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CHAPTER – 1

INTRODUCTION AND PROJECT OVERVIEW

1.1 INTRODUCTION

1.1.1 This Chapter gives an overview of the works involved in the Project. The works to be executed under this contract are related to the East West Corridor (Phase 1B) (Charbagh to Vasant Kunj) of Lucknow Metro Rail Project (here after termed as LKE (02)-01).

1.1.2 This Specification defines the objectives, guidelines and requirements for Design, Supply, Installation, Testing and Commissioning of Power supply & Distribution system, 750 V DC Traction Electrification and SCADA system including 33kV Receiving Sub Station/Auxiliary Main Substation and Depot for East West Corridor Phase-I B for Lucknow Metro Rail Project of UPMRCL.

This Specification is also applicable for power distribution and traction electrification works associated with Depot at Vasantkunj.

1.1.3 The works to be executed under the Contract include Design, verification of preliminary design, transfer of technology, manufacture / supply, installation, testing, including integrated testing and commissioning, technical support, supervision of maintenance, training of Employer's staff and documentation for a complete System, necessary to deliver the requirements of this Specification.

1.1.4 This Specifications should be read in conjunction with the General Conditions of Contract (GCC), the Special Conditions of Contract (SCC), the General Specifications (GS), the Employer's Drawings and any other document forming part of the Tender. In the event of a conflict between the GS and this Specification, this Specification shall prevail. In the event of a conflict between this Specification and any other standards or specification quoted herein, the requirements of this Specification shall prevail. The order of precedence, with item (a) having the highest priority, is

- a. Employer's Requirement - Technical Specifications
- b. Indian Railway Standards
- c. Indian Standards
- d. International Standards referenced herein
- e. Other National Standards, Codes and Manuals
- f. Other International Standards

Notwithstanding the precedence specified, the Contractor shall always immediately seek advice from the Engineer in the event of conflicts between Specifications.

1.1.5 Preliminary design works associated with the Power Supply Receiving / Distribution System, 750 V DC Third Rail Traction Electrification and SCADA System shall be

provided to the successful bidder. However, the Contractor shall be responsible for verification of design. It shall be the responsibility of the Contractor:

- To satisfy himself that the tentative capacities, ratings and quantities of equipment as specified herein meet the operational requirements.
- To verify the ratings, quantities of equipment etc. as specified in this Specification on the basis of technical inputs provided in the document.

1.1.6 If the Tenderer considers any additional equipment, equipment of higher capacities and higher ratings for the systems and sub-systems or any other additions necessary for the complete, safe and reliable operable power supply system, he shall include such items in his Tender, as additional items, providing all clarifications and justifications for the same.

1.1.7 **Preparation of documents for obtaining approvals by Employer from the appropriate statutory authorities. The final design shall include, but not be limited to, a document verifying all requirements of RDSO and CMRS as per their extant guidelines applicable to metro project.**

1.2 OVERVIEW OF THE PROJECT

1.2.1 Lucknow Metro Rail Project: Phase-1B

1.2.1.1 The Lucknow Metro Rail Project includes two corridors, of which North South Corridor- Phase 1A is already completed and fully operational. This tender is issued for the execution of the corridor named as East West Corridor- Phase 1B. The details of Phase 1B are as follows:

- a) Phase 1B: Charbagh to Vasantkunj– 11.165 km (Depot cum workshop at Vasant Kunj and 01 nos. RSS/AMS)

The details are mentioned below:

Sr. No.	Corridor	Route Length	Type Corridors	Stations	Elevated	Underground
1	East West Corridor	11.165 km	Elevated and Under Ground	12 Nos.	5	7

1.2.1.2 Phase-1B (Charbagh to Vasantkunj)

Phase-1B, starts at Charbagh station and connects the major places of the city like Gautam Buddha Marg , Aminabad, Pandeyganj, City Railway Station, Medical Chauraha, Chowk, Thakurganj, Balaganj, Sarfarazganj, Musabagh and ends at Vasantkunj. This corridor has the interchange with North South Corridor at Charbagh Station. This corridor has elevated as well as underground sections.

Rolling stock maintenance depot for East West Corridor Phase- 1B is at Vasantkunj

Depot, which is located at surface level near Vasantkunj Station. The Depot will be serving as a stabling yard and a maintenance centre for Rolling Stock cars running in this Corridor.

- | | |
|---------|---|
| 1.2.1.3 | Deleted |
| 1.2.1.4 | The mode of traction is 750V DC Third Rail bottom collection. |
| 1.2.1.5 | The track is of Standard Gauge (1435 mm). |
| 1.2.1.6 | The network map of the Lucknow MRTS is shown in Figure 1.1. |

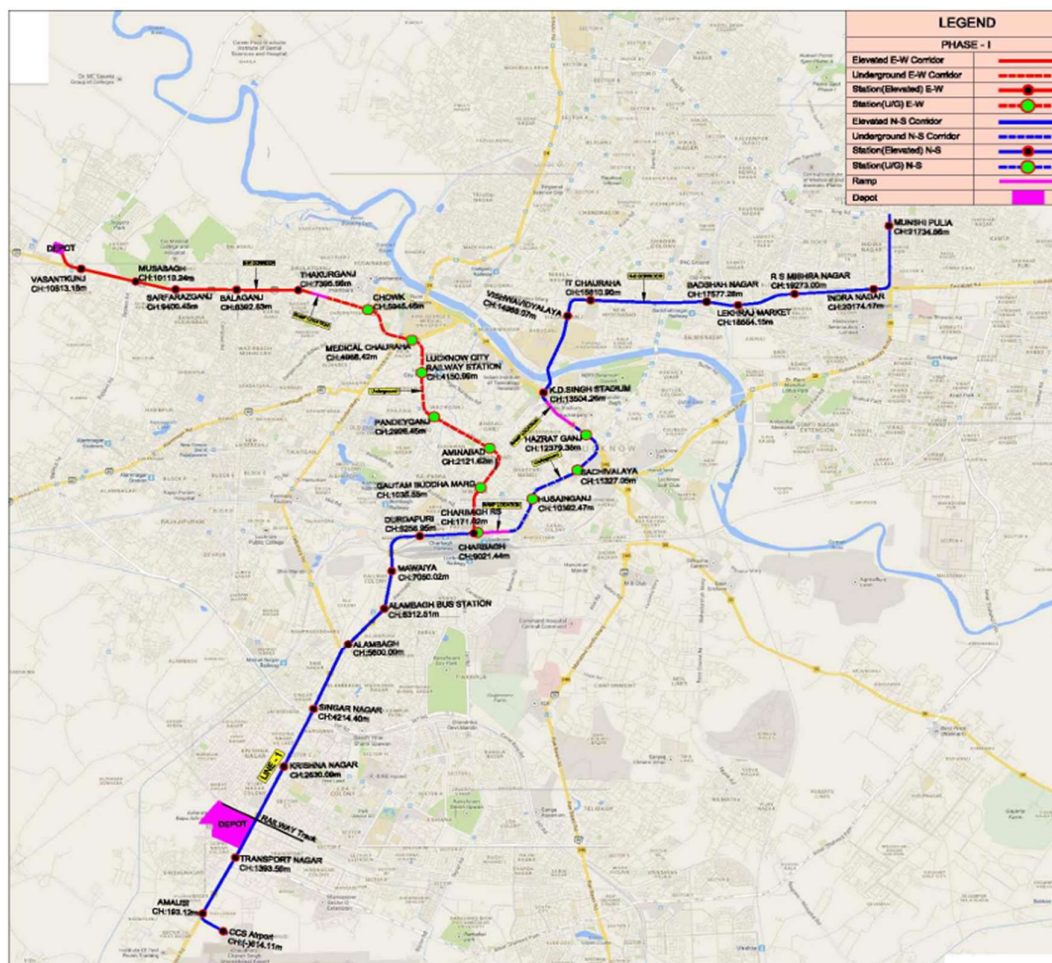


Figure 1.1: Schematic Representation of Lucknow Metro Network

1.2.2 The details of Lucknow Metro East West Corridor is as under:

Table 1.1

Sl. No	Lucknow Metro East West Corridor	Length (Km)
i.	Phase-1B: Charbagh to Vasantkunj	11.165 km

Table 1.2: East West Corridor

Sl. No.	Station Name	Chainage (Meter)	INT (Meter)	Dist	Type (Elevated / at grade)
1	Charbagh	171.025		-	Underground
2	Gautam Buddha Marg	1035.552	864.527		Underground
3	Aminabad	2121.627	1086.075		Underground
4	Pandeyganj	2926.457	804.830		Underground
5	City Railway Station	4150.992	1224.535		Underground
6	Medical Chauraha	4968.426	817.434		Underground
7	Chowk	5945.462	977.036		Underground
8	Thakurganj	7395.566	1450.104		Elevated
9	Balaganj	8392.832	997.266		Elevated
10	Sarfarazganj	9400.459	1007.627		Elevated
11	Musabagh	10110.242	709.783		Elevated
12	Vasantkunj	10813.189	702.947		Elevated

1.2.3 Section wise Schedule for Commercial operations of all the corridors is as under:

Table 1.3: Schedule of Commercial Operations

SN	Section	Completion period from LOA
1	East West Corridor Phase 1B Vasantkunj Depot	18 months
2	East West Corridor Phase 1B Vasantkunj (inc) to Thakurganj (inc))	24 months
3	East West Corridor Phase 1B Thakurganj (Excl) to Charbagh (inc)	27 months

1.2.4 Phased Commissioning of Lines: It is envisaged to open the sections in a progressive manner based on the completion of works. The detailed commissioning schedule of this work is further described in Chapter- 4 of this volume.

1.3 ENVIRONMENTAL AND CLIMATIC CONDITIONS

1.3.1 The Environmental and Climatic conditions and the related data prevailing in Lucknow have been described in Clause 1.12, Chapter 1 of Volume 3 General Specifications. The Contractor will be required to verify the above data for environmental and climatic conditions. All the installation shall suit the environmental and climatic data as defined in the General Specifications.

1.4 OVERVIEW OF POWER SUPPLY SCHEME

1.4.1 DESIGN PHILOSOPHY

1.4.1.1 All equipment of distribution, auxiliary and traction power supply systems, including all subsystems shall be of proven design and shall meet the following design criteria:

- a. Application of state-of-the-art technology
- b. Service proven design
- c. Use of interchangeable, modular components
- d. Extensive and prominent labelling of parts, cables and wirings
- e. High reliability
- f. Low energy loss
- g. System safety
- h. Adequate redundancy in systems
- i. Use of fire-retardant materials
- j. Environment friendly
- k. Adherence to operational performance requirements and Standards
- l. Maximum utilization of indigenous materials and skills, subject to quality conformity

1.4.2 CONCEPTUAL POWER SUPPLY ARRANGEMENT

- 1.4.2.1 Conceptual schematic power supply arrangement diagram, layout of typical distribution/TSS/ASS, and cable runs based on the system design from Detail Design Consultants (DDC Traction Power Supply), are furnished in the Tender Drawings, Volume 5. Based on the Tender drawings, Good for Construction (GFC) drawings shall be engineered and developed by the successful Tenderer during execution stage considering the site and system requirements. The Contractor may devise improved layouts/arrangements and develop further detailed drawings and shop-drawings (for construction) for the systems/sub-systems to effect space saving, also ensuring requirement for RAMS.

1.4.3 INCOMING 33 kV SUPPLY

- 1.4.3.1 The bulk power is planned from Uttar Pradesh Power Transmission Corporation Limited, the power supply authority, ("UPPTCL") grid substations (GSS) through 33kV double cable feeders (three core Al conductor XLPE cables) at One (1) Receiving Substation (RSS)/Auxiliary Main Substation(AMS) of UPMRCL for East West Corridor.

1.4.4 RECEIVING SUBSTATION/AUXILIARY MAIN SUBSTATION

- 1.4.4.1 Deleted
- 1.4.4.2 The 33kV RSS/AMS, shall be indoor cubicle type bays with AIS switchgears.
- 1.4.4.3 The scheme of 33 kV incoming feed and the Receiving Substations/AMS for each Corridors is as follows;

Table 1.5: 33 kV Incoming Feeders and Location of RSS for East West Corridor (Phase-1B)

Grid Substation	Location of RSS of Metro Authority	Approx. length of double circuit HV Cables
One circuit at 33 kV from 220/132/33 kV Hardoi Road GSS	33 kV RSS/AMS at Vasantkunj Depot	2.5 km
One circuit from 400/220/132/33 kV Jehta GSS		6.5 km

- 1.4.4.4 East – West Corridor interlinked with North – South: - Only one RSS/AMS shall be constructed at Vasantkunj Depot, and special arrangement shall be made at Charbagh Interchange Station of North – South Corridor to extend feed to East – West Corridor in case of emergency. The sizing of the RSS/AMS shall be designed so that the complete loss of any one of the two existing RSSs (TPNR RSS and Munshipulia RSS) does not affect normal operation across the entire system.

1.4.5 33 kV CABLE DISTRIBUTION NETWORK

- 1.4.5.1 The 33kV power supply drawn from the RSS/AMS 2 will be distributed along the alignment through 33kV Ring main cable network for feeding to traction and auxiliary

loads. These cables will be laid in dedicated Cable Brackets / Hangers / Cable supports along the viaduct and tunnel. Respective tender drawings to be referred to for tender quantification.

1.4.5.2 The two 33kV feeds from Vasantkunj RSS/AMS will be fed to ASS at Vasantkunj Station .

1.4.5.3 Power supply at 33kV is distributed to various traction substations as well as auxiliary substations located in stations, by means of a 33kV ring main feeder network having 2 cables for 33kV Power Supply to traction (TSS) and auxiliary substations (ASS).

1.4.5.4 Depot ASS and TSS building in Depot to provide Traction power supply for movement of Rolling stock and Auxiliary power supply for depot building services as well as RSS/AMS services.

1.4.5.5 The 33kV power feeding scheme is developed in such a way that it provides flexibility of operation in normal and outage/emergency situations. This is made possible with three RSSs (2 existing RSS (NS Corridor) + One RSS/AMS at Vasantkunj (East West Corridor)) and 33kV cable interconnections between the North South Corridor and East West Corridor . Single outage of any RSS / cable section etc. will not affect the normal traffic though it will involve slight reconfiguration of feeding system. For details, refer to Chapter 13.

1.4.6 AUXILIARY SUBSTATIONS

1.4.6.1 Each elevated station is provided with one Auxiliary Substation (ASS) having 33 kV / 415V, 2 x 500 kVA dry type transformers. Each Underground station is provided with Auxiliary Substations (ASS) having 33 kV /415 V, 2 x 2000 kVA dry type transformers.

1.4.6.2 Normally two transformers of ASS at each elevated / UG stations will be fed through two different 33 kV ring main circuit coming from RSS.

1.4.6.3 For Depot, auxiliary substation having 33 kV / 415 V, 2 x 2000 kVA dry type transformers have been sized.

1.4.6.4 Each of the two auxiliary power transformers for the ASS at elevated / UG station is sized to cater to full load demand of the station. Normally, one of transformers is in load condition, and other one is hot standby. The auto changeover facility is provided at 415 V level (in E&M contractor's scope).

1.4.6.5 The operation of auxiliary 33kV ring is in open mode. Since one transformer is in hot standby, either ring cable fault or transformer fault will not impact the station supply. Therefore, the tripping in such cases will as per interlocking logic and all the ring cable circuits are having circuit breakers

1.4.7 TRACTION SUBSTATIONS

1.4.7.1 33 kV / 750 V DC ASS cum Traction Substations (TSSs) will be provided for the East West Corridor as below:

- ASS for elevated stations (3 nos)

- ASS for underground stations (4 nos.)
- ASS+TSS for elevated stations (2 nos.)
- ASS+TSS for underground stations (3 nos.)

In addition to the above, depot shall be equipped a separate ASS cum TSS catering the depot Traction and aux power requirements.

In these TSS, the 33kV will be transformed and rectified to 750V DC for feeding the Third Rail, from where the rail cars will finally draw power for rolling stock propulsion.

- 1.4.7.2 Each Traction cum Auxiliary Substation (TSS cum ASS) shall receive power at 33kV from the 33kV ring feeder. Every ASS or TSS cum ASS has two 33kV bus section with each having 2 switchgear feeders, for loop-in-loop-out of 33kV feeder for each Ring Circuit, which provides power to 33kV busbars. Traction and Auxiliary transformer(s) are fed from these busbars.
- 1.4.7.3 The feeding to ASSs/TSSs has been designed in with closed ring systems– i.e. from Vasantkunj RSS, two 33kV feeders (one from each half of 33kV busbar in RSS) to feed ASSs/TSSs and the ring is open at the end of the loop, in the normal case scenario.
- 1.4.7.4 Separate ASS/TSS have been envisaged for Depot and in the normal scenario the complete isolation of mainline and depot supplies can be achieved. The depot ASS + TSS is to be fed from Vasantkunj RSS through 33kV feeders from the two 33kV busbar of RSS.
- 1.4.7.5 The above arrangement of ASS/TSS feeding ensures that one ring main cable fault will not put any of the TSS out of service. Directional relays cater for all possible scenarios including feed extension from one ring to another.
- 1.4.7.6 The 750V DC is fed to the third rail system through high-speed circuit breakers (HSCB) and disconnecting switches will be incorporated for sectionalizing the third rail as per the operational requirements.

1.4.8 THIRD RAIL AND STINGER SYSTEM

- 1.4.8.1 The Third rail system at 750 V DC shall be utilized for transferring power to the Rolling Stock. The third rail system shall be of the bottom contact, aluminium / Stainless steel composite type in which vehicle-mounted current collection shoes press upwards onto the underside of the conductor rail.
- 1.4.8.2 The Conductor Rail shall be installed at trackside at the specified distance to the track centreline / top of the rails. In the case of double tracks, the Conductor Rails shall be installed between both tracks. In stations, it is necessary by safety reasons the Conductor Rails be installed to the side of the track opposite to the platform edge.
- 1.4.8.3 The conductor rail and all connected parts shall be kept within a defined space constraint to prevent contact with passing trains.
- 1.4.8.4 The design, procurement, installation, testing and commissioning of Third Rail System in complete, including the accessories, is under the scope of LKE (02)-01 Contractor. Also, all the power supply connection and cable work from Traction Substation to the Conductor Rails and the return current cabling work shall be installed by LKE (02)-01 Contractor.
- 1.4.8.5 Power for tracks inside the workshop building shall be provided via stinger installations and shore supply arrangement for workshop line. Stinger cables attached to contact trolleys shall provide power from overhead conductor rails.

1.4.9 EARTHING, BONDING, STRAY CURRENT MANAGEMENT AND EMC REQUIREMENTS

- 1.4.9.1 System protective earthing shall be provided for electrical safety on entire system including earthing of non-current carrying metallic components, cable supports, transformer neutrals, lightning arrestors, etc. The earthing system shall conform to IEC 61000-5-2, IEC 62305-3, IEEE 80:2000, IS 3043:1987 and EN 50122-1 with the latest amendment.
- 1.4.9.2 The earth system shall consist of:
- 1.4.9.2.1 The earth mats for ASS, ASS+TSS at passenger stations is under the scope of work of E&M Contractors. However, LKE (02)-01 Contractor shall design earth mat and responsible for the overall earthing system for ASS and ASS+TSS on mainline including interface and coordination with other designated contractors.
- 1.4.9.2.2 Structure Earth Conductor (SEC) run on the viaduct to be provided for the entire route.
- 1.4.9.2.3 In ASSs and ASSs/TSSs, earth mat / earth electrodes shall be provided by E&M Contractors, to the requirements of the LKE (02)-01 Contractor.
- 1.4.9.2.4 The Contractor shall review the design of the entire earthing system on the basis of safety to public and maintenance personnel against touch and step potential and fire hazards and finalise the design, sizes and layout of main earth conductors.

1.4.9.2.5 In ASS, ASS+TSS, earth shall be provided, as specified in relevant chapters and Chapter 17 of this Specification. The maximum earth resistance of entire system shall meet the following requirements:

1.4.9.2.6 Maximum Earth Resistance

Table 1.7: Maximum Earth resistance

Location	Earth resistance (ohms)	
	Each electrode	Total earth system
RSS/AMS	5	0.5
ASS	5	1.0
ASS + TSS	5	1.0
Other locations	10	To meet the requirements of EN 50122-1

1.4.9.3 To address the stray current corrosion problem associated with the DC traction system, the traction return circuit (running rails) shall be floating with respect to the earth on the mainlines. Running rails shall be insulated from the structure to comply with the requirements of EN 50122-2.

1.4.9.4 For depots, however, for the safety reasons of workmen, the traction return system shall be earthed in Workshop Building, IBL, Pit Wheel Lathe and Washing Plant. Remaining part of the Depot tracks will be floating however the running rails of Depots are electrically separated from mainlines through Insulated Rail Joints (IRJ), which will be in the scope of Track contractor. These IRJs are placed in-between the main line and the depot line to isolate them from each other.

1.4.9.5 Over voltage protection device (OVPD) at each station (located in ASS/ASS+TSS room) as well as in Depot TSS for floating tracks shall be provided for safety reasons i.e. temporarily short circuiting the running rails to earth in case a rise of running rail potential exceeds prescribed limits as per EN 50122-1.

1.4.9.6 The supply, installation, testing and commissioning of earthing and bonding system in each station and depots shall be under the scope of E&M contractors. Whereas, the design, supervision and integration of earthing and bonding system shall be under the scope of LKE (02)-01 Contractor. Bonding of mainline piers, handrails, track plinth etc., on the viaduct to Structure Earth Conductor shall be under the scope of LKE (02)-01 Contractor. All the structure parts shall be connected to station earth mats and for this purpose Structure Earth Conductor (185 mm² Aluminium), linking all mainline earth mats, shall be provided all along the corridor for both UP and DN lines. For detailed interfaces and scope Chapter 3 to be referred.

1.4.9.7 An EMC control plan, in conjunction with the EMC requirements given in General Specifications and in Chapter 17 of this Specification shall be submitted by Contractor for review by Engineer. All the equipment under this Contract shall meet the EMC/EMI norms as per international standards, as provided under Table 17.4 of this Specification. In regard to the installation practices for cable laying, the designs have been worked out taking into account the EMC compatibility. Contractor shall verify these plans / layouts including the for-construction drawings / plans in respect of EMC compatibility. After all the systems are integrated, the Contractor shall jointly conduct the EMC test along with other system contractors.

1.4.10 SCADA, ETS & POWER SUPPLY PROTECTION SYSTEM

1.4.10.1 The Purpose of the SCADA system shall be for remote monitoring and control from the Operational Control Centre (OCC) and Backup Control Centre of the power supply installations of the Lucknow Metro Rail Project (Phase-1B), i.e., East West Corridor and Vasantkunj Depot. The Operational Control Centre (OCC) will be situated in the Metro Bhawan and the Backup Control Centre will be established in the Vasantkunj RSS area.

1.4.10.2 For protection, interlock and metering of the equipment, protection control unit (PCU) i.e. Digital Protection Control System (DPCS) shall be installed on all switchgear panels. It shall be able to operate the vital components and work as the interface with the remote SCADA system. The communication between OCC SCADA and the RTUs at the power installation ends viz. RSSs, ASSs, TSSs and other location, if any, shall be achieved through OFC network. The OFC network shall be provided by Telecom Contractor of Lucknow Metro rail Phase- 1B. It shall be possible to monitor and log the various voltages, currents, power factor, maximum demand, power consumption and status of various equipment and provide automated control throughout the system at the OCC/BCC through the SCADA system.

1.4.10.3 The SCADA shall also have provision for plugging in a portable control console (laptop) with the RTU. It shall be possible to operate and monitor the status and alarm conditions of all equipment from this local control console.

- 1.4.10.4 An Emergency Trip System (ETS) shall be provided at each end of the station platforms, SCR and ASS/TSS and in Depot as per the requirement of NFPA 130. Traction supply power-off, in case of emergency, shall be achieved locally (hardwired logic) and not through SCADA system as defined in Chapter 18.
- 1.4.10.5 Different levels of communication protocol between RSS/AMS, TSSs, ASSs, station control rooms (SCR) and the OCC/BCC shall be worked out and necessary liaising/interfaces shall be maintained with Telecom Contractor to ensure provision of different levels of communication facilities throughout the system through the Fiber optic main communications bearer to be provided by Telecom Contractor.
- 1.4.10.6 The Contractor shall define the philosophy and furnish a scheme of protection with fast discrimination and reliable operation based on latest state-of-the-art computerized logic protection scheme. The zones of protection shall overlap providing second and third tier back-up protections.
- 1.4.10.7 The Contractor shall submit detailed fault calculations, relay settings and fault co-ordinate curves showing proper protection, discrimination between all upstream and downstream equipment. Pilot wire relaying and inter tripping as per the relevant chapters of ASS and TSS shall be provided.

1.4.11 DESIGN ENVIRONMENT

- 1.4.11.1 The RSS/AMS shall have indoor cubical type 33 kV bays with vacuum circuit breakers.
- 1.4.11.2 All equipment of Traction and Auxiliary Substations shall be installed indoor within ASS and ASS-cum-TSS room, as applicable. The ventilation system for the ASS/ASS+TSS rooms is to be provided by E&M contractor.
- 1.4.11.3 All electrical equipment shall be designed for the environmental class applicable as per Clause no. 1.12 of General Specification.
- 1.4.11.4 The design and construction of the distribution network, auxiliary and traction substations and all other subsystems shall be carried out in accordance with the following governing specifications and other statutory rules:
- Indian Electricity Act 2003 with latest amendments
 - Indian Electricity Rules 1956 with latest amendments
 - Regulations laid down by the Chief Electrical Inspector to the Government
 - Rules and Regulations prescribed by local authorities as applicable
 - Recommendations of relevant national (BIS, NBC etc.) and international standards (IEC, EN, BS, UIC, DIN etc.) as applicable
 - CEA Regulations 2010 with latest amendment.

1.4.12 INTERFACE AND COORDINATION WITH OTHER WORKS

- 1.4.12.1 The LKE (02)-01 Contractor will be responsible for coordinating all interfaces between the systems he is offering and all other packages awarded to other Detailed Design Consultants and contractors which impinge upon his works design – e.g., Traction DDC, Rolling Stock, Signalling and Telecommunication, viaduct, track, station buildings and

platforms, E&M, tunnel, TVS/ECS, maintenance management information system etc.

- 1.4.12.2 The Engineer will oversee the co-ordination between LKE (02)-01 Contractor and other designated contractors. However, the Contractor will allow for liaison with any modifications to his Works to cater for the work of such other Contractors.

1.5 MAKE IN INDIA

- 1.5.1.1 **Minimum Local content for the subject tender is 60% and to ensure compliance of items as listed in the Ministry of Housing and Urban Affairs order no. F. No. K-14011/10/2019 -UT-V dated 1 January, 2021. List of items is as below:**

- i. EHV, HV, LV and Control Cables
- ii. EHV, HV, LV Switchgears
- iii. Vacuum Insulated Switchgear
- iv. Air Insulated Switchgear
- v. Battery Chargers
- vi. Batteries
- vii. Transformers
- viii. Fire protection System
- ix. Control Relay Panel
- x. Conductor wires

CHAPTER-2: SCOPE OF WORK

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2.1. Overview of the Project

2.1.1. GENERAL

This Technical Specification specifies the objectives, guidelines and requirements for Design, Supply, Installation, testing and Commissioning of Receiving Substation/Auxiliary Main Substation, 750 volts DC 3rd Rail Traction System, 33KV ring main, Auxiliary Substations & Traction Substation and SCADA including depot for East West Corridor of Lucknow Metro Rail Project as described below:

Route Km (Approx)	Section Length (KM)	No. of U/G Stations	No. of Elevated Stations	No. of Depot	Completion period from LOA
East West Corridor (Phase- I B): Charbagh to Vasantkunj					
Vasantkunj Depot	6.3	0	0	1	18 months
Thakurganj(inc) to Vasantkunj (inc)	3.77	0	5	0	24 months
Charbagh(inc) to Thakurganj(excl)	7.39	7	0	0	27 months
Total	17.46	7	5	1	

However, the section length, number of stations date may change during design and construction stage.

2.1.2. Deleted

2.1.3. The Works to be executed under the Contract include the design, delivery, installation, testing, commissioning and technical / maintenance support including training of personnel for a complete, integrated Power Supply system and DC Third Rail System, including all Operations Control Centre and trackside equipment necessary to deliver the requirements of this Specification.

2.1.4. The Works to be executed under the Contract include the quality management and quality checking necessary to fulfil the quality requirements contained in Volume 3 and any quality requirements specified in the present volume.

2.1.5. The Power Supply system and DC Third Rail Equipment consists of:

- One 33 kV Receiving Substations (Air Insulated Sub-stations) related Auxiliary Main Substations and civil works including 33kV cables & accessories.
- DC Third Rail Traction System including Earthing & Bonding equipment and stray current monitoring system.
- 33 kV cable rings and the equipment of all the Auxiliary & 750V DC Traction Power Supply equipment for stations and Depots.
- Control and monitoring of the complete 33 kV, 750VDC and 415 Volts power supply system through SCADA system

2.2. Train Operation Data:

E-W Corridor Section	Items	2027	2030	2041	2051	2055
Charbagh to Thakurganj	Cars/Train	3	3	3	3	3
	Headway (sec)	195	168	138	129	129
	Trains/hr	18	21	26	27	27
	PHPDT	17945	20829	25357	27126	27126
Section	Items	2027	2030	2041	2051	2055

Thakurganj to Vasantkunj	Cars/Train	3	3	3	3	3
	Headway (sec)	390	336	276	258	258
	Trains/hr	9	10	13	14	14
	PHPDT	8972	10414	12678	13563	13563

2.2.1. The trains of modern design, lightweight made of stainless steel/aluminium, with 750V DC drive having V.V.V.F control, regenerative braking, suitable for ATP, ATO, UTO etc. shall be provided by other Designated Contractors. The cars shall operate on 750V DC traction system. UPMRC has planned to adopt Communication Based Train Control (CBTC) for signalling system. Rolling stock maintenance Depot for East West Corridor will be near Vasantkunj Station.

2.2.2. 750 V DC third rail traction system shall be provided for East-West Corridor. Closed type Tunnel Ventilation System has been used in U/G stations. The station public areas are air-conditioned while the plant rooms are provided with supply/exhaust system. Tunnel ventilation is primarily achieved by the movement of vehicles inside the tunnel under normal working conditions. Tunnel Ventilation Fans installed at each end of the stations are used to provide supplementary ventilation at times of high temperatures, and under congested traffic or emergency conditions. Booster fans have also been used at appropriate locations for use under emergency conditions or in case of a tunnel fire, the tunnel ventilation system is used for smoke extraction by operating tunnel ventilation fans in push pull mode. During emergency fire condition within a station, the station air handling system is operated for smoke removal.

2.3. Power Supply for East West Corridor

2.3.1. Power supply is received at

- 33kV at Vasantkunj Receiving Substation/Auxiliary Main Substation from the One circuit at 33 kV from 220/132/33 kV Hardoi Road GSS and One circuit from 400/220/132/33 kV Jehta GSS of UPPTCL through double circuit three phase cable feeders, each consisting of 3 single core cables of appropriate capacity

Estimated Power Demand:

Item	Peak Demand-Normal (MVA)	Peak Demand-Emergency (MVA)
Traction Power for design	7.95	7.95
Auxiliary Power for design	23.78	23.78
Total Power requirement	31.73	31.73

Power will be distributed at 33kV level to feed the auxiliary and traction power supply along the Corridor stations.

33kV feeders shall be laid along the Corridor route (Viaduct, Underground and at grade) in ring main configuration to feed power to the auxiliary & traction substations at Corridor stations en route.

The Backup Control Centre (BCC) for the East West Corridor will be located tentatively at Vasantkunj RSS/AMS and the OCC will be located at Centralized OCC at Metro Bhavan. This shall include suitable provision of HMIs and server/front end at the centralized OCC at Lucknow.

2.3.2. Tentative power Supply Diagram

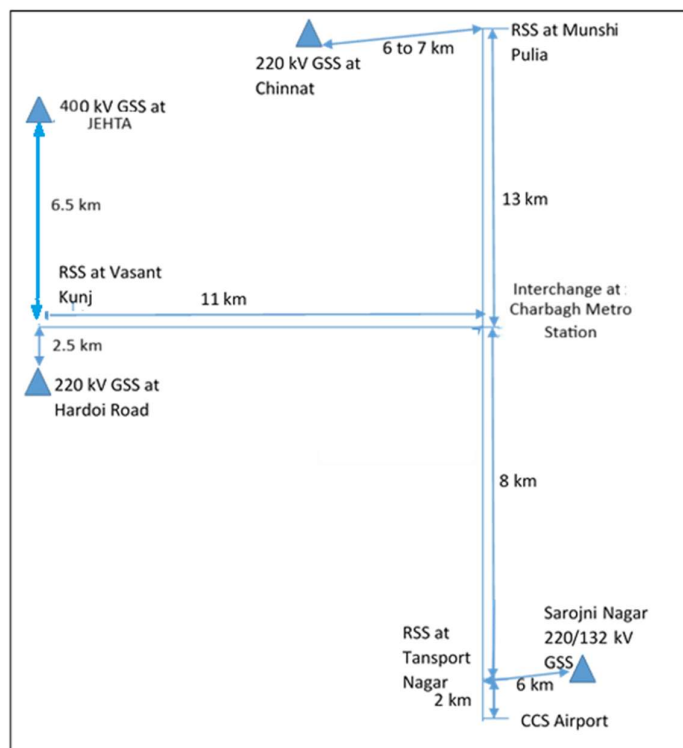


Fig. 10.1: Power Supply Arrangement

2.4. SCOPE OF WORK

2.4.1. General

The contractor shall meet all the design requirement defined in this chapter.

The scope of work comprises of Design, Supply, Installation, testing and Commissioning of Receiving Substation/Auxiliary Main Substation, 750 volts DC 3rd Rail Traction System, 33kV ring main, Auxiliary Substations & Traction Substation and SCADA including depots for East West Corridor of Lucknow Metro Rail Project and shall meet all performance, functions, design and technical requirements as defined in this Specification.

2.4.2. The items of Work, which are included in the LKE (02)-01 Contractors Scope but not be limited to, are described below

A1. Verification of the Preliminary design provided by DDC for East West Corridor (Phase 1 B).

A2. Traction Power Simulation Study of East West Corridor (Phase 1 B) shall be carried out by the contractor for detail design to confirm the TSS Quantity and to ensure that tentative capacities, ratings and quantities of equipment indicated in the tenders document meet various functional, performance and RAMS requirements with objective of having a state of art system.

During design stage the Contractor is required to submit clause wise compliance statement to these specifications with detailed explanations and document reference where such requirements shall be verified. At this stage the Contractor

- can suggest modifications if required. Necessary traction/power supply simulation shall also be carried out if required.
- a. Design of all system/sub system under this contract shall be done as per latest IEC/EN/IEEE/Grid codes and local standards.
 - b. Design, Supply, Installation, Testing and Commissioning of 33 kV switchgear with associated works at 33 kV Receiving Substations/Auxiliary Main Substation.
 - c. Design, Supply, Installation, Testing and Commissioning of 33 kV MV Cable network connecting various ASSs, connecting various TSSs and from Receiving Substations to Auxiliary and Traction Substations
 - d. Design, Supply, Installation, Testing and Commissioning of 33 kV/ 415 V Auxiliary Substation equipment at Stations, RSS and Depot ASS.
 - e. Design, Supply, Installation, Testing and Commissioning of 33 kV AC / 750 V DC Traction Substation equipment at Stations and Depot TSS.
 - f. Design, Supply, Installation, Testing and Commissioning of IGBT inverters along with transformer and associated switchgear at suitable locations of having maximum regeneration.
 - g. Design, Supply, Installation, Testing and Commissioning of 750 V DC Cable and cable connections from TSS to Third Rail.
 - h. Design, Supply, Installation, Testing and Commissioning of DC positive and negative Cables and cable connections from running rails to TSS and rail bonds.
 - i. Design, Supply, Installation, Testing and Commissioning of Third Rail system operating at 750 V DC for feeding power to Rolling Stock on mainlines and depot.
 - j. Design, Supply, Installation, Testing and Commissioning of Stinger System operating at 750 V DC for feeding power to Rolling Stock in workshops including shore supply at 750V DC.
 - k. Design, Supply, Installation, Testing and Commissioning of Control & Monitoring equipment for traction and auxiliary power supply, and necessary interface with OCC (Operation Control Centre) and BCC (Backup Control Centre if any).
 - l. Design, Supply, Installation, Testing and Commissioning of ETS system at all stations and depots.
 - m. Design of Earthing Bonding systems & Stray current management including Stray Current Management System.
 - n. Deal and resolve in co-ordination with the Engineer the interface with other contractors to ensure timely completion of the Works;
 - o. Testing, and commissioning including individual equipment from field, bays, Local control room and integrated from OCC and BCC (if any).
 - p. Installation plan, Design/Engineering, Good for construction (GFC) drawings and method statements for installation works.
 - q. Provision of all the construction drawings, documents, Operation manuals, Maintenance Manuals and Troubleshooting manual, as-built drawings.
 - r. Provision of all plans, manuals methodology/procedure in connection with these installations.
 - s. Supply of spare parts, tools and equipment.
 - t. Provide supervisory maintenance staffs who are expert in all the different levels of fault finding, maintenance and repair of the various systems supplied under the Contract during execution and defect liability period.
 - u. Provide Knowledge Transfer and Training to Employer's staff.
 - v. The scope of work also includes transportation, storage, loading / unloading, insurance and safe custody till handing over of the Facilities.
 - w. The scope of work includes the quality checking and quality management for all the works listed in the contract.
 - x. Ensure all the requirement of Safety, Health and Environment as per Volume 6 of this contract.

- y. Installation, Testing and commissioning of critical items like DC switchgear, Third rail, 33kV GIS etc. shall be done in the supervision of the respective subcontractor /vendor. Necessary certificate shall be submitted to the Engineer before energization.

2.5. Design Responsibility

2.5.1. General

The Contractor shall ensure that design proposed is the most modern and latest available technology internationally. Proposed design supported with references of design adopted in other similar method in India and worldwide most recently with improvements in the design based on the aesthetic working experience or financial saving.

The design shall be as per the latest revisions of IEC/EN/IEEE/NFPA/Indian Standards. The Engineer shall determine the standard/parameter to be used in case of any discrepancy based on the following guidelines:

For 33kV/ASS/Non traction system- Indian Standards/Grid codes/SEB codes

For Traction System- Relevant International standard

The design of DC traction system must comply with EN 50163 and EN 50388.

The System Design shall meet the specified performance and operational requirements stipulated in this Technical Specification.

The Contractor shall submit the basic equipment design philosophy covering various protection, interlocking, indications control modes (Local/Remote/Auto) at equipment level as well as its interface with SCADA.

The Contractor shall carry out Simulation study, to ascertain the load requirement of the system to verify the sizes/rating of the equipment and submit report for approval by the Employer.

The specified level of reliability, availability, maintainability and safety requirements of the System shall be achieved and verified by the Contractor by analysis, simulation, testing and commissioning, and system demonstrations as required in this Specification.

LKE (02)-01 contractor shall be responsible for development of a complete scheme for earthing, bonding, stray current protection/management measures and EMC requirements.

The design of the power distribution system and Third Rail Traction equipment and the related supplies shall be chosen so that power loss are kept as low as possible; power loss shall be measured by contractor to prove the compliance to its design calculation.

The space requirement given in the tentative layouts of ASS, RSS etc. shall be critically reviewed by the Contractor to economize on space and also to provide a layout amenable to good maintenance and operation practices, to achieve an overall economic design.

Submission of Method statement for Installation, testing & commissioning of all equipment covered in this PS/TS are under the scope of LKE (02)-01 contractor.

Submission of Protection Philosophy incorporating Fault Discrimination and Relay Coordination of all equipment including DC protection study covered in this PS are under the scope of LKE (02)-01 contractor.

2.5.2. Deleted

2.5.3. Receiving Sub Station (RSS)/Auxiliary Main Substation(AMS)

- The design besides complying the requirements of these specifications shall also conform to Grid Code and specifications of the transmission licensee.
- The RSS shall be fed from two independent feeders from Grid Sub Station.
- The RSS shall be designed to take the 100% Traction and Auxiliary Power supply load of East West Corridor for design year also taking into consideration its future extensions.
- Earthing calculation for the RSS shall be done by LKE (02)-01 Contractor and submitted for approval of Employer.
- Design of Lightning Protection system, Equipment Protection shall be ensured by LKE (02)-01 Contractor.
- Protection Philosophy of the RSS equipment for fail-safe operation to ensure the safety of equipment & personnel shall be submitted by LKE (02)-01 Contractor for approval of Employer.
- Design and validation of relay setting for various equipment of RSS in this contract is in the scope of LKE (02)-01 Contractor.
- Provision of automatic change over in case of failure of one Incomer Feeder is to be kept.
- Load Optimization among the RSS for North-South and East-West Corridor shall be the responsibility of LKE (02)-01 Contractor

The minimum rating/ capacities of major equipment for Receiving Sub Station (RSS) are as under:

S. No.	Major Equipment	Capacities/Ratings
1	33kV Switchgear	1250A

2.5.4. Auxiliary Sub Station (ASS)

- The design besides complying the requirements of these specifications shall also conform to Grid Code and specifications of the distribution licensee.
- One Auxiliary Transformer at Station to be capable for full load of station.

- ASS Equipment Protection to be designed by LKE (02)-01 Contractor.
- Detailed earthing layout of each ASS is to be submitted for the approval of Employer based on typical earthing layout provided in tender drawing.
- Interlocking Philosophy of all equipment of ASS to be design for failsafe operation to ensure the safety of equipment & personnel shall be submitted by LKE (02)-01 Contractor for approval of Employer.
- Failure of one 33kV incoming feeder or any one auxiliary transformer or any other equipment in a circuit shall not impact its capability to deliver full power at all the relevant stations/Locations.
- Master Trip Relay (MTR) of 33kV AIS/GIS breakers shall be remotely resettable.

The minimum capacities of major equipment for Auxiliary Sub Station (ASS) are as under:-

S. No.	Major Equipment	Capacities/Ratings
1	33kV AIS/GIS	1250A
2	Auxiliary Transformer	500 kVA (elevated section), 2000 kVA (underground section) 2000 kVA (depot ASS, catering to RSS load also)

2.5.5. Traction Sub Station (TSS)

Traction substation is to be designed in conformance to the latest international standards and practices as per the following:

- In case of loss of one rectifier transformer (N-1/2 scenario of TSS) in any of the TSS, there shall not be any impact on the Train normal operation as per the design year requirements.
- In case of loss of one TSS (N-1 scenario of TSS i.e. loss of both rectifier transformer), there shall not be any impact on the Train normal operation as per year 2055 requirements.
- The design of DC switchgear is most critical to the reliability of traction system. The contractor shall incorporate all latest features to achieve state of art design including but not limited to:
 - The feeder HSCB shall employ load measurement for detecting fault on third rail prior to permitting closing.
 - The feeder HSCBs shall have feature of auto reclosing.
 - The feeder HSCBs shall not have lockout except in case of frame leakage fault in HSCB panel. In case design requires a lockout after a specified number of failed reclosure attempts, it shall be remotely resettable.
 - Positive isolator panel shall be designed for high reliability off load operation. The interlocking design shall permit its operation only when there is no power on either side of power contact. Positive isolator shall be motorized and remotely controlled.
 - Use of fiber glass/insulated material body of field proven design shall be preferred.
 - The positive Isolator panel shall be so mounted that even in case of water ingress to the extent of 30cm above the floor level inside the TSS, the TSS bypass function can be remotely performed.

- It shall be possible to bypass any TSS and restoring power to third rail by a single command from OCC or locally from inside of TSS.
- Emergency Trip System to be designed at all station & Depot wherever required for ensuring the safety of personnel as per NFPA 130.
- Minimum number of TSS shall be 5 (five) for main line and one TSS for depot.
- Minimum number of two inverters shall be provided at suitable location for recuperation of maximum regenerative energy. The Contractor will be required to design and select TSS locations for inverter installation which provides the highest recovery of regenerative energy.
- The Contractor can also propose additional locations for installation of inverters where additional cost can be justified by recovery of energy. This shall be subject to the approval of the Engineer. Additional cost shall be payable to the contractor based on the price agreed in the contract for such additional inverter (i.e. beyond four numbers of inverters).
- Configuration of inverter shall be designed and submitted to employer for approval.
- The minimum capacities of major equipment for Traction Sub Station (TSS) are as under:

S. No.	Major Equipment	Capacities/Ratings
1	33kV AIS (RSS / depot / elevated) / GIS (Underground section)	1250A
2	Rectifier	2500 kW
3	HSCB	Incomer 6000A, Busbar 10000A and Outgoing 4000A
4	Inverter	1000kW
5	DC cables	300 Sq.mm Copper 6 runs per feeder

2.5.6. Third Rail System

- Design of the complete third rail system for mainline and depots is in the scope of LKE (02)-01 Contractor.
- Current carrying capacity of conductor rail shall be capable of taking the entire traction load for design year requirement.
- Contractor shall submit a concept third rail sectioning philosophy along with provision of remote operated isolators for the approval of the Engineer.
- Sectioning of third rail in the main lines shall be designed considering the train can be received at platform in case of failure in next section.
- Sectioning at crossover shall be designed for permitting both single line train operation and short turn back in both directions in event of failure in any given section.
- Sectioning of third rail in the depot shall be designed considering the operation of main line shall not be affected.
- Rails of Main line, Depot to be kept at floating voltages excluding the following area:
 - Inspection Bay Line (IBL) area
 - Washing Bay Line (WBL)
 - Pit Wheel Line (PWL)
- IBL area, WBL & PWL at Depot is to be kept earthed.
- Gap analysis with ramp design is to be done by LKE (02)-01 Contractor.
- The ramp design shall be rugged, suitable for withstanding arcing due to repeated braking of full load current of trains without undue wear. All possibilities of avoiding break before make shall be explored and implemented.
- There shall be a secondary insulation at support level.
- The Contractor shall design third rail to earth insulation to high value keeping intended value of 100 ohm-km for running rail in dry condition. This value shall be specified by the contractor at design stage and validated at testing stage.
- Mechanical Loading: The expected worst-case static and dynamic loading in both vertical (downwards and upwards) and horizontal (parallel and perpendicular to the rail) direction shall

be determined by analysis. Destructive and non-destructive loading tests shall be performed on 3 and 5 complete support insulator assemblies respectively to demonstrate the capability of the support assembly to withstand the expected loading.

- Provision of stinger system in Inspection Bay lines as explained in ERTS.
- The minimum rating/ capacities of third rail are as under:

S. No.	Major Equipments	Capacities/Ratings
1	Third Rail	
2	Nominal Current rating	4500A
3	Short circuit capacity	50kA for 1 sec
4	Design life	30 Years
5	Max Nominal Resistance at 15°C	6.5 milliohm per km
6	Nominal thickness of stainless steel in conductor rail	6 mm Nominal
7	Adhesive strength (Aluminum/ Stainless steel)	>60kN
8	Stinger system	
9	Nominal continuous rated current	800A

2.5.7. 33kV MV Cable Network

- LKE (02)-01 Contractor will verify the minimum ratings of MV cable provided by the DDC.
- The design shall validate (N-1) redundancy without impairing capability of taking full load of both corridors
- The 33kV network shall be designed for max 5% voltage drop at the farthest end in the worst-case scenario.
- Protection and earthing & bonding arrangement of MV to be ensured by LKE (02)-01.
- Sheath Induced voltage calculation under both normal and faulty condition shall be done to substantiate design.
- MV network design shall include the following:
 - In case of fault in MV cable in a given section of MV ring main, only the faulty section of MV circuit shall be isolated.
 - In MV circuits having more than one cable per phase, it should be possible to isolate only the faulty cable and thereafter it shall be feasible to reenergize the affected MV circuit with the balance healthy cables.
 - The MV network design shall permit both closed ring as well as open ring operation.
 - The extension of power from normal feeding zone of new RSS to the feeding zone of the other (existing) RSS should be feasible by a single command both remotely from OCC as well as locally.
 - The MV network shall be so configured such that in event of water ingress/fire at any ASS/TSS locations, only MV power supply of that location should be affected. The MV power supply of remaining stations should not be affected in such eventuality.
- The minimum rating/ capacities of 33kV cable and accessories are as under:

S. No	Major Equipment	Capacities/Ratings
1	33kV cable and accessories	1R, 3X1C/300Sq.mm XLPE, Aluminum Cable
2	Rated Voltage	U_0/U_m 19/33 (36KV), FRLS for elevated/at grade/depot section FRLSOH for Underground section
3	Rated short Circuit current carrying capacity of conductor	16kA for 3 second
4	Power frequency withstand voltage (kVrms)	70kV

2.5.8. Stray Current control and management

Stray Current control and management shall be designed as per EN 50122 including but not limited to:

- High value of running rails to earth insulation.
- Validation of running rails to earth insulation and interface with track contractor for running rail to earth insulation validation.
- Verification and validation of potential shift measurement.
- Verification and validation of stray current measurement.
- Provision of stray current monitoring system and setting up acceptable baselines.

External stakeholder engagement including validation as may be required to establish that there is no impact on nearby services on commencement of 750 volt dc traction with support of Engineer / Employer, if required.

2.5.9. SCADA

- The SCADA system shall be designed as per tender drawing.
- No single failure of any of the SCADA component shall results in the failure/blanking of any station/RSS.
- Server license shall be for minimum number of 70 RTUs and min 45000 I/Os.
- Each RTU shall have 20% spare I/O capacity.
- SCADA network shall support necessary protocols such as IEC 61850, 60870-5-101, 103, 104 as and where applicable as per SCADA architecture.
- Each RTU shall have provision for PLC.
- Integration & Up-gradation of existing SCADA System (Make-ABB) installed at BCC server room, TPNR RSS & MSPA RSS of Lucknow Metro shall be in accordance to Chapter 18 (I) & (II) of this TS.

2.5.10. Protection system:

In addition to the scope of work as described in the Employer's Requirements - Technical Specification and other documents forming part of this Contract, the protection system shall comprise, without limitation, to the following:

- LKE (02)-01 Contractor shall design and develop full proof main and backup protection philosophy for various system including EHV cable interfacing with Power Supply Authority, 132kV system, 33kV system and 750V DC system.
- The design of main and backup protection shall be considering fault discrimination of the smallest faulty section and segregation of faulty section.
- Develop time graded protection system interfacing with GSS grid system.
- Design and develop interlocking system for various voltage level equipment.
- Design and validation of relay setting for RSS, ASS, TSS and various equipment supplied in this contract.

2.5.11. Testing and Commissioning Philosophy:

- The testing and commissioning philosophy shall be as per Chapter 7 of ERTS.

2.5.12. Design Submittals:

Designs Submittal shall include the following but not limited to-

- Clause wise compliance statement of tender design and confirmation of its verification
- Various System studies, as required
- Final power supply single line diagram of traction network, MV network, individual RSS, TSS and ASS
- Detailed single line diagram including protection
- Metallic sheath induced voltage calculation
- Earthing and cross bonding calculations
- Detailed layout of RSS/ASS/TSS
- Basic equipment design philosophy including protection, interlocking etc.
- Equipment sizing Calculation, technical specification, general arrangement drawing, schematic drawings
- Harmonic study
- Power Factor study
- Equipment Layout
- O&M manual comprising of preventive maintenance schedule, breakdown maintenance details, condition base maintenance schedule, schematic drawing, logic diagrams troubleshooting directory, line replaceable units etc.

2.5.13. Earthing, Bonding and EMC Requirements

The Contractor's scope of Work includes design, supply, installation, testing and commissioning of complete material for structure earthing and bonding, stray current protection and EMC requirements throughout entire section.

- The LKE (02)-01 Contractor shall be responsible for development of a complete scheme for earthing, bonding, stray current protection measures and EMC requirements.

- The Contractor shall be responsible for the design of the entire earthing system on the basis of safety to public and maintenance personnel against touch and step potential and fire hazards and finalize the design, sizes and layout of main earth conductors.
- To address the stray current corrosion problem associated with the dc traction system, the traction return circuit (running rails) shall be floating with respect to the earth on the mainlines. Running rails shall be insulated from the structure to comply with the requirements of EN 50122-2.
- Provision of Electrical Insulation Membrane for station platforms.
- Provision of OVPD at all the stations and the TSSs and its integration with Stray Current monitoring system.
- Earthing, bonding and Stray current mitigation measures of traction and auxiliary power supply in the Depots and in Mainlines.
- For Depots, however, for the safety reasons of workmen, the traction return system shall be earthed at IBL area, WBL and PWL area.
- The running rails of depots are electrically separated from mainlines through Insulated Rail Joints (IRJ). These IRJs are placed in-between the main line and the depot line to isolate them from each other by a length more than a full train length with three car or one car as appropriate.
- An EMC control plan, in conjunction with the EMC requirements shall be submitted by Contractor for review by Engineer as per ERTS. The EMC control plan shall include measures to reduce conducted, induced and radiated emissions, especially the level of harmonics, to acceptable values as specified by relevant international standards. The Contractor shall be required to conduct EMC tests, as per the relevant standards.

2.6. PERFORMANCE REQUIREMENTS

2.6.1. General

The Contractor shall ensure that all electrical and electronic apparatus are designed and constructed to operate without degradation of quality, performance or loss of function in the electromagnetic environment of the Project.

All subsystems, equipment to be used for the Power Supply system and Third Rail Equipment shall be of proven design and in use in other passenger carrying metro/railway systems.

The reliability and maintainability processes and procedures shall be planned, integrated and developed in conjunction with the operating environment, and the design, development and production functions to permit the most effective and economical achievements of the systems and equipment design objective.

The system shall meet or exceed the requirements of CENELEC Standards EN50126 or equivalent international standards for Reliability, Availability, Maintainability and Safety of electronic equipment as defined in chapter 19 of ERTS.

For all transformers, the transformers losses shall not exceed the expected values specified in this ERTS in relevant chapters.

2.6.2. Availability

The Contractor shall be responsible for providing a System design, maintenance procedures, and defining the recommended spares holdings to ensure that the Availability requirements of the System shall be achieved.

The measures for Availability shall be Mean Time Between Service-Affecting Failures (MTBSAF).

The complete traction power supply system including the DC third rail system shall be designed to meet **99.95%** service availability within 1 (one) year of ROD for each progressively commissioned section.

For the purposes of availability calculations, the Contractor shall assume that the service operating hours are 19 hours per day (05:00 to 24:00) for 365 days a year. Scheduled maintenance is excluded from the availability calculations of the system.

The availability figure shall be calculated on a monthly basis and the Contractor shall demonstrate that the availability figures are met in 6 consecutive months of observation. If the availability figure is not met in 6 consecutive months by the end of DLP period then the DLP for that section shall be extended by 1 month every time till the requirement of achieving availability figures for 6 consecutive months is reached, for each instance of such non-compliance but within a maximum cap of three years from start of DLP.

The System shall be designed and engineered to maximise Availability during traffic hours, to minimise the amount of maintenance required to maintain the System and to ensure that any maintenance can be carried out with the minimum amount of time, the minimum amount of skill and at a minimum cost.

Any incidence/failure while on revenue operation affected for more than 30 minutes due to the reasons attributed to Traction & Power Supply system shall invite penalty not exceeding Rs 15 lakh. Engineer's decision to impose the penalty shall be final.

2.6.3. SERVICE LIFE

All components, materials, software and other support required to repair and service all System shall be available for at least 30 years from the Employer's Taking over of the Works or Section.

2.6.4. Documents and Manuals for Priority Section of East West Corridor

The Contractor shall supply in English language, all the following drawings and documents according to the time table defined below which may be modified according to the contractual planning of the equipment supply.

2.6.4.1. One months after Letter of Acceptance (LoA)

- Detailed Work Program/overall planning of execution of project shall be submitted.
- Detailed Procurement Plan for Priority/Entire Section.
- List of all vendor details with credentials, testimonials, and type test certificates etc. for all the major equipment and cables for priority section.
- Details of CVs for key staff of project organization for the approval of Employer.
- Detailed construction timetable, precisely defining the various equipment construction stages.

2.6.4.2. Two months after Letter of Acceptance (LoA)

- A complete list of sub-contractors.

- List of all vendor details with credentials, testimonials, type test certificates etc. for all the major equipment and cables.
- Method statement for installation and testing commissioning plan for all major equipment shall be submitted.
- The selection of these suppliers is at the Contractor's discretion and entirely under his responsibility. No approval that may have been given to him, in this respect, shall release him from any of his responsibilities under the contract.

Similar timeline shall be followed for Balance section of East West Corridor to meet the key dates provided in the tender document

2.7. Vendor Approval and Selection Procedure

2.7.1. It shall be obligatory for the Contractor to obtain Notice of 'No Objection' from the Engineer for the selection of the vendors for all items of work, even if the name of the vendor is specified in the Contractor's Technical Submission and the works to be done including purchase of materials and equipment is in accordance with the Standards specified in the Contract.

Vendor to be selected who are capable to provide good after sales services available in India during DLP and thereafter.

The Contractor shall send a proposal after ensuring that what he proposes at least meets the specifications both, the quality and safety standard of the stipulated makes, the proposed product should be a proven one. He shall also stand full guarantee to his proposal and if at any stage it is found that the material is not suitable or meeting the tender requirement, the contractor shall replace the material with alternate vendor without any additional cost to UPMRC. The alternate makes can be used only after an approval accorded by the Employer, whose decision will be final in the matter.

The approval of any equipment or product to be used shall be done in two stages:

2.7.2. Stage-I

- Assessment of capability of proposed Vendor to supply a particular equipment or product, with quality and performance requirements, as required by Specifications as well as other contract conditions. The proposed product should be a proven product in service for at least 5 years.
- Assessment of the financial and functional strength of the Vendor to supply the requisite quantity of equipment and product as per delivery schedule acceptable to contractor and engineer to deliver the project in time.

2.7.3. Stage-II

Stage-II called as Technical Submission Approval Stage, selection of Equipment or product from the equipment/products manufactured/supplied by the approved vendor will be done. This stage includes thorough technical assessments about the conformance of the offered equipment/product to the Specifications and other requirements.

To obtain Vendor Approval the Contractor must apply with the two sets of the following documents to the Engineer:

- Company Profile and Experience of the Vendor
- Clause wise compliance of the relevant Clauses of Specifications.
- Details of supplies/orders executed in last ten years for the type of equipment/product offered. Supplies/orders executed for Underground Metro Systems shall be specifically mentioned

- Details of the facilities available at the Works/Manufacturing Unit where the proposed equipment/product shall be manufactured.
- Proof regarding compliance to Manufacturer's Qualifications. The offered products must be proven in service.
- Audited Financial Statements of the Vendor for the last three years.
- Type test certificates/ Performance certificate from accredited laboratories for the proposed type of equipment / products to establish the technical capability of the vendor (In case, specific requirements are mentioned in the relevant sections of Specifications with regard to type testing, same shall also be complied additionally).
- The vendor shall not have been blacklisted by any Govt. Agency /PSUs/ Autonomous Bodies/ SPVs in India.
- ISO9000 Certification for the Works/ Manufacturing Unit where the proposed equipment/product shall be manufactured.
- Any other item as required by Employer / Employer's Representative.
- Contractor must certify the checklist provided that vendor Proposal is complete and all the above documents are available in the Vendor Proposal. In addition, the Contractor must check / certify compliance to the Specifications before forwarding the same.
- Incomplete Vendor Proposal will not be treated as a submission and will be returned.
- Engineer will give Approval to the Vendor Proposal (received complete with all the documents mentioned above) expeditiously.
- Technical submission shall be accompanied with the calculations / other technical documents to justify the selection of any particular model of equipment / product, detailed technical features / parameters of the selected product, type test certificates from the accredited laboratories for the offered products, any other document required by the Engineer.
- Engineer will give Approval to the Technical Proposal (received complete with all the documents mentioned above) expeditiously.

It may be noted that Approval of Vendors shall only be done by Employer / Engineer after the award of the work. Vendor submissions shall not be evaluated during the tender evaluation. Conditional Tender offers received from Tenderers with particular Vendors for supply of equipment/ products will not be evaluated during evaluation and will be dealt with after award of the work.

It may further be noted that Employer / Engineer shall be under no obligation to accept equipment / products manufactured by the successful Tenderer, unless it meets the entire criteria mentioned above.

In addition to above, the following shall also be ensured for the Vendor Approval and Selection:

- **Proven Design**

The Contractor shall develop the design based on this specification and on sound proven and reliable engineering practices. The broad design details shall be submitted with technical support data in the technical bid. Detailed calculations shall be submitted to the Engineer during the design process stage for review and approval.

- **Systems and Sub-Systems**

Manufacturer shall have at least 10 years' experience of design and manufacturing of similar system. Proposed systems from the proposed manufacturing unit shall have been in use and have established their satisfactory performance and reliability for 5 years in minimum.

All sub-systems, equipment and major components etc. (hereinafter referred as 'sub- systems') shall be state-of-art and of proven design.

Proposed Systems/ sub-systems shall have been in use and have established their satisfactory performance and reliability on at least One mass rapid transit systems (including Railway or Airports) in revenue service over a period of Five years or more in one country outside the country of origin or in India. If required by the Engineer, Contractor shall provide certificate of satisfactory performance for a period of five years or more from the Metro operators. Where similar System/ Sub-systems of a same or higher rating are already proven in service as per the above criteria then the supply shall be based on such sub-systems.

All 'sub systems' shall be procured from the approved vendors and sourced from only such manufacturing units that have supplied the sub-systems that fulfill the proven design requirements as above.

In case the contractor proposes to use systems or sub-system(s) that do not fulfill the above said criteria then the contractor shall furnish sufficient information to prove the basic soundness and reliability of the offered systems and sub-system(s) for review of the Engineer.

The Engineer's decision on contractor's proposal shall be final and binding.

For sourcing the equipment from indigenous manufacturing facilities, following conditions shall be complied:

In case the vendor uses his own facilities for indigenization after part supply of equipment from the approved manufacturing unit, no change in design, component type/make, quality standards, manufacture procedure, etc. shall be made without specific approval of the Engineer.

In case OEM wants to use manufacturing facilities in India (other than his own) for items for which the OEM has been approved, it shall enter into an agreement with such selected Indian equipment manufacturer and obtain prior approval from UPMRC. No change in composition, rating, type, model no., manufacturing process, quality standards, design, etc. and make of the components used in assemblies/sub-assemblies of such equipment as manufactured by the approved parent vendor shall be made without specific approval of the Engineer.

In case OEM wishes to change/make/type specifications, etc. of any sub-components for supplies to be sourced from Indian facility, specific prior approval of the Engineer shall be obtained for changes made, model, specification, etc. Responsibility for obtaining such prior approval shall rest solely with the contractor.

Format for submitting the vendor approval request shall be given to the contractor during initial stages and approved format shall be followed throughout the contract.

Tenderer should meet the criteria for the vendor/ Manufacturer of following equipment as detailed below:

SN	Description	Minimum Eligibility	Proveness	Remark
1	DC Switch Gear**	Proposed Vendor/ Manufacturer should have at least 10 Years of Experience for manufacturing of DC switchgear of same rating or higher rating	Proposed Vendor/ Manufacturer should have supplied the same with satisfactory operation for 5 years in a Mono rail/Tram/Metro Project	DC switchgear shall consist of the following item through single Vendor**/ Manufacturer (Rectifiers, High Speed Circuit Breakers Panels, Isolators, OPVD) Following items are also desirable to be supplied by the same vendor** Inverter & Stray Current Monitoring System

2	33kV GIS 33kV AIS	Proposed Vendor/ Manufacturer should have at least 10 Years of Experience for manufacturing of same rating or higher rating	Proposed Vendor/ Manufacturer should have supplied the same with satisfactory operation for 5 years in a Mono rail/Tram/Metro Project/TransCo/DisCom	-
3	Third Rail System	Proposed Vendor/ Manufacturer should have at least 10 Years of Experience for manufacturing of same rating or higher rating	Proposed Vendor/ Manufacturer should have supplied the same with satisfactory operation for 5 years in a Mono rail/Tram/Metro Project	
4	Equipment for SCADA System			
5	Other equipment covered in this PS			
6	33kV cables	Proposed vendor / manufacturer should have at least 10 years of experience for manufacturing of same rating or higher rating	Proposed vendor / manufacturer should have supplied the same with satisfactory operation for 5 years in a Monorail / Tram / Metro Project / TransCo / DisCom	
<p>** DC switchgears and associated items are considered to be the backbone of DC traction system which plays an important role for achieving the RAMS target. The Contractor therefore is required to supply these items from single vendor. If, LKE (02)-01 contractor proposes these items through different vendors, then he has to submit a proposal explaining why such relaxation is sought to the Engineer. The Engineer may permit the same if the contractor is able to establish that either the main contract or the related different vendor of DC switch switchgear have prior experience in dealing with these equipment together in one previous contract. The decision of the Engineer shall be final and binding.</p>				

In case of above mentioned equipment is manufactured in India, then credential of the parent company shall be submitted for approval, provided that the responsibility of design and quality lies with the parent company.

CHAPTER 3: INTERFACES

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CHAPTER – 3

INTERFACES

3.1 INTERFACES

3.1.1 SCOPE

- 3.1.1.1 The design and construction process for Lucknow Metro Rail Project (East West Corridor- Phase 1 B) involves multi-disciplinary agencies, which shall take up the design and construction of various systems like Power Supply Works, Civil Works, Track Works, Signalling Works, and E & M Works etc. The successful implementation of the Project will require close interaction and co-ordination among the various agencies.
- 3.1.1.2 It shall be the responsibility of the LKE (02)-01 Contractor to interface with all the agencies involved in the project for the successful completion of all activities assigned to the Contractor. This Chapter defines as the Scope of Work of multi-disciplinary agencies, in respect of interface required with LKE (02)-01 Contractor for elevated/at-grade/underground sections including mainline & depots, so that the problems which could arise during the execution stage are greatly minimized, if not eliminated. However, it shall be the responsibility of the LKE (02)-01 Contractor to maintain a close interface with the other designated contractors and design consultants, so that the problems anticipated/faced during design/design review, procurement and execution at site are communicated at the appropriate time. Periodical Interface Meetings shall be coordinated by the Engineer, to arrive at logical and expeditious solutions, to ensure smooth progress of the physical works and realization of the scheduled dates for completion of Works.
- 3.1.1.3 The Contractor shall submit an Interface Management Plan in accordance with Clause 3.2.1 of the GS.
- 3.1.1.4 This Chapter defines the interface requirement with the following agencies:
- a. Detailed Design Consultants for all the works
 - b. Power Supply Authorities
 - c. Track work Contractors
 - d. Station Building & Viaduct Contractors (Elevated)
 - e. Tunnel & UG Station Contractor (UG)
 - f. Station Building Finishing Contractor
 - g. E&M Contractor
 - h. Depot Contractors
 - i. Rolling Stock Contractor
 - j. Signalling Contractors
 - k. Telecom Contractors
 - l. ECS/TVS
 - m. Government Agencies
 - n. Any other contractor/agency designated by Employer or working in the section.

3.1.2 INTERFACE WITH DETAILED DESIGN CONSULTANT OF POWER SUPPLY & TRACTION SYSTEM

- 3.1.2.1 Employer has appointed a DDC (Detailed design Consultant) Traction & Power Supply. The DDC Contract involves detailed design for the Power Supply Distribution System, 750 V DC, Third Rail Traction Electrification and SCADA System for the Project.
- 3.1.2.2 The Contractor will be required to interface with the DDC (Traction)/UPMRC for any design/design review related issues, technical clarifications and/or confirmations.

3.1.3 INTERFACE WITH TRACKWORK CONTRACTORS

- 3.1.3.1 The interface items associated with Trackwork Contractor(s) (Elevated/At Grade/Underground), for mainlines and depots are listed in Table 3.1.3 given below:

Table 3.1.3 Interfacing with Trackwork Contractor(s)

Item No.	Item Description	Traction & Power Supply Contractor	Track Contractor(s)
1.	Third Rail Design and Installation (Mainlines and Depots) Ballast less Track	<p>a. Shall obtain track drawings from the Track Contractor and shall arrange to design and indicate the locations of dowels required for installation of third rail bracket in the track drawings provided by the Track Engineers.</p> <p>b. Shall arrange to supply dowels and associated bolts with necessary Jig and fixtures for positioning the dowels at correct locations and correct plane and confirm the same before concreting the plinth casting or sleeper casting for third rail support assembly.</p> <p>c. Shall arrange to procure and install third rail equipment, accessories, special tools, jigs and fixture etc. at site as per the</p>	<p>a. Shall provide relevant track drawings to Traction/Power Supply Contractor and shall arrange to take up installation of dowels as per the details furnished by the Traction & Power Supply Contractor Contractor.</p> <p>b. Shall arrange to install dowels (supply arranged by Traction & Power Supply contractor) for the third rail support assembly, in track plinth/slab over casted by Track contractor with the help of Jigs & Fixtures supply arrange by Traction & Power Supply Contractor for this purpose.</p> <p>c. Any change in track alignment shall be informed timely to Traction & Power Supply Contractor and all traction related civil modifications works have to be executed accordingly.</p>

Item No.	Item Description	Traction & Power Supply Contractor	Track Contractor(s)
		<p>installation drawings.</p> <p>d. Shall arrange to perform post installation tests and shall ensure that the installation tolerances are in accordance with the installation drawings.</p>	
2.	Third Rail Design and Installation (Depots) Ballasted Track on PSC sleeper and turnouts.	<p>a. Shall obtain depot track layout drawings and indicate the location of 3rd rail bracket in normal track sleepers & in turnout sleepers.</p> <p>b. Shall arrange to supply required quantity of dowels for embedding the same in PSC sleepers of track & turnout during manufacturing stage.</p> <p>c. Shall arrange to procure and install third rail equipment, accessories, special tools, jigs and fixture etc. at site as per the installation drawings.</p>	<p>a. Shall arrange to provide the depot track layout & turnout layout along with sleeper layout drawings.</p> <p>b. Shall ensure dowels (supplied by Traction & Power Supply Contractor) are embedded in PSC sleepers during manufacturing stage.</p> <p>c. Shall arrange to install the third rail sleeper of the track and turnouts at locations as indicated in the approved sleeper layout drawing.</p>
3.	750 V DC positive & negative cable crossings	<p>a. Shall arrange to prepare the scheme for the passage of 750V DC positive & negative cable crossing at desired locations & coordinate with the Track Contractor for the availability of space.</p> <p>b. Shall supply and supervise the installation of HDPE/GI pipes for cable crossing beneath the tracks.</p>	<p>a. Shall arrange to provide adequate space in the track structure for 750V DC positive & negative cable crossings etc. at desired locations as provided by Traction & Power Supply Contractor</p> <p>b. Shall install/insert HDPE/GI pipes in to track reinforcement for crossing cables.</p>

Item No.	Item Description	Traction & Power Supply Contractor	Track Contractor(s)
4.	Information regarding track alignment, curves, levels etc.	a. Shall take into consideration the alignment parameters while designing the location of third rail brackets & other fixtures along the track.	a. Shall arrange to provide information regarding alignment parameters to Traction & Power Supply Contractor.
5.	Earthing, bonding and stray current protection measures	<p>a. Shall arrange to develop Earthing, Bonding & Stray Current Management Scheme & shall arrange to coordinate with Track Contractor to ensure that Earthing, Bonding & Stray Current management scheme is implemented properly.</p> <p>b. Shall arrange to install the stray current monitoring device.</p> <p>c. Shall arrange to make connection between track plinth provided with GI/SS plates/Cables & Stray current cable at every alternate span or as per approved drawings.</p> <p>d. Shall specify the required value of track to earth resistance tests to be performed by the Track Contractor.</p> <p>e. Shall witness the track to earth resistance tests to be performed by the Track Contractor.</p>	<p>a. Shall arrange to implement Earthing, Bonding & Stray Current Management scheme related to track in accordance to approved plan.</p> <p>b. Shall arrange to provide continuity through SS flats or as per approved design in each track plinth as per drawing. Shall also arrange to provide continuity of track plinth through GI/SS plates/Cables of suitable size.</p> <p>c. Provision of GI/SS plates/Cables of designed size shall be ensured in each track plinth near expansion joint for connection of stray current cable.</p> <p>d. Shall arrange to perform insulation resistance tests to ensure that measured values are within permissible limits.</p>

Item No.	Item Description	Traction & Power Supply Contractor	Track Contractor(s)
6.	Insulated Rail Joints (IRJ) between main line and the depot line	a. Shall arrange to prepare the scheme for the location of insulated rail joints (IRJ) between the mainline and depot and between the depot and workshop and coordinate for its provision.	a. Shall arrange to provide insulated rail joints (IRJ) at selected locations in the mainline and depot as per the requirement. b. Functionality test of IRJ to be done as per RDSO specification and test results to be shared with Traction & Power Supply Contractor.
7.	Return Cable connections	a. Shall arrange to design scheme of return current cable connections through CAD welding to running rail and advice the location of the same to the Track Contractor. b. Shall arrange to connect return cables through CAD welding to running rails including all hardware and accessories required for the connections.	a. Shall provide clearance and adequate support to Traction contractor for CAD welding at the desired locations for return current connections.
8.	Cross bonding Cable connections (CAD Welding)	a. Shall arrange to design scheme of cross bonding cable connections through CAD welding between running rail and advice the location of the same to the Track Contractor. b. Shall arrange to connect through CAD welding cross bonding cables to running rails including all hardware and accessories required for the connections.	a. Shall provide clearance and adequate support to Traction contractor for CAD welding at the desired locations for cross bonding connections.

Item No.	Item Description	Traction & Power Supply Contractor	Track Contractor(s)
9.	Rail Fastening Systems	a. Shall co-ordinate for the electrical characteristics of the fastening system	<p>a. Shall select & supply a fastening system in accordance to the following acceptance criteria: The insulation shall be preferably more than 100 Ω.KM, or conductance of 0.01 Siemens/KM per track for a new track measured under dry conditions.</p> <p>As per EN 50122-2 Insulation value of 2 Ohm.km or conductance of 0.5 Seimens/km per Track shall be maintained during the system life time. of Traction & Power Supply contractor and maintain a jointly signed acceptance criteria document for Stray current protection.</p> <p>b. Shall provide full protections against concrete spraying which might endanger the rail insulation.</p>
10.	Feasibility study of cross-over	a. Shall conduct feasibility study of crossovers proposed by Track contractor.	a. Will install the cross-over section of the track only after feasibility study by the Traction contractor

3.1.4 INTERFACE WITH ELEVATED STATION BUILDING AND VIADUCT CONTRACTOR

3.1.4.1 Station Building and Viaduct Contracts: Station building and Viaduct contractors of elevated / at-grade stations shall be responsible for structural works associated with station building and viaduct. The interface items associated with Station building Contracts are listed in Table 3.1.4 given below:

Table 3.1.4 Interfacing with Elevated Station building and Viaduct Contractor(s)

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
1.	ASS/ TSS room	<p>a. Shall coordinate with Station Building Contractor to ensure that no expansion joints are provided on the roof above ASS and ASS/TSS room</p> <p>b. Shall coordinate for the room size and other</p>	<p>a. Shall ensure that no expansion joints are provided on the roof above ASS and ASS/TSS room.</p> <p>b. Shall design floor for loads as furnished by the Traction Contractor.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		<p>associated requirements</p> <p>c. Shall furnish the equipment weight and size details to Station Building Contractor for designing floor for appropriate load</p> <p>d. Alternatively, can provide suitably designed anchor fasteners to fix transformers, 33kV panels, 750V DC Equipment, Battery chargers etc. to the basic floor/pedestal as per approved drawings.</p> <p>e. Should ensure height of the rolling shutters are adequate for pushing in the tallest equipment.</p>	<p>c. Shall provide necessary foundations for transformers, Panels other equipment etc.</p> <p>d. Shall provide the necessary cut-outs for cables entry and exit from track level to the room.</p> <p>e.</p>
2.	Installation of 33 kV, 750 V cables, traction return cables and SCADA cable for ETS connection	<p>a. Shall supply, install & connect 33 kV, 750V cables, traction return cables, SCADA cable for ETS connection.</p> <p>b. Shall furnish the detailed cable schedule.</p> <p>c. Shall interface with the Station contractor for the cable path for 33 KV, 750 V cables, traction return cables and SCADA cable for ETS connection in the Station area</p> <p>d. Shall co-ordinate with Station contractor for provision of opening and HDPE pipes of adequate size to carry the cables inside ASS/TSS/ETS and at track crossings.</p>	<p>a. Shall provide suitable opening and HDPE pipe for carrying cables inside ASS /TSS and for ETS as per requirement and agreed drawings. The mounting arrangement of ETS has to be provided in consultation with Traction contractor.</p> <p>b. Shall take into consideration the bending radius of cable and covering of cables in public places.</p> <p>c. Station building Contractor shall provide suitable opening in the TSS/ASS room at appropriate location for raising the cables coming from RSS /TSS at ground to the</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		<p>e. Shall close the opening with fire/watertight EPDM separators after installation of the cables.</p> <p>f. Shall co-ordinate with station building Contractor for suitable opening in the TSS/ASS room at appropriate location for raising the cables coming from RSS/ TSS at ground to the ASS/TSS. Shall co-ordinate with civil contractor for providing a shaft from ground to the TSS/ASS room.</p> <p>g. Shall supply and install HDPE pipes or any other suitable arrangements at corners of cut outs by providing curvature at 45-degree angle for cable entry & exists in ASS/TSS room so that sharp bending of cables shall be avoided.</p>	ASS/TSS by providing a shaft from ground to the TSS/ASS room.
3.	Temporary Power for Installation, testing & commissioning	<p>a. Shall co-ordinate with station contractor for provision of temporary power.</p> <p>b. Shall advise temporary power demand & required capacity and provide temporary cable.</p> <p>c. Shall install the required DB with all safety features for availing the temporary power.</p> <p>d. Shall pay to the station contractor for the power consumption.</p> <p>Note: If temporary power</p>	<p>a. Shall provide sockets for availing temporary power, at main DB or if available, inside ASS/TSS rooms as per requirement</p> <p>b. Shall provide suitable meters for calculating the consumption</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		is not available from Station Contractor, then Traction contractor shall make his own arrangement.	
4.	Installation of Equipment in ASS and TSS	<p>a. Shall provide equipment layout drawing.</p> <p>b. Shall coordinate with Station contractor for suitable design of ASS & TSS rooms to ensure smooth passage for carrying the equipment inside ASS & TSS.</p> <p>c. Shall coordinate with Station contractor for suitable openings in floor/roof/walls for cable and earthing connections.</p> <p>d. Shall provide dimensions and weights of various equipment</p> <p>e. Shall arrange material handling equipment at his own cost.</p> <p>f. Shall supply, transport and install all ASS & TSS Traction Equipment including Transformers, rectifiers, 33 kV Switchgear, HSCB etc. as per Specifications.</p>	<p>a. Shall construct ASS & TSS rooms keeping in view the specific requirements of LKE (02)-01 Contractor regarding passages, ingress / egress routes, door size, knock out panels, floor openings etc. access of heavy equipment forming permanent works</p> <p>b. Shall provide cutouts in floor/roof/walls for cable entry.</p> <p>c. Shall make provision for passage/crossing of various cables in the station along the walls, under the platform copings etc. for cable entry from viaduct cable duct to ASS/TSS room.</p> <p>d. Shall provide hatch, gantry beams for carrying heavy equipment and materials to auxiliary & traction substations. Shall provide lifting hooks in ASS/TSS rooms as per requirements of LKE (02)-01 Contractor</p>
5	Earthing, bonding and stray current protection arrangements at stations	<p>a. Shall provide schematic arrangement of earthing, bonding and stray current protection management in the stations</p> <p>b. Shall connect SEC to MET in ASS/ ASS+TSS.</p>	<p>a. Shall associate with LKE (02)-01 Contractor to verify the earthing-bonding of structure as per approved scheme.</p> <p>b. Shall connect various structures at station to Earth Cable as per</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
			approved schematic.
6	Emergency Trip System (ETS) Installation	<p>a. Shall inform about the requirement of ETS.</p> <p>b. Shall coordinate for locations of ETS at stations as well as cable routing from RTU in TSS/ASS room to ETS locations.</p> <p>c. Shall provide ETS equipment at stations/platforms, and other appropriate locations including ASS/TSS and SCR.</p> <p>d. Shall install PLC/control cables from nearest platforms, ASS, ASS/TSS, SCR to ETS equipment.</p>	a. Shall provide niche in walls of stations or mounting arrangement/cut outs/sleeves on wall/pillars to accommodate ETS equipment and cables.
7	33 kV, 750 V dc, return cables and control cables from RSS/TSS in RSS to Station / mainline tracks	<p>a. Construct cable support, brackets, provide and lay all cables from RSS up to station and mainline boundary/shaft in station area and building.</p> <p>b. Coordinate for cable routes within the station area and building</p>	a. Coordinate for cable routes in the station area and building.
8	Installation of 33 KV, 750 V cables, return cables, control cables, Inter-tripping cables, OFC and other cables on the viaduct	<p>a. To coordinate for area of cable laying in view of the walkway and track etc.</p> <p>b. Shall supply & install 33kV, 750V cables, return cables and any other cable on/in/under the viaduct including cable support infrastructure (Trays, brackets, clamps, etc.)</p> <p>c. Shall take into</p>	<p>a. To give marking for the space on the Viaduct and station area for cable laying.</p> <p>b. Shall coordinate and allow LKE (02)-01 contractor to install suitable cable support infrastructure (metallic brackets, clamps, cable trays etc.) on/in/under the viaduct, in the trench as per requirement for laying of cables</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		consideration the bending radius of cable and covering of cables in public places.	c. Shall provide suitable opening / cutouts in viaduct at appropriate location for raising/laying of cable as per the requirements of LKE (02)-01 Contractor
9	Earthing, bonding and stray current protection arrangements on the viaducts	<p>a. Shall provide schematic arrangement of earthing, bonding and stray current protection management on the viaducts & ensure and certify that earthing, bonding and stray current management scheme is implemented. This will include cast-in-situ / bridge.</p> <p>b. Shall provide schematic of structure earth terminals in track slab.</p> <p>c. Shall supply and install Structure Earth Conductor (SEC) and support/brackets on viaduct including clamping (both UP and DN directions, including the station area)</p> <p>d. Shall install and connect structure earth terminals of viaduct segments to Structure Earth Conductor through cable as per specification</p> <p>e. Shall connect various structures (like handrails, Walkway etc.) on viaducts to Structure Earth Cable as per schematic</p> <p>f. Shall coordinate with civil Contractors for verification of earthing bonding and stray current measures</p>	<p>a. Shall incorporate earthing, bonding and stray current Management requirements.</p> <p>b. Shall provide structure earth terminals of viaduct segments for connecting them to Earth Cable</p> <p>c. Shall coordinate with LKE (02)-01 Contractor for verification of earthing bonding and stray current measures adopted in the structure, as per the recommendations in approved design.</p> <p>d. The viaduct contractor will provide the necessary earth terminals (including holes) for fixing cable lugs on handrail at expansion joint locations (including any discontinuity in handrail) for connection of cable & subsequent connection to Structure earth cable (SEC) as per drawings.</p> <p>e. Provide embedded strips on piers for pier bonding as per drawing.</p> <p>f. To implement the stray current arrangement as per Traction & power GFC drawings.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		<p>adopted in the structure, as per the recommendations in approved design.</p> <p>g. Shall provide typical drawings showing arrangement of earth terminals required to be provided for earthing and bonding of the handrail.</p> <p>h. Shall Connect Handrails with SEC.</p> <p>i. Shall connect the pier head strip to SEC with suitable cable and lug arrangement as per drawing.</p>	
10	Viaduct lightning Protection	<p>a. Shall Design and provide lightning protection as per viaduct lightning protection scheme.</p> <p>b. Lightning protection on viaduct consists of the work of interconnecting the Handrail, connection of handrail to SEC, connecting viaduct segment to Piers</p>	a. Shall facilitate the LKE (02)-01 Contractor for providing the viaduct lightning protection scheme.
11	Viaduct Lighting & Auxiliary Supply	a. Shall design and install the necessary items such as light fixtures, cable support for Viaduct Lighting system and Auxiliary Supply arrangement at viaduct.	a. Shall facilitate the LKE (02)-01 Contractor for providing the viaduct lighting and Auxiliary Supply.
12	Way Side Disconnect Switches on Viaduct	<p>a. Shall coordinate for the space requirement for installing the wayside disconnect switches on viaduct.</p> <p>b. Shall provide the necessary equipment loading to be taken into account of structure design.</p>	<p>a. Shall facilitate the LKE (02)-01 Contractor for providing the necessary design drawing to assess the feasibility of installation within available space.</p> <p>b. Shall take into account the equipment loads in design calculations.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building and Viaduct Contractor
		c. Shall design and install the Wayside Disconnect Switches on Viaduct as per the LKE (02)-01 Contract requirement. All the Fixing and pedestal arrangement shall be done by LKE (02)-01 Contractor.	

3.1.5 INTERFACE WITH STATION BUILDING FINISHING CONTRACTORS

3.1.5.1 Station Building Finishing Contracts: Station building finishing contractors of elevated /at-grade/Underground stations shall be responsible for finishing works associated with station building. The interface items associated with Station building finishing Contracts are listed in Table 3.1.5 given below:

Table 3.1.5 Interfacing with Elevated Station Building Finishing Contractor(s)

Item No.	Item Description	LKE (02)-01 Contractor	Station Building Finishing Contractor
1.	ASS/TSS room	<p>a. Can provide suitably designed anchor fasteners to fix transformers, 33 kV panels, 750 V DC equipment, Battery chargers etc. to the basic floor/pedestal.</p> <p>b. Should coordinate for height of the rolling shutters are adequate for pushing in the tallest equipment.</p> <p>c. Shall coordinate for finishing of the room and epoxy coating etc.</p> <p>d. Shall provide the TSS/ASS equipment layout.</p> <p>e. Shall provide the information Ingress/egress routes for cables.</p> <p>f. Shall provide the</p>	<p>a. Shall design floor for loads as furnished by the Traction Contractor. Shall provide ASS/TSS room complete in all respects, including flooring, access doors, rolling shutters, windows, ventilators and interior finish, but excluding foundations for transformer and panels.</p> <p>b. Shall provide the necessary cut-outs for cables entry and exit from track level/at any other locations for traction requirement in the room.</p> <p>c. Should ensure height of the rolling shutters are adequate for pushing in the tallest equipment.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building Finishing Contractor
		<p>weight and dimensions of cables.</p> <p>g. Shall provide the Cable paths (ducts, trays, brackets etc), gallery size, route alignment, mounting arrangement of cables with respect to the bending radius of cables.</p> <p>h. Shall provide the Earthing Bonding and Stray current management scheme for compliance by station building finish contractor.</p> <p>i. Shall provide the necessary input for ETS fixing arrangement and location of ETS.</p> <p>j. Shall provide the equipment loading for use of Station finish contractor.</p>	<p>d. Shall provide ASS/TSS room complete in all respects, including flooring, access doors, rolling shutters, windows, ventilators and interior finish.</p> <p>e. Shall provide necessary foundations for transformers, Panels other equipment etc.</p> <p>f. Shall apply epoxy coating on the floor of ASS and ASS/TSS as per requirement</p> <p>g. Shall repaint the structure/wall after installation of ETS.</p>
2.	Installation of 33 kV, 750 V cables, traction return cables and SCADA cable for ETS connection	<p>a. Shall supply, install & connect 33 KV, 750V cables, traction return cables, LT power and SCADA cable for ETS connection.</p> <p>b. Shall furnish the detailed cable schedule.</p> <p>c. Shall interface for the cable path for 33 KV, 750 V cables, traction return cables and LT power & SCADA cable for ETS connection in the Station area</p> <p>d. Shall co-ordinate for</p>	<p>a. Shall provide suitable opening and HDPE pipe for carrying cables inside ASS /TSS and for ETS as per requirement and agreed drawings. The fixing arrangement of ETS must be provided in consultation with Traction contractor.</p> <p>b. Shall take into consideration the bending radius of cable and covering of cables in public places.</p> <p>c. shall provide suitable opening in the TSS/ASS room at appropriate</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building Finishing Contractor
		<p>provision of opening and HDPE pipes of adequate size to carry the cables inside ASS/TSS/ETS and at track crossings.</p> <p>e. Shall close the opening with fire/watertight EPDM separators after installation of the cables.</p> <p>f. Shall co-ordinate with station building Contractor for suitable opening in the TSS/ASS room at appropriate location for raising the cables coming from RSS TSS at ground to the ASS/TSS. Shall co-ordinate with civil contractor for providing a shaft from ground to the TSS/ASS room.</p>	<p>location for raising the cables coming from RSS TSS at ground to the ASS/TSS by providing a shaft from ground to the TSS/ASS room</p>
3	Platform insulation at stations	<p>a. Shall furnish the requirements for installation of electrical insulation membrane</p> <p>b. Shall supply, installation, testing and commissioning including adhesive and all components for completion of the work at platforms as per method statement</p> <p>c. Shall measure and certify that the insulation at the platform has been provided as per the method statement.</p>	<p>a. Shall provide the floor suitable for installation of electrical insulation membrane</p> <p>b. Shall finish the platform after installation of insulation membrane.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building Finishing Contractor
4.	Warning and indicator boards	<p>a. Shall co-ordinate and inform locations for provision of sign board & operating instruction boards for each ETS.</p> <p>b. Shall supply and install third rail warning and indicator boards all along the viaduct, stations and depots.</p> <p>c. Drawings for details of size and material will be proposed by the LKE (02)-01 Contractor for the approval of the Engineer.</p>	a. Shall supply and install all warning and indicator boards for each ETS
5.	Third Rail	a. Shall interface with Station building finishing contractor for cleanliness of third rail installations in station area.	a. Shall ensure that the cover of the third rail installations in station area are kept clean and shall cover the third rail installation while painting the area around the third rail.
6	Temporary Power for Installation, testing & commissioning	<p>a. Shall co-ordinate with station contractor for provision of temporary power.</p> <p>b. Shall advise temporary power demand & required capacity and provide temporary cable.</p> <p>c. Shall install the required DB with all safety features for availing the temporary power.</p> <p>Note: If temporary power is not available from Station Contractor, then Traction contractor shall make his own arrangement.</p>	<p>a. Shall provide sockets for availing temporary power, at main DB or if available, inside ASS/TSS rooms as per requirement</p> <p>b. Shall provide suitable meters for calculating the consumption</p>

3.1.6 INTERFACE WITH UNDERGROUND STATION BUILDING & TUNNEL CONTRACTOR

3.1.6.1 Underground Station Building and Tunnel Contracts: Station building, and Tunnel contractor of underground stations shall be responsible for structural works associated with station building and tunnel.

3.1.6.2 The interface items associated with Station building Contracts are listed in Table 3.1.6 given below:

Table 3.1.6 Interfacing with Underground Station Building & Tunnel Contractor(s)

Item No.	Item Description	LKE (02)-01 Contractor	Station Building (UG) & Tunnel
1.	Installation of 33 KV, 750 V cables, traction return cables, LT power & PLC cable for ETS connection and other control cables, earth strips/earth cables in station and tunnel area.	a. Shall supply & install 33 KV, 750 V, return cables , LT power & PLC cable for ETS connection, other control cables, earth strips/earth cables in station and tunnel area. b. Shall co-ordinate and give requirements to the UG E&M/ tunnel contractor for the cable path, gallery size, route alignment and mounting requirements for 33 KV, 750 V, return cables, LT power and PLC cable for ETS connection in the tunnel. c. Shall confirm the requirements for passages for cable crossing and alignment of cables in station area. d. Shall co-ordinate with tunnel contractor for provision of opening and HDPE pipes of adequate size to carry the cables inside ASS /TSS and at track crossings. e. Shall witness installation of cable duct trenches, troughs	a. Shall construct appropriate passages/trenches ducts with necessary cable support arrangement including all fire separation requirements. b. Shall provide suitable opening and HDPE pipe for carrying cables inside ASS /TSS and at track crossings as per requirement. c. Shall take into consideration the bending radius of cable and covering of cables in public places.
2.	Temporary Power for Installation,	a. Shall co-ordinate with tunnel contractor for provision of suitable	a. Temporary Power for Installation, testing & commissioning

Item No.	Item Description	LKE (02)-01 Contractor	Station Building (UG) & Tunnel
	testing & commissioning	sockets for temporary power	
3.	Lighting and ventilation in ASS & TSS	a. Shall interface with Tunnel / Station Build Contractor for any special requirements or preferred locations of lights, fans, exhaust fans and other Tunnel services.	a. Shall provide for special requirements or preferred locations of lights, fans, exhaust fans and other Tunnel services.
4.	Installation of Equipment in ASS and TSS	<p>a. Shall supply, transport and install ASS & TSS equipment including transformers, rectifiers, 33 kV switchgear, HSCB etc. as per Specifications.</p> <p>b. Shall provide equipment layout drawing to Station Building (UG) Contractor for location of foundations/pedestals needed for ASS/TSS equipment. Alternatively, the LKE (02)-01 Contractor can provide suitably designed anchor-fasteners/ channels to fix transformers, 33kV panels, battery chargers etc. to the basic floor/pedestal.</p> <p>c. Shall coordinate with SB & tunnel contractor for suitable design of ASS & TSS rooms to ensure smooth passage for carrying the equipment inside ASS & TSS.</p> <p>d. Shall coordinate with SB & tunnel contractor for suitable opening in floor for cable and earthing connections.</p>	<p>a. Shall provide ASS/TSS in good condition for installation with finished floor.</p> <p>b. Shall provide necessary foundations for transformers, panels other equipment etc. Shall coordinate with LKE (02)-01 contractor for location of foundations & pedestals or any other installation related interface as required.</p> <p>c. Shall provide the required cut-outs/hooks as per LKE (02)-01 Contractor requirements. LKE (02)-01 contractor shall provide the details and locations of the required cut-outs/hooks.</p> <p>d. Shall interface with LKE (02)-01 Contractor for requirement of knockout wall for equipment entrance inside ASS/TSS room. After mutual agreement the knockout wall shall be closed by SB & Tunnel Contractor.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Station Building (UG) & Tunnel
		e. Shall confirm the fire safety provisions f. Shall provide dimensions and weight of various equipment.	
5.	Earthing & Bonding and Stray Current management	a. Shall interface with SB & Tunnel Contractor for the requirement of support inside tunnels or at stations. b. Shall coordinate with SB & Tunnel Contractor for measurement of track to structure resistance insulation as per acceptance criteria jointly agreed and signed. c. Shall provide the requirements along with detailed drawings for implementation of Stray Current Monitoring Scheme.	a. Shall install all necessary support arrangement for earth cable in both tunnels b. Shall provide path and cable support for connecting station earth mats to earth cable c. Shall provide structure earth terminals of tunnel segments for connection to earth cable d. Shall connect various structures at station and inside tunnel to Earth Cable as per schematic e. Shall perform measurement of track to structure resistance insulation as per acceptance criteria jointly agreed and signed with LKE (02)-01 Contractor. f. Coordinate for requirements of stray current monitoring scheme.
6.	Emergency Trip System (ETS) Installation	a. Shall coordinate for locations of ETS at stations, tunnel etc. b. Shall provide ETS equipment at stations, cross passages and other appropriate locations	a. Shall provide niche in walls of stations to accommodate ETS equipment and emergency telephone as per requirement given by LKE (02)-01 contractor

Item No.	Item Description	LKE (02)-01 Contractor	Station Building (UG) & Tunnel
		c. Shall install PLC cable from nearest SCADA RTU & LT power cable to ETS equipment	
7.	Third rail disconnection switch in tunnel box	a. Shall coordinate and inform locations & relevant drawings. b. Shall supply and install the equipment with all accessories.	a. Shall provide space/niches and foundation for switches in tunnel area and crossovers.
8.	Third rails	a. Shall coordinate for delivery/transport of third rails in tunnel	a. Shall provide suitable access for transport of third rails inside the tunnels and underground stations.

