be phase segregated type to eliminate Ph to Ph flashovers

##### **2.4.6.2. Bus bar Connections (LT Side)**

The bidder shall give the provision for busbar / flexible cable connection (as required) with adjacent LT panel. The Contractor shall supply a non-magnetic blank gland plate suitable for drilling at site.

A separate L.V Neutral bushing shall be provided on transformer for LV neutral grounding. Neutral CT of ratio 1000 / 5 / 5A for 630KVA shall be provided between Neutral and Ground connection link provided on transformer (NCT to be mounted before bifurcation of two neutral bushings).

The transformer neutrals should be solidly earthed.

#### **2.4.7. Painting**

The internal and external surfaces including oil filled chambers and structural steel work to be painted, shall be shot or sand blasted to remove all rust and scale or foreign adhering matter. All steel surfaces in contact with insulating oil shall be painted with two coats of heat resistant, oil insoluble, insulating varnish or paint.

All steel surfaces exposed to weather shall be given a primary coat of zinc chromate, second coat of oil and weather resistant varnish of a color distinct from primary, and final two coats of glossy oil and weather resisting non-fading paint of color light Grey corresponding to shade no. 631 of IS 5. Primary paint shall be as per IS: 104 / International Standards and intermediate and final coats of paint shall be as per IS-2932 / International Standards.

All paints shall be carefully selected to withstand heat and extremes of weather. The paint shall not scale off or wrinkle or be removed by abrasion due to normal handling. The total thickness of the

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

paint shall not be less than 240 microns.

#### **2.4.8.Labels and Plates**

All labels shall be of in-corrodible material and shall be attached to the panels with brass screws, which have received rust preventive treatment. If required, labels can be stuck to the panels with suitable (long lasting) adhesive.

Labels shall be provided for all apparatus such as relays, switches, fuses etc. contained in any cubicle or marshalling kiosks.

Descriptive labels for mounting indoors or inside cubicles and kiosks shall be of material that will ensure permanence of numbering. A matt or satin finish shall be provided to avoid dazzle from reflected light. Labels mounted on dark background shall have white lettering. Danger notices shall have red letters on white background.

#### **2.4.9.Bolts and Nuts**

Bolts and nuts of distribution Transformers shall conform to ASTM: A193, B-7 and ASTM-A194-2H. Steel bolts and nuts exposed to atmosphere with suitable finishes like cadmium plated or zinc plated passivity shall be used for diameter above 6 mm. All bolts, nuts and washers in contact with non-ferrous parts shall, which carry current shall be of phosphor bronze, where the transfer of current is through bolts. Suitable spanners shall be provided to reach the bolts where these have been located in inaccessible position.

#### **2.4.10. Control Wiring**

All controls, alarms, indicating and relaying devices provided with the distribution transformers shall be wired by the contractor up to the terminal blocks inside the marshalling box. The contractor shall supply and install the required 1.1 kV grade heavy duty PVC insulated, steel wire armoured, PVC wires with FRLS insulation in conduit of Flame retardant of at least 2.5 sq.mm copper conforming to IS.1554 / International Standards. The cables shall be properly supported.

All devices and terminal blocks within the marshalling box shall be clearly identified by symbols corresponding to those used on applicable schematic or wiring diagrams

Not more than two (2) wires shall be connected to one terminal. At least 20% spare terminals shall be provided. Each terminal shall be suitable for connecting two numbers 2.5 sq. mm stranded copper conductor from each side.

Terminal block for control cable shall be of reputed make. Terminal blocks for CT secondary shall have shorting facility. All cabling from the marshalling box to various equipment shall be in the

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

scope of the Supplier.

Where apparatus is mounted on panels all metal cases shall be separately earthed by means of copper wire of suitable size.

All wiring diagram for control & relay panel shall preferably be drawn as viewed from the back & shall show the terminals boards arranged as in service. All diagram shall show which view is employed.

Terminal board rows should be spaced adequately not less than 100 mm. apart.