3.1.7 INTERFACE WITH STATION E&M SERVICES CONTRACTORS

3.1.7.1 E&M services Contractors of elevated/at grade/Underground stations shall be responsible for works associated with E&M services of station building (Except RSS building). The interface items associated with E&M services Contractor are listed in Table 3.1.7 given below:

Table 3.1.7 Interfacing Requirements with Elevated E&M services Contractor

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
1.	ASS/TSS room	a. Shall develop and incorporate the LT panels layout as provided by E&M Contractor along with ASS/TSS equipment layout of ASS / TSS	a. Shall provide the details of all LT panel layout of ASS / TSS room
2.	Lighting and ventilation in ASS & TSS	a. Shall provide heat load of the equipment inside ASS/TSS. b. Shall interface with E&M Contractors for any special requirements or preferred locations of lights, ventilation/exhaust fans and any other power requirement.	a. Shall design and provide adequate ventilation and lighting system including ventilation/exhaust fans, power sockets for ASS/TSS. b. Shall provide cable connection from MDB/DB to switching panels of ventilation/exhaust fans
3.	Installation of	b. Shall provide schematic	a. Shall coordinate for

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
	Cable Trays in ASS as well as ASS cum TSS & TER	<p>layouts for the HT equipment inside ASS as well as ASS cum TSS</p> <p>c. Shall design, supply and install all the cable trays/hangers/support etc. for cables related to Traction (33kV, 750 V DC positive, return cables, ETS (Power & SCADA), Control cables, earthing cables and any other related cables) inside ASS as well as ASS cum TSS.</p> <p>d. Shall close the opening with EPDM modules after installation of the HT cables.</p> <p>e. Shall provide the cable route for ETS cables from Platform & SCR to ASS, ASS+TSS</p> <p>f. Shall provide the details & coordinate with E&M contractor for cable route from ASS as well as ASS+TSS to TER for SCADA communication cables.</p> <p>g. Shall interface with E&M contractor for cable trays required for LV and HV cables inside ASS as well as ASS + TSS</p>	<p>design, supply and install of LT cable trays inside ASS as well as ASS cum TSS as per the layout.</p> <p>b. Shall close the opening with fire stops after installation of the LT cables/cable trays.</p> <p>c. Shall provide cable tray/support infrastructure for ETS cables from Platform & SCR to ASS, ASS+TSS.</p> <p>d. Shall provide the cable tray/supports as per LKE (02)-01 Contractor requirement from ASS as well as ASS+TSS to TER.</p> <p>e. Shall coordinate with Traction contractor to incorporate the cable tray in E&M WRD.</p>
4.	Cable Connection from Auxiliary Transformer to MDB	<p>a. Shall coordinate and provide the suitable terminals at the secondary of the Auxiliary Transformer</p> <p>b. Shall interface with E&M contractor and co-ordinate for the LT</p>	<p>a. Shall design, supply, terminate and install cable connection from Auxiliary transformer secondary to MDB including the necessary supports required for installation.</p> <p>b. Shall terminate the LT</p>

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
		cables termination on Auxiliary transformer secondary	cables on transformer secondary c. Shall design and provide suitable terminals on the MDB side for facilitating cable connection.
5.	Bus duct Connection from Auxiliary Transformer to MDB, if required.	a. Shall design and provide suitable terminals on the Auxiliary Transformer side for facilitating Bus-duct connection. b. Shall facilitate for termination of bus duct terminals	a. Shall design, supply, terminate and install bus-duct connection from Auxiliary transformer secondary to MDB including the necessary supports required for installation. b. Shall terminate the LT Bus duct on transformer secondary and at MDB
6.	Protection system	a. Shall design and provide all protective devices for Auxiliary Transformer protection. b. Shall coordinate and provide details of CTs to be installed in MDB for various protection e.g. differential, REF protection to E&M contractor. c. Shall design a comprehensive protection system and relay setting in coordination with E&M contractor. d. Display of Status of LT ACB in MDB on OCC SCADA.	a. Shall supply and install CTs in MDB panel as per the requirement given by LKE (02)-01 Contractor. b. Shall coordinate and provide details of protection design with interlocking used for low voltage system. c. Shall provide potential free contacts, as required for power SCADA connection by LKE (02)-01 Contractor for display of LT ACB in MDB to OCC SCADA.
7.	Cable containment	a. Shall coordinate with E&M contractor for cable containment within station area excluding TSS/ASS room, as required.	a. Shall design, supply & install cable containment within Station area excluding TSS/ASS, ASS room & along track in station area as per LKE (02)-01 Contractor

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
			requirements
8.	Earthing in ASS and TSS	<ul style="list-style-type: none"> a. Shall design the earth mat at ASS+TSS, ASS and share the same with E&M Contractors. b. Shall associate during the installation of earth mat and jointly witness for the combined resistance measurement of the earth mat after installation. c. Shall incorporate the MET requirements into equipment layout in ASS as well as ASS+TSS d. Shall provide and connect various equipment to Earth Bus/METs inside ASS/TSS with G.I./Copper strips e. Shall review the E & M drawing of earthing and bonding arrangement pertaining to traction and convey acceptance/approval. f. Shall provide overall philosophical plan of earthing, bonding and stray current protection management scheme. g. Shall coordinate for the provision of MET connected for SCADA equipment. h. Shall connect SCADA equipment with MET as per approved 	<ul style="list-style-type: none"> a. Shall measure and share the soil resistivity data for design of earth mat. b. Shall install, testing and commissioning of earth mat according to approved design. c. Shall install Earth Bus / METs (main earth terminals connected to the earth mats) inside ASS and ASS+TSS to facilitate the connection of equipment in accordance with equipment layout issued by Traction Contractor. d. Shall prepare a combined earthing and bonding drawing of complete station including the philosophical plan of earthing, bonding and stray current protection management scheme. e. Shall provide the MET connection for the use of SCADA contractor.

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
		schematic.	
9.	Emergency Trip System (ETS) Installation	<p>a. Shall interface for the ETS requirements.</p> <p>b. Shall coordinate for locations of ETS at stations as well as cable routing from RTU in ASS as well as TSS+ASS room to platforms.</p> <p>c. Shall provide ETS equipment at platforms, SCR and TSS room including mounting arrangement to be provided on columns/pillar/wall.</p> <p>d. Shall install PLC cable from nearest SCADA RTU to ETS equipment & LT Power cable for ETS</p>	<p>a. Shall accommodate the ETS requirements into the design of cable trays, layouts etc.</p> <p>b. Shall provide cable route and install support (metallic tray, conduit etc.) for PLC cable from SCADA RTU to ETS and LT Power Cable for ETS.</p>
10.	Installing and providing power Supply to ACDB & DCDB at ASS and ASS + TSS from LV panel	<p>a. Shall coordinate for Cable laying from designated LV panel to ACDB at ASS / TSS</p> <p>b. Shall coordinate for cable support from LV panel to ACDB.</p> <p>c. Shall design, procure & install ACDB & DCDB in TSS/ASS.</p> <p>d. Shall supply and install cable from ACDB to DCDB including provision of DCDB.</p> <p>e. Shall coordinate with E&M Contractor to ensure the provision of necessary I/O contacts for SCADA RTU interface for control & monitoring of 415 V Transformer LV panels</p>	<p>a. Shall supply and install cable and Provide emergency supply (DG, UPS) feeder in emergency panel or from other suitable point to ACDB.</p> <p>b. Supply and install cable support from LV panel to ACDB.</p> <p>c. Shall provide dedicated SCADA Terminal blocks, with potential free contacts of LV ACB in MDB Panels for interfacing with SCADA RTU.</p>

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
		<p>from OCC/BCC.</p> <p>f. Shall display status of LV ACB (as per I/O list) at TPC workstations at OCC/BCC through SCADA.</p> <p>g. Shall supply, lay & terminate the control & monitoring cables from LV panels up to the designated TBs in SCADA RTU.</p>	
11.	Inter-tripping between main LV Circuit Breakers and the 33 kV Feeder Circuit Breakers of the Auxiliary Transformer	a. Shall provide and connect wire for inter-tripping circuits as per specification.	a. Shall provide necessary terminal details to facilitate inter-tripping.
12.	Transformer Door interlock	a. Shall provide the interlock scheme and castle lock for the LV Switchgear panel	a. Shall install the castle lock as per the requirement of LKE (02)-01 Traction contractor
13.	Cable support, trays etc. from ASS/TSS to TER Room	<p>a. Shall share cable size, routing details and cable containment required for cables.</p> <p>b. Shall supply, install, test and commission cables.</p> <p>c. Shall provide requirement of cable route and cable tray for laying of SCADA communication cables from ASS RTU to TER.</p> <p>d. Shall supply and lay SCADA communication cables from ASS RTU to TER.</p>	<p>a. Shall supply, install the cable support, trays etc.</p> <p>b. Shall provide cable route and install support (metallic cable tray, conduit etc.) for laying of SCADA communication cables from RTU panel to Telecom rack at Telecom Equipment Room.</p>
14.	Testing	a. Shall involve E&M contractor for local & integrated testing of 415 V Transformer LT Panels with SCADA system.	a. Shall coordinate and support for local & integrated testing of SCADA system.

Item No.	Item Description	LKE (02)-01 Contractor	E&M Contractor
15.	Cable route and Cable tray for SCADA communication cable	a. Shall provide requirement of cable route and cable tray for laying of SCADA communication cables from ASS RTU to TER. b. Shall supply and lay SCADA communication cables from ASS RTU to TER.	a. Shall provide cable route and install support (metallic cable tray, conduit etc.) for laying of SCADA communication cables from RTU panel to Telecom rack at Telecom Equipment Room.

3.1.8 INTERFACE WITH UNDERGROUND STATION E&M SERVICES CONTRACTORS

E&M services Contractors of Underground stations shall be responsible for works associated with E&M services of station building (Except RSS building). The interface items associated with E&M services Contractor are listed in Table 3.1.7 given below:

Table 3.1.8 Interfacing Requirements with Underground E&M services Contractor

Item No	Item Description	LKE (02)-01 Contractor	UG/E&M Contractor
1	Installation of 33 kV, 750 V DC cables, traction return cables and PLC cable for ETS connection and other control cables, earth strips/ earthing cables in station and tunnel area.	a. Shall supply & install 33 kV, 750 V DC Cables, return cables and PLC cable for ETS connection and other control cables, earth strips/earthing cables in station and tunnel area. b. Shall co-ordinate and give requirements to the UG (E&M) for the cable path, gallery size, route alignment and mounting requirements for 33 KV, 750 V, positive & return cables, LV AC cables, LV control cables, earthing strips/cables and LT Power & PLC cable for ETS connection in the tunnel. c. Shall confirm the requirements for passages for cable crossing and alignment of cables in	a. Shall design, supply and install cable trays (including metallic support, brackets, cable ladder including calculations etc.) as per requirement in stations and tunnels. b. Design, supply, installation of cable trays inside the ASS/TSS by UG (E&M) Contractor c. All cable supports and infrastructure inside the tunnel and at station area for 33 kV cable, 750 V DC cable, return cables, ETS cables, earthing cables, other control cables to be provided by E&M contractor

Item No	Item Description	LKE (02)-01 Contractor	UG/E&M Contractor
		station area. d. Shall witness installation of cable duct trenches, troughs.	
3	Lighting in ASS & TSS	a. Shall provide the equipment layout details inside the ASS/TSS for designing of lighting. b. Shall provide load details from UPS backed sources & its appropriate location.	a. Lighting from UPS backed source to be provided to illuminate safety equipment including ETS [blue light stations] traction notices and warning signage b. Power sockets from UPS backed source in ASS/TSS shall be provided as per the requirement of the LKE (02)-01 Contractor. c. Shall design the lighting system inside the ASS/TSS based on the equipment layout plan.
4	Installation of Cable Trays in ASS as well as ASS + TSS	a. Shall provide schematic layouts for the HT equipment inside ASS as well as ASS cum TSS b. Shall design, supply and install all the cable trays/hangers/support etc. for cables related to Traction (33kV, 750 V DC positive, return cables, ETS (Power & SCADA), Control cables, earthing cables and any other related cables) inside ASS as well as ASS cum TSS c. Shall close the opening with EPDM modules after installation of the HT cables. d. Shall provide the cable route for ETS cables from Platform & SCR to ASS, ASS+TSS e. Shall provide the details & coordinate with E&M contractor	a. Shall coordinate for design, supply and install of LT cable trays inside ASS as well as ASS cum TSS as per the layout b. Shall provide cable tray/support infrastructure for ETS cables Platform & SCR to ASS, ASS+TSS. c. Shall close the opening with fire stops after installation of the LT cables/cable trays. d. Shall provide the cable tray/supports as per LKE (02)-01 Contractor requirement from ASS/TSS to TER. e. Shall coordinate with Traction contractor to incorporate the cable tray in E&M WRD.

Item No	Item Description	LKE (02)-01 Contractor	UG/E&M Contractor
		for cable route from ASS as well as ASS+TSS to TER for SCADA communication cables. f. Shall interface with E&M contractor for cable trays required for LV and HV cables inside ASS as well as ASS + TSS	
5	Installation of Equipment in ASS and TSS	a. Shall supply, transport and install ASS & TSS equipment's including transformers, rectifiers, 33 kV switchgear, HSCB etc. as per Specifications. Shall provide the specific requirements for power socket in TSS/ASS room. b. Shall provide Panel flooding system in Traction Equipments.	a. Shall provide lighting & power sockets, ASS/TSS room
6	Earthing, bonding and stray current protection arrangements inside the in the Underground Stations	a. Shall provide schematic arrangement of earthing, bonding and stray current protection management in the stations b. Shall provide schematic of structure earth terminals in track slab at the stations c. Shall coordinate and install stray current monitoring equipment d. Shall install 185 mm ² bare Al. earth conductor in both tunnels	a. Shall install all necessary support arrangement bracket for 185 mm ² bare Al. earth conductor in both tunnels b. Shall supply, provide path and cable support for connecting station earth mats to MET at ASS/TSS room. c. Earth mat shall be designed & Installed by (E&M)/UG, installation by Station (Civil) Contractor accordingly design shall be vetted by LKE (02)-01 Contractor d. Shall connect various utilities at station and inside tunnel to Earth Cable as per schematic

Item No	Item Description	LKE (02)-01 Contractor	UG/E&M Contractor
		<p>e. Shall connect station earth mats to Earth conductor by 185 mm² Al. bare conductor.</p> <p>f. Shall give the requirements of earth mat connections from earth mat to MET in ASS/TSS room.</p>	<p>e. Shall provide and connect the earth mat risers as per the design to MET in liaison with LKE (02)-01 Contractor.</p>
7	Connection (bus duct) from Auxiliary Transformer to MDB	<p>a. Shall design and provide suitable terminals on the Transformer side for facilitating bus duct connection.</p> <p>b. Shall provide location of Auxiliary Transformer to E&M Contractor</p>	<p>a. Shall design supply and install LV bus duct with Bus bar from transformer secondary to MDB including the necessary supports required for installation in coordination with LKE (02)-01 Contractor.</p> <p>b. Shall provide location of MDB to LKE (02)-01 Contractor.</p>
8	Electrical Protection system	<p>a. Shall design and provide all protective devices for Auxiliary Transformer protection.</p> <p>b. Shall coordinate and provide details of CTs to be installed in MDB for various protection e.g. differential, REF protection to UG (E&M) contractor.</p> <p>c. Shall design a comprehensive protection system in coordination with UG (E&M) contractor.</p>	<p>a. Shall provide and install CTs in MDB panel as per the requirement given by LKE (02)-01 contractor.</p> <p>b. Shall coordinate and provide details of protection design used for low voltage system.</p> <p>c. Shall coordinate with LKE (02)-01 Contractor pertaining CT Control cable wiring and also providing potential free contacts at MDB for power SCADA connection for monitoring the LV breaker status.</p>
9	Inter-tripping between main LV Circuit Breakers and the 33 kV Feeder Circuit Breakers of the Auxiliary Transformer	<p>a. Shall provide and connect wire for inter-tripping circuits as per requirements shown in specifications.</p>	<p>a. Shall provide necessary terminal details to facilitate inter-tripping.</p> <p>b. Shall coordinate and provide potential free contacts at the respective LV breakers for inter tripping.</p>
10	Earthing in ASS and TSS	<p>a. Shall provide and connect various equipment to earth bus (MET) inside</p>	<p>a. Shall install earth bus / METs (main earth terminals, connected to the earth mats) inside ASS</p>

Item No	Item Description	LKE (02)-01 Contractor	UG/E&M Contractor
		ASS/TSS with G.I./Copper strips.	and TSS to facilitate the connection of equipment. b. Shall connect the risers from earth mat to MET as well.
11	Emergency Trip System (ETS) Installation	a. Shall provide ETS Load, cable route & cable details. b. Shall coordinate for locations of ETS at stations, tunnel, cross passages, station control room etc. c. Shall provide ETS equipment at stations, cross passages and other appropriate locations. d. Shall install PLC cable from nearest SCADA RTU to ETS equipment and LT Power Cable for ETS	a. Shall provide cable route and install cable support infrastructure (metallic tray, conduit etc.) for PLC cable from SCADA RTU to ETS and LT Power Cable for ETS. b. All cable support infrastructure shall be provided with necessary earthing arrangements.
12	Warning Notices & Indicator boards associated with traction power	a. Shall coordinate and inform locations of third rail warning and indicator boards. b. Shall furnish the relevant drawings. c. Shall review the fixing arrangement. d. Shall supply and install all warning and indicator boards	a. Shall provide the necessary cable support infrastructure and LT Power Supply for illuminated warning and indicator boards. b. Provide Socket for Emergency Signage inside the tunnel
13	Supply to ACDB at ASS / TSS	a. Will Coordinate for Cable Laying for ACDB at ASS/TSS.	a. Cable laying from designated LV panel to ACDB at ASS / TSS. b. Providing 230V/415V AC Power supply to ACDB in ASS/TSS connect by cable.
14.	ASS/TSS Fire Protection	a. Provide gas flooding system in traction equipment (if applicable).	a. Providing 230VAC emergency power supply to control & link to Central Fire alarm system. b. Room fire protection system as per requirements to be provided

3.1.9 INTERFACE WITH DEPOT CONTRACTORS

- 3.1.9.1 Depot Contracts: Different contracts shall be awarded for depot construction works. In
- 3.1.9.2 which contracts shall be awarded in due course excluding Depot E&M Services LKE (02)-01 Contractor shall interface with Depot M&P Contractors for items such as Washing Plant, Pit Wheel Lathe and others as relevant.
- 3.1.9.3 The interface items associated with depot construction Contractors are listed in Table 3.1.9 given below:

Table 3.1.9 Interfacing with Depot (Civil) Contractors

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
1.	ASS/ TSS room	<p>a. Shall coordinate for the room size and other associated requirements</p> <p>b. Shall furnish the equipment weight and size details to Depot Contractor for designing floor for appropriate load</p> <p>c. Alternatively, can provide suitably designed anchor fasteners to fix transformers, 33kV panels, 750V DC Equipment, Battery chargers etc. to the basic floor/pedestal as per approved drawings.</p> <p>d. Should ensure height of the rolling shutters are adequate for pushing in the tallest equipment.</p>	<p>a. Shall provide the passages, door size, Knock out panels, floor opening, flooring, access doors, rolling shutter for smooth passage of equipment.</p> <p>b. Suitable approach road to RSS/TSS/ASS to be provided by depot contractor.</p> <p>c. Shall design floor for loads as furnished by the Traction Contractor.</p> <p>d. Shall provide necessary foundations for transformers, Panels other equipment etc.</p> <p>f. Shall provide the necessary cut-outs for cables entry and exit from/to the room.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
2.	Installation of, 33 kV, 750 V DC cables, ETS, traction return cables and control cables (from boundary of RSS/TSS complex and to various places in Depot such as ASS+TSS, workshop, third rails, ETS Disconnection switches etc.)	<p>a. Shall supply & install 33 kV, 750 V DC cables, ETS cables, traction return cables and control cables.</p> <p>b. Shall co-ordinate and give requirements to the Depot Contractor for the cable trench and cable path for 33 KV, 750V cables, return cables and control cables in the Depot area</p> <p>c. Shall co-ordinate with Depot contractor for provision of opening and HDPE pipes of adequate size to carry the cables</p>	<p>a. Shall construct cable trenches including cable support infrastructure (trays, brackets etc.) for carrying the cables from RSS complex boundary to ASS/TSS and various third rail / return rails in the depot area as required by LKE (02)-01 Contractor.</p> <p>b. Shall provide suitable opening and HDPE pipe for carrying cables as per the requirement.</p> <p>c. Shall take into consideration the bending radius of cable and covering of cables at relevant places.</p>
3.	Temporary Power for Installation, testing & commissioning	<p>a. Shall co-ordinate for provision of temporary power.</p> <p>b. Shall advise temporary power demand & required capacity and provide temporary cable.</p> <p>c. Shall install the required DB with all safety features for availing the temporary power.</p> <p>d. Shall pay to the Depot contractor for the power consumption.</p> <p>Note: If temporary power is not available from Depot, then Traction contractor shall make his own arrangement.</p>	<p>a. Shall provide sockets for availing temporary power, at main DB or if available, inside ASS/TSS rooms as per requirement</p> <p>b. Shall provide suitable meters for calculating the consumption</p>
4.	Installation of stinger system, in	a. Shall provide detailed interface drawings	a. Shall provide the supporting structure for

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
	inspection bay.	<p>including the requirement of mounting plates on columns, drop arms fixed to the trusses, support for termination arrangement on beams /slabs etc.</p> <p>b. Shall supply and install bracket assemblies with fastening arrangement on columns and drop arms</p>	<p>stinger suspension /bracket assembly on the brackets and drop arms fixed on trusses as per drawings.</p> <p>b. Shall interface and allow installation of cable support infrastructure needed for stinger system.</p>
5.	Emergency Trip System (ETS) Installation	<p>a. Shall coordinate for locations of ETS in depot</p> <p>b. Shall provide ETS equipment along with foundation & support structure at appropriate locations.</p> <p>c. Shall install power and control cables from nearest SCADA RTU to ETS equipment</p>	<p>a. Shall provide cable route (trench, ducts (Buried), etc.) for all cable of ETS</p>
6.	Space Requirement for SCADA equipment in OCC/BCC at Depot (OCC Admin Building)	<p>a. Shall coordinate and finalize the equipment layout with OCC building contractor to finalize the space requirement for SCADA server Room equipment and TPC Operator Workstations.</p>	<p>a. Shall provide space for installation of SCADA equipments in SCADA Server Room and Operator Workstations in Theatre room as required by LKE (02)-01 Contractor.</p> <p>b. Restricted entry access doors shall be provided by this contractor for SCADA server room.</p> <p>c. False floor shall be provided by this contractor in SCADA server room and OCC Theatre room.</p>
7.	TPC Furniture Desk at OCC/BCC Theatre Room (OCC Admin Building)	<p>a. Shall interface with OCC Theatre room contractor and shall quantify & submit the requirement of necessary power</p>	<p>a. OCC Theatre room contractor shall supply and install furniture for Traction power controller and operator workstations at OCC</p>

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
		<p>supply switch sockets & cooling fans along with the provision of cut out on bottom plate for cable entry inside the furniture at OCC Theatre Room.</p> <p>b. Shall supply, lay & terminate the power cable from SCADA ACDB to power supply sockets inside the TPC desk.</p>	<p>theatre room. Shall also supply and install power supply strip with required number of universal switch sockets (min. 4 nos. universal sockets per strip), inbuilt 16Amp SP MCB protection and cooling fans inside the furniture desk.</p> <p>b. Shall also provide cut out on bottom plate for SCADA power/communication cable entry inside the desk.</p>
8.	Earthing, bonding and stray current protection measures in Depot	<p>c. Shall coordinate for the provision of MET connected for SCADA equipments.</p> <p>d. Shall connect SCADA's equipment with MET as per approved schematic.</p>	<p>c. Shall provide the MET connection in SCADA server room and OCC theatre room etc. for the use of SCADA contractor.</p>
9.	Emergency Trip System (ETS) Installation	<p>a. Shall coordinate for locations of ETS in depot.</p> <p>b. Shall install power and control cables from nearest SCADA RTU to ETS equipment</p>	<p>a. Shall provide and install supports (metallic tray, conduit etc.) for power and control cables from SCADA RTU to ETS.</p> <p>b. Shall provide emergency (UPS) 230V LT supply to ETS equipment location indication lamp if required.</p>
9.	Cable Route & Cable Tray in OCC/BCC	<p>a. Shall provide requirement of cable route and support for connectivity between various SCADA equipment and power distribution to SCADA equipment.</p> <p>b. Shall supply and lay SCADA communication cables & power cables.</p>	<p>a. Shall provide cable route and install support (metallic cable tray, conduit etc.) for connectivity between various SCADA equipment and power distribution to SCADA equipment among all SCADA equipment rooms (SCADA Server/equipment Room, UPS & Battery</p>

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
			<p>Room and Theatre room) at OCC.</p> <p>b. Shall provide cable tray connectivity under false floor or ceiling suspended cable trays in all SCADA equipment rooms.</p>
10.	Fire Detection, Air Conditioning & Lighting	<p>a. Shall coordinate with OCC building contractor/E&M contractor for the provision of fire detection system, fire-fighting system, air conditioning and lighting works in SCADA Server room and theatre room.</p> <p>b. Shall provide Heat load details for all SCADA equipment.</p>	<p>a. Shall provide and install fire-fighting system, smoke detectors, air conditioning and lighting arrangements in SCADA server room and theatre room.</p>
11.	Protection System	<p>a. Shall design and provide all protective devices for Auxiliary Transformer protection.</p> <p>b. Shall coordinate and provide details of CTs to be installed in MDB for various protection e.g. differential, REF protection to Depot E&M Contractor.</p> <p>c. Shall design a comprehensive protection system in coordination with Depot Contractor.</p> <p>Display of status of LT ACB in MDB on OCC SCADA.</p>	<p>a. Shall supply & install CTs in MDB panel as per the requirement given by LKE (02)-01 Contractor.</p> <p>b. Shall coordinate and provide details of protection design used for Low Voltage system.</p> <p>c. Shall provide potential free contacts for power SCADA connection by LKE (02)-01 Contractor for display of LT ACB in MDB to OCC SCADA.</p>
12.	415 V LV Panels Control & Monitoring (Depot	<p>a. Shall coordinate with E&M Contractor to ensure the provision of</p>	<p>a. Shall provide dedicated SCADA Terminal blocks, with potential</p>

Item No.	Item Description	LKE (02)-01 Contractor	Depot Contractor
	TSS)	<p>necessary I/O contacts for SCADA RTU interface for control & monitoring of 415 V Transformer LV panels from OCC/BCC.</p> <p>b. Shall display status of LV ACB (as per I/O list) at TPC workstations at OCC/BCC through SCADA.</p> <p>c. Shall supply, lay & terminate the control & monitoring cables from LV panels up to the designated TBs in SCADA RTU.</p>	<p>free contacts of LV ACB in MDB Panels for interfacing with SCADA RTU.</p>
13	Testing (Depot TSS)	a. Shall involve E&M contractor for local & integrated testing of 415 V Transformer LT Panels with SCADA system.	a. Shall coordinate and support for local & integrated testing of SCADA system.
14.	Cable route and Cable tray for SCADA communication cable (Depot TSS)	<p>a. Shall provide requirement of cable route and cable tray for laying of SCADA communication cables inside Admin building coming from ASS/TSS RTU to SCADA server room in Admin Building.</p> <p>b. Shall supply and lay SCADA communication cables from ASS/TSS RTU to SCADA server room in Admin Building.</p>	a. Shall provide cable route and install support (metallic cable tray, conduit etc.) for laying of SCADA communication cables inside Admin building coming from ASS/TSS RTU panel to SCADA server room in Admin Building.

Note: In case there are same contractors for E&M and civil than the interfacing has to be done with all the contractors and interface matrix to be submitted for Employer's approval between the agencies however the scope of the work for traction contractor remains same.

3.1.10 INTERFACE WITH DEPOT E&M CONTRACTORS

3.1.10.1 Depot Contracts: LKE (02)-01 Contractor shall interface with Depot E&M Contractor for various items as relevant.

3.1.10.2 The interface items associated with depot E&M Contractor are listed in Table 3.1.10 given below:

Table 3.1.10 Interfacing with Depot E&M Contractors

Item No.	Item Description	LKE (02)-01 Contractor	Depot E&M Contractor
1.	Earthing, bonding and stray current protection measures in Depot	a. Shall provide the earthing design calculations and requirements to Depot E&M contractor. b. Shall review the E & M drawing of earth pits/mats & bonding in depot area with respect to the earthing, bonding and stray current mitigation plan.	a. Shall implement the earthing, bonding and stray current mitigation plan designed by LKE (02)-01 Contractor. b. Shall provide the MET for the use of LKE (02)-01 contractor, as required.
2.	Emergency Trip System (ETS) Installation	a. Shall coordinate for locations of ETS in depot. b. Shall install power and control cables from nearest SCADA RTU to ETS equipment	c. Shall provide and install supports (metallic tray, conduit etc.) for power and control cables from SCADA RTU to ETS. d. Shall provide emergency (UPS) 230V LT supply to ETS equipment location indication lamp if required.
3.	Cable Route & Cable Tray in OCC/BCC	a. Shall provide requirement of cable route and support for connectivity between various SCADA equipment and power distribution to SCADA equipment. b. Shall supply and lay SCADA communication cables & power cables.	a. Shall provide cable route and install support (metallic cable tray, conduit etc.) for connectivity between various SCADA equipment and power distribution to SCADA equipment among all SCADA equipment rooms at OCC/BCC. b. Shall provide cable tray connectivity under false floor or ceiling suspended cable trays among various SCADA

Item No.	Item Description	LKE (02)-01 Contractor	Depot E&M Contractor
			equipment rooms.
4.	Fire Detection, Air Conditioning & Lighting	a. Shall coordinate with Depot E&M contractor for the provision of fire detection system, firefighting system, air conditioning and lighting works in SCADA room, UPS & Battery room, Training setup room and theatre room. b. Shall provide Heat load details to Depot E&M contractor for all LKE (02)-01 related equipment.	a. Shall supply and install firefighting system, smoke detectors, air conditioning and lighting arrangements in SCADA server room, UPS & Battery room, Training setup room and theatre room.
5.	Protection System	a. Shall design and provide all protective devices for Auxiliary Transformer protection. b. Shall coordinate and provide details of CTs to be installed in MDB for various protection e.g. differential, REF protection to Depot E&M Contractor. c. Shall design a comprehensive protection system in coordination with Depot E&M Contractor. d. Display of status of LT ACB in MDB on OCC/BCC SCADA.	a. Shall supply & install CTs in MDB panel as per the requirement given by LKE (02)-01 Contractor. b. Shall coordinate and provide details of protection design used for Low Voltage system. c. Shall provide potential free contacts for power SCADA connection by LKE (02)-01 Contractor for display of LT ACB in MDB to OCC/BCC SCADA.
66.	Installation of Cable Trays in Depot's ASS cum TSS & TER	a. Shall provide schematic layouts for the HT equipment inside Depot's ASS cum TSS. b. Shall design, supply and install all the cable trays/hangers/support etc. for cables related to Traction (33kV, 750 V	a. Shall coordinate for design, supply and install of LT cable trays inside Depot's ASS cum TSS as per the layout. b. Shall close the opening with fire stops after installation of the LT

		DC positive, return cables, ETS (Power & SCADA), Control cables, earthing cables and any other related cables) inside ASS as well as ASS cum TSS c. Shall close the opening with EPDM modules after installation of the HT cables. d. Shall provide the cable route for ETS cables from ASS cum TSS to ETS Location e. Shall provide the details & coordinate with E&M contractor for cable route from ASS/TSS to TER for SCADA communication cables. f. Shall interface with E&M contractor for cable trays required for LV and HV cables inside ASS as well as ASS + TSS	cables/cable trays. c. Shall provide cable tray/support infrastructure for ETS cables. d. Shall provide the cable tray/supports as per LKE (02)-01 Contractor requirement from ASS/TSS to TER. e. Shall coordinate with Traction contractor to incorporate the cable tray in E&M WRD.
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Note: In case there are same contractors for E&M and civil than the interfacing has to be done with all the contractors and interface matrix to be submitted for Employer's approval between the agencies however the scope of the work for traction contractor remains same.

3.1.11 INTERFACE WITH ROLLING STOCK CONTRACTOR

3.1.11.1 Contractor will be required to interface with the Rolling Stock Contractor on the issues listed in Table 3.1.11 given below:

Table 3.1.11 Interfacing with Rolling Stock Contractors

Item No.	Item Description	LKE (02)-01 Contractor	RS Contractor
1.	Supply of Basic data and information regarding following: - Speed/current characteristics - Speed/Tractive Effort curves - Speed/Braking Effort curves - Auxiliary power requirement and its Power factor - Motor KW and specifications	a. Shall incorporate details in design of traction system.	a. Shall supply information to LKE (02)-01 Contractor.

Item No.	Item Description	LKE (02)-01 Contractor	RS Contractor
	<ul style="list-style-type: none"> - Acceleration and braking - Regeneration - Details of harmonic contents of rolling stock power supply. - Current Collection equipment details - General Arrangement Diagram & Power Supply Schematic of Rolling Stock. 		
2.	Arrangement of third rail System, Mainline & Depot sectioning.	a. Shall design and provide information and drawings to RS Contractor.	a. RS Contractor to note the details and confirm their suitability
3.	Detailed drawings of current collection system and shoe gear collectors.	a. Shall take into consideration for the design of the traction System.	a. Shall provide information to LKE (02)-01 Contractor.
4.	Maximum Traction & Return current of Rolling Stock.	a. Shall take into consideration & incorporate into the design of the traction System and bonding plan.	a. Shall provide information to LKE (02)-01 Contractor.
5.	Third rail details	a. Shall provide information regarding third rail dimensions, adjustment/dimensional tolerances, third rail tensions and sectioning for design of shoe gear collectors of rolling stock	a. Shall design the shoe gear collectors on the basis of third rail design particulars
6.	Drawings, material, springing, damping, sway and other relevant details of collector shoe gear	a. Shall incorporate into the design of the third rail System	a. Shall provide information to LKE (02)-01 Contractor.
7.	Electrical and mechanical clearances between third rail support assemblies and collector shoe	a. Shall provide information to rolling stock contractor	a. Shall incorporate into the design of the collector shoe gear
8.	Harmonic Limitations of power supply	a. Shall provide information to RS	a. Shall incorporate into the design of

Item No.	Item Description	LKE (02)-01 Contractor	RS Contractor
		Contractor.	the collector shoes
9.	Testing and commissioning	a. Shall provide 750 V dc power supply and coordinate with RS Contractor to conduct testing and commissioning of Metro Cars. Shall jointly check the electrical loads, harmonic levels and return current coming on Traction sub-station from Rolling stock.	a. Shall request 750V power supply in the Third Rail for testing and commissioning of Metro Cars shall cooperate and ensure that the harmonics generated are within the agreed levels. b. Shall conduct CCD engagement test with third rail in coordination with LKE (02)-01 Contractor.
10.	Location of Third rail & Stinger Warning Boards and Visual indicators.	a. Shall Supply and install the boards and indications.	a. Shall confirm the suitability.
11.	Stinger Plug and Socket	a. Shall confirm the requirements of the plug supplied by RS contractor and install the same in Stinger System.	a. Shall supply the Plug to LKE (02)-01 contractor.
12.	Stinger Plug Position in Rolling Stock	b. Shall incorporate the stinger assembly after confirmation from RS contractor.	a. Shall provide information to LKE (02)-01 Contractor.
13.	Third Rail Gap Study	a. Shall provide information to RS Contractor.	a. Shall confirm the suitability.

3.1.12 INTERFACE WITH SIGNALING CONTRACTOR

3.1.12.1 LKE (02)-01 Contractor will be required to interface with the Signaling Contractor (Elevated/At Grade/Underground), for both mainlines and depots.

3.1.12.2 The interface requirements with the Signaling Contractor are listed in Table 3.1.12 given below:

Table 3.1.12 Interfacing with Signaling Contractor

Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
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Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
1.	Signals for 3rd Rail Transition Location	a. Shall give to Signaling Contractor, location plan of 3rd Rail Transition	a. Will adjust the positioning of stop signals in such a way that a train starting from stop at a stop signal is able to achieve necessary speed to negotiate the 3rd Rail transition locations
2.	Earthing and bonding plan	a. Shall provide earthing and bonding plan.	a. Shall connect in equipment to earth conductor at suitable locations. b. Shall insulate all equipment connected to the Running Rail c. Shall interface with LKE (02)-01 Traction Contractor for level of insulation required d. Shall coordinate with LKE (02)-01 Traction Contractor for ensuring minimum safe distance between any signaling field installation and the live third rail contact point for the purpose of human safety
3.	Signaling cable details	a. Shall 'model' the signaling cables suitably for EMC study.	a. Will furnish specifications of signaling cables and their locations.
4.	Normal and short circuit currents levels in 3 rd Rail	a. Shall provide information to Signaling Contractor	a. Shall use the information for the design.
5.	Cross Bonds	a. Shall provide cross bonds, according to finalized bonding plan and in co-ordination with Signaling Contractor	a. Requirement of mid-section bonds requirement to be given along with station area requirements

Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
6.	Insulated Rail Joints	a. Will coordinate with Signaling Contractor	a. Shall provide details regarding locations of insulated rail joints on the Main line and in the Depot/yard.
7.	Signal Locations	a. Will coordinate with Signaling Contractor	a. Shall provide chainages of signal posts, to LKE (02)-01 Traction Contractor
8.	Power Supply Protection System and trip settings	a. LKE (02)-01 Traction Contractor will advise to Signaling Contractor the protection relay settings.	a. Shall ensure Train Control and Signaling systems are designed suitably.
9.	Return current cables	a. Shall supply and install the negative current return cables with track in coordination with Signaling Contractor	a. Shall suitably coordinate to ensure the correct and safe connections.
10.	ETS	<p>a. To co-ordinate with Signaling Contractor for finalizing location of ETS in SCR</p> <p>b. Shall interface with Signaling Contractor for integrating ETS to signaling plan for stopping the train when ETS is pressed. Also, shall provide a signal in the form of potential free contact from ETS for stopping the train entry to the affected section of third rail during any outage.</p>	<p>a. Signaling contractor to finalize location in co-ordination with civil regarding location of ETS in SCR.</p> <p>b. Shall supply, install & commission all necessary equipment and interfaces for picking up and incorporating the tripping signal from ETS (when pressed) in signaling plan to develop and implement for stopping the train when ETS is pressed or from entering the affected section of third rail during any outage.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
11.	Visual control panel (VCP)/Large Video Display Screen (LVDS)	<ul style="list-style-type: none"> a. Shall interface with Signaling Contractor for the requirement of Visual Control Panel (VCP)/Large Video Display Screen (LVDS) cubes at OCC. b. Shall provide the requirements & details of VCP and number of cubes required from Large Video Wall from Signaling contractor at OCC. c. Shall separately supply and lay power cables for its LVDS cubes and redundant display wall controllers 	<ul style="list-style-type: none"> a. Shall provide details of the OCC layout and VCP design to Traction power supply contractor. b. Shall supply & install combined LVDS/VCP at OCC for Signaling & Traction SCADA system. c. Shall provide required number of VCP cubes with their separate/dedicated redundant display controllers from Large Video Wall to Traction SCADA system at OCC. d. Shall conduct the Ergonomic study of OCC/BCC.
12.	Cable Support Infrastructure	<ul style="list-style-type: none"> a. Shall coordinate for the input for Cable support infrastructures design in viaduct. b. Shall supply and install the cable supports in viaduct for respective cables. 	<ul style="list-style-type: none"> a. Shall provide the necessary input for Cable support design.
13.	UPS	<ul style="list-style-type: none"> c. Shall interface with Signaling contractor for the requirement of Uninterrupted Power Supply (UPS) feeder for Traction SCADA system at OCC. d. Shall provide the Load requirements of Traction SCADA system at OCC to the Signaling contractor. e. Shall supply and lay the power supply feeder cable from S&T UPS room to the SCADA ACDB in SCADA server room. 	<ul style="list-style-type: none"> b. Shall supply and install UPS and Batteries in OCC. c. Shall also cater the Load requirements of Traction SCADA system in the UPS & Battery. d. Shall allocate and provide the power supply feeder (3-Ph, Ph-N: 240 V AC) at UPS output to Traction SCADA system.
14.	Data Exchange for Automated	<ul style="list-style-type: none"> a. Shall have provision to receive input signal 	<ul style="list-style-type: none"> a. Shall have provision to receive input signal

Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
	Earthing of 750V DC Third Rail system to ensure passenger's safety during front evacuation of passengers from the metro train during de-boarding in emergency conditions.	<p>from Signaling system at OCC and display of the same in SCADA HMI along with sharing Third Rail Power/Earthing Status with Signaling system at OCC.</p> <p>b. Applicable data engineering to exchange information with Signaling system at OCC shall be done by Traction SCADA contractor in its system.</p> <p>c. Details of data exchange list along with communication parameters will be shared with Signaling contractor during detail system design and commissioning.</p>	<p>and status from Rolling stock and display of the same at OCC.</p> <p>b. Shall have provision to send digital signal and receive/display digital indication status from Traction SCADA system at OCC.</p> <p>c. Applicable data engineering to exchange information with Rolling stock and Traction SCADA system at OCC shall be done by Signaling contractor in its system.</p> <p>d. Details of data exchange list along with communication parameters will be shared with Rolling Stock contractor and traction contractor during detail system design and commissioning.</p>
15.	Communication hardware at OCC for Automated Earthing of 750V DC Third Rail system to ensure passenger's safety during front evacuation of passengers from the metro train during de-boarding in emergency conditions.	<p>a. Shall provide required nos. of ports in its Hardware Firewall for secured interface with Signaling system.</p> <p>b. Shall provide any other required communication equipments like media convertors etc. at its end.</p> <p>c. Shall share required communication parameters and details with Signaling contractor.</p>	<p>a. Shall provide required nos. of ports in its Hardware Firewall for secured interface with Traction SCADA system.</p> <p>b. Shall provide any other required communication equipments like media convertors etc. & communication cables for connection upto Traction SCADA system in SCADA server room at OCC.</p> <p>c. Shall share required communication parameters and details with Traction contractor.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Signaling Contractor
16.	Testing and Commissioning for Automated Earthing of 750V DC Third Rail system to ensure passenger's safety during front evacuation of passengers from the metro train during de-boarding in emergency conditions.	Shall provide necessary support to Signaling contractor and Rolling Stock contractor during testing & commissioning.	Shall provide necessary support to Rolling Stock contractor and Traction contractor during testing & commissioning.
	Note: Signaling contractor shall lead a joint study and the development of the Electromagnetic Compatibility Management and Testing Plan.		

3.1.13 INTERFACE WITH TELECOM CONTRACTOR

3.1.13.1 LKE (02)-01 Contractor will be required to interface with the Telecom Contractor (Elevated/At Grade/Underground), for both mainlines and depots.

3.1.13.2 The interface requirements with the Telecom Contractor are listed in Table 3.1.13 given below:

Table 3.1.13 Interfacing with Telecom Contractor

Item No.	Item Description	LKE (02)-01 Contractor	Telecom Contractor
1.	Telecom Cables and exchange locations	a. Shall jointly prepare a plan for compatibility of the Telecom system.	a. Will furnish the locations of telecom cables and Telephone exchanges, of Rail corridor in sufficient details for enabling 'modelling' of cables and for performing simulation study on Electro-magnetic compatibility.
2.	Telephone connections to the Rail corridor internal telecom network	a. Furnish the requirements	a. Provide a connected telephone at each RSS, ASS Room, TSS room, Control Rooms, TPC desks, LKE (02)-01 depot, PSA

Item No.	Item Description	LKE (02)-01 Contractor	Telecom Contractor
			Substations.
3.	Laying of C&M cables	a. Supply and install C&M cables in the Telecom cable trough/trays between each traction switching station and the nearest Station Control Room	a. Provide space (approx. 10sqcm) in the Telecom cable trough/Trays
4.	Control & Monitoring data exchange	a. Shall supply and lay suitable dual redundant optic fiber cable from RSS/ASS/TSS RTU to Telecom rack at TER at each RSS/Station/Depot . b. Shall supply and lay suitable dual redundant optic fiber cable from SCADA communication equipments in SCADA server room to Telecom rack at TER at OCC/BCC. c. Shall supply and install necessary Ethernet switches, media converter, network router, FO termination box, FO patch cables, FO cables and other equipment required for connection to Telecom racks at TER at each ASS/TSS/Depot & OCC/BCC. d. Shall interface with telecom contractor and supply communication	a. Shall supply and install optic fiber backbone including the channels required for SCADA system for data exchange between station, depot, OCC and BCC. b. Shall provide minimum 2 nos. fixed bandwidth (10 Mbps) optical Ethernet ports in telecom rack at each RSS, station, depot, OCC & BCC TER for SCADA communication over transparent and dedicated TCP/IP link. c. Shall provide 100 Mbps dual direct link connectivity both OCC and BCC. d. Shall allocate suitable channels and ensure smooth data flow.

Item No.	Item Description	LKE (02)-01 Contractor	Telecom Contractor
		<p>Ethernet switches & other accessories for communication of RTU to TER compatible with the type of FO ports provided by telecom contractor in TER of each RSS, station, depot, OCC & BCC.</p> <p>e. Shall provide bandwidth requirements to Telecom contractor for each RTU/RSS Gateway at ASS/TSS/RSS/De pot.</p>	
5.	Electromagnetic Compatibility	a. Shall give details of the EMC study carried out	a. Shall coordinate jointly to ensure compatibility.
6.	Emergency Trip System (ETS)	<p>a. Coordinate for location of ETS locations</p> <p>b. Supply & Install ETS Equipment</p>	a. Provide emergency telephone at ETS locations including telecom channel, cables etc.
7.	Space Requirements	a. LIU (Light Interface Unit) boxes at both SCADA panel and Telecom panel ends shall be provided by LKE (02)-01 Contractor at each RSS, station, depot and OCC/BCC.	a. Telecom contractor shall provide space inside its Telecom rack at each location TER for mounting of SCADA LIU box/ FO Junction box and shall allow the termination/patching of SCADA FO cable in this LIU box.
8	Master Clock Synchronization	<p>a. Shall synchronise the time of SCADA servers with Master clock over link provided by telecom contractor.</p> <p>b. Shall further synchronise time</p>	<p>a. Shall provide connectivity with Master clock over NTP protocol via TCP/IP link at OCC/BCC.</p> <p>b. Shall broadcast time</p>

Item No.	Item Description	LKE (02)-01 Contractor	Telecom Contractor
		of RTU's with servers over IEC 60870-5-104 protocol. c. Shall supply and lay suitable Ethernet communication cable from Master clock NTP port to SCADA communication network for receiving time synchronization packets.	synchronization packets on this link over a regular interval of time.
9	CCTV in RSS	a. Shall coordinate for the CCTV requirement in RSS and facilitate for the necessary arrangements. b. Shall provide the necessary cable routing for CCTV locations.	a. Shall supply and install the CCTV as per the client requirement and coordination with LKE (02)-01 Contractor.
10	230 V AC Supply in RSS	a. Shall provide the necessary 230 V AC supply for use of telecom services (CCTV, Clock etc).	a. Shall coordinate for the 230 V AC power Supply requirement.
11	Testing & Commissioning	a. Shall lead the Testing & Commissioning	a. Shall co-operate and associate during testing & commissioning.

3.1.14 INTERFACE WITH UG ECS/TVS CONTRACTOR

3.1.14.1 LKE (02)-01 Contractor will be required to interface with the UG ECS/TVS (Underground), for mainline.

3.1.14.2 The interface requirements with the UG ECS/TVS (Underground) Contractor are listed in Table 3.1.14 given below:

Table 3.1.14 Interfacing with UG ECS/TVS Contractor

Item No.	Item Description	LKE (02)-01 Contractor	UG ECS/TVS Contractor
1.	Power Traction	a. Shall provide heat loads of traction power (ASS/ TSS) equipment and	a. Shall interface with LKE (02)-01 contractor for design taking into

Item No.	Item Description	LKE (02)-01 Contractor	UG ECS/TVS Contractor
		<p>associated control panel as required by UG ECS/TVS Contractor.</p> <p>b. Shall provide operating temperature criteria for traction power (ASS/TSS) equipment.</p> <p>c. Shall provide the approved equipment layout for ASS/TSS to UG ECS/TVS Contractor for positioning of ECS ductworks and grills/diffuser.</p>	<p>consideration of heat loads of traction power equipment (ASS/TSS) and associated control panels.</p> <p>b. Shall prepare the layout for ECS ductworks and grills/diffuser positions with respect to approved equipment layouts provided by LKE (02)-01 Contractor.</p>

3.1.15 INTERFACE WITH GOVERNMENT AGENCIES

3.1.15.1 The contractor shall be required to interface with various Government Agencies for successful execution of the work. The interface issues shall include but not limited to following:

- a. Obtaining all permission from road agency and other agencies for digging along road/pavements as necessary.
- b. Restoration of sites, roads as required under the local laws.
- c. Interface with Telecom authorities, Gas Distribution Authorities and other agencies to ensure that functioning of the utilities is not jeopardized by the actions of the contractor
- d. Interface including all documentation, coordination and necessary tests for obtaining statutory approval and clearance of Electrical Inspector to the Government.
- e. Interface, including all documentation, coordination and necessary tests, for obtaining statutory approval and sanction of Commissioner Metro Rail Safety to the Government for opening the system for public carriage of passengers.

3.1.16 INTERFACE WITH POWER SUPPLY AUTHORITIES

UPPTCL is the nodal agency for supplying the power. The Contractor shall be required to interface with agencies like UPPTCL and other relevant agencies.

Power Supply required for Traction and Auxiliary purposes will be obtained from UPPTCL referred to as "Power Supply Authority (PSA)" and the LKE (02)-01 Contractor is required to interface with the PSA for the following items:

- a. Take-off points at PSA Substations
- b. Protection Co-ordination
- c. Metering Equipment

- d. Data exchange
- e. 132 kV Cabling

The LKE (02)-01 Contractor are required to interface with the PSA. The interface requirements with PSA are listed in Table given below:

Table 3.1.15 Interfacing with Power Supply Authority

Item No.	Item Description	LKE (02)-01 Contractor	Power Supply Authority
1.	Take-off points at PSA Substations	a. Shall co-ordinate with PSA to ensure that necessary arrangements are provided by PSA in their switchyard for necessary protection and measurement.	a. PSA will indicate at site as well as schematically, the arrangements for the outgoing feeders to the RSS from PSA Substations.
2	Supply, laying, installation of 132kV Cables from PSA GSS to UPMRCL LKO RSS	a. Shall supply, lay and install cables. b. Shall supply & install cable terminations at either end. c. Shall co-ordinate with PSA for path for laying cable inside PSA GSS. d. Shall co-ordinate with PSA for deciding the location of exiting cables from PSA GSS	a. Shall provide necessary assistance for installation of cables and terminations. b. Shall allow Contractor to lay cables in the existing path wherever possible.
3	Protection Co-ordination	a. Shall propose a protection scheme and obtain approval from PSA. b. Shall provide and install protection relays such as differential protection, distance protection, over current protection at UPMRCL-LKO RSS with the approval of PSA. c. Shall propose protection relay settings to PSA ensuring proper relay co-ordination and obtain approvals.	a. Shall verify and approve the final scheme of protection. b. Shall verify and approve relay settings. c. Shall provide and install the protection relays at UPPTCL GSS. d. Shall provide spare core of protection CT for 132kV cable protection relays.

Item No.	Item Description	LKE (02)-01 Contractor	Power Supply Authority
		<p>d. If any pilot wire is required to be provided, for protection, the same shall be supplied by the LKE (02)-01 Contractor.</p> <p>e. The pilot wire shall be armored type.</p> <p>f. Coordinate with PSA for installation of cable protection relays in PSA switchgears.</p>	
4.	Metering Equipment	<p>a. Shall prepare document which includes specifications and necessary arrangement required for Tariff metering equipment and submit to PSA for approval.</p> <p>b. Shall provide the necessary meters as per the requirements of PSA for measurement of voltage, current, PF, kVA, kWh, kVARh at UPMRCL-LKO RSS.</p>	a. PSA will verify and approve the specifications and necessary arrangement required for metering equipment to measure kWh, kVARh, kVA, PF, current and voltage at UPMRCL-LKO RSS.
5.	Data exchange between GSS and RSS	<p>a. Shall provide and obtain approval of a list of data/information to be exchanged with PSA through SCADA.</p> <p>b. Shall co-ordinate with PSA(GSS/SLDC) for exchange of data and provide necessary arrangement for the same.</p> <p>c. For communication between PSA controller and UPMRCL-LKO RSS Controller Permanent phones will</p>	<p>a. PSA will approve the final list of data/information identified for exchange through SCADA.</p> <p>b. Shall support and permit for necessary installation in PSA(GSS/SLDC) for which data has to be exchanged.</p>

Item No.	Item Description	LKE (02)-01 Contractor	Power Supply Authority
		be provided by Telecom Contractor.	
6.	Cable path with in GSS	a. Shall construct cable trench in coordination with PSA, as per approved design including covers for laying cables in case no spare trench or spare capacity is available in existing trench of PSA.	a. Shall permit laying of cables in existing trench or spare trench if available in the GSS. if no trench is available, PSA shall permit and approve construction and design of new trench for laying cables.
7.	Earthing	a. Shall propose an earthing arrangement in consultation with PSA Shall make necessary arrangement for earthing	a. Shall scrutinize and approve earthing arrangement

CHAPTER 4: PROGRAM REQUIREMENTS

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CHAPTER – 4

PROGRAM REQUIREMENTS

4.1 SCOPE

- 4.1.1 The LKE (02)-01 Contractor shall prepare a detailed plan of all activities and submit to the Engineer for approval. The plan shall be prepared in such a manner that all activities are properly co-related, and all activities are completed within the scheduled time to ensure target dates for commercial operations.
- 4.1.2 This Specification specifies Revenue Operation Dates, Key Dates and Access Dates specific to this contract.

4.2 REVENUE OPERATION DATES

- 4.2.1 The date of commencement of commercial operations shall be referred to as Revenue Operation Date (ROD). Reference RODs for various sections of this contract are indicated in Table 1.4 of Chapter 1 of this Volume.

4.3 KEY DATES

- 4.3.1 Key dates are dates which are to be achieved by the Contractor and which are considered to be essential for the successful completion of the Project to the original planned schedule.
- 4.3.2 Each Key Date includes a number of stages. These stages are inter-related with a flow of activities. For the purpose of effective monitoring and implementation, certain intermediate stages have been identified for each Key Date. These are essential to the completion of the Site Development, Construction, Supply, Installation, Testing and Commissioning Works. The time schedule for these stages has been defined in the Key Dates.
- 4.3.3 The Key Dates are mentioned in terms of the time period reckoned from the commencement of the Works (i.e. NTP – Notice to Proceed), and the deliverables for each Key Date shall be achieved by the midnight of the last day of the week mentioned. If the identified work is not achieved by the stated Key Dates, liquidated damages may become applicable as set out in the Contract.
- 4.3.4 Interfacing with relevant Designated Contractors and other agencies for achievement of Key Dates shall be the responsibility of Contractor.
- 4.3.5 All numbers given below refer to weeks from Commencement date of the work. Description and schedule of each Key Date is also detailed below:

Table 4.1: Schedule of Key Dates

Key Dates	Description	East West Corridor (Charbagh to Vasantkunj)		
		Priority Section		Balance Section
		Vasantkunj Depot	Vasantkunj to Thakurganj (incl) including stations and viaduct	(Thakurganj (excluding) to Charbagh (Incl.)
KD-1	Design and Submittal of Technical proposals of major equipment to Engineer for Approval	10	10	16
KD-2	Submission of Working Drawings/ Shop Drawings	12	12	20
KD-3	Delivery of Major Equipment to Site (For RSS/AMS HV Cable/ ASS/ TSS/ DC Third Rail for Main Line & Depot/ SCADA etc)	46	46	56
KD-4	Commissioning of RSS/AMS including HV Cabling.	65	-	-
KD-5	Completion of Installation Testing and Commissioning of standalone 750V DC Traction Sub Station along with associated cabling	66	77	89
KD-6	Completion of Installation Testing and Commissioning of standalone 33kV/415 V Auxiliary Sub Station along with associated cabling	66	77	89
KD-7	Completion of Installation Testing and Commissioning of standalone 750V DC Third Rail Traction Electrification System	67	92	104
KD-8	System Acceptance Test	69	93	106

KD-9	Traction Energisation	70	94	108
KD-10	Commissioning of SCADA System (Including NS Corridor Upgradation work)	71	96	111
KD-11	Integrated Testing & Commissioning	73	98	114
KD-12	Completion of acceptance test after integrating testing of SCADA System	75	100	118
KD-13	Taking over of the system	ROD date	ROD date	ROD date

- 4.3.6 As per the requirements of Chapter-2 of the General Specification, the Contractor shall submit the Work Program and other sub programs such as Procurement & Manufacturing Program, Installation Program etc. duly complying with the above Key Dates, to the Engineer for approval. Optimum scheduling of the material procurement shall be ensured in tandem with the commissioning and ROD requirements. The Contractor shall go ahead with procurement only after the Procurement Program along with procurement specification of the equipment / material has been approved by the Engineer. "No-Objection" in respect of manufacturer / vendor / subcontractor for material / equipment shall be obtained from Engineer before placement of orders.

4.4 ACCESS SCHEDULE

Access to the site shall be provided on the basis of actual progress of Civil/Viaduct and Track works. Contractor shall coordinate with the Civil/Viaduct contractor and Track contractor for the access date to start 33kV Cable laying, Third rail and ASS/TSS Equipment's installation, However Access to the site shall be provided minimum 3 month before the energization of the respective traction power facility.

4.5 CHANGES IN KEY DATES& ACCESS DATES

- i. The Key Dates and Access Dates indicated above have been identified on the basis of discussions with various groups and agencies involved in the Project. Special attention is drawn to the following facts with respect to the possible changes in the Key Dates and Access Dates.
- ii. It is essential that the Contractor shall achieve the identified work by the specified Key Date mentioned against it, failing which Liquidated Damages shall become leviable as set out in the Contract.
- iii. The Access Dates are dependent on the other agencies e.g. station building contractors, viaduct contractors, Track work Contractor etc., involved in the project. The Contractor shall interface and maintain a close liaison with other agencies for timely availability of the access. In case the Contractor finds that there is slippage and the likely Access Dates may not be adhered to, the Contractor shall inform the Engineer well in advance for the likely delays in access to site.

- iv. The Engineer will, on his part, make all efforts to provide the Contractor with access to information as well as to various locations at stations/track/viaduct/tunnel, depots in stages, in order to plan/execute his activities for time-bound completion of his obligations under the Contract, as per the Access Dates mentioned above. If, however, due to any reasons, the Engineer is not in a position to provide access or shared access, as per the stated Access Dates, the Engineer, in these circumstances, will inform the Contractor, in writing, about the proposed revised Access Dates, at least 4 weeks before the scheduled Access Date. The Contractor shall suitably make necessary changes in his Work Program and shall make all out efforts so that, irrespective of the revised Access Dates, the concerned Key Dates are adhered to.
- v. Where Access Dates overlap, the Contractor shall ensure that there are sufficient resources to meet the Key Dates.

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CHAPTER – 5

SITE FACILITIES

5.1 GENERAL

- 5.1.1 The Contractor shall provide for the use of the Engineer office accommodation throughout the course of the Works and for so long a period of time during the defects liability period as the Engineer may require. The details of the accommodation and other facilities are as under:

5.2 SITE OFFICES

- 5.2.1 Accommodation for the Engineer shall consist of site offices to be leased by the Contractor and located strategically for access to the East West Corridor stations, Vasantkunj Depot RSS and alignment as per the recommendation of Engineer.
- 5.2.2 The site offices shall be of suitable size of useable office area to be located as decided by the Engineer.
- 5.2.3 All offices shall be supplied with electricity at 240V, 50 Hz which shall be distributed to each room in accordance with the Regulations. Lighting and electrical power points shall be provided in each room. The accommodation shall be air-conditioned and with UPS back-up for computer terminals and minimum lighting. Lighting and electrical power points shall be provided in each room. Minimum two toilets shall be provided.
- 5.2.4 Firefighting equipment shall be provided in accordance with the recommendations of the Lucknow City Fire Brigade.
- 5.2.5 The Contractor shall provide, erect and maintain appropriate name boards as specified for each of the offices. The wording on each name board and its location shall be agreed by the Engineer before it is erected.

5.3 FURNITURE AND OTHER OFFICE EQUIPMENT

- 5.3.1 The Contractor shall supply for site office the suitable quantities of new furniture and equipment to the Engineer's offices in the manner required by the Engineer:

5.4 STORAGE OF EQUIPMENTS AND SITE MATERIAL

- 5.4.1 Suitable space for storage of material procured for Lucknow Metro shall be provided by UPMRCL in Lucknow. Contractor shall liaison with Employer for the suitable space as per the material delivery plan at site as per the over all work schedule of the Project.

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CHAPTER – 6

INSTALLATION AND CONSTRUCTION

6.1 GENERAL REQUIREMENTS

- 6.1.1 The Contractor shall comply with all Enactments in executing the Works, including but not limited to all statutory provisions on occupational health and safety.
- 6.1.2 The Contractor shall co-ordinate with other designated contractors in the execution of the Works.
- 6.1.3 The Contractor shall also co-operate with all Relevant Authorities in the execution of the Works.
- 6.1.4 The installation of all equipment shall be undertaken at all times by suitably trained and competent employees of the Contractor, to the satisfaction of the Engineer.
- 6.1.5 Only appropriate tools, plant, equipment and vehicles shall be used.
- 6.1.6 Installation of all equipment shall be in accordance with the Construction and Installation Plan described in the GS.
- 6.1.7 Installation of all equipment shall conform to the best industrial practices.
- 6.1.8 Precautions shall be undertaken to ensure the safety of personnel and equipment for all installation works.
- 6.1.9 The Contractor shall, prior to starting any installation work, identify any possible hazards, and implement measures of eliminating and/or mitigating such potential hazards, in line with safe working practices. The Method Statements, as described in the GS, shall be submitted to the Engineer for review at least 30 days prior to the installation activity commencing On-Site.
- 6.1.10 Further details on site safety management are described in the GS.
- 6.1.11 The Contractor shall ensure that all areas of work are sufficiently illuminated for the works to be undertaken and that a safe system of work is employed for all activities.
- 6.1.12 The Contractor shall operate a robust system for the control of persons entering or working upon the site. The system shall include as a minimum:
- a) Register of all employees;
 - b) personal identification, with photograph;
 - c) levels of competency;
 - d) date of expiry;
 - e) date of issue;
 - f) signature; and
 - g) Register of all visitors.
- 6.1.13 The Contractor shall co-operate, at all times, with the Engineer and other contractors to ensure that the Site is protected from unauthorized admission, either willfully or otherwise.

- 6.1.14 The Contractor shall make do provision for the safe access and egress to the Site of Works for its staff and subcontractors. This access shall be maintained such that it is free of all hazards and is in a safe condition throughout the duration of the Works.

6.2 SPECIFIC REQUIREMENTS

- 6.2.1 The installation work pertaining to this Contract shall include, but not be limited to the following:
- a) Finalisation of the Construction and Installation Programme;
 - b) Surveys on site and reviews of the technical requirements shown in this Specification and the Employer's Drawings;
 - c) Production of the calculation sheets and installation drawings for site installation;
 - d) Installation in accordance with the finalized installation drawings;
 - e) Co-ordination with other contractors;
 - f) Submission of the installation reports and records;
 - g) Testing and commissioning, as per finalized protocol and programme.
 - h) Production of as built drawings, documents, calculation sheets, and records.

6.3 CONSTRUCTION AND INSTALLATION PLAN

- 6.3.1 Key dates have been indicated for the various activities in the TS. The Contractor shall prepare his own plan showing detailed activities and the correlation among the various activities. The Contractor shall ensure that various key dates are adhered to. The plan shall comply with the requirements specified in Clause 3.6 of the GS and shall be submitted to the Engineer for approval. The Contractor shall make necessary changes in the plan as indicated by the Engineer.
- 6.3.2 The Contractor shall undertake installation work as shown & approved in the detailed installation programme. The construction works shall be coordinated in such a manner that installation, testing and commissioning of later stages shall not impact revenue operation of earlier stages. Further, the power shall be available in time for testing & commissioning by other contractors.
- 6.3.3 As a minimum, the detailed Construction and Installation Plan shall include but not be limited to all the activities described in "Scope of Work" in this TS. The plan shall include installation details and methods of all activities (method statements), equipment and tools to be used for installation, safety issues, supervision, temporary land occupation needed and the vehicles to be used for installation.
- 6.3.4 The Contractor shall attend a weekly planning meeting with the Engineer to finalize the work detail, commencing 4-weeks prior to the start of installation on site.
- 6.3.5 The Contractor shall submit a Construction and Installation Plan for review by the Engineer 90 days prior to the start of Installation on Site.
- 6.3.6 The Contractor shall provide his Installation Specification, which shall ensure that installation work and quality conform to the best-accepted metro/railway power supply practices. This Installation Specification shall be submitted to the Engineer for his review and acceptance.
- 6.3.7 Special attention shall also be paid to all equipment whose correct functioning is

essential for the safe and efficient operation of the metro railway system. In particular, the Contractor shall comply with the following requirements:

1. Cables running to the trackside equipment shall not have any jointing.
2. All trackside equipment shall be installed, with safety provisions so that maintenance risk is reduced to a minimum.
3. All trackside equipment shall be installed clear of any stair or door access.
4. All trackside equipment shall be installed not to cause any infringement to the schedule of fixed and moving dimensions.
5. Trackside equipment such as disconnecter switches etc. shall be installed at appropriate locations for ease of maintenance.
6. Appropriate fixed means of access shall be provided for easy and safe maintenance of trackside equipment such as disconnecter switches etc.
7. The Cables on the tracks shall cross the rails at right angle.
8. A temporary works shall also be installed as required for safe integration of works with previously commissioned sections.
9. Where control and SCADA/ETS communication cables are required to cross the power cable or traction return cable, this shall cross the power cables at right angles and where possible at a minimum separation of 600mm.
10. Special protective arrangement for control and SCADA/ETS communication cables shall be adopted in the vicinity of traction feeder lines.

6.3.8 The Installation of trackside equipment shall comply with the requirements of Schedule of Dimensions not only for the fixed structures but also for movable parts like doors etc., as far as possible.

6.4 PACKAGING AND SHIPPING

6.4.1 General

6.4.1.1 All equipment Goods and materials shall be properly inspected to ensure that there are no defects before shipment. An inspection tag bearing the words "INSPECTION PASSED" giving reference number to the inspection date and details to permit verification of inspection details shall be attached to those items inspected satisfactorily.

6.4.1.2 The four adjacent sides of each package shall be marked with permanent paint with the following information:

- a) CONSIGNEE
- b) COMMODITY
- c) CONTRACT No
- d) SHIPPING MARK

6.4.1.3 Appropriate caution notices such as "FRAGILE", "HANDLE WITH CARE", "KEEP DRY", "KEEP UPRIGHT" along with visual display symbols internationally accepted shall be conspicuously displayed on the outside surfaces of boxes, crates and packages.

6.4.2 Delivery

- 6.4.2.1 The Contractor shall be responsible for transportation and delivery of materials to site or to the storage space and shall continue to be responsible for its safe storage, handling, erection and commissioning.

6.4.3 Specific Requirements**6.4.3.1 Power and Control cables**

- a) Cables shall be supplied on drums of adequate strength in the longest possible lengths consistent with the requirement. Contractor shall submit a drum schedule according to the requirements for the approval of Engineer and shall supply the drums of cable length as per the approved drum schedule only.
- b) Each cable drum shall have a distinct identification number displayed on the outside flange. It shall also display following additional particulars
 - i) Voltage designation
 - ii) Length
 - iii) Conductor Size
 - iv) No. of cores
 - v) Drum No.
 - vi) Gross and net weights
- c) An arrow showing direction of rolling shall be shown. Both ends of the cables shall have heat shrinkable caps. The caps shall incorporate a sealant which melt on heating at temperatures well above outdoor ambient expected in Lucknow area.

6.4.4 Sub-assemblies

- 6.4.4.1 All the products shall be completely assembled before packing and shipping. If impracticable, the products shall be delivered in sub-assemblies clearly marking on each such assembly the identity of the particular assembly to which it belongs so that lots of different sub assemblies can be collected and stored together to form full assemblies at site

6.4.5 Deleted.**6.4.6 Third Rail System**

- 6.4.6.1 Necessary precautions shall be taken during shipping, handling and storage as per manufacturer's recommendations.

6.5 MANUAL HANDLING

- 6.5.1 To facilitate handling of equipment during installation and maintenance thereafter, the Contractor shall closely co-ordinate and interface with Station, Viaduct/tunnel and Track Contractors for installation of the material handling equipment as a part of ASS as well as TSS building as below:
- a) Travelling hoists and unloading jib cranes/Unloading platforms for ASS/TSS.
 - b) The work of installation of the hoists and jib cranes shall be closely coordinated with Station Contractors, Viaduct/tunnel and Track Contractors who will design the structures, install the beams at appropriate locations and provide the hoists and jib cranes.

- c) The entire material handling plan for traction substations and auxiliary substations for movement of bulky items such as transformers, 33kV switchgear, 33 kV cable drums and HSCBs etc. shall be carefully and safely planned.

6.6 WORKS AREA

- 6.6.1 The Contractor will be given temporary work sites as per the requirements.
- 6.6.2 The Contractor shall comply with the requirements specified in Chapter 17 of the General Specifications in connection with the use of work sites allocated to the Contractor.
- 6.6.3 The Contractor shall provide required number of sets of construction plant & equipment for construction.
- 6.6.4 An area of suitable size, will be given to the Contractor at nearby locations to corridor for his go down.

6.7 TEMPORARY WORKS

- 6.7.1 The design and a detailed proposal of the Temporary Works shall be submitted to the Engineer for review. The Contractor shall take up the Temporary Works with the prior approval of the Engineer. A suitable interface shall be pursued with other Contractors also.
- 6.7.2 All Temporary Works shall be removed on completion of the Section, or as directed by the Engineer.
- 6.7.3 All Temporary Works shall be clearly distinguishable from the Permanent Works.

6.8 SAFETY ISSUES AND SITE SUPERVISION

6.8.1 Work on safety Critical Subsystems

- 6.8.1.1 The Contractor shall ensure that all safety critical activities are identified prior to the commencement of the Installation.
- 6.8.1.2 Procedures for safety critical activities shall be submitted to the Engineer for review.

6.9 HEALTH AND SAFETY

- 6.9.1 All site personnel shall be required to undertake an induction safety-training course as detailed in the GS and in the Employer's Requirements on Safety, Health & Environment.
- 6.9.2 **Staff Safety**
 - 6.9.2.1 The Contractor shall ensure that all areas of work are sufficiently illuminated for the Works to be undertaken safely and that a safe system of work is employed for all activities.

6.9.2.2 Details of Health and Safety requirements at Site are described in Chapter 18 of the GS.

6.9.3 **Site Supervision**

6.9.3.1 The Contractor shall set up a site supervision system, which shall be part of the overall safety, system assurance and quality management system. In this respect the Contractor shall ensure that his sub-contractors and the Works are adequately supervised by properly trained and competent supervisory staff.

6.9.4 **Resident Engineer**

6.9.4.1 The Contractor shall ensure that a Resident Engineer is available on-Site for the duration of the On-Site Works during normal working hours and on-call to arrive on Site within one hour at all other times.

6.9.4.2 The Resident Engineer shall have sufficient authority to pursue the Contractor's work on site and assume responsibility for safety related matters.

6.9.4.3 The Resident Engineer shall be competent and qualified to act on behalf of the Contractor, and provide upon request information which shall include:

- a) Current progress of the Works;
- b) Planned work for the next 5 weeks;
- c) Audit and inspection reports;
- d) Health and safety information; and
- e) Documents and records pertaining to the Works.

6.9.5 **Quality Management**

6.9.5.1 The Contractor shall adopt an appropriate quality management system throughout the entire site installation period to ensure that the requirements as specified in this TS are achieved.

6.9.5.2 The Contractor shall provide sufficient number of suitably experienced supervisors and skilled workers to ensure that the progress and quality of the work, both on site and in the Contractor's workshops, are maintained to the satisfaction of the Engineer.

6.9.5.3 Supervisors shall have a minimum of five years' previous experience in a supervisory capacity on similar projects and all the skilled workers including linesmen, electricians, fitters and craftsmen, shall have a minimum of two years' previous experience in installation of similar systems.

6.9.5.4 The Contractor's supervision system shall cater not only for the supervision of the concerned system installation but also for the supervision of the installation of the primary fixing system (civil inserts), the earth mats, stray current collection mesh in track plinths, pier casting, viaduct segment casting and systems, etc. that are to be installed by the civil contractors. The supervisors shall work on a full-time basis during the entire installation process.

6.9.5.5 The Contractor shall maintain a set of drawings at each project site, which accurately reflect the current status of field changes. The Contractor shall obtain letter of no objection from the Engineer for any such changes. The Contractor shall prepare final

drawings showing the as built configuration. These drawings shall be developed in a logical format to facilitate routine system maintenance and troubleshooting. All drawings and details shall be endorsed by the Contractor.

- 6.9.5.6 The Engineer reserves the right to undertake, at any time, checks on the proficiency of the Contractors staff, licensing and all associated documentation. Should any of the Contractors staff be found incompetent or unlicensed he shall be removed from the site until competency has been established.

6.10 INSTALLATION AND CONSTRUCTION WORK

- 6.10.1 The Contractor shall undertake installation work in stages as shown in the Special Conditions of Contract. Installation, testing, and commissioning of later stages shall not impact revenue operation of earlier stages.

6.10.2 Transportation of Equipment and Materials

- 6.10.2.1 The transportation of materials, plant or equipment by the Contractor along the railway shall be undertaken in accordance with the requirements of the GS.

6.10.3 Competence of Personnel

- 6.10.3.1 The Contractor shall propose a site organization chart and manpower plan for review by the Engineer, 4 weeks prior to the commencement of work on site. The Site Organization Chart and Manpower Plan shall detail the staff competency and levels of authority.

- 6.10.3.2 The Contractor shall ensure that all his staff and subcontractors are trained and competent in the tasks that they are required to undertake. Such persons shall have their generic competence established and recognised through the holding of an appropriate license and must demonstrate their specific competence and knowledge in the particular systems, environment and procedures.

- 6.10.3.3 In addition to the generic form of license, the Contractor shall provide evidence of specific competence and knowledge, which shall include:

- a) Assessment and certified training in particular systems;
- b) Recording of competence and work in the licence holder's logbook; and
- c) Receiving or in receipt of sufficient and current exposure to the area of work that the holder is licensed for.

- 6.10.3.4 On no account shall the Contractor's staff undertake work for which they are not competent for and for which a current valid license is not held.

- 6.10.3.5 The Engineer reserves the right to undertake, at any time, checks on the proficiency of the Contractor's staff, licensing and all associated documentation.

- 6.10.3.6 Should any of the Contractors staff be found incompetent or unlicensed, they will be removed from the site until their competency has been established.

6.10.4 Equipment Locations

- 6.10.4.1 All equipment shall be located and positioned such that the environmental, maintenance and operational requirements are met. These shall include as a

minimum:

- a) Safety;
- b) Impact on Project Contractors; and
- c) Access and egress.

6.10.4.2 The Contractor shall not place any materials, plant, tools or equipment, whether permanent or temporary, within 2.5 meters of the nearest running rail or the platform edge unless permitted to do so by the Engineer.

6.10.5 Cable Installation

6.10.5.1 General

6.10.5.1.1 All cables shall be installed as per the ducting cable route plans shown in the Employer's drawings. Wherever such ducts are not provided the cables shall be laid & installed in accordance with the standards contained in this TS.

6.10.5.1.2 The Contractor shall coordinate with the civil and other designated contractors for the installation of cables in galleries, trenches, ducts, troughs, risers and other locations.

6.10.5.1.3 The cable system shall, during installation be fully protected from mechanical damage and be generally accessible at all points for inspection along its entire route. Suitable cable markers shall be provided for buried/covered cables upon completion of installation.

6.10.5.1.4 Should it prove necessary to cut any cable during installation, all cut ends shall be properly sealed.

6.10.5.1.5 The maximum pulling force of any cable during installation shall not exceed the design force of cables.

6.10.5.1.6 All cables shall be installed in the formed cable trenches, shafts, hangers, trays and brackets. The minimum recommended bending radius of the cable shall be adhered to during installation.

6.10.5.1.7 All materials used for termination, jointing and installation of cables in confined spaces shall have flame retardant, low smoke, halogen free characteristics.

6.10.5.1.8 All cables shall be installed as per the ducting plans shown in the Employer's drawings wherever such ducts are not provided the cables shall be laid & installed in accordance with the relevant standards.

6.10.5.1.9 Cables shall be installed such that they are accessible for maintenance purposes.

6.10.5.1.10 The Contractor shall ensure that the cabling design minimizes the number of cables running adjacent to or across the running rails.

6.10.5.1.11 Each cable and the circuits therein shall be identified.

6.10.5.1.12 All control cables shall have 20% or 2 cores, whichever is the greater, as spares after completion of the Works.

6.10.5.1.13 No jointing of cables will be allowed, except with the prior approval of the Engineer.

- 6.10.5.1.14 All control and communication cables outside the substation rooms shall be armoured.
- 6.10.5.1.15 All cables shall be protected from extraneous voltage and interference sources, the cables shall be protected as a minimum from lightning, EMI and transient voltages.
- 6.10.5.1.16 All cables that cross the running rail must be protected in a non-conductive pipe that must not affect the track formation. The pipe must be of sufficient strength to resist accidental damage to the cables from track maintenance.
- 6.10.5.2 Laying of Cables
- The Contractor shall co-ordinate with the civil and other designated contractors for the installation of cables in cable galleries, trenches, ducts, troughs, risers and shafts.
- 6.10.5.2.1 The cable system shall, during installation, be fully protected from mechanical damage and be generally accessible at all points for inspection along its entire route. Suitable cable markers shall be provided for covered cables upon completion of installation.
- 6.10.5.2.2 Should it prove necessary to cut any cable during installation, all cut ends shall be properly sealed.
- 6.10.5.2.3 The maximum pulling force of any cable during installation shall not exceed the design force of cables.
- 6.10.5.2.4 All cables shall be installed in the formed cable trenches, shafts, tunnels, hangers, trays, buried and brackets. The minimum recommended bending radii of the cables shall not be exceeded during installation.

6.11 WORKMANSHIP

- 6.11.1 General
- 6.11.1.1 All the installation shall be carried out according to the instructions shown in this Specification and Employer's Drawings.
- 6.11.1.2 All assemblies of equipment and their components and parts shall be completely interchangeable if they are of similar type.
- 6.11.1.3 The style and procedure of the workmanship shall be consistent throughout the Works. Unless otherwise specified, the Engineer shall decide the final colors for all paint work and other finishes to be applied to any part of the Works. All parts which are subject to wear or ingress of water/dust shall be enclosed in suitably approved housings.

6.12 DRAWINGS AND RECORDS

- 6.12.1 The Contractor shall maintain a set of drawings at each project site which accurately reflect the current status of field changes. The Contractor shall obtain a letter of no objection from the Engineer for any such changes. The Contractor shall prepare final drawings showing the as built configuration. These drawings shall be developed in a logical format to facilitate routine system maintenance and troubleshooting. All

drawings and details shall be endorsed by the Contractor.

- 6.12.2 The Contractor shall provide 6 copies of all as-built drawings in a suitable size such that the content is legible and in a minimum A3 size.
- 6.12.3 The Contractor shall ensure that at each equipment location, an as-built copy of the site documentation is provided. The documentation shall include as a minimum each power supply installation including all relevant details such as circuit diagrams, interlocking scheme, layout plans, O&M manuals etc.
- 6.12.4 The Contractor shall ensure that the as-built cabling infrastructure is fully documented and accurate at the time of taking over of the works or section. The documentation shall include (i) schematic of the cable routes, (ii) location of cable joints, (iii) cable types, (iv) installed dates, (v) test data and (vi) core plan indicating the circuit and function of each core for control circuits.
- 6.12.5 The Contractor shall be responsible for marking up the Combined Services Drawings with the cable installation details and the timely supply of these marked up drawings to the Engineer for overall coordination.
- 6.12.6 The Contractor shall provide an as-built integrated earthing and bonding plan – both schematic and layouts. Earthing drawings for each power supply installation including main earth terminals and connection to equipments shall be provided.

6.13 ASSET IDENTIFICATION

- 6.13.1 The Contractor shall submit an asset data base for review by the Engineer. The database shall contain the complete asset listing for the power supply system.
- 6.13.2 The database shall be designed with a minimum of the following information:
- a) Asset details
 - b) Failure history
 - c) Date installed; and
 - d) Date tested
- 6.13.3 All equipment shall have a unique permanent identification number.
- 6.13.4 All line side assets such as cables, third rail and disconnection switches shall be identified.

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CHAPTER – 7

TESTING AND COMMISSIONING

7.1 GENERAL REQUIREMENTS

- 7.1.1 The Contractor shall carry out all the tests and checks required for guaranteeing the Engineer of the satisfactory construction and the satisfactory operation of all power supply installations.
- 7.1.2 The Contractor shall put in place a full testing program to demonstrate that all the requirements of the specification are met.
- 7.1.3 The Contractor shall develop an Integrated Testing & Commissioning Plan including details of all testing activities as specified, to verify the system in all modes of operation and with all necessary interfacing requirements. Test programs, methods and results shall be documented and submitted to the Engineer as per ER-GS (Vol-3).
- 7.1.4 The Contractor shall supply documentation showing how system safety and reliability are ensured. Tests shall be carried out in accordance with Chapter 9 of GS. Five sets of all principal test records and test certificates duly endorsed by the Contractor's authorized engineer are to be submitted for the review by the Engineer in accordance with the specifications of this contract. These test records and certificates shall be supplied for all tests, whether or not the Engineer has witnessed them. The information given on such test certificates shall be sufficient to identify the materials or equipment to which the certificate refers.
- 7.1.5 Possession requirements for installation, testing and commissioning of new sections and their integration with commissioned sections shall be reviewed by the Engineer.
- 7.1.6 The Contractor shall include in the Integrated Testing & Commissioning Plan, methodology of ensuring safety during testing and commissioning and service trials.
- 7.1.7 The Engineer may conduct independent safety audits and will therefore require access to all the relevant equipment design and product information. The Contractor shall provide all necessary assistance for this to the Engineer.
- 7.1.8 All the tests shall be carried out by the Contractor and will be witnessed by the Engineer. The Engineer reserves the right to carry out any additional tests they consider necessary to satisfy themselves that the systems under this Contract meets the requirements of the Specification.
- 7.1.9 The Contractor shall support the Engineer's additional tests as necessary. The Contractor's support shall include, but not be limited to:
- a. Provision of test equipment;
 - b. Attendance of competent staff; and
 - c. Provision of test procedures
- 7.1.10 The Engineer may request that repeat tests be carried out to simulate the failure mode of any critical hardware / software component that is deemed to have a significant effect on the safety or reliability of the system.

- 7.1.11 All alterations to equipment and systems shall be carried out within the scheduled time prior to installation & commissioning.
- 7.1.12 Access shall be granted to the Engineer to any facilities where installation and other tests are in progress and to all inspection and test and commissioning records.
- 7.1.13 The Contractor shall support any testing required by the EIG and Commissioner of Railway Safety in order to obtain approval for Revenue operation.
- 7.1.14 The Engineer reserves the right to access at any time the records of all pre and post installation inspection and testing of equipment. In the absence of adequate documentation, the Engineer shall have the right to request the Contractor to repeat these tests to avoid problems being accumulated at subsequent phases. Testing and commissioning will not be allowed to start until the Post Installation Inspection and Testing phase are completed.
- 7.1.15 This Chapter describes the testing & commissioning relating to the Power supply equipment, in conformity with the requirements of international standards and Metro Railway practices.
- 7.1.16 The testing & commissioning of critical items like DC Switchgear, third rail, 33kV AIS/GIS etc. shall be done under supervision of the respective vendor & sub-contractor.

7.2 TEST PLANS & PROCEDURES

- 7.2.1 The Contractor is responsible for co-ordination of the testing of equipment. For the purpose, the Contractor shall submit detailed test plans, which shall include but not limited to:
- The details of equipment proposed for testing
 - Relevant standards and specifications
 - Proposed schedule of testing
- 7.2.2 The Contractor shall be required to submit various test plans as per the provisions of Chapter 9 of GS.
- 7.2.3 One month prior to in-plant acceptance test of equipment, the Contractor shall draft a test proposal and submit to the Engineer for acceptance. The test proposal shall be submitted individually for each equipment and shall necessarily include:
- The list of proposed in-plant tests,
 - The testing procedure describing how to proceed to perform properly the test along with relevant references,
 - Quality Assurance Plan (QAP) with acceptance criteria duly filled in
 - The testing book indicating the expected result of the various tests and provision to indicate the obtained result during the test and to record all observations.
- 7.2.4 Similarly, one month prior to pre-commissioning test of equipment, the Contractor shall draft a test proposal and submit to the Engineer for acceptance. The test

proposal shall be submitted individually for each equipment and shall necessarily include:

- The list of proposed tests,
- The testing procedure describing how to proceed to perform properly the test along with relevant references including parameters from type tests/factory routine tests, standards, codes, manuals etc.,
- The testing book indicating the expected result of the various tests and provision to indicate the obtained result during the test and to record all observations.
- Details of test equipment proposed for the testing

7.3 SEQUENCE OF TESTS

7.3.1 The various high/medium and low voltage equipment will be subjected to all the tests required under equipment test sheets, as per the relevant IEC and other standards mentioned in the technical & performance specification of each equipment or otherwise. It shall be the responsibility of the Contractor to arrange the testing facilities.

7.3.2 The sequence of tests shall be as follows:

- a. Type Tests;
- b. Factory Acceptance Tests (FAT) / Routine Tests;
- c. Acceptance Tests;
- d. Pre-Installation Tests and Inspection;
- e. Post-Installation Tests and Inspection;
- f. Partial Acceptance Tests (PAT);
- g. System Acceptance Tests (SAT);
- h. Integrated Testing and Commissioning;
- i. Service Trials

7.4 TYPE TEST

7.4.1 Type Tests shall be performed prior to full production and before FAT.

7.4.2 Type Tests shall be used to confirm that the proposed equipment is fit for purpose in the environmental conditions specified, design and meets the requirements of the Specification.

7.4.3 The Contractor shall provide detailed Type Test specifications in respect of tests to be performed for the equipment.

7.4.4 Type tests shall be carried out on the prototype in accordance with provisions contained in governing specifications. If type test conforming to this specification has already been conducted and a valid type test certificate is available for identical / similar equipment defined in respective manufacturing standards i.e. IS, IEC, EN etc. (as applicable), fresh type test shall not be required if it had passed the type tests and no change in design or material used have been made. Certified copies of type test report shall be furnished along with the Tender submission or at the time of vendor approval.

7.4.5 For items/equipment, with a previous Type Test from a competent authority, as mentioned in clause 7.4.4 above, the Contractor may propose that the Engineer waive the requirement for a repeat Type Test. The proposal shall include details of the tests undertaken and the level of approval given by the accepting authority together with a reference in that authority who may be contacted by the Engineer.

7.4.6 For any item that the Engineer does not agree to waive Type testing for the Contractor shall propose the body who will undertake the Type Testing (which may in certain circumstances be the Contractor). The Engineer may specify which authority will witness and approve the results of the Type Testing. The expenses for witnessing and approving the results of the Type Test - such as all the To & Fro Tickets, Conveyance, Boarding and Lodging shall be borne by the Employer.

7.4.7 In this regard the Engineer's decision will be final.

7.5 FACTORY ACCEPTANCE TEST

7.5.1 The Factory Test Plan shall be submitted for the Engineer's review as per the GS. Contractor shall submit the comprehensive list of specifications / standards to be followed. The FAT Plan / submission shall include the appropriate testing and inspection items for approval.

7.5.2 All equipment shall be subjected to routine test as per the provisions of the governing standards and specifications at the manufacturer's works. Routine tests shall be witnessed by the Engineer.

7.5.3 The Engineer, at his discretion can witness design / manufacturing / assembly / testing of the equipment in the Contractor's workshops.

7.5.4 FAT shall demonstrate that each equipment / subsystem meets its functional specification.

7.5.5 No equipment or software should be delivered until the Contractor has demonstrated to the satisfaction of the Engineer that the equipment or software conforms to the Specification by carrying out the FAT.

7.5.6 The final factory tests will be carried out on the fully assembled equipment as specified. Thereafter, if required and permitted by the technical features of the equipment, the equipment may be dis-assembled for transportation purposes. The dis-assembly should not, however, cause any deterioration of the technical performance of the equipment. In respect of certain routine tests, it may be necessary to repeat the tests at more than one stage, and the Contractor should ensure that this is done, as required by the Engineer. The fact that certain tests had to be carried out on the equipment and/or any part, at more than one stage, cannot be claimed by the Contractor as reason for any failure/sub-standard technical performances of the equipment.

7.5.7 All delays which could arise from additional tests from modifications required due to defects will not be used by the Contractor to justify price increase or time extensions.

7.5.8 The Engineer shall witness the FAT or convey waiver of attendance for FAT. In a case when Engineer has conveyed waiver for FAT, Contractor shall depute his representative/Engineer to witness FAT. No additional claim is permitted for

attendance/deputation of Contractor's representative/Engineer to witness FAT.

7.5.9 The Engineer, at his discretion can depute third party (all expenses borne by Employer) on behalf of Engineer to witness FAT in the Contractor's workshops / factory.

7.5.10 After Shipment Test

These tests shall be done to verify that no damages have taken place during transportation.

7.6 PRE-INSTALLATION TESTS AND INSPECTION

7.6.1 Prerequisite for installation and inspection

7.6.2 Prior to installation, the Contractor shall ensure that equipment delivered to Site has not been damaged in transit. Inspection and testing shall be conducted by the Contractor to determine that the equipment has not been damaged or the performance impaired in any manner subsequent to shipment.

7.6.3 Test procedures shall be carefully planned to ensure that the work can be completed in time available. If the time available is restricted, this planning shall include a contingency plan to be implemented if testing proceeds slower than anticipated or defects are identified, which cannot be corrected.

7.6.4 The Contractor's test personnel shall be knowledgeable in the power supply system / subsystems and equipment to the extent that they understand the implications and effects of all interface connections.

7.6.5 Site Preparations

7.6.6 The Contractor shall submit to the Engineer a site preparation plan before installation.

7.6.7 The Contractor shall prepare the site in all respects required for installation of power supply system / subsystem / equipment.

7.7 POST INSTALLATION TEST AND INSPECTIONS

7.7.1 The Contractor shall submit a plan for pre-power up checking, power-on, customization and configuration of equipment for review and approval to the Engineer. The necessary test shall be carried out by the Contractor based on the approved plan and shall be witnessed by the Engineer.

7.7.2 Post Installation tests shall be carried out by the Contractor for each subsystem following installation but before Functional Tests to demonstrate that the installation has been carried out properly.

7.7.3 The Contractor shall submit a Post Installation Inspection and Testing Plan prior to the commencement of the post installation inspection and testing.

7.7.4 The inspection shall verify that equipment has been installed to the procedures and designs that have been reviewed without objection by the Engineer, and that equipment is correctly located and labeled.

- 7.7.5 The inspection shall verify that any false feed, temporary wiring and redundant items have been removed and that equipment is correctly protected against interference, damage and deterioration.
- 7.7.6 The Contractor shall maintain inspection records to demonstrate that each item of equipment has been inspected and found to be satisfactory, and attach to this record a detailed list of any discrepancies found and remedial work carried out. Inspection records shall be kept for all installed equipment and a detailed list attached of any discrepancies.
- 7.7.7 As the discrepancies are rectified, the record sheets shall be amended to record the corrections.
- 7.7.8 The Contractor shall provide post installation test details for relevant test for equipment and the system/subsystems. These shall include, but not be limited to the following for acceptance by the Engineer:
- a. Equipment Check
 - b. Layout and equipment profile check
 - c. Voltage measurements
 - d. Continuity test as per the wiring diagrams
 - e. Cable insulation tests
 - f. Switchgear functional tests
 - g. Wire continuity tests
 - h. Earthing tests
 - i. Software, as applicable is correctly installed with the correct version and meeting functional requirements
 - j. Interface tests with other equipment
 - k. Structure gauge checks for third rail and other track side installations ensuring the installations are within the Schedule of Dimensions
- 7.7.9 Before commissioning tests commence at site, all the interlocking and controls shall be functionally tested at the Site. The Contractor shall provide test certificates on the functional tests performed for the Engineer's acceptance. The Contractor shall, prior to final functional test have carried out all preliminary testing of the system to the requirements of the specifications and approved designs.
- 7.7.10 An inspection and visual verification of ratings and connections of equipment, instrument transformers and auxiliary circuits, installation tests shall be carried out. After installation of equipment, visual inspection and operational tests on un-energized equipment shall be carried out to check the following:
- a. Cleanliness;
 - b. Workmanship;
 - c. Confirmation of items conforming to ratings specified;
 - d. Water and dust proofing;
 - e. Levelling, mounting and positioning;
 - f. Joints and connections tightness;
 - g. Cables – dressing, bending radii, jointing and finish at terminals;
 - h. Clearances and dimensions in conformity with drawings;
 - i. Earthing, bonding, and continuous earth conductors
 - j. Functioning of circuit breakers, interrupters, isolating and earthing switches and their interlocks;
 - k. Protection devices;

- I. Phase sequence verification;
- 7.7.11 Earth resistance measurements
- Earth resistance measurements shall be carried out for individual equipment and of the subsystem /system as required.
- 7.7.12 Insulation Resistance
- The insulation resistance of all 33 kV, 750 V, 415/230 V, 110 V DC circuits shall be tested in accordance with manufacturer's instructions. All LV circuits and traction return cables shall be tested with a 500 V insulation tester.
- 7.7.13 Continuity Test & Contact Resistance
- Continuity of all circuits shall be verified. Contact resistance of all high current joints and bolted contacts, especially the joints of running rails with dc return cables, for the running currents, shall be measured with a Duct or set. Earth system joints shall also be measured.
- 7.7.14 Tests on Protection equipment
- 7.7.14.1 Tests on Current Transformers
- Insulation resistance
 - Winding resistance
 - Polarity or Connections up to equipment terminals.
 - Secondary & primary injection test
 - Ratio and magnetization curve verification
- 7.7.14.2 Tests on Voltage Transformers
- Voltage ratio
 - Insulation resistance
 - Polarity of connections up to the equipment terminals.
 - Secondary & primary injection test
- 7.7.14.3 Secondary and primary injection tests
- Tests shall be carried out at a minimum of three settings if multiple settings are available. Test results of operation boundaries and operating times shall be recorded.
- 7.7.15 Tests on Batteries and Chargers
- Discharge tests and charging tests shall be carried out to verify the capacity of the batteries and all functions available on the charger. Continuous measurements of battery voltages shall be made together with periodic readings of the electrolyte specific gravities and temperatures. No addition of electrolyte is permitted during discharge tests.

The operation of the boost charge facility and the effect of the voltage dropping diodes shall also be demonstrated.

7.7.16 Control, Indication and Alarm Functions

Insulation resistance and continuity of all cores of cables shall be identified and tested. The correct functioning of all control, indication and alarm devices shall be verified.

7.7.17 Switchgear

7.7.17.1 All switchgear, including circuit breakers, interrupters, isolating and earthing switches, shall be operated to prove that the operating gear, tripping devices, protective gear and mechanical interlocking are satisfactory.

7.7.17.2 SF₆ gas leakage test shall be performed where applicable.

7.7.17.3 The opening and closing time for all DC HSCBs shall be verified.

7.7.18 Metering Instruments and Transformers

7.7.18.1 All current and voltage transformers, metering instruments shall be calibrated by voltage and current injection to prove their accuracy classes.

7.7.19 Deleted

7.7.20 Third Rails

7.7.20.1 Dimensional checks to ensure the third rails are correctly installed and are within the structure gauge.

7.7.20.2 Electrical continuity and insulation tests on third rails.

7.7.20.3 Track insulation and conductance measurement (along with track contractor) to ensure compliance with EN 50122-2.

7.7.20.4 Tests on Electrical Insulation Membrane simulating dry and wet conditions.

7.8 POST INSTALLATION TEST TEAM

7.8.1 Site tests shall be carried out by a separate test team independent from the installation team in order to verify that the installation is correct and that when the system as a whole is connected together, they function safely as an integrated system.

7.8.2 The tests to be performed shall cause each system and subsystem to be sequenced through all required operations to prove that the installation is in compliance with the specifications and approved protection and interlocking scheme.

7.8.3 Testing shall progress in a systematic, sequential and logical manner from an

established starting point to predetermined completion points of whole systems, subsystems or staged phases of the project.

7.8.4 All tests shall be documented, tests results recorded and signed by the testing Engineer.

7.8.5 Test certificates with completed test records, which demonstrate equipment and components meet the requirements of the specification shall be submitted for information.

7.8.6 Comprehensive system wide fault calculations and the protection relay setting shall be submitted for review and acceptance by Engineer. Test plan for protection relay testing shall be submitted to Engineer.

7.9 PARTIAL ACCEPTANCE TEST (PAT)

7.9.1 Installation work shall be completed, and inspection records submitted to the Engineer for review before the commencement of each PAT.

7.9.2 These tests form part of on-site and System Acceptance Tests as part testing of the equipment and system.

7.9.3 The PAT plan shall be submitted to the Engineer's review and approval at least 120 days before the commencement of each PAT.

7.9.4 The functional tests shall be carried out on in logical and proper sequence on installed equipment before System Acceptance Test (SAT) to demonstrate that the installed system / subsystem / equipment operates correctly in accordance with the Specifications.

7.9.5 The Contractor shall provide detailed functional test specifications for review and acceptance by the Engineer and shall be carried out by Contractor's personnel.

7.9.6 The functional test specifications for all equipment / subsystem / system shall include but not be limited to the following, and shall be provided for acceptance by the Engineer:

- a. Deleted
- b. 33 kV Switchgear.
- c. Deleted
- d. 33 kV Cable network
- e. 33 kV / 415 V Auxiliary substations
- f. 33 kV / 750 V DC Traction substations
- g. 750 V DC traction power distribution system
- h. Third rail system
- i. SCADA system
- j. Earthing, bonding and stray current protection system'

7.9.7 The functional testing shall contain as a minimum, but not be limited to the following:

7.9.7.1 Functional Tests and Interlock Tests

All control and protection functions and electrical/mechanical interlocks shall be tested.

7.9.7.2 Primary Injection Tests

The Contractor shall carry out primary injection tests on each protective system, to prove the auxiliary circuit connections, the relay fault setting values, the correct metering indications and the stability limits.

7.9.7.3 AC/DC Pressure Tests

The insulation resistance of all circuits shall be measured before and after the dc pressure test using a 5 kV insulation tester. The minimum phase-to-phase and phase-to-earth insulation resistance shall be 100 mega ohms.

Pressure tests shall be carried out on completed cable lengths of high voltage cables in accordance with IEC 60502.

7.10 SYSTEM ACCEPTANCE TESTS (SAT)

7.10.1 General

7.10.1.1 System Acceptance Tests shall comprise comprehensive testing of the completely assembled installation to ensure that every item has been installed, adjusted and that all systems operate in every respect in accordance with the requirements of the Specifications and are available for integrated testing and commissioning.

7.10.1.2 Prior to SAT, the Contractor shall submit a System Acceptance Plan to the Engineer for approval. The plan shall adopt a top down approach and describe the System Acceptance strategies and processes.

7.10.1.3 The System Acceptance Plan shall identify a comprehensive list of specifications, governing standards, method statements, procedures, drawings and records to be submitted to the Engineer for approval. The Plan shall also include a program, which identifies the dates for system acceptance submission and tests.

7.10.1.4 Any tests carried out which are deemed as SAT shall be identified. If these tests have been carried out earlier or form the part of earlier carried tests, the same need not be repeated unless desired by the Engineer. However, these tests should be identified and included in the System Acceptance Test Plan.

7.10.1.5 These tests shall be conducted in the presence of Engineer.

7.10.1.6 Any defects which become apparent in the course of these tests shall be made good and modifications as approved shall be implemented and recorded. All affected equipment shall be retested and certified before the system is accepted.

7.10.2 Prerequisites for SAT

7.10.2.1 The requirements in sub-clauses 7.10.2.2 to 7.10.2.5 shall be satisfied before the commencement of the SAT.

7.10.2.2 All documentation for the safety as per IE Rules and specification shall be submitted to the Engineer for review.

7.10.2.3 All PAT shall be completed, and test records submitted to the Engineer for review.

- 7.10.2.4 Facilities for the maintenance of the System shall be in place.
- 7.10.2.5 The SAT Plan shall be submitted to the Engineer for review at least 120 days before the commencement of the SAT.
- 7.10.3 System Acceptance Test Requirements
- 7.10.3.1 It shall be the Contractor's responsibility to conduct all tests and record data, and restore the power supply system to full operational use following SAT.
- 7.10.3.2 During the SAT, all interfaces with external systems shall be tested.
- 7.10.4 Energization:
- 7.10.4.1 The Contractor shall prepare operation safety rules and procedures for the review of the Engineer before Energisation.
- 7.10.4.2 The Contractor shall carry out all necessary checks to ensure safe Energisation.
- 7.10.4.3 All power equipment shall be subject to inspection by inspectors from the Electrical Inspectorate of Engineer before Energization. The Contractor shall ensure all Engineer's requirements are met.
- 7.10.4.4 The Contractor shall be responsible for the operation of traction and auxiliary power equipment. Upon request by the Engineer, the Contractor shall be responsible for the disconnection and the subsequent reconnections of the power equipment or connections of traction lines.
- 7.10.5 SAT shall include but not be limited to the following:
- a. Functional tests of SCADA system (Ref: SCADA Chapter in Specification)
 - b. Integrated Tests with UPPTCL/DISCOM
 - c. Short Circuit Tests on 3rd Rail
 - d. Short Circuit Tests on the 3rd rail system shall be carried out to prove correct operation of protection equipment and to ensure that the dynamic strength requirements of 3rd rail equipment are met.
 - e. Short Circuit Tests shall be carried out on every 3rd rail equipment line feeder.
- 7.10.6 Considering the impact on the life of service on the equipment after Short Circuit Tests, Engineer at his discretion can waive Short Circuit Tests to be carried out on every 3rd rail equipment.
- 7.10.7 Once the installation of the various pieces of equipment will have been completed, and the common test performed, some equipment will require specific tests. The list of this tests shall be included in the "On site testing" document, which the Contractor will have to supply.
- 7.10.8 Re-testing
- 7.10.8.1 When defects are detected in the equipment accessories, etc. during the tests, the Contractor shall ensure that adequate spares are kept on site. The Contractor shall, on receipt of no objection from the Engineer make use of DLP spares intended to rectify defects detected during Defect Liability Period (DLP). No objection will generally be given to make use of the spares provided the Contractor undertakes to

replenish the spares at the earliest possible date. The Contractor shall submit details of all tests prior to testing and all tests shall be carried out in the presence of the Engineer and to his complete satisfaction.

7.10.8.2 Should the plant or any portion thereof fail to give the performance required, then any further tests that may be considered necessary by the Engineer shall be carried out in a similar manner by the Contractor.

7.10.8.3 If any item fails to comply with the requirements of this Specification in any respect whatsoever at any stage of manufacture, test, erection or on completion at site, the Engineer may reject the item or defective component thereof, whichever is considered necessary and after adjustment or modification as directed by the Engineer, the Contractor is to submit the item for further inspection and/or test. In the event of the defect on any item being of such a nature that the requirements of this Specifications cannot be fulfilled by adjustment or modification, such item is to be replaced by the Contractor at his own expense, for the acceptance by the Engineer.

7.11 INTEGRATED TESTING AND COMMISSIONING

7.11.1 On completion of testing and commissioning of the power supply system to the satisfaction of the Engineer, the Contractor shall carry out all tests necessary to integrate power supply system with all other systems of Lucknow Metro Rail such as Rolling Stock, track system, signaling & communication system, LV power supply system etc. and demonstrate correct operation of all internal and external interfaces.

7.11.2 Integrated Testing and Commissioning refers to those tests undertaken in order to demonstrate that the various components of the metro railway systems operate satisfactorily between one another and meet all specified requirements for design, operability, safety, and integration with other works and systems. These tests shall be entirely within the requirements of one or more of the project contracts or they shall involve a multiplicity of contract procedure. The final Integrated Testing and Commissioning shall be carried out from OCC/BCC through SCADA.

7.11.3 Integrated testing and commissioning plan containing the schedule of integrated tests in coordination with the other designated contractors and test procedures shall be submitted to the Engineer for review and acceptance in accordance with the GS. The tests shall be carried out in coordination with the relevant Designated Contractors.

7.11.4 The Contractor shall be required to lead in certain Integrated Testing & Commissioning where such tests are required to prove the performance of system provided by the Contractor.

7.11.5 All the defects and shortfalls in the Contractor's system discovered in the course of integrated testing and commissioning shall be made good and retested to the satisfaction of the Engineer before the dates fixed for service trials.

7.11.6 Those systems that can be tested without depending on the running of trains, such as 33 kV cable system, receiving substation (RSS), auxiliary power system and SCADA system, the emergency trip system, etc. will have their integration tests scheduled to commence as early as possible. It is preferable that any interface problems associated with these "train less" system tests be identified and resolved prior to the commencement of test running.

- 7.11.7 Contractor shall submit the test specification and procedures for integration of all subsystems of power supply system for review and acceptance by the Engineer such as operation of 33 kV system (SCADA), 33 kV system, auxiliary and traction power system from OCC through SCADA.
- 7.11.8 The following is an indicative listing of those Integrated Testing and Commissioning functions that necessarily be integrated with others to demonstrate that the equipment and controls installed therein meet the Contract Specifications and demonstrate a safe-to-operate condition. This listing is not exhaustive and shall be updated by the appropriate contractor, or by the Engineer, to demonstrate functionality, completeness and safety of the installed works.
- a. Load sharing between rectifiers during train acceleration.
 - b. Load measuring test (HSCB)
 - c. Harmonic measurement (light load and heavy load)
 - d. RSS, TSS and ASS failure mode test'
 - e. Remote control and monitoring test through SCADA system at OCC / BCC
 - f. Emergency trip system tests.
 - g. Power system functional tests.
 - h. Stray current and EMI/EMC tests.
 - i. Touch/step potential tests
 - j. Short circuit tests on 3rd Rail
 - k. Rolling stock regenerative braking tests.
 - l. The power feed section of 750V DC i.e. from O/G +ve DC Cable to third rail to +ve DC cable of next TSS, shall be tested at an elevated voltage level as per IEEE 400 and shall be approved by the Employer.
- 7.11.9 Tests with Rolling Stock and track contractors shall include the following 3rd rail trackside related tests, but not be limited to the following:
- 7.11.9.1 Static Test
- 7.11.9.1.1 The Contractor shall verify that the initial horizontal, vertical and inclination geometry of the 3rd rail conductors agree with the design criteria and that shims can be added / removed to achieve final adjustments.
- 7.11.9.1.2 The Contractor shall ensure that initial dimensional criteria are checked throughout the entire corridor including:
- Mainline straight sections of track
 - Mainline curved sections of track
 - All turnouts
 - All depot electrified track
- 7.11.9.1.3 Prior to 750 V dc power-on, the Contractors shall conduct tests as follows, but be not limited to:
- Insulation resistance and electrical continuity of the 3rd rail sections
 - Manual / remote operation of the 750 V dc trackside isolators
 - Insulation resistance of running rails to earth
 - Conductivity and electrical continuity of rails and turnouts

- Insulation resistance across IRJs

7.11.9.2 Dynamic Tests

- 7.11.9.2.1 Subject to 'permit-to-work' (PTW) being in place prior to 750V dc power-on, dynamic tests with the Rolling Stock and Track Contractors shall be performed firstly at the depots and subsequently along the mainline progressively to demonstrate the following:
- 7.11.9.2.2 Using CCTV and visual recorders mounted on the rolling stock, verify at 'dead slow' that the physical interface between the RS Collector shoes and the 3rd rail is basically correct. Shimming 'in' and 'out' on the 3rd rail supports shall be undertaken to obtain the optimum physical interface.
- 7.11.9.2.3 With the initial loading of the traction power supplies, monitor the electrical parameters and the protection systems at the RSS/AMS, ASS and TSS.
- 7.11.9.2.4 Rolling stock speeds shall be increased progressively and carefully on the depot tracks and final 3rd rail adjustments shall be affected as necessary.
- 7.11.9.2.5 The Contractor in association with the Rolling Stock and Track Contractor shall adopt the same tests throughout the entire corridor until rolling stock service speeds have been attained.
- 7.11.9.3 The Contractor shall provide attendance to the Engineer during integrated test in relation to the earthing of entire section provided by the Traction Contractor and other Civil Contractors.
- 7.11.9.4 The Contractor shall also provide attendance to the Engineer's Representative during integrated test in relation to the insulation of train station platforms.
- 7.11.9.5 On-load Tests and Directional Tests: Once sufficient load current is established, voltages and currents into protection and metering equipment shall be verified to ensure correct operation of protection relays and accuracy of meter readings at local and remote locations.
- 7.11.10 Tests with other Designated Contractors shall include but not be limited to all necessary tests for meeting the interfacing requirements with other systems of Lucknow Metro Rail such as track, signaling and LV power system etc. for the purpose of integrated testing & commissioning.

7.12 SERVICE TRIALS

- 7.12.1 On completion of the integrated testing and commissioning and SAT to the satisfaction of Engineer, the Contractor shall confirm in writing to the Engineer that the works provided by them under the Contract is suitable and ready for the purpose of Service Trials. During service trials, the relevant system wide contractors will run electric trains and simulate the operating condition of the metro railway system.
- 7.12.2 The objective of service trials is to ensure that the functions and operations of the various systems are satisfactorily integrated. The Engineer may issue instructions to the Contractor for particular works or actions required of them during the period. In addition, the Contractor shall make good all defects and complete all outstanding

works within the service trials period so as to permit the commencement of revenue operations.

- 7.12.3 The Contractor shall make all arrangements including temporary provisions in his system to ensure safety during Service Trails.
- 7.12.4 Certification shall be provided by the Contractor that the system is safe for Service prior to the commencement of the service trials.
- 7.12.5 A Service Trail plan for necessary performance and functional tests and demonstrations to be performed during service trails shall be submitted to the Engineer for review at least 120 days prior to the commencement of Service Trails. The Service Trials plan shall be developed as defined in the GS.
- 7.12.6 Service Trails demonstration tests, conducted after all tests have been successfully completed, shall simulate revenue service and be designed to demonstrate that the power supply system is fully operational in conjunction with the control system at OCC under normal and abnormal conditions.
- 7.12.7 It shall cover the entire power supply logic, interlocking, protection, control and monitoring and shall include the demonstration of the requirements specified in the TS are achieved.
- 7.12.8 These tests shall be performed to demonstrate compliance with the requirements of EN 50122-1 (Protective Provisions relating to electrical safety and earthing) and EN 50122-2 (Protective provisions against the effects of stray current caused by DC traction system) such as rail and touch potential being within the prescribed safe limits.
- 7.12.9 The Contractor shall provide special and general attendance during the Service Trials period such that the persons who carried out the On-Site Testing and Commissioning are available on Site to solve any problem arising from the Service Trials.

7.13 REPORTING

- 7.13.1 All failures shall be recorded on a failure report form which shall contain as a minimum the following information:
- a. Identification of the equipment, including nomenclature, serial number, manufacturer's part number and location;
 - b. Operating time of each system including each shut-down and its cause
 - c. Date and time of each incident
 - d. Failure indication, mode, cause and effect
 - e. Classification of the incident (relevant independent failure or dependent failure)
 - f. Corrective maintenance or operational procedures required to restore the power supply system
 - g. Time to restore the power supply system to operation and active repair time; and
 - h. Environmental conditions and supply voltages.
- 7.13.2 Failure investigation reports shall be required for all failures.

7.13.3 The Contractor shall maintain a failure database throughout the execution of the Works. This database shall be handed over to the Engineer at the expiry of the Defects Liability Period.

7.13.4 A failure review board (FRB) shall be established consisting of the Engineer and the Contractor. The FRB shall review failures and assign responsibility.

7.14 PERFORMANCE VERIFICATION

7.14.1 The Contractor shall carry out all Performance Tests to verify that the performance of the System meets the Engineer after the substantial completion of the Works.

7.14.2 Should the performance of the System deviate from the Technical Specification, the Contractor shall make every effort to rectify the deviation in the shortest possible time, and to the satisfaction of the Engineer.

7.14.3 One of the Performance Tests which shall be carried out by the Contractor in conjunction with Other Contractors or relevant parties (e.g. BSNL / Telecom Company) is the measurement of EMI levels at locations to be specified by the Engineer. Such measurements shall be carried out prior to energisation of the Traction Power System, and then during Service Trials and commercial operation of the train services to ensure that the EMI levels comply with the requirements of this Specification

7.14.4 Energization shall be carried out in stages. Energization shall be under scope of LKE (02)-01 Contractor, and shall include 33 kV incoming cables from RSS, RSS/AMS, 33 kV cable network, main line and depot auxiliary substations. Traction power energization shall include, 33 kV incoming cables from RSS, 33 kV cable network, Traction substations and disconnector switches on the mainline and Depot. Energization of the 3rd rail shall be carried out progressively in stages. For the energization of certain sections, turn-on of power may require putting up of temporary works e.g. cable diversion, providing additional disconnector switches, additional earthing provision, etc. to ensure the safety of workers working in the adjacent non-energized area. Such work inclusive of sectional testing of traction power shall be deemed to be included in the Contract.

7.14.5 The Contractor shall be responsible for surveillance and security of the power supply systems including padlocking or otherwise maintaining control of the substation, padlocking of Switchgear and circuit breaker units, distribution switchboards, power panels, etc. throughout all energization stages of the installation. The Contractor shall interface with the other Contractors to assure no downstream cables or other electrical equipment is energized before it has been tested and before other involved contractors facilities are ready and secured. The Contractor's responsibility for surveillance and security of the system shall remain in force for each part of the system until such a time that the Engineer takes over the System.

7.15 SAFETY CERTIFICATE

7.15.1 The Contractor shall submit the safety certificate for each section in the approved format after completion of SAT, certifying that the power supply system is safe for opening for Revenue Operation.

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CHAPTER - 8

OPERATION AND MAINTENANCE SUPPORT

8.1 INTRODUCTION

8.1.1 The scope and requirements of supervision and planning of maintenance are stipulated in Chapter 12 of GS.

8.1.2 The Contractor shall be required to develop a maintenance philosophy for the power supply, third rail and control & monitoring installations taking into account international standards and railway practices.

8.1.3 The maintenance philosophy shall be developed within the framework of the state of the art and general prevailing reference standards with regard to maintenance of equipment / systems (in particular, standards X60-000, X60-101 and X-60-020).

8.1.4 The philosophy shall be based on the results of long practical experiences, along with numerous observations, reflections and experiments which have provided a means of optimizing both the quality of the service offered (safety, reliability) and the cost of obtaining high level of quality.

8.1.5 The following outlines the Employer's maintenance strategy, different levels of maintenance, the Maintenance Management System and the arrangement for maintenance. The Contractor shall make use of all relevant information to provide supervision of maintenance.

8.2 MAINTENANCE MANAGEMENT

8.2.1 The management of the maintenance process entails defining various levels of responsibility and enabling them to implement the strategic orientations defined by the directing authority

- a. by defining their respective missions,
- b. by setting objectives for each person,
- c. by translating these objectives into action plans,
- d. by implementing the means required to carry out action plans,
- e. by diagnosing the causes of any deviation from the set objectives,
- f. by taking corrective measures concerning the action plans or the objectives.

8.2.2 This management process requires a global approach and helps to improve the performance of the maintenance work of different components with quality, on time and at low cost. It must be implemented at three levels:

- a. at the level of human resources and management in the context of the scheduling of work, the allocation of human resources and the training of personnel,
- b. at the skills level to ensure quality, safety and suitable working conditions,
- c. at an economic and financial level to ensure responsible management of production, spare parts, purchasing and miscellaneous costs.

8.2.3 The quality of this management depends on the capability of those entrusted with operation and maintenance responsibilities

- a. to exploit the results of management within their field of responsibility,
- b. to react in the event of any deviation from the action plans defined with a view to achieving the set objectives.

8.2.4 Within the context of this approach, the management control function ensures timely advice to be given to those with operational and maintenance responsibility:

- a. by placing at their disposal, the tools and information required for piloting and diagnosis,
- b. by participating in carrying out this diagnosis,
- c. by participating in the task of defining the objectives to be achieved.

8.2.5 In conclusion, the process of maintenance management must incorporate two major components: the management of human resources and the study of the most suitable means of achieving the set objectives.

8.2.6 This is one of the first guidelines of maintenance organization in the various relevant centers.

8.3 MAINTENANCE STRATEGY

8.3.1 As a first measure, the Contractor shall ensure that the design of the software and hardware of the system supplied, installed and commissioned is supportable throughout the service life of the System to address, as a minimum, the following:

- a. design errors in the system;
- b. operational changes;
- c. environmental changes; and
- d. changes in infrastructure.

8.3.2 All equipment and infrastructure supplied for the 'Project' must be such as to ensure for minimum or no maintenance.

8.3.3 Maintenance activities required must be capable of being performed with little or no impact on the train service.

8.3.4 The maintenance work systems shall ensure safety of personnel and equipment.

8.3.5 During the Defects Liability Period (DLP) maintenance of all Works will be conducted by the Employer under the supervision of the Contractor.

8.3.6 The Contractor shall ensure that in order to supervise maintenance during the DLP, personnel are always available with relevant skills and level of competence.

8.3.7 The Contractor, upon noticing any defects, deficiency in quality and quantity of spares and materials shall without delay, arrange for alternative source of supply and submit his proposal to the Engineer for review.

8.4 LEVELS OF PREVENTIVE MAINTENANCE

8.4.1 The maintenance plan shall be based on four levels of preventive maintenance which differ according to the nature and scope of the interventions carried out there:

8.4.1.1 Level 1

Systematic in-service examinations, which provide a means of detecting (without any specific tools and by personnel who are not necessarily skilled) any anomalies which may have occurred in service according to a random or fortuitous process, and which may affect traffic and safety.

8.4.1.2 Level 2

Systematic periodic inspections, which allow skilled personnel to ensure that, taking account of the service to be provided until the next scheduled intervention of similar importance, the equipment or the element inspected offers predetermined guarantees of reliability.

8.4.1.3 Level 3

The replacement of elements, which are triggered within the framework of systematic preventive maintenance (when the element reaches the end of the programmed potential) or conditional maintenance (when it is noted in the course of an inspection that the normal operation threshold criteria have been reached), but also within the framework of corrective maintenance.

8.4.1.4 Level 4

Interventions on dismantled elements and structural equipment (such as body) carried out to restore the elements concerned to the same level of operation as an identical new one. These interventions (or overhaul operations) usually involve resources related to a reconstruction of the element in question by defining their respective missions.

8.4.1.5 Routine preventative maintenance will be carried out at regular intervals based on condition, reliability, usage, and service history and equipment manufacturers' recommendations. The Operating and Maintenance Manual shall describe the different levels of planned maintenance.

8.4.2 The frequency of the maintenance operations defined in the cycle can be expressed either in time (e.g.: every 6 months) or in units of actual utilization (e.g., months of operation, electrical power or current flowing through an equipment, mechanical wearing). The choice depends essentially on the foreseeable or observed disparity in service of elements belonging to the same family within the relevant cycle.

8.4.3 Supervisory Staff

8.4.3.1 The Contractor shall provide supervisory maintenance staff who are expert in all the different levels of fault finding, maintenance and repair of the various systems supplied under the Contract. The supervisory staff shall be provided at least in the following areas of specialization:

- a. Cabling system (33 kV AC, 750 V DC traction & return and 415 V AC);
- b. Traction substation including disconnection switches, isolating & earthing switches, short-circuiting devices etc.
- c. Auxiliary substation (33 kV / 415 V)
- d. 750 V DC Third Rail system

- e. SCADA
- f. Earthing, bonding and stray current protection
- g. ETS System

8.4.3.2 The stipulation of clauses 12.3.2, 12.3.3 and 12.3.4 of GS shall apply here.

8.5 MAINTENANCE DURING DLP

8.5.1 Maintenance Management System (MMS) and Maintenance Arrangement

8.5.1.1 During non-operation time, sections of line will be closed for maintenance work. The minimum time for possession periods is 3 hours. Ideally, this time shall be the free time available for work. It excludes time required for trains to return to their stabling point and time required to take and give up possession. This time is, however, not available for maintenance in depot.

8.5.2 Competency of Personnel

8.5.2.1 During the DLP the Contractor shall support the Engineer with sufficient trained and competent personnel.

8.5.2.2 Such persons shall have their generic competence established and must demonstrate their specific competence and knowledge in the particular systems, environment and procedures.

8.5.2.3 The Contractor shall provide evidence of specific competence and knowledge, which shall include:

- a. assessment and certified training in particular software applications and operations;
- b. recording of competence and work in the license holder's logbook; and
- c. receiving or in receipt of sufficient and current exposure to the area of work that the holder is licensed for.

8.5.2.4 Routine spot checks on licensing may be carried out from time to time by the Engineer's Representative qualified personnel on the proficiency of the Contractor staff.

8.5.2.5 In the event of a failure, the Contractor shall undertake the management and investigation necessary to identify and rectify the cause.

8.5.2.6 Should the Engineer, during the DLP require further investigations at other Sites throughout the system, the Engineer will formally request the Contractor to undertake such investigations.

8.5.3 Testing and re-commissioning of System and Equipment

8.5.3.1 In the event of a failure requiring modifications to the System, the Contractor shall undertake any testing and re-commissioning required.

8.5.3.2 Any such modification shall be submitted for review by the Engineer's Representative.

8.5.4 Temporary Alterations to Restore Service

8.5.4.1 The Contractor shall undertake any temporary modifications necessary to maintain service.

8.5.4.2 Any such modification shall be submitted for review by the Engineer's Representative.

8.5.5 Discrepancies between Installation and Design Records

8.5.5.1 Should the Contractor discover inconsistencies between the maintenance drawings and documentation and the installed equipment, the Contractor shall correct all such errors within two weeks.

8.5.6 Communications

8.5.6.1 The Contractor shall ensure that adequate communication facilities are provided to its staff during the DLP.

8.5.7 Location of Staff

8.5.7.1 The Contractor shall be responsible for locating staff such that the Contractor meets its obligations.

8.5.8 Storage of Equipment and Materials during the Maintenance Period

8.5.8.1 The Contractor shall ensure that no equipment is to be stored along the trackside.

8.5.8.2 The Engineer will provide defined storage locations for the support of the different levels of Maintenance.

8.5.8.3 The Contractor shall satisfy itself and the Engineer that the storage locations for equipment and materials will meet the performance requirements of this TS.

8.5.9 Maintenance Regimes

8.5.9.1 The Contractor shall provide documented maintenance regimes to be followed by the Engineer upon substantial completion of various components of the work until the end of the DLP.

8.5.9.2 The Contractor shall produce a maintenance regime for the equipment that shall comprise two constituent parts, corrective and routine/preventative maintenance.

8.5.9.3 Routine/preventative maintenance shall be non-intrusive to the day-to-day operation of the train service and be capable of being pre-planned in advance of the work.

8.5.9.4 Corrective maintenance shall be available 24 hours per day, able to respond to all foreseeable circumstances.

8.5.9.5 The maintenance regime shall cover all parts and equipment of the system designed, installed and commissioned by the Contractor.

8.5.9.6 The Contractor shall take into account the requirements of the operations and maintenance when determining and proposing its maintenance regime.

8.5.10 Scope and Hours of Coverage

- 8.5.10.1 The regime and structure of corrective maintenance shall be robust in design.
- 8.5.10.2 The Contractor shall provide a full 24 hour On-Call coverage and shall be such that initial response and rectification of failure are in accordance with the following:
- a. assistance to first line and corrective maintainer within 30 minutes, upon request of first line maintainer;
 - b. 24 hours from notification to collection for third line maintenance; and
 - c. Replacement or repair of component from factory within 2 weeks including transportation time. Any extension to this time shall be agreed with the Engineer and a replacement provided.
- 8.5.10.3 All elements of First Line preventative maintenance shall be carried out and completed during non-traffic hours without interrupting train services.

8.5.11 Failure Investigations

- 8.5.11.1 The Contractor shall conduct failure investigations.
- 8.5.11.2 The OCC Controller will determine priorities in the event of a conflict between the Contractor and other Contractors during failure investigation.
- 8.5.11.3 Disputes between the Contractor and other Contractors will be resolved by the Engineer's Representative.
- 8.5.11.4 The Contractor shall make available to the Engineer all test and failure data as required.

8.6 FACILITY AND TOOL REQUIREMENT

- 8.6.1 The achievement of the objectives assigned to the maintenance division with regard to quality, safety and regularity for the lowest possible overall cost requires the implementation of a number of resources, which must be perfectly tailored to the requirements.
- 8.6.2 The facilities and tools are part and parcel of the resources placed at the disposal of the maintenance division to achieve the set objectives
- 8.6.3 Owing to the cost of these facilities, the number of maintenance centers to be equipped and the necessity of keeping the maintenance actions consistent and uniform, the main choices of facilities and tools are integral part of the System maintenance policy and program.
- 8.6.4 When determining these requirements, in-depth knowledge in the dedicated maintenance plan is needed while taking due account of the experience acquired in similar fixed installation which has been in service for several years.

8.7 SOFTWARE SUPPORT

- 8.7.1 General

- 8.7.1.1 The Contractor shall submit to the Engineer for review, the software support plan at least 90 days before commencement of software installation.
- 8.7.1.2 All changes, bug fixes, updates, modifications, amendments, new versions shall not result in any non-conformance with this Specifications.
- 8.7.1.3 The Contractor shall submit all new versions to the Engineer for review at least 2 weeks prior to their installation.
- 8.7.1.4 The new versions of software shall not degrade the operation of the System.
- 8.7.2 Security Obligation**
- 8.7.2.1 Within 14 days of the installation of any software into the Permanent Works by the Contractor, the Contractor shall submit to the Engineer for retention by the Engineer two backup copies of the software, which shall include, without limitation:
- a. all source and executable code;
 - b. all design documentation relating to the software; and
 - c. Any specified development tools required for maintenance of the software, including, but not limited to, editors, compilers and linkers.
- 8.7.2.2 Any software item delivered by the Contractor to the Engineer pursuant to the above Paragraph shall not be translated or modified by the Engineer without the prior consent of the Contractor unless:
- a. the owner of the software becomes insolvent or has a receiving order made against it or makes an arrangement or assignment or composition with or in favor of its creditors (including the appointment of a committee of inspection) or goes into liquidation or commences to be wound up or has a receiver, liquidator, trustee or similar officer appointed over all or any part of its undertaking or assets or if distress, execution or attachment is levied on, or if an encumbrance takes possession of, any of its assets or any proceeding or step is taken which has an effect comparable to the foregoing in any relevant jurisdiction; or
 - b. the owner of the software ceases to trade; or
 - c. the owner of the software assigns copyright in the software and the Contractor fails within 60 days of such assignment to procure in favour of the Engineer, a license from the new owner in the same terms as that required by the Contract; or
 - d. the Contractor is in breach of any of his obligations under the Contract.
- 8.7.3 Error Correction**
- 8.7.3.1 The Contractor shall inform the Engineer immediately when a fault is discovered within delivered software or documentation.
- 8.7.3.2 On receipt of a request from the Engineer for identification or further diagnosis of a failure or fault, the Contractor shall provide appropriate resources.
- 8.7.3.3 The Contractor shall provide written details as to the nature of the proposed correction to the Engineer.
- 8.7.4 Training**

The Contractor shall provide training for Employer's staff to enable the Employer to make proper use of any new versions.

8.7.5 Fixes or Patches

8.7.5.1 The Contractor shall notify the Engineer promptly of any fixes or patches that are available to correct or patch faults.

8.7.5.2 The Contractor shall detail any effect such fixes or patches are expected to have, upon the System.

8.7.6 New Versions

8.7.6.1 The Contractor shall ensure that all new versions are fully tested and validated on the simulation and development system prior to installation.

8.7.6.2 The Contractor shall ensure that all new versions are fully tested and commissioned once installed on the Site.

8.7.6.3 The Contractor shall deliver to the Engineer any new version, together with the updated Operation and Maintenance Manuals.

8.7.6.4 The Engineer shall not be obliged to use any new version and that shall not relieve the Contractor of any of its obligations.

8.7.6.5 Any effect upon the performance or operation of System that may be caused by a new version shall be brought to the Engineer's attention.

8.7.7 Debugging and Trace Software

8.7.7.1 The Contractor shall provide debugging or trace logging software.

8.7.7.2 The Contractor shall not install debugging or trace logging software that affects the performance or functionality of the System.

8.7.8 Routine and Corrective Maintenance Procedures

8.7.8.1 Routine and corrective maintenance procedures shall be supplied for all equipment. The format shall be as follows:

- a. Uniform format and layout irrespective of equipment supplier;
- b. Colour coding for each activity;
- c. Cross referenced to the Operation and Maintenance Manuals; and
- d. Document control information.

8.7.9 Operation Activities

8.7.9.1 All operational activities shall comply with the Employer's safety rules, and requirements of the Operation and Maintenance Manuals.

8.7.9.2 The Contractor shall recommend in detail the frequencies for preventive and corrective maintenance, and what items of work are to be carried, including but not limited to the following:

- a. Step-by-Step procedure to carry out the task;

- b. Diagrams and flow charts for illustration, if applicable;
- c. Precautions for the maintenance personnel to follow; and
- d. Estimated duration and manpower required.

8.8 SUPPORT DOCUMENTATION

8.8.1 Routine and Corrective Maintenance Procedures

8.8.1.1 Routine and corrective maintenance procedures shall be supplied for all equipment. The format shall be as follows:

- a. Uniform format and layout irrespective of equipment supplier;
- b. Colour coding for each activity;
- c. Cross referenced to the Operation and Maintenance Manuals; and
- d. Document control information

8.8.1.2 The procedures shall be submitted for review by the Engineer; the following shall be included as a minimum:

- a. Frequency of maintenance;
- b. Type of maintenance;
- c. The equipment identification;
- d. Safety precautions to be observed;
- e. Step by step guide to the maintenance required; and
- f. Explanatory diagrams.

8.8.1.3 The Contractor shall supply the Configuration and Customization data, Parameters and Settings in both Hard copy and Electronic format.

8.9 OPERATION AND MAINTENANCE MANUALS

8.9.1 General

8.9.1.1 The Contractor shall be required to submit Operation and Maintenance manuals as well as troubleshooting manuals in terms of requirements of Chapter 11 of GS.

8.9.1.2 Each and every manual shall be divided into indexed sections explaining the subject matter in logical steps.

8.9.1.3 Most manuals shall consist of A4-size printed sheets bound in stiff-cover wear-resistant binders clearly and uniformly marked with the subject matter and reference number.

8.9.1.4 Where alternative sizes are proposed, (e.g. A5/A6 pocketbooks of schematic wiring diagrams) these shall be submitted for review of Engineer.

8.9.1.5 The binding shall allow for all subsequent changes and additions to be readily effected.

8.9.1.6 Information shall be provided in pictorial form wherever possible and shall include step-by-step instructions and views of the particular equipment including exploded views

8.9.1.7 Programmable equipment shall be supplied with sufficient flow charts and fully documented programme to enable faults to be quickly identified and system modification to be undertaken at any time.

8.9.1.8 The Contractor shall provide clarifications and amendments to the Operation and Maintenance manuals as well as Troubleshooting manuals as necessary during the Defects Liability Period. Updates shall be provided for the originals and all copies.

8.9.2 Quantities of Manuals

8.9.2.1 The Contractor shall supply Original plus five hard copies of Operating Manuals; Maintenance Manuals and Subsystems / Systems spare parts catalogue. These Manuals and Catalogue shall also be submitted in electronic and editable format (CD).

8.9.2.2 The Contractor shall also deliver manuals in electronic format. This is in addition to the submission of manuals in hardcopies. The format of Electronic copies of Manuals shall be as per the ISO standards and shall be reviewed and approved by the Engineer. It shall allow for links between parts catalogue and maintenance instructions.

8.9.2.3 The Documents Management System and Language used shall be subject to Engineer's review.

The manuals shall include but not limited to following:

8.9.3 Operation Manual

8.9.3.1 The Contractor shall provide operation manuals explaining the purpose and operation of the complete system together with its component subsidiary systems and individual item of equipment. The characteristics, ratings and any necessary operating limits of the Equipment and Sub-systems shall be provided. The Operation Manuals shall focus on operation aspects under normal and emergency conditions.

8.9.3.2 The Contractor shall submit the operation manual which shall essentially contain, but not be limited to:

- a. The basic design concept of the system
- b. Operation of individual equipment
- c. Operation of the system as a whole
- d. Operation under normal and emergency conditions
- e. Safety and operational interlocks provided in the system
- f. Characteristics, rating and operating limits of equipment and sub-systems
- g. Trouble shooting charts and procedures
- h. Power block procedures
- i. Permit to work procedures

8.9.4 Maintenance Manual

8.9.4.1 The maintenance manual shall be based on the management strategies defined above. The Contractor particulars of operating parameters, tools for dismantling and

testing, methods of assembly and disassembly, tolerances, repair techniques and all other information necessary to set up a repair and servicing programme shall be included in the manuals.

- 8.9.4.2 It shall essentially contain, but not be limited to:
- Details of the equipment used in system. Details shall include equipment description, manufacturer details, expected life, mean time between failure along with rating and specification.
 - Location of usage of each equipment in the system along with exploded views to enable to identify the parts.
 - An indicative list with details such as the price of equipment & important spares, lead time and vendors.
 - Details of tools and equipment required for dismantling, testing and attending defects
 - Methods of assembly, disassembly and usage of special tools
 - Manufacturer documentation supplied along with the equipment
 - Inspection / overhaul and routine maintenance schedules of the equipment along with periodicity
 - Inspection / overhaul procedure during various stages of periodic maintenance
- 8.9.4.3 Apart from above details, the Contractor shall provide documentation for all hardware and software for computer systems and other associated electronic equipment to meet the following requirements, but not be limited to:
- manufacturers' documentation supplied as standard with the equipment;
 - hardware configuration with details of expansion capabilities and options;
 - programme loading instructions, including runtime environment configuration;
 - programme listing including comprehensive 'comment statements' in hard copy and soft format for source code, compilers and development tools necessary to modify and recompile software;
 - flow charts, data flow diagrams and state diagrams as appropriate;
 - description of software modules including purpose, linkage with other modules, error routines and any special considerations;
 - memory maps for both internal and peripheral memory showing description of all programme, data files, overlay areas, memory available for expansion and the like;
 - loading and operating instructions for diagnostic programme and specifically developed debugging tools; and
 - programming manuals relevant to operating systems, languages, development tools, etc.
- 8.9.4.4 The manual shall also include inspection / overhaul procedure and periodicity of various inspection / overhaul schedules in detail including the tools, special tools / plants, and facilities required.
- 8.9.4.5 The manual shall be subject to review by the Engineer.
- 8.9.4.6 The maintenance manual shall also include an illustrated parts catalogue of all plant supplied and shall contain sufficient information to identify and requisition the appropriate part by maintenance staff.
- 8.9.4.7 The catalogue shall comprise 3 sub-sections. The first shall be an alphanumeric parts list, which shall include the following information:

- a. Part number
- b. Description
- c. Name of manufacturer
- d. Quantity and Unit
- e. Part number of next higher assembly (usually a line replaceable unit).
- f. Cross-reference to figure number.
- g. Category: e.g. consumable, line replaceable unit, repairable.
- h. Life-expected life Mean time between failure or mean distance between failure where available.
- i. General or specific purpose

8.9.4.8 The second is a series of illustrations to indicate the location of each replaceable item which shall be clear and progressive with exploded views to enable parts to be identified easily by cross-reference with the alpha-numeric list.

8.9.4.9 And the third an indicative price list which shall list in alpha-numeric sequence the part number with the price, lead time and vendor.

8.9.5 Trouble shooting charts and procedures Manuals

8.9.5.1 The Trouble shooting Charts & Procedures manual shall be based on the requirement of each type of equipment installed in the system for troubleshooting & diagnosing any problem that may occur during the operation of the aforementioned equipments in the system. The Contractor shall compile the data from OEM and any other information necessary to set up a repair and servicing programme shall be included in the manuals.

8.9.6 Training Manuals

8.9.6.1 The Contractor shall provide Training Manuals suitable for use by the Engineer in conducting in-house training. The manuals shall provide in details of all aspect of training covered in Chapter-10.

8.9.7 Electronic Manuals

8.9.7.1 The Contractor shall also deliver manuals in electronic format. This is in addition to the submission of manuals in hardcopies. The format of Electronic copies of Manuals shall be as per the ISO standards and shall be reviewed and approved by the Engineer.

**CHAPTER 9: SPARES, SPECIAL TOOLS, TESTING AND DIAGNOSTIC
EQUIPMENT AND MEASURING INSTRUMENTS**

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CHAPTER –9**SPARES, SPECIAL TOOLS, TESTING AND DIAGNOSTIC EQUIPMENT AND MEASURING INSTRUMENTS****9.1 GENERAL**

- 9.1.1 The Contractor is required to supply tools and spares necessary to operate and maintain the system efficiently after the commissioning as per General Specifications. This Specification specifies a minimum list of tools and spares ("Contract Spares") to be supplied by the Contractor. These tools and spares shall be handed over before the commissioning of the system to enable the Engineer to maintain the system.
- 9.1.2 This list has been developed on the basis of past experiences. However, the list is not exhaustive. On the basis of manufacturer recommendations and past experience, the Tenderer may specify additional tools and spares required for proper handling, operating and maintaining the system for five years. The Tenderer may also specify the cost for these additional tools and spares in the Tender.
- 9.1.3 The Contractor should ensure that the Tools and Plant supplied by him are compatible with the equipment to be supplied under this Contract.
- 9.1.4 The Tenderer shall indicate the total prices in BoQ Schedule. The Tenderer shall include a detailed sheet indicating the price breakdowns considered for individual items in Tools and Spares. This list shall be included in the financial package.
- 9.1.5 The Tenderer shall propose a schedule for phased delivery of Tools and Spares and obtain the Engineer's approval. Stage payment as explained in Bill of Quantity (Financial Package) shall be made on the basis of prices indicated in this detailed breakdown sheet.
- 9.1.6 It should be noted that in case the Tenderer fails to submit the detailed breakdown at the time of Tendering, no stage payments shall be entertained. However, the Contractor shall be still required to supply tools and spares in a phased manner as advised by the Engineer.
- 9.1.7 In addition to the above, the Contractor shall provide an exhaustive list of Commissioning Spares sufficiently in advance (minimum three months prior to PAT) to the Engineer and get it approved and ensure physical availability of these Spares at least one month prior to the beginning of Partial Acceptance Tests of respective section.
- 9.1.8 Likewise, the Contractor shall procure and maintain the Defect Liability Spares as listed in BoQ, sufficiently in advance (minimum one months prior to ROD). The list of DLP spares to be procured shall be submitted in advance and get it approved the Engineer and ensure physical availability of these DLP Spares at least one month prior to the ROD of respective sections.
- 9.1.9 The DLP Spares shall be maintained by the Contractor in his depot/storage, which shall be subject to physical inspection and review by Engineer.

9.2 CONTRACT SPARES

- 9.2.1 The Contract Spares are listed in Table 9.1 below. The total quantities mentioned are provisional and bound for quantity variation and to be procured and supplied in stages or in one lot. Contractor shall submit the list for Contract Spares for Engineer's approval. Contractor shall ensure supply of spares one month prior to ROD as approved by Engineer.
- 9.2.2 The Spare Parts shall be adequate to meet the maintenance requirement for five years. If, however, the Tenderer feels that some more items or more quantities of the items mentioned herein are required for the proper operation and maintenance of the installations supplied and erected by him, for a period of at least 2 years commencing from the expiry of the Defects Liability Period, the Tenderer shall, in that case, add such items and/or quantities to this list and shall include the amended list in his Tender.

Table 9.1: Contract Spares

Sl. no.	DESCRIPTION	Unit	Quantity
A	33 kV Equipment (RSS)		
1.	Lightning/Surge Arrester (Indoor Type)	nos.	3
2	33kV AIS equipment		
2.1	Close coil	nos.	1
2.2	Trip coil	nos.	2
2.3	Handle for CB ES	nos.	4
2.7	One no. O ring of all type	Set	1
C	Control Relay Panel		
1.	One Set of IEDs (Relay/BCU etc. of each type)	Lot	1
D	33 kV Cables and Accessories		
1.	Straight through joint (Set of 3 for 3 Phases)	Set	1
E	Auxiliary Equipment (LT)		
1.	Battery Charger with Battery Set for 33 kV RSS	sets.	1
2.	LT (1.1kV), copper conductor control cables (200m of each type)	Lot	1
F	33 kV equipment (AMS/ASS/ASS+TSS)		
1	Deleted		
2	VCB poles	Set	3
3	Current Transformer of each type and rating	Nos. each.	6
4	33 kV Potential transformer of each type and rating	Nos. each.	6
5	Contactors, Auxiliary relays with base, MCB's, of each type and rating	Nos. each.	10
6	33 kV PT Fuse	Nos.	20
7	Closing coil assembly	Nos.	6
8	Tripping coil assembly	Nos.	6
9	Spring Charge motor	Nos.	5
10	Under-voltage coil	Nos.	5
11	Auxiliary switches for CB status	Nos.	5

Sl. no.	DESCRIPTION	Unit	Quantity
12	33 kV VCB control supply connector with cable	Nos.	2
13	Multifunction meters used in both TSS and ASS 33kV Switchgear panel.	No.	3
14	Miniature relay with base for 33KV panel (of each type)	Set	5
15	Space Heater of each rating	Nos.	5
16	Terminal Blocks of each type	Nos. each	5
17	33kV Voltage indicating unit with Voltage Detecting insulator for Cable charge indication.	Set	5
18	Each type of Cards used in each type of numerical relays	Nos.	5 each
G	33 kV/415 V Auxiliary Transformer		
1	Auxiliary transformer		
1.1	Neutral CT	Nos.	3
1.2	Temperature sensor	Nos.	3
1.3	Temperature Scanner or WTI	Nos.	3
1.4	Door Limit Switches	Nos.	6
H	33 kV/585-585 Rectifier Transformer		
1	Deleted		
2	Temperature sensor	Nos.	3
3	Temperature Scanner or WTI	Nos.	3
4	Door limit switch	Nos.	6
5	Busbar Insulators	Nos.	3
I	Rectifier		
1	Deleted		
2	Semiconductor fuse	Set	30
3	Thermostatic switch (NC) Off: 120°C	Set	3
4	Thermostatic switch (NC) Off: 135.5°C	Set	3
5	Micro-switch for semiconductor fuse	Set	20
6	RC Filter Complete Unit	set	5
7	Snubber Circuit	set	6
8	Rect. Diode	Set	12
9	Support Insulators of each type and size	Nos. each.	6
10	Terminal Blocks of each type and rating	Nos. each	20
J	750 V DC Switchgear		
1	Deleted		
2	Deleted		
3	Deleted		
4	Deleted		
5	Deleted		
6	NRP – Manual Disconnecter Switches	Set	2
7	Motorized Disconnection switches complete Cubicle	Set	2
8	Heater unit for switchgear cubicle	Set	15
9	Surge arrester for DC for NRP	Set	12
10	Frame Leakage relay for NRP	Nos.	2
11	Surge arrester for DC for outgoing feeders	Set	20

Sl. no.	DESCRIPTION	Unit	Quantity
12	Actuator with 2 contacts; 1NO + 1NC	Set	20
13	Voltage Measuring Device	Set	20
14	Current measuring device	Set	20
15	Control & Protection relay complete unit (HSCB Feeder)	Nos.	5
16	Control & Protection relay complete unit (NRP)	Nos.	5
17	Relay Display Units with connecting Cables	Set	5
18	Switches, MCB's, Plug-in relays with base used in DC System (For feeder & incomer HSCBs, DS and NRP)	Nos. each	20
19	Each type of Cards used in each type of numerical relays	Nos.	5 each
K	Battery & Battery Charger for ASS/TSS		
1	Cells of each rating	Nos.	5
2	Interconnecting links of each type	Nos. each	15
3	All card of each Battery charger	Set	2
4	Switches, MCB's/MCCBs, Contactors, Indicating lamps, voltmeter, ammeter of each type and rating	Set each	6
L	ACDB & DCDB for ASS/TSS		
1	Contactors of each rating with 2 NO+2 NC	Nos. each	5
2	RCCBs and MCBs of each rating	Nos. each	5
3	Fuse and fuse Base of each rating	Nos. each	10
4	LEDs Indicating lamps of each type, rating and colour	Nos. each	10
5	UV Relays of each type and rating	Nos. each	5
M	33 kV Cable		
1	33 KV Cable 1Cx300 sqmm Cable FRLS	Mtrs.	500
2	33 KV Cable 1Cx300 sqmm Cable FRLSOH	Mtrs.	500
4	33 KV Cable 1Cx120 sqmm Cable FRLS	Mtrs.	50
5	33 KV Cable 1Cx120 sqmm Cable FRLSOH	Mtrs.	50
6	Straight through joint kit (for single core) of each type	Nos.	6
7	Termination kit (for single core) of each type	Nos.	6
8	Trefoil Clamp of each type with fasteners with nylon	Nos.	50
N	750 V DC Cable		
1	750 V DC, 3.3 kV, 1Cx 300 mm Cable (positive Cable) FRLS	Mtr	400
2	750 V DC, 1.1 kV, 1Cx 300 mm Cable (negative Cable) FRLS	Mtr	200
3	750 V DC, 3.3 kV, 1Cx 300 mm Cable (positive Cable) FRLSOH	Mtr	500
4	750 V DC, 1.1 kV, 1Cx 300 mm Cable (negative Cable) FRLSOH	Mtr	200
5	Termination Kit for positive Cables of each type	Nos.	20
6	Lugs suitable for 750 V DC of each type	Nos. each	100
O	SCADA		
1.	Operating Terminal or Work-stations of similar hardware and software configuration as supplied at OCC	Set	1
2.	Printer Cartridge for each type	Nos.	4
3.	Set of LAN Switches consisting one switch of each type as supplied at OCC/BCC	Nos.	1

Sl. no.	DESCRIPTION	Unit	Quantity
4.	Set of redundant LAN Switches consisting two switches of each type as supplied in RTU	Set	4
5.	Hard Disk of capacity 1TB (with USB 3.0 connector)	Nos.	4
6.	Programming software (of each type on CD with License) (One set contains all OCC/RTU software including communication troubleshooting software)	Set	1
7.	Set of power supply unit consisting of one power supply unit of each type	Set	4
8.	Set of Redundant Processor/CPU Module	Set	4
9.	Set of Input / Output Modules (one of each type of installed) and Communication Cards (one of each type of installed)	Set	8
10.	RTU Rack without card	Set	2
11.	RTU Power Supply Module & DC-DC Converter (Each Type)	Nos.	4
12.	RTU Door Lock and Limit Switch	Set	4
13.	Interposing Relay	Nos.	20
14.	Dummy Latch Relay	Nos.	10
15.	Each Type of Patch Cable	Nos.	5
16.	CAT 6 or latest Ethernet Cable (Armoured)	Set	500
17.	FO Cable (FRLS-OH, Armoured)	Mtrs.	500
18.	RTU MCB (of each type)	Mtrs.	4
19.	Fuse of Fuse Terminal Block	Set	400
20.	RTU L/R Selector Switch	Nos.	6
21.	KVM Switch (as supplied in OCC)		1
P	Third Rail		
1	Third rail conductors of suitable length as per TS	Mtr	200
2	Protective cover suitable for 15 mtr length UPVC and GRP along with fittings	Mtr	500
3	Expansion joint assemblies complete with cover and hardware	No.	10
4	Protective Cover for Expansion joint assemblies complete with hardware	No.	30
5	Deleted		
6	High Speed Ramps assemblies complete with cover and hardware	No.	20
7	Protective cover for HSR along with fittings	No.	20
8	Low Speed Ramps assemblies complete with cover and hardware	No.	10
9	Power Feed assembly complete with cover and hardware	No.	20
10	Protective cover for power feed assembly along with fittings	No.	20
11	Support Bracket complete with all accessories e.g. insulators, structure, plastic bearing, clips, nuts, bolts etc.		
a)	Main line (Straight)	No.	20
b)	Main line (Cross over)	No.	20
c)	Main line (Ramp)	No.	20
d)	Depot	No.	20
12	Splice assemblies	Set	50

Sl. no.	DESCRIPTION	Unit	Quantity
13	Huck bolts and collars	No.	300
14	Grease	Kg	20
15	Anchor assembly complete	No.	30
16	Stinger Rail with cover of suitable length as per TS	mtr.	80
17	Catenary indicator lamp assembly for stringer system	Set	15
18	Impact bumper for stringer system	No.	6
19	Stinger splice assembly	Set	2
20	Stinger disconnecter, 3,0 kV, 4,0 kA	Set	2
21	Stinger Power feed	mtr	12
22	Collection trolley	Set	3
23	Stinger pendant Control cables	Mtr	25
24	Stinger Proximity Control cables	Mtr	10
25	Stinger Control pendant	No.	10
26	Stinger Connector (Train end)	No.	10
27	Deleted		
28	Deleted		
29	Stinger control circuit with box	No.	10
30	Stinger Control cables connector male	No.	10
31	Stinger Control cables connector female	No.	10
32	Stinger DC shoes assembly	No.	10
33	Stinger AC shoes assembly	No.	10
34	Stinger Indication Lamp Red	No.	20
35	Stinger Indication Lamp White	No.	20
36	750VDC stinger Contactor	No.	6
37	Stinger power supply control module (PCB)	No	10
Q	Earthing and Bonding		
1	Structure earth cable	Mtr	500
2	Earthing cable 70 sqmm Cu. / 120 sqmm Al.	Mtr	100
3	Lugs of each type suitable for 70 sqmm cables	No.	100
4	PG clamps for Structure Earth Cable of each type	Nos. Each	100
R	Wayside Disconnectors		
1	Motorized way side Disconnector 1-pole and 2-pole switch complete unit (one each)	Set	1
2	Motor drive for disconnector	Set	2
3	Deleted		
4	ETS set for mainline (box)	Set	5
5	ETS set for depot (box)	Set	3
6	ETS Lamps	Set	50
7	ETS Push button with cover	Set	30
8	ETS set for main workshop (including sign)	Set	5
S	33kV Gas Insulated Switchgear		
1	Tripping coil assembly	Set	2
2	Closing coil assembly	Set	1
3	Monometer	Set	1
4	Test Plug	Set	1

Sl. no.	DESCRIPTION	Unit	Quantity
5	Voltage Plug	Set	1
6	Low Resistive Monitor	Set	1
7	Termination Kits	Set	2
8	Sema Phore Indicator	Set	1
9	LR Switch (Local/Remote)	Set	1
10	NO Contacts	Set	2
11	NC Contacts	Set	2
12	TCS Relay (Trip Circuit Supervision)	Set	1
13	Over Current Relay	Set	1
14	Pilot Wire Relay	Set	1
15	Earth Fault Relay	Set	1
16	Spring Charge Indication	Set	1
17	Counter Indicator	Set	1
18	I/O Breaker Open indicator	Set	1
19	Manual Open Button	Set	1
20	Close open Button	Set	1
21	Trip neutral close switch	Set	1
22	AC & DC MCB of 4Amps	Set	1
23	Each type of Cards used in each type of numerical relays	Nos.	5 each

9.2.3 Second Sourcing

9.2.3.1 The Contractor shall identify principal and second-source suppliers that can supply the Contract Spares.

9.2.3.2 The Contractor shall ensure that second-source supplier information is maintained up to date up to a period of 10 years after taking over of the whole Works. The Contractor shall provide support to the Engineer to a reasonable extent regarding the second source supplier information throughout the service life of the system.

9.2.3.3 The Contractor shall make the second-source supplier information available to the Engineer later than at the time of taking over of the Works.

9.2.4 Long Lead Times

9.2.4.1 The Contractor shall identify the lead times for all spare parts. Parts with long lead times shall be identified in the spares list.

9.2.5 Routine Change

9.2.5.1 In the event that any item of supply requires to be routinely changed or calibrated, regardless of whether it appears in the spares list or not, it shall be identified to the Engineer together with the routine change interval.

9.2.6 Shelf Life

9.2.6.1 In the event that any of the spares identified have a particular life or storage requirements, this shall be made known to the Engineer with the submission of the spares list, including the necessary action for disposal or storage.

9.3 SPECIAL TOOLS, TESTING AND DIAGNOSTIC EQUIPMENT AND MEASURING INSTRUMENTS

9.3.1 The special tools, testing & diagnostic equipment and measuring instruments are listed in Table 9.2 below. The total quantities mentioned are provisional and bound for quantity variation and to be procured and supplied in stages or in one lot. Contractor shall submit the list of special tools, testing & diagnostic equipment and measuring instruments with makes, technical specifications, test certificates, manuals etc., for Engineer's approval. Engineer shall review the specifications/make and may ask the Contractor to resubmit with different makes of the equipment to meet the requirements.

9.3.2 The descriptions shown below are indicative only. The Contractor should ensure that the tools, equipment and instruments supplied by him are compatible with the equipment being supplied by him under the Contract.

9.3.3 If, however, the Tenderer feels that some more items or more quantities of the items mentioned herein are required for the proper handling and maintenance of the installations, supplied and erected by him, the Tenderer shall, in that case add such items and/or quantities to this list and shall include the amended list in his Tender.

Table 9.2: Special Tools, Equipment and Instruments

Sl no.	DESCRIPTION	Unit	Quantity
A	Machinery and Plant		
1.	Oil Filtration Plant (6000 liters capacity) (working off 415V, 3-phase AC)	nos.	1
B	Meters, Test sets etc.		
1.	Multi-meters, Digital Type with Data Logging with expanded memory, recording upto 10000 events, graphical on-screen display and review, download facility to PC with necessary software and test lead sets (FLUKE Make) (latest model) or equivalent	nos.	2
2.	Multimeter for measurement of Voltage (600VAC/ 1000VDC), Current (10A), Resistance (100 mega-ohms) (FLUKE Make) (latest model) or equivalent	nos.	5
3.	Leakage current clamp meter (0-60A) with resolution of 0.01mA (FLUKE Make) (latest model) or equivalent	nos.	2
4.	Clamp meter with external flexible current probe for measurement upto 1600A, AC (FLUKE Make) (latest model) or equivalent	nos.	2
5.	SF6 Gas Leak Detector with thermal camera (MEGGAR make) (latest model) or equivalent	Nos.	1
5a	Dew point measurement kit	Set	1
5b	One no. rupture disc of all type	Set	1
5c	One no. gas monitor of each type	Set	1
6.	Relay Test Kit - A comprehensive relay test kit for testing electromechanical, static and numerical relays with 6 phase current + 4 phase voltage output, transient recording, harmonic analysis, power quality and trend measurement and recording etc., in complete with accessories with necessary software (Omicron CMC 356 (or latest)	Nos.	1

Sl no.	DESCRIPTION	Unit	Quantity
	or MEGGAR make SMRT410 (or latest) or equivalent)		
7.	Electricians standard toolbox Complete all types of Spanners, Pliers, & Test Kits. (List will be prepared by bidder and approval shall be taken from UPMRCL).	nos.	14
8.	Mechanical tool box essentially containing torque wrenches, spanners screw-drivers, ratchets hammers Set, L end Key sets etc.	nos.	14
9.	3-Phase energy analyzer with activated options for - transient and converter measurements - harmonic analysis - power interference analysis Complete with the necessary software, memory card slot all essential accessories measurement cables, mains power cable, carrying case and operating instructions (FLUKE Make) (latest model) or equivalent	Nos.	1
10.	On-line battery impedance test kit (Meggar make latest model or equivalent)	Nos.	1
11.	Digital Battery Hydrometer suitable for NiMH batteries (SBS make latest model or equivalent)	Nos.	2
12.	Megger 5000 V with downloading facility to PC, 25 feet extension test leads	Nos.	1
13.	Megger 10000 V with downloading facility to PC, 25 feet extension test leads	Nos.	1
14.	Thermal imaging Camera with colour LCD display, range upto 2500C, with expandable memory and PC interface. (Make: FLIR/FLUKE/MEGGAR make or equivalent)	Nos.	1
15.	Digital clamp earth resistance meter (MEGGAR or equivalent)	Nos.	1
16.	Handy kit for substation having high accuracy digital Multimeter, continuity tester, wire stripper & cutter, Banana clips for shorting CT secondary, soldering iron etc.	Nos.	4
17.	High Voltage detector portable type suitable upto 132kV installation and able to sense presence of HT from a distance of approx. 2 meter	Nos.	2
18.	High Voltage cable testing adapter in 132kV GIS	Nos.	1
19.	Hand crimping tool (for cable below 10 sq. mm with dies)	Nos.	4
20.	Digital Vernier Calliper (MITU TOYO or equivalent)	Nos.	4
21.	Digital Screw Gauge (MITU TOYO or equivalent)	Nos.	4
22.	High Pressure Water Jet Washer (BOSCH or equivalent)	Nos.	4
23.	Discharge rods (Earthing Rods) for RSS bus bars (for 132kV)	Nos.	6
24.	Ratcheting type torque wrench with socket	Nos.	10
25.	Head Torch rechargeable working more than 17 hours	Nos.	10
26.	Binocular	Nos.	1

Sl no.	DESCRIPTION	Unit	Quantity
27.	Electric crimping tools (for cables 10 sq. mm and above with dies suiting different size of cables used in the RSS)	Nos.	2
28.	Cordless Impact Wrench (DEWALT model No. DCF880M2 (or latest) or equivalent)	Nos.	2
29.	Cordless Drill Drive (DEWALT model No. DCD785M2(or latest) or equivalent)	Nos.	4
30.	DC current Injector	Nos.	1
31.	DC Voltage injector	Nos.	1
32.	OTDR	Nos.	1
33.	Portable welding machine	Nos.	1
34.	Digital heavy duty weighing machine	Nos.	1
35.	Conductance tester	Nos.	1
36.	Hydraulic bottle jack	Nos.	2
37.	Wooden key box	Nos.	4
38.	Table	Nos.	12
39.	Godrej Store well Plain	Nos.	14
40.	Godrej 4 Drawers Vertical Filing Cabinet	Nos.	6
41.	Godrej 4 Drawers Bookcase	Nos.	6
42.	Godrej Glass door almirah	Nos.	6
43.	Chair Executive Medium Back	Nos.	16
44.	Lockers 6 doors	Nos.	2
45.	Lockers 10 doors	Nos.	2
C	Tools and Devices		
1.	Digital thermometers (upto 120°C)	nos.	4
D	Others		
1.	Helmets	nos.	30
2.	Safety harness	nos.	10
3.	Flood light fittings to work off 230V, Single phase AC, 200W, LED type	nos.	4
4.	Laptop (512 GB SSD, 16GB RAM of latest configuration) with necessary cables and preloaded software	Nos.	2
E	Tools		
1.	Hydraulic crimping tool for Cables from size 10 mm ² to 400 mm ² including dies of all sizes	Nos.	1
2.	Cordless Electric crimping tool for Cables from size 10 mm ² to 400 mm ² including dies of all sizes	Nos.	2
3.	Cordless Electric cutting tool for Cables from size 10 mm ² to 400 mm ² including dies of all sizes	Nos.	2
4.	Hand crimping tool for Cables from size 1.5 mm ² to 6 mm ² suitable for Insulated and non-insulated Ring, Pin, Banana lugs.	Nos. each	2
5.	Electricians standard tool box complete all types of insulated screw driver set, insulated pliers (Combination, Nose), Heavy duty Tester.	Nos	3

Sl no.	DESCRIPTION	Unit	Quantity
6.	Mechanical tool box essentially containing Digital torque wrenches – 5Nm to 90Nm with ½ inch square male adapter, ½ in female adapter socket of range 6 to 32 Metric size, spanners of size 6 to 32 metric Size double ended ring and Open end, screw drivers set, ratchets with ½ inch square male adapter with quick release including ½ in female adapter socket of range 6 to 32 Metric size. hammers set (Ball pein, Sledge, Claw) , Allen keys set (T type 1 mm to 20mm), feeler Gauge of all sizes, Torx set (T handle T5 to T40 size), Vice grip, C Clamp.	Nos	5
7.	Sound meters / decibel meter	Nos	1
8.	Portable electric blowers	Nos	5
9.	Battery Operated Impact Wrench with ½ inch male adapter 180Nm with 4Ah battery Along with ½ inch female adapter impact socket of range 6 to 28 Metric size and 6mm to 18mm Allen bits.	Nos.	5
10.	Battery Operated Impact Driver ¼ inch internal hexagon 100Nm	Nos.	5
11.	Soldering iron (25 W)	Nos.	2
12.	Soldering workstation (temperature regulated) and solder wires	Nos.	2
13.	Battery Operated Hand portable drill machine up to 16mm with drill bits	Nos.	6
14.	Battery Operated Hand portable Hammer drill machine up to 13mm on masonry with titanium drill bits	Nos.	2
15.	Digital Vernier Caliper up to 300mm	Nos.	2
16.	Battery operated Angle grinder for steel	Nos.	4
17.	Battery operated Torque wrench (torque settable) with spike screw dye up to 200Nm	Nos.	2
18.	Torch (Head mounted) made of ABS plastic, IP6x ingress protection, fall proof for 3mts.	Nos.	30
19.	Laser distance meter (100mtr)	Nos.	5
20.	Chain pulley block	Nos.	2
21.	Bench wise	Nos.	4
22.	Hydraulic Jack	Nos.	4
23.	Huck Bolt Machine (1 phase)	Nos.	1
F	Instruments		
1.	500/1000/2500/5000 V megger – Rechargeable Battery operated with 15mts Probe Megger MIT 515 or equivalent	Nos.	5
2.	High precision RMS Multimeter with following measurement function: Voltage– AC & DC Current - AC & DC Resistance & Continuity Diode Check	Nos.	5

Sl no.	DESCRIPTION	Unit	Quantity
3.	Basic RMS Multimeter with following measurement function: Voltage – AC & DC Current - AC & DC Resistance & Continuity Diode Check	Nos.	10
4.	Automated BDV test kit with calibrator 0 – 100kV with all accessories conforming to IEC and Safety standards Megger OTS100AF(or latest) or Equivalent	Nos.	2
5.	CT / PT analyzer kit with data logging facility Megger MVCT or equivalent	Nos.	1
6.	Contact resistance Meter, 600A Megger DLRO600(or latest) or Equivalent	Nos.	1
7.	Earth resistance tester with all accessories and probe open alarm. Megger DET4TC2(or latest) or Equivalent	Nos.	2
8.	Variac, Three phase 415V AC, 2A	Nos.	2
9.	33kV Voltage Detector	Nos.	4
10.	750VDC Voltage Detector	Nos.	16
11.	33kV Discharge Rod	Nos.	6
12.	Infrared remote temperature sensor (M/s Bosch or equivalent)	Nos.	4
13.	Digital thermometer with temperature probe	Nos.	2
14.	Clamp on meter for AC and DC upto 1600A AC /1000A DC with detachable remote display (M/s Fluke or equivalent)	No.	2
15.	Current Clamp Meter AC 0.01mA to 60A with WiFi	Nos.	2
16.	mA DC clamp meter 0 to 24mADC	Nos.	2
17.	Process Calibrator with 0 to 20mADC source and 0 to 10VDC source. Fluke 726 or Equivalent	Nos.	2
18.	110VDC 2A industrial grade variable Power supply with 230VAC input	Nos.	2
19.	DC Power Supply, Output; 0-30 V DC , 0-30 A DC Input : 230 VAC (Powertron) Model No. 3030DCPST or latest	Nos.	1
20.	DC Voltage and current source with arbitrary waveform generation capability Keysight B2962A (or latest) or Equivalent	Nos.	1
21.	Remote Area lighting System 24000 lumens with integrated battery.	No.	2
22.	Cutting saw mounted on a dismountable table with vice	No.	2
23.	Third Rail cutting saw mountable on third rail	No.	2
24.	Set of Calibrated torque wrenches for third rail installation (ratchet type)	Set	2
25.	Set of files assorted flat and round with wooden handles	Set	2
26.	Measuring tapes, steel and fibre glass – 10 meters, 30 meters, 100 meters	Set	3
27.	Brass copper or stainless steel wire brushes	Set	10
28.	Rubber mallet or dead blow hammer	Set	6
29.	Spirit level (magnetic)	Set	6

Sl no.	DESCRIPTION	Unit	Quantity
30.	Portative saw suitable for GRP and UPVC plastic cutting (Jig saw)	Set	3
31.	Complete set for Huck Bolts equipment including nose assembly, hydraulic tools, powering and hose set	Set	2
32.	Set of manufacturer recommended special tools for installation and maintenance of third rail and stringer system essentially including as a minimum rail end drill jig, power feed rail drill jig, midpoint anchor rail drill jig, rail setting gauge, rail track gauge, power feed cutting mask, structure gauge, ramp cover cutting jig	Set	2
33.	OFC Splicing Kit battery operated with loss assessment	No.	1
34.	Partial Discharge Camera	No.	1
35.	Battery discharging kit	No.	1
36.	Snap ON Power tool	No.	1
37.	Power Quality Meter	No.	1
38.	Time Interval Kit	No.	1
39.	Tan delta and capacitance measurement kit	No.	1
40.	Specific Gravity battery tester for Battery bank (digital)	No.	1
41.	Battery Analyzer Fluke 500 or equivalent	No.	1
42.	Electric Motorized Trolley for material movement (speed up to 25 kmph)	No.	1
G	COMPUTER AND PERIPHERALS		
1.	Maintenance Laptop (16GB RAM, 1 TB HDD, 13"/15" screen, Serial RS232 comm. port) installed with all maintenance & troubleshooting software with license (For SCADA) latest version	Nos.	2
2.	Printer with Scanner (Laser Colour A4 and A3)	Nos.	1
3.	Printer with scanner (Laser type, monochrome, A4)	Nos.	1
4.	DC simulation software tool	Nos.	1
H	Maintenance Tools for SCADA		
1.	Maintenance Laptop (24GB RAM, 1 TB HDD, 13"/15" screen, Serial RS232 comm. port) installed with all maintenance & troubleshooting software with license (For SCADA) latest version	Nos.	2
2.	LAN Tester	Nos.	2
3.	Modbus (RS232/RS422/RS485 Serial to USB) Converter	Nos.	2
4.	Each type of Interface cable required between RTU & Server for troubleshooting/ downloading data from Laptop (USB type)	Nos.	2

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CHAPTER - 10

TRAINING AND TRANSFER OF KNOWLEDGE

10.1 GENERAL REQUIREMENTS

- 10.1.1 The Contractor shall provide comprehensive training to the Employer's staff in accordance with the requirements contained in Clause 10 of GS, operation & maintenance support envisaged in Chapter-8 of TS and elsewhere in the tender document.
- 10.1.2 The training shall be carried out at such locations where the greatest benefit for trainees may be gained. This may be in India, abroad, at place of manufacture, assembly or testing, other functional metro rail systems or at such other locations as may be necessary. All places of training shall be subject to review by Engineer.
- 10.1.3 The training shall be aimed towards developing the capabilities of the Employer's staff and instructors for smooth functioning of the system.
- 10.1.4 The training courses and/or sessions shall include system performance requirements and all major equipment and works designed, by the Contractor.
- 10.1.5 The specific objectives of each course, training facilities to be used, the qualification and experience of the training instructors and the assessment criteria shall be developed by the Contractor and submitted to Engineer for review at least three months before any course is conducted.
- 10.1.6 Manuals to be used for training, including the manuals to the instructors and trainees, shall be delivered to the Engineer at least six months before the issue of the Substantial Completion Certificate for the Works, as required under Chapter 10 of GS. The training manuals shall be submitted in original plus five hard copies and in electronic editable format in Pendrive/HDD/SSD.
- 10.1.7 The Contractor shall provide full-time on-Site management and co-ordination of the entire training programme to ensure the continuity of classes, and proper distribution of training materials, and be responsible for interfacing with the instructors.
- 10.1.8 The training courses shall be delivered to all relevant Employers' staff, including instructors, operation and maintenance engineering staff.
- 10.1.9 The proposed training requirements are given at the end of this chapter.

10.2 TRAINING PLAN AND MANUALS

- 10.2.1 The Contractor shall submit a comprehensive Training Plan in accordance with the requirements of the General Specification. In addition, the Training Plan shall include the following:
- Details of the Contractor's ability to carry out the necessary training;
 - Details of the proposed approach to structuring and providing the courses required;
 - Identification of topics on which trainings shall be imparted;

- d. Course details for each topic along with duration of course, proposed place of training, number of trainees, ratio of trainees to trainers, facilities required or available and prerequisites for attending the course;
- e. Proposal for the instructors along with specialization details
- f. Assessment criterion to assess the usefulness of training
- g. Recommendation and proposal for additional training or alternative means by which the Employer's training objectives may be met.

10.2.2 The Training Plan shall be submitted for review by the Engineer and shall be implemented in a timeframe such that complete and comprehensive training has been received by the designated Employer's staff prior to the System Acceptance tests.

10.2.3 During the course of training, the Contractor shall handover training material to all relevant Employers' staff, including instructors and operation & maintenance engineering staff.

10.3 TRAINING FORMAT

10.3.1 The training shall be structured in modular format; each module shall be capable of being delivered independently or together with other modules of a similar these.

10.3.2 The Contractor shall make full and appropriate use of multi-media and computer techniques in the design and delivery of training packages.

10.3.3 The Contractor shall provide a training plan which shall include as a minimum:

- a. Schedule of training course;
- b. Objectives;
- c. Syllabus;
- d. Format of course;
- e. Training facilities required or to be provided;
- f. List of training materials and documentation;
- g. Examination procedures;
- h. Employer's Training Instructors' qualifications
- i. Course evaluation methods

10.3.4 The Contractor shall provide all training material required to deliver the requirements of this Chapter. The material shall include as a minimum:

- a. Course agenda
- b. Objectives
- c. Lesson plans
- d. Mock-Up Equipments
- e. General requirements
- f. Outline presentations
- g. Training aids; and
- h. Computer based training requirements

10.4 MOCK-UP EQUIPMENTS

- 10.4.1 The Contractor shall install mock-up equipments for the installed system and any such facilities considered necessary for the training of Employers' staff in the training school or at a place as advised by the Engineer.
- 10.4.2 Mock-up equipments shall include but not limited to the following:
- CClear cut section drawings / photographs of the major equipments e.g. Circuit Breaker, Transformer, Third Rail Conductor, Current Transformer, Potential Transformer, Isolator, Lightning Arrestor, Cables, Rectifier, inverter, SCD, Stinger, ETS, Rectifier Transformer, protection relays, battery and battery chargers etc.
 - Cut section drawings / photographs of MV and DC cables
 - Clear photographs of transformers, their windings, bushings etc.,
 - Third Rail system components, including insulator supports and the samples of various clamps and fittings used in the third rail and stinger system
 - Traction Power Feed assembly, its termination and cable connection to conductor rail.
 - Samples of various clamps and fitting used;
 - Control panel, protection schemes, earthing and bonding arrangement;
 - Stray dc current Corrosion Prevention equipment
 - Clear drawings and photographs of SLD, Control panel, protection schemes, earthing & bonding arrangement, stray current protection scheme etc.
- 10.4.3 The Contractor shall also install laminated boards of SLDs, protection schemes, earthing and bonding arrangements.
- 10.4.4 The Contractor shall submit full details of the training span and other mockup equipment, photographs etc. including proposed training activities and objectives, for the Engineer's review in accordance with Clause 10.1 of this Specifications.
- 10.4.5 CV of Contractor Training Instructor (CTI) shall be submitted by Contractor for prior approval of Employer.

10.5 TRAINING

- 10.5.1 There shall be three categories of trainees as follows:
- Employer's Training Instructor (ETI)
 - Operating staff & Maintenance staff
- 10.5.2 The Contractor shall design separate training modules for each class of trainees. Separate training materials shall be developed. Each module shall focus on developing specialized capabilities in the trainees according to the functional requirements of the trainees.
- 10.5.3 Training shall be a combination of classroom training, mockup training, onsite training, training at manufacturer works and training at specialized training centers.
- 10.5.4 **Employer's Training Instructor**
- 10.5.4.1 The objective of the training is to enable the Employer's Training Instructors (ETI) to be competent and capable to deliver future training courses for other employees of the Employer.

10.5.4.2 The Contractor shall provide training to the ETIs on the various systems and the training shall essentially include, but not be limited to:

- a. Entire system configuration including interface with the supply system at the feeding points;
- b. Feature and functional principles of the entire system;
- c. System design aspects including but not limited to design standards, design criteria and parameters, short-circuit and other calculations, insulation and protection coordination;
- d. Details of major equipment and material including but not limited to 33 kV switchgears, 33 kV cables, DC switchgears, DC cables, third rail, stinger system, fittings, assemblies, protection relays etc.
- e. System operation and maintenance management and procedures;
- f. Earthing, bonding and stray current protection system duly covering safety aspects of touch and step potential, safety to personnel, passengers and outsiders;
- g. SCADA system

10.5.5 **Operating and Maintenance Staff**

10.5.5.1 The objective of the training is to enable the Employer's operations and maintenance staff to be familiar with the Systems, with focus on the operational and maintenance aspects under normal and emergency conditions.

10.5.5.2 The training shall also enable the trainee to acquire full capability for identification, trouble shooting and rectification of faults in the specified duration. After classroom training which includes mockups of equipment, the staff shall be trained in actual operation.

10.5.5.3 The training shall include but not be limited to:

- a. Full understanding of all the equipment, sub-systems and system, their function, maintenance and overall requirements;
- b. Procedures to be followed for unscheduled maintenance and repair;
- c. Identification of failed components and sub-systems in electronic equipment by use of special test kit as necessary;
- d. Modification in the software to extend or modify the control, monitoring and protection functions.

10.6 **COMPUTER BASED TRAINING (CBT)**

10.6.1 The Contractor shall submit, for the Employer's review, the following CBT information documents:

- a. Operation of the Receiving, Traction and Auxiliary Power Systems;
- b. Maintenance of Receiving, Traction and Auxiliary Power Systems;
- c. Operation of the SCADA System
- d. Maintenance of SCADA System

10.6.2 The CBT Information Document on operation of individual system shall contain, but not be limited to, the following:

- a. General introduction of the System, its functionality and objectives (including the RAMS requirement);
- b. Single line diagrams;
- c. Description of the System operation principles, for both normal and emergency operation conditions;
- d. An overview on the System configuration, including interface with other agencies;
- e. General description of the functions of each key equipment and components of the System with photographs showing the appearance of each of them;
- f. Where they are located throughout the MRTS, Lucknow;
- g. List of potential hazards that may arise in operating the System; and
- h. Any specific points to note in operating the System to ensure safety to personnel (the Employer's staff and members of the public) and equipment;
- i. Electric shock treatment

10.6.3 The CBT Information Document on Maintenance of individual system shall contain, but not limited to following:

- a. General description of the functions of key components of the System, with photographs showing the appearance of each of them;
- b. A general description of the proposed maintenance strategy of the System and major components;
- c. The maintenance plan and procedures proposed for the System and major components in accordance with the manufacturer recommendation;
- d. A general description of the 1st, 2nd and 3rd maintenance activities required for the System and major components;
- e. An introduction to the special tools and equipment required for maintaining the System and major components;
- f. A description of the symptoms of the common faults found on the System;
- g. Simulation of faults on the entire System, and how to promptly restore the system; and
- h. Other points to be noted in effectively maintaining the System

10.7 TRAINING REQUIREMENTS

10.7.1 Training shall be imparted in India and abroad as per the details given below. The following may be noted:

- a. The man weeks defined below for Training in India are for the Contractor's Training Instructor
- b. The man weeks defined below for Training Abroad are for the Employer's Training Instructor/Personnel.

10.7.2 Man-weeks of contractor's Training Instructors for training Employer's maintenance personnel in India.

Table 10.1: Contractor's Training Instructors Man-week for O & M staff

SN	Training	Man-weeks
1	Third Rail and all accessories	2
2	DC systems (Switchgear, OVPD, SCD, DS & LBS)	3

SN	Training	Man-weeks
3	Stinger System & Shore Supply	1
4	33kV AIS	1
5	33kV GIS	1
7	SCADA	2
8	SCMS	1
9	Transformers (Auxiliary & Rectifier)	3
10	Rectifier	1
11	Electrical Safety, Earthing & Bonding and Stray current protection	2
12	Protection relaying and coordination	2
13	Interlocking & Protection	1
14	Other systems (to be decided by Engineer like , HV and DC Cables)	2
15	Troubleshooting	1
16	Special Tools	1

10.7.3 Man-weeks of Employer's Instructor/Personnel for offshore training:

Table 10.2: Employer's Instructor/Personnel Man-week for offshore training

SN	Training	Personnel	Man-weeks
1	750 V DC System includes Rectifier, Negative Return Panel, HSCB, OVPD, Protection relaying, track insulation & Stray Current Monitoring System, communication of IEDs with SCADA etc.,	As decided by Lucknow Metro officials	4
2	Third Rail, Stinger and its components		2
3	Other systems (to be decided by the Engineer)		4

10.7.4 The training of Employer's maintenance and operation staff shall be arranged at functioning metro systems and / or at manufacturers' works.

10.7.5 The training requirements as quantified under Clauses 10.7.2 to 10.7.3 are indicative only and Engineer's approval shall be required to be obtained prior to the actual training for the training program, the place of training and subsystems for which training is to be arranged.

10.7.6 Employer shall provide classrooms at suitable location at free of cost.

10.8 TRANSFER OF KNOWLEDGE

10.8.1 Tenderer shall submit the detailed plan of transfer of knowledge for the use Technology (ToT).

10.8.2 ToT shall include system assembly, installation, maintenance and software modification / customization and training of Employer's personnel to cover the systems/ subsystems:

- a. 3rd Rail
- b. SCADA System

- c. DPCS including PCUs
 - d. Traction Power Supply equipment
 - e. Stray Current Monitoring System
 - f. Earthing Bonding system and rail touch potential regulation
- 10.8.3 ToT shall essentially include the following aspects as a minimum:
- a. Engineering or extensions and up gradations of the System
 - b. Re-engineering to suit changed traffic conditions
 - c. Incorporation of optional facilities
 - d. Addition / Modifications to depot yards
 - e. Change in parameters of Rolling Stock
 - f. Any other configuration / programme required for maintenance / up gradation of hardware software.
- 10.8.4 The Transfer of Technology shall require involvement of Employer's personnel in each of Sub-systems during the Contract period. The sponsored engineers shall be under the technical administrative control of the Contractor. It is tentatively proposed to deploy 2 No. Employer's personnel for this purpose.
- 10.8.5 The Contractor shall undertake to supply or make arrangement with the original manufacture supply additional equipment required for replacement or expansion of the network in future.
- 10.8.6 The Contractor shall undertake to provide, if required during the life of the equipment ordered, technical assistance in the form of additional drawings, maintenance practices and technical advice.

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CHAPTER – 12

33 kV RSS/AMS

12.1 GENERAL

The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in Chapter-2 along with clause wise compliance and suggest similar or better design for the approval of Employer.

12.1.1 RSS/AMS TYPE

12.1.1.1 The East West Corridor of Lucknow Metro Rail will have one 33 kV Receiving Substations/Auxiliary Main Substation, viz. Vasantkunj shall be Air Insulated Switchgear type substation.

12.1.1.2 The above RSS/AMS shall have similar schematic and the arrangement as defined below.

12.1.1.3 The subsequent sections contain the technical specifications and requirements for individual equipment to be installed in the RSS/AMS.

12.1.1.4 RSS/AMS SCHEMATIC AND DESIGN LAYOUT

12.1.1.4.1 The RSS room shall have two incoming 33 kV bays, four outgoing feeder bays (1 for each circuit of ring main (with Line PT).& 1 for each circuit for Depot ASS/TSS (with Line PT)) and two bus PT and two identical spare outgoing feeder along with space provision for two additional feeder and one bus coupling bay. The 33kV RSS/AMS shall have 33kV switchgears for distributing power further to auxiliary and traction networks.

12.1.1.5 The equipment shall be installed according to the group phase layout, whereby the three phases of each circuit are installed side-by-side and advance function-by-function.

12.1.1.6 The architectural configuration of the receiving substation shall be as compact as possible with clear and logical layout of the busbar, facilitating, in addition, accessibility to all actuating devices and possible extensions to accommodate equipment to be installed subsequently.

12.1.1.7 The supply shall include all supporting structures, embedded parts, auxiliary equipment, mechanical linkages, , auxiliary circuits wiring, interlocking devices, current and voltage transformers, cable end boxes necessary for their efficient operation. All such parts and accessories shall be deemed to be within the scope of this Specification whether specifically mentioned or not.

12.1.1.8 The proposed substation layouts are enclosed. Typical layout of RSS/AMS & Control room building for RSS are shown in tender drawing. The Contractor is at liberty to optimize the layout, if considered necessary, without compromising the electrical clearance, accessibility to equipment inside the RSS/AMS, safety requirements and provisions for future, if any. The layout shall be subject to approval by the Employer and shall not have any functional implications.

12.1.1.9 The means of access to the various equipment for the maintenance staff shall be safe. The maintenance personnel shall have access to and shall be capable of moving freely around each element in the cubicles.

12.1.1.10 Deleted

12.1.1.11 The arrangement for the protection, control, monitoring and logging of important parameters shall be provided in common control room of RSS in addition to at OCC/BCC. The protection and control monitoring system in RSS/AMS has been defined in Section 12.6 below.

- 12.1.1.12 The earthing system of RSS/AMS shall be constructed in accordance with the stipulations of Section 12.7 below of this Chapter.
- 12.1.1.13 Deleted
- 12.1.1.14 Space provision for spare bay for 33 kV AIS shall be considered.
- 12.1.2 33 kV HIGH VOLTAGE BAYS (RSS)**
- 12.1.2.1 The high voltage bays shall contain:
- a) Two incoming sections equipped with circuit breaker
 - b) One bus coupling section equipped with a circuit breaker
 - c) Four outgoing feeder Bays (1 for each circuit) consisting of; Bus Bar extension links for connection of MV outgoing cables to Vasantkunj ASS or Depot ASS/TSS.
- 12.1.2.2 Incoming Section
- Each incoming bay section shall consist of:
- a) Circuit Breaker (CB-x)
 - b) Current Transformer (CT-x)
 - c) Maintenance Earth Switch (ES-x)
 - d) Voltage Transformer of rated insulation (VT-x)
 - e) Indoor Lightning/Surge Arrestor (LA-x)
 - f) Other items as required for connection to the two bus bars 33 kV incoming cables through lightning arrestor and for completing the intent of work.
- 12.1.2.3 Outgoing Section
- Each outgoing bay section shall consist of:
- g) Circuit Breaker (CB-x)
 - h) Current Transformer (CT-x)
 - i) Maintenance Earth Switch (ES-x)
 - j) Voltage Transformer of rated insulation (VT-x)
 - k) Indoor Lightning/Surge Arrestor (LA-x)
 - l) Other items as required for connection to the two bus bars 33 kV outgoing cables through lightning arrestor and for completing the intent of work.
- 12.1.2.4 Deleted
- 12.1.2.5 Deleted
- 12.1.2.6 Deleted
- 12.1.2.7 Deleted
- 12.1.2.8 Deleted
- 12.1.2.9 Bus-coupler Bay/Section
- The three-phase busbar section shall consist of:
- a) Circuit Breaker (CB-x)
 - b) Current Transformer (CT-x)
 - c) Other items as required for connection to bus bars, cables etc. and for completing

the intent of work

12.1.2.10 Bus VT Module

- a) Voltage Transformer (VT-x)
- b) Other items as required for completing the intent of work.

12.1.2.11 Clearances and creepage paths:

The minimum clearances and creepage paths as per Indian electricity rules, 1956 to be maintained for 33 kV insulation level shall be as follows:

- Minimum distance between phases (IEC 61936-1) 320 mm
- Minimum clearance from the earth (IEC 61936-1) 320 mm

12.1.2.12 The incoming 33 kV cable terminals shall have lightning/surge arrestor. Lightning protection arrangement shall meet the stipulations of IS-2309:2005.

12.1.3 ENVIRONMENTAL DATA

12.1.3.1 The environmental and climatic conditions prevailing in Lucknow are defined in the General Specification.

12.1.3.2 All the equipment such as circuit breakers, transformers and accessories, to be supplied against this Specification shall be suitable for satisfactory continuous operation under the above-mentioned environmental conditions.

12.1.4 AUXILIARY CONTACTS

12.1.4.1 Unless other stated, all the relevant 33 kV switchgears shall be provided with auxiliary contacts of adequate rating (5A minimum) and shall be provided in sufficient numbers with about 30% spares.

12.2 33 kV AIS EQUIPMENT SPECIFICATION (For RSS/AMS part, For Depot ASS/TSS part Refer Chapter 14)

12.2.1 SCOPE OF WORK

12.2.1.1 The scope of work comprises of design, manufacture, shop testing, supply, delivery at site, installation, testing and commissioning of 3-phase, 33 kV, 1250 A, 40 kA for 1 sec Air insulated indoor type receiving sub-station. The supply will include all supporting structures, auxiliary equipment, mechanical linkages, auxiliary circuits wiring, interlocking devices, current and voltage transformers, and cable end boxes.. The scope of work includes the following but not limited to:

12.2.1.2 Each Incomer Bay - 2 Nos. consisting of;

- a) Circuit Breaker – 1 No.
- b) Current Transformer – 1 No. (as per SLD)
- c) Maintenance Earth Switch– 1 No.
- d) Voltage Transformer of rated insulation – 1 No.
- e) Indoor Lightning/Surge Arrestor – 1 No.
- f) Other items as required for connection to the two bus bars 33 kV incoming cables through lightning arrestor and for completing the intent of work

12.2.1.3 Outgoing Feeder Bay- 4 No. (1 for each circuit for Ring Main Feeder & 1 for each circuit for Depot ASS/TSS) consisting of

- a) Circuit Breaker – 1 No.
- b) Current Transformer – 1 No. (as per SLD)

- c) Maintenance Earth Switch– 1 No.
- d) Voltage Transformer of rated insulation – 1 No.
- e) Indoor Lightning/Surge Arrestor – 1 No.
- g) Other items as required for connection to the two bus bars 33 kV incoming cables through lightning arrestor and for completing the intent of work
- 12.2.1.4 Deleted
- 12.2.1.5 Deleted
- 12.2.1.6 Deleted.
- 12.2.1.7 Deleted.
- 12.2.1.8 Deleted.
- 12.2.1.9 Deleted
- 12.2.1.10 Each Bus Coupler Bay- 1 No. consisting of;
 - a) Circuit Breaker – 1 No.
 - b) Current Transformer – 2 Nos.
 - c) Other items as required for connection to bus bars, cables etc. and for completing the intent of work
- 12.2.1.11 Each Bus VT Module - 2 Nos. consisting of;
 - a) Voltage Transformer with manual isolating link – 1 No.
 - b) Other items as required for completing the intent of work
- 12.2.1.12 Deleted.
- 12.2.1.12.1 Deleted .
- 12.2.1.12.2 Deleted.
- 12.2.1.12.3 Design, Supply, erection, testing and commissioning of all items of work required to make the MV bays (33 kV) fully functional.
- 12.2.1.13 Main Feature required
- 12.2.1.13.1 The 33 kV equipment shall be built according to the air insulation technology.
- 12.2.1.13.2 33 kV AIS as offered should be fully type tested as per latest IEC standards at the time of submitting the vendor approval. The bidder would be required to submit the detailed type test reports as per latest IEC standards from authorized test labs which are NABL accredited or equivalent.
- 12.2.1.13.3 The equipment installed shall offer all necessary facilities for equipping and connecting the equipment sections to follow, without entailing any shut down of equipment already in service.
- 12.2.1.13.4 In the event of arching in a compartment, the arches should not extend to the neighbouring compartment. Any failure to the enclosure of the compartment shall not lead to damages in the neighbouring compartments. In view of this, continuous busbar without air segregation is preferably not acceptable. However, any alternative proven design without air segregation conforming to international standards and if the requirements of service continuity concept as per IEC 62271-203 can be met, such designs shall also be acceptable during detailed engineering stage. In this regard the decision of Employer is final and binding
- 12.2.1.13.5 Deleted
- 12.2.1.13.6 Deleted
- 12.2.1.13.7 Deleted

- 12.2.1.13.8 AIS should be of modular design, and it should be possible to add feeder bays for additional bays , if required. The layout of AIS equipment should show space earmarked for the future provision.
- 12.2.1.13.9 The incoming 3 phase 33 kV three core double cable feeders in each circuit shall be of minimum size of 300 sq.mm Aluminium and shall be verified by the contractor. The termination arrangement shall however be designed for two such cables, so that additional cables can be terminated later, if required. The outgoing connections from AIS shall be in enclosure, designed in such a way that vibration from AIS equipment are not transmitted to each other..
- 12.2.1.13.10 The earthing switches shall be electrically and mechanically interlocked against mal-operation. Feeder earthing switch shall be isolated from earthed enclosures and shall permit testing of switchgear. It shall also be possible to carryout high voltage testing of cable cores without having to open the breaker assembly without disconnecting the cables. Suitable adapter for such testing should be provided. This adapter is to be quoted as a separate item in List of tools. The installation of the same shall be demonstrated at site. For other routine maintenance also, dismantling of switchgear should be required.
- 12.2.1.13.11 Conductors/Busbars shall be made of Copper/Aluminium alloy, suitable for the specified voltage and current ratings. The electrical connections between the various sections shall be made by means of multiple contact connectors (plug-in type) so that electrical connection is automatically achieved when fixing one section to another. Field welding of the conductor is not acceptable. The surface of the contacts shall be silver-plated.
- 12.2.1.13.12 Deleted
- 12.2.1.13.13 Deleted
- 12.2.1.13.14 Deleted
- 12.2.1.13.15 Adequate burden capacity shall be available in instrument transformers to permit provision of additional test, protection on measuring instruments. The instrument transformer shall have separate metering cores to permit measurement of values of energy, power, current and voltage as per required accuracy, giving due consideration to the fact that load during initial stages may be much lower than designed capacity. The instruments shall also be sized and positioned so that a 5'-5'6" height operator can read the instrument without additional support. CT cores will be as per SLD.
- 12.2.1.13.16 Clear visual indication of earthing switch, switch blade position, whether open or closed shall be provided.
- 12.2.1.13.17 Each component shall be modular and complete with ancillary equipment.
- 12.2.1.13.18 . The Operating Mechanism for the circuit breaker shall be Spring/Spring or to give highest reliability to the system, following loss of supply voltage the operating mechanism shall have local storage sufficiency for a duty cycle of O –0.3 sec CO–3 min-CO without the need for recharging. The circuit breakers shall be provided with an “anti-hunting” coil for all commands going to the switchgear. All interlock and automatic systems within the actuation system shall be designed so that the circuit breaker executes operations only when it is in a position enabling to do so completely and reliably. During detailed engineering stage, considering the reliability of operation and the overall compactness of the AIS, Contractor may propose any alternative proven design of AIS CB Compartment for Engineers approval. In this regard the decision of Employer is final and binding.
- 12.2.1.13.19 Deleted
- 12.2.1.13.20 In case of any internal arc fault – regardless whether it occurs in a bus bar section, or the circuit breaker- repair works should be possible without shutting down the substation; at least one busbar and the undisturbed feeder should remain in operation. It should be possible to remove and replace a fully assembled circuit breaker without interfering the operation of the adjacent feeder. All circuit breakers should be interchangeable.

- 12.2.1.13.21 The AIS equipment shall be arranged in such a manner that in case of maintenance work on any of the equipment, at least one bus bar should be available for operation.
- 12.2.1.13.22 Deleted
- 12.2.1.13.23 The Local Control Cubicles shall be integrated with the AIS and should house IEC 61850 compliant Bay Control Unit (BCU) which should be SCADA compatible. Free standing LCC with conventional system for monitoring and indication shall not be accepted.
- 12.2.1.13.24 Deleted
- 12.2.1.13.25 Deleted
- 12.2.1.13.26 Deleted
- 12.2.1.13.27 The inter bay width shall be sufficient to allow access to all drive mechanisms and other termination boxes without the need of dismantling other apparatuses.
- 12.2.1.13.28 The design of the cable termination shall allow plugging and unplugging the HV cable without need of opening the AIS .
- 12.2.1.14 STANDARD SPECIFICATIONS
- The switchgear conforms to the following IEC standards:
- 12.2.1.14.1 SWITCHGEAR, GENERAL:
- IEC 62271-1 (Latest): High-voltage switchgear and control gear Part 1: Common specifications
- IEC: 62271-103-latest: Switches for rated voltages above 1 kV up to and including 52 kV
- IEC 60028-latest: International standard of resistance for copper
- IEC: 62271-200-latest: AC metal-enclosed switchgear and control gear for rated voltage above 1 kV and up to and including 52 kV
- IEC 62271-100-latest: High-voltage switchgear and control gear Part 100: Alternating-current circuit-breakers
- IEC 62271-101(Latest): High-voltage switchgear and control gear Part 101: Synthetic testing
- IEC 62271-102-latest: High-voltage switchgear and control gear Part 102: Alternating-current dis connectors and earthing switches
- IEC 61000(Latest): Electromagnetic compatibility (EMC) IEC 60060 High voltage test techniques
- IEC 60255(Latest): Electrical relays
- IEC 60529(Latest) : Degrees of protection provided by enclosures (IP Code)
- IEC 60815(Latest): Guide for the selection of insulators in respect of polluted conditions
- IEC 61869-1,2,3(Latest): Instrument transformers
- IEC 60364 / 60479 / IEEE std. 80 Standards for station grounding
- CENELEC/SVDB Pressure vessel codes.

12.2.1.14.2 Deleted

12.2.1.14.3 Deleted

12.2.1.14.4 LOCAL CONTROL CUBICLES:

IEC 61439 -1(Latest): Low-voltage switchgear and control gear assemblies Part 1: General rules.

IEC 62271-1(Latest): High-voltage switchgear and control gear Part 1: Common specifications for alternating current switchgear and control gear.