#### **2.4.11. Packing and Transport**

- i 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 Purchaser keeping in view the transport limitations. Special arrangement shall be made to facilitate handling and to protect the projecting connections from damage in transit. The conservator, the bushings, the cooling equipment and the wheels shall be removed and packed separately with weather proof wrapping and bags of dehydrating material for the parts which might suffer from moisture during transport. The openings of the mounting flanges of coolers and bushings shall be covered with blind flanges;
- ii In case the transformer is transported without oil, the tank shall be filled with dry nitrogen gas under low pressure. To provide for any leakage through the temporary covers fitted to the tank, a cylinder of nitrogen with appropriate equipment shall also be transported along with the transformer so that the tank can be maintained permanently under pressure. The oil may be supplied in non-returnable standard sealed drums;
- iii 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.

#### **2.5. GUARANTEES FOR 1500KVA (SAT), 630KVA (UAT) and 160KVA DISTRIBUTION Transformers:**

The following parameters shall be guaranteed:

- a) No load losses in kilowatts at rated voltage and rated frequency without +ve tolerance.
- b) Load losses (Total losses minus no load losses) in kilowatts at rated output, rated voltage and rated frequency without +ve tolerance
- c) Maximum power in kW consumed by pumps/fans without +ve tolerance.

Maximum permissible losses for Distribution Transformers have been specified as below:

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

KVA	No Load Losses	Load Losses at Principal tap at 75° C	Total Losses
160KVA	0.28 kW(max.)	1.7 kW (max.)	2.38 kW (max.)
630KVA	2.0 kW(max.)	7.0 kW (max.)	9.0 kW (max.)
1500KVA	2.8 kW(max.)	14 kW (max.)	16.8 kW (max.)

Penalties shall be separately evaluated for:

- The excess of test figures of the no load losses in kilowatts over the corresponding guaranteed figures.
- The excess of the difference between the test values of the load losses in kilowatts over the corresponding guaranteed values. No tolerance shall be permitted over the test figures of the losses.
- The excess of power consumed by pumps/ fans in kW over the corresponding test values guaranteed by the Bidder

Following penalties shall be levied on the manufacturer/contractor (as the case may be) if losses measured during routine test are found to be within +2% tolerance of the losses specified above, beyond which the transformer shall be liable for rejection. No benefit shall be given for supply of transformer, with losses (measured during routine tests) less than the losses specified above.

Differential of specified losses vs Measured losses	Rate (in INR per KW) for Liquidated Damage
No load losses	Rs.10,00,000/KW
Load losses	Rs.8,00,000/KW
Auxiliary losses	Rs.8,00,000/KW

The penalties will be applied pro-rata for fraction of a kilowatt.

## 2.6. Guarantees for 5MVA, 220/33kv Station Service Transformer:

The following parameters shall be guaranteed:

- No load losses in kilowatts at rated voltage and rated frequency without +ve tolerance.
- Load losses (Total losses minus no load losses) in kilowatts at rated output, rated voltage and rated frequency without +ve tolerance.
- Maximum power in kW consumed by pumps/fans without +ve tolerance.

Penalties shall be separately evaluated for:

- The excess of test figures of the no load losses in kilowatts over the corresponding guaranteed figures.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

- b) The excess of the difference between the test values of the load losses in kilowatts over the corresponding guaranteed values. No tolerance shall be permitted over the test figures of the losses.
- c) The excess of power consumed by pumps/fans in kW over the corresponding test values guaranteed by the Bidder.

Following penalties shall be levied on the manufacturer/contractor (as the case may be) if losses measured during routine test are found to be within +2% tolerance of the losses specified in Guaranteed Technical Particular (GTP) by the contractor, beyond which the transformer shall be liable for rejection. No benefit shall be given for supply of transformer/reactor, with losses (measured during routine tests) less than the losses specified in Guaranteed Technical Particular (GTP).

Differential of specified losses vs Measured losses	Rate (in INR per KW) for LD
No load losses	Rs.10,00,000/KW
Load losses	Rs.8,00,000/KW
Auxiliary losses	Rs.8,00,000/KW

The penalties will be applied pro-rata for fraction of a kilowatt.