12.2.1.14.5 ENCLOSURE

CENELEC standard or other equivalent mentioned above

12.2.1.14.6 MODULAR DESIGN

The manufacturing and testing of the housings are state-of-the-art technology. Each housing is subject to compliance with the requirements of the relevant CENELEC or equivalent standard.

Paint Shade

Paint Shade: Indoor RAL 7038 (Agate grey)/ RAL 7035 (Light grey)

Outdoor RAL 9010 (Pure white)

12.2.1.14.7 Deleted

12.3 33 kV AIR INSULATED SWITCHGEAR at RSS/AMS**12.3.1 GENERAL SPECIFICATION**

12.3.1.1 The intent of this specification is to provide the work enumerated to be fully complete in every detail for the function designated. It is hereby required that the BIDDER, in accepting the contract, agrees to furnish all apparatus, appliances, material not herein specifically mentioned or included, but which may be found necessary to complete, perfect or test any portion of the apparatus or equipment herein specified in a substantial manner, and in compliance with the requirements implied in this specification and without extra cost to the PURCHASER/OWNER. The AIS manufacturer must have (1) manufacturing facility and prompt after sale service support in India as on date of bid (2) having HV 703 testing kit & (3) provide supporting documents for the same.

12.3.1.2 AIS supplier should have minimum 5 years' experience in design and manufacturing of similar AIS.

12.3.2 ELECTRICAL RATINGS:

The AIS equipment shall be provided with one enclosure per phase for all gas compartments. The apparatus shall have the following basic electrical and design characteristics:

Table 12.1: AIS Equipment Rating

Sl. No	Description	Unit	RATING
i)	Phase design		3-ph
ii)	Rated voltage	kV	33
	Rated lightning impulse withstand voltage (peak)	kV	Across open contacts

		Phase to earth Across open contacts		170
		Power frequency 1 minute (r.m.s.) Phase to earth Across open contacts	kV	70
	B			
iii)	Rated frequency		Hz	50
iv)	Rated current (bus bars) [At 40°C]		A	1250A
v)	Rated short-time current (r.m.s) (1s)		kA	40 kA
vi)	Rated making current (peak)		kA	62.5
vii)	Rated short circuit breaking current		kA	25

12.3.3 EQUIPMENT SPECIFICATION

It is understood that each manufacturer has their own particular AIS design concept and it is not the purpose of this specification to impose any unreasonable restrictions. However, in the interest of safety, reliability and maintainability, the switchgear offered shall meet the following minimum requirements stipulated herein.

12.3.3.1 General

12.3.3.1.1 The switchgear shall be constructed as per the relevant standards and specifications. The switchgear shall conform to the requirements of service conditions.

12.3.3.1.2 Each cubicle will be metal clad type, air insulated, made of:

- a) Bus bar compartment
- b) Cable end compartment
- c) Low voltage (measurement, protection & monitoring) compartment
- d) Equipment connector compartment with shutter/breaker compartment

12.3.3.1.3 Compartments shall be physically separated from each other by metal partitions, confirming to PM (Partition Metallic) class and Loss of Service Continuity (LSC) of 2B as per IEC 62271-200, which shall not heat up due to induced magnetic fields.

12.3.3.1.4 All panels, separating partitions and accessories shall be mounted similarly, in such a way so as to withstand indefinitely the vibrations transmitted, in particular by the resetting mechanism of the circuit breakers and their actuation.

12.3.3.1.5 All non-welded assemblies shall be assembled by means of bolts and nuts/rivets with mandatory use of lock-washers.

12.3.3.1.6 Internal and external metal partitions shall be connected to the earth; high voltage electrical links are realized with bushing.

12.3.3.1.7 All parts of the cubicle (bus-bars, sliding connector, partition passages) shall be capable of permanently withstanding the temperature rise caused by the currents and shall match the nominal rating of the circuit breaker / interrupter. 33 kV motorised vacuum interrupter shall be compatible and interchangeable with 33 kV vacuum circuit breaker for interoperability.

12.3.3.1.8 Multiple termination points shall be ensured for relay (RJ-45) in order to have required inputs from multiple sources/cables.

12.3.3.2 Switchgear Cubicles

12.3.3.2.1 The cubicles shall be of dust and vermin proof cabinet sheet metal. Structure made of Alu-zinc/GI material to reduce the corrosion effect. However, the GI switchgear cubicle shall be of proven design. Front door & rear cover can be of CRCA sheet with powder coating. All cubicles shall be of same type. All non-welded assemblies shall be assembled by means of bolts and nuts/rivets with mandatory use of lock-washers.

12.3.3.2.2 It is envisaged that the panels shall be designed for all cable entries from the top/bottom for elevated, underground stations & Depot and bottom entry for panels at RSSs.

- 12.3.3.2.3 The auxiliary contacts shall be of adequate rating (5A minimum) and shall be provided in sufficient numbers with about 20% spares, with a minimum of 5 NO and 5 NC. The contractor shall propose designs for approval by the Engineer.
- 12.3.3.2.4 Three display lamps for "voltage on" fed by capacitive dividers and annunciation lamps shall be installed on the front face of the cubicle.
- 12.3.3.2.5 Cubicle Compartments
- The cubicles shall be metal-clad draw out switchgear type, closed by a door forming the facade, equipped with riveted marking plates and single-wire diagrams also fitted with display lamps indicating the presence of 33 kV voltage.
 - The cubicles shall consist of basically two parts viz. fixed and moving parts to facilitate maintenance, replacement or even modification operation with shut down affecting only the involved circuits.
 - The fixed part shall be divided into four compartments - bus bar, trolley receptacle/breaker compartment, cabling compartment and low voltage (protection, monitoring and metering) compartments which are separate by means of barriers/shutters to prevent fault propagation between compartments. The barriers / shutters shall not heat up due to induced magnetic fields action. Moving parts consist of withdrawal trolley on which the circuit breaker shall be mounted. Vacuum Circuit Breaker shall be rated for minimum 100 nos. full short circuit to ascertain the life of Vacuum Circuit Breaker. Tenderer should submit the Type Test Reports for Short Circuit Duty with this breaker.
 - Surge Suppressor shall be implemented in the cubicles as per requirement for suppressing the surges/transients coming in the system.
- 12.3.3.2.6 Seal off bushings shall be provided between breaker compartment to busbar and cable compartment to ensure that no ionized gases from breaker compartment is transmitted to either of these two fixed compartments.
- 12.3.3.2.7 Bus bar Compartments
- Bus bar compartments shall house bus bars. The bus bars shall be of rectangular/tubular cross-section suited to withstand 25kA for 3 sec peak short circuit.
 - Bus bars shall be supported on insulating supports or support less bus bar is also acceptable. Bus bars shall be air insulated and fully voltage sleeved to withstand line to line voltages continuously and the main bus bar joints shall be covered with epoxy or polycarbonate shrouds.
 - Bus bars shall be capable of handling all sorts of temperature rise caused by the current. Temperature rise of various parts of the switchgear shall be within limits as per IEC. All necessary precaution to shield corona discharges shall be taken in the bus bar jointing. The manufacturer/Contractor shall highlight these provisions during detailed engineering stage.
 - Bus bars shall have continuous rating capacity and shall withstand short circuit. All bus bars shall be of copper conforming to the relevant IS/IEC. The bus bars shall be clean smooth, mechanically sound and free from other defects. Provisions shall be made where necessary, to allow extensions both in section and length at any time without difficulty.
 - All necessary precautions shall be implemented in order to prevent bus bar arcing due to moisture retention.
- 12.3.3.2.8 Trolley Receptacle Compartments
- This compartment shall house the trolley. It shall essentially consist of:
- A shutter automatically protecting live parts when the equipment is plugged-out.
 - Provision for fixed earthing plug-in contact,
 - Grounding of the frame of the trolley,

- d) A safety interlocking access to the fixed insertion connectors if the circuit-breaker / interrupter is not engaged or if it is in the withdraw position,
- e) A precise device for displaying the end of insertion travel with limit switch or any other proven mechanical arrangement,
- f) A fixed plug-in socket enabling the flexible connection to be made for control and monitoring of the circuit-breaker / interrupter,
- g) The interlocking corresponding to the function of the cubicle,
- h) A general connecting terminal for low voltage circuits of the cubicle. The terminal shall be tightened by screws, no other connecting device shall be used
- i) An annunciation device for "33 kV voltage on", by means of a **capacitive divider/graded capacitor** with neon lamps (one per phase), glowing permanently in live conditions. Capacitive divider/graded capacitor shall be provided in the fixed part of the cubicle.
- j) All operations shall be possible with closed door condition to ensure complete protection to the operator

12.3.3.2.9 Cable Compartments

- a) The cable compartment shall have the provision for mounting of CTs, PTs & earth switches as per requirement. CT/PT shall be fully cast resin type. The cabling compartment should be designed in such a way that sufficient space is made available for termination of 3 or 6 cables of single core feeder XLPE cable for each feeder through heat sink terminations as applicable.
- b) The cable compartment's depth shall be less than one meter and the clearance between the bottoms of the bus bars to base plates minimum 500 mm. The compartment height shall be at least 700 mm to facilitate the cable connection and be equipped with an external cable support device.
- c) The copper bus shall be provided with holes size 14mm or suitable size dia in requisite number for termination of cable on each feeder. It shall also provide the cable- supporting clamp.
- d) End-boxes for 33kV cables shall be supplied complete with all the necessary materials for installing the cable and making the end connection.
- e) The connection braids between the two sets of bus bar, the current transformers and the cable end-boxes., shall have sufficient gap so that when the braids are removed, the output terminals from the cable box are sufficiently distant from any earth, thus enabling the high voltage cable to undergo dielectric tests or any fault finding to be carried out by applying high voltage.
- f) All panels shall have integral earth switches for cable side earthing. A cable head earthing isolator, actuated manually, complete with the necessary interlock shall be provided. Positions of the earthing isolator shall be visible through a glazed port/mechanical indicator.

12.3.3.2.10 Low Voltage Compartments

The low voltage compartment shall consist of all control, monitoring and measurement devices. Auxiliary voltage shall be 110 V dc (+10%, -15 %) for motors, monitoring and control circuits.

In elevated sections, FRLS cables shall be used in all LV control and power circuits. In underground sections, FRLSOH cables shall be used in all LV control and power circuits.

The LV compartment shall consist of as a minimum:

- a) Voltage presence capacitor dividers, relay and facade indicator lights
- b) Breaker Open/closed, test/service, local/remote, spring charge/discharge and E/S close/open position indicator lights and contacts.
- c) Facade measurement indicators (ammeter & voltmeter when required)

- d) Control and monitoring devices for the CB (programmable logic control)
- e) Control and monitoring, multi pin connector
- f) Lockable access door
- g) Numerical relays with MIMIC Display SLD control
- h) SCADA compatible interlocks and auxiliary relays and meters
- i) Emergency trip

12.3.3.2.11 Space Heater Element

Each cubical shall be provided with a space heater element of sufficient capacity with thermostat/hygrostat control of 35°C over ambient temperature and humidity at loading condition.

12.3.3.2.12 Withdrawal Trolley

- a) The switchgear compartment shall be fully draw out self-contained trolley arrangement with breakers mounted on the same. The interchangeability of cubicles and switchgear shall be ensured by quality production and assembly works.
- b) A separate front door shall be provided in each circuit breaker/interrupter cubicle, which shall be opened for inserting or withdrawing the breaker from the cubicle. A racking handle shall be provided to facilitate insertion and withdrawal of the breaker truck to and from the service position.
- c) The switchgear trolley shall have three positions.
 - i. Service position (Plugged-in)
 - ii. Test position (Plugged-out)
 - iii. Withdrawn position (Out of the cubicle)
- d) The circuit breaker mobile truck shall be provided with a metal shield on the front which prevents any access to the live parts of the circuit breaker even when the doors of the cubicles are open. Additional features shall be available so that front door can be even closed even when the breaker is in test and withdrawn position.
- e) The trolley shall have a control button and the open and closed position annunciation via mechanical display. It shall have auxiliary annunciation contacts displaying whether the circuit-breaker is in open or closed position, connected to the terminal board of the low voltage circuits. Spare open and closed contacts shall be available in addition to those used for low voltage control and monitoring circuits.
- f) The trolley shall have a grounding contact connecting the frame circuit of the circuit-breaker to the cubicle grounding bus-bar, interlock mechanisms, plugging actuator, manual actuating auxiliary system and operating counter.
- g) The actuating system shall be of energy accumulation type, with low transient current consumption when arming the circuit breaker. The closing action of the circuit of the circuit breakers shall compress the opened spring ready for instantaneous tripping. It shall be equipped with an anti-hunting device, electric & manual arming capability.

12.3.3.2.13 Cubicles Arrangement

- a) All cubicles, boxes or sheaths shall be rigidly fastened to the floor.
- b) Cubicle level adjustment shall be realized with special steel sections initially anchored in position.
- c) The assembly level thus executed shall enable smooth movement of the trolleys in the cubicles. The width of the cubicles should not be more than 1000 mm width.

12.3.3.2.14 Cubicle Grounding

- a) Each cubicle shall comprise with motorized grounding/earthing system with suitable capacity of copper grounding bus-bar to which each of the metal masses of the component parts of the cubicle shall be connected, together with those of the instrument transformers.
- b) The grounding bus-bars of the various cubicles shall form a linkage interconnected together and a common collector line shall be provided for connecting both ends to the earthing circuit of the station.
- c) The withdrawal trolley shall be connected to this grounding bus-bar via a plug-in/out contact.
- d) The cable end manual earthing isolator position shall be visible, through a glazed port/mechanical indicator.
- e) Internal and external metal partitions shall be connected to the earth.
- f) Suitable arrangement for earthing cable sheath

12.3.3.2.15 Paint

- a) Painting should be suitable for polluted atmosphere and has to comply with IEC 60 721-2-5 standard.
- b) As a minimum, an initial coat of rust-proofing and anti-corrosion paint will be applied after baring of all metal surfaces; then they will be covered with two coats of paint and one finishing coat, colour to be defined.
- c) The Contractor shall submit to the Engineer, the complete details of the Switchgear Cubicles Metal work and Paintwork details, including details of the structure, process of finish and painting etc. for Engineer's approval. The total thickness should not be less than 60µm and withstand 120°C.

12.3.3.2.16 Nuts & Bolts

- a) The threads and hexagons of all nuts, bolts and stud shall confirm to relevant IS or BS.
- b) No bolt or stud shall project through its nut(s) more than 6mm (or) four threads, except when otherwise approved for terminating stud/bolts.
- c) If bolts and nuts are so placed that they are inaccessible by means of ordinary spanners
- d) All terminals should be provided with suitable cadmium plated and passivated high tensile steel hard wires facilitate cables termination.

12.3.3.2.17 Fitting & Accessories

As a minimum following fittings and accessories shall be provided

- a) Mechanically operated tripping and closing device
- b) Local / Remote /off control switch and indication lamps
- c) Operation counter
- d) Supporting frame if needed
- e) Name plate
- f) Foundation bolts
- g) LED status of breaker/earth switch position
- h) Meters
- i) CTs & PTs as required

12.3.3.2.18 The degree of protection shall be IP 5X or higher.

12.3.3.2.19 Identification : The front of each cubicle shall carry a nameplate indicating its identification number and function. The text and type of nameplate shall be defined later during detailed engineering stage.

12.3.3.3 TECHNICAL SPECIFICATION OF THE HIGH VOLTAGE COMPONENTS OF AIS

12.3.3.3.1 CIRCUIT BREAKER

General

Make-up & equipment: Each circuit breaker shall be three pole vacuum type. The Circuit Breaker shall be tested for the duty cycle of E2, C2, M2 class in accordance with IEC62271-100 and type test reports to be submitted. Vacuum Circuit Breaker shall be rated for minimum 100 nos. full short circuit to ascertain the life of Vacuum Circuit Breaker. Tenderer should submit the Type Test Reports for Short Circuit Duty with this breaker. Circuit breakers shall include:

- a) Up & down stream plug-in connectors
- b) Live insulated poles with epoxy encapsulation poles
- c) Energy accumulation type actuation system (electromechanical springs)
- d) Electric and manual arming capability (Tripping and closing coils motor)
- e) Under-voltage tripping coil (auxiliary voltage off)
- f) Locking and interlocking devices
- g) Open / Closed auxiliary contacts
- h) Low voltage multi-pin connector and flexible cable
- i) Redundant tripping coils shall be considered for each circuit breaker in the switchgear.

Technical Particulars

SN	Description	33 kV Switchgear
1.	Type	Draw out Indoor type Vacuum Circuit Breaker
2.	Rated Service Voltage	33 kV
3.	Insulation level (minimum)	36 kV
4.	No. of poles/phases	Three
5.	Rated Frequency	50 Hz
6.	Rated normal current	1250A As per Tender SLD
7.	Busbar current rating	1250A As per Tender SLD
8.	Allowable overcurrent for 3 sec	25kA
9.	Instantaneous overcurrent	62.5kA Peak
10.	Rated short circuit withstand capacity	25kA for 3 Sec
11.	Auxiliary DC supply voltage	110 V dc
12.	Allowable variation range of control supply voltage	+10%, -15%
13.	Protection Degree	IP 3X
14.	Current transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.
15.	Potential transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.
16.	Earthing isolator making capacity	25kA for 3 sec
17.	Rated short time duration power frequency withstand voltage	70 kV rms
18.	Rated short time duration impulse withstand voltage	170 kV peak
19.	Auxiliary supply ac voltage	230 V, 1 phase, 50 Hz
20.	CB Opening time	<60ms
21.	CB Breaking time	<80ms
22.	CB Closing time	<80ms
23.	Rated operating duty	O-0.3sec-CO-3min-CO

SN	Description	33 kV Switchgear
24.	Total arc interruption duration	Less than 3 cycle
25.	Number of mechanical operations	10,000 operating sequences

12.3.3.3.1.2 Auxiliary electrical equipment shall be suitable for operation on the following supply system.

a	Power Devices like drive Motors of rating maximum 1 kW	110V DC, 2 wire
b	Lighting, space heaters	240V, single phase, 50 Hz neutral grounded AC supply.
c	Alarm, control and Protective devices.	110V DC, 2 wire

12.3.3.3.2

12.3.3.3.2 MAINTENANCE EARTHING SWITCH

General

The AIS earthing switches shall comply with the general requirements and the latest revision of the relevant IEC standards. Maintenance earthing switches shall be three pole, group operated, no-load break. They shall also have facilities for emergency manual operation and the necessary operating handles or hand cranks shall be supplied.

Maintenance earthing switches shall be electrically interlocked to prevent the earthing switch from closing on an energized bus section. However, any alternative proven conforming to international standards and if the requirements of service continuity concept as per IEC 62271-203 can be met, such designs shall also be acceptable during detailed engineering stage. In this regard the decision of Employer is final and binding.

All main contacts shall either be silver plated or shall have silver inserts. Each earthing switch shall open or close only due to manual operation. The switch contact shall not move due to gravity or other means, even if a part fails.

The maintenance earthing switches shall be located as shown in the single line diagram.

Technical Particulars

Table 12.2: Technical Particulars of Maintenance Earthing Switch

Description	Unit	Rating
Rated Voltage	kV	36
- Lightning impulse withstand voltage	kV	170
- Power frequency with stand voltage	kV	70
Nominal operating current (at 40°C)	A	1250
Rated short-circuit withstand current (r.m.s.), 1sec	kA	40
Control voltage (DC)	V	110 DC

Operating mechanism

Manual operation shall be prevented if the interlocking system does not allow the operation of the earthing switch.

The auxiliary energy shall be electrically uncoupled from the motor when the switch is operated manually.

The mechanisms shall be arranged for locking in the open and in the closed position. Facilities shall be available to allow the switch to be padlocked in any position.

Position indicating devices

External mechanically connected position indicators shall be provided showing either open or close position.

12.3.3.3.3 CURRENT TRANSFORMERS

- a) Each current transformer shall be installed in the cable end compartment between the downstream pole and the cable connector. Cable end compartment volume shall allow easy access for current transformer and removal.
- b) Current transformers shall be cast resin and fixed type.
- c) Current transformer performances shall be as per technical sheets (GTP) included into this Specification.
- d) Elevated CT should be fixed for top entry and UG CT to be fixed for bottom entry.

Technical Particulars

Table 12.4: Technical Particulars of Current Transformer

Description	Unit	Rating
Core number per phase	Nos.	5-Core
Accuracy - Metering - Protection		0.2s PS & 5P20,
Rating Primary	A	As per SLD
Rated secondary current	A	1
Continuous Thermal rating	%	120

All parameters shall be valid at the highest tap.

12.3.3.3.4 POTENTIAL TRANSFORMERS (PT): Bus PT

- a) Each voltage transformer shall be installed in the cable end compartment, connected between the downstream pole and the cable connector through HRC fuses
- b) Cable end compartment volume shall allow for easy access for voltage transformer and removal.
- c) Voltage transformers shall be cast resin & withdrawable type.
- d) Voltage transformer performances shall be as per technical sheets included in this Specification.

Technical Particulars

Table 12.5: Technical Particulars of Potential Transformer

Description	Unit	Rating
Rated voltage	kV	36
Primary winding	kV	(33)/√3
Secondary winding	V	110/√3
No of secondary windings	Nos.	2
Accuracy of secondary winding		
Class		0.2S /0.2 /3P
Burden*		20 / 20
Partial discharge level at 1.5 U//3	pC	As per IEC

*Burden shall be finalized during detailed engineering.

12.3.3.3.5 Motion and plug-in mode Special devices

- a) All complete sets of plug-in accessories shall be provided for each type of circuit-breaker, together with four sets of auxiliary plug-in actuating devices, where the circuit-breaker has such devices.

12.3.3.3.6 33 kV POWER CABLE CONNECTION

General

The design of the cable end box shall fully comply with the latest relevant IEC standard.

The cable end unit design shall include a facility for high voltage AC testing of the connected power cable on site. Removable bolted links or similar connections will be accepted. The design of the link and connections shall ensure that when removed the resulting gap can withstand the impulse and power frequency test voltages applicable to the switchgear and the cable high voltage AC test voltage.

Interface definition

Dimensions and division of work shall fully comply with relevant IEC standard.

12.3.3.3.7 LOCAL CONTROL CUBICLE

General

One local control cabinet (LCC) shall be supplied for the local control and operation of each circuit breaker bay. Each LCC shall contain the local control, interlocking, operation and indication devices for the associated AIS feeder bay.

The LCC shall operate as a link between AIS and Control, protection and DPCS in Control Room.

For easy overview, the LCC's should be integrated in the switchgear in the related circuit breaker bay. A general arrangement drawing showing the installation position shall be submitted with the quotation. Height of the LCC panel of 33 kV AIS so as to operator can read the instrument without additional support (approx. 5' - 5'6").

The control and operation circuits shall be well shielded and with safety measures to

protect operator from touching energized parts. Power frequency withstand of control circuits shall be 2 kV for 1 minute. The LCC shall be factory tested and shipped together with the bay as one transport unit.

DC Supplies and Circuits

DC supplies shall be provided by the tenderer for all control, interlocking, alarm, indication and power supply circuits. The normal maximum and minimum voltage levels that will occur on the supply are specified.

The design of all circuits must be such that separately fused or sub fused circuits are always kept electrically separate.

A.C. Supplies and Circuits

A.C. power for heaters and other auxiliary loads(power socket, lighting) will be provided by the tenderer by two 240 V, 50 Hz, 3-phase circuits.

The normal maximum and minimum voltages that will occur in the supply are as specified. All equipment supplied shall be capable of running continuously or switching the AC current within the range of the normal maximum and minimum voltages specified.

Cable connections within the AIS and their LCC's

All cable connections between the various AIS modules and the LCC shall be made by prefabricated multi-core cables with multi-point plug-in connections on both ends. PT and CT shall be hard wired.

All cables shall be shielded and adequate for their application (indoor / outdoor).

Space Heater: Each panel shall be provided with a space heater rated for 240V, single phase, 50 Hz Ac supply for the internal heating of the panel.

12.3.3.3.8 TESTING & COMMISSIONING:

(a) TYPE TEST:

Type tests shall be according to the IEC 62271-200 and other relevant IEC standards. These type tests should have been conducted in a Recognized independent institution / Laboratory. The type test reports of the manufacturer or its principal (holding company) shall be acceptable, if the manufacturer is of international repute.

(b) ROUTINE TESTS:

Routine tests shall be as per the IEC 62271-200 and other relevant standards. The manufacturer shall provide all the testing equipment required for the site tests.

(c) COMMISSIONING TESTS/ON SITE TESTS AFTER ERECTION:

After erection, and before putting into service, the gas-insulated metal enclosed Switchgear shall be tested as per the IEC 62271-200 for the correct operation and dielectric strength of the equipment.

These tests and verifications shall comprise:

- (1) Tests to be conducted on the circuit breaker at site at all required operating sequences
 - Measurement of operating time
 - Checking of wiring and connections and dielectric checks Indications, alarms and

- interlocks, auxiliary contacts
- Operation at minimum and maximum control supply voltage/pressure Operation of anti-pumping device.
- (2) Deleted
- (3) Other Tests at Site
 - Dielectric tests on auxiliary circuits
 - Measurement of the resistance of the main circuit
 -
 -
 - General verifications
- (4) Power Frequency Test: on site testing of AIS
 - Power frequency tests for the completed AIS at site shall be complied as per IEC62271-200.
 - The power frequency test voltage at site shall be 80% of the factory test voltage for 1 min at 50Hz.
 - Voltage tests on main circuits at reduced voltage (80% p.f.) comprising:
50 Hz A.C. voltage test for 1 min

12.3.4 SAFETY FEATURES

- 12.3.4.1 The design shall incorporate / provide full perception for safety of all those working personal associated with maintenance of the switchgear. The following safety features shall be provided as a minimum.
- 12.3.4.2 It shall not be possible to insert CB into the service when it is in the closed condition.
- 12.3.4.3 It shall not be possible to withdraw the CB from service position unless it is in the open condition.
- 12.3.4.4 It shall not be possible to close the CB in any position except when fully engaged in the service, test and isolated positions.
- 12.3.4.5 All access to the fixed plug-in parts is prevented when the CB is withdrawn.
- 12.3.4.6 A general diagram of the key interlocks for the station, indicating all the locks provided for the present equipment shall be prepared.
- 12.3.4.7 It shall invariably be possible to padlock the interlocks through castle keys.
- 12.3.4.8 The cubicles shall be protected against fire by means of automatic fire detector and extinguisher system with linear fire detection tube based clean agent direct gas flooding system. The detection has to be done by the linear heat detection tube which will be routed inside the panel as per the design calculation. The tube shall be double layered & made of Hi-tech Polymer either Fire Detec, Fire Trace or equivalent. The system shall utilize unique flexible tubing that shall be attached to the top of the container valve. This tubing shall be pressurized with Dry Nitrogen to 230 psig (≈ 16 bar) at 70°F (1,034 KPA @ 21°C), is temperature sensitive and shall act as a continuous linear thermal detector that shall rupture upon flame impingement. Once the detection tubing is ruptured, forming a nozzle at the rupture point, it shall allow the Clean Agent through the nozzle into the protected area. The clean agent offered should be as designated in NFPA 2001 [Section A.5.5.1(B)] and ISO 14520 Clean Agent Standards. Its 'ASHRAE'

nomenclature is (FK5-1-12 or its equivalent (Novec 1230)). Gas should have lowest Global Warming potential. The quantity of clean agent required should be calculated as per NFPA 2001 and BIS standards. Clean agent container shall be designed, fabricated, certified with stamp on the containers in accordance with the requirements of NFPA. Containers shall be standard model and size for ease of replacement and addition. Fill containers with required Clean Agent (FK5-1-12 or its equivalent (Novec 1230)). Pressurise with Dry Nitrogen to 230 psig (≈ 16 bar) at 70°F (1,034 KPA @ 21°C). Container/cylinders shall have PESO approval /Govt. Approved Lab. A separate and stand alone gas cylinder with protection system shall be provided for a group of panels.

Gas flooding system healthiness status shall be communicated to BMS (Building Management system). Necessary interface & accessories shall be taken care of by LKE(02)-01 contractor with concerned agencies involved.

Demonstration of fire protection system on switchgear panel shall be done at site as required by Employer. (Combined for all equipments/sub-system)

12.3.5 INTERLOCKINGS

12.3.5.1 Self-interlocking's

12.3.5.1.1 All interlocking's as per approved scheme shall be incorporated. The following self-interlocking shall be necessarily incorporated:

- a) When unplugged and withdrawn from the cubicle, the mechanisms shall inhibit opening of the flaps covering the receptacles and shall enable the key to be turned.
- b) By turning the lock and withdrawing the key, it shall not be possible to plug-in the circuit breaker / interrupter.
- c) In addition, for the breaker cubicles, it shall be possible to actuate the earth isolator only after first unplugging the breaker and withdrawing the first key.
- d) Conversely, the earth isolator being closed, it shall not be possible to unlock the cubicle in order to plug the circuit breaker in.
- e) The type of lock shall be selected among equipment considered as being safety equipment.
- f) The above self-interlocks shall be achieved through castle lock & key. Contractor shall submit the interlocking scheme for Engineer's approval during detailed engineering stage.

12.3.5.2 33 kV Switchgear Interlocking

12.3.5.2.1 All interlocking as per approved scheme shall be incorporated. Interlocking has been elaborated in SCADA Chapter 18.

12.3.5.2.2 This interlocking has several purposes such as to avoid paralleling of 33 kV supplies from different sources in remote and local control mode and to avoid earthing of a live cable.

12.3.5.2.3 For this purpose, the auxiliary 33 kV network is divided into suitable loops. Normally, the ASS's connected to the various loops will derive power supply from the respective loop only.

12.3.5.2.4 However, in an emergency situation, when one of the RSSs is totally out-of-service, it shall be necessary to link the loops. When this is required, the linking breakers which are provided for this purpose are closed in a sequence so as to ensure that the two loops are not linked when both loops are live. Suitable interlocking shall be provided for this purpose. If required, both circuits shall be compatible to operate under close/open loop configuration via suitable interlockings as required for the operation.

12.3.5.3 33 kV Network Inter-loop Interlocking

- 12.3.5.3.1 When potential transformer of a consecutive loop is showing voltage, extending power from one loop to other should not be possible. This feature shall also be available on SCADA.
- 12.3.5.4 Interlocking In Remote Control Mode
- 12.3.5.4.1 In remote control mode it shall be possible to operate 33 kV switchgear without any mechanical interlocking. This shall be possible through the medium of the remote/local switch when in remote position.
- 12.3.5.4.2 The SCADA software shall authorize closing / opening sequence in such a way that paralleling of 33 kV supplies is not possible in any circumstances.
- 12.3.5.5 Interlocking In Local Control Mode
- 12.3.5.5.1 In local control mode it shall be possible to operate 33 kV switchgear with a mechanical interlocking. This shall be possible through the medium of the remote/local knob when in local position.
- 12.3.5.5.2 The mechanical/electrical interlocking shall be designed in such a way that paralleling of 33 kV supplies is not possible in any circumstances.
- 12.3.5.6 Earthing Interlocking
- 12.3.5.6.1 A mechanical interlocking linkage shall be built in to prevent the grounding switch being closed if the ring CB is closed. Nonetheless, it shall be possible to operate the grounding switch with the compartment door open, but it shall be impossible to close the ring interrupter when the grounding switch is closed.
- 12.3.5.6.2 On the other hand, an electrical interlocking shall forbid the earthing isolator closing until the motorized interrupter at the other extremity of the same cable of the nearest ASS is locked in open position.
- 12.3.5.7 Local Interlocking
- 12.3.5.7.1 Each 33 kV board shall include a non-return interlocking system, formed by security locks/castle lock & key arrangement, to allow safe inspection of the transformer.
- 12.3.5.7.2 This interlocking system shall make it possible to open a main LV circuit breaker (in others' scope) and lock it open and unplugged before closing the protection bay ground isolating switch. Once this switch has closed, it shall be possible to open the door of the transformer bay.
- 12.3.5.7.3 All 33 kV cable coupling bays shall include systems to interlock interrupters and grounding isolators to make it possible to work on a bay without cutting the main 33 kV cable. High-security locks shall form these interlocks.

12.4 DELETED

12.5 33 kV/415V AUXILIARY TRANSFORMER

Refer Chapter 14, Clause 14.3, as applicable

12.6 PROTECTION AND CONTROL MONITORING

12.6.1 SCOPE

- 12.6.1.1 This Specification applies to the protection system envisaged for the HT sides of equipment at Receiving & Auxiliary Main Substation and 33kV cables. The schematic protection scheme is attached. The Contractor shall design and propose a comprehensive system to meet the protection requirements of individual equipment and the system as a whole. The proposal shall be submitted for the Employer's approval.
- 12.6.1.2 The Contractor shall be responsible for the design, manufacture, and delivery to site, installation, testing and commissioning of Protection and Control Monitoring system

including Control & Relay Panel ("C&R Panel"). The C&R panel design shall utilize the latest state of the art proven technology to suit all requirements of the system.

- 12.6.1.3 All the instantaneous relays should be capable of operating the circuit breaker within a duration of 120ms from the occurrence of the fault. This time duration should include the dead time of the relays and this feature should be demonstrated during testing of the relays.

12.6.2 SPECIFICATION

- 12.6.2.1 The protection relays shall conform to IEC 60255 or BS 142 and shall have electromagnetic compatibility as defined in IEC 61000-4-2 Class 3, IEC 61000-4-4 Class 4 and IEC 61000-4-5 Class 3.

12.6.3 GENERAL

- 12.6.3.1 The C&R Panel shall be of highly reliable and of purpose built design for switchgear protection. Relays shall have proven records of successful service for similar ratings, configuration and design. The C&R panel shall provide data acquisition, data processing, overall protection, interlocking, inter-tripping for 33 KV incoming cables and 33 kV HT bays including transformers. Relays shall be programmable as per requirement.
- 12.6.3.2 The Contractor shall design the C&R panel based on the following design philosophy:
- 12.6.3.2.1 Based on modular sets to comply with a high performance standard regarding reliability, maintainability & availability.
- 12.6.3.2.2 High reliability by the elimination of hard wiring and mechanical contacts as far as practically possible.
- 12.6.3.2.3 Minimize maintenance by the use of self-diagnostic software program built into the system.
- 12.6.3.2.4 Open system design concept for each functional expandability.
- 12.6.3.2.5 Comprehensive data logging and event reporting system.
- 12.6.3.2.6 Fail safe design that will not result in dangerous situation for personnel.
- 12.6.3.2.7 Necessary communication protocols for data exchange with RTU as per SCADA requirement
- 12.6.3.2.8 Appropriate test terminal blocks for testing of meters and relays for online and offline
- 12.6.3.2.9 Provision of fuses of appropriate rating in different circuits like PT supply for metering protection, dc supply for control etc.
- 12.6.3.2.10 Ergonomic design of panel – proposal shall be submitted by Contractor, duly keeping in view the space available in control room, for approval by Employer
- 12.6.3.2.11 Appropriate number (min three) of additional auxiliary relays for future use
- 12.6.3.2.12 Redundant DC control supply shall be provided for reliability purpose

12.6.4 PERFORMANCE REQUIRED

- 12.6.4.1 The protection system based on modular sets must comply with a high performance standard regarding reliability, maintainability, availability and safety.
- 12.6.4.2 Reliability
- This criteria defines the mean time between failures (MTBF) which shall be calculated for 10 years.
- 12.6.4.3 Maintainability
- This criteria represents the mean time for repairing (MTTR) and shall be considered only for replacement of mal functions or sub assembly failures.

The MTTR shall not exceed 2 hours (not including the dead time to reach the site), 48 hrs for distant agency or 12 hrs. for Lucknow based agency.

12.6.4.4 Availability

This is expressed in terms of ratio using the formula:

$$\frac{MTBF}{MTBF + MTTR} \%$$

and shall represent a level of 99.95 %

12.6.4.5 Safety of operation

Safety is ensured by the means of cyclic self-test ensuring general supervision on software of equipment.

In case of fault, a watchdog is activated. All of inputs are insulated in galvanic and capacitive view and complemented.

12.6.5 PROTECTION SYSTEM FUNCTIONS

12.6.5.1 The function of protection systems is mainly (a) to isolate the affected portion as quickly and as expeditiously as possible while maintaining normal supply to the rest and (b) to provide alternative circuits with automatic changeover wherever applicable to minimize the extent and duration of power supply outage.

12.6.5.2 The Contractor shall prepare a comprehensive protection scheme and protection relay settings and submit to the Employer for approval. The Contractor shall provide proper relay coordination to ensure:

12.6.5.2.1 Selectivity: Protection will be arranged in zones, which will cover the complete power system completely, leaving no part unprotected. When a fault occurs, the protection will trip only the nearest circuit breaker. The discrimination shall be achieved by two general methods

- Unit protection system
- Time graded system

12.6.5.2.2 Stability: Stability of the protection system refers to the ability of the system to remain inert to all load conditions and faults external to relevant zone.

12.6.5.2.3 Speed: The function of protection system is to isolate faults from the rest of the power system in a time as short as possible. The object is to safeguard continuity of supply by removing each fault before it leads to total collapse of the system with widespread damage and total loss of power supply.

12.6.5.2.4 Sensitivity: Sensitivity of the protective system will be such that it will be able to sense and operate at minimum fault current.

12.6.5.2.5 Reliability: A system is not properly designed and managed if it is not adequately protected by a reliable protection system. Reliability will be enhanced by providing primary and backup protection.

12.6.6 PROTECTION RELAYS

All relays shall conform to the requirements of IS: 3231/IEC-60255/IEC 61000 or other applicable standards. Relays shall be suitable for flush or semi-flush mounting on the front with connections from the rear.

12.6.6.1 Numerical Relays

The numerical relays comprising of a PCU (Protection and Control Unit) shall be in full compatibility with the RTU (remote terminal unit) of SCADA and shall be capable of providing single point monitoring, control, logging and protection for the system.

12.6.6.2 Draw-out / Plug-in Type

Protection devices (numeric protective relay, PCU) shall be built up with a modular concept. All protective relays shall be draw out or plug-in type/modular cases with proper testing facilities. Necessary test plugs/test handles shall be supplied loose and shall be included in Contractor's Scope of Supply.

12.6.6.3 Operating Voltage / Current

All AC operated relays shall be suitable for operation at 50 Hz. AC Voltage operated relays shall be suitable for 110 Volts VT secondary and current operated relays for 1 amp CT secondary. All DC operated relays and timers shall be designed for the DC voltage specified, and shall operate satisfactorily between 80% and 110% of rated voltage. Voltage operated relays shall have adequate thermal capacity for continuous operation.

12.6.6.4 Auxiliary Relays / Contacts

The protective relays shall be suitable for efficient and reliable operation of the protection scheme described in the Specification. Necessary auxiliary relays and timers required for interlocking schemes for multiplying of contacts suiting contact duties of protective relays and monitoring of control supplies and circuits, lockout relay monitoring circuits etc. also required for the complete protection schemes described in the specification shall be provided. All protective relays shall be provided with at least two pairs of potential free isolated output contacts. Auxiliary relays and timers shall have pairs of contacts as required to complete the scheme; contacts shall be silver faced with spring action. Relay case shall have adequate number of terminals for making potential free external connections to the relay coils and contacts, including spare contacts.

12.6.6.5 Reset

All protective relays, auxiliary relays and timers except the lock out relays and interlocking relays specified shall be provided with self-reset type contacts. All protective relays and timers shall be provided with externally hand reset positive action operation indicators with inscription. All protective relays which do not have built-in hand-reset operation indicators shall have additional auxiliary relays with operating indicators (Flag relays) for this purpose. Similarly, separate operating indicator (auxiliary relays) shall also be provided in the trip circuits of protections located outside the board such as Buchholz relays, oil and winding temperature protection, sudden pressure devices, fire protection etc.

12.6.6.6 Timers

Timers shall be of solid state type. Time delay in terms of milliseconds obtained by the external capacitor resistor combination shall be avoided.

12.6.6.7 De-energization of Control Relay

No control relay which shall trip the power circuit breaker when the relay is de-energized shall be employed in the circuits.

12.6.6.8 Facilities for fault diagnosis

The relays shall have the following tools for fault diagnostics:

12.6.6.8.1 Fault record – The relay shall have the facility to store fault records with information on cause of trip, date, time, trip values of electrical parameters.

12.6.6.8.2 Event record – The relay shall have the facility to store time stamped event records with 1ms resolution.

12.6.6.8.3 Disturbance records – At least 5 secs of disturbance records shall be provided in the offered numerical relays. Each record shall store data from at least 5 analogue channels and 16 digital channels. The data from DR function shall be available in IEEE

- / COMTRADE format and shall be compatible with the relay test kit.
- 12.6.6.9 Security measures shall be built in to gain access to vital data and functions. No security measures shall be required for access to system currents and voltages.
- 12.6.6.10 The Contractor shall furnish detailed proposal of batteries preferably in the Electrical Erasable Programmable Read Only Memory (EEPROM). This is to allow PCU settings to be changed in the foreground without affecting the actual operating values in the background.
- 12.6.6.11 Where PCUs are required to trip circuit breakers, actuate signals or perform control duties, PCUs shall be designed to avoid inadvertent or simultaneous switching operations and shall give precedence to protective functions required due to unfavourable conditions, e.g., short circuit, internal faults, power supply failure, voltage fluctuation, etc.
- 12.6.6.12 Isolation of Trip Circuit for Testing
- Provision shall be made for easy isolation of trip circuits of each relay for the purpose of testing and maintenance.
- 12.6.6.13 Shunt / Series Relays
- 12.6.6.13.1 Auxiliary seal-in-units provided on the protective relays shall preferably be of shunt reinforcement type. If series relays are used the following shall be strictly ensured:
- 12.6.6.13.2 The operating time of the series seal-in-unit shall be sufficiently shorter than that of the trip coil or trip relay in series with which it operates to ensure definite operation of the flag indicator of the relay.
- 12.6.6.13.3 Seal-in-unit shall obtain adequate current for operation when one or more relays operate simultaneously.
- 12.6.6.13.4 Impedance of the seal-in-unit shall be small enough to permit satisfactory operation of the trip coil on trip relays when the D.C. Supply Voltage is minimum.
- 12.6.6.13.5 Trip-circuit seal-in is required for all trip outputs, irrespective of the magnitude of the interrupted current. The trip-circuit seal-in logic shall not only seal-in the trip output(s), but also the relevant initiation signals to other scheme functions, (e.g. initiate signals to the circuit-breaker failure function, etc.), and the alarm output signals.
- 12.6.6.13.6 Two methods of seal-in are required, one based on the measurement of AC current, catering for those circumstances for which the interrupted current is above a set threshold, and one based on a fixed time duration, catering for those circumstances for which the interrupted current is small (below the set threshold).
- 12.6.6.13.7 For the current seal-in method, the seal-in shall be maintained until the circuit breaker opens, at which time the seal-in shall reset and the seal-in method shall not now revert to the fixed time duration method. For this seal-in method, the sealing shall be maintained for the set time duration. For the line protection schemes, this time duration shall be independently settable for single- and three-pole tripping.
- 12.6.6.13.8 Seal-in by way of current or by way of the fixed duration timer shall occur irrespective of whether the trip command originates from within the main protection device itself (from any of the internal protection functions), or from an external device with its trip output routed through the main protection device for tripping.
- 12.6.6.13.9 Trip-circuit lock-in shall not take place under sub-harmonic conditions (e.g. reactor ring down).
- 12.6.6.14 Visual display
- 12.6.6.14.1 Visual display or indication shall be provided for the operator to read out the setting of functional parameters and annunciations. In the event of a fault, all information relating

to the fault shall be captured and stored in the PCU. The PCU shall have optical LED indicators to display any abnormal conditions. The memories of the LEDs shall be safeguarded against supply voltage failure. The optical indicators shall be the reset type.

- a) Locally by operating the reset button on the PCU.
- b) Remote by energizing the remote reset input at RCC.
- c) Automatically on occurrence of a few picks-up signal.

12.6.6.15 Spare pair of contacts

All protective relays and alarm relays shall be provided with one extra isolated pair of contacts wired to terminals exclusively for future use.

12.6.6.16 List of Installations using the types of relays

The bidder shall include in his bid a list of installations where the relays quoted have been in satisfactory operation.

12.6.6.17 Phase Indications

All relays and their drawings shall have phase indications as R-Red, Y-Yellow and B-Blue.

12.6.6.18 Scope of Numerical Relays

For numerical relays, the Scope shall include the following:

- a) Necessary software and hardware to up/down load the data to/from the relay from/to the personal computer installed in the substation. However, the supply of a PC is not covered under this Clause.
- b) The relay shall have a suitable communication facility for connectivity to SCADA. The relay shall be capable of supporting the SCADA communication standard.

12.6.6.19 Communication Ports

The relays shall have communication ports for local communication for relay settings, modifications, extraction and analysis of fault/event/ disturbance records from a laptop and for communication with the SCADA system.

12.6.7 CONTROL MODULE

12.6.7.1 The control module shall include all the equipment necessary to enable the system to work satisfactorily.

12.6.7.2 A local/remote key lockable selector switch with indicator shall be provided on the control panel. This local/remote selector switch shall enable controls to be activated either remotely or locally, with indication to OCC.

12.6.7.3 All control, Inter- tripping, interlocking, indications and switching required to operate the HT power supply shall ensure that the design takes into consideration high security and reliability required for the execution of critical control functions, e.g. interlocking, tripping and inter – tripping.

12.6.7.4 Controls shall be performed either at the PCU or at the OCC as commanded. Indication shall be available both at the PCU and OCC.

12.6.7.5 Any modification required to the control sequence and logic shall be easily changed by simple program rewriting. All PCUs shall be capable of performing all necessary control functions required at local RSS/AMS in the event of failure of Operational Control system.

12.6.7.6 Additional spare input terminals upto 20% of installed inputs and corresponding

processing capacity shall be provided for future expansion. It shall also be capable of taking additional modules upto 50% of the installed capacity to be able to provide complete digital protection and control features for the other equipment of the traction substation in future.

- 12.6.7.6.1 Control & Protection equipments shall be having provision of controlling with SLD mimic display.

12.6.8 PCU TECHNICAL FEATURES

- 12.6.8.1 Each PCU shall be integrated with a protection relay module within which standard protective relay features are incorporated. The equipment shall comply with IEC 60255 or BS 142 or relevant latest. The application, performance and testing of protection relay modules shall be in accordance with the appropriate IEC standards.

- 12.6.8.2 Electromagnetic compatibility

- 12.6.8.2.1 Due to interference levels inside RSS/AMS, protection equipment shall present sufficient level of immunity defined by the following standards:

- a) IEC 61000.4-2 Class 3 or latest,
- b) IEC 61000.4-4 Class 4 or latest,
- c) IEC 61000.4-5 Class 3 or latest

- 12.6.8.2.2 Such criteria shall be obtained by using either numerical type relays or specific PLC cards.

- 12.6.8.3 All protection relay modules shall comply in accordance with the following IEC test requirements:

- a) Dielectric test voltage (IEC 60255-5 or latest) 2.0 kV, 50 Hz, 1 min
- b) Impulse test voltage (IEC 60255-5 or latest) 5 kV, 1.2/50 μ s, 0.5 j
- c) High Frequency disturbance test (IEC 60255-22-1 Class III or latest)
- d) Common Mode 2.5 kV, 1 MHz, 2 s
- e) Differential mode 1.0 kV, 1 MHz, 2s
- f) Electrostatic discharge test (IEC 60255-22-2 & IEC 801-2 Class IV or latest)
- g) Air Discharge 15 kV
- h) Contact discharge 8 kV
- i) Fast transient (IEC 60255-22-4 Class IV or latest)
- j) Power supply inputs 4 kV
- k) Other inputs 2 kV
- l) Magnetic field (IEC 61000-4-8 or latest) 100 A/m
- m) Electromagnetic field test (IEC 60801-3 Class III or latest) 10 V/m 50 kHz to 1000M Hz

- 12.6.8.4 The protective relay modules shall be microprocessor based with continuous monitoring and self-diagnostic features to identify the modules or components. The protective scheme shall be so designed that the system remains stable during switching operations and other disturbances.

- 12.6.8.5 In the event of a system fault, the protection module shall record values of current and voltage at a scan frequency no lower than 1 kHz over a time window of at least 1 second before the event to 1 second after the event with time stamping. The fault data shall be captured and recorded and shall be downloaded in the OCC for fault analysis.

12.6.8.6 Safety is ensured by the means of Cyclic self-test ensuring general supervision on software of equipment. In case of a fault, a watchdog is activated. All inputs are insulated in galvanic and capacitive view and complemented.

12.6.8.7 The individual protection relay module within the PCU shall continuously monitor the DC trip supplies for the circuit breakers.

12.6.9 HIGH VOLTAGE PROTECTION

12.6.9.1 INCOMER LINE PROTECTION

The input power shall be at 33 KV level. The power shall be supplied through cables. The Contractor shall interface and coordinate with UPPTCL for ensuring compatibility of protection as per requirements of UPPTCL. The incomer line shall have the following main protection.

12.6.9.2 LINE DIFFERENTIAL PROTECTION (87C/87L)

12.6.9.2.1 The line differential protection relay should be numerical with full compliance to IEC 61850 standards in every respect and Interoperability with other manufacturers' relays and tools shall be verified.

12.6.9.2.2 The protection relays shall be suitable for protection, control and monitoring of overhead lines and UG cables for all voltage levels in solidly or impedance grounded networks.

12.6.9.2.3 It should be possible to integrate protection and control functionality in the protection relays. The Protection Relays shall have complete functionality for single and multi-breaker arrangements with single or three phase tripping.

12.6.9.2.4 At least four independent parameter setting groups shall be included.

12.6.9.2.5 Protection relays shall have extensive self-supervision including analogue channels

12.6.9.2.6 A restrained dual bias operating characteristic shall be used and the highest phase current in any line shall be utilized as bias current

12.6.9.2.7 Charging current compensation for increased sensitivity for long lines and cables shall be included.

12.6.9.2.8 The protection relays should be suitable for multiplexed, route switched or dedicated fibre networks.

12.6.9.2.9 The protection unit should be based on phase segregated line differential principle and use advanced and proven algorithms and shall support user friendly Engineering tools and disturbance handling tools. Cables required for the protection & to be laid along the route of 33 kV Cable shall be in the Scope of Contractor.

12.6.9.2.10 For Line differential communication it shall be possible to select between a master-master system or master slave system depending on the functional or economical requirements. An automatic changeover to master-slave communication should take place if an interruption occurs in communication channels in master-master communication system.

12.6.9.2.11 A backup high speed full scheme distance protection with at least three zones should be possible to include in order to get fault clearance in case of communication failure. It shall be possible to have the distance protection continuously in operation or only released for operation at communication failure. The distance protection shall have characteristics that will give load encroachment discrimination and load current compensation of the reactance line in the first zone to avoid over reach. It should be possible to set the distance protection zone in forward, reverse or non-directional mode. Each zone should have individual resistive and reactive reach settings. Separate phase selection logic and automatic switch onto fault logic should be included. Distance

- protection shall be provided for all incoming feeders.
- 12.6.9.2.12 Protection relays/IEDs shall be provided with a front mounted HMI and front port for connection to a personal computer. The communication channel shall be continuously monitored and an automatic switchover to a redundant channel shall be possible.
- 12.6.9.2.13 The protection relays shall be provided with communication interface for connection to the SCADA system as per IEC 61850 standards.
- 12.6.9.2.14 Power supply modules from 48V to 250V AC/DC shall be available.
- 12.6.9.2.15 The protection at PSA end for both RSS Incomers shall be in scope of LKE(02)-01 Contractor.
- 12.6.9.3 Distance protection (21)
- A backup high speed full scheme distance protection with at least three zone should be possible to include in order to get fault clearance in case of communication failure, it shall be possible to have the distance protection continuously in operation or only released for operation at communication failure. The distance protection shall have characteristics that will give load encroachment discrimination and load current compensation of the reactance line in the first zone to avoid over reach. It should be possible to set the distance protection zone in forward, reverse or non-directional mode. Each zone should have individual resistive and reactive reach settings. Separate phase selection logic and automatic switch onto fault logic should be included.
- 12.6.9.4 BACKUP O/C PROTECTION (50/51, 50N/51N)
- 12.6.9.4.1 Over current tripping shall operate with selectable characteristics such as definite time inverse, very inverse, extremely inverse and long-time of the four inverse time (IDMT) type characteristics as specified in IEC 60255 and BS 142 The current and time setting shall be variable continuously over the range. The relay shall necessarily have:
- Three over-current elements
 - Shall be of numerical type with full compliance to IEC 61850 standard
 - Facility to select any type inverse characteristics as per IEC to suit requirement
 - Separate high set element for instantaneous function.
 - Built in configuration logic to assign inputs/outputs to any functions
 - Directional feature
 - LED for relay serviceability
- 12.6.9.5 33 kV BUS BAR PROTECTION (87B)
- 12.6.9.5.1 A comprehensive low impedance bus bar protection scheme shall be installed. It shall have the following features:
- Numerical bus bar differential protection scheme with full compliance to IEC 61850 standards shall be provided for each main bus at the receiving substation.
 - Bus bar protection for each busbar shall incorporate a main protection and check feature.
 - Each bus bar protection scheme shall operate selectively for each bus bar. It shall give hundred percent security up to 40 kA fault level.
 - Shall incorporate continuous supervision for CT secondary against any possibility of open circuit and if this occurs, shall render the relevant zone of protection inoperative and initiate an alarm
 - Shall not give false operation during normal load flow in bus bars

- f) Shall incorporate clear zone indication
- g) Shall be of phase segregated and triple pole type
- h) Shall provide independent zones of protection
- i) Shall include individual high speed electrically reset tripping relays for each feeder
- j) Shall be transient free in operation
- k) Shall include continuous D.C. supplies supervision
- l) Shall not cause tripping for the differential current below the load current of heaviest loaded feeder
- m) CT switching and external zone formation is not acceptable.
- n) Shall include trip relays, CT switching relays (if applicable), auxiliary CT's (if applicable) as well as additional power supply modules, input modules etc. as may be required to provide a bus-bar protection scheme for the complete bus arrangement i.e. for all the bay or breakers under this specification as well as for the future bays as per the single line diagram for new substations.
- o) Built-in local breaker backup protection feature as a part of bus bar protection scheme shall also be acceptable.
- p) The bus bar protection relays shall be equipped with built-in DR and event recorder
- q) LED for relay serviceability
- r) Have maximum operating time up to trip impulse to trip relay for all types of faults of 25ms at 5 times setting value.
- s) Operate selectively for each bus bar .
- t) Shall incorporate continuous supervision for CT secondaries and shall render the relevant zones of protection in operative against possible open circuit and protection transferred to check zone only.

12.6.9.5.2 The Bus Bar protection relays shall be equipped with built-in DR and Event recorder. It shall have LED for relay healthiness & un-healthiness.

12.6.9.6 33 KV BUS COUPLER PROTECTION

12.6.9.6.1 Bus coupler protection shall have the following features

- a) Backup O/C protection (50/51, 50N/51N, both time delayed and Instantaneous)
- b) shall be numerical type and have three over current elements
- c) have facility to select any type inverse characteristics as per IEC to suit requirement.
- d) Shall have separate high set element for instantaneous function.
- e) Built in configuration logic to assign inputs/outputs to any functions.

12.6.10 LINE THROW OVER DEVICE

12.6.10.1 For 33 kV switchgear at RSS & AMS, there shall be a provision for transfer of power from one feeder cable to the other feeder in case of failure of power. This transfer of power shall be through an automatic device called Line Throw Over Device (LTO). The interlocking and operation logic for this device shall be discussed during detail engineering stage.

12.6.10.2 The Contractor shall ensure installation of this device in the Control & Relay Panel and demonstrate operation during the Factory Acceptance Test.

12.6.11 METERING

- 12.6.11.1 The following metering arrangements shall be provided on the incoming feeders from UPPTCL:
- a) Ammeters (to read the value of current in each phase of each of the incoming feeders)
 - b) Voltmeter (to read the value of line voltages R-Y, Y-B, B-R, in each of the incoming feeders)
 - c) Energy meter (Electronic energy meter, Accuracy class "0.2s", to enable measurement of Active energy (kWh), Reactive energy (kVARh), Apparent energy (kVAh), phase angle, frequency, power factor, instantaneous maximum demand, integrated maximum demand, total harmonic distortion etc. The energy meter shall be similar to Power Supply Authority & tri-vector type having Availability Based Tariff (ABT) feature and data ports.
 - d) The meters should have recording and memory facilities which shall be able to indicate/record/store the total energy of the incoming feeder, through suitable connections). Covered space, if required by Power Supply Authority, shall be provided by Contractor in RSS/AMS. The energy meter should be similar to Power Supply authority meter.

12.6.12 CONSTRUCTION FEATURES (Protection Panel)

12.6.12.1 Panel

- 12.6.12.1.1 The Simplex panel shall consist of a vertical front panel with equipment mounted thereon and having wiring access from rear for control panels & either front or rear for relay panels. In case of the panel having a width more than 800mm, double leaf-doors shall be provided. Doors shall have handles with either built-in locking facility or shall be provided with pad-lock.
- 12.6.12.1.2 It is the responsibility of the Contractor to ensure that the equipment specified and such unspecified complementary equipment required for completeness of the protective/control schemes is properly accommodated in the panels without congestion and if necessary, provide panels with larger dimensions. No price increase at a later date on this account shall be allowed. The Contractor shall decide suitable dimensions depending upon the availability of space in the control room.
- 12.6.12.1.3 The panels shall be completely metal enclosed and shall be dust, moisture and vermin proof. The enclosures shall provide a degree of protection not less than IP-54.
- 12.6.12.1.4 The panels shall be free standing, floor mounting type and shall comprise structural frames completely enclosed with specially selected smooth finished, cold rolled sheet steel of thickness not less than 3 mm for weight bearing members of the panels such as base frame, front sheet and door frames, and 2.0mm for sides, door, top and bottom portions. There shall be sufficient reinforcement to provide level transportation and installation.
- 12.6.12.1.5 All doors, removable covers and panels shall be gasketed all around with neoprene gaskets. Ventilating louvers, if provided shall have screens and filters. The screens shall be made of either brass or GI wire mesh.
- 12.6.12.1.6 Design, materials selection and workmanship shall be such as to result in neat appearance, inside and outside with no welds, rivets or bolt head apparent from outside, with all exterior surfaces true and smooth.
- 12.6.12.1.7 The panels shall have base frames with smooth bearing surfaces, which shall be fixed on the embedded foundation channels/insert plates. Anti-vibration strips made of shock absorbing materials which shall be supplied by the Contractor, shall be placed between

- panel & base frame.
- 12.6.12.1.8 Cable entries to the panels shall be from the bottom. Cable gland plates fitted on the bottom of the panels shall be connected to earth of the panel/station through a flexible braided copper conductor. Relay panels of modern modular construction shall also be acceptable.
- 12.6.12.2 Mounting
- 12.6.12.2.1 All equipment on and in panels shall be mounted and fully wired to the terminal blocks ready for external connections. The equipment on front of panel shall be flush mounted. No equipment shall be mounted on the doors.
- 12.6.12.2.2 The equipment shall be mounted such that removal and replacement can be accomplished individually without interruption of service to adjacent devices and are readily accessible without use of special tools. Terminal marking on the equipment shall be clearly visible.
- 12.6.12.2.3 Spare cut outs shall be provided in adequate numbers and shall be properly blanked off with blanking plates.
- 12.6.12.2.4 The centre lines of switches, push buttons and indicating lamps shall be not less than 750mm from the bottom of the panels. The centre lines of relays, meters and recorders shall be not less than 450mm from the bottom of the panels.
- 12.6.12.2.5 The centre lines of switches, push buttons and indicating lamps shall be matched to give a neat and uniform appearance. Likewise the top lines of all meters, relays and recorders etc. shall be matched.
- 12.6.12.3 Panel Internal Wiring
- 12.6.12.3.1 Panels shall be supplied complete with interconnecting wiring provided between all electrical devices mounted and wired in the panels and between the devices and terminal blocks for the devices to be connected to equipment outside the panels. When panels are arranged to be located adjacent to each other all inter panel wiring and connections between the panels shall be furnished and the wiring shall be carried out internally.
- 12.6.12.3.2 All internal wiring shall be carried out with FRLS, 1100V grade, single core, stranded copper conductor wires with PVC insulation. The minimum size of the multi-stranded copper conductor used or internal wiring shall be as follows:
- a) all circuits except current transformer circuits and voltage transfer circuits meant for energy metering - one 1.5mm sq. per lead.
 - b) all current transformer circuits one 2.5 sq.mm lead.
 - c) voltage transformer circuit (for energy meters): Two 2.5 mm sq. per lead.
- 12.6.12.3.3 All internal wiring shall be securely supported, neatly arranged, readily accessible and connected to equipment terminals and terminal blocks, wiring PVC trays/troughs shall be used for this purpose.
- 12.6.12.3.4 Auxiliary bus wiring for AC and DC supplies, voltage transformer circuits, annunciation circuits and other common services shall be provided near the top of the panels and running throughout the entire length of the panels.
- 12.6.12.3.5 Wire termination shall be made with solder less crimp type and tinned copper lugs, which firmly grip the conductor. Insulated sleeves shall be provided at all the wire terminations. Engraved core identification plastic ferrules marked to correspond with panel wiring diagram shall be fitted at both ends of each wire. Ferrules shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks.

- All wires directly connected to trip circuit breaker or device shall be distinguished by the addition of red coloured unlettered ferrule.
- 12.6.12.3.6 Longitudinal trays/troughs extending throughout the full length of the panel shall be preferred for inter panel wiring. Inter-connections to adjacent panel shall be brought out to a separate set of terminal blocks located near the slots of holes meant for taking the inter-connecting wires.
- 12.6.12.3.7 The Contractor shall be solely responsible for the completeness and correctness of the internal wiring and for the proper functioning of the connected equipment.
- 12.6.12.4 Terminal Blocks
- 12.6.12.4.1 All internal wiring to be connected to external equipment shall terminate on terminal blocks. Terminal blocks shall be 1100 V grade and have 10 Amps., continuous rating, moulded piece, complete with insulated barriers, stud type terminals, washers, nuts and lock nuts. Markings on the terminal blocks shall correspond to wire number and terminal numbers on the wiring diagrams. All terminal blocks shall have shrouding with transparent unbreakable material.
- 12.6.12.4.2 Disconnecting type terminal blocks for current transformers and voltage transformers secondary leads shall be provided. Also current transformer secondary leads shall be provided with short circuiting and earthing facilities.
- 12.6.12.4.3 At least 20% spare terminals shall be provided on each panel and these spare terminals shall be uniformly distributed on all terminal blocks.
- 12.6.12.4.4 Unless otherwise specified, terminal blocks shall be suitable for connecting the following conductors of external cable on each side
- All CT & PT circuits: minimum of two of 2.5 sq.mm copper.
 - AC/DC Power Supply Circuits: One of 4 sq.mm copper.
 - All other circuits: minimum of one of 2.5 sq.mm Copper.
- 12.6.12.4.5 There shall be a minimum clearance of 250mm between the first row of terminal blocks and the associated cable gland plate or panel side wall. Also the clearance between two rows of terminal blocks edges shall be minimum of 150mm.
- 12.6.12.4.6 Arrangement of terminal block assemblies and the wiring channel within the enclosure shall be such that a row of terminal blocks is run in parallel and close proximity along each side of the wiring-duct to provide for convenient attachment of internal panel wiring. All wiring shall be provided with adequate support inside the panels to hold them firmly and to enable free and flexible termination without causing strain on terminals.
- 12.6.12.5 Painting
- 12.6.12.5.1 All sheet steel work shall be phosphate in accordance with the IS:6005 "Code of practice for phosphating iron and steel".
- 12.6.12.5.2 Oil, grease, dirt and swarf shall be thoroughly removed by emulsion cleaning. Rust and scale shall be removed by pickling with dilute acid followed by washing with running water rinsing with a slightly alkaline hot water and drying.
- 12.6.12.5.3 After phosphating, thorough rinsing shall be carried out with clean water followed by final rinsing with dilute dichromate solution and oven drying.
- 12.6.12.5.4 The phosphate coating shall be sealed with application of two coats of ready mixed, stove type zinc chromate primer. The first coat may be "flash dried" while the second coat shall be stove type.
- 12.6.12.5.5 After application of the primer, two coats of finishing synthetic enamel paint shall be applied, each coat followed by stoving. The second finishing coat shall be applied after

- inspection of first coat of painting. The exterior colour of paint shall be of a slightly different shade to enable inspection of the painting.
- 12.6.12.5.6 A small quantity of finished paint shall be supplied for minor touching up required at site after installation of the panels.
- 12.6.12.5.7 In case the Contractor proposes to follow any other established painting procedure like electrostatic painting, the procedure shall be submitted for the Employer's review and approval.
- 12.6.12.6 Name Plates and Markings
- 12.6.12.6.1 All equipment mounted on front and rear sides as well as equipment mounted inside the panels shall be provided with individual name plates with equipment designation engraved. Also on the top of each panel on front as well as rear sides, large and bold nameplates shall be provided for circuit/feeder designation.
- 12.6.12.6.2 All front mounted equipment shall also be provided at the rear with individual name plates engraved with tag numbers corresponding to the one shown in the panel internal wiring to facilitate easy tracing of the wiring.
- 12.6.12.6.3 All relays and other devices shall be clearly marked with manufacturer's name, manufacturer's type, serial number and electrical rating data.
- 12.6.12.6.4 Name plates shall be made of non-rusting metal or 3 ply laminoid. Name plates shall be black with white engraved lettering.
- 12.6.12.6.5 All the panels shall be provided with name plates mounted inside the panel bearing LOA No. & date, name of the substation & feeder and reference drawing number.
- 12.6.12.7 Miscellaneous Accessories
- 12.6.12.7.1 Apart from the above mentioned equipment, the panel shall be provided with the following accessories.
- 12.6.12.7.2 7 Plug Point: 240V, Single phase 50Hz, AC socket with switch suitable to accept 5 Amps and 15 Amps pin round standard Indian plug, shall be provided in the interior of each cubicle with ON-OFF switch.
- 12.6.12.7.3 Interior Lighting: Each panel shall be provided with a fluorescent lighting fixture rated for 240 Volts, single phase, 50 Hz supply for the interior illumination of the panel controlled by the respective panel door switch. Adequate lighting shall also be provided for the corridor in duplex panels.
- 12.6.12.7.4 Switches and Fuses: Each panel shall be provided with necessary arrangements for receiving, distributing and isolating of DC and AC supplies for various control, signalling, lighting and space heater circuits. The incoming and sub-circuits shall be separately provided with miniature circuit breakers (MCB). Selection of the main and sub-circuit MCB rating shall be such as to ensure selective clearance of sub-circuit faults. MCBs shall conform to IS: 13947. Each MCB shall be provided with one potential free contact and the same shall be wired for annunciation purpose. However, voltage transformer circuits for relays and metering shall be protected by fuses. All fuses shall be HRC cartridge type conforming to IS: 13703 mounted on plug-in type fuse bases. Fuse carrier base as well as MCBs shall have imprints of the fuse 'rating' and 'voltage'.
- 12.6.12.7.5 Redundant control power supply for control & protection shall be implemented.
- 12.6.12.7.6 Space Heater: Each panel shall be provided with a space heater rated for 240V, single phase, 50 Hz Ac supply for the internal heating of the panel to prevent condensation of moisture. The fittings shall be complete with switch unit.
- 12.6.12.8 PANEL EARTHING
- 12.6.12.8.1 All panels shall be equipped with an earth bus securely fixed. Location of the earth bus shall ensure no radiation interference for earth systems under various switching

conditions of isolators and breakers. The material and the sizes of the bus bar shall be at least 25 X 6 sq. mm perforated copper or 50x6 mm GI strip with threaded holes at a gap of 50mm with a provision of bolts and nuts for connection with cable armours and mounted equipment etc for effective earthing. When several panels are mounted adjoining each other, the earth bus shall be made continuous. Provision shall be made for extending the earth bus bars to future adjoining panels on either side.

- 12.6.12.8.2 The connection of panels containing low voltage electronic equipments like SCADA, Relays, PC etc. to be done suitably as per recommendations of manufacturers of these items with a confirmation from them that such earthing connection will not interface in the proper functioning of these devices. A separate earthing system to be installed by separate earth electrodes for these devices, panels.
- 12.6.12.8.3 Provision shall be made each busbar of the end panels for connecting substation earthing grid. Necessary terminal clamps and connectors for this purpose shall be included in the Scope of Contractor.
- 12.6.12.8.4 Looping of earth connections which would result in loss of earth connection to other devices when the loop is broken, shall not be permitted. Earthing may be done in such a manner that no circulating current shall flow in the panel.
- 12.6.12.8.5 All metallic cases of relays, instruments and other panel mounted equipment including gland plates, shall be connected to the earth bus by copper wires of size not less than 2.5 sq. mm. The colour code of earthing wires shall be green.
- 12.6.12.8.6 VT and CT secondary neutral or common leads shall be earthed at one place only at the terminal blocks where they enter the panel. Such earthing shall be made through links so that earthing may be removed from one group without disturbing continuity of earthing system for other groups.
- 12.6.12.8.7 An electrostatic discharge point shall be provided in each panel connected to the earth bus via 1 Mega Ohm resistor.
- 12.6.12.8.8 LKE(02)-01 Contractor shall be liable to get suitable protection scheme which shall be acceptable to PSA (Power Supply Authority).

12.7 EARTHING

12.7.1 SCOPE

- 12.7.1.1 This specification applies to the Earthing system used inside the Receiving cum Auxiliary Main Substations (RSS/AMS). It includes laying of earth mat and connection of various equipment and structures with earth mat. The earthing system shall consist of:
- i. Earth mats
 - ii. Risers to various equipment and structures
 - iii. Earthing conductors running in cable trenches/galleries/cellars in the RSS & AMS.
- 12.7.1.2 The LKE(02)-01 Contractor will have to provide a buried Earth Mesh in the substation site. The area over which the RSS/AMS and Control Room are situated, a separate earth mat suitably designed, shall be provided apart from the main Earth Mesh. The other way, that can also be adopted for RSS/AMS and control room building is to bond the building structure steel reinforcement and use it as foundation earth electrode. Earth electrode of Control room has to be interconnected. The design of the Main Earth Mesh shall be done by LKE(02)-01 Contractor, taking into account the site conditions (Soil Resistivity etc.).
- 12.7.1.3 The scope shall include all embedded parts, auxiliary equipment, mechanical linkages.

All such parts and accessories shall be deemed to be within the scope of supply of LKE(02)-01 Contractor, whether specifically mentioned or not.

12.7.2 SPECIFICATIONS

12.7.2.1 The system protective earthing for providing electrical safety includes earthing of metallic components, cable supports, lightning arresters etc, and shall conform to IS 3043:1987 and EN 50522 or latest.

12.7.2.2 The earth mat design and installation shall conform to IEEE 80-2013. The specifications in the manner altered, amended or supplemented and the Indian electricity Rules shall apply.

12.7.3 EARTH MAT

12.7.3.1 The Substation installation is subject to various faults such as operating over voltages, short circuits or lightning. In order to ensure protection to people and equipment, an earth mesh, sized to limit the step and touch voltages below the dangerous values, shall be provided.

12.7.3.2 The earthing network of switchyard and control building shall be designed by LKE(02)-01 Contractor taking into account the conductors' temperature rise in regard to the fault current levels.

12.7.3.3 The Contractor shall provide a buried earth mesh in the Substation site. As far as the area over which the 33 kV switchgear & Control Room are situated, a separate earth mat suitably designed shall be provided under the building, apart from the main earth mesh. The main earth mesh will be linked, to:

- a) the earth mat under the 33kV switchgear & control room
- b) All equipment structures supporting 33kV
- c) Substation fencing
- d) Lightning protection earthing

12.7.3.4 Parameters affecting the design of the earth mat

12.7.3.5 Several variable factors are involved in the design of an earth mat of Substations. The following are some of the parameters which affect the design of earthing mats.

- i. Magnitude of earth fault current (under consideration of current division factor)
- ii. Fault clearance time
- iii. Soil resistivity (under consideration of seasonal variations)
- iv. Resistivity of surface material
- v. Earthing mat geometry

12.7.3.6 Earth mat for each Receiving substation shall be designed individually. The earth mat shall be designed for the site conditions and shall ensure a low overall resistance of not more than 0.5 Ohm and current carrying capacity consistent with the fault current magnitude.

12.7.3.7 Short Circuit Level and Short Circuit Current

12.7.3.7.1 The maximum short circuit power (Isc) to be considered for the RSS/AMS, for different voltage levels, is as follows:

12.7.3.7.2 For 33kV: 2300 MVA Accordingly, the short circuit current to be taken into consideration, for the earth mesh design at Substations, shall be 40 kA for 33kV.

12.7.3.8 Duration of Fault Current

12.7.3.8.1 In India, the short term rating of most of the equipment is based on 1.0 second duration of fault. Therefore, 1 second shall be adopted for the duration of fault in the calculations to determine the size of earthing conductors. For the purpose of determining the safe step and mesh potentials, a duration of 0.5 second can be adopted. However, it shall be ensured that, on the basis of the protective gear and protective scheme provided, the fault is cleared within a period not exceeding 0.5 seconds. Corrosion factor of 2 is to be considered for MS.

12.7.3.9 Determining Max Grid Current (I_G)

12.7.3.9.1 The design value of the maximum grid current I_G is given by the following formula:

$$I_G = C_P \cdot D_f \cdot I_g$$

Where,

I_G = Maximum grid current in Amperes

C_P = Corrective projection factor

D_f = Decrement factor

I_g = Symmetrical grid current (RMS) in A

$$I_g = S_f (3 \cdot I_o)$$

Where,

I_o = Zero Sequence fault current

12.7.3.9.2 S_f = Current division factor (which relates to the magnitude of the portion of fault current to that of its portion flowing between the earth mat and surrounding earth, to the total fault current)

12.7.3.9.3 The calculation of S_f is done by deriving an equivalent representation of the overheard ground wires, neutrals etc, connected to the earthing mat and then solving the equivalent circuits to determine the fraction of the total fault currents which flow between the mat and the earth and through the ground wire or neutrals. In practice, at the design stage, it will be fairly accurate to adopt a value of 0.5 for S_f to determine the fault current that flows through the grid to earth.

12.7.3.9.4 Hence, the values of maximum grid current I_G to be considered for design of Earth mat for Substations of different voltage levels, may be taken as follows:

$$33\text{kV} \quad 0.5 \times 40 = 20\text{kA}$$

Important Note: The above values of max grid current are applicable only for determining the estimated values of Step and touch potentials. For determining the cross-sectional area of the earth mat conductor, full fault current should be considered.

12.7.3.10 General Design

12.7.3.10.1 A mesh made of earth conductor should be preferably cylindrical hard drawn copper conductor. Alternatively, mild steel flats/rods of appropriate size are acceptable. Earth conductors should be buried as deep as possible to keep a significant cylindrical equipotential area ensuring the earth resistance decreasing. Corrosion factor of 2 shall be considered for MS flat/rods.

12.7.3.10.2 The common practice is to bury the mesh at 0.8 to 1m depth, to avoid soil conductivity variation as regard to the variation of dryness or humidity conditions.

12.7.3.10.3 The connections to power equipment should be made by conductors in loops to guard

- against power equipment insulation from the earth mesh in case of a break in conductors.
- 12.7.3.10.4 The earth connections to equipment in antenna mode are strictly prohibited except if a redundant second connection is made.
- 12.7.3.10.5 Earth conductors shall be linked by fixed connection.
- 12.7.3.10.6 Earth conductors shall be MS/GI Conductor of appropriate size. The earthing connections between equipment and earth mesh may be realized by means of copper (min. 25 sq mm) or equivalent (see Clause 12.13.5 below).
- 12.7.3.10.7 The earth mesh implementation should avoid any permanent or occasional contact of earth conductors with other different metals.
- 12.7.3.10.8 In the case of frame in π configuration one mesh connection is installed at each base of masts. A bare cable fixed by bolted clamp runs along the masts and the beam of the structure
- Detailed Design earthing calculations for RSS/AMS (Complete) shall be submitted by contractor to the Employer for approval. GI Pipe electrode of suitable dia. to be used for earth pits.
- 12.7.3.11 Particular Arrangement to Minimize Voltage Rise
- 12.7.3.11.1 The ground is considered as a pure resistance regarding electrical phenomenon.
- 12.7.3.11.2 Only adverse resistivity conjugated with very high frequencies involve ground capacitive parameters.
- 12.7.3.11.3 To minimize electromagnetic coupling between low voltage cables and HV equipment, the cables shall be annealed types earthed at each end.
- 12.7.3.11.4 The aims shall be:
- Decrease the loop length given by cable shielding and the earth,
 - Limit the current in these shields in case of short circuit,
- The earth conductors may be buried as far as possible under the LV cable routing. The distance between LV cables and earth conductors shall be 0.30 m. at minimum to avoid any impact on LV cables in case of earth conductor overheating.
- 12.7.3.11.5 The earth mesh density shall be increased around circuit breakers and power transformer cells.
- 12.7.4 33 KV SWITCHGEAR & AMS/RSS & CONTROL ROOM BUILDING EARTHING**
- 12.7.4.1 Before laying the foundations of the building, a well interconnected earthing mesh using Cu/MS flat / rod of appropriate size will be laid (buried conductors under the foundation raft). It should be noted that MS flat/rod connection with Cu Earth mat poses problem of corrosion. Hence, Foundation Earthing can also be utilised, as Steel in concrete can be connected with copper in the soil as per IEC 62305-3 or latest (E. 5.6.2.2.1).
- 12.7.4.2 This mesh will connect with the 33 kV Switchgear Room and C&M via several rising links, with at least 2 links on each face of the building, at the building basement level. The screen/armour of cables between switchyard and control building will act as additional bonding conductors between both earth meshes.
- 12.7.4.3 This mesh will be connected to the general one by at least two connecting points using crimped connections.
- 12.7.4.4 Mild steel network of concrete structures shall be equipped with rising links with at least two links per face of the building.
- 12.7.5 EQUIPMENT/STRUCTURE CONNECTION TO EARTH MAT**
- 12.7.5.1 Main gantries, frames, equipment frame or tank and all metallic structures shall be

- connected via uninterrupted loops to the earth mesh
- 12.7.5.2 Clamps located at structure food shall be the connection point of riser conductors from earth mat. Riser conductors shall be exothermic welded to the earth mat conductors and bi-metallic connections to the structure shall be used where required to avoid corrosion.
- 12.7.5.3 All conductors linking equipment and support structures to the earth mat shall be sized for the maximum short circuit current and shall therefore have the same cross section as the earth mesh conductors.
- 12.7.5.4 When the equipment connection is only made for equipotential purpose, the cable cross section can be 25 mm² Cu or equivalent.
- 12.7.5.5 Earth cable fixings along the structures: All cables shall be fixed along the masts and beams as follows:
- a) Barecables shall be isolated from the metallic supporting structure to avoid any electrolytic corrosion. They shall be fixed via metallic (i.e. bronze or copper alloy) bolted clamp with bi-metallic sheet plates.
 - b) Insulated cables shall be fixed to the structure in the same manner as above when earth connections to the structure is necessary.
- 12.7.5.6 CT/PT Connections
- 12.7.5.6.1 The voltage transformers and current transformers shall be connected to earth as follows:
- a) Voltage transformers: To reduce high frequency interference transmission at the secondary side; the P2 terminal (cold point) of primary winding, located inside the transformer connection box shall be connected to the earth mesh .
 - b) Current transformers: The S2 terminal of secondary windings should be connected to the earth mesh, with a connection as short as possible.
- 12.7.5.7 Circuit Breaker Connections
- 12.7.5.7.1 CBs earthing shall be ensured through the supporting frame, itself connected to the earth, except when one part of the equipment is painted. In this case it is necessary to install an earth cable. In the first case a copper cable shall jump the mechanical connection between the CB and the frame:
- 12.7.5.8 Power Transformer Connections
- 12.7.5.8.1 Each line of running rails (if any) and rollers shall be earthed directly
- 12.7.5.8.2 The tank, which is insulated from the rollers shall be earthed via the tank protection current transformer
- 12.7.5.8.3 The S2 current transformer terminal shall be earthed via a separated connection.
- 12.7.5.8.4 The tap changer control box and auxiliary terminal box shall be installed insulated from the transformer tank in order not to by-pass the tank protection.
- 12.7.5.9 Isolator Connections
- 12.7.5.9.1 Incoming isolators earth blades should be linked to the isolator base by copper braid, the base being directly connected to the mesh.
- 12.7.5.9.2 Electrical control boxes should be earthed (dual point) directly to main earth mat.
- 12.7.5.10 Lightning Arrester Connections
- 12.7.5.10.1 For AIS connections, Lightning Arrester shall be provided with separate dual earthing.
- 12.7.5.10.2 The lightning arrester earth terminal shall be directly connected to an earth electrode and also to the earth mesh through separate bare copper cables fixed on the frame.

12.7.6 LIGHTNING PROTECTION

- 12.7.6.1 The entire Substation shall be protected against lightning strikes by providing either shield wires or lightning rods on gantries and dedicated masts, suitably spaced, to cover the substation area.
- 12.7.6.2 The height and locations of lightning masts shall be designed appropriately, with due consideration to the equipment layout in the RSS/AMS. Their implementation shall assure that all the equipment are within the protection zone provided by the lightning conductor/rod.
- 12.7.6.3 The Lightning conductor consists of:
- a) the lightning receiver projecting above the object to be protected
 - b) the earthing grid, and
 - c) the conductor which shall connect the receiver with the earthing grid.
- 12.7.6.4 The Contractor shall indicate the height and locations of the lightning masts, on the Substation Layout Drawing, He shall also submit supporting design calculations / drawings proving that all equipment are protected against lightning.

12.8 DIGITAL PROTECTION CONTROL SYSTEM**12.8.1 General**

- 12.8.1.1 This shall be read in conjunction with protection requirements stated elsewhere in this Specification.
- 12.8.1.2 The Contractor shall be responsible for the design, manufacture, delivery to site, installation, testing and commissioning of the Digital Protection Control System (DPCS). The DPCS design shall utilize the latest state of the art of proven technology to suit all requirements of the system.
- 12.8.1.3 The DPCS shall be highly reliable and of purpose built design for switchgear control and protection. The DPCS shall have proven records of successful service for similar ratings, configuration and design.
- 12.8.1.4 The DPCS shall provide data acquisition, data processing, overall protection control, interlocking, inter-tripping and monitoring of the entire power supply system consisting of 33kV AC switchgear, transformers, 33kV UG cables and associated electrical equipment as specified in this Specification. The DPCS shall have necessary interface with SCADA system.
- 12.8.1.5 The Contractor shall design the DPCS based on the following design philosophy:
- a) High reliability by the elimination of hard wiring and mechanical contacts.
 - b) Minimum maintenance by the use of self-diagnostic software program built into the system.
 - c) Open system design concept for each functional expandability.
 - d) Comprehensive data logging and event reporting system.
 - e) Fail safe design that will not result in dangerous situation for human and equipment due to component failure or malfunction in DPCS.
- 12.8.1.6 The Contractor shall be responsible for the complete design and successful implementation of the DPCS. The Contractor shall furnish detailed proposals of the DPCS for review by the Employer.
- 12.8.1.7 The DPCS shall consist of two levels, viz.:
- a) Remote Terminal Unit (RTU) level.

b) Protection and Control Unit (PCU) level.

- 12.8.1.8 The RTU level shall be a part of SCADA system from which RTUs shall receive and process data from the OCC / BCC. The RTUs shall then channel the processed data to PCUs through a communication link. The PCUs will interpret the data received and initiate the command to operate the associated equipment.
- 12.8.1.9 Likewise, PCUs will pick up the data from the associated equipment, process and transmit them to RTUs. Thus RTU and SCADA, data can be transmitted and reflected on the operational control terminal at OCC / BCC. Remote monitoring and controlling of power supply system can thus be achieved at the OCC / BCC.
- 12.8.1.10 The communication between PCUs and RTUs shall be established over IEC 61850 protocol in redundant configuration.
- 12.8.1.11 The design of DPCS shall take into consideration the onerous environmental conditions (i.e. temperature, humidity, dust content etc.) of the switch room in which it shall be installed.
- 12.8.1.12 The RTUs shall be supplied by LKE(02)-01 Contractor. Refer Chapter-18 for SCADA specifications and integration.
- 12.8.1.13 The DPCS shall be so designed that local control, overall protection, interlocking and inter-tripping of switchgear shall not be affected in any way in the event of communication failure between PCU and RTU.
- 12.8.1.14 A failure of either hardware or software in the DPCS shall not result in any unintended operation of associated equipment under all normal or abnormal conditions.
- 12.8.1.15 Upon detection of failures in the DPCS, the associated equipment shall be in fail-safe positions. Output of controls and tripping signals are prohibited.

12.8.2 Protection and Control Unit (PCU)**12.8.2.1 General Requirement**

- 12.8.2.1.1 The PCUs shall be rated to operate continuously at the battery float charge voltage.
- 12.8.2.1.2 The PCU shall be an intelligent microprocessor based self-diagnostic, protection, monitoring, control and metering unit. The PCU shall consist of protection relay module, monitoring module, control module and metering module functioning as a complete unit for continuous control, monitoring, metering, protection, interlocking and inter-tripping of the system.
- 12.8.2.1.3 The PCUs shall be flush mounted on local control panel/switchgear cubicles. The degree of protection for the PCU shall be IP53 as a minimum. The PCU shall be fully tropicalized to withstand the temperature, humidity and dust conditions to be encountered at site. The housing for the PCU shall be made of non-corrosive materials with high immunity against electrical disturbances in accordance with IEC 255 and other effects such as electromagnetic interference.
- 12.8.2.1.4 The PCU shall incorporate interface facilities which accept inputs from stand-alone protection relays, switchgear and other associated electrical substation equipment to achieve overall control, interlocking, inter-tripping, protection, monitoring and annunciation. All information within the PCU shall be made available OCC / BCC. All settings shall be activated at the remote OCC / BCC.
- 12.8.2.1.5 The PCU shall be designed with high availability and security of operation. A self-supervision scheme shall be incorporated to ensure early detection of internal faults in the PCU without any disturbance to the system. An internal fault once detected in any module shall be displayed on the PCU as well as at OCC / BCC (i.e. annunciator and printout). In the event of a failure of any module, the faulty module shall be easily replaceable with the plug-in/plug-out design without affecting the system.
- 12.8.2.1.6 The Contractor shall provide membrane keyboard panel or equivalent on the PCUs, to

- allow the Operator to change all appropriate settings, initiate test routines and view the data.
- 12.8.2.1.7 For most operational functions, the input of a personal password shall be necessary. This applies for all entries via the membrane keyboard or portable computer through the input/output port, which include operation on the relay such as:
- a) Setting of functional parameters (threshold functions)
 - b) Initiation of testing procedures etc.
- The password shall not be required for the read-out only for annunciation, setting parameters and fault data.
- 12.8.2.1.8 All data settings shall be stored in the non-volatile memory without the use of batteries preferably in the Electrical Erasable Programmable Read Only Memory (EEPROM). This is to allow PCU settings to be changed in the foreground without affecting the actual operating values in the background.
- 12.8.2.1.9 Visual display or indication shall be provided for operator to read out the setting of functional parameters and annunciations. In the event of a fault, all information relating to the fault shall be captured and stored in the PCU. The PCU shall have optical LED indicators to display any abnormal conditions. The memories of the LEDs shall be safeguarded against supply voltage failure. The optical indicators can be reset:
- a) Locally by operating the reset button on the PCU
 - b) Remotely by energizing the remote reset input at OCC / BCC
 - c) Automatically on occurrence of a new pick-up signal
- 12.8.2.1.10 The PCU shall perform bi-directional transmission for all data even under the busiest data transmission conditions within 300ms including data acquisition, processing and making data ready for transmission. The Contractor shall submit all necessary data and calculations in the design stage to demonstrate it and they shall be subject to review by the Employer.
- 12.8.2.1.11 All IEDs shall have separate IP address to enable the Employer to download the data, upload/modify the settings including downloading of disturbance records from the centralized Work Station.
- 12.8.3 Control & Monitoring Module**
- 12.8.3.1 The control & Monitoring module shall include but not limited to the following:
- 12.8.3.1.1 All controls of RSS/AMS shall be centralized at a control panel with mimic diagram in the control room.
- 12.8.3.1.2 A local/remote key lockable selector switch with indicator shall be provided on the control panel. This local/remote selector switch shall enable controls to be activated either remotely or locally, with indication to OCC / BCC.
- 12.8.3.1.3 The mimic diagram shall be colour coded for different voltage groups with LED indication lamps and operating switches indicating clearly the schematic layout including indication of manually operated isolators and voltage transformers.
- 12.8.3.1.4 All control, Inter-tripping, interlocking, indications and switches required to operate the power supply system shall include but not limited to the requirements as specified in this Specification. The Contractor shall ensure that the design shall take into consideration high security and reliability required for the execution of command to high voltage switchgear. Redundant circuitry shall be incorporated for critical control functions, e.g. interlocking, tripping and inter-tripping.
- 12.8.3.1.5 Controls shall be performed either at the PCU or at the remote OCC / BCC as commanded. Indication shall be available both at the PCU and Remote OCC / BCC.
- 12.8.3.1.6 Any modification required to the control sequence and logic shall be easily changed by simple program rewriting. All PCUs shall be capable of performing all necessary control functions required locally in the event of failure of SCADA system.

- 12.8.3.1.7 The control module shall process inputs from ancillary signals such as SF₆ gas pressure low and spring charge failure. The Contractor shall be responsible to ensure that enough input terminals are provided on the PCU, and an additional 25% of spare input terminals and processing capacity is provided for additional inputs and future expansion.
- 12.8.3.1.8 Where PCUs are required to trip circuit breakers, actuate signals or perform control duties, PCUs shall be designed to avoid inadvertent or simultaneous switching operations and shall give precedence to protective functions required due to unfavourable conditions, e.g. short circuits, internal faults, power supply failure, voltage fluctuation, etc.
- 12.8.3.1.9 The interlocking of the power supply system shall not be limited to the requirement specified herein. The Contractor shall also comply with the interlocking requirements elsewhere in this Specification. The Contractor shall ensure that inadvertent operation which will result in human injury or equipment damage is prohibited by the interlocking scheme. In general, the interlocking shall be achieved through redundant means such as:
- a) Programme logic
 - b) Electrical circuits
 - c) Mechanical key/ castle lock & key etc.
- 12.8.3.1.10 The Contractor shall submit detailed proposal for the interlocking facilities for review by the Engineer.
- 12.8.4 Metering Module**
- 12.8.4.1 The specific requirements for the metering module within the PCU shall include but not limited to the following:
- 12.8.4.1.1 Ammeter (ac ammeter with phase selector switch or DC ammeter as the case may be) for current indication in the following:
- a) All 33 kV AC circuit breaker panels for RSS/AMS
- For the three-phase ammeter, the phase selection shall be via push button, and the scale of all ammeters (AC or DC) shall be selectable by software. Monitoring of maximum phase current for main intake transformers, rectifier transformers and auxiliary transformers shall also be provided.
- 12.8.4.1.2 Voltmeter
- a) All 33 kV AC circuit breaker panels for RSS/AMS
- 12.8.4.1.3 Energy meter (kWh, 15min/30min summated kVA, kVAR) and power factor meter (PF).
- a) 33 kV AC Main Incoming breakers at RSS/AMS .
- Energy meter (kWh, kVAR) shall be of registered value type with demands aggregated every fifteen minutes or half an hour, as required, the interval being adjustable. Demand meter shall be synchronized with system clock. Stamping of maximum demand over a pre-determined period shall be possible.
- 12.8.4.1.4 The above metering requirements shall be read in conjunction with metering requirements as specified elsewhere i.e. in this chapter.
- 12.8.5 Protection Relay Module**
- 12.8.5.1 General requirement
- 12.8.5.1.1 Each PCU shall be integrated with a protection relay module within which standard protective relay features are incorporated. The protection system to be designed for bus bars, feeders, auxiliary transformers, , power transformers and other equipment shall comply with IEC 255 or BS 142. The application, performance and testing of protection relay modules shall be in accordance with the appropriate IEC standards.
- 12.8.5.1.2 All protection relay modules shall comply in accordance with the following IEC test

requirements:

Table 12.34: Compliance Standards for Relays

(a)	Dielectric test voltage (IEC 255-5)	2.0kV, 50Hz, 1min
(b)	Impulse test voltage (IEC 255-5)	5kV, 1.2/50μs, 0.5J
(c)	High frequency disturbance test (IEC 255-22-1 Class III)	
(i)	Common mode	2.5kV, 1MHz, 2s
(ii)	Differential mode	1.0kV, 1MHz, 2s
(d)	Electrostatic discharge test (IEC 255-22-2 and IEC 801-2 Class IV)	
(i)	Air discharge	15kV
(ii)	Contact discharge	8kV
(e)	Fast transient (IEC 255-22-4 Class IV)	
(i)	Power supply inputs	4kV
(ii)	Other inputs	2kV
(f)	Magnetic field (IEC 61000-4-8)	100 A/m
(g)	Electromagnetic field test (IEC 801-3 Class III)	10V/m 150kHz to 1000MHz

- 12.8.5.1.3 The protective relay modules shall be microprocessor based numerical type with continuous monitoring and self-diagnostic features to identify faulty modules or components. The protective scheme shall be so designed that the system remains stable during switching operation and other disturbances.
- 12.8.5.1.4 In the event of a system fault, the protection module shall be able to record values of a minimum latest five cycles with time stamping such as phase currents and earth fault current. The fault data shall be captured and displayed at the PCU's digital display, and at the remote OCC / BCC. The system should remain disabled until manual reset/ acknowledgement is done at the local or at the remote OCC / BCC. The local manual reset shall be capable of being reset without the necessity of opening the front cover.
- 12.8.5.1.5 The DC trip supply for the circuit breaker shall continuously be monitored by the individual protection relay module within the PCU.
- 12.8.5.1.6 In cases where two or more phase elements are included in one protection module, identification of each element shall be provided.
- 12.8.5.2 Types of Protection Relay Modules
- 12.8.5.2.1 The protection relay modules shall include all the protection requirements. The protection requirements shall comply with the latest IEC standards. The protection scheme shall include as required for each circuit, relaying out of following types or requirement defined elsewhere in this Specification (as relevant for various installations defined in respective chapters and drawings):
- 12.8.5.2.2 Over current Protection
- Over current with high set instantaneous tripping module shall operate with selectable characteristic such as definite time or normal inverse, very inverse, extremely inverse and long-time of the four inverse time (IDMT) type characteristics as specified in IEC 255 and BS 142 or latest. The current and time setting shall be variable continuously over the range.
- 12.8.5.2.3 Earth fault protection
- The requirement of earth fault protection shall be the same as the over current protection as specified in Clause 12.16.5.2.2 above.
- 12.8.5.2.4 Under voltage Protection

Three-Phase AC or single phase DC under voltage protection shall detect low voltage or loss of incoming supply voltage (disregarding transient voltage sags). The under voltage element and the operating time shall be adjustable to a suitable range to suit the system application. The under voltage protection shall monitor at least two of the phase voltages. Loss of voltage or low voltage on either phase shall initiate an alarm. If required, on selected feeders, loss of voltage on either phase shall initiate trip. The operating characteristic of the under voltage shall be selectable to either definite time or an inverse time characteristic.

12.8.5.2.5 Overvoltage Protection

Three phase AC over voltage protection shall be installed at the 33 kV Main Incoming breaker panel against any high voltages that may arise under severe transient fault conditions. The over voltage element and the operating time shall be adjustable to a suitable range to suit the system application. The over voltage protection shall monitor at least two of the phase voltages. Over voltage on either phase shall initiate an alarm. The operating characteristic of the over voltage shall be selectable to either definite time or an inverse time characteristic.

12.8.5.2.6 No voltage protection

No voltage relay shall be provided with adjustable voltage setting and time delay to detect live/no voltage status of measured circuit.

12.8.5.2.7 Touch voltage earth fault protection

The Contractor shall be required to design and provide a discriminative protection system to protect against step and Touch voltage exceeding the limit as specified

12.8.5.2.8 Phase Sequence Protections

Phase sequence protections shall be provided for monitoring each main power transformer including auxiliary transformer incoming circuit's phase sequence. Upon detection of incorrect phase sequence, incoming circuit breaker shall be inhibited from closing and an alarm shall be sent to OCC/BCC/LCC. Phase sequence elements and the operating times shall be adjustable to a suitable range to suit the system application.

12.8.5.2.9 Reverse Power Relay

Reverse Power relays shall be included in the incoming circuits at receiving substations to provide an instantaneous trip signal.

12.8.5.2.10 Pilot Wire Protection

The pilot wire protection scheme shall be of differential protection for each 33kV feeder cable. Delay time of pilot wire protection shall be specified. The differential protection shall be via differentials pilot wire relays with isolating (insulation) transformers to protect the pilot circuit. Pilot wire supervision scheme shall be capable of detecting pilot wire short circuits, open circuits or wrong connections. Adequate insulation shall be provided between pilot and relay circuits to prevent insulation failures due to induced voltages or differences in earth potential between the two feeder ends.

12.8.5.2.11 Busbar Protection

- i. If the detailed system analysis requires provision of busbar differential protection at a substation, the same shall be provided having one zone per busbar section with overlapped protective zones. The details of this protection scheme, wherever applicable, shall be subject to review by the Employer.

- ii. The protection shall include a bus supervisory scheme for alarm monitoring at the OCC/BCC. In the event of an operation of the busbar protection, the pertinent fault data shall be displayed at the PCU and at OCC/BCC.
- iii. The busbar protection scheme shall be such that any secondary component failure shall not cause the operation of the busbar protection.

12.8.5.2.12 Trip Circuit Supervision (TCS)

- i. Trip circuit supervision protection shall be provided to continuously supervise the integrity of each circuit breaker tripping circuit with the circuit breaker in the open or close position, and shall initiate an alarm in the event of the following fault conditions:
 - a) Loss of DC tripping supply,
 - b) In open circuit in trip circuit
 - c) A fail-to-trip condition after closing of a trip contact
- ii. Such trip circuit supervisory protection signals shall be interfaced with the respective PCUs for the supervisory operations. The alarm shall be time-delayed to prevent it operating during momentary dips in the DC supply voltage, or when the circuit breaker is opening.

12.8.5.2.13 Hand Reset Lockout Protection

Hand reset lockout protection in each switchgear bay shall be provided to prevent reclosing of breaker following operation of certain protection relay circuits, e.g. differential or pilot wire, earth (ground) fault and second level over temperature of transformer. Such hand reset lockout protection shall also be interfaced with the PCUs for the necessary functions.

12.8.6 Fault-Diagnostic Facilities

12.8.6.1 Full built-in tests (BIT) shall be incorporated in PCU system. The BIT shall test all hardware, software and interfaces of the systems. The BIT shall enable the operator/maintenance personnel to carry out trouble-shooting and maintenance of the system effectively.

12.8.6.2 Critical faults are defined as faults that will cause stoppage or major degradation of system performance. The protection and control system shall be designed to achieve a minimum of 99.99% fault detection capability of all critical faults using BIT. For critical faults not covered by BIT, the Contractor shall provide a list of these faults and explain how they can be readily detected by other means.

12.8.6.3 The Scope of the BIT diagnostics shall include but not limited to the following:

12.8.6.3.1 Power-up test

This test shall be executed during system start-up. Every part of the system shall be tested to indicate the readiness of the system as a whole. It shall be activated at system cold start or upon operator request.

12.8.6.3.2 Background test

This BIT shall run continuously with background test during system operation. The purpose of this procedure is to alert the operator if a fault is found. In the running, the BIT shall update the status on the BIT-Page on the display, and it shall be intelligent enough to help the operator to perform off-line BIT effectively. This test shall at least cover line replaceable unit.

12.8.6.3.3 Off-line test

This BIT shall be activated when in-depth troubleshooting is required to diagnose the failure. This BIT shall be able to locate a faulty shop replaceable unit (SRU) card and allow the maintenance and troubleshooting to be carried out.

12.8.7 Testing Facility

12.8.7.1 Contractor shall provide and install the interfacing software/tool (Employer's Computers) to communicate with relays and IEDs required for testing, commissioning, simulating, programming and parameterization of protection control system. These notebook computers shall be connected to the PCU interface port to perform the following functions as a minimum:

- a) Configuration and parameterization protection control system
- b) Load, read out of configuration data
- c) Control, interlocking, inter-tripping logic re-programming
- d) Relay simulation test
- e) Simulation of the control system
- f) Read out and display of protection control system diagnostic messages.
- g) Fault Diagnostic Functions.

12.9 OPERATION LOGIC & INTERLOCKS

12.9.1 RSS/AMS LEVEL LOGICS

12.9.1.1 The electrical energy shall be fed from Power Supply Authority grid at the nominated sub stations. The power shall be provided at 33kV level. The system shall consist of one new 33kV RSS/AMS i.e. at Vasantkunj.

12.9.1.2 RSS/AMS is with two 33kV incoming feeders, one shall be in SERVICE and other as HOT STANDBY to achieve 100% redundancy in the incoming feeder level. Each feeder shall be capable of feeding the entire load of respective loops feeding from that RSS/AMS and a coupling switchgear shall be provided at the incoming level to facilitate the power transfer from one bus to other.

12.9.2 Line Throw Over (LTO)

12.9.2.1 A line throw over device (LTO) is operational logic to be achieved with electrical and SCADA interlocks which are built-in to a suitable IED. LTO shall be installed for the incoming 33kV feeders in control and relay panel.

12.9.2.2 LTO Philosophy: In case of failure of the incoming 33 kV feeder which was in SERVICE, the LTO will automatically transfer from affected line (SERVICE) to the healthy line (HOT STANDBY) within a certain setting time delay. It shall be as fast as possible in terms of milli-second but the room shall be kept to allow the upstream level bus transfer (should be around 100 milliseconds) to be performed.

12.9.2.3 The waiting time for reclosing of incoming feeder to the RSS/AMS (a few seconds) is not recommended due to the following reasons:

- a) The changeover shall be rapid as the metro rail services are priority public transport

services;

b) The downstream time coordination chain consists of many steps

c) Hot standby feeder is available at each RSS/AMS

12.9.2.4 The above LTO logic shall be developed & implemented by LKE(02)-01 Contractor in 33 kV Control & Relay Panel installed at RSS/AMS. However, LTO activation / failure alarm shall be captured in SCADA in RSS/AMS, OCC and BCC.

12.10 110V DC POWER SUPPLY SYSTEM

12.10.1 SCOPE

12.10.1.1 This Specification applies to the 110 V DC Power Supply System, including battery & battery Charger used in for supply of 110 V DC power supply at Receiving Substations. The Scope of Work includes design, supply, installation, testing and commissioning of battery & battery charger, along with accessories.

12.10.1.2 The supply shall include all supporting structures, embedded parts, auxiliary equipment, mechanical linkages, auxiliary circuits wiring, interlocking devices necessary for their efficient operation. All such parts and accessories shall be deemed to be within the Scope of this Specification whether specifically mentioned or not.

12.10.1.3 The Contractor shall submit proposal for the supporting structure for installation of battery and battery chargers to the Employer for approval.

12.10.2 SPECIFICATIONS

12.10.2.1 The batteries shall conform to IEC 60623 or latest. The specifications in the manner altered, amended or supplemented and the Indian Electricity Rules wherever applicable shall apply.

12.10.2.2 The battery charger shall comply with IEC 60146 or latest. Its main components shall comply with the following specifications which shall be applied in the manner as altered, amended or supplemented by this Specification and the Indian Electricity Rules where ever applicable.

a) Mono-Crystalline Semi-conductor rectifier assembly: IS 4540-1968

b) Rectifier transformer: IS 2026 1977&81

c) Mono-Crystalline Semi-Conductor rectifier cells & stacks: IS 3895-1966

d) Electrical indicating instrument: IS 1248-1983

12.10.2.3 The battery protection shall be as close as possible to the battery and shall be contained in a separate enclosure for negative and positive pole respectively. The enclosure shall be made of insulating material. The connection between the battery and its protection shall consist of a single conductor and shall be run in such a manner so that they are protected from physical damage.

12.10.3 RATINGS

12.10.3.1 The Battery & Battery Charger shall be designed for the rating and other parameters indicated in Table 12.35;

Table 12.35: Battery & Battery Charger Rating

SN	Description	Battery & Battery Charger Rating
A	Battery	
1	Battery Type	Maintenance free Ni-Cd
2	Capacity	2 x 450 AH
3	Rated operating voltage	110 V

SN	Description	Battery & Battery Charger Rating
4	Material container	Translucent polypropylene
5	Backup capacity	8 hrs.
B	Battery Charger	
6	Battery Charger Type	Float cum Boost charger, two rates, Silicon diode/thyristor or full wave thyristor bridge type, suitable for floor mounting,
7	Nominal Input	3 Φ , 415Volt, Subject to variation of +10% & -10%
8	Nominal Output	110 V DC, Allowable voltage variation for +10 % / -15% variation of voltage or +3% variation of frequency is +1%.
9	Frequency	50 Hz Subject to variation of +3% & -3%
10	Short circuit current	7000 A for 1 sec
11	Recharge to 80% of battery capacity	4 hrs.
12	Residual ripple ratio	Less than 3%
13	Cooling	Natural
14	IP Protection	IP 41
15	Total number of chargers	3 numbers (2 regular and one stand by)

12.10.4 DESIGN PRINCIPLES FOR 110 V DC POWER SUPPLY SYSTEM

12.10.4.1 The DC system shall be robust, simple and clearly arranged. The DC system shall be based on the following principles:

12.10.4.1.1 High selectivity

12.10.4.1.2 Main distribution board located adjacent to the battery room

12.10.4.1.3 No common fuse for battery

12.10.4.1.4 An installation, which is free from the risk of short-circuits between the battery and the distribution board.

12.10.4.2 The DC system shall be earthed across a high resistance resistor, so that a simple earth fault shall not cause tripping of the system. For detection of an earth fault an insulation monitoring system shall be installed.

12.10.4.3 The DC system shall be designed to allow unloading tests, boost charging and maintenance of each component to be carried out during normal operation. This implies that provision shall be made for isolating the battery and the associated rectifier from the load.

12.10.4.4 Since the entire system cannot be designed so that a short circuit will never occur, circuit protection shall be provided and these shall provide absolute and safe selectivity, so that tripping is confined to the minimum. Only rapid protection characteristic may be used.

12.10.5 SYSTEM DESCRIPTION

12.10.5.1 The system shall consist of three battery chargers. The control and monitoring circuits shall be supplied with 110 V dc via two battery charger sets. In case of failure of one set, automatic changeover to the other set shall enable back up supply of the circuits normally supplied by the faulty one. A stand-by battery charger shall permit the preventive or corrective maintenance of one of the battery chargers.

12.10.5.2 For each one of the two 110 V dc supply sets, an automatic and manual change-over system from one source to the other shall be provided and operate as follows:

- 12.10.5.2.1 Automatic Mode: When a circuit breaker trips by lack / absence of voltage, the system switches automatically to the other source.
- When the voltage comes back to the normal source then after a delay (delay is to ensure that the voltage has stabilized) the system switches back automatically to the normal source by closing, first, the normal circuit breaker, then the opening the coupling circuit breaker. Paralleling between the both sources shall be as short as possible.
- 12.10.5.2.2 Manual mode with break: In this mode, only two of the three circuit breakers should be closed simultaneously. It shall be necessary to open one circuit breaker before closing another one.
- 12.10.5.2.3 Manual mode without break: In this mode, it shall be necessary to choose between which set the transfer shall be made.
- First source and coupling
 - Second source and coupling
- It shall never be possible to make a transfer directly between the first and the second sources. The transfer shall be obtained by closing the circuit breaker which shall remain closed at the end of the operation. The opening of the other one shall be obtained automatically. Paralleling between the both sources shall be as short as possible, but enough to ensure a good transfer.
- 12.10.5.3 The equipment supplied shall be highly safe and reliable and shall be described in detail when submitting the relevant drawings (equipment characteristics, layout plan, protections, monitoring) and it shall be guaranteed to eliminate all risks of incidents which may occur during the changeover operation from one source to the other.
- 12.10.5.4 In the normal situation and for each normal battery-charger set, the charger shall supply the control and monitoring circuits and shall deliver the battery trickle charge. The third battery-charger set being in stand-by mode.
- 12.10.5.5 In case of fade-out of the AC voltage, the battery shall immediately and without break replace the charger to ensure permanent power supply of the circuits and controls.
- 12.10.5.6 The entire 110V dc distribution system and the batteries shall be isolated from the earth satisfactorily. The overall condition of this isolation shall be monitored permanently by a specific and highly reliable device.
- 12.10.5.7 Each battery shall also ensure a supply to safety lighting when AC sources are not available.
- 12.10.6 BATTERY CHARGER**
- 12.10.6.1 The battery charger shall be float cum boost type suitable for charging Ni-Cd cells and duly certified, accepted by the battery manufacturer. Modular type battery charger to be considered.
- 12.10.6.2 Constant power drain shall be decided by the Contractor, to deliver the full duty. The minimum capacity of the battery shall not be less than 2 x 450 AH.
- 12.10.6.3 The charger shall comprise of an input transformer and silicon diode/thyristor or thyristor bridge (full wave).
- 12.10.6.4 The regulation system shall consist of plug-in modules fitted with polarization devices.
- 12.10.6.5 The System shall consist of 3 battery chargers, 2 Nos. battery chargers each shall be acting as a backup to the other. The third battery charger shall act as a standby to any of the normal battery chargers. In case of failure of any one of the normal battery chargers, automatic changeover to the other set shall enable backing-up of the supply of the circuits normally supplied by the faulty one. The third battery charger, acting as stand-by battery charger shall permit the preventive or corrective maintenance of one of the two normal battery chargers. Its actuation shall be obtained only after putting out

- of service one of the concerned battery charger to be maintained.
- 12.10.6.6 The charger shall include the following monitoring and measuring devices:
- a) Maximum and minimum DC voltages (threshold values to be defined)
 - b) Charger shut-down due to an internal fault.
 - c) General alarm for remote monitoring
- 12.10.6.7 The charger shall include the following control devices:
- a) A main ON/OFF Switch,
 - b) A normal/boost selector switch,
 - c) A control deliberate discharge
- 12.10.6.8 The AC and DC terminal strips shall be separated from each other.
- 12.10.6.9 The chargers shall be thyristors/IGBT regulated type, wired as a Graetz bridge. The incoming supply to the three-phase Thyristor Bridge is through a three phase double wound step-down transformer. The triggering of thyristor shall be controlled by an AVR unit, which senses feedback from output voltage and current.
- 12.10.6.10 Each battery charger shall be designed to ensure operation according to the battery ratings.
- 12.10.6.11 The battery chargers shall be installed in sheet cabinets. Ventilation shall be natural.
- 12.10.6.12 Operating and floating rates
- 12.10.6.12.1 The voltage at the charger current output terminals shall be automatically kept within +1% for variations of +10% / -15% of the AC voltage and of +1% of the frequency, whatever may be the output required.
- 12.10.6.12.2 The residual ripple ratio shall be as low as possible (less than 3.0%) so as not to disturb the various operating circuits.
- 12.10.6.13 Equalization charge operation
- This charge shall be able to take place up to the floating voltage within +1% under the same conditions as above.
- 12.10.6.14 Automatic change-over from floating to equalization charge and conversely. Following any failure of more than five minutes of the AC supply network, the charger shall automatically revert to the charge position right upon return of the voltage and shall remain on this position throughout the time set by an adjustable timer (from 1 hour to 20 hours). After this time, the charger shall return to floating operation. The charger shall remain in floating operation if the network failure is shorter than five minutes.
- 12.10.6.15 Direct operation
- The charger shall be capable of operating directly, without the battery, under the same conditions of accuracy as for the floating and charge modes.
- 12.10.6.16 Manually controlled operation
- Operation in manual control shall be possible, i.e. it shall be possible to execute manual adjustment of the voltage in case of malfunction of the regulator.
- 12.10.6.17 Alarms
- 12.10.6.17.1 The status of all battery chargers shall be indicated at the RSS/AMS, as well as at the OCC (through SCADA), as per the following convention.
- 12.10.6.17.2 Green – Healthy and in-service, Yellow – Healthy and standby, Red – Defective.
- 12.10.6.17.3 The change of status from “Healthy” to “Defective” shall be accompanied by an audible alarm/hooter, both at the control room of RSS/AMS and in the OCC. However, if the

RSS/AMS is unmanned, it shall be possible to annul the audible alarm function at the unmanned RSS/AMS.

12.10.6.17.4 The battery charger shall consist of following alarms and annunciations:

- a) AC Main Fail
- b) DC Over voltage
- c) DC Under voltage/Fail
- d) Charging Fail
- e) Battery Low
- f) Float/Boost charger failure
- g) Float output DC fuse failure/MOCB Trip
- h) Boost output DC fuse failure/MOCB Trip
- i) Earth leakage
- j) Controller Card Defective

12.10.6.17.5 One pair of potential free contacts grouping all faults shall be provided for remote annunciation at OCC.

12.10.6.18 Protections and monitoring

The charger shall be fitted with the following protections installed at its rear:

- a) A device limiting the current output by the rectifier to its rated current value with sufficient capabilities of adjustment and possible pick-up of the set point value
- b) Switching diodes,
- c) Breakers with fuse elements for overall protection on the transformer primary,
- d) Breakers with fuse elements in series with each rectifier component (diodes and thyristors)
- e) Breakers for the various auxiliary circuits,
- f) An on/off switch controlling a three pole make-break switch with magneto-thermal protection on the AC circuit and a two pole make-break switch with magneto-thermal protection on the DC circuit.
- g) The specific protection to ensure satisfactory operation and protection of the set
- h) Soft start feature
- i) Surge suppressor
- j) HRC Fuse at rectifier output
- k) Battery reverse polarity protection

12.10.6.19 Miscellaneous

The battery charger equipment shall also include:

- a) a signalling light denoting the opening of the make-break switch on the AC side, controlled by the tripping of one of the Miniature Circuit Breaker protecting the various circuits of the apparatuses,
- b) a signalling light denoting the opening of the make-break switch on the DC side through actuation of the magneto-thermal relay,
- c) a voltmeter indicating the voltage on the AC side

- d) a voltmeter indicating the voltage on the DC side
- e) A center-zero ammeters which shall indicate whether the battery is under charge or the battery is only delivering the load.
- f) the position of the various circuit-breakers and of the protection and fault relays shall be monitored through two flip-flop stages.
- g) An inspection light shall be fixed inside the charger compartment, which will automatically come "on" when the charger compartment is opened for inspection. This shall be independent of the "on/off" position of battery charger and shall be operative when the 415 V supply is available to the charger.
- h) The regulation systems shall consist of plug-in modules fitted with polarization devices.

12.10.7 BATTERY

- 12.10.7.1 Each battery shall be of stationary compact, nickel-cadmium type. They shall be maintenance free.
- 12.10.7.2 The batteries shall be of insulated pole type and wired in flowing voltage mode.
- 12.10.7.3 The capacity of the battery shall be reviewed by the Contractor taking into account the permitted voltage tolerance of the individual loads, the power consumption of various loads, the length of time they are in operation and the manner in which they draw power.
- 12.10.7.4 The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 (eight) hours as required to retain the power supply of the standby lighting and of the control/monitoring auxiliaries in case of total failure of the AC sources.
- 12.10.7.5 The battery protection shall be as close as possible to the battery and shall be contained in separate enclosure for negative and positive pole respectively. The enclosure shall be made of insulating material. The connection between the battery and its protection shall consist of single conductor and shall be run in such a manner so that they are protected from physical damage. Battery bank shall have On-line monitoring system.
- 12.10.7.6 Each battery half shall be connected through its own battery distribution board to the main board, and each battery half section shall have its own supervisory equipment to indicate and alarm for the maximum and minimum voltage levels on float-charge and earth fault.
- 12.10.7.7 The Contractor shall design to the Employer's approval. The Contractor's proposal shall include, but not limited to the following:
 - a) Type of mounting structure for the batteries
 - b) The material used for interconnecting the cells
 - c) Polarity markings on the cells
 - d) The material and size of lugs
 - e) Accessories like cell testing volt meters, rubber gloves etc.
 - f) Tapping of end cell for boost charging
 - g) Specifications like finishing current, maximum current for Trickle and boost
 - h) Rating of Trickle/ Boost charger
 - i) Wiring- size of the wires, colour code for DC and AC
 - j) Phase sequence of AC supply
 - k) The required rating of MCCB
 - l) Continuous rating of transformers, type of cooling, class of insulation

m) Painting, drawings etc.

12.10.8 GTP FOR BATTERY & BATTERY CHARGER

- 12.10.8.1 The Contractor shall submit the following minimum details at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Employer.
- 12.10.8.2 The list indicated below is the minimum requirement of details to be provided by the Contractor and it is not exhaustive. Contractor may provide additional relevant details, if any.
- 12.10.8.3 The Contractor shall be required to submit the detailed dimensioned and control circuit drawings in five hard copies and one soft copy in CD/DVD.

Table 12.36: GTP for Battery & Battery Charger Rating

SN	Description	Unit	Values
A	BATTERY		
1	Standards		IEC 60623 (Latest)
2	Type		
3	Stationary compact		
4	Maintenance free		
5	Capacity offered for 10 hours discharge duration	AH	2x450
6	Voltage per cell	V	
7	Number of cells		
8	Rated operating voltage	V DC	110
9	Maximum output current	A	
10	Documentation to be supplied		
11	Dimensions Length Width	mm mm	
12	Total weight	kgf	
B	BATTERY CHARGER		
1	Manufacturer		
2	Type of battery charger		
3	Standards		
4	3 Phases power supply	V AC	
5	Frequency	Hz	
6	Rated DC voltage	V DC	
7	Power conversion		
8	Cooling		
9	Allowable output voltage variation for +10%/ -15% variation of supply voltage for +3% variation of frequency		
10	Average winding Temperature rise over Ambient	Degree	
11	Internal Cabling / Wiring		
12	Residual ripple ratio		
13	Recharge to 80% of the battery capacity		
14	Voltmeter on AC side		
15	Voltmeter on DC side		

SN	Description	Unit	Values
16	Ammeter on DC side		
17	AC Main Fail Alarm		
18	DC Overvoltage Alarm		
19	DC Under Voltage Alarm		
20	Charging fail Alarm		
21	Battery low Alarm		
22	One pair of Potential Free Contact grouping all fault to be provided for remote Annunciation at OCC		
23	Current Limit Protection		
24	Soft start Feature		
25	Surge suppressor		
26	HRC Fuse at rectifier Output		
27	Battery Reverse Polarity protection		
28	Automatic Changeover feature		
29	Switchgear		
30	Input Side		
31	Output side		

*The capacity of the battery shall be designed by the contractor taking into account the permitted voltage tolerance of the individual loads, the power consumptions of various loads, the length of time they are in operation and the manner in which they draw power. The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 hours. Battery capacity shall not be less than 450 AH, in any case.

12.10.9

TEST SHEET FOR BATTERY & BATTERY CHARGER

(As per IEC 60623, IEC: 62259, IS 10918 & 8320(Latest))

Table 12.37: Test Sheet for Battery & Battery Charger Rating

INDICATIONS	TYPE of TEST			
	Type	Routine	On site	Specials
1) BATTERY				
Electrical specifications checking (on one cell)	X			
Visual inspection (Dimensions, Weight, Markings & Layout)		X	X	
Capacity measurement		X	X	
Discharge test		X	X	
Air Pressure Test	X		X	
Field Tests	X		X	
Cranking Ability (When applicable)	X		X	
Retention of Charge	X		X	
Insulation Resistance	X		X	
2) BATTERY CHARGER				
Temperature rise*	X			
Rated short duration power frequency withstand voltage	X	X		

INDICATIONS	TYPE of TEST			
	Type	Routine	On site	Specials
Floating operation mode test	X	X	X	
Equalization operation mode test	X	X	X	
Direct operation mode test	X	X	X	
Protection devices operation	X	X		
Setting test	X	X	X	
Visual inspection	X	X	X	
Functional Test	X	X	X	
Efficiency	X	X	X	
Ripple test	X	X	X	
Regulation	X	X	X	
Insulation resistance test	X	X	X	
Output short circuit test	X	X	X	
HV test	X	X	X	

*For this type test, the Contractor could provide a report on a similar equipment

12.11 DC DISTRIBUTION BOARD

12.11.1 SCOPE

12.11.1.1 This Specification applies to the 110 V DC distribution board used for distribution of DC power at 110 V DC at Receiving Substations. The Scope of Work includes design, supply, installation, testing and commissioning of dc distribution along with accessories.

12.11.1.2 The supply shall include all supporting structures, embedded parts, auxiliary equipment, mechanical linkages, auxiliary circuits wiring, interlocking devices necessary for their efficient operation. All such parts and accessories shall be deemed to be within the Scope of this Specification whether specifically mentioned or not.

12.11.2 SPECIFICATIONS

12.11.2.1 The distribution board covered by this Specification comply with relevant Indian Standards and shall confirm to the IE Rules as amended up to date wherever applicable. Protection rating shall be IP 43.

12.11.3 RATINGS

12.11.3.1 The DCDB shall be designed for the expected below rating and other parameters ;

Table 12.38

SN	Description	DCDB Rating
1	Circuit Breakers	MCCB
2	CB Rating	200 A
3	Busbar Rating	500 A
4	Short circuit rating	4KA for 1 sec.

12.11.4 Design Principles

The fundamental demand on a DC system is that it must be robust, simple and clearly arranged.

The DC system shall be based on the following principles:

1. High selectivity
2. Main distribution board located adjacent to the battery room
3. No common main fuse for battery
4. An installation, which is free from the risk of, short-circuits between the battery and the main distribution board.

The DC system shall be earthed across a high resistance resistor, so that simple earth fault shall not cause tripping of the system.

The DC system shall be designed to allow unloading tests, boost charging and maintenance of each to be carried out during normal operation; this implies that provision shall be made for isolating the battery and the associated rectifier from the load.

Since the entire system cannot be designed so that short-circuit shall never occur, it must be provided with circuit protection, these shall provide absolute and safe selectivity, so that tripping is confined to the minimum. Only rapid protection characteristic may be used.

12.11.5 CONSTRUCTION FEATURES

12.11.5.1 Distribution of the 110 V DC sources shall be gathered inside three specific cabinets with two incomers & bus coupler.

12.11.5.2 These cabinets shall be equipped with doors, fitted with flexible seals, close via lock-bars and on which shall be installed a mimic diagram with signalling lights status the position of the main equipment.

12.11.5.3 Equipment

Each cabinet shall include the following as a minimum (list not restrictive):

- a) Isolating switch
- b) Master power supply circuit breakers
- c) Non-return diodes and set of normal/stand by supply bars
- d) The current and voltage protection relays
- e) The isolation monitoring
- f) The automatic and manual device for change-over from one source to the other, with selector switches for automatic and manual, with or without break
- g) The coupling circuit-breaker for the both 110 V DC sources

12.11.5.4 Outgoing Feeders

The outputs, protected by circuit-breakers, whose rating shall be selected according to the power of the installation services, corresponding to the distribution circuits intended to supply notably:

- a) the control, monitoring and protection devices
- b) the power transformer tap changers monitoring
- c) the auxiliaries of the fire protection installations
- d) the safety lighting installations
- e) the output circuit breaker as spare

- f) The signalling lights
- g) An interlocking device prohibiting paralleling
- h) The position limit switches of the main apparatuses

12.11.5.5 Provision of the indications shall be made at the level of these cabinets of the auxiliaries section.

12.11.6 TEST SHEET FOR DCDB (As per IEC 60439, 60529, 60947(Latest))

Table 12.39

Sl. No	INDICATIONS	TYPE OF TEST			
		Type	Routine	On site	After Shipment
1	Rated short duration power frequency withstand voltage Test	X	X	X	
2	Operation Checking	X	X		
	a. All switchgear ON/OFF	X	X	X	
	b. All lamp ON/OFF	X	X	X	
	c. Control circuit check as per schematic	X	X	X	
	d. All relay & all meters	X	X	X	
	e. Verification of providing interfacing with SCADA System	X	X	X	
3	Visual Inspection (Verification of Dimensions, Layout, BOM)	X	X	X	
4	Dielectric test	X	X		
5	Degree of Protection	X			
6	Field Test			X	
7	Insulation resistance test	X	X	X	

12.12 AC DISTRIBUTION BOARD

12.12.1 SCOPE

12.12.1.1 This Specification applies to the AC Distribution Board used for distribution of AC power at 415/240 V AC at Receiving Substations. The Scope of Work includes design, supply, installation, testing and commissioning of ACDB along with accessories.

12.12.1.2 The supply shall include all supporting structures, embedded parts, auxiliary equipment, mechanical linkages, auxiliary circuits wiring, interlocking devices necessary for their efficient operation. All such parts and accessories shall be deemed to be within the Scope of this Specification whether specifically mentioned or not.

12.12.2 SPECIFICATIONS

12.12.2.1 The ac distribution board (ACDB) covered by this Specifications shall comply with the relevant Indian Standards and shall conform to the I.E. Rules as amended up to date wherever applicable. Protection rating shall be IP 43.

12.12.2.2 This Specification shall be read in conjunction with relevant drawings provided in Tender Drawings.

12.12.3 RATINGS

12.12.3.1 The ACDB shall be designed for the expected rating and other parameters indicated in Table 12.40;

Table 12.40: ACDB Rating

SN	Description	ACDB Rating
1	Circuit Breakers	ACB
2	CB Rating	630 A

3	Busbar Rating	1000 A
4	Short circuit rating	7KA for 1 sec.

12.12.4 CONSTRUCTION FEATURES

12.12.4.1

Note: For Vasantkunj RSS/AMS, no separate 200kVA transformers are provided as the requirements are being met from depot auxiliary transformers. Refer tender drawings.

12.12.5 DESCRIPTION

12.12.5.1

Distribution of the low voltage circuits shall be provided with two incomer with coupler cabinet, each supplied by the corresponding auxiliary transformer.

12.12.5.2

These cabinets shall be placed side by side to form a consistent assembly and shall include a bar-type mimic diagram with indicating lights showing the status of the equipment. Each Cabinet shall include a master protection circuit breaker, plug-out type, lockable by lock and key. The two incomer circuit breakers from auxiliary transformers and the bus coupling circuit breakers shall be interlocked in such a way that normally only one out of the two can remain in a closed position at any point of time. An automatic changeover switch shall be included. In case of restoration of power to ensure that the auxiliary transformer power doesn't get shorted among themselves.

12.12.5.3

In normal operation two main breakers are closed and coupling breaker is open. In case of no volts on one of the two bus bars, the relevant circuit breaker trips and the coupling circuit breaker closes with two (2) seconds delay to determine that there are no volts (not to change for a temporary voltage transient).

12.12.5.4

On restoration of the normal supply, the coupling circuit breaker shall trip with a delay of two seconds to ensure that the voltage has stabilized and the tripped circuit breaker shall close within 300 ms to ensure not to parallel both auxiliary transformers.

12.12.5.5

In addition, these circuit breakers shall be interlocked with the auxiliary transformer cubicle to ensure that:

- It is not possible to open the door of the transformer cubicle if the circuit breaker of the particular transformer is in 'closed' position.
- When, due to an overload on the downstream of the breaker, the circuit breaker trips, it causes the corresponding 33 kV circuit breaker on the upstream of the particular transformer also to trip.
- When, due to a 'transformer fault' the 33kV circuit breaker of the concerned transformer trips; it causes the corresponding LV circuit breaker also to trip.
- If door of the transformer cubicle is opened with its key, it should trip the particular 33 kV circuit breaker and LVCAB i.e. both side circuit breakers, in case any of these are in closed position

12.12.5.6

Other Components

12.12.5.6.1

The main circuit breaker cabinets shall include the following as a minimum (list is only indicative and not restrictive).

- A master protection circuit breaker, plug-out type, lockable by lock and key
- A set of four pole copper bus bars 1000A (7 kA for 1 sec. as required) for supply.
- A set of output circuit-breakers including battery chargers
- Auxiliary contacts
- An interlocking device prohibiting paralleling

- f) Similarly, the coupling cabinet shall include the following:
 - g) A master protection circuit breaker, plug-out type, lockable by lock and key
 - h) A set of four pole copper bus bars (short Circuit current 7kA for 1 sec. as required) for supply.
 - i) Protection circuit breakers for protection of the stand by battery charger
 - j) Automatic change over for the supply of the stand by battery charger
- 12.12.5.6.2 The supply of the stand by battery charger set shall be realized through the medium of an automatic changeover contactor set.
- 12.12.5.6.3 As far as the outgoing feeders for control room and maintenance room lighting, fans, air-conditioning etc. and those for 33kV Switchyard, 33 kV Switchgear, Battery chargers and for the 415 V distribution board requirements are concerned, the Contractor shall provide adequate number of feeders to meet the full requirements. The details shall be submitted by the Contractor to the Employer, for his review and approval.
- 12.12.5.6.4 The following is the minimum expected requirement in each of the main circuit breaker cabinets.
- a) 4 feeders each with 25A MCB, for Control Room & 33 kV Switchgear room lighting, fans, air-conditioning etc.
 - b) 3 feeders each with 25A MCB, for 33 kV Switchyard
 - c) 2 feeders each with 25A MCB, for Transformers, OLTC
 - d) 2 feeders each with 25A MCB's for 33 kV Switchgear
 - e) 2 feeders each with 25A MCB, for Relay Panels
 - f) 2 feeders each with 100A MCCB's for Battery Chargers
 - g) 2 feeders each with 25A MCB's for Aux. Transformer (as applicable)
 - h) 2 feeders each with 25A MCB's for NIFPS (as applicable)
 - i) 6 feeders each with 25A MCB, as spares
- 12.12.6 LOW VOLTAGE CIRCUIT BREAKER**
- 12.12.6.1 The moving part of incoming circuit breaker shall consist of a metal chassis fitted with a withdrawal system. This chassis shall carry a manually controlled four-pole circuit breaker with a current rating of 630 A.
- 12.12.6.2 The circuit breakers shall have sufficient breaking capacity to sustain any short-circuit which could occur without suffering damage.
- 12.12.6.3 They shall be fitted with:
- a) A four pole, microprocessor based numerical trip out relay and a differential module. These shall ensure a good selectivity with downstream protection, and should have adjustable current & time setting.
 - b) Eight power connectors split into two groups of four (inlet and outlet connectors),
 - c) A mechanical "closed" and "open" indicator (red and green)
 - d) An interlocking system which prevents any movement of the chassis if the circuit-breaker is closed,
 - e) A lock which only releases the key when the moving section is unplugged and which engages in the fixed part,
 - f) A manual control system consisting of a lever that can be operated from outside

- g) A grounding system, which maintains the chassis ground during plugging-in until the power and monitoring connectors are engaged and which still ensures the chassis is grounded in the unplugged position.

12.12.7 VOLTAGE MONITORING

12.12.7.1 A voltage monitoring system shall be mounted upstream of the miniature circuit breaker on each main inlet. This system shall comprise:

- a) A moving-iron voltmeter and a selector switch to select voltages across phases and between each phase and the neutral,
- b) A 415 V indicator light protected by HRC fuses,
- c) An On/Off voltage relay with a permanent power supply.

12.12.8 CURRENT MONITORING

12.12.8.1 There shall be a current monitoring system mounted downstream of the main circuit breaker protected by HRC fuses. This monitoring system shall comprise three 5A, 15 VA, class 2 current transformers each feeding a moving-iron ammeter.

12.12.9 PROTECTION

12.12.9.1 These shall be installed in, or on the front panel of the upper compartment together with the monitoring systems.

12.12.9.2 They shall comprise:

- a) Auxiliary relays (Alarms, voltage etc.),
- b) Test point boxes,
- c) Indicator lights and a "lamp test" push button,
- d) Selector switches and push button,
- e) The fuses required to protect this equipment and the monitoring systems.
- f) Metering instruments like ammeters, voltmeters etc.

12.12.9.3 However, in general, all accessory equipment which contributes to the operation of a power switching component shall be mounted in the same cabinet as the component.

12.12.9.4 The Contractor shall submit comprehensive proposals for control, monitoring and protection (including alarm at OCC) to Employer for approval.

12.12.10 MANUFACTURING AND OPERATING PRINCIPLES

12.12.10.1 General

12.12.10.1.1 The equipment used in the cabinets shall consist of single insulation pre-fabricated units complying with IEC standard 157-1.

12.12.10.1.2 The Contractor shall supply a copy of the test report for the equipment.

12.12.10.1.3 The main inlets and outlets shall include compact plug-in circuit breakers designed such that the circuit breaker can be removed and replaced quickly without needing access to live parts.

12.12.10.1.4 The contactors used in permanent board and permanent stand-by board shall be fixed.

12.12.10.2 Interchangeability

All moving components of plug-in units of the same type and with the same electrical characteristics shall be interchangeable.

12.12.10.3 Installation

12.12.10.3.1 The boards used in primary cabinets shall be listed and allocated an identification

- number to indicate its function.
- 12.12.10.3.2 The structure shall comprise:
- The uprights
 - The hardware
 - The main busbars
 - The inlets and / or coupling busbars
 - The identification
- 12.12.10.3.3 Primary cabinet shall consist of three such structures:
- One for first incomer
 - One for second incomer
 - One for coupling board
- 12.12.10.4 Equipment
- The board shall comprise the following compartments, from the bottom:
- A fixed compartment housing the monitoring systems and relays
 - A plug-in compartment for the incoming circuit breakers;
 - A fixed compartment containing the protection equipment or the changeover switch gear between the two power supplies for the permanent stand-by cabinet;
 - The draw out compartments for the main outlets (> 63A);
 - The fixed compartment for the other outlet;
 - And the terminal strips on the rear panel
- 12.12.10.5 The boards shall be protected against fire by means of an 'automatic fire detector and extinguisher system', 'Fire trace' type or equivalent, complete with clean agent direct gas flooding system (NOVEC)/CO₂ Gas cylinder, approved by Chief Controller of Explosives, valve, flexible detection and delivery system in the form of a flexible tube made of special polymer, capable of withstanding a normal pressure of 12 bar and a maximum pressure of 20 bar, suitably routed inside the panel for detection of fire. The gas cylinder shall be suitably mounted on the panel and shall be capable of flooding the cubicle with the gas, within the shortest response time, not more than 10 seconds after the fire is sensed by the flexible detector tube. The Contractor shall submit the complete technical data of the system to the Employer, for approval. Any alternative method of achieving the above requirement, if proposed by the Contractor, may also be accepted by the Employer.
- 12.12.10.6 The keys for all LV cabinets and boxes shall be of the same type.
- 12.12.10.7 Wiring and Grounding
- 12.12.10.7.1 Only copper cable, multi-wire or single wire cables, with a cross section area of 1.5 mm² or more, shall be used for control, protection and monitoring wiring. All power connections shall be made at the bottom of the board. The terminal strips shall be designed to accept cables one gauge higher in cross-section than the cable used. Separators shall protect the strip against the danger represented by failing conductive objects.
- 12.12.10.7.2 Frames shall be made electrically continuous by connection with copper bar, at least 30 x 3 mm or 50 x 6 mm GI strip, provided for the grounding of the outlets.
- 12.12.11 TEST SHEET FOR ACDB (As per IEC 60439, 60529, 60947(Latest))**

Table 12.41

Sl. No	INDICATIONS	TYPE OF TEST			
		Type	Routine	On site	After Shipment
1	Rated short duration power frequency withstand voltage Test	X	X	X	
2	Operation Checking	X	X		
	a. All switchgear ON/OFF	X	X	X	
	b. All lamp ON/OFF	X	X	X	
	c. Control circuit check as per schematic	X	X	X	
	d. All relay & all meters	X	X	X	
	e. Verification of providing interfacing with SCADA System	X	X	X	
3	Visual Inspection (Verification of Dimensions, Layout, BOM)	X	X	X	
4	Dielectric test	X	X		
5	Degree of Protection	X			
6	Field Test			X	
7	Insulation resistance test	X	X	X	

12.13**LV CABLES****12.13.1****SCOPE**

12.13.1.1 This Specification covers all LV AC & DC cables used in distribution, control and monitoring. These cables shall be used in Receiving Substations, depots & Auxiliary Main Substations. The scope of work includes design, supply, installation, testing and commissioning of cables.

12.13.1.2

The Specification defined hereunder shall be applicable to the RSS/AMS.

12.13.2**SPECIFICATIONS**

12.13.2.1

The cable used for LV systems shall comply with IEC 60502 & IS 7098 for cables, and IS 694 for Wires. The specifications shall be applied in the manner altered, amended or supplemented by the latest version of these specifications and also the relevant provisions of the latest Indian electricity rules wherever applicable.

12.13.2.2

Cables/wires shall be Fire Retardant Low Smoke Type (FRLS) with XLPE insulation.

12.13.3**RATINGS**

12.13.3.1

The cables shall be designed for the rating and other parameters indicated in Table 12.42;

Table 12.42: LV Cable Rating

SN	Description	Values
1	Type	Semi flexible
2	Conductor	Bare or tinned copper
3	Rated voltage	1.1 kV
4	Fire retardant property	FRLS

12.13.4**CONSTRUCTION FEATURES**

12.13.4.1

The cables shall be manufactured by a company having ISO accreditation for quality.

12.13.4.2

Conductors supplied for low voltage or remote-control lines shall have a bare or tinned copper core. Semi flexible conductors shall be used; rigid conductors shall be prohibited. The conductors' cross-section shall be a standard value, and shall never exceed 240 mm²; above this value, the appropriate number of conductors shall be connected in parallel.

12.13.4.3

The minimum cross-section of conductors shall not be less than 1.5 mm². The

minimum cross-section of current transformers secondary circuits shall not be less than 6 mm². The minimum cross-section of voltage transformers secondary circuits shall not be less than 4 mm². The voltage rating of distribution cables shall be 1100 Volts.

12.13.4.4 Grounding conductors shall have green/yellow-stripped insulation. Neutral conductors are to be deemed as being active conductors.

12.13.4.5 Cables and wires shall be treated to withstand flames propagation. All LV cables and wiring shall be FRLS Type at Receiving Substation.

12.13.5 CABLE CROSS SECTION

12.13.5.1 Determining the technical core section of a cable implies determining the smallest standard cross-section in the type of cable selected which, under the applicable environmental conditions, shall satisfy the following criteria:

12.13.5.1.1 Normal temperature rise

12.13.5.1.2 Maximum voltage drop

a) 3% for main distribution lines (between primary and secondary cabinets)

b) 3% for lighting circuits

c) 5% for power circuits

d) 12% for motor circuits during start-up

12.13.5.1.3 Overload and short-circuit

12.13.5.1.4 Protection against indirect contact

12.13.5.1.5 If heavy currents are to be carried, the economic section must also be taken into account.

12.13.6 TESTS

12.13.6.1 All cables shall comply with the IEC standards (IEC 288 and IEC 227) in force and shall, at least, have satisfied the required tests

12.13.7 IDENTIFICATION

12.13.7.1 All conductors, cables, wiring, terminals and equipment shall be identified according to the indications on the diagrams.

12.13.7.2 This identification shall be placed so as to be easily read from the accessible face of the cable or wiring. In all structures, cables shall be marked both at their ends and approximately every 20 meters over their full length, particularly when they change of direction, enter conduits, etc.

12.13.7.3 Along the track, cables shall be identified in the pulling chambers and at their ends.

12.13.7.4 The identification shall be realized with tag-holder providing the following guarantees:

a) Easy fastening,

b) Non flammable,

c) Permanence of the marking

d) Easy reading

12.13.7.5 The tag-holder and its bi-directional marking type shall be submitted for the Employer's approval.

12.13.8 CONNECTION

12.13.8.1 All connections, whether made by end-fittings, sleeves or terminals, shall comply with good trade practice.

12.13.8.2 The connection terminal blocks supplied by the Contractor shall be identified and includes space enabling precise referencing of all terminals, also possessing all guarantees of permanence and fastening.

12.13.8.3 The crimped section of cables shall be insulated by heat-retractable sleeve.

12.13.8.4 The screen of screened cables shall be connected to earth and continuity shall be ensured.

12.13.9 LV CABLE INSTALLATION

12.13.9.1 This Specification is made to define the characteristics of low voltage cables used for distribution, control and monitoring. They shall be supplied either in A.C. or in D.C. They shall be used for electrical connection between equipment of RSS/AMS, TSSs and ASSs.

12.13.9.2 All wiring shall be carried out with 1100V grade, single core, stranded copper conductor wires with PVC insulation. Semi flexible conductors shall be used; rigid conductors shall be prohibited.

12.13.9.3 In general, the cable laying shall comply with the principle of separation between the control and monitoring circuits and the auxiliary circuits of the building (lighting, power, and miscellaneous auxiliaries).

12.13.9.4 Wire terminations shall be made with solder less crimp type and tinned copper lugs, which firmly grip the conductor. Insulated sleeves shall be provided at all the wire terminations. Engraved core identification plastic ferrules marked to correspond with panel wiring diagram shall be fitted at both ends of each wire. Ferrules shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks.

12.13.9.5 The Contractor shall be solely responsible for the completeness and correctness of the internal wiring and for the proper functioning of the connected equipment.

12.13.9.6 Systematically, for control and monitoring cables, all the links of a section shall include 15% spare conductors with at least one spare conductor per cable.

12.13.9.7 Cable ways of perforated sheet:

12.13.9.7.1 This shall be the normal laying mode of the link conductors.

12.13.9.7.2 It shall be used systematically along wiring runs necessitating special mechanical protection, precaution or when it is necessary to carry several cable-way levels inside limited space.

12.13.9.7.3 Their width shall be defined to enable addition of at least 15% of the number of the cables initially foreseen.

12.13.9.7.4 In general, when sheets shall be superimposed, the clear heights between one another shall be defined so as to provide perfect accessibility to the cable layers they carry.

12.13.9.7.5 All necessary arrangements shall be taken to enable addition or possible replacement of a conductor in a layer and, consequently, to enable its pulling. Several superimposed layers of cables may use the same support sheet but superimposition shall be limited to cables of the same section. If crossings are required between cables or layers coming from different sections, a metal element shall be placed between the layers in way of the crossing. The extent and number of the fastening fittings shall be determined so as to avoid all distortions between rests. The anchoring process of the fittings shall be suited to the supporting element concerned.

12.13.9.8 Cable ways on fittings or bridges:

12.13.9.8.1 This arrangement shall be used only for small layers, not justifying the use of slabs.

12.13.9.8.2 The fittings or bridges shall be sized accounting for possible addition of 15% additional cables.

- 12.13.9.8.3 One independent fitting shall be provided per set of conductors coming from a same section; in no event may conductors coming from different sections be fastened to a common fitting or bridge.
- 12.13.9.9 Insulating tubes
- When conductors are gathered in strands, they may be laid inside an insulating tube. This solution shall be used only for short runs.
- 12.13.9.10 Metal Tube
- Certain circuits may have to be protected by means of rigid steel tubes or flexible metal tube; all the necessary precautions shall be taken to insulate the fastening so as not to cause contacts between masses of different categories. These metallic tubes shall be properly earthed.
- 12.13.9.11 Fastening of cables and conductors to their supports:
- 12.13.9.11.1 Fastening of the cables to their supports, whether perforated steel, fittings or bridges, shall be made by means of loosening-proof clamps made of flexible insulating material and by mean of mechanical tightening.
- 12.13.9.11.2 If several cables of the same section use a common horizontal run, they shall be able to be gathered and clamped by the same fastening clamp.
- 12.13.9.11.3 Fastening of conductors shall always be provided immediately next to their connection ends. In no event may connection to a terminal block be deemed as being fastening and permanent strain may be exerted on the terminals.
- 12.13.9.12 Mechanical protection of cables and conductors:
- 12.13.9.12.1 In all cases when the layout of the conductors of bar set of the earthing circuits could render them vulnerable (floor crossings, vertical layers or horizontal crossings through service passages), the necessary mechanical protection for the cables and conductors shall be ensured.
- 12.13.9.12.2 These protections shall show sufficient strength to prevent any damage to the cables and conductors following impacts, which may occur during equipment handling operations; they shall also possess good resistance against corrosion.
- 12.13.9.12.3 For vertical layers, the Contractor shall ensure supply and installation of sheet casing ensuring efficient protection up to a height of 2 meters above ground. In case of single or limited number of conductors a spare tube shall always be laid.
- 12.13.9.12.4 Whenever LV cables or conductors are placed along a run adjacent to or crossing MV cables, full steel protection on the LV cables shall be provided. It shall enable possible pulling of the MV cables without risking to damage the insulating material of MV cable.
- 12.13.9.12.5 This metal protection shall be connected to the nearest LV earthing collector and shall ensure electrical protection in the event. All cable trays and supports shall be suitably connected to earthing systems at two distinct and separate points.
- 12.13.10 Lighting & power**
- 12.13.10.1 Normal lighting and power supplies
- 12.13.10.1.1 The lighting and power auxiliary outgoings located in AC auxiliary cubicles, forming the exit point for all the normal lighting supplies and power connections, shall be supplied from both LT auxiliary transformers.
- 12.13.10.1.2 Each outgoing circuit shall be protected by a miniature circuit breaker, provided with differential protection.
- 12.13.10.1.3 The circuits shall always be cut off on all poles. For instance, in the case of three-phase distribution, the three conductors shall be cut-off by a four poles circuit breaker.
- 12.13.10.1.4 In the case of 2-wire supply, this shall be cut-off by a two-pole switch and shall again take place on all poles.
- 12.13.10.1.5 Design & Supply of Power socket circuits shall be made through 5 conductor cables (3

phases, neutral and ground)

12.13.10.2 Stand-By lighting

12.13.10.2.1 This lighting shall automatically come into service as soon as a voltage deficiency is detected on either of the two auxiliary cabinets and shall not go through any intervening switch. The power source for this lighting shall come from two supplies of 110 V DC battery/battery charger sets together with the AC and DC protection systems and the corresponding remote annunciation systems, associated to the 110 V DC distribution cabinet described above, which will include a changeover device between the two 110 V DC supplies.

12.13.10.2.2 As soon as the normal half station 415/240 V AC auxiliary sources fail and in order to prevent untimely operation when the cut-off period is too short, automated closure of the contactor shall be provided so as to energise the standby lighting system which shall take over until normal power supply is restored.

12.13.10.2.3 This installation shall ensure minimum lighting in the AMS building guaranteeing personnel safety and permitting, at the points where necessary, all isolation or re-supply operations following total cut-off of the medium voltage sources. The standby lighting fixtures shall also be controllable.

12.13.10.3 Emergency lighting

12.13.10.3.1 An emergency lighting system will be provided evenly by means of self contained units in the various accesses and ways to indicate the way to exit.

12.13.10.4 Ventilation

The Control Room/Meeting Room/C&R Panel Room, as needed, shall be air-conditioned with industrial category heavy duty type VRF AC with logic controller
The High Voltage rooms shall be suitably ventilated by air circulation as follows:

- Air inlet louver at the 33 kV switchgear base,
- Air inlet at the base of each transformer cell
- Air exit at the top of each transformer cell

1st case: Ambient air is less than 35°C, the equipment does not need any forced ventilation;

The transformer room is at least equal or higher than the 33 kV switchgear room temperature due to the fact that there is no energy spent into the switchgear. When the transformer room temperature is higher than the switchgear room temperature, a natural air convection is made through the both air inlets and air exit;

2nd case: Ambient air is more than 35°C, the equipment needs forced ventilation: in that case, the transformer air fans reinforce the natural air cooling.

The fans shall be mounted on each transformer room to extract air from the room. A trap shall close automatically the aperture in case of fire detection.

On the other hand, a louver shall close automatically the air inlet in case of fire detection

12.13.11 VENTILATION SYSTEM FOR RSS & AMS HALL

12.13.11.1 Ventilation system: Proper Ventilation arrangement shall be done by the contractor in the RSS/AMS switchgear as per latest version of relevant standard.

12.14 ADDRESSABLE FIRE DETECTION AND ALARM SYSTEM

12.14.1 GENERAL

This section of the specification includes the furnishing, installation, connection and testing of the microprocessor controlled, addressable intelligent fire alarm with equipment required to form a complete, operative, coordinated system. it shall include, but not be limited to, alarm initiating devices, alarm notification appliances, control

panels, auxiliary control devices, annunciators, power supplies and wiring as per drawings and as itemized in Bill of Quantities.

12.14.2 SCOPE OF WORK:

The scope under this covers design, supply, of materials including packing and transportation, receipt and storage and site, installation, testing & commissioning and handing over of Fire Detection and Alarm System.

The rates quoted by the Contractor for successful completion of jobs listed in Schedule of Rates shall cover all points mentioned in "Scope of Work" and the contractor shall not seek any additional financial implications. All the jobs shall be carried out as per standard practices and instructions.

12.14.3 APPLICABLE CODES / STANDARDS:

The design, supply, installation, testing, commissioning of the package shall be as per all relevant & applicable codes /standards, however specifically the following:

IS:2189 – Code of practice for selection, Installation & Maintenance of Automatic Fire Detection & Alarm System.

NFPA 72 – National Fire Alarm and Signalling Code

12.14.4 TECHNICAL SPECIFICATION FOR FIRE DETECTION AND ALARM SYSTEM:

12.14.4.1 Micro Processor Based Fire Alarm Control Panel:

- i. The technical requirement of Microprocessor based analogue addressable type intelligent fire detection and alarm system (FDAS). All equipment's & components shall be new & manufacturer current model. The system shall be consisting of central processing units (CPU), various man machine interface module communication system, microprocessor-based fire alarm control panel.
- ii. The computer aided microprocessor based addressable fire alarm panel shall be software controlled automatic system and shall be provide necessary programmed functions and various controls. Cross zoning should be implemented in the software before raising any alarm form any detector. Fire alarm control panel shall have facility to process the input signals and also have facility to control all the input data received from addressable analogue type detectors / addressable interface unit.
- iii. The panel shall identify open circuit, short circuit, earth fault, removal or failure of detectors, components or connection failure as a fault and shall provide a fault warning and indication. In addition, the system shall show all the below said items in LED-System Power Indicator, System Common Alarm, System Common Trouble, System Common Supervisory, System Common Monitor, System Ground Fault, System CPU Fault, System Disabled, System Test Point(s), System Reset Switch, System Alarm Silence Switch. The panel shall be suitable for input supply of 230 Volts +/- 5% A.C. single phase, 50Hz and 24V D.C. standby battery supply, in the event of mains failure. The SMF batteries shall be provided in the panel. The standby power shall be provided by means of batteries of sufficient ampere-hour capacity.

12.14.4.2 The control panels shall also incorporate the following salient features:

- i. Fire alarm control panel shall have main processor board with necessary with loop

modules for detector loops, alarm output modules for external hooter / lamp, control output modules for various control functions through relay contacts and communication module for interacting with CPU.

- ii. The panel shall monitor each device on every scan and give a fault signal for any of the following conditions within 30 seconds,
 - Detector removed.
 - Address unit removed.
 - Incorrect device type.
 - Faulty calibration or sensitivity.
- iii. Fire alarm control panel shall have facility to process the input signals and also have facility to control all the input data received from addressable analogue type detectors / addressable interface unit located in various loop at different locations.
- iv. Addressable analogue Detectors / manual call point and required field devices in the various areas shall be connected to fire alarm panels by Class A wiring to the loop module. However, the number of such detectors per loop shall be minimum of 125 detectors.
- v. The detectors, manual call point, modules, LED indicators etc., can be connected to the fire alarm control panel through inbuilt addressable interface unit in the addressable loop.
- vi. Fire alarm control panel shall have number of electronic filters to ignore false alarm and increase sensitivity to real fires for detectors. The sensitivity of each analogue addressable detector should be automatically raised if detectors are gradually polluted due to dust and other particles entering inside the detector. If detectors are more polluted, the control panel shall give warning that the detectors need service. The electronic filters shall recognize the unwanted alarm from detectors due to electrical spikes, pipe smokes etc., and raise the sensitivity limit accordingly.
- vii. The fire alarm control panel shall have separate fluorescent display area to indicate the address of each devices and clear text about the location of alarm/trouble.
- viii. The fire alarm control panel shall have optional printer facility to print out the alarm/trouble occurrences with suitable firefighting measures.
- ix. Status checks of disable alarm addresses before they are restored. Storing of alarms and the possibility of internal organization of alarms.
- x. The possibility of expanding to a bigger system with several control panels and control and information units.
- xi. Individually controlled, monitored alarm outputs for external hooters, lamps, etc.,
- xii. Fire control panel shall have facility to brief user guide menu to enable the operator for proper use of various menu functions.
- xiii. Users menu structure for carrying various events shall be provided in the fire alarm control panel.
- xiv. The sensitivity of each addressable analogue detector shall be changeable from

control panel from normal to low or normal to high. The sensitivity of each addressable detector will be readable at the control panel.

- xv. The control panel shall have facility to set date and time and display the same.
- xvi. Each addressable detector, interface units can be disabled from panel for maintenance purpose and restore the same whenever required.
- xvii. The status checks of each detector, interface units for alarm, pre-warning, trouble, disabling shall be possible from control panel.
- xviii. The fire alarm control panel shall have mains on, disable, fault, pre-warning, more alarm (for two or more alarms) LEDs and flashing fire signs on front panel.
- xix. Fire alarm control panel shall have the sounder silence, reset, more alarm, push buttons and also push buttons for user menu structures.
- xx. Power supply to the fire alarm control panel shall be 230V; 50 Hz, 1 Ph AC supply & 24 V DC batteries back up.
- xxi. The control unit shall continuously monitor the analogue status of all sensing device and initiate action when a fire of smoke condition is present.
- xxii. The addressable loop must be monitored for short circuit or open circuit. The occurrence of an open circuit shall cause a fault signal on the panel, but all detectors or devices shall function correctly. The occurrence of a short circuit shall cause not more than 20 detectors to cease operating and all remaining devices shall function correctly.
- xxiii. There shall be no limit to the number of devices that may be in alarm simultaneously.

12.14.4.3 Analogue Addressable MultiSensor (Heat+Smoke) Detector:

- i. Alarm conditions shall be based upon the combined input from the photoelectric and heat detection elements.
- ii. Separately mounted photoelectric detectors and heat detectors in the same location, clustered at the manufacturer are listed spacing is an acceptable alternative.
- iii. The system shall have the ability to set the sensitivity and alarm verification of each individual detector on the circuit.
- iv. It shall be possible to automatically set the sensitivity of individual analog/addressable detectors for the day and night periods.
- v. Smoke detectors shall be addressable and shall connect with two wires to the Fire Alarm Control Panel Signalling Line Circuit.
- vi. The detectors shall use the photoelectric (light-scattering) principal to measure smoke density.
- vii. The detectors with fixed thermal sensors shall alarm at a fixed temperature of 135°F. The detectors shall be ceiling-mount and shall include a twist-lock base.

- viii. The detectors shall provide a test means whereby they will simulate an alarm condition and report that condition to the control panel. Such a test may be initiated at the detector itself (by activating a switch) or initiated remotely on command from the control panel.
- ix. The detectors shall provide address-setting means on the detector head using decimal switches. The detectors shall also store an internal identifying code that the control panel shall use to identify the type of detector.
- x. The detectors shall provide an alarm and power LED. The LED shall flash under normal conditions, indicating that the detector is operational and in regular communication with the control panel. The LED is placed into steady illumination by the control panel indicating that an alarm condition has been detected.
- xi. The terminals in detectors shall be suitable for connections of copper conductor wires of minimum size of 1.5 Sq.mm.

12.14.4.4 Manual call point unit

An iron hammer of sufficient weight, which could be used to break the glass cover. The iron hammer shall be suspended on a hook fixed to the enclosure by means of a non-corrode iron chain of sufficient length and ply to facilitate easy breaking of the glass cover.

An identification number (on a number plate) shall be provided for which each push button station.

12.14.4.5 Addressable Loop Sounders:

- i. The sounders should be wall / ceiling mounted, electronic speakers with solid-state circuitry with 2 tone systems (viz. alert and evacuation working on 24V D.C). Alarm devices shall be electronic types, suitable for low voltage and low power consumption. The conventional sounders shall looped using modules in fire alarm panel.
- ii. The alarm devices shall be configured via software to operate individually or in groups; totally independent of the way they have connected to the loops.
- iii. The sound intensity of the sounders shall be maximum of 105 dB at 1 Mts from the Hooter.
- iv. The alarm sounder shall be suitable for dry, wet or dusty atmosphere.

12.14.4.6 Fault Isolation Module:

Isolators shall be provided to electrically isolate different sections of an addressable detector loop in order to isolate short circuit in the loop. It should be possible to use such isolators in both loops and radials.

The isolator module shall protect against short circuits, and partial short circuits, on the loop by isolating that section of the wire where the short circuit occurred, thus maintaining the integrity of the remainder of the system.

12.14.4.7 Enclosure Classification:

- i. Degree of protection of equipment shall be as per IEC 947.1.1988 and IS 13947.

- ii. IP 42 for Panels, Boxes and Centers in electrical rooms
- iii. IP 54 for Panels and Boxes in heavy environment condition
- iv. IP 65 for Field devices

12.14.4.8 Technical conditions for lighting

The technical conditions for carrying out the works and providing the supplies are as follow:

Lighting equipment

This shall be of LED type.

Average lighting intensity will be 300 lux in the control rooms, and in technical rooms

- 100 lux in the low voltage auxiliary transformer rooms
- 80 lux in all other levels and in the stairway.

The LED tubes shall be mounted beneath cover glasses (as shall also be the case for the standby lighting)

In the battery rooms, they shall also be mounted with glands to keep out acid vapours and hydrogen.

The sealed LED light fittings shall be capable of withstanding impacts and shall be explosion-proof (as for those in the transformer cubicles).

The light fittings proposed by the contractor are subject to approval by the Employer.

12.14.4.9 Power sockets

They shall be of sealed, wall mounted type, with four poles plus central ground, rated for 16 A and 500 V AC and with a cover flap fitted with a plug holding pin.

The external sockets shall be mounted on mast, at the level of each circuit breaker.

12.14.4.10 Fire protection

Auxiliary supply of each fire detection system shall be 110 V DC.

12.14.4.11 Fire detection system

In case of fire in any transformer, the fire detection system shall instantaneously come into action isolating the transformer by tripping the upstream and the downstream transformer circuit-breakers and put the fire extinction system into action. Coming into action, it shall also stop the fan working and close all apertures (air inlet and air exit) to avoid or minimise any fire propagation.

The thermo element detectors shall be mounted at the cover level of the transformer.

The detectors shall detect at any moment an abnormal temperature rise generated by a fire on the tank, the terminals or even on the transformer bed.

The detectors shall be designed and equalized such that they do not operate at slow temperature rise, which may occur due to a variation of ventilation, variation load, solar beam, etc.

The design of the detectors shall ensure complete security, such that it will not operate due to any reason except for fire, and complete dependability in case of fire.

If more than one detector is necessary, they shall be series mounted by a fire resistant

electric cable, which is connected to a detection unit.

The detectors shall be of simple, sturdy inspect vibration proof, moisture acid resistant construction.

Provision shall be made for a guard current flowing through the detectors. Interruption of the guard current due to break of the elements series connecting cable or loose terminal shall activate an audible and visible alarm signal at the detection unit of the equipment indicating interruption of guard current.

This signal must not activate the extinction system and the signal can be used for blocking of the extinction system on request.

The detection shall be completed with a smoke detector mounted in series with thermos detector.

12.14.4.12 System Voltage

Auxiliary Supply to the fire detection system shall be 110 V, DC.

12.14.4.13 Fire fighting equipment

The contractor shall supply atleast 4 nos. of 5 kg CO2 portable fire extinguishers distributed throughout the power equipment room.

12.14.4.14 Safety equipment

The contractor shall supply one safety tool board comprising at least :

- Insulated gloves
- Insulating stools
- Protecting glasses
- Body lifting pole
- Single pole voltage detection pole
- Insulated cable cutting pliers
- Notice about care to electrified peoples
- Salt to avoid kidney blocking
- Discharge Rods (33 kV & 33kV –5Nos.)
- Salt to avoid kidney blocking
- Fire Buckets filled with clean dry sand and ready for immediate use for extinguishing fire.
- Fire Extinguishers suitable for dealing with electric fire.
- First Aid Boxes
- Gas Masks.
- Artificial respirator.
- Instructions in Hindi & English for restoration of person suffering from electric shocks.

The battery rooms shall be fitted with eye washer equipment.

12.15 UNINTERRUPTED POWER SUPPLY (UPS)

Inverter of suitable capacity shall be provided for station HMI and its peripheral devices e.g. printer etc. In the event of Power failure, necessary safeguard software shall be built for proper shutdown and restart.

12.15.1 TECHNICAL REQUIREMENTS FOR UNINTERRUPTED POWER SUPPLIES

The UPS for providing uninterrupted power supply to the Control & monitoring Equipment installed at the Receiving Substations is included in the scope. The scope of work shall also include the power distribution from the UPS to the servers, workstations, printers etc.

The UPS shall comprise:

- a. one AC/DC converter (battery charger) (100% standby)

- b. one Ni-Cd battery
- c. one inverter (100% standby)
- d. one static bypass switch
- e. one emergency switch
- f. one AC output protection circuit breaker

In normal operation, the supply of equipment is made directly from the source through the static bypass switch in normal supply position. The AC/DC converter maintains the battery in floating mode. In case of supply failure, the thyristors switches automatically, without breaking, on the stand by supply made by battery and inverter.

For maintenance purpose or in case of static standby switch failure, the emergency switch shall ensure the supply of the connected equipment with the following operations:

- Automatically in case of standby switch failure. This transfer shall be made with a maximum delay of 20ms. In such a case, the coming back to the normal situation, after repair, shall be only manual without breaking.
- Manually for maintenance purpose. This transfer shall be made without breaking in the both ways.

The emergency switch shall be fitted with:

- Automatic/manual change over switch
- One transfer push button

According to the previous description, the transfer push button shall close the open contactor, then open the previously closed contactor. This push button shall be active only in manual position of the changeover switch.

12.15.1.1 Technical Characteristics for UPS

The UPS shall comply with the following characteristics:

Table 12.43: UPS Technical Characteristics

Standards		IEC 60146
1) ELECTRICAL CHARACTERISTICS	Unit	
Type		Indoor
Rated power (at cos = 0.8)	kVA	20
Input voltage	V	415 V (3-phase)/ 240 V (1-phase)
Input voltage variations	%	+10, -15
Input frequency	Hz	50
Permitted variations of frequency	%	± 3
Output voltage	V	415 V (3-phase)/ 240 V (1-phase)
Output voltage variations	%	± 0.5
Output frequency	Hz	50
Output frequency tolerance	%	0.5
Harmonic content of output voltage	%	≤3
System efficiency	%	>90
Minimum time of emergency supply	hr	4

12.15.1.2 Test sheet of UPS

The test sheets include type tests, routine tests, after shipment tests and on-site tests.

The tests shall be performed in accordance with the IEC standards defined into the technical sheets.

Table 12.44: Test sheet of UPS

INDICATIONS	TYPE of TEST		
	Type	Routine	On site
Temperature rise	X		
Rated short duration power frequency withstand voltage	X	X	
Floating operation mode test	X	X	
Direct operation mode test	X	X	X
Protection devices operation	X	X	
Battery discharge duration			X
Setting test	X	X	
Visual inspection	X	X	X
Emergency switch operation			X
Inspection of continuity of earth circuits and dangerous voltage protective measures.	X	X	X
Synchronization Test	X		
Measurement of Inherent Voltage Regulation	X	X	X
Overload capacity Test	X	X	X
Alternating Current Input failure test	X	X	X
Alternating Current Input return test	X	X	X
Manual switching from Inverter to Mains and back at full load.	X	X	X
Rated Full-load Test	X	X	X
Measurement of Neutral to Ground Voltage.	X	X	X
High Voltage Test	X	X	
Insulation Resistance Test	X	X	X
No-load Test	X	X	X
Output Test	X	X	X
Climatic Test	X		
Harmonic Content Test	X		
Field test	X		X

12.16

Civil works

12.16.1

General

Unless stated otherwise in the Contract Documents the whole of the civil, structural, utility work, services and finishing works shall be constructed to comply with relevant laws and regulations of the Indian Government and of UP state government as well as complying with the requirements of the UP public utility authorities, fire regulations and such additional requirements as may be stated in the documents. The design requirements relating to fire safety and escape shall be generally in accordance with

NFPA, BS 476 and other applicable standards. The Contractor will be required to execute civil works at the RSS/AMS locations.

The specific nature of civil works, required to be done at different locations, will be different and will depend upon the locations. Broadly, at the RSS/AMS location, the Contractor will be required to arrange for land preparation, erection of boundary wall, entrance gate, , provide architectural services, civil and structural design services and other auxiliary services like water supply, lighting, ventilation, air-conditioning, fire detection and alarm etc, for the RSS, AMS and Control Room Building. The services to be provided by the Contractor are broadly described in the subsequent paragraphs. Civil Works/RSS/AMS Building shall be in line with the requirement of the NBC and other requirements for Green Building in line with LEED/IGBC shall be implemented in civil works. It shall be responsibility of LKE(02)-01 contractor for the whole of the civil, structural, utility work, services and finishing works.

The grade of concrete should be as per approved design but not inferior than M-25 as per IS 456 for all civil construction in RSS/AMS.

12.16.2 Site Facilities

The contractor shall provide and maintain its own site accommodation at locations consented to by the Engineer. Offices, sheds, stores, mess rooms, garages, workshops, latrines and other accommodation on the site shall be maintained in a clean, stable and secure condition. Living accommodation shall not be provided on the site. The contractor shall comply with the requirements of Employer's requirements. In addition contractor shall provide and maintain field offices for use of UPMRC staff during the contract period at the RSS/AMS location of area not less than 30 sqm with toilet & electricity facility including services for office upkeep, consumables, furniture etc.

12.16.3 Land Preparation

The Bidder is advised to inspect the sites for various RSS-cum-AMS locations and gather for himself various details such as topography, backfilling, compacting and land levels, soil condition including the safe bearing capacity, soil resistivity etc, HFL (highest flood level) at the Substation site, drainage requirements etc, in order to ensure that the work content is fully appreciated by him at the time of preparation of bid.

The site will have to be cleared of all existing encumbrances, levelled and compacted. The finished ground level of the Substation site shall be above the Highest Flood Level (HFL) in the Region, to be ascertained by the AGE 1&2 Contractor and confirmed by the Local Authorities. In any case, the finished ground level shall be at least 60 cm above the main rail/ road level, near to the site& finished floor level shall be at least 30cm above the finished ground level. The compaction of soil shall be done in accordance with Standard Engineering practices and the site, after compaction shall be fit, without any detriment to support the heavy equipments, including transformers whose weight may be in the region of 100-110 tonnes, supported on 4 wheels which are spaced approximately 2.4 metres, running on a Standard Gauge (1435mm) track. During land preparation, if it becomes necessary to cut or transplant trees, it shall be done by the Contractor with the permission of Forest authorities/relevant authorities and with the approval of UPMRC, strictly in accordance with the Local laws.

12.16.4 Access Roads

The Contractor will be required to provide suitable access road to the Substation site,

from the nearest main road, which has the necessary width and strength to carry the Power Supply equipments. The access road shall be black topped and transformer area of CC/RCC as per MOST specifications.

For this purpose, the Contractor shall prepare the necessary design and calculations and submit them to the Employer/Employer's Representative, for approval. On approval of designs and calculations, the LKE(02)-01 shall construct the approach roads as per approved designs. The approach roads should, at the minimum, be 4.5m wide and shall be able to support 100 – tonne trailers.

12.16.5 Plumbing & Drainage

Drainage of the Substation site shall be provided as per the best engineering practices, so as to prevent surface flooding and pooling of water. For this purpose, suitably designed drains and sumps shall be provided and if the water level inside the sump rises above a predetermined level, the sump water shall be arranged to be evacuated by means of suitable electric pumps fixed in the sump. In addition, suitable precautions shall also be taken to prevent transformer insulating oil from being discharged into the environment in the event of a ruptured transformer tank.

This shall be realised by a retention tank for each transformer

- dimensioned in order to be able to contain the whole transformer oil with facility of removing oil from pit;
- laid below the transformer;
- covered by a net to maintain a 5 cm width stone bed on which the oil might fall;
- fitted with a beside extraction pit to be used for oil or raining water pumping.

Contractor shall provide with water supply system fully functional for toilets and maintenance room wherever required he may construct sump, overhead tank etc. The pumping shall be realised with a portable manual or electrical pump, which is to be stored in the maintenance room. The drainage system of RSS/AMS shall be connected to the local drainage system of the city by the RSS/AMS contractor with the permission of local authorities and it should be suitably protected to ensure prevention of back flow of outside drainage water to RSS/AMS.

12.16.6 Control Room Building

12.16.6.1 Detailed Design

The LKE(02)-01 Contractor will have to study the General Layout of the AMS & Control Room Building, shown in the RSS/AMS Layout drawing and propose any changes to the Employer during execution stage. The structure shall be of RCC framed structure based on BIS codes. Based on this, the Contractor will be required to prepare and submit detailed design of civil, structural, architectural and electrical works. All applicable building regulations must be observed, and also the rules for good building practice. After obtaining the Employer's/Employer's representative's approval, the Contractor will construct the building along with auxiliary works, in accordance with approved drawings and designs. Contractor shall submit a detailed safety policy and execute the work as per policy. Contractor shall carry out finishing work for RSS/AMS buildings as per no objection issued by Employer/Employer representative for finish material. All operation, maintenance, store, and office room shall be suitably design and furnished.

Proposed RSS/AMS , if needed to be built on the filled earth; contractor shall survey the area, conduct geotechnical survey to identify safe bearing capacity and shall design the building with suitable foundation and structure. The contractor shall obtain notice of no objection from the employer or employer's representative, before start of construction.

12.16.6.2 Civil and Structural Design

The Contractor shall perform the civil and structural design, including the preparation of calculations, drawings, specifications, cost estimates and other documents, for but not limited to:

- General arrangement (layout and elevation);
- Structures and sub-structures;
- Foundations;
- Drainage (Covered type);
- Networks (Water, sewage, etc.)
- Boundary walls.
- Earthquake resistance as per zone of Lucknow.

12.16.6.3 Architectural services

The Contractor shall perform the Architectural services design, including the preparation of calculations, drawings, specifications, cost estimates and other documents, for but not limited to:

- General arrangement (layout and elevation);
- Section and details
- Walls, floors, ceiling finishing
- Doors, frames and windows
- Toilet rooms, and partitions including equipments
- Concrete (types and treatments)
- Thermal and moisture protection
- Electrical and mechanical fittings
- Building surrounding environmental arrangement
- Epoxy Floor Finishing/Painting (RSS/AMS , store Room)

The standard of architectural work should be of the same level as existing for other surrounding buildings of UPMRC.

The internal finishes and facade finish of the RSS/AMS building shall be similar to Depot building and station buildings of UPMRC. All structure and finishing work shall confirm to Indian Standards, wherever Indian standards are not available the work shall comply to relevant international standard or as per manufacturer's instructions.

Following suggested finishes and materials are options, the contractor shall study in detail the proposed options and station building finishes, he may also come with other alternatives, provided employer or employer's representative issue notice of no objection.

- a) RSS/AMS Hall and Store room shall have hard granolithic cement concrete flooring, with vacuum de-watered smooth finish. Walls of these rooms shall be plastered and finished with acrylic emulsion paint over and above suitable wall putty.
- b) Transformer room shall be finished with plastering and acrylic emulsion painting.
- c) LVSWGR shall also be finished with plastering and acrylic emulsion paint, over and above suitable wall putty. Floor of this room to be with Hard granolithic cement concrete, with vacuum de-water finish.
- d) Office room, Storeroom and Maintenance room shall be plastered and painted with acrylic emulsion paint, floor shall be vitrified I ceramic tile laid to standards.
- e) Toilets shall be designed for adequate urinals, counter type washbasins, mirror, etc. Room shall be finished with anti-skid ceramic tile on floor, walls shall be dado for 2.5m height with glazed ceramic tile, remaining area shall be finished with acrylic emulsion paint over plastered surface.

- f) Battery room shall be finished with hard floor - acid resistant, walls to be with glazed ceramic tile for 2.5m (minimum), above it shall be finished with acrylic emulsion paint. This room to be air-conditioned to maintain the room temperature as per design requirement.
- g) Control room in the RSS/AMS shall be finished with vitrified tile on floor and acrylic emulsion paint on the walls. As temperature is to be maintained in this room, it shall be airconditioned.

12.16.6.4 Auxiliary services

The Contractor shall perform the Auxiliary service design, including the preparation of calculations, drawings, specifications, other documents, for but not limited to:

- Lighting, fans and sockets
- Ventilation and air conditioning
- Fire detection
- Cables routing (cable trenches, trough, trays etc...)
- Earthing
- Water pumps
- Water supply and sanitary
- Storm water drainage
- Door & Ironmongeries
- Solar Power Panel on roof of the Control Room Building of RSS/AMS.

The contractor shall design and furnish the building with tables, chairs, etc, Design of furniture requirement shall be submitted for notice of no objection from employer/ employer's representative. A master key, with all required ironmongeries shall be provided. Toilet doors can be FRP doors to the standards.

12.16.6.5 Design Quality Control Plan and Design services

The Contractor shall prepare and submit a Design Quality Control Plan to the Employer's Representative and perform the Design Services in accordance with the Design Quality Control Plan.

The Contractor shall be responsible for the correctness and technical merits of his design, calculation, drawings, specifications and all other documentation.

All documents shall be delivered, submitted and approved by the Employer's representative prior to start the construction work.

For each submission the Contractor will submit an original, 5 copies and the electronic file.

12.16.7 Control room Building requirements

12.16.7.1 General

While planning and constructing the buildings and rooms for electrical equipment, care must be taken to ensure that

- all operational requirements are satisfied
- the rooms are free from groundwater and flooding
- adequate accesses are provided for operation, transport and fire-fighting services
- all applicable building regulations are respected
- the building is structurally and functionally adequate in all respects and aesthetically presents a good look.
- Materials used for the construction of the building shall be new and of good quality Materials shall be so chosen that the buildings when erected shall have good heat and sound insulation properties in normal conditions, as well as when combined with the heating or air-conditioning equipment installed by the Contractor. Height of the control room and RSS/AMS rooms shall be as per product design which shall be included in Building Design.

12.16.7.2 Walls, ceiling & floors

Walls, ceiling and floors must be dry. Both external and internal walls shall be sound proof and 2 hours fire proof. The inside surfaces of the walls should be as smooth as possible to prevent dust deposits. The ceiling shall be finished in such a way that the equipments are not endangered by falling plaster. The floor surface must be easy to clean, pressure-resistant, non-slip and wear-resistant. Concrete floor with adequate strength to withstand movement of equipment/panels wear-resistant protective coating with ceramic tiles (non skidding type) is recommended for the control room. Attention must be paid to floor loadings when taking the equipment in and out. In front of control panels and Switchgear panels, insulated mats of approved design, shall be provided. The internal walls & ceiling shall be finished with plastic emulsion in control room and oil bound distemper in other rooms.

Civil construction for RSS/AMS building shall keep in consideration the requirement of solar panels installation of approx. power rating 10kW that shall be installed at the roof. All civil related parameters shall be kept in provision for these installations.

12.16.7.3 Doors and Windows

Windows to each room shall be of an area, not less than 20% of the floor area. Windows must be so arranged that they can be opened and closed without any personnel coming dangerously close to any live parts. All windows of the ground floor building shall be fitted with burglar bars firmly attached to the structure of the building. The window shall be aluminium of appropriate section.

All opening windows shall be fitted with locks. Internal doors shall be Three hours fire rated and shall be fitted with door closers, lever latches, mortise lock and keys.

External doors shall have barrel bolts both at top and bottom of one leaf and a Yale lock on the other leaf, they shall be equipped with an Anti-Panic system permitting urgent door opening by mean of a bar located at 0.7 m high from floor level.

Emergency fire exit doors with panic bars should be provided in AMS control room building and shall be accordingly marked.

External doors shall be of solid external quality and hung with heavy-duty hinges.

12.16.7.4 Ventilation

The rooms must be sufficiently ventilated. In the control room, where people are likely to be present constantly, the following indoor climatic parameters should be possible to be maintained

Temperature	-	20°C Minimum
	-	27°C Maximum
Humidity	-	60% Maximum

The control room should be provided with VRF type AC with logic controllers to achieve the above results. The rooms where switchgear are installed, the maximum relative humidity should not exceed 70%. The maximum ambient temperature inside the room, averaged over 24 hours shall not exceed 35°C.

12.16.7.5 VARIABLE REFRIGERANT FLOW SYSTEM (Industrial category Heavy Duty Type)

12.16.7.5.1 SYSTEM DESCRIPTION

The Variable Refrigerant Volume VRV / Variable Refrigerant Flow VRF - R 410a refrigerant System should be air cooled, split type air conditioning systems consisting of modular condensing units connected to multiple indoor units, each having the capability of individual set point control. Each modular condensing unit should incorporate at least one inverter / digital scroll compressors to obtain 10% to 100% stepless capacity control for enhanced Power saving. The indoor units should be provided with Cordless Remote Control as a standard accessory.

The VRV / VRF units shall be capable of operating within a wide range of ambient temperatures. The Condensing units should be capable of provide cooling within an ambient range of -5 Deg. C to 45 Deg. C DB and heating in the range -10 Deg. C to 15 Deg. C DB.

The refrigerant piping shall be extendable minimum 150 m with 50 m level without any oil trap.

12.16.7.5.2 OUTDOOR UNIT

The outdoor unit shall be a factory assembled unit housed in a sturdy weather proof casing constructed from rust-proofed mild steel panels coated with a baked enamel finish. The ODU must deliver 100% cooling capacity at ambient Temperature.

The noise level shall not be more than 68 dB(A) at normal operation measured horizontally 1m away and 1.5m above ground. The outdoor unit shall be modular in design and shall be allowed for side by side installation.

12.16.7.5.3 Compressor

The compressor shall be of highly efficient hermetic Inverter / Digital Vapor Injection Scroll capable of capacity modulation by time averaging method and Vapor injection Technology. Each ODU should have minimum 1 no. variable compressor upto 16 HP capacity, 2 nos. variable compressors upto 32 HP capacity, 3 nos. Variable compressors upto 48 HP capacity & 4 nos. variable e compressors upto 64 HP capacity.

12.16.7.5.4 Heat Exchanger

The heat exchanger shall be constructed with copper tubes mechanically bonded to aluminium fins to form a cross fin coil. The aluminium fins shall be covered by anti-corrosion resin film. The System must have sub-cooling heat exchanger further to Condenser to increase refrigerating effect in Indoor units. The Condenser fins must be coated with Anti-corrosive treatment.

12.16.7.5.5 Fan Motor Speed Control

The condensing unit fan motors to have at least two speed operation to maintain constant head pressure control at all ambient temperatures and modes of operation.

12.16.7.5.6 Refrigerant Circuit

The refrigerant circuit shall include an accumulator, liquid and gas shut off valves and a solenoid valves or pulse width modulation valve.

All necessary safety devices shall be provided to ensure the safety operation of the system.

12.16.7.5.7 Safety Devices

The following safety devices shall be part of the outdoor unit;
High Pressure Switch, Low Pressure Switch, Fan Motor Safety Thermostat, Over Current Relay, Fusible Plugs, Fuses.

12.16.7.5.8 Oil Recovery System

Each unit shall be equipped, with an oil separator to ensure stable operation with long refrigerant piping.

12.16.7.5.9 INDOOR UNIT

Indoor unit shall be mix-match of ceiling mounted type as specified in scope of work. It shall have electronic control valve to control refrigerant flow rate in response to load variations of the room. The fan shall be of the dual suction multi blade type and statically and dynamically balanced to ensure low noise and vibration free operation.

The address of the indoor unit shall be set automatically in case of individual and group control. In case of centralized control, liquid crystal remote controller shall set it.

12.16.7.5.10 Electronic Expansion Valve

Each indoor unit shall be fitted with an electronic expansion valve to control the refrigerant flow in response to the load variations in the room. The electronic expansion valve is to be controlled via a computerized control sensing the return air temperature, refrigerant inlet and outlet temperatures. During the cooling operation the electronic expansion valve shall control the refrigerant superheat degree at the evaporator.

12.16.7.5.11 Indoor Unit Fans

Shall be direct driven of the DIDW multi-blade type, statically and dynamically balanced to ensure low noise and vibration free operation. The noise level shall not exceed 42 dbA.

12.16.7.5.12 Cooling Coils

Shall be direct expansion, constructed from copper tubes expanded into aluminium fins to form a rigid mechanical bond.

12.16.7.5.13 Unit Control Board

It shall Include in the indoor unit a printed circuit board complete with, address switches for a variety of operation controls, emergency operation switch and fault / operation indication LED's. The fan motors shall be thermally protected.

12.16.7.5.14 Unit Casing

The indoor unit casing shall be fully insulated and sealed to prevent condensation.

12.16.7.5.15 CENTRALIZED SYSTEM TOUCH SCREEN REMOTE CONTROLLER

A multifunctional compact Touch Screen centralized controller shall be provided with the system.

The System Controller shall act as an advanced air conditioning management system to give complete control of VRV / VRF air conditioning equipment. It shall have following functions :-

- Starting/stopping of Air conditioners as a zone or group or individual unit.
- Temperature setting for each indoor unit or zone.
-
- Switching between temperature control modes, switching of fan speed and direction of airflow, enabling/disabling of individual remote controller operation.
-
- Monitoring of operation status such as operation mode & temperature setting of individual indoor units, maintenance information, trouble-shooting information.

12.16.7.5.16 CABLING BETWEEN INDOOR AND OUTDOOR UNITS

The cable between indoor and outdoor units shall run in steel conduit.

12.16.7.5.17 REFRIGERANT PIPEWORK:

Scope of Refrigerant Piping work shall include Supply, installation, testing and commissioning of all interconnecting pipe-work between the condensing unit & indoor units. Refrigerant quality seamless copper tubes with brazed connections and the appropriate Distribution joints and headers shall be used. The piping should be routed at site in such a manner, that brazed joints in the Refrigeration Piping are kept to a minimum.

- 12.16.7.5.18 **Joint Orientation :**
Proprietary Distribution refrigeration pipe joints and headers shall be installed in an appropriate orientation to enable correct distribution of refrigerant. The Distribution joints shall be factory insulated with pre-formed sections of expanded Polystyrene / equivalent.
- 12.16.7.5.19 **Cleanliness Of Piping :**
All pipe-work must be kept clean and free from contamination to prevent breakdown of the system. All pipe ends shall be kept sealed until immediately prior to making a joint.
- 12.16.7.5.20 **Pressure Testing :**
After complete installation of refrigerant piping, it shall be pre-pressure tested and repaired if necessary and further pressure tested to 3,800 Pa, to hold for a minimum 24 hours with dry nitrogen prior to insulating the joints. After satisfactory testing, the refrigerant pipe shall be evacuated and dehydrated to (- 755 MM HG) and held for one to four hours depending on the pipe length.
- 12.16.7.5.21 **Refrigerant Charge**
Refrigerant charge must be calculated based on the actual length of the refrigerant pipe work. The refrigerant charging process must be carried out with an appropriate charging station and under supervision of Consultancy.
- 12.16.7.5.22 **Piping Insulation**
All suction & liquid lines of the Refrigerant pipe work shall be insulated with Nitrile rubber /expanded polyethylene pipe sections as specified to avoid condensation. The exposed piping insulation shall be painted with U/V paint
- 12.16.7.5.23 **Fixing Pipe Work & Electrical Conduit :**
The insulated refrigerant piping and electrical conduit shall run on GI tray properly supported by GI rods. The exposed tray on terrace shall be covered by openable GI covers.

The OD & wall thickness of copper refrigerant piping shall be as follows:
- 12.16.7.5.24 **DRAIN PIPING**
The indoor units shall be connected to drain of GI pipe. The pipes shall be laid in proper slope for efficient drainage of condensate water.
- 12.16.7.5.25 **Drain Pipe Insulation**
Drain pipes carrying condensate water shall be insulated with 6 mm Nitrile rubber having a 'K' value of 0.037 W/mk at a mean temperature of 20 deg C and a minimum density of 55 Kg/Sqm.
The joints shall be properly sealed with synthetic glue to ensure proper bonding of the ends.
- 12.16.7.5.26 **TESTING**
The units shall be tested for capacity and COP as per ARI conditions at manufactures premises before delivery, Owners / their representative reserve the right to witness the tests.
- 12.16.8 Battery Rooms**

In battery rooms, the following additional precautions have to be taken.

- the walls & floor must be resistant to electrolyte action and provided with acid resistant tiles.
- ceilings should be painted with acid-resistant paint which does not give off harmful vapour.
- Ventilation by means of induced draught is preferred. An air change rate of 5 times the room volume per hour is recommended.

12.16.9 Water supply, electricity, sanitation and fire fighting

Building shall be supplied with continuous (24 hour) running potable cold water to the pantry and wash rooms. One reverse osmosis (RO) water cleaning plant of suitable capacity (suitable storage of at least 30 ltrs) with cooling facility for drinking water shall be provided in the RSS/AMS.

A bore well of suitable capacity shall be provided with permission of local authorities in the RSS/AMS for water requirement. Rain Water Harvesting should be provided in RSS/AMS.

The toilets may use raw water for flushing, shall be equipped with water closets and sitting type stools and urinal and shall be adequately ventilated through the ceiling.

The Contractor shall also design and provide necessary arrangements for the constant and hygienic disposal of all effluent, sewage and rubbish from the buildings to the nearest sewer line or septic tank.

Storage and septic tanks shall be required due to restricted hours of water supply in the Lucknow Area.

All buildings shall be supplied with electricity at 240 volts, at 50 Hz.

Firefighting equipment shall be provided in accordance with the recommendations of the Lucknow City Fire Brigade.

12.16.10 Exterior finish

External finish of the Control Room Building shall be attractive and pleasing to the eye preferably of stable and durable cladding of sandstone or equivalent of approved shade and design. Considering that the RSS/AMS locations and Control Room Buildings are prestigious installations and should blend smoothly and aesthetically with the surroundings, the AMS and Control Room Building shall have a good exterior finish. Use of an ingenious combination of stone cladding and grit finish, or suitable combination of glass and stone or any other arrangement of exterior finish shall be adopted, subject to Employer's approval.

12.16.11 Internal equipment

The AMS and control room building shall be designed and constructed to accommodate the following equipment and facilities:

- 1) 33kV Switchgear room
 - 33 kV switchgear
 - Low voltage auxiliary transformers 33 kV / 415-240 V
 - Low voltage distribution cubicles (AC and DC)
 - Battery chargers
 - HV equipment auxiliary cubicle
- 2) Battery room
 - Batteries
- 3) Control room
 - SCADA equipment, including work stations
 - SCADA system
 - UPS
- 4) Rest room/Store Room and toilets
- 5) Maintenance

- 6) Control and Relay panel Room
- 7) Outdoor store room
- 8) Indoor store Room (2)
- 9) Meeting room with complete video conferencing setup for at least 20 people.
- 10) Kitchen
- 11) Janitor Room

The building shall have sufficient room to accommodate above equipments and requirements in case of RSS/AMS with all partition walls, openings, and all facilities, designed to receive power supply installations.

Facilities should include but not restricted to :

- Water; network and equipment (supply, sanitary, sewage...)
- Cables trenches and conduits
- Low voltage installation (lighting socket, fans, ventilation, fire protection...)
- Doors and locks
- Painting

12.16.12 Cable paths

12.16.12.1 General

The LKE(02)-01 Contractor shall provide all cable paths in the HV yard, in the AMS area and inside the AMS & Control Room Building.

12.16.12.2 In Open Yard

The cable path in the open yard shall be in the form of suitable RCC cable trenches with necessary ladder type (for HV cable) & perforated cable tray (for LT & control cable) of GI steel dully supports on GI steel support and with appropriate RCC covers having peripheral edge protection angles /MS sheet for precast covers or in the form of Heavy Duty PVC pipes of suitable diameter, subject to Employer's approval.

12.16.12.3 Inside Rooms

The cable paths inside the building/rooms shall be in the form of cable trenches with necessary cable supports of GI steel and covered by steel/GI checker plates of good and aesthetic quality.

12.16.12.4 Separation of different voltage families

As the cable routes are dealing with different voltage family, they have to be physically separated.

12.16.12.5 Cable Route Plan

The LKE(02)-01 Contractor shall submit cable route plan, cable trench cover drawings, to the Employer, for approval, well in time.

12.16.12.6 Boundary Walls

Along the periphery of the Substation site, a boundary wall with suitable earthing provision & matching with the finish of building, consisting of RCC retaining wall ,columns, beams as per UMRC design & specification in accordance with the standard UPMRC Specifications, shall be constructed by the LKE(02)-01 Contractor. Appropriate suitable MS gates of approved design shall also be provided to permit movement of personnel/goods.

Suitable size of GI pipe and bracket shall be provided on the top of the boundary wall with concertina wire with minimum height of 0.5m above 3.0m as per standard design.

The Boundary wall shall be provided with a gate with sliding barrier which shall be motor-operated. It shall be possible to open or close the gate from a push-button control inside the guard room.

RCC pre-cast panels with UPMRC Logo to be used for boundary wall as per Employer's approval.

12.16.12.7 Guard room

The RSS/AMS shall be provided with a Guard Room, near the main gate. Suitable communication link between the Guard and the Substation operator located in the Control Room, shall be provided. The Guard shall be able to open the gate only when he is authorized by the Substation Operator to do so and a suitable interlocking arrangement to achieve this Security arrangement, shall be provided. The specification shall be similar or matching to main building. The guard room shall be equipped with Air-Cooler and toilet.

12.16.12.8 Signages

The entire RSS/AMS premises shall be provided with suitable Signages as per standard/ specification. Depending upon the layout and construction finally adopted, the various installations (eg. RSS/AMS, HV Bay, Transformers, Control Room etc) shall be provided with Sign boards, both in Hindi and English. These Sign boards are in addition to Equipment labeling, which shall be provided as per approved drawing. The Contractor shall submit drawings for the proposed Signages, for Employer's approval and the Signages shall be provided in accordance with approved drawings.

12.16.12.9 STORAGE SPACE

Covered storage space for spares, oil drums, cable drums etc of approx. 150 sq.m area (as per Employer Requirement) should be provided in the RSS/AMS as specified in BOQ. The land will be decided at execution stage. The storage space should be made of covered shed of rain proof material, with brick walls, suitable rolling shutters and doors for bigger size of spares to be provided.

Fans, exhaust fans, lighting provisions should be provided. The floor to be of cemented type. All materials should be of durable quality and of reputed makes as used in other civil works of RSS/AMS.

12.16.12.10 LAND SCAPING

The RSS/AMS shall be provided with land scaping and plantation on vacant areas left after the construction of substation.

The plantation shall be provided on the both sides of approach road to the control room from the Main Gate, along the boundary walls inside the RSS/AMS boundary, on the both sides of entry doors of the control room. Good quality plants, green plants, shrubs should be provided and suitably placed. The care and maintenance of land scaping and plantations provided shall be carried out upto the end of the DLP period.

CHAPTER 13: 33kV DISTRIBUTION CABLE WORKS

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CHAPTER – 13

33kV DISTRIBUTION CABLES WORKS

13.1 33kV CABLE DISTRIBUTION NETWORK

13.1.1 GENERAL

13.1.1.1 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in chapter-2 & Chapter 19 along with clause wise compliance and suggest similar or better design for the approval of Employer.

13.1.1.2 The received 33kV supply at the RSS shall be distributed to the Lucknow Metro network through a ring main feeder cable network. The network is divided into loops as shown in the relevant drawing of Tender Drawings.

13.1.1.3 The power supply at 33kV is distributed to various traction substations as well as auxiliary substations located in stations, by means of 2 nos. 33kV ring main feeder cable network for traction as well as auxiliary substations. These cables shall be laid on brackets/hangers/ducts along the viaduct or inside tunnel.

13.1.2 33 kV CABLE FEEDERS

13.1.2.1 33kV power from outgoing bay 33kv RSS to 33kV Switchgear in Depot AMS/ASS+TSS is transferred through 33kV cables.

13.1.2.2 The 33kV feeds are fed to
Corridor-1: (i) Vasantkunj (Elevated) from Vasantkunj AMS/ASS+TSS,
(ii) Charbagh (Under Ground) from Charbagh (Elevated) of North South Corridor

LKE (02)-01 contractor shall perform AC load flow study in order to finalise the 33kV cable size for East West Corridor (Phase 1 B).

13.1.2.3 Power supply at 33kV is distributed to various traction substations as well as auxiliary substations located in stations, by means of a 33kV ring main feeder network having 2 circuits for 33kV Power Supply to traction (TSS) and auxiliary substations (ASS). Refer Clause 13.4 below in this chapter.

13.1.2.4 Depot ASS+TSS is part of Vasantkunj Depot and further distribution 750 V DC Traction Supply from Depot ASS+TSS shall be under the scope of Traction Contractor and 415 V AC auxiliary supply shall be carried out by E&M Contractor.

13.1.2.5 In order to provide more flexibility of power supplies in emergency situations, the operation of 33kV distribution network is envisaged as under;

Circuit Description	Feed by	Desirable operation	Location of NO for normal operation
East West Corridor			
Circuit -1	Vasantkunj RSS	Vasantkunj to Charbagh	Vasantkunj/Charbagh/All TSS stations

Circuit Description	Feed by	Desirable operation	Location of NO for normal operation
East West Corridor			
Circuit -2	Vasantkunj RSS	Vasantkunj to Charbagh	Vasantkunj/Charbagh/All TSS stations
Emergency Condition (Vasantkunj RSS is out of service)	Charbagh ASS	Vasantkunj to Charbagh	Vasantkunj/Charbagh/All TSS stations (can be modified as per actual conditions)

- 13.1.2.6 The Contractor shall develop interlocking for feed extension from one circuit to another in case of failure. Also the extension of power feed shall be developed in case of RSS failure or from Circuit-1 to Circuit-2 in case of power failure. The interlocking shall be developed by LKE (02)-01 contractor and submitted during detail engineering stage.