For the purpose of comparison of bids, the quoted prices shall be equalized for the guaranteed transformer losses. Taking the lowest values of no-load and load losses and other losses indicated by any of the Bidders as the reference, the quoted prices of various Bidders will be loaded for excess losses (difference of guaranteed losses and the reference losses) at the half of the rate as given above for liquidated damages computation. All losses considered shall be without any +ve tolerance. For bid evaluation purpose, following table shall be considered.

Differential of specified losses vs Measured losses	Rate (in INR per KW) for loss capitalisation
No load losses	Rs.5,00,000/KW
Load losses	Rs.4,00,000/KW
Auxiliary losses	Rs.4,00,000/KW

## 2.7. Testing

Each distribution transformer shall be completely assembled and tested at the factory. Tests shall be performed in the presence of Purchaser's representative. Tests shall be performed in compliance with latest edition of IS: 2026 / IEC 76. No material shall be shipped until the test reports are duly approved by the Purchaser or his representative. Copies of type test reports for type tests carried out, on similar rated transformer, shall be submitted with the offer.

The following electrical and mechanical tests shall be carried out on the transformer unless otherwise stated in the schedule of requirements.

### 2.7.1.Type Tests

Type test reports for the following type tests (conducted on a similar rated transformer) shall be submitted for review / approval by Purchaser / Engineer. These tests shall include but may not be limited to the following:

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

- a) Measurement of winding resistance;
- b) Voltage ratio on each tapping and check of voltage vector relationship;
- c) Impedance voltage at principal tapping, short-circuit impedance and Load losses;
- d) No load losses and no load current;
- e) Separate-source voltage withstand;
- f) Induced over voltage withstand test;
- g) Lightning impulse test;
- h) Temperature rise test;
- i) Partial Discharge test;
- j) Meggar test / Insulation resistance test

### 2.7.2. Routine tests

Each completed transformer shall be subjected to routine tests.

- Transformer routine tests shall include tests stated in latest issue of IS: 11171. These tests shall include but may not be limited to the following:
  - a) Measurement of winding resistance;
  - b) Voltage ratio on each tapping and check of voltage vector relationship;
  - c) Impedance voltage at principal tapping, short-circuit impedance and Load losses;
  - d) No load losses and no-load current;
  - e) Separate-source voltage withstand;
  - f) Induced over voltage withstand test;
  - g) Heat run test on one unit;
  - h) Partial Discharge test;
  - i) Insulation Resistance (IR) test.
- In addition to the routine tests specified above, the following routine tests shall also be made on each of the transformers:
  - a) Measurement of exciting current at 100% of rated voltage;
  - b) Measurement of exciting current at 120% of rated voltage;
  - c) Regulation at rated load and at unity power factor, 0.8 lagging power factor and 0.8 leading power factor.

### 2.7.3. Special tests

Special tests as specified in IS: 11171 and mutually agreed shall also be carried out. The Bidder shall clearly state the testing facilities available with them for conducting short circuit,



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

measurement of acoustic level, and Partial discharge and other special tests as per the standards.

Detailed test schedule and procedures shall be formulated by the contractor and submitted for Consultant's / Purchaser's approval. Contractor shall specify the maximum allowable tolerance against each test parameters in line with applicable standards. All the tests shall be witnessed by Purchaser or his representative. Necessary modifications or corrections shall be made by the contractor in case equipment fails to meet any requirements of the specifications during testing.

#### **2.7.4. Tests on associated equipment:**

The test certification of associated equipment shall be provided by the manufacturer at time of the testing.

#### **2.7.5. Tests at Site:**

After erection at site, the transformers shall be subjected to the following tests:

- a) Measurement of winding resistance;
- b) Voltage ratio on each tapping and check of voltage vector relationship;
- c) Impedance voltage at principal tapping;
- d) No load current;
- e) Separate-source voltage withstand;
- f) Insulation Resistance (IR) test;
- g) Protection devices checks;
- h) Transformer protective relays checks;
- i) Any other tests as per IS or manufacturer's recommendations.