33kV, 3 Phase power distribution, three single core cables shall be used. The cables will be with Aluminium conductor, of the specified cross-sectional area and insulated with chemically cross-linked polyethylene (XLPE), with semi-conducting screen over conducting core, and insulating envelope and fire-retardant polyvinyl chloride (PVC) protective sheath. All elevated/at grade sections, cables shall be Fire Retardant Low Smoke (FRLS) class & all underground sections, cables shall be Fire Retardant Low Smoke Zero Halogen (FRLSOH).

- 13.1.2.7 The 33kV distribution cables shall be laid in;

- At Viaduct/Elevated Section:** Cable shall be laid on metallic bracket provided by LKE (02)-01 contractor
- Inside the elevated/U/G ASS/ASS+TSS:** All cables within the scope of LKE (02)-01 contractor shall be laid on suitable cable tray provided & arrangement (supply & erection) done by LKE (02)-01 contractor. For finalization of route of cable tray inside ASS contractor will interface with E&M contractor.
- At U/G tunnel Area:** Cable shall be laid on metallic bracket provided by E&M contractor

- 13.1.2.8 33kV cables are to be contained in trefoil for which suitable non-metallic trefoil clamps are to be used. Supply and installation of trefoil clamps at every cable support with all necessary hardware (SS with NYLON LOCK Nut) is under the scope of the Contractor.

- 13.1.2.9 The LKE (02)-01 contractor shall co-ordinate and give requirements to the Viaduct/Tunnel Contractor for the cable path, gallery size, route alignment and mounting requirements requirement for 33 kV, 750 V DC, control cables and return cables and their crossings under tracks (if required) for connection with Third Rail/Running Rails, on the viaduct/tunnel as per interface matrix.

- 13.1.2.10 The LKE (02)-01 contractor shall co-ordinate with Viaduct/Tunnel Contractor for provision of opening and HDPE pipes of adequate size at track crossings for the DC cables as per interface matrix.

13.1.2.11 The LKE (02)-01 contractor shall co-ordinate with Viaduct/Tunnel Contractor and station building contractor for suitable opening in the viaduct at appropriate location for raising the cables coming to/from viaduct to/from the line side substations at RSS/ASS/TSS as per interface matrix.

13.1.2.12 Cutouts for entry-exit of the 33kV cable and associated control cables are required to be sealed with appropriate EPDM modules to avoid ingress of water inside the substation. Supply and installation of all necessary accessories and hardware to seal the cutouts is under the scope of the Contractor.

13.2 33kV CABLE SPECIFICATIONS

13.2.1 SCOPE

13.2.1.1 This Specification applies to 33kV cables for Lucknow Metro Rail project (here after termed as LKE (02)-01, namely East West Corridor Phase 1 B). The incoming voltage of 33 kV shall be received at the 33kV RSS/AMS and further distributed to ASSs/TSSs through 33kV cable ring circuits for the purpose of traction and auxiliaries loads at stations and along the line in the viaduct, tunnels and depots.

13.2.1.2 In addition to 33kV cables, armoured Optic Fibre Cables (OFC) of suitable sizes shall be provided for cable differential protection and interlockings. Also, control cables of suitable sizes are laid for various interlocking alongside 33kV cables in different bracket/supports. These control cables shall be FRLS for elevated and at-grade / depot sections and FRLSOH for tunnel/underground sections. Separate control cables for traction and auxiliary networks shall be used. The Contractor shall submit detailed proposal including technical particulars of these control cables to the Engineer for approval.

13.2.2 SPECIFICATIONS

13.2.2.1 The 33kV cables shall, otherwise specified generally conform to IS 7098 Part II, IEC 60502-Part 2, IEC 60228, and IEC 60811 for construction and IEC 60840 for testing. It shall conform to latest specifications be applied in the manner altered, amended or supplemented by this Specifications, the Indian Electricity Rules and the relevant regulations of Electricity Supply Authority concerned, wherever applicable.

13.2.2.2 The list of standards applicable is provided in "List of Standards" at the beginning of the PS. The following standard/specifications of latest version updated to as on date of opening of the tender document will govern supply, laying testing and commissioning of cables and their accessories to be used in this Contract.

Table 13.1: List of Standards

SN	Title of Specification	Specification No.
1.	Extruded solid dielectric insulated power cables and their accessories for rated voltage from 6 kV ($U_m = 7,2 \text{ kV}$) up to 30 kV ($U_m = 36 \text{ kV}$)	IEC:60502-2-latest (For manufacture)
2.	Conductors for insulated cables.	IEC: 60228 – Latest
3.	Test on cable over Sheath which have a special protective function and are applied by extrusion.	IEC 60229 – Latest

SN	Title of Specification	Specification No.
4.	Code of Practice for installation and maintenance of Power Cables up to and including 33kV rating.	BIS: 1255 latest
5.	HDPE pipes	BIS: 4984 latest
6.	Impulse test on cables & their accessories.	IEC 60230 latest
7.	Cyclic and emergency rating of cable	IEC 60852-2 latest
8.	Common test methods for insulating and sheathing material of electrical cables.	IEC 60811 latest
9.	Electric test methods for Electric cables – Test methods for Partial Discharge measurements on lengths of extruded power cables.	IEC 60885- Part 3 latest
10.	XLPE insulated PVC sheathed cables for working voltages up to 220 kV	IS 7098 Part-II
11.	Tests on electric cable under fire conditions	IEC 60332 Part 1 and Part 3 (latest)
12.	Tests on electric cables (Limited Oxygen Index and Temperature Index of 260 °C)	ASTM D 2863
13.	Measuring of smoke density of cables burning under defined conditions	IEC 61034 BS 7622 ASTM D 2843
14.	Method of determination of amount of Halogen acid gas evolved during combustion	IEC 60754 – Part 1 and 2

13.2.3 RATINGS

13.2.3.1 The cables shall be designed for the expected rating and other parameters indicated in Table 13.2:

Table 13.2: 33kV Cable Rating

SN	Description	33kV Cable Rating
1.	Type	Dry insulated, radial field
2.	Conductor cross section	300mm ² & 120 mm ²
3.	Conductor material	Aluminium
4.	No. of cores	1
5.	Fire Retardant Property (Conforming to UTE Standard 32 700, test N°2, IEC 60502-1 or equivalent)	FRLS for elevated, at-grade sections & depots FRLSOH for UG stations
6.	Rated voltage	U0/U (Um) = 19 / 33 (36) kV (Suitable for use in 33kV earthed system)
7.	Maximum Voltage	36 KV
8.	Neutral	Earthed through NGR of 19 ohm
9.	Frequency	50 Hz
10.	Short circuit current carrying capacity of conductor	16 kA for 3 sec
11.	Short circuit current carrying capacity of metallic screen	1 kA for 3 sec
12.	Permissible Frequency variation	± 3%
13.	Rated short circuit duration power	70 kV rms

SN	Description	33kV Cable Rating
	frequency withstand voltage	
14.	Rated lightning impulse withstand voltage	170 kV Peak

13.2.3.2 Environmental and Climatic Data

- The environmental and climatic data in Lucknow are provided in General Specifications.
- The thermal resistivity of soil may be assumed to be 120-150⁰ C-cm/Watt (For laying in ground from RSS to Depot AMS/ASS+TSS & from Depot AMS/ASS+TSS to ASS/TSS). The Contractor shall furnish the current rating of 300 mm² Aluminium cable at assumed thermal resistivity of soil. However, the Contractor has to measure the soil thermal resistivity along the cable route and the cable has to be designed suitably.
- It should be noted that environmental conditions will be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

13.2.3.3 General Requirements

- 13.2.3.3.1 The Contractor shall confirm the section of these cables as regard to the route installation, the thermal conditions in service, the climatic conditions, the energy and currents flowing through these cables, taking into account the worst electrical conditions i.e. operation under permissible overload conditions. and operation when Vasantkunj RSS of a corridor is out of service.

- 13.2.3.4 The 33kV cables shall be used at different locations. The minimum cable size requirement for different sections is indicated in Table 13.3. & Annexure-I

Table 13.3: 33kV Cable Sizing[#]

SN	Location	Cable Size (for each circuit)
1.	From 33 kV RSS outgoing bay to 33 kV Depot ASS+TSS incoming CB	2x[3 x (1C x 300 mm ²)] Aluminium Conductor FRLS cable for Vasantkunj RSS/AMS
2.	From 33kV CB in RSS/AMS to ASS or ASS+TSS	2x[6 x (1C x 300 mm ²)] Aluminium Conductor FRLS cable for Vasantkunj RSS/AMS
3.	From 33kV CB Charbagh(Elev) to 33kV CB, Charbagh(UG)	2x[3 x (1C x 300 mm ²)] Aluminium Conductor FRLS cable
4.	33kV loop-in-loop-out for Ring main cables	[3 x (1C x 300 mm ²)] Aluminium Conductor FRLS cable for Ring Main Loops [3 x (1C x 300 mm ²)] Aluminium Conductor FRLSOH cable for Ring Main Loops. (FLRS Cable for Elevated/at grade stations and FRLSOH Cable for Underground section)
5.	33kV CB to Auxiliary Transformer	[3 x (1C x 120 mm ²)] Aluminium Conductor, FRLS for elevated / at-grade section and Depot

SN	Location	Cable Size (for each circuit)
	/Traction	[3 x (1C x 120 mm ²)] Aluminium Conductor, FRLSOH for tunnel / underground section

LKE (02)-01 contractor shall perform AC load flow study in order to finalise the 33kV cable size for East West Corridor.

13.2.4 CONSTRUCTION FEATURES

13.2.4.1 Manufacturing Process

The cables shall be manufactured by a company having ISO accreditation for quality. The manufacturing process of XLPE cable shall consist of conductor screen, insulation & insulation screen shall be extruded in a single process (triple extrusion) and cross linked by dry curing technology to ensure homogeneity and absence of micro voids. The cables shall be manufactured by "Dry Curing" Process. The extrusion process shall be by CCV or VCV method. The ovality and eccentricity shall be less than or equal to 2% i.e., $(D_{max} - D_{min}) / D_{max} \leq 0.02$ (IS 7098 part-2).

13.2.4.2 Conductor

13.2.4.2.1 The conductor shall be made of bare aluminium with a voltage class and cross section described in Table 13.3 above. The conductor shall be formed from stranded by Pure EC Grade Aluminium conductor complied with IEC latest publications 60228. The conductor shall be compact circular stranded. The conductor shall be clean, reasonably uniform in size and shape, smooth and free from harmful defects. The Geometrical cross-sectional area of the conductor shall be better and proportional to the specified cross-sectional area with a tolerance of (-) 3%, This tolerance should be calculated only on the cross-sectional area of the conductor, and not on the maximum conductor resistance requirement as per IEC 60228(latest).

13.2.4.2.2 By using the formula which is related to specific resistivity, the manufacturer has to prove that the conductor of the cable is not only meeting the required area (mm²), but also the resistance of aluminium conductor is better and lower than the maximum specified in IEC 60228.

13.2.4.2.3 The manufacturer shall specify precisely the characteristics of the components of the conductor i.e.:

- a) number of wires,
- b) diameter of wires,
- c) aluminium quality.

13.2.4.2.4 The maximum temperatures admissible for the conductor, as per IEC 60502-2(latest), shall be as follows:

- a) permanent service: 90°C
- b) short-circuit condition: 250°C on the conductor
- c) over-load condition: 105°C

13.2.4.3 Conductor Screen

13.2.4.3.1 The conductor screen shall be provided over the conductor by extrusion of semi-conducting compound. A semi conducting tape (s) shall be provided below the extruded semi conducting conductor screen to prevent penetration of compound in to the under lying conductor. Nominal thickness of conductor screen shall not be less than as per applicable standard. The smallest of the observed value shall not fall below 0.7 mm.

13.2.4.4 Insulation

13.2.4.4.1 The conductor with screening shall be provided with cross linked polyethylene (XLPE) insulation applied by extrusion. The nominal thickness of insulation shall not be less than 8 mm and subject to tolerance as per IEC – 60502-2(latest), Table 6.

13.2.4.4.2 The insulation shall be XLPE complying with IEC 60502 and IEC 60811(latest). The insulation shall have a degree of cross linking, free of contaminants and air voids, heat resistant and shall be applied by the extrusion process.

13.2.4.4.3 The insulation compound shall be of high quality, heat, moisture, ozone and corona resistant. XLPE compound shall preferably be from DOW US, Borealis Sweden or NUC Japan or equivalent. The insulation shall be suitable for operation in wet or dry locations at conductor temperature not exceeding 90 °C for normal operation, and 250 °C for short circuit conditions.

13.2.4.4.4 The insulation shall be applied by extrusion and vulcanized using dry curing process to form a compact homogenous body free from micro voids and contaminants.

13.2.4.5 Insulation Screen

13.2.4.5.1 The Insulation screening shall be applied directly upon the insulation. Insulation screen shall consist of extruded non-metallic semi conducting thermosetting compound in combination with metallic layer, firmly and totally bonded to the insulation. Semiconducting compound shall preferably be from DOW US, Borealis Sweden or NUC Japan or equivalent. Nominal thickness of insulation screen shall be 0.7mm. The smallest of the observed value shall not be less than 0.6 mm.

13.2.4.6 Triple Extrusion

13.2.4.6.1 The conductor screen, insulation & insulation screen shall be extruded in a single process.

13.2.4.7 Water Swellable Tape

13.2.4.7.1 The tape(s) shall be semi-conducting water swellable to be applied over the extruded insulation screening to block and prevent moisture propagation in a longitudinal direction. The semi-conducting tape shall be suitable for the operating temperature of the cable and compatible with the insulation.

13.2.4.8 Metallic Screen

13.2.4.8.1 The metallic screen shall be plain copper round wires /copper tape applied helically over the semi-conductor bedding tape(s). The area of the copper wire /copper tape shall be able to withstand specified earth fault current. The Contractor shall submit the calculations giving details of the area of copper wire screen/copper tape.

13.2.4.8.2 The minimum area of copper wires/copper tape shall be designed to meet the requirement of the system short circuit rating of 1 kA for 3 sec.

13.2.4.8.3 An annealed plain copper binder tape shall be applied in the form of an open helix, over the copper wire screen.

13.2.4.8.4 The sheath shall be impervious to moisture, reasonably close fitting and free from defects and impurities such as oxide, which give rise to failure under working conditions.

13.2.4.9 Inner Sheath

13.2.4.9.1 FRLS Cables: A polypropylene/PVC/polyolefin tape shall be applied over the metallic screen.

13.2.4.9.2 FRLSOH Cables: An inner layer of FRLSOH tape shall be applied over metallic screen followed by Polyethylene laminated aluminium tape.

13.2.4.10 Armouring

13.2.4.10.1 Double Tape armoring should be applied over the inner sheath and the thickness of the same should be as per IEC 60502.

13.2.4.11 Outer Sheath

13.2.4.11.1 FRLS Cable: The outer sheath shall be extruded black colour with anti-rodent, anti-termite protected and UV resistant (compliant for outdoor installation), FRLS PVC conforming to the requirements of IEC specifications and extruded continuously. Retention of tensile & elongation of outer sheath Should not be less than 75%, on UV exposure of 14 days when tested in accordance with ASTM G 53.

13.2.4.11.2 FRLSOH Cable: The outer sheath shall be extruded orange colour, halogen free, flame-retardant Polyolefin conforming to requirement of IEC specifications and extruded continuously. Outer sheath shall be treated with Anti Termite & corrosion Resistant Compound.

13.2.4.11.3 Such cables shall have phase identification at an interval of 50 meters.

13.2.4.11.4 FRLS PVC conforming to the requirements of IEC specifications and extruded continuously. Retention of tensile & elongation of outer sheath Should not be less than 75%, on UV exposure of 14 days when tested in accordance with ASTM G 53.

13.2.4.12 External Marking

13.2.4.12.1 The protective sheath shall carry the indications listed below, in letters and digits at least 6 mm high:

- a) Designation of ownership,
- b) Meter marking
- c) Year of manufacture
- d) Material cross-sectional area of conductors,
- e) specified cable voltage,
- f) phase numbering,
- g) Manufacturer's name.

13.2.5 TESTS

13.2.5.1 All the 33kV cables shall comply with the test requirements defined in IEC 60502-2(latest) & IS 7098-2.

- a) IEC 60332 Part 1 and 3(latest), category A, test on single and bunched cables under fire condition.
- b) All Insulation is to be moisture and heat resistant, with temperature rating appropriate to the application conditions and in no case lower than 90 °C.

13.2.5.2 Following Type test shall be conducted as per IEC 60502-2(latest) and IS 7098, Pt –II

- a) Bending Test followed by a partial discharge test.
- b) Tan delta measurement
- c) Heating cycle voltage test, followed by a partial discharge measurement, which shall be carried out after the final cycle or, alternatively, after the impulse voltage test.
- d) Impulse voltage test followed by a power frequency a.c. voltage test.
- e) Partial discharge test
- f) Non-electrical type tests in accordance with IEC 60502-2(latest)/IS 7098 Pt-II
- g) Tests on conductor
- h) Tests on armouring
- i) Test for thickness of insulation and sheath
- j) Physical tests for insulation
- k) Physical tests for outer sheath
- l) Dielectric power factor test
- m) Insulation resistance
- n) Flammability test
- o) Water Penetration Test

13.2.5.3 The routine test will be conducted on sample cable drums as per provision laid down in IS 7098, Pt –II -1985, IEC 60502-2(latest), but shall not be limited to the following:

- a) Conductor resistance Partial discharge on whole drum.
- b) High voltage test
- c) Cold impact test for outer sheath
- d) Any other relevant test in accordance with the standards.

13.2.5.4 The acceptance tests will be conducted on sample cable drums as per provision laid down in IS 7098, Pt –II -1985, IEC 60502-2(latest), but shall not be limited to the following:

- a) Tan delta measurement
- b) Conductor resistance test and cross-sectional area
- c) Conductor Resistance and calculation of area of the Metallic Screen Wires
- d) Test for thickness of insulation and sheath
- e) Hot set test for insulation
- f) Tensile strength and elongation at break test for insulation and sheath
- g) Partial discharge test (for screened cables only)
- h) High voltage test and
- i) Insulation resistance (volume resistivity) test
- j) IEC 60332 Part 1 and 3(latest), category A, test on single and bunched cables under fire condition.
- k) Limiting oxygen index of at least 31 as per ASTM D 2863
- l) Temperature index on FRLS/FRLSOH sheath shall of 260 °C as per ASTM D 2863
- m) 3 m cube Smoke emission test, when tested in accordance with IEC 61034(latest)/BS 7622 & Maximum smoke emission shall be 40% & Minimum light transmission shall be 60% (FRLS) & Maximum smoke emission shall be 20% & Minimum light transmission shall be 80% (FRLSOH)

- n) All Insulation is to be moisture and heat resistant, with temperature rating appropriate to the application conditions and in no case lower than 90° C.
- o) Determination of the amount of halogen acid gases as per IEC 60754 Part 1(latest) (maximum HCL gas shall not exceed 20% by weight for FRLS sheath & shall not exceed 0.5% by weight for FRLSOH sheath)
- p) Ovality and eccentricity confirmatory test

13.2.5.5 The onsite/pre-commissioning are defined below in this Chapter.

13.2.6 CABLE JOINTS & TERMINATIONS

13.2.6.1 The straight through joint kits and indoor/outdoor termination shall be of heat-shrinkable 'Raychem' type or equivalent, suitable for 33kV (E) grade or higher, single core, XLPE insulated cables. The MV cable heads shall be connected to cable junction boxes with the MV apparatus.

13.2.6.2 The accessories should be compatible with the size of the conductor, the insulation and the voltage class of the cable. The components of the accessory shall not be affected by contact with the component materials of the cable, and shall not corrode any metal, with which they come in contact. The accessory, in the assembled condition, shall be capable of operating under the normal and fault temperature conditions of the cable. Accessories offered shall be of proven design. The cable accessories should be procured only from reputed manufacturers and type test reports shall be submitted along with the Tender.

13.2.6.3 The cable joints and terminations shall suitable for the cable supplied to comply with applicable IEC/IS Standards. The applicable standard for joints and terminations is IS 13573/IEC 60502-4(latest).

13.2.6.4 The straight through joints shall be suitable for 33kV (E) grade or higher, single core, XLPE insulated cables confirming to latest relevant IEC specification. The joints shall be suitable for size of the conductor, the insulation, voltage and current ratings of the cable. The required service conditions are, horizontal installation, directly buried in earth laid in RCC cable duct and intermittently or continuously submerged in water.

- 13.2.6.5 The cable end terminations shall be out door self-supporting type suitable to for 33kV (E) grade or higher, single core, XLPE insulated cables confirming to latest relevant IEC specification. The outdoor termination should have a device for electrical stress control at the end of screen/shield. It should avoid partial discharges and surface corona under the service conditions. It should seal any ingress of atmospheric elements. The minimum creepage distance shall not be less than 1850 mm. Outdoor installation with usual and unusual supporting structure (i.e. directly on transmission towers with lightning arrestors), heavily polluted atmosphere. The termination should be directly exposed to Solar radiation and precipitation.
- 13.2.6.6 Connecting junctions shall reconstitute perfectly all elements of the MV cables, so as to obtain electrical and mechanical characteristics at least equal to those of the cable.
- 13.2.6.7 The Contractor shall submit to the Engineer for approval, a detailed description of the technique foreseen for execution of connections in MV lines.
- 13.2.6.8 However, as maintenance and repair can only be carried out during short periods at night, due consideration shall be given to connection processes having the following characteristics, quality being otherwise equal:
- a) quickness of execution,
 - b) possibility of replacement without having to disturb the cable,
 - c) Small bulk.
- 13.2.6.9 The joints and terminations shall meet the type test requirement of the governing standard i.e., IS or IEC.

13.2.7 EXECUTION RULES

- 13.2.7.1 The entire supply shall be executed according to all rules-of-the-art pertaining to professional-grade equipment and in compliance with the technical specifications and specifications of the International Electrotechnical Commission relative to power supply cables (IEC 60055-1, 60055-2 and 60502-1(latest)). The supply shall be delivered, upon request by the Employer, only after execution of in-plant inspection operations and satisfactory testing according to the technical requirements imposed.
- 13.2.7.2 The cables shall pass all the tests stipulated in the IEC 60502(latest) rules in force on the date of the order.
- 13.2.7.3 The sleeves and the insulating materials used shall meet the guarantee requirements imposed.
- 13.2.7.4 The equipment cables, termination, straight through joints kits shall be capable of withstanding intensive use without alteration, and of performing its duty even after extended idle periods.

13.2.8 CABLE TECHNICAL AND TEST SHEET

- 13.2.8.1 The tests shall be performed according to the corresponding latest IEC standard.
- 13.2.8.2 After completion of laying of the cable and its accessories, a dielectric test shall be carried out between the conductor and metallic screen

- a) test for 5 minutes with the phase to phase voltage of the system applied between the conductor and the metallic screen
- b) test for 24 hours with normal operating voltage of the system. As an alternative to ac test, a dc test voltage equal to $4U_0$ may be applied for 15 minutes

13.2.9 GTP FOR 33kV CABLES

13.2.9.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

13.2.9.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 13.4: GTP for 33kV Cables

SN	Description	Unit of Measurement	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Relevant Specification		
4	Type of cable		
5	Size of cable	mm ²	
6	Rated voltage		
a.	Nominal	KV	
b.	Highest	KV	
7	Suitable for earthed system or unearthed system		
8	Conductor		
a.	Material		
b.	Shape		
c.	Diameter of conductor		
d.	Nominal cross section area of conductor		
e.	No. of strands in conductor		
f.	Nominal dia of each inlet wire before compacting		
g.	Thickness of semiconducting tape		
9	Conductor screen		
a.	Material		
b.	Thickness of semiconducting tape	Mm	
c.	Min thickness at any point	mm	
d.	Max volume resistivity	ohm-cm	
10	Maximum value of electric stress	KV/mm	
a.	at conductor screen		
b.	At the insulation (to be shown separately)		
11	Insulation		
a.	Curing process (furnish details separately)		

SN	Description	Unit of Measurement	Manufacturer's Data
b.	Material / composition		
c.	Dia of cable over the insulation	Mm	
d.	Radial thickness min average		
e.	Radial thickness min at any point		
f.	Maximum value of electric stress at insulation surface	KV/mm	
12	Insulation Screen		
a.	Material		
b.	Nominal thickness	Mm	
c.	Min thickness at any point	mm	
d.	Max volume resistivity at $90 \pm 2^{\circ}\text{C}$	ohm-cm	
13	Water Swellable Tape		
a.	Material		
b.	Thickness	mm	
c.	Tolerance		
14	Metallic Screen		
a.	Material		
b.	Thickness	Mm	
15	Inner Sheath & Armouring		
a.	Inner sheath		
b.	Armouring		
16	External Overall Sheath :-		
a.	Material/Type		
b.	Thickness	Mm	
c.	Min thickness at any point	Mm	
17	Conductive coating over external overall sheath		
a.	Material		
b.	Thickness	mm	
18	Overall cable		
a.	External diameter	Mm	
b.	Minimum bending radius during pulling	M	
c.	Minimum bending radius below terminals	M	
d.	Permissible max tension in cable (of conductor)	Kg	
19	Rated Current		
a.	In air : at Ambient temp laid in trefoil formation ,	A	
b.	In ground : Ground temp 30°C , depth of laying 1.0 mtr laid in trefoil / flat formation	A	
20	Conductor Temp		
a.	At rated current		
b.	Max permissible conductor temperature		

SN	Description	Unit of Measurement	Manufacturer's Data
21	Resistance		
a.	Maximum DC resistance of conductor at 20 °C	ohm/km	
b.	Maximum AC resistance of conductor at 90 °C	ohm/km	
c.	Minimum insulation resistance at 20 °C	Mohm/km	
22	Short circuit capacity		
a.	Of conductor for 1 sec assuming conductor temp of 90 °C before short circuit and 250 °C during short circuit	KA	
b.	Of metallic screen for 1 sec assuming screen temp of 75 °C before short circuit and 200 °C during short circuit	KA	
23	Dielectric dissipation factor at rated voltage		
24	Power frequency withstand voltage (30 min)	KV	
25	Maximum partial discharge at 1.50 U ₀		
26	Impulse test voltage (KV)		
27	Tan Delta at 50 Hz (at U ₀ kV and 90 - 5/+10 °C)		
28	Sheath voltage at maximum load single Amps: Point bonded, trefoil touching (both circuits alive) V/km		
29	Withstand voltage of sheath on spark test		
30	Approximate impedance at 50 Hz per km		
a.	At 20 °C	Ohm/km	
b.	At 90 °C	Ohm/km	
31	Sheath resistance at 20 °C	Ohm/km	
a.	Screen resistance		
b.	Combined resistance		
32	Charging current at rated voltage per km		
33	Shipping weight and size of cable drum		
a.	Size of drum		
b.	Diameter of drum	m	
c.	Width of drum	m	
d.	Gross weight	kg	
e.	Length of cable per drum (maximum)	m	
f.	Weight of cable	Kg/m	
34	Jointing		
a.	Type of jointing recommended		

SN	Description	Unit of Measurement	Manufacturer's Data
b.	Name of manufacturer of jointing kit		
c.	Permissible temp rise of joint		
35	Termination		
a.	Type of termination recommended		
b.	Name of manufacturer of jointing kit'		
36	No. of voids per cubic/inch of insulations		
a.	voids between 2 and 3 mils		
b.	Voids larger than 3 mils		
37	No. of contaminations per cubic/inch of insulation		
a.	Contaminations between 2 & 7 mils		
b.	Contamination larger than 7 mils		
38	Brief process of manufacture indicating the method of cross-linking and type of curing		

13.3 33kV CABLE INSTALLATION

13.3.1 GENERAL REQUIREMENTS

13.3.1.1 The 33kV cables shall be used to transmit the power from RSS/AMS to Depot ASS+TSS and stations ASSs & TSSs. These cables shall be laid all along the line on viaduct, and in ground wherever required. They shall be supplied on reels, the standard of which shall be determined according to the laying conditions.

13.3.1.2 This Specification defines the type of work related to installation of cables, paying out and laying of the cables, at grade, on viaduct. The Contractor shall produce a stake-out plan at 1:500 scale, which shall indicate the precise laying position and the type of routing (in channel or inside duct), accounting for all specific location of the line (track crossing and entry into ASS / TSS).

13.3.1.3 The various cable sections are defined in Table 13.3. Following principles shall be applicable for laying of 33kV Cables.

13.3.1.4 From RSS/AMS to Depot ASS+TSS

13.3.1.4.1 Cables shall be laid from the 33kV switchgear in the RSS/AMS to 33kV switchgear in the Depot ASS+TSS. Routing of the cables between the RSS/AMS switchgear and the Depot ASS+TSS incoming circuit breakers shall be realized in cable channel from the outgoing bus of 33 kV RSS/AMS switchgear to the cable heads of the 33 kV Depot ASS+TSS incoming circuit breaker cells.

13.3.1.5 FROM RSS/AMS TO NEAREST ASS / TSS

13.3.1.5.1 Cables shall be laid from the outgoing 33kV switchgear at the RSS/AMS to the designated incomer breakers at ASS/TSS. From the outgoing circuit breakers in the RSS/AMS downstream to the base of the viaduct, cables shall be laid into channels and ducts up to the RSS/AMS boundary wall and buried underground beyond that. If

the road crossings/track crossings are involved the cable shall be laid through open trench/ trenchless method in HDPE pipe. Cables shall be laid in trefoil formation. Erection of cable support structure from ground level to viaduct to be in LKE (02)-01 contractor's scope for laying of 33kV cable laying from RSS/AMS to nearest ASS/TSS on viaduct

- 13.3.1.5.2 From the base of the viaduct to the ASS/TSS and between the ASS/TSS for ring formation, the cables shall be laid on suitable GI cable mounting structure and cable tray. They shall be fixed on the cable tray every 0.75 m and on each side of change of way.

13.3.1.6 **ON VIADUCT / ELEVATED STATIONS/ UNDERGROUND STATIONS**

- 13.3.1.6.1 On viaducts normally, cables shall be laid on metallic supports/channels, anchored to the wall or parapet wall of viaduct, under the walkway as per the drawings. The cable support brackets, pipes for track crossing on viaduct / at-grade shall be provided by LKE (02)-01 Contractor and cable supports in UG section will be provided by E&M Contractor for which LKE (02)-01 Contractor will have to do necessary interface. LKE (02)-01 contractor shall provide suitable means for secured cable laying on hangers, cable support brackets, trays etc. with approval of Employer. Cables shall be laid in trefoil formation.

- 13.3.1.6.2 33kV cable are to be contained in trefoil for which suitable trefoil clamps are to be used. Supply and installation of trefoil clamps at every support with all necessary hardware is under the scope of the Contractor Trefoil clamps shall be suitable for outdoor application (open to sky) and capable of withstanding the forces developed during short circuit in 33kV system.

- 13.3.1.6.3 In tunnels, the cables shall be laid on the bracket supports, under the walkway, provided on the tunnel walls. The cable support brackets, pipes (to be provided by E&M contractor to the designated contractor) for track crossing in tunnels shall be provided by other Designated Contractors, for which the LKE (02)-01 Contractor will have to interface. In some cases where the cable trench is not available. The Contractor shall provide suitable means for secured cable laying on hangers, cable support brackets, trays etc. with approval of the Engineer. Cables shall be laid in trefoil formation.

13.3.1.6.4 **CABLE SEALING SYSTEM**

Cutouts for entry-exit of the 33kV cable, DC Positive & Negative Cables and associated control cables are required to be sealed with appropriate EPDM modules to avoid ingress of water inside the substation. Supply and installation of all necessary accessories and hardware to seal the cutouts is under the scope of the contractor. In underground station the bottom entry to be sealed by LKE (02)-01 Contractor.

- 13.3.1.6.4.1 Contractor to fill up voids and openings with fire resistant materials to protect fire or smoke from spreading out from one room to other room or one floor to another floor through these voids and opening
- 13.3.1.6.4.2 Fool proof sealing system is a pre-requisite for proving protection against Fire, Water, Energy/Power Loss, Humid Temperature Variations, Pull Tension and Rodents, wherever cables are entering in to the ASS or ASS/TSS
- 13.3.1.6.4.3 Cable entry/exit to a building shall be sealed with 2 hour fire rating and meet the requirement of National Building Code. Modular based Cable and Pipe Sealing (Foolproof) System shall be adopted with adjustable layer with following features

wherever cables are entering in to the Electrical sub-station, Control Room, SCADA Room, Electrical Equipments, Cabinets, Power and UPS Room, Transformers, Buildings and Power equipments.

- a) Protection against Energy/Power Loss in the form of leakages in AC rooms.
- b) Water protection according to IP54, IP66 and IP67 ratings.
- c) Protection from rodents such as rats, snakes, lizards, etc.
- d) Possibility for future capacity expansion.
- e) Area efficient cable penetration to minimize heat induction.
- f) Fire stopper and gas proof.
- g) Applicable for retrofit during operation of site

13.3.1.6.4.4 The specification lays down the acceptance tests and type tests to be carried out on the sealing system with EPDM rubber modules with adjustable layers and the internal test results of the materials to be submitted by the supplier.

13.3.1.6.4.5 Modular based cables sealing system shall mainly consist of following sub-assemblies.

- a) Modules
- b) Frames (Metallic/Non-Metallic)
- c) Compression Unit (Separate or Integrated)
- d) Stay Plates (For rectangular frames)
- e) Lubricants &/ or Assembly Gel

13.3.1.6.4.6 Module diameter shall be adjustable by adding on or peeling off procedure so as to suit the cable outer diameter. The modules shall consist of two halves for each cable, and each module shall be a length of 30 mm or 60 mm. The modules should be able to accommodate cables or pipes of diameter 3.5 to 99 sq mm, a range that encompasses the commonly used sizes. The spare modules may be supplied /with /without re-adjustable and reusable plug /wrap /core for sealing the cables for spare

13.3.1.6.4.7 **SPECIFICATION OF EPDM**

13.3.1.6.4.7.1 Composition: Low Smoke Index, Halogen free rubber compound based on Ethylene Propylene Diene Terpolymer (EPDM). The Material (EPDM rubber) of module with centre plug/wrap/core shall be fire resistant as per UL 1479 or BS 476/20 and ensure protection against Dust, Water, & penetrating solid objects as per IP54, IP66 and IP67 (IEC 60529). If no IP protection is mentioned during the tendering stage, then it shall be supplied with IP 67.

13.3.1.6.4.8 **ADJUSTABLE DIAMETER MODULES**

13.3.1.6.4.8.1 Modules shall be of adjustable diameter so that by adding on or peeling off the layers, cables of different outer diameters can be accommodated. The spare modules may be supplied /with /without re adjustable and reusable plug /wrap /core for sealing the cables for spare.

13.3.1.6.4.9 **PHYSICAL AND CHEMICAL PROPERTIES**

- a) State: Solid
- b) Odour: Rubber
- c) Specific gravity: 1200-1600 kg/m³
- d) Temperature of Decomposition: - > +300°C
- e) Solubility: Insoluble in water

- f) Temperature Range: -60 to +80 Degree C
- g) Certificates in respect of the following-
 - i. Fire Protection: - Fire protection for more than 180 minutes as per UL 1479 or BS 476/20. Moreover, it should also stop burning within 10 seconds on vertical specimen, no drips allowed as per UL94 V-0 or equivalent.
 - ii. Environmental Sealing: Protection against Dust, Water and penetrating solid objects: IP54, IP66 and IP67 (IEC 60529(latest)).
 - iii. Temperature Variations.
 - iv. Pull Tension
 - v. Protection against Rodents, tested by any NABL/ international laboratory

13.3.1.6.4.10 **FRAME**

13.3.1.6.4.10.1 The Frames should be available in different designs and materials. The depth of the frames shall be 30 mm and 60 mm as compatible with module size. The choice of frame shall depend primarily on the material used in the application area and the method of attachment. The frames can either be cast, bolted, welded, riveted or fitted into sleeves

13.3.1.6.4.10.2 Material used for frames shall have good impact strength, Tensile strength and should withstand the temperature variations. Material used for the frame shall be as follows: -

- a) Metallic: - M.S galvanized, SS, Aluminium (for the application required in concrete)
- b) Non-Metallic: - Nylon 6/6 with 30% GF (for the application required in Puff Shelter).

13.3.1.6.4.11 **COMPRESSION UNIT/ WEDGE/PRESS WEDGE**

13.3.1.6.4.11.1 The Compression Unit (wedge/press wedge) is used in frames with a rectangular packing space for uniform compression of Cables, Pipes, Modules, and Stay plates. The compression unit should save valuable installation time both when it comes to installation and re-installation of the Modular based Cable and Pipe Sealing System with adjustable layer. When tightened/ loosened, the complete compression unit should compress/ decompress the wedge and compression unit/ press wedge.

13.3.1.6.4.11.2 For Round Type Seals, the Compression unit is integrated in the seal i.e. for round seal there should be built in compression unit and no separate compression unit should be required as in rectangular arrangements

13.3.1.6.4.11.3 Material of wedge should be similar to that of modules i.e. Low Smoke Index, Halogen free rubber compound based on Ethylene-Propylene rubber (EPDM). The bolts shall be of galvanized steel.

13.3.1.6.4.12 **STAY PLATES**

13.3.1.6.4.12.1 To increase stability and to secure Mechanical anchorage within the frame, Stay Plates should be placed between each row of blocks. Material of construction shall be SS316

- a) Dimensions: 120 millimeters and 60 millimeter (4.724" und 2.362") width or as compatible with frame
- b) Stay plates shall be of galvanized steel

13.3.1.6.4.12.2 Lubricants/ Assembly gel shall be used in all installations for IP 54 rating or more to assure the proper sealing performance

13.3.1.7 **DEPOT**

13.3.1.7.1 In depot, Depot ASS+TSS are part of Depot..

13.3.1.7.2 However, due to change in design during execution stage/detailed engineering stage i.e., Depot ASS and/or Depot TSS forming a separate installation(s), LKE (02)-01 Contractor to interface with Depot Civil Contractor for cable ducts/trenches.

13.3.1.7.3 In depot, the cables from RSS/AMS to Depot ASS+TSS shall be laid by the Contractor. Routing of the cables between the 33kV switchgear room in Depot ASS+TSS and the 33kV circuit breakers at the RSS/AMS shall be realized in cable channel rising up from the respective 33kV outgoing panel in RSS/AMS to the cable head of the incoming circuit breaker in Depot ASS+TSS .

13.3.1.7.4 The 33kV cables from RSS/AMS to Depot ASS+TSS shall be laid in channels, support brackets and cable ducts / trenches. These channels, support brackets and cable ducts / trenches shall be provided by the Depot Contractors, for which LKE (02)-01 Contractor shall provide the necessary design and construction interface.

13.3.1.7.5 Wherever the cable trenches are provided cables are to be laid on the brackets and if cable ducts are not available, cables are to be buried in open trenches in accordance with IS1255 and also confirming the manufacturer's recommendations (refer clause no.13.3.3).

13.3.1.8 **From 33kV CB to Auxiliary Transformers in ASS & Rectifier Transformers in TSS**

13.3.1.8.1 The cables shall be laid on cable trays of suitable dimensions. The cables shall be laid in such a manner that they are clearly segregated and do not touch ground. Suitable identification tags of 8 x 5 cm PVC shall be attached to the cables at the ends and at every 10 m intervals.

13.3.1.8.2 The necessary provision of cable supports, cable tray, brackets etc. shall be provided by the Traction Contractor inside ASS and ASS+TSS room at elevated stations, underground stations and Depot(RSS and Depot AMS/ASS+TSS) for all the cables pertaining to traction. LKE (02)-01 Contractor shall interface and provide schematics for cable tray routing for cable laying to E&M Contractor in underground sections.

13.3.1.9 **Interface**

13.3.1.9.1 The LKE (02)-01 Contractor shall do interface with other Designated Contractors for availability of suitable path for cables. The LKE (02)-01 Contractor shall also suitably interface with the other Designated Contractors for suitable track crossings wherever desired, entry and exit paths for ASS/TSS.

- 13.3.1.9.2 For arrangements outside depot boundary and on the path up to the viaduct, the lifting arrangements up to the parapet of the viaduct and other related works are within the Scope of the LKE (02)-01 Contractor. For detailed interfaces and scope refer Chapter 3

13.3.2 LAYING ON VIADUCT / AT GRADE / TUNNEL

- 13.3.2.1 The 33kV distribution cables shall be laid on the cable brackets along the viaduct at a spacing of approx.1.0m and as an exceptional case on the ducts where track crossing are involved. 33kV cable support/ containment infrastructure excluding brackets on parapet wall & tunnels is under the scope of the LKE (02)-01 contractor. Inside UG station, cables shall be laid in undercroft/cellar, in HDPE pipes along/across track, in cable galleries, shaft etc. Location of joints shall be properly marked in tunnels, viaduct, undercroft, shaft, trench etc.
- 13.3.2.2 33kV cable are to be contained in trefoil for which suitable non-metallic trefoil clamps in elevated/UG section Al clamps are to be used. Supply and installation of trefoil clamps at every support with all necessary hardware is under the scope of the contractor. Contractor shall design the cable support/bracket and submit for Engineer's approval.
- 13.3.2.3 Cutouts for entry-exit of the 33kV cable and associated control cables are required to be sealed with appropriate EPDM modules to avoid ingress of water inside the substation. Supply and installation of all necessary accessories and hardware to seal the cable cutouts is under the scope of the Contractor.
- 13.3.2.4 The cables shall be delivered to the work site in suitable unit lengths, coiled on reels whose average weight shall not exceed 6000 kg for aluminium-cored cables. Selection of cable drums for each run shall be so planned so as to avoid straight through joints. Cable joints / splices shall not be allowed except where called for by the drawings or is unavoidable and permitted by the Engineer. A comprehensive drum schedule shall be prepared by the Contractor and submitted to the Engineer for approval before procurement. Care should be taken while laying the cable so as to avoid damage to cables.
- 13.3.2.5 If cables are laid after the track is in position, then these cable drums shall be delivered by suitable means as close as possible to the point of utilization, accounting for the constraints generated by the actual traffic on the existing line. In case cables are required to be laid before the track is in position, the Contractor shall devise suitable means of transport and laying of cable with the approval of Engineer.
- 13.3.2.6 Laying out of the cables can be made manually or mechanically. The mechanical devices (motorized winch or pneumatic) used for paying out the cables shall be so constructed that there is no damage to the cables. These devices shall be submitted to the Engineer for approval.
- 13.3.2.7 The laying team shall be under the authority of a supervisor qualified for this type of work. All necessary precautions shall be implemented during operation to prevent any deterioration of the cables; the cables shall not be subjected to any twisting around its axis, and not be bent to a radius smaller than the minimum bending radius specified by the cable manufacturer. The cables shall be subjected only to the traction efforts strictly required to pay them out. In no event may the cables bare against the ground or against fixed stops. The cables shall rest onto rollers, situated sufficiently close to one another.

- 13.3.2.8 The ends of two successive reel lengths shall overlap by a minimum two meters to enable cropping the cable ends before execution of the connection sleeves.
- 13.3.2.9 When the Engineer is of the opinion that paying out of cables in a single length 200 to 500 m risks generating abnormal strains in the cable, one or several looping shall be made. A cable looping is defined as being any operation that requires previous paying out of the cable outside the channel or cableways.
- 13.3.2.10 When two cable courses are superimposed inside channels, each course shall be separated by means of isolating plates every 3 m.
- 13.3.2.11 **Tagging**
- 13.3.2.11.1 All cables laid inside channels, or on cable-trays shall carry an 8 x 5 cm PVC tag (for elevated section and metallic tag for Underground section) placed every 10 m with cable ties at every meter in the intervening space and in specific locations such as connection sleeves, entry into and exit from ducts and possible pulling chambers. These tags, fastened via two clamps/cable ties, shall bear the labels approved by the Engineer. Tagging of cables plays a part in safety as regard identification of the cables in case of incident and shall be made very carefully. The Contractor shall be responsible for any error or for any incident subsequent to such an error. The tags shall be fastened right after the paying out of each reel.

13.3.3 LAYING IN GROUND

- 13.3.3.1 The cable laying shall be generally in accordance with IS1255-1983 and the manufacturer's recommendations. The 33kV cables between RSS and ASS rooms of nearest station shall be laid in ground at a min. depth of 1.2m on 100 mm sand filling duly protected by RCC slabs. Protection/warning concrete slabs each approx 0.55m x 0.60m x 0.05m (Thick) shall be laid above the sand. The trenches for carrying the cables shall be at least 1.3m deep and 1.0m wide. The trenches are to be filled with sand up to a depth of 0.8m below ground level. A warning tape shall be laid above the earth (at 200mm depth below ground level). The trenches shall be filled with earth up to 200mm below the ground level. In case of 2 or more circuits to be laid in a single suitable trench, the required clearances between circuits to be maintained as per applicable standards/manuals.
- 13.3.3.2 **HDPE Pipes**
- 13.3.3.2.1 In case of road crossings, the cables shall be laid through trenchless method with cables passing through HDPE pipes of appropriate size (not less than 100mm). Track crossings are also through HDPE pipes. In case of open cut the HDPE pipes shall be embedded in concrete. Each power cable (single core) shall be laid in separate HDPE pipe.
- 13.3.3.2.2 HDPE pipes shall be of PN 6 class with welding on one side and conforming to BIS: 4984 latest. The internal diameter of the HDPE pipes for laying power cables shall be minimum 100 mm subject to the diameter of the cable and in case of pilot cables, both the lengths of the cables shall be laid in 100mm internal diameter pipe. Spare loops of cable shall be provided at road crossing locations and other critical locations as per IS 1255.

13.3.3.3 One spare pipe (100 mm dia) shall be provided. In addition to the conduits for power cables, two additional conduits, each of not less than 100 mm dia, shall be provided to carry control and monitoring cables, one operational and one spare. The horizontal distance between two adjacent conduits shall not be less than 75mm.

13.3.3.4 The route shall be marked by suitable cable route markers at intervals of 100 mtrs and the positions of straight through joints shall be indicated by suitable boards.

13.3.4 INSPECTION AND TESTING OF ERECTED WORKS

13.3.4.1 All the erected works shall be subject to inspection by the Engineer to ensure that the work is done as per Specification and approved drawings.

13.3.4.2 As soon as the work is completed and ready for inspection and testing, the Contractor shall advise the Engineer in writing. Tests will be carried out by the Engineer jointly with the Contractor. Testing equipment and staff required for the tests shall be provided by the Contractor free of charge. The Contractor shall take full responsibility for these tests *inter alia* his other responsibilities.

13.3.4.3 The Contractor shall notify the manufacturer of cable and cable accessories regarding likely date of the pre-commissioning tests, one month in advance so that their representative may be available at site at the time of the tests. It shall be the Contractor's responsibility to ensure that the cable and accessories are commissioned as per laid down procedures.

13.3.4.4 Pre-commissioning Tests for the facility as a whole

13.3.4.4.1 The following site tests shall be conducted on a completed power cable installation as per Specification IEC 60502-2/ IS 7098-2 latest versions.

- a) Visual Inspection and Continuity Check: A visual inspection shall include checks for satisfactory workmanship
- b) Continuity check shall be carried out on the cable to ensure that the cable is continuous.
- c) DC voltage test of the over sheath: The test shall be conducted as per IEC 60229
- d) AC/DC voltage test for the installation: The test shall be conducted as per IEC 60502-2/IS 7098 Pt-II.
- e) The insulation resistance of the cable shall be checked before & after the HV test on cable.
- f) The core resistance shall be measured and the value corrected in accordance with IEC 60228.
- g) The cable must be discharged on completion of DC High Voltage Test and the cable shall be kept earthed until it is put into service.

13.3.4.4.2 The values obtained during these tests shall be in conformity with the values obtained during inspection of the materials at the manufacturer's works.

13.3.5 TESTS

13.3.5.1 33kV cables for use in elevated section shall comply with tests as per IEC 60502. The cables for underground section shall comply with the additional tests:

- a) Aluminium resistance for full drum and Weight of conductor for one meter sample
- b) Tensile test for Aluminum Conductor

- c) Wrapping Test for Aluminum
- d) Impulse test for 33kV Cable in house
- e) Test for Thickness of insulation and Sheath
- f) Hot Set Test for Insulation
- g) Tensile and Elongation tests for Insulation and sheath
- h) High Voltage test
- i) Insulation Resistance test
- j) Armour Diameter and Resistance test
- k) IEC 332 Part 1 and 3, category A, test on single and bunched cables under fire condition.
- l) Limiting Oxygen Index of at least 31 as per ASTM D 2863
- m) A Temperature index of 260 ° C as per ASTM D 2863
- n) 3 m cube smoke emission test, when Tested in accordance to IEC 61034/BS 7622- Maximum smoke emission of 40% & Minimum Light Transmission of 60% for FRLS and Maximum smoke emission of 20% & Minimum Light Transmission of 80% for FRLSOH.
- o) All Insulation is to be moisture and heat resistant, with temperature rating appropriate to the application conditions and in no case lower than 90° C.
- p) Determination of the amount of halogen acid Gases as per IEC 754 Part 1 (maximum HCL gas shall not exceed 20% for FRLS & 0.5% for FRLSOH) and IEC 754 Part –II.

13.3.5.2 The routine test will be conducted on sample cable drums as per provision laid down in is 7098, Pt –II -1985, IEC 60502-1 but shall not be limited to the following:

- a) Conductor resistance
- b) High voltage test
- c) Armour resistance
- d) Any other relevant test

13.3.5.3 The manufacturer shall conduct all the routine tests as prescribed in the standard on entire lot/ drums.

13.3.5.4 All FRLS/FRLSOH cables shall comply with the IEC 60502-1 in force and shall, at least, have satisfied the following tests:

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
High Voltage Test	X	X	X	X
Conductor Resistance Test	X	X	X	X
Conductor Examination	X		X	X
Test for thickness for insulation & sheath, overall diameter if applicable, core identification & visual check.	X		X	
Armour wires/strip dimensions and type of armour	X		X	
Armour resistance	X	X	X	
Tensile strength & Elongation at break of insulation and sheath before ageing.	X		X	

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
Hot set test.	X		X	
Insulation Resistance (Volume Resistivity test) at room temp.	X		X	
Oxygen Index Test	X		X	
Temperature Index Test	X		X	
Smoke Density Test (as per ASTM 2843)	X		X	
Acid gas evaluation test (IEC 60754)	X		X	
Flammability Test as per IEC 60332-1	X		X	
Light Transmission Test as per IEC 61034	X			
Flammability Test as per IEC 60332-3	X		X	
UV & ATAR Testing	X			
Insulation Resistance(Volume) Test				X

13.4 ANNEXURE- I (Cable Sizes)

**Table 13.5 Station Wise 33kV AC Cable Sizes for LKE (02)-01 Package
(East West Corridor)**

Sl. No	Station/ Equipment Name (From)	Station/ Equipment Name (To)	Section Location (Elevated/At Grade/UG)	Type (FRLS/ FRLSOH)	Total Runs & 33kV AC RSS/Depot/ Ring Cable Size
East West Corridor: Cable sections between Stations					
1.	Charbagh (ELE)	Charbagh (UG)	Elevated/UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
2.	Charbagh (UG)	Gautam Budh Marg	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
3.	Gautam Budh Marg	Aminabad	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
4.	Aminabad	Pandeyganj	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
5.	Pandeyganj	City Railway Station	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
6.	City Railway Station	Medical Chauraha	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
7.	Medical Chauraha	Chowk	UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
8.	Chowk	Thakurganj	Elevated/UG	FRLSOH	Double Circuit 3R#1Cx300sq.mm
9.	Thakurganj	Balaganj	Elevated	FRLS	Double Circuit 3R#1Cx300sq.mm
10.	Balaganj	Musabagh	Elevated	FRLS	Double Circuit 3R#1Cx300sq.mm
11.	Musabagh	Vasantkunj	Elevated	FRLS	Double Circuit

Sl. No	Station/ Equipment Name (From)	Station/ Equipment Name (To)	Section Location (Elevated/At Grade/UG)	Type (FRLS/ FRLSOH)	Total Runs & 33kV AC RSS/Depot/ Ring Cable Size
					3R#1Cx300sq.mm
East West Corridor Cable sections from RSS/AMS to Stations					
12.	Vasantkunj RSS/ AMS	Vasantkunj	At-grade/ Elevated	FRLS	Double Circuit 6R#1Cx300sq.mm
East West Corridor Cable sections from RSS to Depot ASS+TSS					
13.	Vasantkunj RSS	Vasantkunj Depot ASS+TSS	At-grade/ Elevated	FRLS	Double Circuit 6R#1Cx300sq.mm

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CHAPTER – 14

AUXILIARY SUBSTATIONS

14.1 INTRODUCTION

14.1.1 GENERAL

14.1.1.1 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in chapter-2 & Chapter 19 along with clause wise compliance and suggest similar or better design for the approval of Employer.

14.1.1.2 The various electrical and electro-mechanical installations in passenger stations and depots are required to be provided with electrical power at 415 V, 3-phase. For this purpose, power at 33 kV level from the 33 kV switchgear room located in the Receiving Substations (RSS)/Auxiliary Main Substation(AMS), is transmitted to the Auxiliary Substations (ASS) located in the passenger stations and depots, through feeders made up of 33 kV cables. The 33 kV power is transformed to 415 V power by means of 33 kV / 415 V Cast Resin Dry type transformers of suitable capacity installed in the ASS's. The auxiliary power network essentially consists of the following:

- a) 33 kV duplicate feeders from the RSS/AMS feeds the designated ASS/TSS in the Corridor, wherever applicable (as detailed in Chapter 13 of ERTS/Employer's Requirements).
- b) A 33 kV cable network, comprising of 33 kV cables of suitable capacity, laid on the cable bracket along the viaduct/tunnel and as an exceptional case on the ducts where track crossing are involved.
- c) Loop-in-loop-out connections of the 33 kV cables to the 33 kV panels / transformers located in the ASSs/ASS+TSSs (as detailed in Chapter 13 of ERTS/Employer's Requirements).
- d) 33 kV / 415 V auxiliary transformers of suitable capacity and associated 33 kV switchgear and other auxiliary equipment, installed in the ASSs/ASS+TSSs at various passenger stations and depots

14.1.1.3 Each auxiliary substation consists of 33 kV circuit breakers, 33 kV/415 V, auxiliary transformers and DC and AC control power supply system. Regarding LV power supply, Traction Contractor's Scope of Work excludes LV bus duct connection from auxiliary transformer secondary to Main Distribution Board (MDB). LV Bus duct (E&M's scope) connection is envisaged for 1000 kVA and above Auxiliary Transformers. For Auxiliary Transformers below 1000 kVA cable connections are envisaged. LV Cable supply, laying, testing and commissioning from auxiliary transformer secondary to Main Distribution Board (MDB) is under the scope of E&M Contractor. From MDB (including) onwards, the Scope of works belong to other contractors & the connections at auxiliary transformer secondary shall be carried out by E&M Contractor.

14.1.1.4 The Works which form part of this Contract shall consist of Design, supply, erection, testing and commissioning of all equipment at all ASS's, including, but not limited to, 33 kV / 415 V Cast Resin Dry Type transformers, 33 kV Panels and Switchgear, 33 kV and 415 V Cables, all measuring and protective devices, batteries and battery chargers, ACDBs & DCDBs including LV and control cables downstream, cable paths

and earthing, safety equipment and all other items (e.g. Chequered Plates/EPDM etc.) required for successful and satisfactory working of the ASS, RSS/AMS, at all ASS/AMS's shall be within the Scope of this Contract.

14.1.2 ASS LOCATIONS AND CAPACITY

- 14.1.2.1 Chainage wise station locations for the East West Corridor (Phase 1 B) are provided in Table 1.2 to Table 1.5 of Chapter-1, and capacities of ASSs and TSSs in various stations is provided in Chapter-2.
- 14.1.2.2 All the ASSs of elevated stations are provided with one ASS having 2 x 500 kVA transformers & underground stations are provided with one ASS having 2 x 2000 kVA transformers. Wherever, additional commercial loads are to be accommodated, the sizes of the transformers shall be chosen accordingly from the list detailed in BOQ (Bill of Quantities), as applicable. At stations having TSS, the TSS and ASS are housed in the same room.
- 14.1.2.3 Depot is provided with one ASS (and TSS) having 2 x 2000 kVA transformers and the Depot ASS/TSS shall be housed in Depot location.
- 14.1.2.4 The ASS equipment in those ASS's will be installed in a suitable room at concourse level in the passenger stations. For depot the ASS/TSS equipment will be installed in Depot switchgear room.
- 14.1.2.5 The room for accommodating the ASS (and TSS) equipment will be built by other designated contractors. Room sizes and shapes may be different at different stations in this corridor. Nevertheless, an approximate area of 160 m² (for ASS only) and 450 m² (for ASS and TSS) with a minimum height of 5.0 m (in the Transformer and Panel area) will be provided for accommodating equipment. Typical equipment layout plans for ASS and TSS are included in Tender Drawings. The LKE(02)-01 Contractor will, however, be required to submit equipment layout plans for every substation, depending upon the types, sizes etc. of the equipment proposed to be used by him.

14.1.3 ASS/TSS TYPES (as per type of stations)

14.1.3.1 Station ASS/TSSs

Substations are categorized as per their configuration and whether these are elevated or underground. The table below shows the types with appropriate details. However the design to be Verified and confirmed by the Contractor. The Final responsibility lies with the Design and Build Contractor.

Table 14.1: Station and Substation Type Information East West Corridor (Phase 1 B)

Type	Station Type	ASS Type	Attributes						Stations in this category
			IC from RSS	Ring Feeders	Bus Coupler	Aux Trafo	Trac Trafo	Bus PTs	
A	Elevated	ASS	2	2+2(FUTURE)	1	2		2	Elevated End ASS With IC from RSS/ASS – Vasantkunj,
B	Elevated	ASS		4		2			Mid elevated ASS -, Sarfarazganj, Balaganj

Type	Station Type	ASS Type	Attributes						Stations in this category
			IC from RSS	Ring Feeders	Bus Coupler	Aux Trafo	Trac Trafo	Bus PTs	
C	Elevated	ASS+TSS		4	1	2	2	2	Mid Elevated ASS+TSS -, Thakurganj, Musabagh,
D	UG	ASS	2	2+2(FUTURE)	1	2		2	End ASS With IC from RSS/ASS – Charbagh (UG)
E	UG	ASS		4		2			Mid ASS UG – Aminabad, City Railway Station, Chowk
F	UG	ASS+TSS		4	1	2	2	2	Mid ASS+TSS (UG) Pandeyganj, Gautam Buddh Marg, Medical Chauraha
Depot ASS+TSS									
		ASS+TSS	2		1	2	3	2	Depot ASS+TSS With IC from RSS

NOTE: The contractor shall take into consideration for providing two additional 33kV spare switchgears at each end station (Charbagh and Vasantkunj) & RSS/AMS of East West corridor (total six (2+2+2) numbers of CBs) and it shall be included in the cost of the tender.

14.1.3.2 Depot ASS+TSS

14.1.3.2.1 Since Depot ASS/TSS is physically located in the depot ,the depot 33 kV supply for TSS and ASS is drawn from RSS/AMS switchgear panel.

14.1.3.2.2 The Key single line diagram for these ASS/TSS shows the basic interconnection between 33 kV ring main feeders, positive bus of 750 V dc to third rail and negative bus of 750 V dc to running rail. From 750 V DC busbar, feeders are provided to feed supply to various sections of stinger system in workshop and third rail in the depot.

14.1.4 INTERFACE ISSUES

14.1.4.1 Cable cut-outs for entry / exit of HT, LT and Control and Monitoring (C&M) cables will be provided by the Station Contractor. For this purpose the LKE(02)-01 Contractor shall maintain an interface with the Station/Finishing Contractor.

- 14.1.4.2 The Traction contractor shall design, supply and install all the cable trays/hangers support etc. inside ASS and ASS+TSS Room for elevated, depot ASS+TSS and Underground Stations. Cable paths required for management of HT & LT (from ACDB/DCDB to the 33 kV panels and DC switchgear and the other accessories e.g., battery, battery charger etc.) and Control & Monitoring cables, inside the ASS and ASS+TSS Rooms, shall be provided by the LKE(02)-01 Contractor. Cable trenches on the floor are to be avoided and cable trays etc. fixed to the ceiling may be adopted. However, if needed, cable trench inside Depot may be proposed by LKE(02)-01 contractor in interface with Depot Contractor (Civil/E&M) subject to Engineer's approval. Depot contractor shall provide the necessary cable path & support as per LKE(02)-01 contractor's requirement. Cable shall also be laid such that unnecessary cable trays are avoided by better planning of routes.
- 14.1.4.3 Heavy equipment, such as transformers and 33 kV panels shall be brought by road by the LKE(02)-01 Contractor. Wherever required, suitable loading / unloading platforms shall be constructed and the equipment shall be lifted to these loading / unloading platforms for elevated stations and Hatch cut-outs /as per site availability for underground stations with the help of cranes etc. by the LKE(02)-01 Contractor. The equipment shall be moved to respective positions/ foundations, with the help of trolley / rollers/ Lifting hooks by the Traction Contractor.. In elevated stations, rolling shutters & in underground stations knock out wall shall be used for placing heavy equipment like transformers, 33kV panels etc. inside ASS/TSS room (Preferably all the equipments will be placed before the finishing of the knockout wall). The LKE(02)-01 Contractor will interface with civil contractor in respect of capacity of hooks and their appropriate location. No mono-rails or rails on the floor shall be provided in the ASS / TSS room.
- 14.1.4.4 Earthing strip is to be embedded in the floor of the substation. For this purpose earthing strip shall be laid by the LKE(02)-01 contractor as per equipment earthing layout arrangement prior to the floor concreting/finishing work carried out by the station building contractor. In this respect, LKE(02)-01 contractor shall interface with station/finishing contractor.
- 14.1.4.5 Civil contractor will provide a finished floor. The LKE(02)-01 Contractor shall interface with Finishing Contractor for epoxy coating/finishing on the floor of the ASS and ASS+TSS room before/after installation of equipment.
- 14.1.4.6 The LKE(02)-01 Contractor may, if required, fix equipment on the floor with the help of anchor fasteners. In general, no additional concreting is considered necessary to be provided in the ASS / TSS Rooms. If any pedestals are required to be provided to mount transformers / equipment, the same shall be provided by the LKE(02)-01 Contractor, after obtaining approval from the Engineer.
- 14.1.4.7 The detailed interfaces are provided in Chapter-3.

14.1.5 ENVIRONMENTAL AND CLIMATIC DATA

- 14.1.5.1 The environmental and climatic data in Lucknow are provided in Volume-3 (General Specifications).
- 14.1.5.2 It must be noted that environmental conditions can be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

14.2 33 KV SWITCHGEAR**14.2.1 FOR ELEVATED SECTION/AT-GRADE/DEPOT AMS – AIR INSULATED SWITCHGEAR (AIS)****14.2.2 SCOPE**

14.2.2.1 This Specification applies to triple pole trolley mounted, horizontally with drawable indoor type (floor mounted) circuit breakers for a nominal voltage 33 kV for installation at auxiliary sub-stations. The Scope of Work includes design, supply, installation, testing and commissioning of switchgear along with accessories.

14.2.2.2 The switchgear cubicles shall be provided with voltage transformers, current transformers, protection relays, space heaters, linear fire detection tube based fire protection system and all other components, as required, to comply with functional and technical specifications, in full.

14.2.2.3 The switchgear offered shall be complete in all respect with all parts and accessories including frame work, necessary for their efficient operation, maintenance and protection. All such parts and accessories shall be deemed to be within Scope of this Specification whether specially mentioned or not.

14.2.2.4 For elevated section/at-grade/Depot, Auxiliary/Traction substations 33 kV switchgear shall be with Air Insulated Switchgear (AIS) with vacuum circuit breakers and for underground section, Auxiliary/Traction substations 33kV switchgear shall be with Gas Insulated Switchgear (GIS) with vacuum circuit breakers.

14.2.2.5 The contractor shall take into consideration for providing two additional 33kV spare switchgears at each end station (Charbagh and Vasantkunj) & RSS/AMS of East West corridor (total Six (2+2+2) numbers of CBs) and it shall be included in the cost of the tender.

14.2.3 SPECIFICATIONS

14.2.3.1 The switchgear shall, unless otherwise specified, generally conforming to the following standards or their latest issue as applied in the manner altered, amended or supplemented by this Specification and the Indian Electricity rules wherever applicable. For the equipment or component which forming part of the switchgear for which standards are not mentioned, the respective IS, IEC, BS EN etc., shall prevail. Numerical protection relays shall comply with IEC 60255 and compatible with IEC 61850 protocol for communication.

Table 14.2: Applicable Standards

S.No	Title of Specification	Specification No.
1.	Instrument transformers - Part 1: General requirements	IEC 61869-1-latest
2.	Instrument transformers - Part 2: Additional requirements for current transformers	IS 2705 latest IEC 61869-2-latest
3.	Instrument transformers - Part 3: Additional requirements for inductive voltage transformers	IS 3156 latest IEC 61869-3-latest

S.No	Title of Specification	Specification No.
4.	Switches for rated voltages above 1 kV up to and including 52 kV	IEC: 62271-103-latest
5.	AC metal-enclosed switchgear and control gear for rated voltage above 1 kV and up to and including 52 kV	IEC: 62271-200–latest
6.	International standard of resistance for copper	IEC 60028-latest
7.	High-Voltage Alternating-current circuit breaker	IEC: 62271-100–latest
8.	Alternating current disconnectors and earthing switches	IEC: 62271-102–latest

14.2.3.2 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for elevated/at grade sections & Fire Retardant Low Smoke Zero Halogen (FRLSOH) Type for underground sections.

14.2.4 RATINGS

14.2.4.1 The 33 kV circuit breaker and complete switchgear shall be designed for the expected rating and other particulars indicated in Table 14.3 & 14.4 below;

Table 14.3: 33 kV Breaker Rating

SN	Description	33 kV Vacuum Circuit Breaker
1	Type	Draw out Indoor type Vacuum Circuit Breaker
2	Rated Service Voltage	33 Kv
3	Insulation level (minimum)	36 kV
4	No. of poles	Three
5	Rated Frequency	50 Hz
6	Rated normal current	1250A As per Tender SLD
7	Busbar current rating	1250A As per Tender SLD
8	Rated breaking capacity	25kA for 3 Sec
9	Closing capacity	62.5 kA Peak
10	Rated short circuit withstand capacity	25kA for 3 Sec
	CB Opening time	< 60ms
11	CB Breaking time	< 80 ms
12	CB Closing time	< 80 ms
13	Rated operating duty	O-0.3sec-CO-3min-CO
14	Total arc interruption duration	Less than 3 cycle
15	Number of mechanical operations	10,000 operating sequences
16	DC control supply voltage	110 V dc
17	Allowable variation range of control supply voltage	+10%, -15%
18	Protection Degree	IP 5X
19	Current transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.

SN	Description	33 kV Vacuum Circuit Breaker
20	Potential transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.
21	Earthing isolator making capacity	25kA for 3 sec
22	Rated short time duration power frequency withstand voltage	70 kV rms
23	Rated short time duration impulse withstand voltage	170 kV peak
24	Auxiliary supply ac voltage	230 V, 1 phase, 50 Hz

Table 14.4: 33 kV Incomer Rating at RSS AMS

SN	Description	33 kV Switchgear
1.	Type	Draw out Indoor type Vacuum Circuit Breaker
2.	Rated Service Voltage	33 Kv
3.	Insulation level (minimum)	36 kV
4.	No. of poles/phases	Three
5.	Rated Frequency	50 Hz
6.	Rated normal current	1600A As per Tender SLD
7.	Busbar current rating	1600A As per Tender SLD
8.	Allowable overcurrent for 3 sec	25kA
9.	Instantaneous overcurrent	62.5kA Peak
10.	Rated short circuit withstand capacity	25kA for 3 Sec
11.	Auxiliary DC supply voltage	110 V dc
12.	Allowable variation range of control supply voltage	+10%, -15%
13.	Protection Degree	IP 3X
14.	Current transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.
15.	Potential transformer accuracy class	Shall be in accordance with SLD/Relevant Tender Drawings.
16.	Earthing isolator making capacity	25kA for 3 sec
17.	Rated short time duration power frequency withstand voltage	70 kV rms
18.	Rated short time duration impulse withstand voltage	170 kV peak
19.	Auxiliary supply ac voltage	230 V, 1 phase, 50 Hz
20.	CB Opening time	<60ms
21.	CB Breaking time	<80ms
22.	CB Closing time	<80ms
23.	Rated operating duty	O-0.3sec-CO-3min-CO
24.	Total arc interruption duration	Less than 3 cycle
25.	Number of mechanical operations	10,000 operating sequences

14.2.4.2 The cubicles shall be capable of withstanding without any damage the loads generated by 1428MVA peak short-circuits. The number and frequency of those are not limited in time.

14.2.4.3 Environmental and Climatic Data: The environmental and climatic data in Lucknow are provided in General Specifications.

14.2.5 CONSTRUCTION FEATURES

14.2.5.1 General / Make-up

14.2.5.1.1 The switchgear shall be constructed as per the relevant standards and specifications. The switchgear shall conform to the requirements of service conditions.

14.2.5.1.2 Each cubicle will be metal clad type, air insulated, made of:

- a) Bus bar compartment
- b) Cable end compartment
- c) Low voltage (measurement, protection & monitoring) compartment
- d) Equipment connector compartment with shutter/breaker compartment

14.2.5.1.3 Compartments shall be physically separated from each other by metal partitions, conforming to PM (Partition Metallic) class and Loss of Service Continuity (LSC) of 2B as per IEC 62271-200, which shall not heat up due to induced magnetic fields.

14.2.5.1.4 All panels, separating partitions and accessories shall be mounted similarly, in such a way so as to withstand indefinitely the vibrations transmitted, in particular by the resetting mechanism of the circuit breakers and their actuation.

14.2.5.1.5 All non-welded assemblies shall be assembled by means of bolts and nuts/rivets with mandatory use of lock-washers.

14.2.5.1.6 Internal and external metal partitions shall be connected to the earth; high voltage electrical links are realized with bushing.

14.2.5.1.7 All parts of the cubicle (bus-bars, sliding connector, partition passages) shall be capable of permanently withstanding the temperature rise caused by the currents and shall match the nominal rating of the circuit breaker / interrupter. 33 kV motorised vacuum interrupter shall be compatible and interchangeable with 33 kV vacuum circuit breaker for interoperability.

14.2.5.1.8 Multiple termination points shall be ensured for relay (RJ-45) in order to have required inputs from multiple sources/cables.

14.2.5.2 Switchgear Cubicles

14.2.5.2.1 The cubicles shall be of dust and vermin proof cabinet sheet metal. Structure made of Alu-zinc/GI material to reduce the corrosion effect. However, the GI switchgear cubicle shall be of proven design. Front door & rear cover can be of CRCA sheet with powder coating. All cubicles shall be of same type. All non-welded assemblies shall be assembled by means of bolts and nuts/rivets with mandatory use of lock-washers.

14.2.5.2.2 It is envisaged that the panels shall be designed for all cable entries from the top/bottom for elevated corridor stations, underground stations and Depot and bottom entry for panels at RSSs.

14.2.5.2.3 The auxiliary contacts shall be of adequate rating (5A minimum) and shall be provided in sufficient numbers with about 20% spares, with a minimum of 5 NO and 5 NC. The contractor shall propose designs for approval by the Engineer.

- 14.2.5.2.4 Three display lamps for “voltage on” fed by capacitive dividers and annunciation lamps shall be installed on the front face of the cubicle.
- 14.2.5.2.5 Cubicle Compartments
- a) The cubicles shall be metal-clad draw out switchgear type, closed by a door forming the facade, equipped with riveted marking plates and single-wire diagrams also fitted with display lamps indicating the presence of 33 kV voltage.
 - b) The cubicles shall consist of basically two parts viz. fixed and moving parts to facilitate maintenance, replacement or even modification operation with shut down affecting only the involved circuits.
 - c) The fixed part shall be divided into four compartments - bus bar, trolley receptacle/breaker compartment, cabling compartment and low voltage (protection, monitoring and metering) compartments which are separate by means of barriers/shutters to prevent fault propagation between compartments. The barriers / shutters shall not heat up due to induced magnetic fields action. Moving parts consist of withdrawal trolley on which the circuit breaker shall be mounted. Vacuum Circuit Breaker shall be rated for minimum 100 nos. full short circuit to ascertain the life of Vacuum Circuit Breaker. Tenderer should submit the Type Test Reports for Short Circuit Duty with this breaker.
 - d) Surge Suppressor shall be implemented in the cubicles as per requirement for suppressing the surges/transients coming in the system.
- 14.2.5.2.6 Seal off bushings shall be provided between breaker compartment to busbar and cable compartment to ensure that no ionized gases from breaker compartment is transmitted to either of these two fixed compartments.
- 14.2.5.2.7 Bus bar Compartments
- a) Bus bar compartments shall house bus bars. The bus bars shall be of rectangular/tubular cross-section suited to withstand 25kA for 3 sec peak short circuit.
 - b) Bus bars shall be supported on insulating supports or support less bus bar is also acceptable. Bus bars shall be air insulated and fully voltage sleeved to withstand line to line voltages continuously and the main bus bar joints shall be covered with epoxy or polycarbonate shrouds.
 - c) Bus bars shall be capable of handling all sorts of temperature rise caused by the current. Temperature rise of various parts of the switchgear shall be within limits as per IEC. All necessary precaution to shield corona discharges shall be taken in the bus bar jointing. The manufacturer/Contractor shall highlight these provisions during detailed engineering stage.
 - d) Bus bars shall have continuous rating capacity and shall withstand short circuit. All bus bars shall be of copper conforming to the relevant IS/IEC. The bus bars shall be clean smooth, mechanically sound and free from other defects. Provisions shall be made where necessary, to allow extensions both in section and length at any time without difficulty.
 - e) All necessary precautions shall be implemented in order to prevent bus bar arcing due to moisture retention.
- 14.2.5.2.8 Trolley Receptacle Compartments
- This compartment shall house the trolley. It shall essentially consist of:
- a) A shutter automatically protecting live parts when the equipment is plugged-out.
 - b) Provision for fixed earthing plug-in contact,
 - c) Grounding of the frame of the trolley,

- d) A safety interlocking access to the fixed insertion connectors if the circuit-breaker / interrupter is not engaged or if it is in the withdraw position,
- e) A precise device for displaying the end of insertion travel with limit switch or any other proven mechanical arrangement,
- f) A fixed plug-in socket enabling the flexible connection to be made for control and monitoring of the circuit-breaker / interrupter,
- g) The interlocking corresponding to the function of the cubicle,
- h) A general connecting terminal for low voltage circuits of the cubicle. The terminal shall be tightened by screws, no other connecting device shall be used
- i) An annunciation device for “33 kV voltage on”, by means of a **capacitive divider/graded capacitor** with neon lamps (one per phase), glowing permanently in live conditions. Capacitive divider/graded capacitor shall be provided in the fixed part of the cubicle.
- j) All operations shall be possible with closed door condition to ensure complete protection to the operator

14.2.5.2.9 Cable Compartments

- a) The cable compartment shall have the provision for mounting of CTs, PTs & earth switches as per requirement. CT/PT shall be fully cast resin type. The cabling compartment should be designed in such a way that sufficient space is made available for termination of 3 or 6 cables of single core feeder XLPE cable for each feeder through heat sink terminations as applicable.
- b) The cable compartment's depth shall be less than one meter and the clearance between the bottoms of the bus bars to base plates minimum 500 mm. The compartment height shall be at least 700 mm to facilitate the cable connection and be equipped with an external cable support device.
- c) The copper bus shall be provided with holes size 14mm or suitable size dia in requisite number for termination of cable on each feeder. It shall also provide the cable- supporting clamp.
- d) End-boxes for 33kV cables shall be supplied complete with all the necessary materials for installing the cable and making the end connection.
- e) The connection braids between the two sets of bus bar, the current transformers and the cable end-boxes., shall have sufficient gap so that when the braids are removed, the output terminals from the cable box are sufficiently distant from any earth, thus enabling the high voltage cable to undergo dielectric tests or any fault finding to be carried out by applying high voltage.
- f) All panels shall have integral earth switches for cable side earthing. A cable head earthing isolator, actuated manually, complete with the necessary interlock shall be provided. Positions of the earthing isolator shall be visible through a glazed port/mechanical indicator.

14.2.5.2.10 Low Voltage Compartments

14.2.5.3 The low voltage compartment shall consist of all control, monitoring and measurement devices. Auxiliary voltage shall be 110 V dc (+10%, -15 %) for motors, monitoring and control circuits.

14.2.5.4 In elevated sections, FRLS cables shall be used in all LV control and power circuits. In underground sections, FRLSOH cables shall be used in all LV control and power circuits.

The LV compartment shall consist of as a minimum:

- a) Voltage presence capacitor dividers, relay and facade indicator lights

- b) Breaker Open/closed, test/service, local/remote, spring charge/discharge and E/S close/open position indicator lights and contacts.
- c) Facade measurement indicators (ammeter & voltmeter when required)
- d) Control and monitoring devices for the CB (programmable logic control)
- e) Control and monitoring, multi pin connector
- f) Lockable access door
- g) Numerical relays with MIMIC Display SLD control
- h) SCADA compatible interlocks and auxiliary relays and meters
- i) Emergency trip

14.2.5.4.1 Space Heater Element

Each cubical shall be provided with a space heater element of sufficient capacity with thermostat/hygrostat control of 35°C over ambient temperature and humidity at loading condition.

14.2.5.4.2 Withdrawal Trolley

- a) The switchgear compartment shall be fully draw out self-contained trolley arrangement with breakers mounted on the same. The interchangeability of cubicles and switchgear shall be ensured by quality production and assembly works.
- b) A separate front door shall be provided in each circuit breaker/interrupter cubicle, which shall be opened for inserting or withdrawing the breaker from the cubicle. A racking handle shall be provided to facilitate insertion and withdrawal of the breaker truck to and from the service position.
- c) The switchgear trolley shall have three positions.
 - i. Service position (Plugged-in)
 - ii. Test position (Plugged-out)
 - iii. Withdrawn position (Out of the cubicle)
- d) The circuit breaker mobile truck shall be provided with a metal shield on the front which prevents any access to the live parts of the circuit breaker even when the doors of the cubicles are open. Additional features shall be available so that front door can be even closed even when the breaker is in test and withdrawn position.
- e) The trolley shall have a control button and the open and closed position annunciation via mechanical display. It shall have auxiliary annunciation contacts displaying whether the circuit-breaker is in open or closed position, connected to the terminal board of the low voltage circuits. Spare open and closed contacts shall be available in addition to those used for low voltage control and monitoring circuits.
- f) The trolley shall have a grounding contact connecting the frame circuit of the circuit-breaker to the cubicle grounding bus-bar, interlock mechanisms, plugging actuator, manual actuating auxiliary system and operating counter.
- g) The actuating system shall be of energy accumulation type, with low transient current consumption when arming the circuit breaker. The closing action of the circuit of the circuit breakers shall compress the opened spring ready for instantaneous tripping. It shall be equipped with an anti-hunting device, electric & manual arming capability.

14.2.5.4.3 Cubicles Arrangement

- a) All cubicles, boxes or sheaths shall be rigidly fastened to the floor.
- b) Cubicle level adjustment shall be realized with special steel sections initially anchored in position.

- c) The assembly level thus executed shall enable smooth movement of the trolleys in the cubicles. The width of the cubicles should not be more than 1000 mm width.

14.2.5.4.4 Cubicle Grounding

- a) Each cubicle shall comprise with motorized grounding/earthing system with suitable capacity of copper grounding bus-bar to which each of the metal masses of the component parts of the cubicle shall be connected, together with those of the instrument transformers.
- b) The grounding bus-bars of the various cubicles shall form a linkage interconnected together and a common collector line shall be provided for connecting both ends to the earthing circuit of the station.
- c) The withdrawal trolley shall be connected to this grounding bus-bar via a plug-in/out contact.
- d) The cable end manual earthing isolator position shall be visible, through a glazed port/mechanical indicator.
- e) Internal and external metal partitions shall be connected to the earth.
- f) Suitable arrangement for earthing cable sheath

14.2.5.4.5 Paint

- a) Painting should be suitable for polluted atmosphere and has to comply with IEC 60 721-2-5 standard.
- b) As a minimum, an initial coat of rust-proofing and anti-corrosion paint will be applied after baring of all metal surfaces; then they will be covered with two coats of paint and one finishing coat, colour to be defined.
- c) The Contractor shall submit to the Engineer, the complete details of the Switchgear Cubicles Metal work and Paintwork details, including details of the structure, process of finish and painting etc. for Engineer's approval. The total thickness should not be less than 60µm and withstand 120°C.

14.2.5.4.6 Nuts & Bolts

- a) The threads and hexagons of all nuts, bolts and stud shall confirm to relevant IS or BS.
- b) No bolt or stud shall project through its nut(s) more than 6mm (or) four threads, except when otherwise approved for terminating stud/bolts.
- c) If bolts and nuts are so placed that they are inaccessible by means of ordinary spanners
- d) All terminals should be provided with suitable cadmium plated and passivated high tensile steel hard wires facilitate cables termination.

14.2.5.4.7 Fitting & Accessories

As a minimum following fittings and accessories shall be provided

- a) Mechanically operated tripping and closing device
- b) Local / Remote /off control switch and indication lamps
- c) Operation counter
- d) Supporting frame if needed
- e) Name plate
- f) Foundation bolts
- g) LED status of breaker/earth switch position
- h) Meters
- i) CTs & PTs as required

14.2.5.4.8 The degree of protection shall be IP 5X or higher.

14.2.5.4.9 Identification

The front of each cubicle shall carry a nameplate indicating its identification number and function. The text and type of nameplate shall be defined later during detailed engineering stage.

14.2.5.5 Equipment

14.2.5.5.1 Circuit breakers

Make-up & equipment: Each circuit breaker shall be three pole vacuum type. The Circuit Breaker shall be tested for the duty cycle of E2, C2, M2 class in accordance with IEC62271-100(latest) and type test reports to be submitted. Vacuum Circuit Breaker shall be rated for minimum 100 nos. full short circuit to ascertain the life of Vacuum Circuit Breaker. Tenderer should submit the Type Test Reports for Short Circuit Duty with this breaker. Circuit breakers shall include:

- a) Up & down stream plug-in connectors
- b) Live insulated poles with epoxy encapsulation poles
- c) Energy accumulation type actuation system (electromechanical springs)
- d) Electric and manual arming capability (Tripping and closing coils motor)
- e) Under-voltage tripping coil (auxiliary voltage off)
- f) Locking and interlocking devices
- g) Open / Closed auxiliary contacts
- h) Low voltage multi-pin connector and flexible cable
- i) Redundant tripping coils shall be considered for each circuit breaker in the switchgear.

14.2.5.5.2 Current transformers

- a) Each current transformer shall be installed in the cable end compartment between the downstream pole and the cable connector. Cable end compartment volume shall allow easy access for current transformer and removal.
- b) Current transformers shall be cast resin and fixed type.
- c) Current transformer performances shall be as per technical sheets (GTP) included into this Specification.
- d) Elevated, CT should be fixed for top entry and UG, CT to be fixed for bottom entry.

14.2.5.5.3 Voltage transformers

- a) Each voltage transformer shall be installed in the cable end compartment, connected between the downstream pole and the cable connector through HRC fuses
- b) Cable end compartment volume shall allow for easy access for voltage transformer and removal.
- c) Voltage transformers shall be cast resin & withdrawable type.
- d) Voltage transformer performances shall be as per technical sheets included in this Specification.

14.2.5.5.4 Motion and plug-in mode Special devices

- a) All complete sets of plug-in accessories shall be provided for each type of circuit-breaker, together with four sets of auxiliary plug-in actuating devices, where the circuit-breaker has such devices.

14.2.6 SAFETY FEATURES

- 14.2.6.1 The design shall incorporate / provide full perception for safety of all those working personal associated with maintenance of the switchgear. The following safety features shall be provided as a minimum.
- 14.2.6.2 It shall not be possible to insert CB into the service when it is in the closed condition.
- 14.2.6.3 It shall not be possible to withdraw the CB from service position unless it is in the open condition.
- 14.2.6.4 It shall not be possible to close the CB in any position except when fully engaged in the service, test and isolated positions.
- 14.2.6.5 All access to the fixed plug-in parts is prevented when the CB is withdrawn.
- 14.2.6.6 A general diagram of the key interlocks for the station, indicating all the locks provided for the present equipment shall be prepared.
- 14.2.6.7 It shall invariably be possible to padlock the interlocks through castle keys.
- 14.2.6.8 The cubicles shall be protected against fire by means of automatic fire detector and extinguisher system with linear fire detection tube based clean agent direct gas flooding system. The detection has to be done by the linear heat detection tube which will be routed inside the panel as per the design calculation. The tube shall be double layered & made of Hi-tech Polymer either Fire Detec, Fire Trace or equivalent. The system shall utilize unique flexible tubing that shall be attached to the top of the container valve. This tubing shall be pressurized with Dry Nitrogen to 230 psig (≈ 16 bar) at 70°F (1,034 KPA @ 21°C), is temperature sensitive and shall act as a continuous linear thermal detector that shall rupture upon flame impingement. Once the detection tubing is ruptured, forming a nozzle at the rupture point, it shall allow the Clean Agent through the nozzle into the protected area. The clean agent offered should be as designated in NFPA 2001 [Section A.5.5.1(B)] and ISO 14520 Clean Agent Standards. Its 'ASHRAE' nomenclature is (FK5-1-12 or its equivalent (Novec 1230)). Gas should have lowest Global Warming potential. The quantity of clean agent required should be calculated as per NFPA 2001 and BIS standards. Clean agent container shall be designed, fabricated, certified with stamp on the containers in accordance with the requirements of NFPA. Containers shall be standard model and size for ease of replacement and addition. Fill containers with required Clean Agent (FK5-1-12 or its equivalent (Novec 1230)). Pressurise with Dry Nitrogen to 230 psig (≈ 16 bar) at 70°F (1,034 KPA @ 21°C). Container/cylinders shall have PESO approval /Govt. Approved Lab. A separate and stand alone gas cylinder with protection system shall be provided for a group of panels.
- Gas flooding system healthiness status shall be communicated to BMS (Building Management system. Necessary interface & accessories shall be taken care of by LKE(02)-01 contractor with concerned agencies involved.
- Demonstration of fire protection system on switchgear panel shall be done at site as required by Employer. (Combined for all equipments/sub-system)

14.2.7 INTERLOCKINGS

- 14.2.7.1 Self-interlocking's
- 14.2.7.1.1 All interlocking's as per approved scheme shall be incorporated. The following self-interlocking shall be necessarily incorporated:

- a) When unplugged and withdrawn from the cubicle, the mechanisms shall inhibit opening of the flaps covering the receptacles and shall enable the key to be turned.
 - b) By turning the lock and withdrawing the key, it shall not be possible to plug-in the circuit breaker / interrupter.
 - c) In addition, for the breaker cubicles, it shall be possible to actuate the earth isolator only after first unplugging the breaker and withdrawing the first key.
 - d) Conversely, the earth isolator being closed, it shall not be possible to unlock the cubicle in order to plug the circuit breaker in.
 - e) The type of lock shall be selected among equipment considered as being safety equipment.
 - f) The above self-interlocks shall be achieved through castle lock & key. Contractor shall submit the interlocking scheme for Engineer's approval during detailed engineering stage.
- 14.2.7.2 33 kV Switchgear Interlocking
- 14.2.7.2.1 All interlocking as per approved scheme shall be incorporated. Interlocking has been elaborated in SCADA Chapter 18.
- 14.2.7.2.2 This interlocking has several purposes such as to avoid paralleling of 33 kV supplies from different sources in remote and local control mode and to avoid earthing of a live cable.
- 14.2.7.2.3 For this purpose, the auxiliary 33 kV network is divided into suitable loops. Normally, the ASS's connected to the various loops will derive power supply from the respective loop only.
- 14.2.7.2.4 However, in an emergency situation, when one of the RSSs is totally out-of-service, it shall be necessary to link the loops. When this is required, the linking breakers which are provided for this purpose are closed in a sequence so as to ensure that the two loops are not linked when both loops are live. Suitable interlocking shall be provided for this purpose. If required, both circuits shall be compatible to operate under close/open loop configuration via suitable interlockings as required for the operation.
- 14.2.7.3 33 kV Network Inter-loop Interlocking
- 14.2.7.3.1 When potential transformer of a consecutive loop is showing voltage, extending power from one loop to other should not be possible. This feature shall also be available on SCADA.
- 14.2.7.4 Interlocking In Remote Control Mode
- 14.2.7.4.1 In remote control mode it shall be possible to operate 33 kV switchgear without any mechanical interlocking. This shall be possible through the medium of the remote/local switch when in remote position.
- 14.2.7.4.2 The SCADA software shall authorize closing / opening sequence in such a way that paralleling of 33 kV supplies is not possible in any circumstances.
- 14.2.7.5 Interlocking In Local Control Mode
- 14.2.7.5.1 In local control mode it shall be possible to operate 33 kV switchgear with a mechanical interlocking. This shall be possible through the medium of the remote/local knob when in local position.
- 14.2.7.5.2 The mechanical/electrical interlocking shall be designed in such a way that paralleling of 33 kV supplies is not possible in any circumstances.

- 14.2.7.6 Earthing Interlocking
- 14.2.7.6.1 A mechanical interlocking linkage shall be built in to prevent the grounding switch being closed if the ring CB is closed. Nonetheless, it shall be possible to operate the grounding switch with the compartment door open, but it shall be impossible to close the ring interrupter when the grounding switch is closed.
- 14.2.7.6.2 On the other hand, an electrical interlocking shall forbid the earthing isolator closing until the motorized interrupter at the other extremity of the same cable of the nearest ASS is locked in open position.
- 14.2.7.7 Local Interlocking
- 14.2.7.7.1 Each 33 kV board shall include a non-return interlocking system, formed by security locks/castle lock & key arrangement, to allow safe inspection of the transformer.
- 14.2.7.7.2 This interlocking system shall make it possible to open a main LV circuit breaker (in others' scope) and lock it open and unplugged before closing the protection bay ground isolating switch. Once this switch has closed, it shall be possible to open the door of the transformer bay.
- 14.2.7.7.3 All 33 kV cable coupling bays shall include systems to interlock interrupters and grounding isolators to make it possible to work on a bay without cutting the main 33 kV cable.
- 14.2.7.7.4 High-security locks shall form these interlocks.
- 14.2.8 PROTECTION SYSTEM**
- 14.2.8.1 The numerical type protection relays for the protection of incomers, couplers and transformer feeders shall be normally mounted on the panel. A separate panel with complete metering and protection equipment shall also be acceptable subject to availability of suitable space in the room.
- 14.2.8.2 Protection System Function
- 14.2.8.2.1 The function of the protection system is mainly (a) to isolate the affected portion as quickly and as expeditiously as possible while maintaining normal supply to the rest and (b) to provide alternative circuits with automatic changeover wherever applicable to minimize the extent and duration of power supply outage.
- 14.2.8.2.2 The Contractor shall prepare a comprehensive protection scheme and protection relay settings and submit to the Employer for approval. The Contractor shall provide proper relay coordination to ensure the following:
- 14.2.8.2.3 Selectivity
- Protection will be arranged in zones, which will cover the entire power system, leaving no part unprotected. When a fault occurs, the protection will trip only the nearest circuit breaker. The discrimination shall be achieved by two general methods
- Unit protection system
 - Time graded system
- 14.2.8.2.4 Stability
- Stability of the protection system refers to the ability of the system to remain inert to all load conditions and faults external to relevant zone.

14.2.8.2.5 Speed

The function of protection system is to isolate faults from the rest of the power system in a time as short as possible. The object is to safeguard continuity of supply by isolating each fault before it leads to total collapse of the system with widespread damage and total loss of power supply.

14.2.8.2.6 Sensitivity

The protective system is said to be sensitive if the primary operating current is low. Sensitivity of the protective system will be such that it will be able to sense and operate at minimum fault current.

14.2.8.2.7 Reliability

A system shall be not properly designed and managed if it is not adequately protected by a reliable protection system. Reliability will be enhanced by providing primary and backup protections.

14.2.8.3 Protection Relay Features

14.2.8.3.1 The protection relays shall comply to IEC 60255. CT secondary terminals shall be shorted automatically when the relay is withdrawn. The relays comprising of PCU (Protection and control unit) shall be in full compatibility with the RTU (remote terminal unit) of SCADA and shall be capable of providing single point monitoring, control, logging and protection for the system.

14.2.8.3.2 Protection devices (numeric protective relay, PCU) shall be built up with modular concept. All protective relays shall be in draw out or plug-in type/modular cases with proper testing facilities. The relays shall operate at control voltage of 110 V DC.

14.2.8.3.3 All AC operated relays shall be suitable for operation at 50 Hz. AC Voltage operated relays shall be suitable for 110 Volts VT secondary and current operated relays for 1 amp CT secondary. All DC operated relays and timers shall be designed for the DC voltage specified, and shall operate satisfactorily between 80% and 110% of rated voltage. Voltage operated relays shall have adequate thermal capacity for continuous operation.

- 14.2.8.3.4 The protective relays shall be suitable for efficient and reliable operation of the protection scheme described in the specification. Necessary auxiliary relays and timers required for interlocking schemes for multiplying of contacts suiting contact duties of protective relays and monitoring of control supplies and circuits, lockout relay monitoring circuits etc. also required for the complete protection schemes described in the specification shall be provided. All protective relays shall be provided with at least two pairs of potential free isolated output contacts. Auxiliary relays and timers shall have pairs of contacts as required to complete the scheme; contacts shall be silver faced with spring action. Relay cases shall have adequate number of terminals for making potential free external connections to the relay coils and contacts, including spare contacts.
- 14.2.8.3.5 All protective relays, auxiliary relays and timers except the lock out relays and interlocking relays specified shall be provided with self-reset type contacts. All protective relays and timers shall be provided with externally hand reset positive action operation indicators with inscription. All protective relays which do not have built-in hand-reset operation indicators shall have additional auxiliary relays with operating indicators (Flag relays) for this purpose. Similarly, separate operating indicator (auxiliary relays) shall also be provided in the trip circuits of protections located outside the board such as Buchholz relays, oil and winding temperature protection, sudden pressure devices, fire protection etc.
- 14.2.8.3.6 Timers shall be of solid state or electronic/numerical type. Time delay in terms of milliseconds obtained by the external capacitor resistor combination shall be avoided.
- 14.2.8.3.7 The relays shall include the tools for fault diagnostics. These tools shall have stored records for faults, events and disturbance. Disturbance shall be recorded for at least 5 sec. Faults and events shall be stored with resolution of 1 ms. Relays shall be capable of storing minimum of 10 disturbance records and 200 events with overflow.
- 14.2.8.3.8 Security measures shall be built in to gain access to vital data and functions. No security measures shall be required for access to system currents and voltages.
- 14.2.8.3.9 The Contractor shall furnish detailed proposal of batteries preferably in the Electrical Erasable Programmable Read Only Memory (EEPROM). This is to allow PCU settings to be changed in the foreground without affecting the actual operating values in the background.
- 14.2.8.3.10 Where PCUs are required to trip circuit breakers, actuate signals or perform control duties, PCUs shall be designed to avoid inadvertent or simultaneous switching operations and shall give precedence to protective functions required due to unfavourable conditions, e.g. short circuit, internal faults, power supply failure, voltage fluctuation, etc.
- 14.2.8.3.11 Provision shall be made for easy isolation of trip circuits of each relay for the purpose of testing and maintenance by means of RTB (relay Test Block). Visual display of SLD of each bay shall be made available with HMI (control).
- 14.2.8.3.12 Visual display or indication shall be provided for the operator to read out the setting of functional parameters and annunciations. In the event of a fault, all information relating to the fault shall be captured and stored in the PCU. The PCU shall have tri colour optical LED indicators to display any abnormal conditions. The memories of the LEDs shall be safeguarded against supply voltage failure. The optical indicators shall be able to be reset by following means.
- Locally by operating the reset button on the PCU.
 - Remote by energizing the remote reset input at RCC.
 - Automatically on occurrence of a few pick-up signals.

- d) The relay should have USB/RJ 45 port for local communication with Laptop and redundant Fibre Optic Ports to communicate on latest edition of IEC 61850 protocol.. No protocol converters shall be acceptable. Should have in built MIMIC display. Should be provided with free software for programming and analyzing the disturbance records.
- 14.2.8.3.13 Control & Protection equipments shall be having provision of controlling with SLD mimic display.
- 14.2.8.4 Protection Relay Specification
- 14.2.8.4.1 Each PCU shall be integrated with a protection relay module within which standard protective relay features are incorporated. The equipment shall comply with IEC 255 or BS 142. The application, performance and testing of protection relay modules shall be in accordance with the appropriate IEC standards.
- 14.2.8.4.2 Due to the consequent interference level, protection equipment shall present a sufficient level of immunity defined by the following standards:
- IEC 61000.4-2 Class 3,
 - IEC 61000.4-4 Class 4,
 - IEC 61000.4-5 Class 3.
- 14.2.8.4.3 Such criteria shall be obtained by using either numerical type relays or specific PLC cards.
- 14.2.8.4.4 All protection relay modules shall comply in accordance with the following IEC test requirements:'
- a) Dielectric test voltage (IEC 60255-5) 2.0 kV, 50 Hz, 1 min
 - b) Impulse test voltage (IEC 60255-5) 5 kV, 1.2/50 μ s 0.5 j
 - c) High Frequency disturbance test (IEC 60255-22-I Class III)
 - Common Mode 2.5 kV, 1 MHz, 2 s
 - Differential mode 1.0 kV, 1 MHz, 2s
 - d) Electrostatic discharge test (IEC 60255-22-2 & IEC 801-2 Class IV)
 - Air Discharge 15 kV
 - Contact discharge 8 kV
 - e) Fast transient (IEC 60255-22-4 Class IV)
 - Power supply inputs 4 kV
 - Other inputs 2 kV
 - f) Magnetic field (IEC 61000-4-8) 100 A/m
 - g) Electromagnetic field test (IEC 801-3 Class III) 10 V/m 50 kHz to 1000 MHz
- 14.2.8.4.5 The protective relay modules shall be microprocessor based with continuous monitoring and self-diagnostic features to identify the modules or components. The protective scheme shall be so designed that the system remains stable during switching operation and other disturbances.
- 14.2.8.4.6 In the event of a system fault, the protection module shall be able to record values of current and voltage at a scan frequency no lower than 1 kHz over a time window of at least 1 second before the event to 1 second after the event with time stamping. The fault data shall be captured and recorded and shall be downloaded in the OCC for fault analysis.
- 14.2.8.4.7 Safety is ensured by the means of Cyclic self-test ensuring general supervision on software of equipment. In case of fault, a watchdog is activated. All of inputs are insulated in galvanic and capacitive view and complemented.

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- 14.2.8.4.8 The individual protection relay module within the PCU shall continuously monitor the DC trip supply for the circuit breaker.
- 14.2.8.5 Protections for ASS Switchgear
- 14.2.8.5.1 Fault on a 33 kV Incoming cable
- 14.2.8.5.2 A fault may occur between phases on the 33 KV cables or on the bus bars in the boards. In either case, the main supply circuit breaker (auxiliary network) on the 33 kV cable from the supplying RSS. To locate and isolate the fault, a pilot wire differential relay installed on each incoming/outgoing 33 kV boards, of each ASS will send to the OCC an indication that it detects & isolate a fault. This will be seen on the screen of the OCC equipment and the fault could be located & also isolated by tripping of respective circuit breaker (CB). In addition, the Over current & earth fault protection provided on the ring main CBs shall work as a backup to pilot wire protection. Pilot wire differential relay will be a separate unit independent of OC & EF Relay unit. With these indications the operator will be able to take the necessary measure to isolate the faulty section and to reenergize the healthy part of the network.
- 14.2.8.5.3 Fault on a Transformer 33kV Supply
- 14.2.8.5.3.1 A short-circuit inside the transformer, or in the transformer protection line or a short-circuit insufficiently isolated by the transformer downstream LV protection shall be detected with selection by the transformer breaker protection and it shall trip the respective CB. Additionally, transformer breaker shall be equipped with differential & restricted earth fault relay. LKE(02)-01 contractor shall interface with E&M contractor for matching necessary CT characteristics for installing the required protection functions.
- 14.2.8.6 Grounding Fault on ASS 33kV ring cables
- 14.2.8.6.1 To achieve the protection requirements specified herein, the switchgear provided for auxiliary substations shall incorporate minimum following protections but not limited any additional protection required for successful operation shall be considered and provided by the contractor.
- 14.2.8.6.2 Protections on Auxiliary Transformer feeder circuit breaker shall consist of:
- a) 50: Instantaneous over current protection
 - b) 51: Time delayed over current protection
 - c) 50 N: Instantaneous earth fault protection (zero sequence)
 - d) 51 N: Time delayed earth fault protection (zero sequence)
 - e) 86: Master trip relay
 - f) 74: Trip circuit supervision relay
 - g) 49A: Temperature Alarm, first threshold
 - h) 49T: Temperature tripping, second threshold
 - i) 33: Door interlocking
 - j) 87T: Differential Protection (for UG and Depot only)
 - k) 64R: REF Protection (for UG and depot only)
- 14.2.8.6.3 The protection on 33 kV incoming & outgoing feeder to/from other station/corridor as per SLD
- a) 50: Instantaneous over current protection
 - b) 51: Time delayed over current protection
 - c) 50 N: Instantaneous earth fault protection (zero sequence)
 - d) 51 N: Time delayed earth fault protection (zero sequence)
-

- e) 27: Under voltage relay
- f) 67: Directional Overcurrent
- g) 67N: Direction Earth Fault.
- h) 59: Overvoltage Relay.
- i) 74: Trip Circuit Supervision relay.
- j) 87L: Line Differential (Pilot Wire)

14.2.8.6.4 The protection on 33 kV incoming feeder in RSS AMS

- a) 50: Instantaneous over current protection
- b) 51: Time delayed over current protection
- c) 50 N: Instantaneous earth fault protection (zero sequence)
- d) 51 N: Time delayed earth fault protection (zero sequence)
- e) 27: Under voltage relay
- f) 59: Overvoltage Relay.
- g) 74: Trip Circuit Supervision relay.
- h) 87L: Line Differential (Pilot Wire)
- i) 87T: Power T/F diff

14.2.9 METERING

14.2.9.1 The transformer feeder CBs shall be equipped with metering instruments. The metering system required is as follows:

14.2.9.1.1 Digital ammeters (to read the value of current delivered to each transformer)

14.2.9.1.2 Digital voltmeters (to read the value of primary voltage of each transformer, whether on-load or as hot standby)

14.2.9.1.3 Energy Meter/ Multi-Function Meter with metering accuracy class 0.2S shall be provided in each transformer feeder including incomer feeder at RSS 33 kV Switchgear) as per the latest guideline of electricity tariff rules and regulation and compatible with redundant communication protocol of IEC 61850, RS485 (Modbus) and IEC 103 etc. for SCADA Integration with redundant optic fibre/RS485 Ports.

14.2.9.2 The Contractor shall submit proposals regarding range and other technical details of ammeter, voltmeters and energy meters for approval by the Engineer.

14.2.9.3 SCADA compatibility of all the protection, monitoring and metering equipment shall be ensured by the Contractor.

- 14.2.9.4 A panel mounted online Power Quality Analyser (PQA) shall be provided in the incoming 33 kV feeder from the RSS to Depot AMS. Power Quality Analyser (PQA) needs to be bright color LCD Display with meter dimension of not more than 200 X 200 mm and shall comply to active energy accuracy of Class 0.2 as per IEC 62053-22. Power Quality Analyser (PQA) needs to monitor basic parameters of Current, Voltage, Frequency, Active Power, Reactive Power, Apparent Power, Power factor, Active Energy, Reactive Energy, Apparent Energy, demand parameters of Active, Reactive, Apparent Power – Total and per phase, Settable accumulation modes, Present & Peak demand with DTS, Synchronization of the measurement window and setting of calculation mode – Block / Sliding. Power Quality Analyser (PQA) needs to comply to a minimum sampling rate of 1024 Samples/ Cycle with simultaneous sampling of Voltage and current channels and capable of monitoring Voltage Sags/Swells over waveform Capturing Feature. Power Quality Analyser (PQA) needs to be capable of capturing transients as short as 20micro Seconds at 50HZ. Power Quality Analyser (PQA) needs to monitor individual harmonics up to 63rd for Voltage & Current. Device needs to be capable of PQ compliance reporting as per IEC 61000-4-30 Class A, EN50160 Compliance, CBEMA Curve reporting. Power Quality Analyser (PQA) needs to have onboard 01 Ethernet port and Modbus Mastering capability by connecting Slave devices over 02 RS485 port. Power Quality Analyser (PQA) needs to have 8 digital status inputs for Breaker ON/OFF/ Trip monitoring & 3 Form C Relays. Device should be capable of expandable DI/DO, ADI/ADO. Power Quality Analyser (PQA) needs to have minimum 10MB of standard non-volatile memory for logs of Min/max of instantaneous values, Event logs, Trending/ forecasting, SER (Sequence of event recording). Power Quality Analyser (PQA) needs built-in with Disturbance Direction Detection to determine the direction of the disturbance relative to the meter captured in the event log. Power Quality Analyser (PQA) needs to access historical data at the front panel. Display, trend and continuously update historical data with date and timestamps for up to four parameters simultaneously and the parameters shall be accessible from SCADA at OCC/BCC. PQA shall also generate alarms, annunciations in RSS SCADA and OCC/BCC as well.

14.2.10 GTP FOR 33 KV TRIPLE POLE VACUUM CIRCUIT BREAKER

- 14.2.10.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 14.2.10.2 The list indicated below is expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 14.5: GTP for 33 kV Vacuum CB & Complete Switchgear

S. No.	Description	Unit	Manufacturer's Data
A	GENERAL		
1	Manufacturer		
2	Place of manufacture		
3	Standards		
B	CUBICLE (FIXED PART)		
1	Class		
2	Rated insulation voltage	kV	
3	Rated operating voltage	kV	
4	Rated frequency	Hz	

S. No.	Description	Unit	Manufacturer's Data
5	Rated short time duration power frequency withstand voltage	kV rms	
6	Rated lightning impulse withstand voltage	kV peak	
7	Cubicle rated current		
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
8	Busbar material		
9	Phase barrier/heat shrinkable sleeve for busbar		
10	Epoxy or polycarbonate shrouds for busbar joints		
11	Busbar connection		
12	Busbar support spacing	mm	
13	Bar set rated continuous current		
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
14	Allowable overcurrent for 1 second	kA rms	
15	Instantaneous overcurrent	kA peak	
16	Number of flip-flop contacts for circuit-breaker plugging-in and plugging-out monitoring	Minimum	
17	Number of flip-flop contact for earthing isolator open/closed position monitoring	minimum	
18	Number of flip-flop contacts for isolator open/closed position monitoring	minimum	
19	Maximum dimensions of the cubicle		
a.	Width	mm	
b.	Depth	mm	
c.	Height	mm	
d.	Depth with circuit-breaker plugged-out	mm	
20	Protection degree		
21	Earthing isolator making capacity	kA	
22	Overall dimension drawing number		
C	CIRCUIT-BREAKER (MOVABLE PART)		
1	Type		
2	Rated insulation voltage	kV	
3	Rated operating voltage	kV	
4	Rated frequency	Hz	
5	Rated short time duration power frequency withstand voltage	kV rms	
6	Rated lightning impulse withstand voltage	kV peak	
7	Rated current	A	
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
8	Allowable overcurrent for 1 second	kA rms	
9	Instantaneous overcurrent	kA peak	
10	Breaking capacity	kA rms	
11	Making capacity	kA peak	

S. No.	Description	Unit	Manufacturer's Data
12	Breaking mode		
13	Opening time	ms	
14	Breaking time	ms	
15	Closing time	ms	
16	Rated operating cycle		
17	Breaking capacity of cable at no load	A	
18	Number of auxiliary contact for open/closed position of the circuit-breaker	O/O O/C	
19	Auxiliary supply voltage	V dc	
20	Supply voltage for motor drive circuits	V dc	
21	Allowable variation range of supply voltage	%	
22	Power consumption of auxiliary	VA	
23	Coils consumption		
a.	engagement coil	A	
b.	release coil	A	
24	Consumption of arming motor	A	
25	Maximum noise level during opening and closing actuation	dB	
26	Degree of protection for auxiliary circuit		
27	Trolley design (Shall be suitable for direct withdrawal on Floor)		
D	CURRENT TRANSFORMER		
1	Type		
2	Manufacturer		
3	Place of manufacture		
4	Standards		
5	Rated insulation voltage	kV	
6	Operating voltage	kV	
7	Rated frequency	Hz	
8	Rated power frequency short duration withstand voltage	kV	
9	Rated lightning impulse withstand voltage	kV	
10	Actual transformation ratio		
11	Protection secondary		
a.	Accuracy class		
b.	Rated output	VA	
12	Measuring secondary		
a.	Accuracy class		
b.	Rated output	VA	
13	Short-circuit current allowable for 1 seconds	kA	
14	Permanent operation without danger	In	
15	Overheating	In	
16	Overcurrent class		
17	Temperature rise over 40 °C ambient	°C	
E	VOLTAGE TRANSFORMER		
1	Type		

S. No.	Description	Unit	Manufacturer's Data
2	Manufacturer		
3	Place of manufacture		
4	Standards		
5	Primary insulation voltage	kV	
6	Operating voltage	kV	
7	Rated frequency	Hz	
8	Rated short-time duration power frequency withstand voltage	kV	
9	Rated lightning impulse withstand voltage	kV	
10	Actual transformation ratio - Primary winding - secondary windings	kV V	
11	Accuracy class Protection core Measuring core		
12	Rated output (minimum) Protection core Measuring core (As required for different purposes to be indicated. The value provided in 'required' column is indicative only)	VA VA	
13	Secondary winding type and insulation		
14	Secondary winding voltage grade	V	
15	Secondary winding conductor material		
16	Earth bus		
F	Accessories		
1	Earthing equipment		
G	Finish of Switchgear		
1	Inside and outside the panel		
H	Internal wiring of panel		
1	Elevated / at-grade sections		
2	Underground sections		
I	NUMERICAL RELAYS		
1	Manufacturer		
2	Place of manufacture		
3	Relevant Standards		
4	Protections		
5	Communication Protocols		
6	Auxiliary Supply	V dc	

14.2.11 TEST SHEET FOR 33 KV TRIPLE POLE VCB (AIS)**Table 14.6: Test Sheet for 33 kV Vacuum CB**

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
1) Breaker					

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Dielectric tests	X				
Radio interference voltage tests	X				
Measurement of the resistance of the main circuit	X				
Temperature-rise tests	X				
Short-time withstand current and peak withstand current tests	X				
Tightness tests	X				
EMC tests	X				
Mechanical operation test at ambient temperature	X				
Short-circuit current making and breaking tests	X				
Capacitive current switching tests (cable charging)	X				
Switching of shunt reactors and motors	X	X	X		
Dielectric test		X	X		
Dielectric test on auxiliary and control circuits		X	X		
Tightness test		X	X		
Design and visual checks		X	X		
Mechanical operating tests		X	X		
Functional test			X		
CRM, Breaker opening and closing time			X		
Power frequency withstand voltage test main circuit	X	X	X	X	
Power frequency withstand voltage test auxiliary circuit	X	X	X	X	
E2, M2, C2 Duty cycle test as per IEC 62271-100	X				
2) Complete Switchgear					
Dielectric tests	X				
Measurement of resistance of circuits	X			X	
Temperature rise test	X				
Short-time withstand current and peak withstand current tests	X				
Internal faults arcing effects	X				
Verification of protection	X				
Electromagnetic compatibility test (EMC)	X				
Additional tests on auxiliary and control circuits	X				
Verification of making and breaking capacities	X				
Mechanical operation tests	X				
Dielectric tests (IR Test)		X	X	X	

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Tightness test		X	X	X	
Design and visual checks		X	X	X	
Mechanical operating tests		X	X	X	
Functional test		X	X	X	
Primary current Injection		X	X		
Relays settings and meter calibration		X	X	X	
Protection and Interlocking test		X	X	X	
Instrumentation & relays calibration				X	
High voltage				X	
Power frequency withstand voltage test main circuit	X	X	X	X	
Power frequency withstand voltage test auxiliary circuit	X	X	X	X	
2) MOVABLE PART					
Temperature rise	X				
Lightning impulse withstand voltage test	X				
Partial discharge	X				
Over-voltage	X				
Short circuit Current making & breaking capacity	X				
Magnetising & small inductive current switching	X				
Peaks & short time current withstand	X				
Aux. circuits dielectric withstand		X	X		
Main circuits resistance value		X	X		
Withstand voltage at 50 Hz		X	X		
Mechanical operations at rated, max. & min voltage		X	X	X	
Functioning times		X	X	X	
Interlocking		X	X	X	
Visual inspection		X	X	X	
Contact Resistance		X	X	X	
3) CURRENT TRANSFORMER					
Temperature rise	X				
Lightning impulse withstand voltage	X				
Short circuit withstand	X				
Primary windings power frequency withstand voltage test		X	X		
Secondary windings power frequency withstand voltage test		X	X		
Between section power		X	X		

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
frequency withstand voltage test					
Transformer ratio		X	X	X	
Terminal marking		X	X	X	
Visual inspection		X	X	X	
Exchangeability of similar devices		X	X		
Insulation Resistance Test				X	
Continuity Test			X	X	
Secondary Winding Resistance Test				X	
Knee Point Voltage Test				X	
4) VOLTAGE TRANSFORMER					
Temperature rise	X				
Lightning impulse withstand voltage	X				
Short circuit withstand	X				
Primary windings power frequency withstand voltage test		X	X		
Secondary windings power frequency withstand voltage test		X	X		
Between section power frequency withstand voltage test		X	X		
Transformer ratio		X	X	X	
Terminal marking		X	X	X	
Visual inspection		X	X	X	
Exchangeability of similar devices		X	X		
Insulation Resistance Test				X	
Continuity Test			X	X	
Secondary Winding Resistance Test				X	

14.2.12 FOR UNDERGROUND SECTION - GAS INSULATED SWITCHGEAR (GIS)

14.2.13 SCOPE

14.2.13.1 This Specification applies to design, supply, installation, testing and commissioning of switchgear along with accessories.

14.2.13.2 The switchgear cubicles shall be provided with CB voltage transformers, current transformers, protection relays, space heaters, linear fire detection tube based fire protection system and all other components, as required, to comply with functional and technical specifications, in full.

14.2.13.3 The switchgear offered shall be complete in all respect with all parts and accessories including frame work, necessary for their efficient operation, maintenance and protection. All such parts and accessories shall be deemed to be within Scope of this Specification whether specially mentioned or not.

- 14.2.13.4 For UG section, Auxiliary/Traction substations 33 kV switchgear shall be with with Gas Insulated Switchgear (GIS) with vacuum circuit breakers.

14.2.14 GENERAL

- 14.2.14.1 The switchgear shall be of the single busbar with 3-phase enclosure indoor metal-enclosed extendable type, which, when erected, shall form a complete switchboard.
- 14.2.14.2 The metal-enclosed switchgear shall be gas insulated and the circuit interrupting device shall be of vacuum type.
- 14.2.14.3 The switchgear offered shall have a basic insulation level (BIL) of not less than 170kV peak.
- 14.2.14.4 The switchgear shall be capable of operating in class B environment stipulated in General Specification.
- 14.2.14.5 The switchgear shall, unless otherwise specified, generally conforming to the following standards or their latest issue as applied in the manner altered, amended or supplemented by this Specification and the Indian Electricity rules wherever applicable. For the equipment or component which forming part of the switchgear for which standards are not mentioned, the respective IS, IEC, BS EN etc., shall prevail. Numerical protection relays shall comply with IEC 60255 and compatible with IEC 61850 protocol for communication.

Table 14.7: Applicable Standards

S.No	Title of Specification	Specification No.
1.	Instrument transformers - Part 1: General requirements	IEC 61869-1-latest
2.	Instrument transformers - Part 2: Additional requirements for current transformers	IS 2705 latest IEC 61869-2-latest
3.	Instrument transformers - Part 3: Additional requirements for inductive voltage transformers	IS 3156 latest IEC 61869-3-latest
4.	Switches for rated voltages above 1 kV up to and including 52 kV	IEC 62271-103-latest
5.	AC metal-enclosed switchgear and control gear for rated voltage above 1 kV and up to and including 52 Kv	IEC 62271-200–latest
6.	International standard of resistance for copper	IEC 60028-latest
7.	High-Voltage Alternating-current circuit breaker	IEC 62271-100–latest
8.	Alternating current disconnectors and earthing switches	IEC 62271-102–latest
9.	Specification of technical grade sulphur hexafluoride (SF ₆) and complementary gases to be used in its mixtures for use in electrical equipment	IEC 60376-2018
10.	High-voltage switchgear and controlgear - ALL PARTS (as applicable)	IEC 62271 latest
11.	International standard of resistance for copper	IEC 60028 latest

14.2.15 Switch gear cubicles

- 14.2.15.1 General Description

- 14.2.15.2 All non-welded assemblies shall be assembled by means of bolts and nuts with mandatory use of lock-washers. All panels, separating partitions and accessories shall be mounted similarly, in such a way so as to withstand indefinitely the vibrations transmitted, in particular by the resetting mechanism of the circuit-breakers and their actuation.

- 14.2.15.3 Electrical characteristics

Rated Voltage	36kV
Operation Voltage	33kV
Frequency	50Hz
Rated busbar current	1250A As per Tender SLD
Rated current of feeders	1250A As per Tender SLD
Rated current of transformer feeders	1250A As per Tender SLD
Rated short time withstand current	25kA for 3sec
Rated short circuit breaking current	25kA
Rated short circuit making current	62.5kA
Lightning impulse test (BIL) voltage	170kVp
Power frequency test voltage	70kVrms
Auxiliary Supply Voltage	110V DC
Degree of protection (HV Compartment)	IP 65
Degree of protection (LV Compartment)	IP3X

14.2.16 General Requirement

- 14.2.16.1 GIS supplier should have minimum experience of 05 years for manufacturing of similar GIS substations. The type of GIS offered should have been in satisfactory operation for at least Five years. Contractor should submit performance certificate from the employer.
- 14.2.16.2 The 33kV equipment shall be built according to the SF6 gas insulation technology.
- 14.2.16.3 33kV GIS as offered should be fully type tested as per latest IEC standards at the time of submitting vendor approval.
- 14.2.16.4 The equipment installed shall offer all necessary facilities for equipping and connecting the equipments sections to follow, without entailing any shut down of equipment already in service.
- 14.2.16.5 In the event of arcing in a compartment, the arces should not extend to the neighbouring compartment/Panel. Any failure to the enclosure of the compartment shall not lead to damages in the neighbouring compartments.
- 14.2.16.6 Suitable means of expansions should be provided in the metal enclosure and pipelines to absorb the actual thermal expansion and contraction of the SF6 equipment and to facilitate the alignment of the switchgear assembly.
- 14.2.16.7 The metal enclosure for the SF6 gas insulated equipment modules shall be made from aluminium alloy/ stainless steel.
- 14.2.16.8 GIS should be of modular design, and it should be possible to add feeder panels if required.

- 14.2.16.9 Inter-panel auxiliary and control wiring shall have terminals in each relevant cubicle so placed for the bus wiring to be readily run from unit to unit. Auxiliary and control wiring to be connected to other equipment shall be wired to terminals at the rear of individual cubicles, suitably located for the wiring to be extended via multi-core cabling run in floor ducts. All auxiliary and control wiring shall be separated from high-voltage conductors, even though the latter are insulated by earthed metal enclosures.
- 14.2.16.10 All auxiliary and control cables and wirings shall have suitable marking, such as ferrule markers, which shall clearly identify their function and shall match the control schematic drawings and wiring diagrams. The markers shall fit firmly over the outer diameter of individual cable and each wire core. Marks shall be printed and legible. For easy identification, colour coding shall be used to differentiate various functions of the cable and wires. All auxiliary and control wirings shall also be complete with cable lugs for termination.
- 14.2.16.11 A relay and instrument compartment shall be located at the front of each switchgear unit and shall be provided with a hinged door for access to the internal wiring and terminals. Gaskets shall be used to provide close sealing. The height of the instrument panel above floor level shall not exceed 2,000mm unless otherwise reviewed without objection by the Engineer who may require the Contractor to provide, at its own cost, suitable means for easy access to the instrument panel.
- 14.2.16.12 Anti-condensation heaters with humidity control function shall be installed for each switchgear panel.
- 14.2.16.13 The switchboard shall be designed to cater for future extension.

14.2.17 Detail Description –Equipment & Accessories

- 14.2.17.1 Circuit Breakers
- 14.2.17.1.1 Circuit breakers shall employ vacuum interrupters and shall have busbar side integral isolation facilities, i.e. a 3-position isolator with On-Off-Earth positions.
- 14.2.17.1.2 The circuit breakers shall have rated operating sequence (duty cycle) of: O-0.3sec-CO-3min-CO.
- 14.2.17.2 Operating Mechanisms
- 14.2.17.2.1 The circuit-breaker and switch mechanisms shall be of spring-powered stored energy operation by means of a motor charged spring with manual and electrical released, or solenoid operated.
- 14.2.17.2.2 The mechanism shall be of the trip free type so that the circuit-breaker shall be free to open during the closing operation immediately after the operation of its tripping device. The circuit-breaker shall be capable of closing fully and latching, against its rated making current. The various parts shall be of substantial construction, carefully fitted to ensure free action, and designed to reduce mechanical shock during operation to a minimum.
- 14.2.17.2.3 In the event of a spring breaking, it shall still be possible to open the circuit-breaker safely and it shall be possible to close the circuit-breaker or switch adequately to carry its rated current in accordance with IEC60056.
- 14.2.17.2.4 Circuit-breaker spring operated mechanisms shall have the following additional features:

- If the circuit-breaker is opened and the springs charged, it shall be possible to close, and then trip the circuit-breaker;
 - If the circuit-breaker is closed and the springs charged, there shall be sufficient energy to trip, close, and then trip the circuit-breaker;
 - Mechanical indication shall be provided to indicate the state of the spring; and
 - Motor charged mechanisms shall be provided with means for charging the springs by hand. A shrouded push button for releasing the springs and an electrical release coil shall also be provided.
- 14.2.17.2.5 All circuit-breaker operating mechanisms shall be fitted with an electrical shunt trip release coil and a mechanical hand tripping device.
- 14.2.17.2.6 Tripping and closing circuits shall be provided with a fuse or miniature circuit breaker on each unit and shall be independent of each other and all other circuits. A trip circuit supervision scheme shall be incorporated for every circuit. Redundant tripping coils shall be considered for each circuit breaker in the switchgear.
- 14.2.17.2.7 The electrical tripping and closing devices shall be operated satisfactorily, with a maximum temperature of 55°C inside the 33kV switchgear enclosure, over a DC voltage range as follows:
- Closing solenoids 80 to 120% of rated voltage
 - Spring charging motor 80 to 120% of rated voltage
 - Closing release coil 80 to 120% of rated voltage
 - Shunt trip release coil 70 to 120% of rated voltage
- 14.2.17.2.8 All operating coils for use on the DC supply shall be connected in such a way that failure of insulation to earth does not cause the coil to become energised.
- 14.2.17.2.9 Auxiliary switches shall be provided in circuit breaker tripping circuits to interrupt the tripping supply as soon as the circuit breaker has completed the tripping operation. An auxiliary switch shall be provided in closing circuits to ensure that the closing circuit is open after a close has been made.
- 14.2.17.2.10 A proven positively-driven mechanically-operated indicating device shall be provided to show whether a circuit breaker is in the open or closed position.
- 14.2.17.2.11 Locking facilities shall be provided so that the circuit breaker, if required, can be prevented from being closed when it is open, and from being manually tripped when it is closed. It shall not be possible to gain access to the tripping toggle or any part of the mechanism which would defeat the locking of the manual trip.
- 14.2.17.3 Busbars and Connections
- 14.2.17.3.1 Busbars and connections between the pieces of apparatus forming the equipment of a cubicle shall be of high-conductivity copper. The conductivity shall not be less than 99.9% of that of a "Standard Annealed Copper", as defined in IEC Publication No. 60028.
- 14.2.17.3.2 Busbar connections and their supports shall be of an approved type, designed to withstand all normal and abnormal conditions arising in the System. They shall be capable of carrying the current equivalent to the breaking capacity of the switchgear for 1 seconds.
- 14.2.17.4 Insulation Gas

- 14.2.17.4.1 All live conductors shall be inside SF6 gas insulating medium /Hybrid model of GIS. The Contractor shall submit details on quantity, quality and density of SF6 gas to be used in the switchgear in accordance with IEC 60376.
- 14.2.17.4.2 The GIS shall be grouped into suitable gas compartments with each compartment fitted with a monitoring pressure gauge/sensors and a pressure relief device.
- 14.2.17.4.3 The gas leakage rate shall be guaranteed to be less than 0.1% of gas mass in the tank over a period of One Year.
- 14.2.17.4.4 The GIS shall be so designed that an internal arc fault in a compartment will not affect other gas compartments, and compartments for operating mechanism and protection relays. The high pressure gas or air from the GIS during an internal arc fault shall be directed or vented to a direction away from the operator. The Contractor shall provide type test reports for the internal arc test.
- 14.2.17.4.5 SF6 Gas apparatus warning sign shall be provided on the GIS. Dual alarm for gas pressure low to be provided and after second stage alarm CB shall trip and lock.
- 14.2.17.5 Switchgear Interlocking
- 14.2.17.5.1 Where a circuit breaker or other switchgear is fitted with means for mechanical or electrical operation, interlocks shall be provided so that it is impossible for the electrical and mechanical devices to operate simultaneously.
- 14.2.17.5.2 An electrical or a mechanical key interlocking system shall be provided whereby it is not possible to apply an earth to a section of the busbar until all circuit breakers which can feed that section are locked open.
- 14.2.17.5.3 The earthing devices shall be provided with interlocks to ensure correct operation in conjunction with the associated circuit breaker.
- 14.2.17.5.4 The isolators and the associated circuit breaker which are integral parts of the switchboard shall be equipped with mechanical interlocking to ensure that the isolators cannot be operated unless the associated CB is opened. For the same reason, motorised isolator shall be installed with electrical interlock to provide the same interlocking logic.
- 14.2.17.5.5 Means shall be provided whereby the electrical tripping of the circuit breaker is rendered inoperative during earthing operations both when closing and when closed in the earthed position. It shall not be possible to return to the service position and close the circuit breaker until the electrical tripping is again operative.
- 14.2.17.5.6 Where interlocking over a distance is required, two independent criteria shall be used, e.g. absence of a voltage and remote feeding circuit breaker open. Indication of the remote condition shall be by single purpose circuit, care being taken that the conductors used are adequately screened and shielded to minimise both transverse and longitudinal voltages resulting e.g. from electromagnetic induction, differences in earth potential or other causes. The Contractor shall ensure that voltages dangerous to personnel or deleterious to correct operation shall not arise.
- 14.2.17.5.7 When there is provision for isolation of sections of cable between two “either-or” interlocked circuit breakers, a key-operated over-ride shall be provided to permit both circuit breakers to be closed at the same time provided that the circuit between them is broken. It shall not be possible to restore the connection without tripping one of the two circuit breakers and releasing the key.
- 14.2.17.5.8 The mechanical closing button of circuit breaker shall be interlocked with the closing conditions of the circuit breaker such that operation of the mechanical closing button shall be prohibited if the closing conditions of the circuit breaker are not fulfilled.

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- 14.2.17.6 Locking Facilities
- 14.2.17.6.1 Padlocking facilities shall be provide for mechanical close on circuit breakers to prevent manual closing
- 14.2.17.6.2 All cubicle access doors, other than those which are interlocked with a switching device, shall be provided with pad-lock type locking facility.
- 14.2.17.7 Earthing and Earthing Devices
- 14.2.17.7.1 All earth bars and terminals including those in the switchboard and inside the ASS shall be tinned copper.
- 14.2.17.7.2 All metal parts other than those forming part of an electrical circuit shall be directly connected to a high conductivity copper earth busbar which shall run the full length of and be bolted to the main frame of the switchboard.
- 14.2.17.7.3 At the position where joints or terminations occur, the earth busbar shall also be tinned. The earth busbar shall be rated to carry currents equal in magnitude and duration to that associated with the short circuit rating of the equipment.
- 14.2.17.7.4 The metallic cases of all instruments, relays or other associated components mounted on the switchgear shall be connected to the earth busbar by copper conductors of not less than 2.5mm² cross-sectional area.
- 14.2.17.7.5 When components are provided for mounting separately, each shall be provided with an earthing terminal of not less than 30mm² cross-sectional area.
- 14.2.17.8 Control Facilities
- 14.2.17.8.1 All circuit-breakers shall be capable of being operated electrically from the OCC via the SCADA system.
- 14.2.17.8.2 Proven, positively driven mechanical indicating devices shall be provided on all equipment to indicate whether the primary equipment is in the OPEN or CLOSED position. Care shall be exercised in the design and fitting of these indicators to ensure that the indicating device and associated apparatus does not interfere with the correct operation of the circuit-breaker or isolator.
- 14.2.17.8.3 Each circuit breaker shall be provided with the necessary auxiliary contacts and internal wiring to permit remote control and indication.
- 14.2.17.8.4 Separate switches for local electrical operation shall be installed for each circuit breaker and they shall be of a proven pistol-grip type. They shall have CLOSE and TRIP positions, with a spring return to a NEUTRAL position. The switches shall be lockable in the NEUTRAL position by means of a padlock
- 14.2.17.8.5 A separate LOCAL / REMOTE CONTROL selector switch shall be provided for each circuit-breaker. In addition to the contacts in the control circuits, the switch shall have contacts closed in the LOCAL position for remote indication of switch positions. The switch shall have two positions, and shall be lockable at both positions by means of a padlock.
- 14.2.17.8.6 Electrical tripping and closing devices shall be suitable for operation from 110V DC batteries.
- 14.2.17.8.7 Exposed LV 220V AC terminals inside each Control cubicle shall be adequately shrouded to avoid accidental human contact.
- 14.2.17.9 Auxiliary Switches
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- 14.2.17.9.1 Proven, positively direct-driven auxiliary switches shall be provided on all primary switching devices as required for indication, control and interlocking. Auxiliary switches shall be robust, shall have a positive wiping action when closing and shall be mounted in an accessible position clear of operating mechanisms. Three sets of spare switches comprising of normally-open and normally-closed contacts shall be provided on each unit.
- 14.2.17.9.2 Auxiliary switches shall be of the changeover type to be either normally-open or normally-closed, and shall be positively lockable in the desired position.
- 14.2.17.9.3 Auxiliary switches shall be designed to make, break and carry, without undue heating, the current of their associated circuit or a current of three amperes DC, whichever is the higher.
- 14.2.17.10 Cable entry
- 14.2.17.10.1 Cable connection shall be preferably top entry for elevated/UG station and for depot it may top or bottom entry as per Contractor's design. Cable termination shall be inner/outer cone plug in type with test plug/dummy plug available in switchgear for testing.
- 14.2.17.11 Testing Facilities
- 14.2.17.11.1 All fixed and moving portions of the switchgear shall be provided with facilities to enable high voltage tests to be carried out.
- 14.2.17.11.2 When current transformers and protective relays are fitted, facilities including but not limited to isolation links, test blocks and test plugs shall be provided for primary and secondary injection tests to be performed. These facilities shall be such that wires and connections need not be disconnected for the tests to be made.
- 14.2.17.12 Current transformers
- 14.2.17.12.1 When CTs are used for protection and measurement purposes, they shall have the appropriate ratio, class and burden in line with the functions they are used for.
- 14.2.17.12.2 All current transformers shall have a short-time current rating of not less than the maximum System fault level.
- 14.2.17.12.3 Current transformers shall have an output rating adequate to cater for the burden connected to them and shall function satisfactorily under the maximum system fault condition.
- 14.2.17.12.4 All current transformers shall be installed with the P2 terminals adjacent to the busbars (refer tender SLDs).
- 14.2.17.12.5 All connections from secondary windings shall be brought out and taken by means of separate insulated leads to a terminal board mounted in an accessible position. Where multi-ratio secondary windings are required, a label shall be provided at the secondary terminal board clearly indicating the connections required for each ratio. The connections and ratios in use shall be shown on all diagrams of connections.
- 14.2.17.12.6 Current transformers shall have the appropriate ratio depending upon their application.
- 14.2.17.12.7 Secondary connection wirings shall have a minimum size of 4mm² copper conductors.
- 14.2.17.12.8 The class of all protection CTs shall be as per GTP/ SLD.

- 14.2.17.12.9 The Contractor shall prepare a schedule of CTs to be installed, and submit the same for the Engineer's review.
- 14.2.17.12.10 The secondary windings of current transformers shall adopt single point earthing. The earth connection shall be made at a terminal block via a removable link.
- 14.2.17.13 Voltage transformers
- 14.2.17.13.1 Voltage transformers of the metal-enclosed encapsulated type are preferred. Other types may be submitted to the Employer's Representative for review and approval.
- 14.2.17.13.2 The secondary windings shall be connected to the secondary circuit through a LV fuse or a miniature circuit breaker (MCB).
- 14.2.17.13.3 The nominal VT ratio shall be $33\text{kV}/\sqrt{3}/110\text{V}/\sqrt{3}$.
- 14.2.17.13.4 For protection and measurement applications, the VTs shall be of dual Class 3P/0.2. The burden of VTs shall be decided by the Contractor with a margin of 40% for future additions of instrumentations, and submitted to the Employer's Representative for review and approval.
- 14.2.17.14 Paint-work
- 14.2.17.14.1 Painting should be suitable for polluted atmosphere and has to comply with IEC 60 721-2-5 standard
- 14.2.17.14.2 As a minimum, an initial coat of rust-proofing and anti-corrosion paint will be applied after baring of all metal surfaces; then they will be covered with two coats of paint and one finishing coat, colour to be defined. The Contractor shall submit to the Employer, the complete details of the Switchgear Cubicles Metal work and Paintwork details, including details of the structure, process of finish and painting etc, for Employer's approval.
- 14.2.17.15 Identification
- 14.2.17.15.1 The front of each cubicle shall carry a nameplate indicating its identification number and function. The text and type of nameplate shall be defined.
- 14.2.17.16 Fitting & Accessories
- 14.2.17.16.1 As a minimum following fittings and accessories shall be provided
- Mechanically operated tripping and closing device
 - Local / Remote /off control switch and indication lamps
 - Operation counter
 - Supporting frame if needed
 - Name plate
 - Foundation bolts
 - Semaphore indicators
 - Meters
 - CTs & PTs as required
 - Protection as required

14.2.18 Medium voltage switchgear interlocking

- 14.2.18.1 The medium voltage switchgear interlocking has several purposes:
- To avoid any paralleling in remote control mode
 - To avoid any paralleling in local control mode
 - To avoid the earthing of a cable under voltage presence
- 14.2.18.2 For this purpose, the 33 kV network is divided into suitable loops.
- 14.2.18.2.1 Normally, the ASS's connected to the various loops will derive power supply from the respective loop only. However, in an Emergency situation, when one of the RSS is totally out-of-service and consequently the loop connected to this RSS is in itself not able to derive power from the RSS, it would be necessary to resort to linking of the loops. When this is required to be done, the linking circuit breakers which are provided for this purpose are closed in a sequence so as to ensure that the two loops are not linked when both loops are live. Suitable interlocking is provided for this purpose.
- 14.2.18.2.2 All interlocking as per approved scheme shall be incorporated.
- 14.2.18.3 33 kV Network Inter-loop Interlocking
- 14.2.18.3.1 When potential transformer of a consecutive loop is showing voltage, extending power from one loop to other should not be possible. This feature shall also be available on SCADA.
- 14.2.18.4 Interlocking In Remote Control Mode
- 14.2.18.4.1 In remote control mode it shall be possible to operate 33 kV switchgear without any mechanical interlocking. This shall be possible through the medium of the remote/local switch when in remote position.
- 14.2.18.4.2 The SCADA software shall authorize closing / opening sequence in such a way that paralleling of 33 kV supplies is not possible in any circumstances.
- 14.2.18.5 Interlocking In Local Control Mode
- 14.2.18.5.1 In local control mode it shall be possible to operate 33 kV switchgear with a mechanical interlocking. This shall be possible through the medium of the remote/local knob when in local position.
- 14.2.18.5.2 The mechanical interlocking shall be designed in such a way that paralleling of 33 kV supplies is not possible in any circumstances.
- 14.2.18.6 Earthing Interlocking
- 14.2.18.6.1 A mechanical interlocking linkage shall be built in to prevent the grounding switch being closed if the ring CB is closed. Nonetheless, it shall be possible to operate the grounding switch with the compartment door open, but it shall be impossible to close the ring interrupter when the grounding switch is closed.
- 14.2.18.6.2 On the other hand, an electrical interlocking shall forbid the earthing isolator closing until the motorized interrupter at the other extremity of the same cable of the nearest ASS is locked in open position.
- 14.2.18.7 Local Interlocking
- 14.2.18.7.1 Each 33 kV board shall include a non-return interlocking system, formed by security locks/castle lock & key arrangement, to allow safe inspection of the transformer.

14.2.18.7.2 This interlocking system shall make it possible to open a main LV circuit breaker (in others' scope) and lock it open and unplugged before closing the protection bay ground isolating switch. Once this switch has closed, it shall be possible to open the door of the transformer bay.

14.2.18.7.3 All 33 kV cable coupling bays shall include systems to interlock interrupters and grounding isolators to make it possible to work on a bay without cutting the main 33 kV cable.

14.2.18.7.4 High-security locks shall form these interlocks.
Above mentioned interlocks are the minimum interlocks required but its not exhaustive.

14.2.19 PROTECTION SYSTEM

14.2.19.1 The numerical type protection relays for the protection of incomers, couplers and transformer feeders shall be normally mounted on the panel. A separate panel with complete metering and protection equipment shall also be acceptable subject to availability of suitable space in the room.

14.2.19.2 Protection System Function

14.2.19.2.1 The function of the protection system is mainly (a) to isolate the affected portion as quickly and as expeditiously as possible while maintaining normal supply to the rest and (b) to provide alternative circuits with automatic changeover wherever applicable to minimize the extent and duration of power supply outage.

14.2.19.2.2 The Contractor shall prepare a comprehensive protection scheme and protection relay settings and submit to the Employer for approval. The Contractor shall provide proper relay coordination to ensure the following:-

14.2.19.2.3 Selectivity

Protection will be arranged in zones, which will cover the entire power system, leaving no part unprotected. When a fault occurs, the protection will trip only the nearest circuit breaker. The discrimination shall be achieved by two general methods

- Unit protection system
- Time graded system

14.2.19.2.4 Stability

Stability of the protection system refers to the ability of the system to remain inert to all load conditions and faults external to relevant zone.

14.2.19.2.5 Speed

The function of protection system is to isolate faults from the rest of the power system in a time as short as possible. The object is to safeguard continuity of supply by isolating each fault before it leads to total collapse of the system with widespread damage and total loss of power supply.

14.2.19.2.6 Sensitivity

The protective system is said to be sensitive if the primary operating current is low. Sensitivity of the protective system will be such that it will be able to sense and operate at minimum fault current.

14.2.19.2.7 Reliability

A system shall be not properly designed and managed if it is not adequately protected by a reliable protection system. Reliability will be enhanced by providing primary and backup protections.

14.2.19.3 Protection Relay Features

14.2.19.3.1 The protection relays shall comply to IEC 60255. CT secondary terminals shall be shorted automatically when the relay is withdrawn. The relays comprising of PCU (Protection and control unit) shall be in full compatibility with the RTU (remote terminal unit) of SCADA and shall be capable of providing single point monitoring, control, logging and protection for the system. Main and backup protection relay shall be separate.

14.2.19.3.2 Protection devices (numeric protective relay, PCU) shall be built up with modular concept. All protective relays shall be in draw out or plug-in type/modular cases with proper testing facilities. The relays shall operate at control voltage of 110 V DC.

14.2.19.3.3 All AC operated relays shall be suitable for operation at 50 Hz. AC Voltage operated relays shall be suitable for 110 Volts VT secondary and current operated relays for 1 amp CT secondary. All DC operated relays and timers shall be designed for the DC voltage specified, and shall operate satisfactorily between 80% and 110% of rated voltage. Voltage operated relays shall have adequate thermal capacity for continuous operation.

14.2.19.3.4 The protective relays shall be suitable for efficient and reliable operation of the protection scheme described in the specification. Necessary auxiliary relays and timers required for interlocking schemes for multiplying of contacts suiting contact duties of protective relays and monitoring of control supplies and circuits, lockout relay monitoring circuits etc. also required for the complete protection schemes described in the specification shall be provided. All protective relays shall be provided with at least two pairs of potential free isolated output contacts. Auxiliary relays and timers shall have pairs of contacts as required to complete the scheme; contacts shall be silver faced with spring action. Relay cases shall have adequate number of terminals for making potential free external connections to the relay coils and contacts, including spare contacts.

14.2.19.3.5 All protective relays, auxiliary relays and timers except the lock out relays and interlocking relays specified shall be provided with self-reset type contacts. All protective relays and timers shall be provided with externally hand reset positive action operation indicators with inscription .All protective relays which do not have built-in hand-reset operation indicators shall have additional auxiliary relays with operating indicators (Flag relays) for this purpose. Similarly, separate operating indicator (auxiliary relays) shall also be provided in the trip circuits of protections located outside the board such as Buchholz relays, oil and winding temperature protection, sudden pressure devices, fire protection etc.

14.2.19.3.6 Timers shall be of solid state type. Time delay in terms of milliseconds obtained by the external capacitor resistor combination shall be avoided.

Breaker shall have the provision of two individual trip circuit with individual MCB and same shall be reported to SCADA for the monitoring purpose.

14.2.19.3.7 The relays shall include the tools for fault diagnostics. These tools shall have stored records for faults, events and disturbance. Disturbance shall be recorded for at least 5 sec. Faults and events shall be stored with resolution of 1 ms. Relays shall be capable of storing minimum of 100 disturbance records and 1024 events with overflow.

- 14.2.19.3.8 Security measures shall be built in to gain access to vital data and functions. No security measures shall be required for access to system currents and voltages.
- 14.2.19.3.9 The Contractor shall furnish detailed proposal of batteries preferably in the Electrical Erasable Programmable Read Only Memory (EEPROM). This is to allow PCU settings to be changed in the foreground without affecting the actual operating values in the background.
- 14.2.19.3.10 Where PCUs are required to trip circuit breakers, actuate signals or perform control duties, PCUs shall be designed to avoid inadvertent or simultaneous switching operations and shall give precedence to protective functions required due to unfavourable conditions, e.g. short circuit, internal faults, power supply failure, voltage fluctuation, etc.
- 14.2.19.3.11 Provision shall be made for easy isolation of trip circuits of each relay for the purpose of testing and maintenance by means of RTB (relay Test Block).
- 14.2.19.3.12 Visual display or indication shall be provided for the operator to read out the setting of functional parameters and annunciations. In the event of a fault, all information relating to the fault shall be captured and stored in the PCU. The PCU shall have optical LED indicators to display any abnormal conditions. The memories of the LEDs shall be safeguarded against supply voltage failure. The optical indicators shall be able to be reset by following means.
- e) Locally by operating the reset button on the PCU.
 - f) Remote by energizing the remote reset input at RCC.
 - g) Automatically on occurrence of a few pick-up signals.
 - h) The relay should have USB/RJ 45 port for local communication with Laptop and RJ45 ports (with redundant port) to communicate on native IEC 61850 protocol for future integration. No protocol convertors shall be acceptable. Should have in built MIMIC display SLD Control. Should be provided with free software for programming and analyzing the disturbance records.
- 14.2.19.4 Protection Relay Specification
- 14.2.19.4.1 The Protective relays shall be complied to IEC 60255 or equivalent latest.
- 14.2.19.4.2 Due to the consequent interference level, protection equipment shall present a sufficient level of immunity defined by the following standards:
- IEC 61000.4-2 Class 3,
 - IEC 61000.4-4 Class 4,
 - IEC 61000.4-5 Class 3.
- 14.2.19.4.3 Such criteria shall be obtained by using either numerical type relays or specific PLC cards.
- 14.2.19.4.4 All protection relay modules shall comply in accordance with the following IEC test requirements:
- h) Dielectric test voltage (IEC 60255-5) 2.0 kV, 50 Hz, 1 min
 - i) Impulse test voltage (IEC 60255-5) 5 kV, 1.2/50 ms, 0.5 j
 - j) High Frequency disturbance test (IEC 60255-22-I Class III)
 - Common Mode 2.5 kV, 1 MHz, 2 s
 - Differential mode 1.0 kV, 1 MHz, 2s
 - k) Electrostatic discharge test (IEC 60255-22-2 & IEC 801-2 Class IV)
 - Air Discharge 15 kV
 - Contact discharge 8 kV
 - l) Fast transient (IEC 60255-22-4 Class IV)
 - Power supply inputs 4 kV

- | | | |
|----|--|---------|
| | - Other inputs | 2 kV |
| m) | Magnetic field (IEC 61000-4-8) | 100 A/m |
| n) | Electromagnetic field test (IEC 801-3 Class III) 10 V/m 50 kHz to 1000 MHz | |
- 14.2.19.4.5 The protective relay modules shall be microprocessor based with continuous monitoring and self-diagnostic features to identify the modules or components. The protective scheme shall be so designed that the system remains stable during switching operation and other disturbances.
- 14.2.19.4.6 In the event of a system fault, the protection module shall be able to record values of current and voltage at a scan frequency no lower than 1 kHz over a time window of at least 1 second before the event to 1 second after the event with time stamping. The fault data shall be captured and recorded and shall be downloaded in the OCC for fault analysis.
- 14.2.19.4.7 Safety is ensured by the means of Cyclic self-test ensuring general supervision on software of equipment. In case of fault, a watchdog is activated. All of inputs are insulated in galvanic and capacitive view and complemented.
- 14.2.19.4.8 The individual protection relay module within the PCU shall continuously monitor the DC trip supply for the circuit breaker.
- 14.2.19.5 Protections for ASS Switchgear
- 14.2.19.5.1 Fault on a 33 kV Incoming cable
- 14.2.19.5.2 A fault may occur between phases on the 33 KV cables or on the bus bars in the boards. In either case, the main supply circuit breaker (JB feeding auxiliary network) on the 33 kV cable from the supplying RSS. To locate and isolate the fault, a pilot wire differential relay installed on each incoming/outgoing 33 kV boards, of each ASS will send to the OCC an indication that it detects & isolate a fault. This will be seen on the screen of the OCC equipment and the fault could be located & also isolated by tripping of respective circuit breaker (CB). In addition, the Over current & earth fault protection provided on the ring main CBs shall work as a backup to pilot wire protection. Pilot wire differential relay will be a separate unit independent of OC & EF Relay unit. With these indications the operator will be able to take the necessary measure to isolate the faulty section and to reenergize the healthy part of the network.
- 14.2.19.5.3 Fault on a Transformer 33kV Supply
- 14.2.19.5.3.1 A short-circuit inside the transformer, or in the transformer protection line or a short-circuit insufficiently isolated by the transformer downstream LV protection shall be detected with selection by the transformer breaker (JC) protection and it shall trip the respective CB (JC). Additionally, for underground section transformer breaker shall be equipped with differential & restricted earth fault relay. LKE(02)-01 contractor shall interface with E&M contractor for matching necessary CT characteristics for installing the required protection functions.
- 14.2.19.5.4 Grounding Fault on ASS 33kV ring cables
- 14.2.19.5.4.1 This fault shall trip the 33kV cable main supply circuit breaker (respective CB) in the RSS.
- 14.2.19.5.5 To achieve the protection requirements specified herein, the switchgear provided for auxiliary substations shall incorporate following minimum protections:
- 14.2.19.5.6 Protections on Auxiliary Transformer feeder circuit breaker shall consist of:

- a) 50: Instantaneous over current protection
- b) 51: Time delayed over current protection
- c) 50 N: Instantaneous earth fault protection (zero sequence)
- d) 51 N: Time delayed earth fault protection (zero sequence)
- e) 86: Master trip relay
- f) 74: Trip circuit supervision relay
- g) 33: Door Interlock
- h) 49A: Temperature Alarm, first threshold
- i) 49T: Temperature tripping, second threshold
- j) 87T: Differential Protection (for greater than equal to 2000 kVA only)
- k) 64R: REF Protection (for greater than equal to 2000 kVA only)

14.2.19.5.7 The protection on 33 kV incoming & outgoing feeder to/from other station/corridor

- a) 50: Instantaneous over current protection
- b) 51: Time delayed over current protection
- c) 50 N: Instantaneous earth fault protection (zero sequence)
- d) 51 N: Time delayed earth fault protection (zero sequence)
- e) 27: Under voltage relay
- f) 67: Directional Overcurrent
- g) 67N: Directional Earth Fault protection
- h) 59: Over voltage
- i) 87L: Line Differential (Pilot Wire)

14.2.20 METERING

14.2.20.1 Energy meter for both auxiliary and traction transformers at each ASS and TSS. The metering system required is as follows:

- a) Digital ammeters (to read the value of current delivered to each transformer)
- b) Digital voltmeters (to read the value of primary voltage of each transformer, whether on-load or as hot standby)
- c) Energy Meter/Multi Function Meter with metering accuracy class 0.2S shall be provided in each transformer feeder including incomer feeder at RSS 33 kV Switchgear) as per the latest guideline of electricity tariff rules and regulation and compatible with redundant communication protocol of IEC 61850, RS485 (Modbus) and IEC 103 etc. for SCADA Integration with redundant fibre/RS485 Ports

14.2.20.2 The Contractor shall submit proposals regarding range and other technical details of ammeter, voltmeters and energy meters for approval by the Engineer.

14.2.20.3 SCADA compatibility of all the protection, monitoring and metering equipment shall be ensured by the Contractor. The Protection relays, MFM/Energy meter shall be compatible and Support for the latest standards of IEC 61850, RS485 (Modbus) and IEC 103 etc., protocol for substation automation. All devices must support redundant communication channels to enhance reliability.

14.2.21 GTP FOR 33 KV TRIPLE POLE GIS VACUUM CIRCUIT BREAKER

14.2.21.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

- 14.2.21.2 The list indicated below is expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 14.8: GTP for 33 kV Vacuum CB & Complete Switchgear (GIS)

S. No.	Description	Unit	Manufacturer's Data
A	GENERAL		
1	Manufacturer		
2	Place of manufacture		
3	Standards		
B	CUBICLE (FIXED PART)		
1	Class		
2	Rated insulation voltage	kV	
3	Rated operating voltage	kV	
4	Rated frequency	Hz	
5	Rated short time duration power frequency withstand voltage	kV rms	
6	Rated lightning impulse withstand voltage	kV peak	
7	Cubicle rated current		
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
8	Busbar material		
9	Phase barrier for busbar		
10	Cast resin shrouds for busbar joints		
11	Busbar connection		
12	Busbar support spacing	mm	
13	Bar set rated continuous current		
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
14	Allowable overcurrent for 1 second	kA rms	
15	Instantaneous overcurrent	kA peak	
16	Number of flip-flop contacts for circuit-breaker plugging-in and plugging-out monitoring	Minimum	
17	Number of flip-flop contact for earthing isolator open/closed position monitoring	minimum	
18	Number of flip-flop contacts for isolator open/closed position monitoring	minimum	
19	Maximum dimensions of the cubicle		
a.	Width	mm	
b.	Depth	mm	
c.	Height	mm	
d.	Depth with circuit-breaker plugged-out	mm	
20	Protection degree		
21	Earthing isolator making capacity	kA	
22	Overall dimension drawing number		
C	CIRCUIT-BREAKER (MOVABLE PART)		
1	Type		

S. No.	Description	Unit	Manufacturer's Data
2	Rated insulation voltage	kV	
3	Rated operating voltage	kV	
4	Rated frequency	Hz	
5	Rated short time duration power frequency withstand voltage	kV rms	
6	Rated lightning impulse withstand voltage	kV peak	
7	Rated current	A	
a.	Aux. Transformer CB	A	
b.	Other CBs	A	
8	Allowable overcurrent for 1 second	kA rms	
9	Instantaneous overcurrent	kA peak	
10	Breaking capacity	kA rms	
11	Making capacity	kA peak	
12	Breaking mode		
13	Opening time	ms	
14	Breaking time	ms	
15	Closing time	ms	
16	Rated operating cycle		
17	Breaking capacity of cable at no load	A	
18	Number of auxiliary contact for open/closed position of the circuit-breaker	O/O O/C	
19	Auxiliary supply voltage	V dc	
20	Supply voltage for motor drive circuits	V dc	
21	Allowable variation range of supply voltage	%	
22	Power consumption of auxiliary	VA	
23	Coils consumption		
a.	engagement coil	A	
b.	release coil	A	
24	Consumption of arming motor	A	
25	Maximum noise level during opening and closing actuation	dB	
26	Degree of protection for auxiliary circuit		
27	Trolley design (Shall be suitable for direct withdrawal on Floor)		
D	CURRENT TRANSFORMER		
1	Type		
2	Manufacturer		
3	Place of manufacture		
4	Standards		
5	Rated insulation voltage	kV	
6	Operating voltage	kV	
7	Rated frequency	Hz	
8	Rated power frequency short duration withstand voltage	kV	
9	Rated lightning impulse withstand voltage	kV	
10	Actual transformation ratio		
11	Protection secondary		
a.	Accuracy class		

S. No.	Description	Unit	Manufacturer's Data
b.	Rated output	VA	
12	Measuring secondary		
a.	Accuracy class		
b.	Rated output	VA	
13	Short-circuit current allowable for 1 seconds	kA	
14	Permanent operation without danger	In	
15	Overheating	In	
16	Overcurrent class		
17	Temperature rise over 40 °C ambient	°C	
E	VOLTAGE TRANSFORMER		
1	Type		
2	Manufacturer		
3	Place of manufacture		
4	Standards		
5	Primary insulation voltage	kV	
6	Operating voltage	kV	
7	Rated frequency	Hz	
8	Rated short-time duration power frequency withstand voltage	kV	
9	Rated lightning impulse withstand voltage	kV	
10	Actual transformation ratio - Primary winding - secondary windings	kV V	
11	Accuracy class Protection core Measuring core		
12	Rated output (minimum) Protection core Measuring core (As required for different purposes to be indicated. The value provided in 'required' column is indicative only)	VA VA	
13	Secondary winding type and insulation		
14	Secondary winding voltage grade	V	
15	Secondary winding conductor material		
16	Earth bus		
F	Accessories		
1	Earthing equipment		
G	Finish of Switchgear		
1	Inside and outside the panel		
H	Internal wiring of panel		
1	Elevated / at-grade sections		
2	Underground sections		
I	NUMERICAL RELAYS		
1	Manufacturer		

S. No.	Description	Unit	Manufacturer's Data
2	Place of manufacture		
3	Relevant Standards		
4	Protections		
5	Communication Protocols		
6	Auxiliary Supply	V dc	

14.2.22 TEST SHEET FOR 33 KV TRIPLE POLE VCB (GIS)**Table 14.9: Test Sheet for 33 kV Vacuum CB**

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
1) Breaker					
Dielectric tests	X				
Radio interference voltage tests	X				
Measurement of the resistance of the main circuit	X				
Temperature-rise tests	X				
Short-time withstand current and peak withstand current tests	X				
EMC tests	X				
Mechanical operation test at ambient temperature	X				
Short-circuit current making and breaking tests	X				
Capacitive current switching tests (cable charging)	X				
Switching of shunt reactors and motors	X	X	X		
Dielectric test		X	X		
Dielectric test on auxiliary and control circuits		X	X		
Tightness test	X	X	X	X	
Design and visual checks		X	X		
Mechanical operating tests		X	X		
Functional test			X		
Lightning and switching impulse test	X	X	X		
HV Test/Power frequency (Main Circuit)	X	X	X	X	
HV Test at Power Frequency (Auxiliary Circuit)	X	X	X	X	
Partial Discharge Test	X	X	X		
Residual Voltage Test (Lightning and Switching Impulses)	X	X			
Long term stability under continuous operation	X	X			
Repetitive Charge transfer withstand	X	X			
Heat dissipation behaviour verification	X				

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Operating Duty Test	X	X	X		
Power Frequency voltage versus time	X	X			
Short-Circuit Tests	X				
Internal Grading Component	X				
(Chopped) Lightning impulse voltage withstand test on primary terminals	X	X	X	X	
Accuracy test	X	X	X	X	
CRM, Breaker opening and closing time				X	
Tripping/Closing Coil Resistance Measurement				X	
Spring charging motor Current measurement				X	
Mechanical Impact test	X	X	X		
Transmitted Overvoltage test	X				
Measurement of Capacitance and Dielectric dissipation factor	X	X	X		
Pressure Test		X	X	X	
2) Complete Switchgear					
Dielectric tests	X				
Measurement of resistance of circuits	X			X	
Temperature rise test	X				
Short-time withstand current and peak withstand current tests	X				
Internal faults arcing effects	X				
Verification of protection	X				
Electromagnetic compatibility test (EMC)	X				
Additional tests on auxiliary and control circuits	X				
Verification of making and breaking capacities	X				
Mechanical operation tests	X				
Dielectric tests (IR Test)		X	X	X	
Tightness test		X	X	X	
Design and visual checks		X	X	X	
Mechanical operating tests		X	X	X	
Functional test		X	X	X	
Primary current Injection		X	X		
Relays settings and meter calibration		X	X	X	
Protection and Interlocking test		X	X	X	
Instrumentation & relays calibration				X	
SF6 Gas Pressure Test			X	X	
Corrosion Test	X				
Fire Hazard test	X				

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Auxiliary & Control Circuit checks of Individual Drives		X	X	X	
2) MOVABLE PART					
Temperature rise	X				
Lightning impulse withstand voltage test	X				
Partial discharge	X				
Over-voltage	X				
Short circuit Current making & breaking capacity	X				
Magnetising & small inductive current switching	X				
Peaks & short time current withstand	X				
Aux. circuits dielectric withstand		X	X		
Main circuits resistance value		X	X		
Withstand voltage at 50 Hz		X	X		
Mechanical operations at rated, max. & min voltage		X	X	X	
Functioning times		X	X	X	
Interlocking		X	X	X	
Visual inspection		X	X	X	
Contact Resistance		X	X	X	
SF6 Gas Pressure Test			X	X	
3) CURRENT TRANSFORMER					
Temperature rise	X				
Lightning impulse withstand voltage	X				
Short circuit withstand	X				
Primary windings power frequency withstand voltage test		X	X		
Secondary windings power frequency withstand voltage test		X	X		
Between section power frequency withstand voltage test		X	X		
Transformer ratio		X	X	X	
Terminal marking		X	X	X	
Visual inspection		X	X	X	
Exchangeability of similar devices		X	X		
Insulation Resistance Test				X	
Continuity Test			X	X	
Secondary Winding Resistance Test				X	
Knee Point Voltage Test				X	
4) VOLTAGE TRANSFORMER					

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Temperature rise	X				
Lightning impulse withstand voltage	X				
Short circuit withstand	X				
Primary windings power frequency withstand voltage test		X	X		
Secondary windings power frequency withstand voltage test		X	X		
Between section power frequency withstand voltage test		X	X		
Transformer ratio		X	X	X	
Terminal marking		X	X	X	
Visual inspection		X	X	X	
Exchangeability of similar devices		X	X		
Insulation Resistance Test				X	
Continuity Test			X	X	
Secondary Winding Resistance Test				X	

14.3 33 kV/415 V AUXILIARY TRANSFORMER

14.3.1 SCOPE

14.3.1.1 This Specification applies to 33 kV/415 V dry type auxiliary transformer to be used at auxiliary substations for feeding auxiliary supply at 415 V. The Scope of Work includes Design, supply, installation, testing and commissioning of auxiliary transformer along with accessories.

14.3.1.2 The transformer offered shall be complete in all respects with all parts and accessories necessary for their efficient operation in sub-stations. All such parts & accessories shall be deemed to be within the Scope of this Specification whether specifically mentioned or not.

14.3.2 SPECIFICATIONS

14.3.2.1 The transformers shall unless otherwise specified, conform to IS 11171(to be read in conjunction with IS 2026), IS 2026, IEC 60076-11, or latest and IE Rules , applied in the manner altered, amended or supplemented by this specification, wherever applicable. In all cases, latest revision to these specifications referred to above shall apply.

14.3.3 RATINGS

14.3.3.1 The transformers shall be designed for the expected rating and other particulars indicated in Table 14.10:

Table 14.10: 33 kV/415 V Auxiliary Transformer Rating & GTP

S.NO	Description	500 kVA	2000 kVA
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S.NO	Description	500 kVA	2000 kVA
1.	Type	3-Φ Dry Type for indoor installation	3-Φ Dry Type for indoor installation
2.	Relevant Specification	IEC 60076, IS 2026, IS 11171	IEC 60076, IS 2026, IS 11171
3.	Insulation type	Cast resin	Cast resin
4.	Configuration/vector group	Dyn11	Dyn11
5.	Primary rated highest voltage	36 kV	36 kV
6.	Primary operating voltage	33 kV	33 kV
7.	Secondary rated voltage	415 V/230 V	415 V/230 V
8.	Secondary system highest voltage	460 V	460 V
9.	Rated short duration power frequency withstand voltage for primary winding	70 kV	70 kV
10.	Rated lightning impulse withstand voltage for primary winding	170 kV	170 kV
11.	Rated short duration power frequency withstand voltage for secondary winding	3 kV	3 kV
12.	Duty	Continuous	Continuous
13.	Winding material	Aluminium	Aluminium
14.	Secondary Voltage at off load with 33 kV primary	415 V	415 V
15.	Secondary Voltage at full load & PF 0.8 lag	390 V	390 V
16.	Insulation rated voltage (primary side)	36 kV	36 kV
17.	Power frequency withstand level	70 kV	70 kV
18.	Surge withstand voltage (BIL)	170 kV	170 kV
19.	Short circuit rating for primary side (at all tapping)	25kA for 3 seconds	25kA for 3 seconds
20.	Short circuit rating for secondary side (at all tapping)	As per IEC 60076-5	As per IEC 60076-5
21.	Secondary Neutral earthing	Solidly earthed	Solidly earthed
22.	Class of insulation	HV :- F LV :- H	HV :- F LV :- H
23.	Cooling	AN	AN
24.	Tap changer	Off load	Off load
25.	Tap positions	-5%, -2.5%, 0, 2.5%, 5%	-5%, -2.5%, 0, 2.5%, 5%
26.	Overload rating	As per IEC 60076-12	As per IEC 60076-12
27.	% age impedance	4%	6.25%
28.	Max noise level at 1.5m	68 db	68 db
29.	Enclosure IP	Min. 31	Min. 31

14.3.3.2 Transformer Losses

- 14.3.3.2.1 The transformers shall be designed for minimum losses and it shall be within the maximum limit as described.

SN	Transformer rating	Max Iron Losses (in kW at ambient temperature)	Max. Load Losses (in kW at 95°C)
1	500 kVA	1.73	4.95
2	2000 kVA	4.00	15.3

14.3.3.2.2 DELETED

14.3.3.2.3 DELETED

14.3.4 CONSTRUCTION FEATURES

14.3.4.1 The transformer shall be designed for all cable entries from the top/bottom for at grade/elevated station/UG station and Depot AMS/ASS+TSS,

14.3.4.2 The primary and the secondary windings shall be capable of withstanding a symmetrical three-phase short-circuit regardless of the tapping selected.

14.3.4.3 Core

14.3.4.3.1 The core shall be built up of low-loss oriented-grain silicon steel sheet cold rolled conforming to IS 3024-1965 or relevant Indian standard Specification. Transformer shall be double wound, core type with low loss, non-ageing, high permeability PRIME GRADE, CRGO with M4 Grade or Better, perfectly insulated and clamped to minimize noise and vibrations. Followings should be Mandatory for any manufacturer/Contractor:

- a. All laminations used for stacking the core shall be levelled, free from waves, deformations, scoring of core plating insulation or signs of rust. The core shall be electrically connected to the core clamping frame for providing earthing to drain off any electrostatic potential that may be built up.
- b. Stage inspection of the core shall be done at manufacturer's premises & inspection call shall be given with following documents.
 - i. Invoice of the supplier
 - ii. Packing list
 - iii. Bill of landing & Bill of Entry certificate by customs
 - iv. The insulation structure for the core to bolts and core to clamp plates shall be such as to withstand a voltage of 2000 V for one minute.

14.3.4.3.2 Each of the core bolts and parts of the core clamping frame work shall be insulated from the laminations and tested after completion of the core assembly to withstand an AC pressure of 2kV AC rms for duration of one minute. All parts of the core shall be of robust capable of withstanding shocks to which they may be subjected to during lifting, transportation, installation and service.

14.3.4.4 Winding

- 14.3.4.4.1 The transformer winding shall be made of aluminium. The HV winding shall be designed so as to facilitate better heat dissipation and withstand mechanical forces. The windings and connectors of the transformer shall be brazed/crimping/bolting and suitably designed, so as to withstand shock which may occur during transport or due to switching and other transient conditions during services. The aluminium terminal bars shall be provided as same as of winding material. The transformer shall be mounted on bi-directional type flanged wheels for forward and across wise movement.
- 14.3.4.5 Tap Changer
- 14.3.4.5.1 The transformer shall be supplied with externally operated off load tap links for varying its effective transformation ratio covering the specified voltage range as indicated in Table 14.10 above. The transformer shall be of the rated kVA without exceeding the rated temperature on any tapping at a voltage of $\pm 2.5\%$ of the rated voltage of that tapping. Each tap shall also be capable of withstanding a voltage of 10% above the rated voltage of the tap.
- 14.3.4.6 Transformer Cubicle
- 14.3.4.6.1 The transformers may be supplied in a cubicle with enclosure having a degree of protection of not less than IP 31 and without any MV & LV portions exposed. The door shall be provided with a mechanical system interlock, to ensure that it is possible to open the door only when the protection circuit breakers on the HV side as well as LV side of the transformer are in 'Open' position. The cubicle shall provide protection against direct contact with the power transformer. It shall include connections for the MV lines from the protection bay and connections for the low voltage circuit. The temperature monitoring device as explained in Clause 14.3.5.2.1 below shall be located on the upper part of the secondary winding.
- 14.3.4.6.2 Two doors containing two windows to allow observation of the transformer accessories shall be provided in the front face. These doors shall be closed and locked to prevent access to the transformer while either the MV or the LV side is live. Consequently, ventilation louvers shall be installed at the bottom of the front doors and in the bay rear panel and roof. A metal sheet shall be installed at 10 to 15 cm from the top grating to provide protection against any falling water. The cable arrangement shall facilitate the exchange of either of the two transformers without any difficulty; i.e. the cables shall be laid along each side and connected to the transformer in such a way that it will not obstruct the passage for removal of any of the transformer during service.
- 14.3.4.6.3 Proper clearances shall be maintained on both HV & LV side between Transformer & Transformer Cubicles.
- 14.3.4.7 Terminal Arrangements
- 14.3.4.7.1 The terminal arrangement for high voltage and low voltage side shall be suitable for required size of cables/bus duct (as applicable) with FRLS/FRLSOH outer sheath. Suitable arrangements shall be available for cable terminations so that the cable/bus duct weight doesn't come on the terminals. The terminal on MV & LV shall be suitable for receiving XLPE cable end termination/bus duct with cable gland and anodized hard wire for the cable termination. The terminals on the primary side shall be of the 36 kV type.
- 14.3.4.8 Fittings & Accessories
- 14.3.4.8.1 A winding temperature indicator with alarm and trip arrangement shall be provided. The device shall have two thresholds (alarm and tripping). Sensors shall be located on the upper part of the secondary windings. Each phase of LV winding should have 2 PT-100 sensors.

- 14.3.4.8.2 Following accessories shall be provided:
- a) Installed on rollers with locking arrangement after installation
 - b) Lifting rings
 - c) Nameplate-2 Nos.
 - d) Grounding terminal
 - e) Clamps shall be provided inside the enclosure for formation of horizontal & vertical earthing ring
 - f) Limit Switches 2Nos for enclosure Doors
 - g) Danger Plates as per safety rules

14.3.4.9 Painting

- 14.3.4.9.1 All steel surfaces shall be painted which shall be suitable for polluted atmosphere and has to comply with ICE-60072-2-5, ISO 12944 clause C2 standard. After baring of all metal surface an Intel two coat of rust proofing and anti-corrosive paint shall be applied then they will be covered with three coated of glossy oil & weather resistance non fading paint shall be validated through scratch test after temperature rise test. The total thickness should not be less than 60 µm and withstand 120°C.

14.3.4.10 Nuts & Bolts

- 14.3.4.10.1 The threads and hexagons of all nuts, bolts and stud shall confirm to relevant IS or BS. No bolt or stud shall project through its nut(s) more than 6mm (or) four threads, except when otherwise approved for terminating stud/bolts. If bolts and nuts are so placed that they are inaccessible by means of ordinary spanners. All terminals should be provided with suitable cadmium plated and passivated high tensile steel hard wires facilitate cables termination.

14.3.5 SAFETY FEATURES

- 14.3.5.1 The design shall incorporate / provide full perception for safety of all those working personal associated with maintenance of transformers. The following safety features shall be provided as a minimum.

14.3.5.2 Temperature Protection

- 14.3.5.2.1 Transformer shall be fitted with a temperature indication and protection system that allows winding temperature to be monitored. This shall consist of two sensors placed on each low voltage winding one for spare (future) and one to connect for temp. Monitoring and protection device. It shall have two stage alarm & trip features. At stage 1 it shall initiate an alarm. At stage 2 it shall trip the Circuit Breaker. The device shall consist of alarm and trip contacts communicated to with server. The device shall be suitable for communication with OCC through SCADA.

14.3.5.3 Fire Detection & Suppression System

- 14.3.5.3.1 The cubicles shall be protected against fire by means of automatic fire detector and extinguisher system with linear fire detection tube based clean agent direct gas flooding system. The detection has to be done by the linear heat detection tube which will be routed inside the panel as per the design calculation. The tube shall be double layered & made of Hi-tech Polymer either Fire Detect, Fire Trace or equivalent. The system shall utilize unique flexible tubing that shall be attached to the top of the container valve. This tubing shall be pressurized with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C), is temperature sensitive and shall act as a continuous linear thermal detector that shall rupture upon flame impingement. Once the detection tubing is ruptured, forming a nozzle at the rupture point, it shall allow the Clean Agent through the nozzle into the protected area. The clean agent offered should be as designated in NFPA 2001 [Section A.5.5.1(B)] and ISO 14520 Clean Agent Standards. Its 'ASHRAE' nomenclature is (FK5-1-12 or its equivalent (Novec 1230)). Gas should have lowest Global Warming potential. The quantity of clean agent required should be calculated as per NFPA 2001 and BIS standards. Clean agent container shall be designed, fabricated, certified with stamp on the containers in accordance with the requirements of NFPA. Containers shall be standard model and size for ease of replacement and addition. Fill containers with required Clean Agent (FK5-1-12 or its equivalent (Novec 1230)). Pressurise with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C). Container/cylinders shall have PESO approval /Govt. Approved Lab. A separate and stand alone gas cylinder with protection system shall be provided for a group of panels.
- 14.3.5.4 The transformer cubicle door shall be provided with a mechanical system interlock, to ensure that it is possible to open the door only when the protection circuit breakers on the HV side as well as LV side of the transformer are in 'Open' positions. Fire protection system to be integrated to E&M in elevated or BMS system in U/G stations.
- 14.3.5.5 Enclosure door interlock with castle key shall be provided.
- 14.3.5.6 Surge Arrestors/Suppressors shall be installed in the transformers as per requirement to arrest the surges in the system as per Employer's approval. System shall be designed to ensure protection from surges and surge performance analysis need to be submitted.
- 14.3.6** Packaging & Transportation
- 14.3.6.1 Shall be as per ERGS/Employer's Requirements.
- 14.3.7** **GTP FOR 33 kV/415 V AUXILIARY TRANSFORMER**
- 14.3.7.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 14.3.7.2 The list indicated below is expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 14.11: 33 KV/415V AUXILIARY TRANSFORMER GTP

S.No.	Description	Unit	Manufacturer's Data
1	Type		
2	Name of the manufacturer		
3	Country of manufacture		
4	Port of embarkation		

S.No.	Description	Unit	Manufacturer's Data
5	Manufacturer drawing reference		
6	Relevant Specification		
7	Insulation type		
8	Number of phases		
9	Frequency	Hz	
10	Vector group		
11	Nominal rated power	kVA	
12	Cooling Mode		
13	Primary rated insulation voltage	kV	
14	Primary operating voltage	kV	
15	Secondary system highest voltage	V	
16	Secondary rated operating voltage	V	
17	Rated short duration power frequency withstand voltage for primary winding	kV	
18	Rated lightning impulse withstand voltage for primary winding	kV	
19	Rated short duration power frequency withstand voltage for secondary winding	kV	
20	Rated lightning impulse withstand voltage for secondary winding	kV	
21	Percentage Impedance	%	
22	Voltage setting (off load tap changer)	%	
23	Winding material		
24	Max. efficiency		
25	% loading at maximum efficiency		
26	No load loss at rated voltage (refer to ITT for capitalization of losses)	kW	
27	Copper loss at rated voltage (refer to ITT for capitalization of losses)	kW	
28	Total loss at rated voltage (refer to ITT for capitalization of losses)	kW	
29	Impedance at rated current and frequency	%	
30	Reactance at rated current and frequency	%	
31	Voltage regulation at full load	%	
32	Type of core		
33	Weight		
a.	Core	Kg	
b.	Winding	Kg	
c.	Total	Kg	
34	Dimensions		

S.No.	Description	Unit	Manufacturer's Data
a.	Length	Mm	
b.	Width	Mm	
c.	Height	Mm	
d.	Overall for packages	Mm	
35	Max Noise level	dB	
36	Enclosure housing		

14.3.8**TEST SHEET FOR 33 kV/415 V AUXILIARY TRANSFORMER****Table 14.12: Test Sheet for 33 kV/415 V Auxiliary Transformer as per IS 11171**

INDICATIONS	TYPE of TEST				
	Type*	Routine	Acceptance	On Site	Specials
Temperature rise*	X				
Lightning impulse withstand voltage test*	X				
Separate-source voltage withstand test	X	X	X		
Measurement of winding resistance	X	X	X	X	
Measurement of voltage ration and check of phase displacement	X	X	X	X	
Measurement of no-load loss and current	X	X	X		
Partial Discharge Test	X				
Visual inspection	X	X	X	X	
Phase Displacement	X	X			
Impedance Voltage & Load Loss	X	X	X		
Induced Overvoltage withstand test	X				
Measurement of Sound Level	X		X		X
Short Circuit withstand test	X				
Insulation Resistance Test				X	
Magnetic Balance Test				X	
Turns Ratio			X	X	
Magnetization Current Test				X	
* For these type tests, the contractor could provide a report on similar equipment.					

14.4**110 V DC POWER SUPPLY SYSTEM****14.4.1****GENERAL****14.4.1.1**

The 110 V DC power required for the equipment at the ASS (and TSS), shall be met from the 110 V DC power supply system provided at the ASS (or ASS/TSS room, wherever applicable). Hence there shall be 4 types of systems provided for the 110 V dc power supply system for ASS and ASS/TSS.

- a) Type-1: Designed to cater to the DC power requirement of equipment at elevated stations type with ASS only.
- b) Type-2: Designed to cater to the DC power requirement of equipment at elevated stations type with ASS & TSS.

- c) Type-3: Designed to cater to the DC power requirement of equipment at underground stations type with ASS.
- d) Type-4: Designed to cater to the DC power requirement of equipment at underground stations type with ASS & TSS

14.4.2 SYSTEM DESCRIPTION

14.4.2.1 General Requirements

- 14.4.2.1.1 The equipment supplied shall be highly safe and reliable; it shall be described in detail when submitting the relevant drawings (equipment characteristics, layout plan, protections, monitoring) and it shall be guaranteed to eliminate all risks of incidents which may occur during the change-over operation from one source to the other.
- 14.4.2.1.2 The batteries shall be of insulated pole type and wired in floating voltage mode.
- 14.4.2.1.3 In case of the AC voltage failure, the battery shall immediately and without break replace the charger to ensure permanent power supply to the circuits and controls.
- 14.4.2.1.4 The entire 110 VDC distribution and the batteries shall be isolated from earth; satisfactorily. The overall condition of this isolation shall be monitored permanently by a specific and highly reliable device.
- 14.4.2.1.5 Each battery shall also ensure power to safety lighting as soon as an ac outage occurs.
- 14.4.2.1.6 The fundamental demand on the DC system is that it shall be robust, simple and clearly arranged.
- 14.4.2.1.7 The DC system shall be based on the following principles:
 - a) High selectivity
 - b) Main distribution board located adjacent to the battery room
 - c) No common main fuse for battery
 - d) An installation, which is free from the risk of, short-circuits between the battery and the main distribution board.
- 14.4.2.1.8 The DC system shall be earthed across a high resistance resistor, so that simple earth fault shall not cause tripping of the system.
- 14.4.2.1.9 The DC system shall be designed to allow unloading tests, boost charging and maintenance of each to be carried out during normal operation;
- 14.4.2.1.10 Since the entire system cannot be designed so that a short-circuit will never occur, it shall be provided with circuit protection, these shall provide absolute and safe selectivity, so that tripping is confined to the minimum. Only rapid protection characteristic shall be used.
- 14.4.2.2 Type-1 System (Elevated)
- 14.4.2.2.1 Type 1 system shall consist of 1 battery set and 2 battery chargers. The battery set shall be designed to cater for the full requirement of 110 V DC power of all equipment in the ASS, with 8-hours (480 mins) backup.
- 14.4.2.2.2 The capacity of the battery shall be designed by the Contractor taking into account the permitted voltage tolerance of the individual loads, the power consumption of various loads, the length of time they are in operation and the manner in which they draw power.

- 14.4.2.2.3 The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 hours as required to retain the power supply of the control/monitoring auxiliaries in case of total failure of the AC sources.
- 14.4.2.2.4 The battery capacity selected shall not be less than **180 AH** and charger rating shall not be less than 100 A.
- 14.4.2.2.5 Of the 2 battery chargers in Type-1 System, one shall be in service normally and the other shall act as standby. In the case of failure of the 'In Service' battery charger, the 'standby' battery charger shall come into service through an 'Automatic Changeover' system.
- 14.4.2.3 Type-2 System (Elevated)
- 14.4.2.3.1 Type 2 system shall consist of 1 battery set and 2 battery chargers. The battery set shall be designed to cater to the full requirement of 110 V DC power of all equipment in the ASS/TSS or ASS/TSS (including dead end) as the case may be, with 8-hours backup.
- 14.4.2.3.2 The capacity of the battery shall be designed by the Contractor taking into account the permitted voltage tolerance of the individual loads, the power consumption of various loads, the length of time they are in operation and the manner in which they draw power.
- 14.4.2.3.3 The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 hours as required to retain the power supply of the control and monitoring auxiliaries in case of total failure of the AC sources.
- 14.4.2.3.4 The battery capacity selected shall not be less than **300 AH** and charger rating shall not be less than 100 A.
- 14.4.2.3.5 Of the 2 battery chargers in Type-2 System, one shall be in service normally and the other shall act as standby. In the case of failure of the 'In Service' battery charger, the 'standby' battery charger shall come into service through an 'Automatic Changeover' system.
- Note:** For Depot ASS & TSS, this Type-2 system applies.
- 14.4.2.4 Type-3 System (Underground)
- 14.4.2.4.1 Type 3 system shall consist of 1 battery set and 2 battery chargers. The battery set shall be designed to cater for the full requirement of 110 V DC power of all equipment in the ASS only, with 8-hours (480 mins) backup.
- 14.4.2.4.2 The capacity of the battery shall be designed by the Contractor taking into account the permitted voltage tolerance of the individual loads, the power consumption of various loads, the length of time they are in operation and the manner in which they draw power.
- 14.4.2.4.3 The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 hours as required to retain the power supply of the control/monitoring auxiliaries in case of total failure of the AC sources.
- 14.4.2.4.4 The battery capacity selected shall not be less than **180 AH** and charger rating shall not be less than 100 A.
- 14.4.2.4.5 Of the 2 battery chargers in Type-4 System, one shall be in service normally and the other shall act as standby. In the case of failure of the 'In Service' battery charger, the 'standby' battery charger shall come into service through an 'Automatic Changeover' system.

- 14.4.2.5 Type-4 System (Underground)
- 14.4.2.5.1 Type 4 system shall consist of 1 battery set and 2 battery chargers. The battery set shall be designed to cater to the full requirement of 110 V DC power of all equipment in the ASS cum TSS or ASS cum TSS (including dead end) as the case may be, with 8-hours backup.
- 14.4.2.5.2 The capacity of the battery shall be designed by the Contractor taking into account the permitted voltage tolerance of the individual loads, the power consumption of various loads, the length of time they are in operation and the manner in which they draw power.
- 14.4.2.5.3 The precise capacity of battery shall be determined to ensure total autonomy of the station for 8 hours as required to retain the power supply of the control and monitoring auxiliaries in case of total failure of the AC sources.
- 14.4.2.5.4 The battery capacity selected shall not be less than **300 AH** and charger rating shall not be less than 100 A.
- 14.4.2.5.5 Of the 2 battery chargers in Type-4 System, one shall be in service normally and the other shall act as standby. In the case of failure of the 'In Service' battery charger, the 'standby' battery charger shall come into service through an 'Automatic Changeover' system.
- 14.4.3 BATTERY SPECIFICATION**
- 14.4.3.1 Scope
- 14.4.3.1.1 The Specification applies to stationary Ni-Cd maintenance free batteries for installation at Auxiliary/Traction Substations. The battery shall be complete in all respects with all parts and accessories fitted. All such parts and accessories shall be deemed to be within the Scope of this Specification whether specifically stated or not. The Scope of Work includes design, supply, installation, testing and commissioning of batteries & battery charger along with accessories.
- 14.4.3.2 Specifications
- 14.4.3.2.1 The batteries shall conform to IEC-60623 and IEC 62259 specification latest revision for ultra-low maintenance type battery..
- 14.4.3.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment, proposed by the Contractor, will be given due consideration, provided full particulars with justification thereof are furnished.
- 14.4.3.3 Ratings
- 14.4.3.3.1 The battery set shall be designed to cater for the full requirement of 110 V DC power of all equipment in the station, with a 8-hours backup. The precise capacity of the battery shall be determined by the Contractor to ensure total autonomy of the station for 8 hours as required to retain the power supply of the control/monitoring auxiliaries in case of total failure of the AC sources.
- 14.4.3.3.2 The Contractor shall submit battery sizing calculations for Engineer's approval. The battery shall be designed for the rating and other particulars indicated in Table 14.13;

Table 14.13: Battery

SN	Description	Battery
1	Type	Maintenance free Ni-Cd
2	Minimum Capacity	Type 1: 180 AH (elevated)

SN	Description	Battery
		Type 2: 300 AH (elevated) Type 3: 180 AH (UG) Type 4: 300 AH (UG)
3	Rated voltage	110 V
4	Material container	Translucent polypropylene
5	Backup capacity	8 Hrs

14.4.3.4 Construction Feature

14.4.3.4.1 Lids used with sealed - in - type cells shall be of moulded composition or ebonite with close fitting terminal post outlets and with vent holes suitable for accommodating the vent plugs.

14.4.3.4.2 The batteries shall be of insulated pole type and wired in floating voltage mode.

14.4.3.4.3 Glass / alternate transparent containers shall be sufficiently robust and free from foreign matter.

14.4.3.4.4 The following information shall be indelibly marked on the outside of the cell or battery:

- a) Manufacturer's type and trade name.
- b) Country of manufacture
- c) Electrolyte level (Upper & Lower limits)
- d) Capacity in Ampere Hour

14.4.3.4.5 A suitable two-tier battery stand made of MS with alkali resistant epoxy powder coating to accommodate the battery shall be supplied with each battery set.

14.4.3.4.6 The terminal lugs for each cell shall be clearly distinguishable from the each other as to polarity. Suitable Ni plated inter cell, inter row and inter tier connectors shall be provided to enable jointing on cells. The two terminals from where supply is taken shall be marked red and black for (+) Ve and (-) Ve polarity respectively. Bolts and nuts for connecting the cells shall be SS.

14.4.3.4.7 The battery protection shall be as close as possible to the battery and shall be contained in separate enclosure for negative and positive pole respectively. The enclosure shall be made of insulating material. The connection between the battery and its protection shall consist of single conductor and shall be run in such a manner so that they are protected from physical damage.

14.4.4 BATTERY CHARGER SPECIFICATION

14.4.4.1 Scope

14.4.4.1.1 The Specification applies to battery chargers for charging Ni-Cd maintenance free batteries specified above. The battery chargers shall be complete in all respect with all parts and accessories fitted all such parts and accessories shall be deemed to be within the scope of this specification whether specifically stated or not. The Scope of Work includes design, supply, installation, testing and commissioning of batteries & battery charger along with accessories.

14.4.4.1.2 There shall be various configurations in this corridor. Accordingly, the requirement of battery chargers shall be different at different locations. The various configurations have been defined under Clauses 14.4.2.2 to 14.4.2.5 above.

14.4.4.2 Specifications

14.4.4.2.1 The battery charger shall comply to IEC 60146. It's main components shall comply with the following specifications which shall be applied in the manner as altered, amended or supplemented by this specification and the Indian electricity rules where ever applicable.

- a) Mono-Crystalline Semi-conductor rectify assembly: IS 4540-1968
- b) Rectifier transformer: IS 2026 1977&81
- c) Mono-Crystalline Semi-conductor rectifier cells & stacks: IS 3895-1966
- d) Electrical indicating instrument: IS 1248-1983

14.4.4.2.2 The Contractor shall ensure compatibly of battery charger with batteries. Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment, proposed by the tenderer, will be consideration, provided full particulars with justification thereof, are furnished. Constant power drain shall be decided by the Contractor, to deliver the full duty.

14.4.4.2.3 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for elevated stations and Fire Retardant Low Smoke Zero Halogen (FRLSOH) for underground stations..

14.4.4.3 Ratings

14.4.4.3.1 The Battery Charger shall be designed for the rating and other particulars indicated in Table 14.14;

Table 14.14: Battery Charger

SN	Description	Battery
1	Type	Float cum Boost charger, two rate, Silicon thyristor/IGBT or full wave thyristor bridge type, suitable floor mounting,
2	Nominal Input	3Φ, 415 Volt, Subject to variation of +15% & - 10%
3	Nominal Output	110 V DC, Subject to variation of +10% & - 15%
	Charger Rating (A)	50A & 100A
4	Frequency	50 Hz Subject to variation of +3% & -3%
5	Short circuit current	7 kA for 1 sec
6	Recharge to 80% of battery capacity	4 hrs
7	Residual ripple ratio	Less than 3%
8	Cooling	Natural
9	Degree of protection	IP 5X
10	Current Harmonics	In accordance with IEEE 519
11	Input power factor	Shall not be less than 0.85 lag

14.4.4.4 Operation Features

14.4.4.4.1 The DC system shall be based on the principles of high selectivity and reliability. With galvanic isolation for mains and input protected with MCB and fuse.

14.4.4.4.2 The battery chargers shall be equipped with automatic and manual change-over systems from one source to the other.

14.4.4.4.3 In manual mode, it shall be possible to switch from one source to another source.

14.4.4.4.4 In the normal situation the charger shall supply the control and monitoring circuits and shall deliver the battery trickle charge. The second battery charger shall be in the standby mode.

- 14.4.4.4.5 In case of outage of the AC voltage, the battery shall immediately and without break replace the charger to ensure permanent power supply of the circuits and controls.
- 14.4.4.4.6 The battery charger shall have the provision of alarm in case of battery low volts and also have the feature of battery reverse polarity protection. The battery charger shall have potential free contacts to indicate the status of battery chargers at ASS/TSS as well as OCC through SCADA. Also potential free contacts shall be provided for giving alarm signal to SCADA system for failure of main battery charger and switching of the load on the other hot standby battery chargers.
- 14.4.4.4.7 Ripple content in the out voltage shall not be more than 3%.
- 14.4.4.4.8 Following any failure of more than five minutes of the AC supply network, the charger shall automatically revert to the charge position upon return of the voltage and shall remain in this position throughout the time set by an adjustable timer (from 1 hour to 20 hours). After this time, the charger shall return to floating operation. The charger shall remain in floating operation if the network failure is shorter than five minutes.
- 14.4.4.4.9 The entire 110 VDC distribution and the batteries shall be isolated from earth satisfactorily. The overall condition of this isolation shall be monitored permanently by a specific and highly reliable device.
- 14.4.4.4.10 The charger shall be designed to allow unloading tests, boost charging and maintenance of each to be carried out during normal operation;
- 14.4.4.4.11 The charger shall be capable of operating directly, without the battery, under the same conditions of accuracy as for the floating and charge modes.
- 14.4.4.4.12 Since the entire system cannot be designed so that short-circuit will never occur, it must be provided with circuit protection, which shall provide absolute and safe selectivity, so that tripping is confined to the minimum. Only rapid protection characteristic shall be used.
- 14.4.4.5 Construction Features
- 14.4.4.5.1 The charger shall be designed with all cable connections from the top for at grade/elevated corridor stations.
- 14.4.4.5.2 Rectifier Transformer
- The rectifier transformer shall be double wound, vacuum impregnated, natural air cooled and liberally rated. The core shall be made of for low loss silicon steel laminations.
- 14.4.4.5.3 Rectifier Stacks
- The charger shall comprise of silicon thyristor/IGBT or thyristor bridge wired as Graetz bridge for converting 3 phase supply to DC voltage. The rectifier stacks shall be liberally rated, suitable for battery load. The rectifiers shall be suitably protected against over loading when short time heavy currents are drawn closing circuit breakers and over voltages. Necessary of short time overload capacity of the rectifier cells with the characteristics of the protective devices shall be made. The protection arrangement proposed shall be stated by the Contractor.
- 14.4.4.5.4 Cabinet

The equipment shall be housed in a sheet steel casing which shall be provided with side and bottom perforated metal panel with louvers to provided adequate ventilation. Adequate protection against entry of insects, lizards etc. shall be made. The chargers shall be of robust in construction and the noise level shall be kept to maximum.

14.4.4.5.5 Switches, Meters, Fuses

The switches, meters and fuses shall be reputed manufacture and flush-mounted. These shall confirm to the relevant Indian Standard Specification. The framework shall be given a protective under-coat and two coats of varnish paint and stove enameled.

14.4.4.5.6 Fitting & Accessories

The fittings and accessories shall be provided in the battery charger as per standard design requirement but not limited to the following:

- a) MCB on AC side – 2 Nos.
- b) HRC fuses for AC side.
- c) Pilot lamps for AC side
- d) Rectifier transformer for boost and float- 2Nos.
- e) Silicon rectifiers stack- 2 set.
- f) Smoothing choke & and condenser
- g) HRC fuses for DC side
- h) Auxiliary contact for float to boost
- i) Volt-meter on AC side (0 – 500 Volts)
- j) Volt-meter on DC side (0- 300 Volt)
- k) Ammeter on DC side (0 – 20A) for float
- l) Ammeter on DC side (0 – 50A) for boost
- m) Earthing terminal
- n) Name plate with connection diagram engraved on it
- o) Relay: (i) Single phasing protection and (li) Earth, Faulty Relay
- p) FRLS/OH PVC insulated cables of adequate capacity to connect battery chargers & battery
- q) Lifting hook

14.4.4.5.7 The above components shall be housed in a sheet steel, which shall be designed for natural air cooling with adequate ventilation covered by mesh wire, floor mounting and indoor installation. The equipment shall be complete with internal wiring and input/output etc. complete. The frame work will be elegantly painted with primers and finishing coats to match other equipment. All caution plates and station names to be riveted on the panels.

14.4.4.6 Protections and Safety Features

14.4.4.6.1 Alarms

14.4.4.6.1.1 The status of all battery chargers shall be indicated at the ASS/TSS, as well as at the OCC (through SCADA). Serviceable and in-service, Serviceable and on standby. The defective status shall be available. Any change of status shall be accompanied by an audible alarm/hooter, both at the ASS/TSS and in the OCC. It shall be possible to disable the audible alarm function at the ASS/TSS.

14.4.4.6.1.2 The battery charger shall consist of the following alarms and annunciations:

- a) AC Main Fail
- b) DC Over voltage

- c) DC Under voltage/Fail
- d) Charging Fail
- e) Battery Low
- f) Float/Boost charger failure
- g) Float output DC fuse failure/MOCB Trip
- h) Boost output DC fuse failure/MOCB Trip
- i) Earth leakage
- j) Controller Card Defective
- k) One pair of potential free contact grouping all fault shall be provided for remote annunciation at OCC.

14.4.4.6.2 Protections & Monitoring

The charger shall be fitted with the following protection.