#### **2.7.6. Transformer routine tests shall include tests stated in latest issue of IS: 2026 / IEC 76.**

**These tests shall include but may not be limited to the following:**

- a. Measurement of windings resistance;
- b. Voltage ratio on each tapping and check of voltage vector relationship;
- c. Impedance voltage at principal as well as on two extreme tapping , short-circuit impedance and Load losses;
- d. No load losses and no load current;
- e. Insulation resistance;
- f. Dielectric tests;
- g. Heat run test on one unit of each rating (type test);
- h. Dielectric test and dissolved gas analysis of oil samples taken before and after the Heat run

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

test and analysis of the two values obtained;

i. Zero sequence impedance test.

➤ L.V. windings:

- Separate source A.C. voltage withstand test on line terminals.

➤ H.V. Neutral / H.V. Terminals:

- Power frequency voltage withstand test.

**2.7.7. In addition to the routine tests specified above, the following routine tests shall also be made on each transformers :**

a. Magnetic circuit test:

After assembly each core shall be tested for 1 minute at 2000 volts a.c. between all bolts, side plates and structural steel work. Immediately prior to the dispatch of the transformer from the manufacturer's works, the magnetic circuit shall be pressure tested for 1 minute at 2000 volts a.c. between the core and the earth.

b. Oil leakage test on transformer tank:

All tanks and oil filled compartments shall be tested for oil tightness by completely filling with air / oil of a viscosity not greater than that of insulating oil conforming to IS: 335 at the ambient temperature and applying a pressure equal to the normal pressure plus 35 KN / m<sup>2</sup> measured at the base of the tank. This pressure shall be maintained for a period of not less than 12 hours for oil and 1 hour for air during which no leakage shall occur.

c. Measurement of exciting current at 110% of rated voltage;

d. Measurement of excitation losses at 90% and 110% of rated voltage after the impulse tests are completed;

e. Regulation at rated load and at unity power factor, 0.9, 0.8 lagging power factor and 0.98, 0.95, 0.9 leading power factor;

f. Measurement of no-load current at 415 V, 50 Hz.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
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#### 2.7.8. Tests at site:

After erection at site, the transformers shall be subjected to the following tests:

- i Windings and Insulation resistance test;
- ii Ratio and polarity test;
- iii Dielectric test of oil, moisture content and Dissolved Gas Analysis;
- iv Zero sequence impedance test;
- v Measurement of no load current at 415 V, 50 Hz;
- vi Protection devices checks:
  - Buchholz relay;
  - Pressure relief device;
  - MOG;
  - OTI and WTI.
- vii Transformer protective relays checks;
- viii Other tests as per I.S. or manufacturer's recommendations.

#### 2.7.9. Tests on associated equipment (at works):

Bushings, current transformers, winding temperature indicating devices, dial thermometers, buchholz relays, auxiliary motors and motor starting contactors, coolers, control devices, insulating oil and other associated equipment included in the scope shall be tested by the Supplier in accordance with relevant IS or IEC. If such equipment are purchased by the Supplier on a sub-contract, he shall have them tested to comply with these requirements and the test certificates shall be furnished to the Purchaser. Inspection of tests at the sub-contractor works shall be arranged by the Supplier, if required by the Purchaser.

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

#### 2.7.10. Test reports:

- After all tests have been completed, six certified copies of each test report shall be furnished. Each report shall supply the following information:
  - a) Complete identification data including serial number of the transformer / equipment tested. Calibrated oscillographs of impulse test shall form part of the test report;
  - b) Method of application, where applied, duration and interpretation of results for each test. Quantities corrected to 75°C shall be given;
  - c) Temperature and pressure data including ambient temperature and atmospheric pressure.
- Routine test reports shall also furnish the following information:
  - a) Calculated value of regulation at unity, 0.8 lagging and 0.8 leading power factors;
  - b) Calculated values of efficiency of transformer at 50, 75 and 100 percent of rated capacity with unity and 0.8 power factor.
- The Bidder shall state in his proposal the testing facilities available at his works. In case full capacity testing facilities are not available, the Bidder shall state the method proposed to be adopted so as to ascertain the transformer characteristics corresponding to full capacity testing. The Bidder shall also indicate tests recommended to be carried out at site during installation and commissioning. These tests shall be carried out by the Supplier during erection supervision;
- The Purchaser and / or his representative including a third party inspection agency appointed by the Purchaser shall have the right to witness any or all tests;
- The Purchaser reserves the right to reject the transformer, if losses exceed the declared losses beyond tolerance limits as per IS / IEC or temperature rise in oil and of winding exceed the value specified.

#### 2.7.11. Shop Inspection

No equipment or material shall be dispatched to the site prior to its inspection at manufacturer's works by the Purchaser or his authorised representative. The Purchaser's representative shall have access and facilities for un-restricted inspection of manufacturer's works at all times.

### 2.8. Erection, Testing and Commissioning

The transformers are to be installed at the location as mentioned elsewhere / shown in the drawings. The installation of the transformers includes but not limited to the following:

- Transport and unloading of the transformers from the trailer to the respective locations of the transformers. The Purchaser shall provide the transformer foundation based on the dimensions

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

and weight given by the Supplier;

- Welding, jointing and clamping, soldering, brazing as per drawings and as per engineering practices and Quality Assurance Plan;
- Installation of control cabinet;
- Filling and treatment of oil;
- Installation of pumps, coolers and other accessories;
- Field tests comprising Commissioning, operational or other tests as per technical provisions and / or applicable standards, whether specifically mentioned or not;
- Performance / Final acceptance tests as applicable in accordance with provisions of technical specifications;
- Corrections (if any) in erection or during assembly for the transformers shall be done as per approved drawings;
- Any other activities / services not specially mentioned in technical provisions but necessary for completeness of the Equipment, its commissioning, performance testing or sustained operation / maintenance;
- Implementation of quality assurance plan and control of quality.

The transformer is proposed to be installed on the platform. The erection agency shall be responsible to arrange all the tools and tackles necessary for the erection, testing and commissioning of the transformer. The Supplier shall submit the foundation design for the same to the Purchaser for approval.

The Contractor shall maintain at his site office up-to-date copies of all drawings. He shall also maintain continuous record of all stages of erection, test data and changes made in the drawings and supply one corrected copy to Purchaser.

## **2.9. Drawings, Data, Manuals and Guaranteed Particulars**

### **2.9.1. 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:

- a. General outline dimensional drawings showing front and side elevation and plan of transformer and all accessories including coolers and external features, spacing of wheels in either direction of motion, net weight and shipping weight, quantity of insulating oil, centre of gravity;

The drawing should indicate location of LV and HV terminals with respect to centre line

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

and ground.

- b. Detailed dimensioned drawing showing clearances required for the transformer from the Power Plant wall, fire walls, ground clearance, clearance from Over Head conductor;
- c. Assembly drawings and weights of main component parts;
- d. Shipping drawings showing dimensions and weights of each package. Arrangement for inert gas retention and monitoring and other protective arrangements during transportation;
- e. Drawings giving the design loads for foundations;
- f. Tap changing and name plate diagrams;
- g. Descriptive brochures for all auxiliary equipment;
- h. Detailed arrangement drawings and specifications of each type of bushings;
- i. A complete Bill of Material for the equipment;
- j. Type tests and special test reports conducted on similar transformer;
- k. Quality Assurance Programme and fire fighting scheme as proposed by Bidder.

The Bidder shall submit the dimension and clearance drawings in a CD.

Any Bid lacking complete information in this respect is likely to be rejected.

**2.9.2. Drawings, data manuals, etc. and documentation to be furnished by the Supplier after award of contract:**

After award of contract, the Supplier 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:

- a. General outline drawing showing front and side elevation and plan of the transformer and all accessories including coolers and extreme features with details of dimensions, spacing of wheels in either direction of motions, net and shipping weights, crane lift for untanking, size of lifting lugs and eyes, bushing lifting dimensions, clearance between HV and LV terminals and ground, quantity of insulating oil, etc.;
- b. Foundation plan showing loading on each wheel and jacking points with respect to centre

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification Volume II Section-I Transformers
---	--	--

line of rail track;

- c. Details of each type of bushing and terminal connections;
- d. Busbar trucking details / Cable box details;
- e. Name plate drawing with terminal marking and connection diagram;
- f. Wheel locking arrangement;
- g. Transportation dimension drawing;
- h. Magnetising characteristic curves of current transformers;
- i. Efficiency Curve;
- j. Inter connection diagram;
- k. Schematic and control wiring diagram for all accessories and auxiliary equipment;
- l. Over-fluxing withstand time characteristics of transformer;
- m. Sectional view showing the general constructional features of the transformers, core, winding, tap changer etc.;
- n. Large scale drawings of high and low tension windings of the transformers, showing the nature and arrangement of insulation and terminal connections;
- o. Typical Operation and Maintenance Manual of the Equipment supplied by the Supplier for a Project.

Operation, maintenance and erection manuals (10 copies) shall be supplied by the manufacturer one month prior to the shipment of the transformer. The manuals shall contain all the drawings and information required for erection, operation and maintenance of the transformers.

Descriptive literature and data on transformers, windings, bushings, heat exchangers, tap changing gear, temperature detector, buchholz relay, instruments and controls, etc. shall also be supplied by the manufacturer along with the instruction manuals.

## **2.10. Quality Assurance Program**

A quality assurance program detailing specific control procedure proposed to be adopted for controlling the quality characteristics relevant to each item of equipment shall be furnished. This shall include, but not be limited to the following to ensure conformance of equipment specification and relevant Codes / Standards:

1. Inspection of incoming raw materials;
2. Tests to Verify chemical and physical properties of all materials including test certificates of bought-out items like motors, contactors, circuit breakers, instruments / gauges etc. as per relevant Indian Standards;
3. Tests during manufacture / assembly of transformer, its fittings and accessories including

Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

customer hold points etc.

Other tests shall be as part of manufacturer's standard quality assurance plan

## **2.11. Spare Parts & Tools**

The distribution transformers shall be supplied with the following mandatory tools and spare parts for erection and trouble-free operation and maintenance for five (5) years. These spare parts shall not be used as erection / commissioning spares required during commissioning.

### **2.11.1. A) Tools (Mandatory)**

A full outfit of tools, spanners, jacks, special tools for assembling and dismantling the transformer, with a rack for holding them. All spanners shall be single ended and case hardened.

### **2.11.2. B) Spares for each rating- Mandatory spare parts to be included and supplied**

The following spare parts shall be mandatorily included in the supply. A set in the list below shall imply quantity provided for one (1) complete set for each type distribution transformer.



Procurement of Transformers for Heo Hydro Electric Project (240 MW), Arunachal Pradesh.		Technical Specification
		Volume II Section-I
		Transformers

S.No.	Description	Qty.
<b>Oil Type Distribution Transformers (for each type)</b>		
1	H.V bushing complete with gaskets etc.	1 set.
2	L.V terminal bushing as specified in technical specifications.	1 set.
3	Neutral bushing and gaskets.	1 No.
4	Gaskets for all openings with tank requiring gaskets	1 set
5	Silica gel drying agent / required for one filling of transformer	1 Lot
6	Diaphragm and spares for conservator tank & explosion vent and pressure relief valve	1 set
7	Buchholz relay	1 set
8	Neutral Current Transformer	1 set
9	Fuses, MCCB and MCB's, Terminal Block	1 set
10	Oil and winding temperature indicators	1 set
11	Indicating Lamps with holders and Lens	1 set
12	Magnetic oil level gauge	1 set
<b>Dry Type Distribution Transformers (for each type)</b>		
1	HV and LV Bushings / Insulators	1
2	Temperature scanner and associated accessories	1
3	Door Handle + Safety Limit Switches+ louvers	1 Set
4	Spare links	1 Set
5	Neutral current transformer	1 No

If any additional spare-parts required for trouble free operation are recommended by bidder, these shall be listed as Recommended Spare Parts and the unit price shall be quoted in the price schedule. The Purchaser reserves the right to order any or all of such spares.

## 2.12. Completeness of Equipment

All fittings and accessories of the transformers and associated equipment though may not have been specifically mentioned in the specification but are usually necessary for the completeness of the above equipment shall be deemed to be covered by the specification and shall be indicated and furnished by the contractor without any extra charges