- a) A device limiting the current output by the rectifier to its rated current value with sufficient capabilities of adjustment and possible pick-up of the set point value
- b) switching diodes,
- c) breakers with fuse elements for overall protection on the transformer primary,
- d) breakers with fuse elements in series with each rectifier component (diodes and thyristors).
- e) breakers for the various auxiliary circuits
- f) an on/off switch controlling a three pole make-break switch with magneto-thermal protection on the AC circuit and a two pole make-break switch with magneto-thermal protection on the DC circuit.
- g) the specific protection to ensure satisfactory operation and protection of the set.
- h) Soft start feature
- i) Surge suppressor
- j) HRC Fuse at rectifier output
- k) Battery reverse polarity protection

14.4.4.6.3 Miscellaneous

The battery charger equipment shall also include:

- a) a signaling light denoting the opening of the make-break switch on the AC side, controlled by the tripping of one of the Miniature Circuit Breaker protecting the various circuits of the apparatuses,
- b) a signaling light denoting the opening of the make-break switch on the DC side through actuation of the magneto-thermal relay,
- c) The regulation system shall consist of plug-in modules fitted with polarization devices.
- d) Centre-zero ammeters which shall indicate whether the battery is under charge or the battery is only delivering the load.
- e) the position of the various circuit-breakers and of the protection and fault relays shall be monitored through two flip-flop stages.
- f) An inspection lights shall be fixed inside the charger compartment, which will automatically come "on" when the charger compartment is opened for inspection. This shall be independent of the "on/off" position of battery changer and shall be operative when the 415 V supply is available to the charger.

14.4.5 DC DISTRIBUTION BOARD

14.4.5.1 Scope

- 14.4.5.1.1 This Specification covers the 110 volts DC distribution board to be installed in the Auxiliary/Traction Sub – stations for control and distribution of 110 volt DC supply within the substation.
- 14.4.5.1.2 The equipment offered shall be complete with all parts and accessories or materials which are useful for efficient operation of the distribution system. Such accessories and materials shall be deemed to be within the Scope of this Specification whether specifically mentioned or not. There shall be various configurations in this corridor. Accordingly, the requirement of DCDBs shall be different at different locations. The various configurations available in the Metro corridor are as follows:
- Type 1:- At grade/elevated station ASS.
 - Type 2:- At grade/elevated station ASS plus TSS.
 - Type 3:- Underground station ASS.
 - Type 4:- Underground station ASS plus TSS.
- 14.4.5.2 Specifications
- 14.4.5.2.1 The distribution board covered by this Specifications and its main shall comply with the relevant Indian Standards and shall comply to the I.E. Rules as amended up to date wherever applicable. Protection rating shall be IP 43.
- 14.4.5.2.2 Any deviation from the specifications intended to improve the performance utility and efficiency of equipment proposed by the Contractor will be given due consideration provided full particulars with justification thereof are furnished.
- 14.4.5.3 DC DISTRIBUTION BOARD RATING
- 14.4.5.3.1 The schematic drawings for the various types of DCDBs shall be as per type mentioned. **be** The 110 Volt DC supply from the battery chargers shall be connected to the 110 Volt DC bus bar through a double change over switch so that only one of the chargers is connected to the DC Bus bars at a time. The bus bars are also connected to the 110 Volts battery installed at the Sub Station. The battery is thus floating on the DC bus bars. Outgoing circuits are connected to the DC bus bar through the MCBs of suitable ratings. 110 Volt DC panel shall comprise, but not limited to of the following of suitable rating:
- One incoming MCB/MCCB
 - 1 No. DC bus bar chamber, air cooled, Cu bus.
 - 1 No. DC volt meter & ammeter
 - Indication lamps
 - Isolating switch
 - Master power supply circuit breakers
 - Non-return diodes and set of normal/stand by supply bars
 - The current and voltage protection relays
 - The isolation monitoring
 - The automatic and manual device for change-over from one source to the other, with selector switches for automatic and manual, with or without break
 - The coupling circuit-breaker for the both 110 V DC sources
 - Outgoing feeders as per the relevant drawings as provided in above table
- 14.4.5.4 Construction Features
- 14.4.5.4.1 Distribution of the 110 V DC sources shall be contained inside cabinet equipped with doors, fitted with flexible seals, close via lock-bars and on which shall be installed a mimic diagram with indicating lights denoting the status of the main equipment.

- 14.4.5.4.2 The distribution boards shall be of heavy sheet steel construction and shall be completely dust, moisture and vermin proof. These shall be supplied complete with frame work, fixing bolts, barriers enclosure, internal wiring cable end boxes, labels etc.
- 14.4.5.4.3 Bus bars of DCDB shall be electrolytic copper with heat shrinking sleeves. Internal cabling/wiring of DCDB shall be fire retardant low smoke type (FRLS) for elevated section & fire retardant low smoke zero halogen (FRLSOH) for underground station .Wiring of suitable sizing shall be selected to carry the full load current. MCBs shall be selected for providing discrimination between incoming and outgoing feeders.
- 14.4.5.4.4 The distribution board for ASSs shall be of heavy sheet construction suitable for wall mounting. The board shall not, however, be mounted directly on the wall and a suitable MS angle Iron frame shall be used to maintain a gap of 100 mm between the wall and the DCDB.
- 14.4.5.4.5 All units of the distribution boards including supporting frame works shall be made rust proof by at least two coats of primary paint applied on the interior and exterior surface and followed by a finishing coat of light blue enamel paint.
- 14.4.5.4.6 The bus bars shall be made of high conductivity electrolytic tinned copper supported on LT porcelain insulators. Busbar chamber shall be made of heavy sheet and should be provided with detachable covers at both ends and suitable opening on top as well as at the bottom to enable installation of incoming and outgoing feeders.
- 14.4.5.4.7 The various items constituting the distribution board shall be neatly and securely fixed on a channel from framework designed for wall mounting.
- 14.4.5.4.8 The indicating lamps shall be of the low watt consumption which shall be interchangeable and replaceable on front of the panel.
- 14.4.5.4.9 Suitable markings for identification of circuits shall be provided on the distribution panel. Suitable name plate shall also be provided on the DCDBs.
- 14.4.5.5 Earthing
- 14.4.5.5.1 All metallic parts of the panel shall be connected to the main earth ring. Suitable earth terminals for this purpose shall be provided.

14.4.6 GTP FOR BATTERY

- 14.4.6.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 14.4.6.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 14.15: GTP for Battery

S.No	Description	Unit	Manufacturer's Data
1	Standards		
2	Type		
3	Stationary compact		
4	Maintenance free		
5	Capacity offered for 8 hours discharge duration	Ah	

S.No	Description	Unit	Manufacturer's Data
6	Voltage per cell	V	
7	Number of cells		
8	Rated operating voltage	V DC	
9	Maximum output current	A	
10	Documentation to be supplied		
11	Dimensions Length Width	mm mm	
12	Total weight	Kgs	

14.4.7 TEST SHEET FOR BATTERY

Table 14.16: Test Sheet for Battery

INDICATIONS	TYPE of TEST				
	Type	Routine	Accept	On site	Specials
1) BATTERY					
Electrical specifications checking (on one cell)	X				
Visual inspection		X	X	X	
Capacity measurement				X	
Discharge test			X	X	
Air Pressure Test				X	
Field Tests				X	
Cranking Ability (When applicable)				X	
Retention of Charge				X	
Insulation Resistance				X	

14.4.8 GTP FOR BATTERY CHARGER

14.4.8.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

14.4.8.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 14.17: GTP for Battery Charger

SN	Description	Unit	Quoted
1	Manufacturer		
2	Type of battery charger		
3	Standards		
4	3 Phases power supply	V AC	
5	Frequency	Hz	
6	Rated DC voltage	V DC	
7	Power conversion		
8	Cooling		
9	Allowable output voltage variation for +10% variation of supply voltage for +5% variation of frequency		

SN	Description	Unit	Quoted
10	Average winding Temperature rise over Ambient	°C	
11	Internal Cabling /Wiring		
a.	Elevated / at-grade sections		
b.	Depots		
12	Residual ripple ratio		
13	Recharge to 80% of the battery capacity		
	Meters		
14	Voltmeter on AC side		
15	Voltmeter on DC side		
16	Ammeter on DC side		
17	Alarms		
18	AC Main Fail Alarm		
19	DC Overvoltage Alarm		
20	DC Under Voltage Alarm		
21	Charging fail Alarm		
22	Battery low Alarm		
23	One pair of Potential Free Contact grouping all fault to be provided for remote Annunciation at OCC		
	Protections		
24	Current Limit Protection		
25	Soft start feature		
26	Surge suppressor		
27	HRC Fuse at rectifier Output		
28	Battery Reverse Polarity protection		
29	Automatic Changeover feature		
30	Switchgear		
31	Input Side		
32	Output side		

14.4.9

TEST SHEET FOR BATTERY CHARGER

Table 14.18: Test Sheet for Battery Charger

INDICATIONS	TYPE of TEST				
	Type*	Routine	Acceptance	On site	Specials
Temperature rise*	X				
Rated short duration power frequency withstand voltage		X	X		
Floating operation mode test		X	X	X	
Equalization operation mode test		X	X	X	
Direct operation mode test		X	X	X	
Protection devices operation		X	X	X	
Setting test		X	X	X	
Visual inspection		X	X	X	
Functional Test		X	X	X	
Efficiency	X				
Ripple test	X				

Regulation	X				
Insulation resistance test	X				
Output short circuit test	X				
HV test	X				

14.5 AC DISTRIBUTION BOARD

14.5.1 SCOPE

14.5.1.1 This Specification covers the 415/230 volts AC distribution board to be installed in the Auxiliary/Traction Sub – stations for control and distribution of 415 volt three Phase/ 230 volt single phase AC supply within the substation.

14.5.1.2 The equipment offered shall be complete with all parts and accessories or materials which are useful for efficient operation of the distribution system. Such accessories and materials shall be deemed to be within the scope of this specification whether specifically mentioned or not. There shall be various configurations in this corridor. Accordingly, the requirement of the ACDBs shall be different at different locations. The various configurations available in the Metro corridor are as follows

- a) Type 1:- At grade/elevated station ASS.
- b) Type 2:- At grade/elevated station ASS plus TSS.
- c) Type 3:- Underground station ASS.
- d) Type 4:- Underground station ASS plus TSS.

14.5.1.3 The design, supply, laying and connection of cable from MDBs or from any other suitable panel to ACDBs shall be in the Scope of LKE(02)-01 Contractor.

14.5.2 SPECIFICATIONS

14.5.2.1 The AC distribution board complies with IEC 61439 1/2:2020, and other relevant Indian Standards and shall comply to the I.E. Rules as amended up to date wherever applicable. Protection rating shall be IP 53.

14.5.2.2 Any deviation from the specifications intended to improve the performance utility and efficiency of equipment proposed by the Contractor will be given due consideration provided full particulars with justification thereof are furnished.

14.5.3 AC DISTRIBUTION BOARD RATING

14.5.3.1 The schematic diagrams for the various ACDBs shall be as per types mentioned. The AC Distribution Board shall comprise of the following accessories of suitable rating, but not limited to:

- a) One No. 415V, TPN MCB/MCCBs
- b) Bus bar chamber with copper bus of adequate size
- c) Single Pole & Triple Pole MCBs for distribution
- d) Fuses
- e) Indication lamps
- f) Connection to SCADA for AC supply failure

- g) Outgoing feeder as per the relevant drawings as provided in above table
- h) In UG stations, ACDB should have provision for 2 inputs for power supply and automatic changeover switch for the same.
- i) ACDB has a protection relay for UV, OV protection.

14.5.4 CONSTRUCTION FEATURES

- 14.5.4.1 The distribution boards shall be of heavy sheet steel construction and shall be completely dust, moisture and vermin proof. These shall be supplied complete with frame work, fixing bolts, barriers enclosure, internal wiring cable end boxes, labels etc.
- 14.5.4.2 The distribution boards for ASSs shall be of heavy sheet construction suitable for wall mounting. The boards shall not, however, be mounted directly on walls and a suitable MS angle iron frame shall be used to maintain a gap of 100 mm between the walls and the ACDB.
- 14.5.4.3 Bus bars of the ACDB shall be electrolytic copper with heat shrinking sleeves. Internal cabling/wiring of ACDB shall be fire retardant low smoke type (FRLS) for elevated section & fire retardant low smoke zero halogen (FRLSOH) for underground station. Wiring of suitable sizing shall be selected to carry the full load current. MCBs shall be selected for providing discrimination between incoming and outgoing feeders.
- 14.5.4.4 All units of the distribution boards including supporting frames shall be made rust proof with at least two coats of primary paint applied on the interior and exterior surface and followed by a finishing coat of light blue enamel paint.
- 14.5.4.5 The bus bars shall be made of high conductivity electrolytic tinned copper supported on LT porcelain insulators. Bus bar chambers shall be made of heavy sheet and should be provided with detachable covers at both ends and suitable opening on top as well as at the bottom to enable installation of incoming and outgoing feeders.
- 14.5.4.6 The circuit breaker, changeover switch shall be arranged neatly and mounted on the panel which shall be of standard design and provided within a hinged cover to facilitate inspection.
- 14.5.4.7 The various items constituting the distribution board shall be neat and secured on a channel from framework designed for wall mounting.
- 14.5.4.8 The indicating lamps shall be of the low watt consumption, which shall be interchangeable and replaceable on front of the panel.
- 14.5.4.9 Suitable markings for identification of circuits shall be provided on the distribution panels. Suitable name plates shall also be provided on the ACDBs.

14.5.5 EARTHING

- 14.5.5.1 All metallic parts of the panel shall be connected to the main earth ring. Suitable earth terminals for this purpose shall be provided.

14.6 LV CABLING AND WIRING

14.6.1 SCOPE

- 14.6.1.1 This Specification covers all LV AC & DC cables used in distribution, control and monitoring. These cables shall be used in auxiliary substations and Traction substations. The Scope of Work includes design, supply, installation, testing and commissioning of cables.
- 14.6.1.2 The Specification defined hereunder shall be applicable to all ASSs, TSSs and depots.

14.6.2 SPECIFICATIONS

- 14.6.2.1 The cable used for LV system shall comply with BS 6724 for cables, BS 7211 for wires and BS 7846/IS 5831 for FRLSH and IEC 60502-1(latest)/BS 7655 for FRLSOH cables, for cables used for emergency services and for the safety system like ETS. Further these cables should have reduced flame propagation properties to BS EN 50268 /61034. The specifications shall be applied in the manner altered, amended or supplemented by the latest version of these specifications and also the relevant provisions of the latest Indian Electricity Rules wherever applicable.
- 14.6.2.2 Cables shall be Fire Retardant Low Smoke Zero Halogen Type. (FRLSOH) for underground sections, and Fire-Retardant Low Smoke Type. (FRLS) for elevated sections.

14.6.3 Ratings

- 14.6.3.1 The cables shall be designed for the rating and other parameters indicated in Table 14.19;

Table 14.19: LV Cable Rating

SN	Description	Elevated & At-grade section
1	Type	Semi flexible
2	Conductor	Bare or tinned copper
3	Rated voltage	1.1 KV
4	Fire retardant property	FRLS/FRLSOH

14.6.4 Construction Features

- 14.6.4.1 The cables shall be manufactured by a company having ISO accreditation for quality.
- 14.6.4.2 Conductors supplied for low voltage or remote-control lines shall have a bare or tinned copper core. Semi flexible conductors shall be used; rigid conductors shall be prohibited.
- 14.6.4.3 The minimum cross-section of conductors shall not be less than 1.5 mm². The minimum cross-section of current transformers secondary circuits shall not be less than 6 mm². The minimum cross-section of voltage transformers secondary circuits shall not be less than 4 mm². The voltage rating of distribution cables shall be 600/1000 Volts.
- 14.6.4.4 Grounding conductors shall have green/yellow-stripped insulation. Neutral conductors are to be deemed as being active conductors.

- 14.6.4.5 Cables and wires shall be treated to withstand flames propagation. All LV cables and wiring shall be FRLS Type for elevated and at level section & FRLSOH Type for underground section.

14.6.5 Cable Cross Section

- 14.6.5.1 Determining the technical core section of a cable implies determining the smallest standard cross-section in the type of cable selected which, under the applicable environmental conditions, shall satisfy the following criteria:
- 14.6.5.2 Normal temperature rise
- 14.6.5.3 Maximum voltage drop
- 3% for main distribution lines (between primary and secondary cabinets)
 - 3% for lighting circuits
 - 5% for power circuits
 - 12% for motor circuits during start-up
- 14.6.5.4 Overload and short-circuit
- 14.6.5.5 Protection against indirect contact
- 14.6.5.6 If heavy currents are to be carried, the economic section must also be taken into account.

14.6.6 Tests

- 14.6.6.1 All armoured control cables shall comply with the IS 7098-1 in force and shall, at least, have satisfied the following tests:

Table 14.20: TESTS

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
Annealing Test (Test on Copper Conductor)	X		X	
High Voltage Test	X	X	X	
Conductor Resistance Test	X	X	X	X
Conductor Examination	X		X	X
Test for thickness for insulation & sheath, overall diameter if applicable, core identification & visual check.	X		X	
Armour wires/strip dimensions and type of armour	X		X	
Armour resistance	X	X	X	
Tensile strength & Elongation at break of insulation and sheath before ageing.	X		X	
Hot set test.	X		X	
Insulation Resistance (Volume Resistivity test) at room temp.	X		X	
Oxygen Index Test	X		X	

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
Temperature Index Test	X		X	
Smoke Density Test (as per ASTM 2843)	X		X	
Acid gas evaluation test (IEC 60754)	X		X	
Flammability Test as per IEC 60332-1	X		X	
HCL ACID GSA emission	X			

- 14.6.6.2 All unarmoured control cables shall comply with the IS 7098-1 in force and shall, at least, have satisfied the following tests:

Table 14.21: Unarmoured cable tests

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
Annealing Test (Test on Copper Conductor)	X		X	
High Voltage Test	X	X	X	
Conductor Resistance Test	X	X	X	X
Conductor Examination	X		X	X
Test for thickness for insulation & sheath, overall diameter if applicable, core identification & visual check.	X		X	
Tensile strength & Elongation at break of insulation and sheath before ageing.	X		X	
Hot set test.	X		X	
Insulation Resistance (Volume Resistivity test) at room temp.	X		X	
Oxygen Index Test	X		X	
Temperature Index Test	X		X	
Smoke Density Test (as per ASTM 2843)	X		X	
Acid gas evaluation test (IEC 60754)	X		X	
Flammability Test as per IEC 60332-1	X		X	
HCL ACID GSA emission	X			

- 14.6.6.3 All Fire Survival (FS) cables shall comply with the IS 7098-1 and BS 7846 in force and shall, at least, have satisfied the following tests:

Table 14.22: Fire Survival Cable test

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
Annealing Test (Test on Copper Conductor)	X		X	

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	On site
High Voltage Test	X	X	X	
Conductor Resistance Test	X	X	X	X
Conductor Examination	X		X	X
Test for thickness for insulation & sheath, overall diameter if applicable, core identification & visual check.	X		X	
Tensile strength & Elongation at break of insulation and sheath before ageing.	X		X	
Hot set test.	X		X	
Insulation Resistance (Volume Resistivity test) at room temp.	X		X	
Oxygen Index Test	X		X	
Temperature Index Test	X		X	
Smoke Density Test (as per ASTM 2843)	X		X	
Acid gas evaluation test (IEC 60754)	X		X	
Flammability Test as per IEC 60332-1	X		X	
Resistance to fire at a temp of 950°C, category C, for a time duration of 3 hrs as per BS-6387	X			

14.6.7 Identification

- 14.6.7.1 All conductors, cables, wiring, terminals and equipment shall be identified according to the indications on the diagrams.
- 14.6.7.2 This identification shall be placed so as to be easily read from the accessible face of the cable or wiring. In all structures, cables shall be marked both at their ends and approximately every 20 meters over their full length, particularly when they change of direction, enter conduits, ... etc.
- 14.6.7.3 Along the track, cables shall be identified in the pulling chambers and at their ends.
- 14.6.7.4 The identification shall be realized with tag-holder providing the following guarantees:
- Easy fastening,
 - Non-flammable,
 - Permanence of the marking
 - Easy reading
- 14.6.7.5 Cables and Single-Phase wires shall be colour coded as given below
- Red, Yellow, Blue Phase Conductor

- | | |
|-----------|-------------------|
| (b) Black | Neutral Conductor |
| (c) Green | Earth Conductor |

- 14.6.7.6 The tag-holder and its bi-directional marking type shall be submitted for the Engineer's approval.

14.6.8 Connection

- 14.6.8.1 No cable joints shall be allowed without the prior Approval of the Engineer / Engineer. All joints, accessories and cable joint locations shall be submitted to the Engineer for Approval prior to any jointing of cables. All cable jointing shall be performed by a qualified jointer and preferably by the manufacturer of the jointing kits.
- 14.6.8.2 All connections, whether made by end-fittings, sleeves or terminals, shall comply with good trade practice.
- 14.6.8.3 The connection terminal blocks supplied by the Contractor shall be identified and includes space enabling precise referencing of all terminals, also possessing all guarantees of permanence and fastening.
- 14.6.8.4 The crimped section of cables shall be insulated by heat-retractable sleeve.
- 14.6.8.5 The screen of screened cables shall be connected to earth and continuity shall be ensured.

14.6.9 LV Cable Installation

- 14.6.9.1 This Specification is made to define the characteristics of low voltage cables used for distribution, control and monitoring. They shall be supplied either in A.C. or in D.C. They shall be used for electrical connection between equipment of RSSs, TSSs and ASSs.
- 14.6.9.2 All wiring shall be carried out with 1100V grade, single core, stranded copper conductor wires with PVC insulation. Semi flexible conductors shall be used; rigid conductors shall be prohibited.
- 14.6.9.3 In general, the cable laying shall comply with the principle of separation between the control and monitoring circuits and the auxiliary circuits of the building (lighting, power, and miscellaneous auxiliaries).
- 14.6.9.4 Wire terminations shall be made with solder less crimp type and tinned copper lugs, which firmly grip the conductor. Insulated sleeves shall be provided at all the wire terminations. Engraved core identification plastic ferrules marked to correspond with panel wiring diagram shall be fitted at both ends of each wire. Ferrules shall fit tightly on the wire and shall not fall off when the wire is disconnected from terminal blocks.
- 14.6.9.5 The Contractor shall be solely responsible for the completeness and correctness of the internal wiring and for the proper functioning of the connected equipments.
- 14.6.9.6 Grounding conductors shall have green/yellow-stripped insulation. Neutral conductors are to be deemed as being active conductors.

-
- 14.6.9.7 Systematically, for control and monitoring cables, all the links of a section shall include 15% spare conductors with at least one spare conductor per cable.
- 14.6.9.8 Cable ways shall be preferably provided with perforated sheet:
- 14.6.9.9 This shall be the normal laying mode of the link conductors.
- 14.6.9.10 It shall be used systematically along wiring runs necessitating special mechanical protection, precaution or when it is necessary to carry several cable-way levels inside limited space.
- 14.6.9.11 Their width shall be defined to enable addition of at least 15% of the number of the cables initially foreseen.
- 14.6.9.12 In general, when sheets shall be superimposed, the clear heights between one another shall be defined so as to provide perfect accessibility to the cable layers they carry.
- 14.6.9.13 All necessary arrangements shall be taken to enable addition or possible replacement of a conductor in a layer and, consequently, to enable its pulling. Several superimposed layers of cables may use the same support sheet but superimposition shall be limited to cables of the same section. If crossings are required between cables or layers coming from different sections, a metal element shall be placed between the layers in way of the crossing. The extent and number of the fastening fittings shall be determined so as to avoid all distortions between rests. The anchoring process of the fittings shall be suited to the supporting element concerned.
- 14.6.9.14 Cable ways on fittings or bridges:
- 14.6.9.15 This arrangement shall be used only for small layers, not justifying the use of slabs.
- 14.6.9.16 The fittings or bridges shall be sized accounting for possible addition of 15% additional cables.
- 14.6.9.17 One independent fitting shall be provided per set of conductors coming from a same section; in no event may conductors coming from different sections be fastened to a common fitting or bridge.
- 14.6.9.18 Insulating tubes
- 14.6.9.19 When conductors are gathered in strands, they may be laid inside an insulating tube. This solution shall be used only for short runs.
- 14.6.9.20 Metal Tube
- 14.6.9.21 Certain circuits may have to be protected by means of rigid steel tubes or flexible metal tube; all the necessary precautions shall be taken to insulate the fastening so as not to cause contacts between masses of different categories. These metallic tubes shall be properly earthed.
- 14.6.9.22 Fastening of cables and conductors to their supports:
-

- 14.6.9.23 Fastening of the cables to their supports, whether perforated steel, fittings or bridges, shall be made by means of loosening-proof clamps made of flexible insulating material and by mean of mechanical tightening.
- 14.6.9.24 If several cables of the same section use a common horizontal run, they shall be able to be gathered and clamped by the same fastening clamp.
- 14.6.9.25 Fastening of conductors shall always be provided immediately next to their connection ends. In no event may connection to a terminal block be deemed as being fastening and permanent strain may be exerted on the terminals.
- 14.6.9.26 Mechanical protection of cables and conductors:
- 14.6.9.27 In all cases when the layout of the conductors of bar set of the earthing circuits could render them vulnerable (floor crossings, vertical layers or horizontal crossings through service passages), the necessary mechanical protection for the cables and conductors shall be ensured.
- 14.6.9.28 These protection shall show sufficient strength to prevent any damage to the cables and conductors following impacts, which may occur during equipment handling operations; they shall also possess good resistance against corrosion.
- 14.6.9.29 For vertical layers, the Contractor shall ensure supply and installation of sheet casing ensuring efficient protection up to a height of 2 meters above ground. In case of single or limited number of conductors a spare tube shall always be laid.
- 14.6.9.30 Whenever LV cables or conductors are placed along a run adjacent to or crossing MV cables, full steel protection on the LV cables shall be provided. It shall enable possible pulling of the MV cables without risking to damage the insulating material of MV cable.
- 14.6.9.31 This metal protection shall be connected to the nearest LV earthing collector and shall ensure electrical protection in the event. All cable trays and supports shall be suitably connected to earthing systems at two distinct and separate points.

14.7 LIGHTING ALONG THE VIADUCT

- 14.7.1.1 The work involves Design, supply, installation, testing & commissioning of LED light fittings including all accessories mounting arrangement etc. including necessary supports, Cabling, accessories and hardware as per specifications & as required at site on the elevated viaduct section.
- 14.7.1.2 The LKE(02)-01 Contractor shall interface with E&M Contractor of station for availability of cable path inside the Station building and availability of Lighting distribution board with all other accessories inside the Distribution Board.

14.7.2 Luminaire minimum specifications and requirements

- 14.7.2.1 Luminaires should operate at +/- 6% voltage fluctuation for continuous use to comply to IEC.
- 14.7.2.2 All the components including the internal wiring of the luminaries to be used shall be manufactured of material, which are of FRLS type. All luminaires shall be manufactured to relevant sections of IEC60598 or other approved international standards and the type tests for all luminaries shall be provided.

- 14.7.2.3 All internal wiring within the lighting fixtures shall be heat-resisting FRLS cables.

14.7.3 Luminaire Specification

- 14.7.3.1 Viaduct luminaire shall be LED type consisting of an extruded anodised aluminium alloy body sealed onto an extruded polycarbonate prismatic protector with high impact resistance IK10; a removable sliding plate equipped with control gear on one side and lamp(s) on the other; one or two frames made out of injection moulded on the other; one or two frames made out of injection moulded two polycarbonate covers closed with two stainless steel screws. This system ensures tightness of IP-67 for the whole luminaire. The fixture suitable with all mounting accessories and 2 nos. glands (suitable for loop in & loop out with armoured cable).

a) Luminaire minimum specifications and requirements

- i. Luminaires should operate at +/- 6% voltage fluctuation for continuous use to comply to IEC. PF > 0.95; for EM circuits PF > 0.85.
- ii. All the components including the internal wiring of the luminaries to be used shall be manufactured of material, which are of FRLS type. All luminaires shall be manufactured to relevant sections of IEC or other approved international standards and the type tests for all luminaries shall be provided.
- iii. All internal wiring within the lighting fixtures shall be heat-resisting cables.
- iv. All equipment shall confirm with the objective of the European Directives on EMC
- v. It shall comply with Input volt shall be 240V, 50Hz, Voltage tolerance: 180 - 270V, With Tolerance of Performance: +6% to 8% --- 202 to 254 V, With Tolerance of Safety: +/-10% --- 198 to 264 V
- vi. Light output regulation: shall maintain constant light output of all LED lamps over operating ranges of 170Volts to 265 Volts. Luminous flux should not change more than +/-2%.
- vii. Input total harmonic content shall not exceed 10%.
- viii. The following general LED lamp parameters shall be applicable unless otherwise specified in specific design data;

b) LED lamp

- i. Type: High output, minimum 2600 lumen output nominal, 25-28 W
- ii. Color Rendering Index Ra: 80
- iii. Color Temperature: 4000 K
- iv. Life: More than 50000 hours
- v. IP rating IP66

- 14.7.3.2 The Lighting distribution board at platform for viaduct lighting shall be provided by E&M Contractor. LKE(02)-01 Contractor shall interface with E&M Contractor for the same. For Lux level refer NFPA 130; Latest Version. For fixing arrangement shall be made on parapet of the viaduct or any other suitable location such that not to hinder the movement of passengers during emergency evacuation.

14.8 POWER SOCKETS ALONG THE VIADUCT

- 14.8.1.1 Power sockets shall be installed along the viaduct. From each station 02 cables have to be laid, one on each direction.

- 14.8.1.2 Sockets shall be placed every 50 meters or near points & crossings. These power sockets shall be laid on the same side of cable brackets where 33 kV cable runs along track. They shall be 16 A rated current with 5 pins/ 3 phases plus neutral plus earth. They shall ensure a protection of IP 65. Not more than 2 sockets will be operated in one circuit at any time. That is to say, the cable should be designed for carrying a continuous rated current of 32A, after considering the derating factors as applicable.
- 14.8.1.3 The cable along the via duct should be of the same cross section (min. 25 sq. mm.) throughout. The 5 wires cables shall be laid along the line on the parapet, under the sockets with space enough between them to install the connection box. The cables will be laid in PVC conduits fixed on the parapet. They shall be fixed, at least, every two meters. The tube shall enter into the connecting box to ensure proper sealing of the system. One PVC conduit shall ensure the cabling between the connecting box and the socket.
- 14.8.1.4 The connecting box shall ensure the connection of the socket by means of 5 wires cable. Due to the difference in size between the main cables and the socket cable, connecting plates will ensure this reduction. The connecting box, PVC made, shall include five connecting plates, mounted on insulators. Each connecting plate, copper made, shall ensure the connection of three cables, one for the socket, the two others for the incoming and the outgoing cable.
- 14.8.1.5 The fixing of the cables will be done by corrosion resistant bolt and nuts or bolt directly screwed in the connecting plate. The cable termination shall not be open but shall only permit the screwing in order the cable do not fall and touch any other parts in case of bad tightening of the bolt. The connecting box shall be fixed on the parapet, under the socket
- 14.8.1.6 The connecting box shall be waterproof and dust-proof, with PVC tubes placed in position with a protection level of IP 65.
- 14.8.1.7 All armoured cables should meet the design criteria specified for LV cables.
- 14.8.1.8 The Supply for the power sockets at viaduct shall be provided from Main Lighting Panel in ASS/TSS Room. LKE(02)-01 Contractor shall do necessary interfacing with E&M Contractor.

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CHAPTER – 15

TRACTION SUBSTATIONS

15.1 INTRODUCTION

15.1.1 Scope of Work

- 15.1.1.1 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in chapter-2 & Chapter 19 along with clause wise compliance and suggest similar or better design for the approval of Employer.

15.1.2 GENERAL

- 15.1.2.1 This chapter constitutes the technical specification of the Auxiliary cum Traction Power sub-station (ASS/TSS) for the East West corridor (Phase 1 B) of the Lucknow Metro Project. It describes the functional requirement and the main technical requirement to be fulfilled by the ASS/TSS to be provided. General requirements regarding design, manufacturing, supply, installation, testing and commissioning are also defined to provide Tenderers with the general framework for the project to help them for the tendering stage.
- 15.1.2.2 The rolling stock is required to be provided with traction power at 750 V DC. For this purpose, power at 33 kV level from the 33 kV switchgear room located in the premises of the Receiving Substations (RSS)/Auxiliary Main Substation (AMS), is transmitted to the Auxiliary cum Traction Substations (ASS/TSS) located along the corridor, in the premises of passenger stations and depots, through duplicate feeders made up of 33 kV insulated cables. The 33 kV power is converted to 750 V DC power by means of 33 kV / 585-585 V Cast Resin Dry type rectifier transformers and rectifier of suitable capacity installed in the ASS/TSS's. The traction power network essentially consists of the following:
- a) A 33kV feeder from the AMS to a designated ASS/TSS in the Corridor (details provided in Chapter 13)
 - b) A 33kV cable network, comprising of redundant 33 kV insulated cables of suitable capacity, laid in cable trenches/cable duct/cable bracket in the viaduct/tunnel or at-grade, as applicable. In addition, there will be 33 kV cable interconnections between station to the 33 kV panels located in the ASS/ TSS (details provided in Chapter 13)
 - c) 33 kV /585-585 V, 2850 kVA capacity Rectifier Transformers, associated 33 kV switchgear, 2500 kW 12-pulse parallel connected rectifiers, high speed circuit breakers, Disconnecter switches, DC positive & negative cables and other auxiliary equipment, installed in the ASS/ TSS's at various passenger stations and depots.
 - d) Connection of 750 V DC power supply to Third rail system from where the rolling stock finally draws power for propulsion purpose (details in Chapter-16 and return feeders from running rails to negative bus of DC switchgear in ASS/TSS).
- 15.1.2.3 ASS/TSS includes 33 kV/585-585 V, 2850 kVA rectifier transformers, 2500 KW rectifiers, 33 kV AC and 750 V DC switchgear (including high speed circuit breakers), protection and control unit, indication and metering arrangement, AC/DC control source and systems, 750 V DC positive and negative cables, protective provisions related to electrical safety and earthing etc. with all accessories and auxiliary equipment.

- 15.1.2.4 The works which form part of this Tender shall consist of design, supply, erection, testing and commissioning of all equipment at all ASS/TSSs, including, but not limited to the equipment described above, batteries and battery chargers, ACDBs & DCDBs, cable paths and earthing, safety equipment and all other items (e.g. cable sealing arrangement) required for successful and satisfactory working of the ASS/TSS.
- 15.1.2.5 The overall feeding diagram, ASS/TSS single line diagrams and protection drawings may be referred to Tender drawings.
- 15.1.2.6 For type of stations ASS/TSS, please refer Chapter 14. However, the minimum number of stations which have ASS+TSS in the Corridor shall be five (5) numbers.
- 15.1.3 DESIGN BASIS**
- 15.1.3.1 The traction power supply system shall be designed to meet the following requirements:
- 15.1.3.1.1 With one rectifier out of service the remaining healthy substations will permanently meet the entire demand of peak time service.
- 15.1.3.1.2 The capacity of every substation as well as transformer rectifier sets in every substation, is determined as per EN 50163 to ensure that the following voltage requirements are met at any current collection point along the Third Rail System:
- | | | |
|----|--|-----------|
| a) | Nominal voltage U_n | 750 V DC |
| b) | Highest Permanent Voltage U_{max1} | 900 V DC |
| c) | Lowest Permanent Voltage U_{min1} | 500 V DC |
| d) | Highest non-Permanent Voltage U_{max2} | 1000 V DC |
- 15.1.3.1.3 The running rail potential shall be compliant to EN 50122-1:2011 i.e.,
- | | | |
|----|-------------------|-------|
| a) | For > 300 seconds | 120 V |
| b) | Up to 300 seconds | 150 V |
| c) | Up to 1 second | 170 V |
- 15.1.3.2 The traction system for mainlines is that of floating negative/return system so that stray currents are controlled. Depot tracks are also floating, however for safety reasons, the tracks in workshop/ Inspection-bay lines/pit wheel lathe in depots are negative earthed one. The mainline tracks shall be isolated from depots tracks through insulated rail joints (IRJs) in order to minimize the stray currents. Insulated rail joints shall also be proposed for workshop/Inspection-bay lines/pit wheel lathe tracks to isolates these lines from other part of Depot.
- 15.1.3.3 A separate traction substation is therefore provided in depot, so as to facilitate isolation of depot traction power supply from mainline in order to prevent the leakage of return currents to main line. Remote operated sectionalizing switches are provided to feed power from depot to main line equipment and vice-versa in case of failure of mainline or depot ASS/TSS.
- 15.1.4 ASS/TSS LOCATIONS AND CAPACITY**
- 15.1.4.1 The locations and capacity of ASS/TSSs in the East West Corridor (Phase 1 B) and Depot has been indicated in Chapter 2.
- 15.1.4.2 Between the rectifier group and 750 V DC Positive bus bars, single pole HSCB, interlocked with the traction transformer incoming CB shall be installed. For connection of negative terminals of rectifier with DC negative bus bars, motorized no load switch,

interlocked with corresponding HSCB shall be provided. From the 750V DC positive bus bar, feeder HSCB shall be provided to operate the feeders to third rail.

- 15.1.4.3 All the ASS/TSS are proposed with four third rail feeders. However depot ASS/TSSs are proposed with different configuration (refer tender drawings).
- 15.1.4.4 For continuity of control DC power supply an alternate feeding arrangement through battery bank (combined with ASS) is considered to ensure normal performance of the system in the event of total AC power failure to the installation.
- 15.1.4.5 For the elevated stations, the ASS/TSS will be located preferably at concourse level and depots they shall be located at ground level. For the underground stations, the TSS will be located at platform or concourse level.
- 15.1.4.6 The ASS/TSS equipment in those ASS/TSSs which are located on the elevated sections will be installed in a suitable room preferably at concourse level & for underground sections will be installed at platform/concourse level, in the passenger stations. For depot, the TSSs equipment are to be installed in suitable rooms part of Depot ASS/TSS.
- 15.1.4.7 The Room for accommodating the ASS/TSS and ASS equipment in elevated & underground stations will be built by other designated contractors. Room sizes and shapes may be different in different stations of the corridor. Nevertheless, an approximate area of 400 m² (for typical TSS and ASS combined) with a minimum height of 3.8 m (in the Transformer and Panel area) will be provided for accommodating equipment. Typical Equipment Layout Plans for ASS and TSS are included in Tender drawings. The LKE(02)-01 will, however, be required to submit Equipment Layout Plans for every Substation, depending upon the types, sizes etc. of the equipment proposed to be used .

15.1.5 INTERFACES

- 15.1.5.1 Cable cut-outs for entry/exit of HT, LT, DC power cables and Control and Monitoring (C&M) cables will be provided by the Station Contractor. For this purpose the LKE(02)-01 contractor will have to maintain an interface with the Station Contractor.
- 15.1.5.2 Cable sealing shall be under the scope of LKE(02)-01 Contractor.
- 15.1.5.3 The Traction contractor shall design, supply and install all the cable trays/hangars support etc. inside ASS cum TSS Room for elevated and depot ASS/TSS and for Underground Stations, the same shall be provided by the E&M Contractor. Cable paths required for management of HT/LT (from ACDB to the 33 kV and DC switchgear and the other accessories e.g., battery, battery charger etc.) and Control & Monitoring cables, inside the ASS cum TSS Rooms, shall be in the scope of LKE(02)-01 contractor. Cable trenches on the floor are to be avoided and cable trays etc. fixed to the ceiling may be adopted.
- 15.1.5.4 DC cable route planning has to be done in such a way that overcrowding of cables is avoided to maintain the weight limits of the tray and support system. Glanding into panels has to be done appropriately.
- 15.1.5.5 Heavy equipment, such as transformers, rectifiers, DC panels and 33 kV panels shall be brought by road by the LKE(02)-01 (Power Supply) Contractor. Wherever required, suitable loading / unloading platforms shall be constructed and the equipment shall be lifted to the loading / unloading platforms for elevated and Hatch cut-outs for underground stations with the help of cranes etc. by the LKE(02)-01 (Power Supply) Contractor. The equipment shall be moved to respective positions/ foundations, with the help of trolley / rollers/ Lifting hooks by the Traction Contractor.. In elevated stations, rolling shutters & in

underground stations knock out wall shall be used for placing heavy equipment like transformers, 33kV panels etc. inside ASS/TSS room (preferably the work will be completed before the finishing of the knockout wall). The LKE(02)-01 contractor will interface with civil contractor in respect of capacity of hooks and their appropriate location. No mono-rails or rails on the floor shall be provided in the ASS / TSS room.

15.1.5.6 The Station Contractor will provide a finished floor. The LKE(02)-01 contractor may, if required, fix equipment on the floor with the help of anchor fasteners. In general, no additional concreting is considered necessary to be provided in the ASS / TSS Rooms. If any concrete pedestals / foundations are required to be provided to mount equipment, the same shall be provided by the LKE(02)-01 (Power Supply) Contractor, after obtaining approval from Engineer in coordination with the Station Contractor.

15.1.5.7 The detailed interfaces are provided in Chapter 3.

15.2 33 kV SWITCHGEAR

15.2.1.1 REFER Chapter 14 Cl.14.2

15.3 HIGH SPEED CIRCUIT BREAKER

15.3.1 SCOPE

15.3.1.1 This specification applies to indoor DC High speed circuit breaker (HSCB) and load breaker panel. It shall meet the technical requirements as specified herein. The circuit breaker shall be manufactured for traction power system of Lucknow Metro Rail project. The scope of work includes design, supply, installation, testing and commissioning of switchgear along with accessories.

15.3.1.2 The DC switchgear shall be of metal enclosed dead front design consisting of a bank of High Speed Circuit Breakers (HSCBs) in accordance with the finished design for traction power supply and sectioning arrangement for main line and depot sections as applicable, fed from rectifiers and feeder circuit breakers.

15.3.1.3 The High speed circuit breakers and load breaker panels offered shall be complete in all parts and accessories necessary for their efficient performance / operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.

15.3.2 SPECIFICATIONS

15.3.2.1 The High Speed Circuit Breaker shall, unless otherwise specified conform to latest versions of IEC 61992-2, EN 50123-1,2 or ANSI C37, 14 -199, C37,16-1980, or BS4752, IEC 60947-2 & latest I.E. Rules applied in the manner amended or supplemented by this specification wherever applicable. In all cases latest revision to these specifications referred to above shall apply.

15.3.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with the approval of employer.

15.3.2.3 Internal cabling shall be Fire Retardant Low Smoke Type, (FRLS) for elevated section and FRLSOH for underground section.

15.3.2.4 Switchgear assemblies and major components shall comply with the requirements given in IEC 61992-2, EN 50123 and shall be tested in accordance with the requirement given in IEC as applicable. Circuit breakers shall be capable of performing within the applicable rating and operating characteristics limits established in accordance with IEC. Materials used for circuit breaker insulation shall be of a type that is non-combustible and non-

hygroscopic. The mechanical strength and physical characteristics of the insulation structure shall match the stresses imposed by the circuit breaker required closing and latching current capability. The High Speed Circuit Breaker shall, unless otherwise specified conform to IEC 61992, EN 50123-1, 2, 3, IEC 60947 & IEC 157-1 & latest I.E. Rules applied in the manner amended or supplemented by this specification wherever applicable. In all cases latest revision to these specifications referred to above shall apply any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with the approval of employer.

- 15.3.2.5 The switchgear/panel shall be metal enclosed, free standing, dust / vermin proof. Air filter, if required, shall be easily removable, and replaceable. The switchgear/panel shall be self-cooled type adequate to meet the full load at an ambient temperature.
- 15.3.2.6 Each switchgear/panel shall be complete with internal buses, connections and flanges for external bases, protective devices, control wiring, terminal blocks, lockable doors, foundation bases and all other necessary accessories, Carrying handles shall be provided for all removable plates or covers.
- 15.3.2.7 Suitable venting shall be provided for each switchgear/panel chamber to relieve the high pressure developed during fault interruption and to ensure that the arc products are directed safely away from operating personnel.
- 15.3.2.8 Fuses, power auxiliary transformers, potential transformers, current transformers, heaters, relays, meters and all other accessories required to provide a complete and operable switchgear assembly shall be provided.
- 15.3.2.9 Equipment shall be constructed and assembled such that it can reasonably be moved to installation locations through doorways provided in the building design.
- 15.3.2.10 Edge or other surface shall be smooth.
- 15.3.2.11 Channel base or base plates with mounting bolts & nuts for installation of Switchgear/panel shall be provided. The bases may be shipped separately and earlier as instructed after contract.
- 15.3.2.12 The DC switchgear enclosure shall be insulated from ground by an insulated floor topping and allowing for circuit breaker removal from the front. Wherever the switchgear enclosure is less than one meter from any vertical building surface, such as a wall or column, the Contractor shall furnish non-hygroscopic sheet insulation to cover the vertical surfaces to protect against any accidental contact between DC switchgear enclosure and the grounded surface. A 2.5 kV high potential insulation test shall be performed on the insulation between the enclosure and ground, and between the enclosure and any vertical walls, upon completion of the installation. The DC switchgear enclosure shall be furnished with insulating joints to provide electrical isolation from the rectifier enclosures.

15.3.3 RATINGS

- 15.3.3.1 The switchgear shall be designed to ensure rapid opening of its main contact on detection of a short-circuit, and to quickly extinguish the arc by generating a constant over-voltage during the whole interruption process. The rating mentioned in this specification is the expected requirement. The others are indicated in Table 15.1;

Table 15.1: DC High Speed Switchgear Rating

SN	Description	High Speed DC Switchgear Rating
1.	Type	Indoor horizontal type suitable for floor mounting
2.	Relevant Specification	EN 50123, IEC 61992-1
3.	Rated Insulation Voltage	1800 V DC

15.3.3.2

SN	Description	High Speed DC Switchgear Rating	
4.	Highest non-permeant voltage as per IEC 60850	1000 V DC	
5.	Rated continuous current at +35 ⁰ C (includes overload rating of 150 % for 2hrs and 300 % for 1 minute as per Class-VI defined in EN 50328)	4000 A (Feeder & Bypass HSCB/DS)	6000 A (Incomer HSCB)
6.	Bus bar rating	6.7kA Continuous & 10kA for 2 hours	
7.	Short circuit rating	IN _{SS} 125 kA for 100 ms	
8.	Mechanical lifetime	Not less than 25000 cycles	
9.	Insulation level of circuit breaker		
a.	One-minute dry power frequency voltage withstands	6.9 kV, AC 50 Hz main circuit to earth 8.3kV, AC 50 Hz Pole to Pole	6.9 kV, AC 50 Hz main circuit to earth 8.3kV, AC 50 Hz Pole to Pole.
b.	Impulse withstand 1.2/50 micro seconds (full)	15kV, main circuit to earth 18kV, Pole to Pole	15kV, main circuit to earth 18kV, Pole to Pole.
c.	Auxiliary Circuit	2 kV for 1 minute	
10.	Rated making current	IN _{SS} 125 kA for 100msec	
11.	Rated Breaking Current		
12.	Type of main contacts	Fix and moving contact	
13.	Contacts	Copper	
14.	Whether contacts are silver faced or plated	Contact pad – Silver alloy Contact – Silver plated	
15.	Arc control device	Compartmented arc chute	
16.	Opening time from the instant of trip circuit energization	< 20 msec (direct tripping)	< 20 msec (direct tripping)
17.	Total interrupting time from the moment of trip coil energization to final extinction of arc	According to di/dt	
18.	Rated auxiliary supply voltage	230 V AC 50 Hz	
19.	Closing & Tripping	110 V DC	
20.	Auxiliary Contacts		
a.	Normally Open	5 NO	
b.	Normally Closed	5 NC	
21.	Degree of protection	IP 3X	
22.	Type of Cable Entry	Top Entry (Elevated Stations), Top/Bottom Entry (UG station) & Bottom Entry (Depot)	

- 15.3.3.2.1 The environmental and climatic data in Lucknow are provided in General Specifications.
- 15.3.3.2.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.
- 15.3.3.2.3 Submittals
- The submittals shall have the following details
- i. Description of equipment
 - ii. Single Line Diagram
 - iii. Details of interconnection
 - iv. Cross Section and DC bus details
 - v. Wiring diagrams & cable termination details
 - vi. Schematic diagrams
 - vii. Elevation drawings
 - viii. Temperature rise data
 - ix. Production test data
 - x. Surge arrester details
 - xi. Bill of material
 - xii. Testing Procedure
 - xiii. Certified copies of factory tests in accordance with referenced standards

15.3.4 CONFIGURATION

- 15.3.4.1 The HSCB shall consist of various types of panels depending on the adopted configuration at a specific location. The site specific configurations have been indicated in the Power Schematic Diagram and sectioning schemes. A typical configuration at a ASS/ TSS may be as follows;
- a) 2 incoming feeder panel from rectifiers
 - b) 4-line feeder panels
 - c) 4 nos. motorized isolator feeding third rail
 - d) 2 load bypass breaker / disconnecter panels (as per tender drawings)

15.3.4.2 Incoming Feeder Panel

- 15.3.4.2.1 The incoming feeder connects the 750 V DC busbar with the rectifier. The design of the incoming feeder shall include following features:
- a) High Speed Circuit Breaker mounted on a truck
 - b) Protection relay with reverse current protection
 - c) Trip operation in case of a frame fault in the DC switchgear
 - d) A local and remote alarm indications
 - e) Physical Local/Remote Selector Switch on the panel door/Selector switch functionality on touch screen display
 - f) Push Buttons for HSCB ON/OFF on the panel door/ON/OFF functionality on the touch screen display.

- g) Mechanically operated position indicator to indicate the circuit breaker 'disconnected', 'test' and 'service position'
- h) Operation counter
- i) Panel heater with on/off switch and automatic temperature control
- j) Current measurement and indication (Operation to be also performed by display)

15.3.4.3 **Line Feeder Panel**

15.3.4.3.1 The line feeder connects the 750 V DC busbar with the 3rd rail. The design of the line feeder shall include following features:

- a) High Speed Circuit Breaker mounted on a truck
- b) Protection relay with di/dt protection detecting short circuits on the 3rd rail
- c) Test equipment for reclosing the Line Feeder breaker after di/dt protection trip
- d) Transfer trip operation
- e) Trip operation in case of a frame fault in the DC switchgear
- f) A local and remote alarm indication
- g) Physical Local/Remote Selector Switch on the panel door/Selector switch functionality on touch screen display
- h) Voltage relay for measuring third rail 'live/dead' status and third rail voltage to be tele-signaled to OCC
- i) Push button for CB ON Direct which will bypass the line test procedure (Operation to be also performed by display)
- j) Push Buttons for HSCB ON/OFF on the panel door/ON/OFF functionality on the touch screen display
- k) Mechanically operated position indicator to indicate the circuit breaker 'disconnected', 'test' and 'service position'
- l) deleted
- m) deleted
- n) Functional requirements of i), j), k), l) & m) shall be integrated in HMI on the face of the panel
- o) Operation counter (shall be transmitted to SCADA)
- p) Panel heater with on/off switch and automatic temperature control
- q) Emergency tripping scheme (through the operation of ETS)

15.3.4.4 **Bypass Dis-connector Panel**

15.3.4.4.1 The Bypass Disconnector Panel connects two adjacent 3rd rail sections in case of an outage of an ASS/TSS. These panels shall be placed at track side/inside TSS room. The design of the Dis-connector Panel shall include following features:

- a) Dis-connector switch
- b) Push button for ON/OFF with LEDs for status indication
- c) Voltage monitoring relay
- d) A local alarm indication
- e) A Local/Remote selector switch
- f) Anti-condensation heating in the low voltage compartment

15.3.4.5 **HSCB Line Isolators/Disconnector**

Independent offload disconnectors for each line HSCB on the outgoing side to be accommodated on the track side/Inside TSS Room. Line disconnectors shall be off-load type and motor operated with all necessary safety interlocks between HSCB and disconnector. Hardwired and mechanical interlocks to be provided to prevent disconnector opening when the respective HSCB is ON. These line isolators shall be capable of remote monitoring and operation from SCADA. The current and voltage rating of the disconnectors shall similar to feeder HSCB and shall also comply with over load duty cycle. Moving and fixed contacts of disconnector shall be of copper and all other technical compliance shall be in accordance with EN 50123-3 or latest IEC to be followed.

- 15.3.4.6 The disconnector shall be designed for the rating and other particulars indicated in Table 15.2;

Table 15.2: Line Feeder Disconnector and Coupling Dis-connector Switch Rating

Sl. no.	Description	Values	
1.	Type	Feeder Disconnector switch	Coupling Dis-connector Switch
2.	Governing Specifications	EN 50123 or IEC 61992	EN 50123 or IEC 61992
3.	Nominal Voltage	750 V DC	750 V DC
4.	Rated Insulation voltage	1800 V	1800 V
5.	Rated continuous current	4000 A	4000 A
6.	Short circuit current	125 kA for 250 ms	125 kA for 250 ms
7.	Operation	Offload, Motorized	Off-load Motorized
8.	Main Contacts	2	2
9.	Dry one-minute power frequency withstand voltage	11.2kV, AC 50 Hz main circuit to earth 11.2kV, AC 50 Hz Pole to Pole.	
10	1.2/50 μ s dry impulse level	20kV, main circuit to earth 20kV, Pole to Pole.	
11	Cabinet	Standalone panel GRP preferred	Standalone panel GRP preferred
12	Application	Indoor/Outdoor	Indoor/Outdoor
13	Type of Cable Entry	Top Entry or Bottom Entry depending on final locations	

15.3.5 CONSTRUCTION FEATURES

15.3.5.1 General

- 15.3.5.1.1 The switchgear metal enclosure inclusive of exhaust vent for de-ionized gases shall be of robust construction and shall be designed to prevent the ingress of moisture and vermin. Metal parts shall be provided with inter-panel dustproof seals of corrosion resistant material. All panel doors shall have latching mechanism to be held in fully open position.

- 15.3.5.1.2 All circuit breakers shall be single pole, high speed, draw out type with protection against entering or withdrawing a closed breaker. The breaker shall have a power disconnected rack out position with the control still connected for test.
- 15.3.5.1.3 Removable feeder circuit breaker elements of the same rating shall be completely interchangeable.
- 15.3.5.1.4 All breakers shall have trip free and anti-pumping facility suitable for automatic reclosing. The breakers shall have solenoid closing and shunt trip from 110 V DC control circuit.
- 15.3.5.1.5 All circuit breakers shall have 'service', 'test' and 'disconnected' positions. When the breaker is in 'test' position, local/remote switching and trip tests shall be able to be carried out.
- 15.3.5.1.6 Each circuit breaker shall be easily maneuvered, and its position shall be fitted with guide rails to locate the truck with sufficient 'lead in' to permit ease of entry without damage to either truck or housing. Front door shall also be able to close and have provision for interlocking and pad locking at all switchgear track position
- 15.3.5.1.7 To prevent access to live bus bars when a truck is withdrawn for maintenance, provision shall be made on each fixed housing for lockable electrical insulated shutters to cover the equipment of the main fixed contacts the shutter shall have latching mechanism to be held in open position for ease of access during maintenance. The shutter automatically be closed when the breaker is racked out. The shutter automatically be closed when the breaker is racked out.
- 15.3.5.2 Panels shall be designed in such a manner that preferably the cable entry is from the top for the at grade/elevated/UG corridor stations. In case it is not feasible to provide panels with top entry, the contractor shall make suitable provisions in the room for mounting of the switchgear. Minimum height of the lowest beam has to be take into account for providing equipments in ASS/TSS room. For Depot ASS/TSS cable entry shall be from top or bottom.
- 15.3.5.3 The platform so designed shall also be checked for a factor of safety of 2.5 for normal condition and 1.65 for short circuit condition against sliding, overturning and pullout. The same factors shall be used as partial safety factor over loads in limit state design.
- 15.3.5.4 Following factors are to be considered while designing mounting platform for HSCB:
- a) The structure design shall be such that during operation of circuit breaker vibrations are reduced to minimum.
 - b) The Contractor shall provide suitable access and means on both sides of the circuit breaker for easy accessibility for monitoring.
 - c) All the elements shall be accessible without removing support structures for routine inspections and possible repairs. The removal of individual enclosure parts, or entire breaker bays shall be possible without disturbing the enclosures of neighboring bays.
 - d) The enclosure & support structure shall be designed that a mechanic 1780 mm in height and 80 Kg in weight is able to climb on the equipment for maintenance.
- 15.3.5.5 **Cubicle**

- 15.3.5.5.1 The cubicle shall be of dust and vermin proof cabinet employing sheet metal of thickness and with provision for locking more than one breaker shall be arranged in one formation. All non-welded assemblies shall be assembled by means of bolts and nuts with mandatory use of lock-washers. All panels, separating partitions and accessories shall be mounted similarly, in such a way to withstand indefinitely the vibrations transmitted, in particular by the resetting mechanism of the circuit-breakers and their actuation.
- 15.3.5.6 **Cubicle Compartments**
- 15.3.5.6.1 The cubicles shall be draw out type consisting of basically two parts viz. fixed and moving part to facilitate maintenance, replacement or even modification operations with shutdown affecting only the involved circuits. The fixed part shall be divided in to four compartments bus bar, cabling compartment, trolley compartment and low voltage metering compartment which are separated by means of barriers / shutter to prevent fault propagation between compartments. Seal off bushings / shutters are to be provided between Breaker compartment to Busbar and Cable compartment to ensure no ionized gases from breaker compartment is transmitted to either of fixed compartments.
- 15.3.5.6.2 Bus Bar Compartment
- 15.3.5.6.3 Bus bar compartments shall house Bus bars. The bus bar shall be of rectangular cross-section. Bus bars shall be supported on insulating supports. Bus bars shall be air insulated. Bus bars shall be capable of handling all sorts of temperature rise caused by the current.
- 15.3.5.6.4 Bus bars shall have continuous rating capacity and shall withstand short circuit. All bus bar shall be of copper conforming to relevant international standards. The bus bar shall be clean smooth, mechanically sound and free from other defects. Provision shall be made where necessary, to allow extension both in section and length at any time without difficulty.
- 15.3.5.6.5 Cabling Compartment
- 15.3.5.6.5.1 The cabling compartment should be designed in such a way that sufficient space is made available for termination of feeders. It may be noted that multiple number of feeder cables shall be connected to each terminal through heat sink termination. The cable compartment depth shall be less than one meter and the clearance between the bottom of the bus bar to base plate is of minimum 500 mm. The bus bar shall be provided with suitable holes of 300 Sqmm cable for termination of minimum 6 (six) copper cables per feeder and also to accommodate the cables for load bypass breaker. It shall also be provided with the cable-supporting clamp. Care should be taken during design stage so as to ensure proper cable termination of the panel.
- 15.3.5.6.5.2 The cable compartment shall have the provision for shunt connections and series resistor or current and voltage measurement or preferably Hall Effect Current sensor and Voltage Sensor.
- 15.3.5.6.6 Trolley and Trolley Receptacle Compartment

- 15.3.5.6.6.1 The breaker compartment shall be fully draw out self-contained truck arrangement type. The inter-changeability of cubicles and circuit breaker shall be ensured by the use of very accurate production and assembly works. A front door shall be provided in each circuit breaker cubicles, which shall be opened for inserting or withdrawing the breaker from the cubicle.
- 15.3.5.6.6.2 The switchgear compartment shall be fully draw out self-contained truck arrangement with breakers mounted on the same. A racking handle shall be provided to facilitate for case of insertion and withdrawal of breaker truck to and from the service position. The switchgear truck shall have three positions.
- a) Service position
 - b) Test position
 - c) Withdrawn position.
- 15.3.5.6.6.3 The trolley shall have the control button (may be installed on door of LV compartment) and the open and closed position annunciation/indication via display. It shall have auxiliary annunciation contacts displaying whether the circuit-breaker is in open or closed position, connected to the terminal board of the low voltage circuits. Spare open and closed contacts shall be available in addition to those used for low voltage control and monitoring circuits. It shall have a grounding contact connecting the frame circuit of the circuit-breaker to the cubicle grounding bus-bar, interlock mechanisms, plugging actuator, manual actuating auxiliary system and operating counter.
- 15.3.5.6.6.4 The actuating system shall be of solenoid type, with low transient current consumption when arming the circuit breaker. The closing action of the circuit of the circuit breakers shall be ready for instantaneous tripping. It shall be equipped with an anti-hunting device capability.
- 15.3.5.6.7 LV Compartment
- 15.3.5.6.7.1 The low voltage compartment shall consist of all control, monitoring and measurement devices. Auxiliary voltage shall be 110 VDC (+10%, -20 %) for motors, monitoring and control circuits. In all other section HSCBs cabling shall be done with FRLS/FRLSOH cables. Following shall be necessarily provided:
- a) Relay and facade indicator light/LED
 - b) Open/closed and connect/disconnect position indicator lights and contacts.
 - c) Facade measurement indicators (counter, Ammeter & Voltmeter when required)
 - d) Facade mimic visual diagram on HMI display
 - e) Control and monitoring devices for the CB (programmable logic control)
 - f) Control and monitoring, multi pin connector
 - g) Numerical relays
 - h) Lockable access door

- 15.3.5.6.8 Each cubicle shall be provided with space heater element of sufficient capacity with thermostat control of 35°C over ambient temperature at loading condition. The cubicles shall be capable of withstanding without any damage the loads generated by short-circuits. The degree of protection shall be IP 3X.
- 15.3.5.6.9 The circuit breaker cubicle shall have features that prevents any access to the live parts. The cubicle shall be so designed that adequate ventilation window covered with wire mesh protection shall be provided on the top of each cubicle.
- 15.3.5.7 **Grounding**
- 15.3.5.7.1 The DC switchgear and rectifier enclosure shall be insulated from ground (earth) and connected to earth bus to enable operation of the frame leakage relay. Contractor shall submit the technical details of methods of achieving the insulation in the technical proposal.
- 15.3.5.7.2 Each cubicle shall comprise a copper grounding bus-bar of suitable cross-section to which each of the metal masses of the component parts of the cubicle shall be connected, together with those of the instrument transformers. The grounding bus-bars of the various cubicles shall form a linkage interconnected together and a common single collector line shall be provided for connecting it to the substation earth system through frame leakage relay. The withdrawal trolley will be connected to this grounding bus-bar via a plug-in/out contact.
- 15.3.5.8 **Paint**
- 15.3.5.8.1 Painting should be suitable for polluted atmosphere and has to comply with IEC 60721-2-5 standard. As a minimum, an initial coat of rust-proofing and anti-corrosion paint will be applied after baring of all metal surfaces; then they will be covered with two coats of paint and one finishing coat, colour to be defined. The Contractor shall submit to the Engineer, the complete details of the switchgear cubicles metal work and paintwork details, including details of the structure, process of finish and painting etc, for Engineer's/Employer's approval. The total thickness should not be less than 60µm and withstand 120°C.
- 15.3.5.9 **Nuts & Bolts**
- 15.3.5.9.1 The threads and hexagons of all nuts, bolts and stud shall confirm to relevant IEC or EN subject to interchangeability with equivalent metric size. No bolt or stud shall project through its nut(s) more than 6mm (or) four threads, except when otherwise approved for terminating stud/bolts. If bolts and nuts are so placed that they are inaccessible by means of ordinary spanners. All terminals should be provided with suitable cadmium plated and passivated high tensile steel hard wires facilitate cables termination.
- 15.3.5.9.2 All Nuts and Bolts shall be of SS type.
- 15.3.5.9.3 **Fitting & Accessories**
- 15.3.5.9.4 As a minimum following fittings and accessories shall be provided for each circuit breaker:
- a) Mechanically operated tripping and closing device

- b) Local / Remote /off control switch
- c) Operation counter
- d) Supporting frame if needed
- e) Name plate
- f) Foundation bolts if required
- g) Semaphore indicators (if required)
- h) Meters
- i) Line testing device (LTD), shunts, voltage measuring devices as required

15.3.5.10 The degree of protection shall be IP3X or higher.

15.3.5.11 The Contractor will furnish along with rates for requirement of spares essential for maintenance for five years.

15.3.6 SAFETY FEATURES

15.3.6.1 The design shall incorporate / provide full precaution for safety of all those working personal associated with maintenance of the Switchgear. The following safety features shall be provided as a minimum.

- a) It shall not be possible to insert CB into the service when it is in closed condition.
- b) It shall not be possible to withdraw the CB from service Position unless it is in open condition.
- c) It shall not be possible to close the CB in any position except when properly brought to service, test and isolated position.
- d) All access to the fixed plug-in parts is prevented when the apparatus is withdrawn.

15.3.6.2 The cubicles shall be protected against fire by means of automatic fire detector and extinguisher system with linear fire detection tube based clean agent direct gas flooding system. The detection has to be done by the linear heat detection tube which will be routed inside the panel as per the design calculation. The tube shall be double layered made of Hi-tech Polymer either Fire Detect, Fire Trace or equivalent. The system shall utilize unique flexible tubing that shall be attached to the top of the container valve. This tubing shall be pressurized with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C), is temperature sensitive and shall act as a continuous linear thermal detector that shall rupture upon flame impingement. Once the detection tubing is ruptured, forming a nozzle at the rupture point, it shall allow the Clean Agent through the nozzle into the protected area. The clean agent offered should be as designated in NFPA 2001 [Section A.5.5.1(B)] and ISO 14520 Clean Agent Standards. Its 'ASHRAE' nomenclature is (FK5-1-12 or its equivalent (Novec 1230)). Gas should have lowest Global Warming potential. The quantity of clean agent required should be calculated as per NFPA 2001 and BIS standards. Clean agent container shall be designed, fabricated, certified with stamp on the containers in accordance with the requirements of NFPA. Containers shall be standard model and size for ease of replacement and addition. Fill containers with required Clean Agent (FK5-1-12 or its equivalent (Novec 1230)). Pressurise with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C). Container/cylinders shall have PESO approval /Govt. Approved Lab.

15.3.7 INTERLOCKINGS

- 15.3.7.1 The interlocking of power supply system shall not be limited to the requirement specified herein. The Contractor shall also comply with the interlocking requirements elsewhere in this Specification. The Contractor shall ensure that inadvertent operation which will result in human injury or equipment damage is prohibited by the interlocking scheme. In general the interlocking shall be achieved through redundant means such as:
- a) Program logic
 - b) Electric circuits
 - c) Mechanical key/pad lock etc.
- 15.3.7.2 The Contractor shall submit detailed proposal for the interlocking facilities for the review by the Engineer.
- 15.3.7.3 All interlocking as per approved scheme shall be incorporated. Following interlocking shall be necessarily incorporated:
- a) When unplugged and withdrawn from the cubicle, the apparatus shall enable the key to be turned.
 - b) By turning the lock and withdrawing the key, it shall not be possible to plug-in the circuit breaker.
 - c) The type of lock shall be selected among equipment considered as being safety equipment.
- 15.3.7.4 Electrical/Mechanical interlocking between negative return switch and concerned rectifier HSCB shall be provided.
- 15.3.7.5 Necessary interlocks in remote and local control modes shall be provided as per the final approved scheme.
- 15.3.7.6 Key interlock assembly shall be provided for interlocking main breaker with rectifier negative disconnect switch.
- 15.3.7.7 Electrical and mechanical interlock between line disconnect and line HSCB to be provided to ensure the line disconnect is forbidden to open when HSCB is closed and vice versa.
- 15.3.7.8 Display lamps for voltage on, annunciation lamps shall be installed on the front face of the cubicle and via display.
- 15.3.8 MAIN CONTACTS**
- 15.3.8.1 The main fixed and moving contacts of the circuit breakers shall have ample cross section and contact pressure for carrying the rated current and short time current without excessive temperature rise, pitting or welding.
- 15.3.9 OPERATING MECHANISM**
- 15.3.9.1 The circuit breaker operating mechanism shall be Electro-magnetic closing and with electric or magnetic holding as approved by Engineer or solenoid actuating mechanism which shall be so designed as to enable continuous sequence of opening and closing operations through a control switch as long as power is available.
- 15.3.9.2 The power operated closing and tripping or solenoid actuating mechanism shall be suitable for operation from a 110 V battery supply subject to voltage variation of + 10% and -15%.

- 15.3.9.3 The operation of the power operated closing device when the circuit breaker is already closed shall not cause damage to the circuit breaker or endanger the operator. The control system shall be such as to enable min 3 (Three) closing operations to be made successively at intervals of 30 seconds.
- 15.3.9.4 Although the operating mechanism shall normally be operated by remote control even then, local electrical closing and tripping facilities shall also be provided. For that purpose, the following items shall be provided:
- a) A three-way control switch with local / remote / off position
 - b) A "trip" button and
 - c) A "Close" button
- 15.3.9.5 In addition to the above, a mechanical closing and tripping device shall also be provided. This device as well as local electrical control switches shall facilitate to operate the circuit breaker conveniently by a person standing on the ground.
- 15.3.9.6 All entries of cables into the cabinet shall be through suitable glands which shall not allow access of water in to the cabinet. All wiring shall be provided with suitable identification ferrules at the ends. All the terminal marking shall be indelible and preferably engraved. Separate terminal blocks for DC and AC wiring shall be provided in the cabinet.
- 15.3.10 AUXILIARY CONTACTS**
- 15.3.10.1 At least 5 (five) pairs (five each of NO and NC) of auxiliary contacts shall be provided for the exclusive use of purchaser in the external circuits.
- 15.3.10.2 The auxiliary contacts shall have a continuous current carrying capacity of at least 5A and shall be capable of breaking 5A current at 110 V DC without any problem.
- 15.3.10.3 All ferrous parts used shall be hot dip galvanized to applicable IEC/EN.
- 15.3.11 LABELS**
- 15.3.11.1 Description labels of non-corrosive material or vitreous enamelled iron plate (preferably SS) shall be of approved design and material that will ensure permanence of lettering. The finish shall be such that provides dazzle free look from the reflected light. The colour used shall be permanent and non-fading. All the screws used for fixing the labels shall be of brass or with steel screws, which have received an approved rust preventive treatment.
- 15.3.12 PROTECTION SYSTEM**
- 15.3.12.1 Numerical relays shall be used for protection. The protection system function, protection relay features and protection relay specifications as defined under Clauses 14.2.7.2 to 14.2.7.4 of Chapter 14 (ASS) shall be generally applicable to these protection relays, with compliance to the following standards for EMC immunity (instead of the ones defined under Clause 14.2.7.4):
- EN 50121-4:2000 Railway applications – Electromagnetic compatibility Part 4: Emission and immunity of the signaling and telecommunications Apparatus
- EN 50121-5: 2000 Railway applications – Electromagnetic compatibility Part 5: Emission and immunity of fixed power supply installations and Apparatus
- IEC 61000-6-2:1999, modified / EN 61000-6-2:2001 Electromagnetic compatibility (EMC) Part 6-2: Generic standards - Immunity for industrial environments

15.3.12.2 **Protections**

- 15.3.12.2.1 The protection relays for the protection of incomers and feeders shall be normally mounted on the panel.
- 15.3.12.2.2 Each PCU shall be integrated with a protection relay module within which standard protective relay features are incorporated. The Equipment shall comply with IEC 60255 or EN. The application, performance and testing of protection relay modules shall be in accordance with the appropriate IEC standards.
- 15.3.12.2.3 Separate/Dedicated frame leakage protection to be considered for HSCB Cubicle (Feeder & Incomer HSCBs) as a group.
- 15.3.12.2.4 The relay display shall have a provision of the mimic diagram on HMI with live status.

15.3.12.3 **Protections for HSCB**

- 15.3.12.3.1 The HSCB shall Include minimum of flowing protection but not limited any additional protection required for successful operation shall be considered and provided by the contractor.

15.3.12.3.2 Incomer from Rectifier

The protection of this circuit shall consist of:

- a) 27: Under voltage relay
- b) 59: Over voltage relay
- c) 50: Instantaneous overcurrent protection and time delayed feature
- d) 51: Time delayed over current protection
- e) 32: Reverse power relay
- f) 76: DC Over current series trip relay
- g) 64: Frame leakage protection (~~separately~~)
- h) Instantaneous electro-mechanical element
- i) Anti-pumping protection

15.3.12.3.3 Feeder to Third Rail

- a) The protection of this circuit shall consist of:
- b) 50: Instantaneous over current protection and time delayed feature
- c) 59: Over voltage relay
- d) di/dt protection
- e) 85: Inter tripping relay (Inter tripping between ASS/TSS shall be achieved through 33kV pilot wire)
- f) 27: Under voltage relay
- g) 21: Line testing device

- h) 82: Auto reclosing relay
- i) 64: Frame leakage protection (~~separately~~)
- j) Instantaneous electro-mechanical element
- j) Anti-pumping protection

15.3.12.4 **Other Features**

- 15.3.12.4.1 The signal of current value for protection unit is taken from the instrument shunt of 6000A/60mV. The power is supplied to the protection unit from the auxiliary power source with rated voltage 110 V DC.
- 15.3.12.4.2 The protection unit shall be able to control the circuit breaker on trip event. Capability of voltage holding between protection unit case and main input of bus bars shall be 50 Hz, 1min, 2000 V.
- 15.3.12.4.3 The protection unit shall be able to communicate with RTU of remote-control SCADA system.
- 15.3.12.4.4 The inter-tripping of 750 V DC feeder HSCB shall be achieved through the pilot wire (FO cable) laid between NRP of one TSS to other TSS. .
- 15.3.12.4.5 Where applicable, lightning and switching surge arresters shall be provided for feeder and of feeder circuit breakers and sectionalizing switches.
- 15.3.12.4.6 All the DC relays shall be communicated with the Ethernet switch installed in NRP panel in Star topology configuration with redundant path through PRP (Parallel Redundancy Protocol) over IEC 61850 protocol.
- 15.3.12.4.7 Traction contractor shall supply and lay redundant Communication cables up to SCADA RTU for Communication of relays/ IEDs signals over IEC 61850 protocol.

15.3.13 **TYPE AND ROUTINE TESTS**

- 15.3.13.1 Type tests are to be carried out on the proto type Circuit Breaker in accordance with the provision contained in this specification which are governed by manufacturing and testing standards as applicable.
- 15.3.13.2 If prototype test confirming to this specification has already been conducted then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the Contractor for consideration.
- 15.3.13.3 All circuit breakers shall be subjected to the routine test at the manufacturer's works with the attendance of Engineer's representative.
- 15.3.13.4 Manual closing and tripping operation shall be carried out to ensure satisfactory operation.
- 15.3.13.5 Routine tests on the solenoid actuating mechanism in accordance with relevant IEC or EN to be submitted for approval.

15.3.14 VIBRATION AND NOISE

- 15.3.14.1 Every care shall be taken to ensure that the design and manufacture of the equipment and auxiliary plant shall be such as to reduce noise and vibration to the minimum level as applicable IEC.
- 15.3.14.2 Every care shall be taken to ensure that the noise produced by this machine is minimum. Necessary noise reducing methods may be applied and the noise at the machine shall not be more than as specified in the EN or applicable IEC.
- 15.3.14.3 The Contractor shall submit five sets of detailed technical literature and descriptive pamphlets for the equipment to be supplied. The technical document of equipment shall also contain the maintenance & operation manuals.

15.3.15 GTP FOR DC HIGH SPEED CIRCUIT BREAKER

- 15.3.15.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 15.3.15.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.3: GTP for DC High Speed Switchgear

SN	Description	Unit Of Measurement	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Relevant Specification		
4	Manufacturer's type designation		
a	Circuit breaker		
b	Operating mechanism		
5	Rated voltage	V	
6	Max operational voltage	V	
7	Operation peak overvoltage	V	
8	Rated continuous current at +35C temp	A	
9	Short time current rating for 2 min	A	
10	Short time current rating for 1 min	A	
11	Short time current rating for 10 sec	A	
12	Tripping time		
13	Mechanical life time	Cycles	
14	Insulation level of circuit breaker		
a	One minute dry power frequency voltage withstand	kV	
b	Impulse withstand 1.2/50 micro sec full wave	kV	
15	Rated making current	kA	
16	Rated breaking capacity		
17	Short time current		
a	1 Sec	kA	
b	3 Sec	kA	

SN	Description	Unit Of Measurement	Manufacturer's Data
18	Length of contact travel	mm	
19	Type of main contacts	mm	
20	Type of arcing contacts		
21	Material of contacts (Including chemical composition)		
a	Main contacts		
b	Arcing contacts		
c	Whether contacts are silver faced or plated		
22	Type of arc control device		
23	Net weight of CB with operating mechanism etc	Kg	
24	Impact for foundation design (Including dead load plus maximum impact value on opening)	Kg	
25	Maximum Dimensions of cubicle		
a	Length		
b	Width		
c	Height		
26	Operating time from the instant of trip circuit energization		
a	With no current	msec	
b	At rated current	msec	
c	At rated breaking current	msec	
27	Making time from the instant of close circuit energization	msec	
28	Opening time from the instant of trip circuit energization		
29	Arcing time		
a	At rated current	msec	
b	At rated breaking current	msec	
30	Total interrupting time from the moment of trip coil energization to final extinction of arc	msec	
31	Total duration of arc	msec	
32	At normal rated current minimum time between successive operation	msec	
33	Rated auxiliary supply voltage		
a	Closing coil	V	
b	Trip coil	V	
34	Type of tripping mechanism		
35	Details of operating counter		
36	Auxiliary contacts		
a	Normally open	Nos.	
b	Normally closed	Nos.	
c	Continuous rating of contacts	A	
d	Breaking capacity of contacts	A	

SN	Description	Unit Of Measurement	Manufacturer's Data
37	Maximum noise level during opening and closing actuation	dB	
38	Degree of protection of cubicle		
39	Degree of protection of auxiliary circuit		
40	Protection relays provided for HSCB		

15.3.16

TEST SHEET FOR HSCB

**Table 15.4: Test Sheet for DC High Speed Switchgears
(IEC-61992-2: 2014 & EN-50123-6: 2003)**

Test Description	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Verification of conformity to the manufacturing drawings and to characteristics of assembly and Circuit Breaker.		X	X	X	
Operation		X	X	X	
Dielectric withstand: - impulse withstand	X	X	X		
Insulation resistance		X	X	X	
Dielectric withstand: - power-frequency voltage withstand test for main circuit and auxiliary circuits	X	X	X		
Short-time withstand current - main circuits - busbars - earthing circuits - circuit breakers	X		X		
Mechanical operation	X	X	X	X	
Verification of degree of protection	X				
Temperature-rise	X				
Electrical operation	X	X	X	X	
Measurement of Breaker contact resistance test		X	X	X	
Measurement of Breaker opening & Closing time		X	X	X	
Verification of the adjustment of the relays and releases		X	X	X	
Electrical Endurance	X				
Mechanical Endurance	X				
Short Circuit behavior	X				
Search for critical currents and low current test duty	X				
Wiring		X	X	X	
Function		X	X	X	

Test Description	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Interlocking		X	X	X	
Painting & external visual inspection		X	X	X	X
Visual inspection		X	X	X	X
Frame Leakage			X	X	
Line test Device Test			X	X	
Relay & Protection			X	X	
SCADA Testing			X		
Arcing due to internal fault test	X				
Verification of the making and breaking characteristics in short circuit condition and of the H characteristic	X				

15.4 RECTIFIER

15.4.1 SCOPE

15.4.1.1 This specification applies to Silicon Rectifier assemblies and equipment for indoor installation at Lucknow Metro Traction Substations. It shall meet the technical requirements as specified herein. The Rectifier shall be manufactured for traction power system of Lucknow Metro Project. The scope of work includes design, supply, installation, testing and commissioning of Rectifiers along with accessories.

15.4.1.2 The equipment offered shall be complete in all parts and accessories necessary for their efficient performance / operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.

15.4.1.3 For the purpose of this specification, the following definitions shall apply:

- a) **Rectifier Cell:** The elementary rectifying device consisting of one or more rectifier diodes which represents an asymmetrical conductivity complete in its envelope and with cooling fins integral part of it.
- b) **Rectifier Stack:** A single structure of one or more rectifier cells with their associated mountings, cooling attachments and connections whether electrical or mechanical.
- c) **Rectifier Assembly:** An electrically and mechanically combined assembly or stacks, complete with all its connections, together with means of cooling if any, in its own mechanical structure.
- d) **Rectifier Equipment:** An operative assembly comprising of one or more rectifier assemblies together with essential protection devices and other auxiliaries, if any, for conversion of AC into DC working along with AC circuit breakers, which withstand and clear the DC side fault as per this specification.
- e) **Cell String:** This comprises of a suitable number of cells connected in series or parallel forming a part of the arm of the bridge.
- f) Rectifier assembly should be provided with top covers to avoid fall of dust and entrance of insects, etc.

15.4.2 SPECIFICATIONS

- 15.4.2.1 The silicon rectifier assembly shall unless otherwise specified, conform to:
- i. IEC 62589 - Railway applications – Fixed installations – Harmonization of the rated values for converter groups and tests on converter groups
 - ii. IEEE 519 – Recommended Practice and requirements for Harmonic Control in Electrical Power System.
 - iii. IEC 60146-1-2 – Semiconductor convertors; general requirements and line commutated convertors; part 1-2: application guide.
 - iv. IEC 62590 - Railway applications – Fixed installations – Electronic power converters for substations
 - v. IEC 60850 - Railway applications – Supply voltages of traction systems
 - vi. IEC 60747-2 - Semiconductor devices
 - vii. EN 50327 – Railway applications- Fixed installations- Harmonization of the rated values for converter groups and type test on converter groups.
 - viii. EN 50328 – Railway applications- Fixed installation- Electronic power converters for substations.
 - ix. EN 50124-1 – Railway applications – Insulation, coordination – Part 1: Basic requirements; Clearances and creepage distances for all electrical and electronic equipment.
 - x. EN 50122-1 – Railway applications – Fixed installations – Part 1: Protective provisions relating to electrical safety and earthing.
 - xi. EN 50163 – Supply voltage of traction system.

15.4.3 Submittals

- 15.4.3.1 Submittals shall include the following:

- i. Description of equipment
- ii. Arrangement drawings
- iii. Details of interconnection
- iv. Diode technical data
- v. Wiring diagrams & cable termination details
- vi. Schematic diagrams
- vii. Elevation drawings
- viii. Temperature rise data
- ix. Production test data
- x. Surge arrester details
- xi. Bill of material
- xii. Certified copies of factory tests in accordance with referenced standards

- 15.4.3.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with approval of Employer/Engineer.

- 15.4.3.3 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for all elevated section.

15.4.3.4 Fire Retardant Low Smoke Zero Halogen Type (FRLSOH) for all Underground section.

15.4.4 RATINGS

15.4.4.1 Type: The rectifier shall be indoor, convection-cooled in a free standing steel enclosure, 750 Volt DC rated, 12-pulse, configured for full wave parallel bridge rectifier operation.

15.4.4.2 The rating mentioned in this specification is the expected requirement. The other indicated in Table 15.5:

Table 15.5: Rectifier Rating

SN	Description	Rectifier Rating
1	Type	Indoor type diode based twelve pulse converter with two parallel connected six pulse converters one fed from Y and other fed from D secondary winding.
2	Type of connection	Connection no. 9 according to IEC 60146 without IPT
	Governing Specification	EN 50328/IEC 60146/IEC 60747-2
2	Rated input voltage (AC)	3 AC, 50 Hz, 585-585 V (6 Phases)
3	Rated output voltage (DC)	750 V
4	Maximum output voltage (DC)	1000 V (as per EN 50163)
5	Rated current (DC)	3,333 A continuous
6	Rated output power	2.5 MW
7	Operation rating	Class VI EN 50328, a. 100% continuous – 3,333 A b. 150% for 2 Hrs – 5000 A (after a) c. 300% for 1 min – 9,999 A (after a)
8	Regulation characteristics including inherent regulation	Inherent regulation < 5% on the DC side from light transition load to 100 % full load
9	No Voltage	790 VDC
10	Min. Efficiency	> 99.4%
	Displacement Factor	> 95 %
11	Rated Short circuit withstand current	50 kA for 150 ms sec
12	No. of pulses	12
13	Type of bridge construction	Np+1 with fuse (additional diode in each branch in order to provide full performance after one failure diode in each branch).
14	Ripple	Within 4.5%
15	Cooling	AN, Natural air convection
16	Short circuit withstand level	The rectifier shall be protected against DC short circuits by AC breakers provide on 33kV side. The fault clearance time shall not exceed 8 cycles. The rectifier unit shall be capable of withstanding this short circuit level.

SN	Description	Rectifier Rating
17	Ingress protection	3X
18	Noise level	<75 dB at 100 % load

15.4.4.3 The equipment covered by this specification shall be run in parallel.

15.4.4.4 **Environmental and Climatic Data**

15.4.4.4.1 The environmental and climatic data in Lucknow are provided in General Specifications.

15.4.4.4.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

15.4.4.5 The Contractor shall substantiate with calculations as per IEC 60146-1-1 & 60146-1-2 that above performance criterions are being satisfied with the proposed equipment.

15.4.5 **CONSTRUCTION FEATURES**

15.4.5.1 The connection from rectifier transformer to rectifier is through 2 x 1600 A top entry bus duct for all ASS/TSSs. For DC side connections, the rectifier shall be designed for all cable connections from the top for at grade / elevated/ Underground corridor stations. In Elevated and UG Stations, the cable entry shall be from top. In depots, top entry is advised, however, the type of cable entry may be decided during detail design as suited to site conditions.

15.4.5.2 Rectifier shall be metal enclosed, free standing, connected in a double full wave bridge in parallel configuration complete with surge suppression equipment, input and output terminals and the control cubicle in a mounted frame with lockable (castle key & lock) doors. Access and internal arrangement shall allow for easy inspection and maintenance. Mesh screen of air inlet and outlet shall be designed to maintain the degree of protection IP 3X.

15.4.5.3 The rectifier assembly with all the necessary alarm, trip, indication, controls and auxiliaries shall be enclosed in steel cubicles which shall be vermin proof, free standing and suitable for indoor floor / pedestal mounting. The cubicles shall be of robust design and capable of withstanding shocks to which it may be subjected to during lifting, transport, and other transient conditions during service.

15.4.5.4 All doors of the cubicles shall be fitted with hinges and locking facility for easy access to the cubicle for inspection and maintenance purposes. The cubicle components shall be numbered and marked to facilitate correct erection.

15.4.5.5 The power and control equipment of the rectifier shall be made robust and compact as far as possible.

15.4.5.6 The insulation shall be of best quality and suitable for working at the temperature specified and shall withstand variation of temperature arising due to working condition without deterioration or setting up of under strain in any part and also without affecting the strength and suitability of the work which it has to perform. The insulating materials used shall conform to relevant EN/IEC specifications and shall carry manufacturers test certificate.

The anode bus shall be metal enclosed copper bus duct with an insulating section between the transformer and the rectifier enclosure. Voltage and current rating and short circuit withstand capability shall be adequate for the rectifier and DC system requirements. Insulating section rating shall equal to the bus insulating rating. A continuous copper ground bus connected to each section of the enclosure up to insulated section shall be provided and connected to transformer enclosure.

- 15.4.5.7 The assembly shall be designed and manufactured in such a way so that it does not give any excessive noise or vibration under worst operating conditions.
- 15.4.5.8 The construction of the cubicle / assembly shall facilitate to easy removal of diode & other components without disturbing to other components apart from giving easy access to inspection, cleaning, repair, maintenance and operation.
- 15.4.5.9 The General Arrangement and other associated drawings shall be got approved by Engineer before their manufacturing is started.
- 15.4.5.10 **Rectifier Cells**
- 15.4.5.10.1 It is the elementary rectifying device consisting of one or more rectifier diodes which presents an asymmetrical conductivity complete in its envelope and with cooling fins integral part of it. Cell string shall comprise of a suitable number of cells connected in series or parallel forming a part of the arm of the bridge.
- 15.4.5.10.2 The rectifier shall contain requisite number of cells connected in series as well as parallel in different arms. The cells shall be made of silicon, heavy duty, the high quality and sealed in a metal glass or metal ceramic case to protect it from the outside environment. Suitable provision shall exist for the attachment of the cooling fins to the diodes. The leads from the diodes shall be of flexible and of adequate cross-section and robust construction with a suitable lug on the terminals. Diode side cooled button tube devices shall preferably be employed in the rectifier assembly. If single side cooled devices are used the leads from the devices shall be flexible.
- 15.4.5.10.3 The rectifiers shall be cooled by means of natural air convection. An adequate air supply must be available for this purpose. The air should preferably be drawn from the space below the cubicle, however, sufficient air for cooling the heat sinks can also be drawn from the front-side and rear side of the cubicle through the air slits in the doors and rear wall respectively.
- 15.4.5.10.4 Each cell shall have its own attenuation device to protect it. Suitable DC attenuation circuit shall be incorporated and located in an easily accessible place in the cubicle.
- 15.4.5.10.5 Each string of diode shall be provided with a properly rated HRC and a micro switch to give an indication alarm to remote.
- 15.4.5.11 **Rectifier Stacks**
- 15.4.5.11.1 A single structure of one or more rectifier cells with their associated mountings cooling attachment and connections whether electrical or mechanical.

- 15.4.5.11.2 The assembly of the stacks shall be made with suitable number of cells and the stacks shall be simple construction as such to facilitate easy replacement of any cell or cleaning of fins attached to the cells.
- 15.4.5.11.3 The number of cells per stack and the number of stacks per assembly shall be so selected that it shall withstand the reverse voltage rating which are related to the maximum voltage likely to occur in service including allowances for supply of over voltage under no load condition and transients.
- 15.4.5.11.4 The arms of the bridge connection shall be of sufficient rating to carry the specified loads and overloads even with one string being out of service and to withstand a maximum prospective short circuit current for a duration long enough to permit the protective equipment to operate and clear the faults. In case of failure of string visual as well as audible alarms shall be given in sub-station and the remote-control panel.
- 15.4.5.11.5 The rectifier shall be automatically tripped and locked out of circuit if two parallel paths are out. Visual and audible indications shall be given in the panel as well as at the remote-control center. Necessary interposing relays shall be supplied along with the rectifier for connection to the remote control equipments.
- 15.4.5.12 **Rectifier Assembly**
- 15.4.5.12.1 An electrically and mechanically combined assembly or stacks, complete with all its connections, together with means of cooling if any, in its own mechanical structure.
- 15.4.5.12.2 The construction features of the rectifier assembly and as described in Clause 15.4.5.1 to 15.4.5.9.
- 15.4.5.13 **Terminal Arrangement**
- 15.4.5.13.1 The AC terminal shall normally be provided at the top of the rectifier assembly cubicle with adequate clearance between terminals and earth so as to facilitate easy connection to the rectifier transformer secondary terminals by sandwiched bus duct. The terminal arrangements shall be suitable to receive sandwiched bus duct accordingly.
- 15.4.5.13.2 The DC output terminal shall normally be provided at the top for elevated / at-grade / UG stations (or bottom with conditions indicated in Chapter 14) of rectifier cubicles (on one side of AC terminals, DC +ve and other side of it DC -ve terminals) with adequate clearance so as to facilitate easy connection to HSCB by cables passing through the cable tray. The terminal arrangements shall be suitable to receive minimum 6 (six) numbers of 300 mm² copper cables for both +ve and -ve. Adequate arrangement to be made for the suitable cable entry at the designated stations.
- 15.4.5.13.3 The general arrangements & other associated drawings for terminal arrangements shall be subject to approval by the Engineer before start of bulk manufacturing, so as to incorporate the changes / modification required per the site condition.
- 15.4.5.14 **Fitting and Accessories**
- 15.4.5.14.1 The rectifier assembly shall be provided with the following fittings and Accessories as a minimum:

- a) One DC Voltmeter, flush mounting type with suitable capacity and wide scale and accurate as per EN or applicable IEC.
- b) One DC ammeter flush mounting type with suitable capacity and wide scale and accurate as per EN or applicable IEC.
- c) Lifting lugs
- d) Foundation bolts
- e) Replaceable front and back door of the cubicle
- f) Earthing terminals
- g) Indication lamps and alarm
- h) Protective equipment, properly located on the control cabinet
- i) Name plate and connection diagram.
- j) Connecting cables of suitable capacity from rectifier assembly input

15.4.5.15 **Paint**

- 15.4.5.15.1 Painting should be suitable for polluted atmosphere and has to comply with IEC 60721-2-5 standard. As a minimum, an initial coat of rust-proofing and anti-corrosion paint will be applied after baring of all metal surfaces; then they will be covered with two coats of paint and one finishing coat, colour to be defined. The Contractor shall submit to the Engineer, the complete details of the Switchgear Cubicles Metal work and Paintwork details, including details of the structure, process of finish and painting etc. for Engineer's approval. The total thickness should not be less than 120µm and withstand 120°C.

15.4.6 **PROTECTIVE DEVICES AND SAFETY FEATURES**

- 15.4.6.1 The rectifier assembly shall be provided with the essential and minimum protection for the equipment conforming to EN or applicable IEC.
- 15.4.6.2 The design shall incorporate / provide full perception for safety of all those working personal associated with maintenance of the Rectifier.
- 15.4.6.3 Where the supplier feels that additional protective devices are necessary the details of the same with justification thereof may be furnished.
- 15.4.6.4 The following safety features shall be provided as a minimum:
- a) 110V (+10%, - 20%) DC supply from a battery/battery charger set. Auxiliary supplies will be made available for control and other purpose. In the event of the failure of the auxiliary supply, the rectifier shall be put under shut down and visual / audible alarm indication be arranged at the sub-station as well as at the remote-control center.
 - b) The plant should be installed with insulation (leakage resistance: $\geq 50 \text{ k}\Omega$). The insulating strips supplied should be used for this purpose.
 - c) Suitable frame leakage protection shall be provided
 - d) Two stage rectifier diodes over temperature detection unit with alarm and trip contacts shall be provided

- e) Rectifier door interlock shall be provided
 - f) Rectifier equipped with fuses and fuse status monitored by micro switch
- 15.4.6.5 The equipment's shall work normally on remote operation, but facilities shall also be provided for local control of the equipment.
- 15.4.6.6 Each rectifier assembly and each main item of the rectifier auxiliaries shall be marked as per EN or equivalent IEC.
- 15.4.6.7 The cubicles shall be protected against fire by means of automatic fire detector and extinguisher system with linear fire detection tube based clean agent direct gas flooding system. The detection has to be done by the linear heat detection tube which will be routed inside the panel as per the design calculation. The tube shall be double layered made of Hi-tech Polymer either Fire Detec, Fire Trace or equivalent. The system shall utilize unique flexible tubing that shall be attached to the top of the container valve. This tubing shall be pressurized with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C), is temperature sensitive and shall act as a continuous linear thermal detector that shall rupture upon flame impingement. Once the detection tubing is ruptured, forming a nozzle at the rupture point, it shall allow the Clean Agent through the nozzle into the protected area. The clean agent offered should be as designated in NFPA 2001 [Section A.5.5.1(B)] and ISO 14520 Clean Agent Standards. Its 'ASHRAE' nomenclature is (FK5-1-12 or its equivalent (Novec 1230)). Gas should have lowest Global Warming potential. The quantity of clean agent required should be calculated as per NFPA 2001 and BIS standards. Clean agent container shall be designed, fabricated, certified with stamp on the containers in accordance with the requirements of NFPA. Containers shall be standard model and size for ease of replacement and addition. Fill containers with required Clean Agent (FK5-1-12 or its equivalent (Novec 1230)). Pressurise with Dry Nitrogen to 230 psig (≈ 16 bar) at 700F (1,034 KPA @ 210C). Container/cylinders shall have PESO approval /Govt. Approved Lab. A separate and standalone gas cylinder with protection system shall be provided for a group of panels.
- 15.4.6.8 Demonstration of a fire protection system on dummy panel shall be done at the site as required by the Employer. (Combined for all equipment/sub-system).
- 15.4.6.9 The Gas-flooding system healthiness status shall be communicated to BMS (Building management System)
- 15.4.6.10 Contractor shall submit a comprehensive proposal for the above to Engineer for approval.
- 15.4.6.11 Other General Information
- 15.4.6.11.1 The positive busbar of the substation is connected with the third rail of the track through HSCB and isolator.
- 15.4.6.11.2 The negative busbar of the substation is connected to running rails, which are kept at floating. A voltage limiting device also called (over voltage protection device (OVPD) shall be provided connecting temporarily the negative busbar to the station earth, in case of rail potential exceeding the specified values. The OVPD shall protect passengers against excessive rail potential in accordance with EN 50122-1.
- 15.4.7 TYPE AND ROUTINE TESTS**
- 15.4.7.1 Type tests are to be carried out on the prototype equipment in accordance with EN 50328/IEC 60146 and the provision contained in this specification.

15.4.7.2 If prototype test confirming to this specification has already been conducted and certificate issued after conducting type test by recognized laboratories then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the contractor for consideration.

15.4.7.3 Routine tests shall be carried out on each item of equipment or on combined equipment in accordance with EN 50328/IEC 60146 at the manufacturer's works.

15.4.8 GTP FOR RECTIFIERS

15.4.8.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

15.4.8.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.6: GTP for Rectifier

SN	Description	Unit of Measurement	Manufacturer's Data
A	Detail Particulars of Cells		
1	Makers name		
2	Country of manufacture		
3	Governing specification		
4	Manufactures type, designation & explanation, designation code		
5	Type of cells		
6	Limiting RMS forward current	A	
7	Limiting average forward current	A	
8	Limiting peak repetitive forward current	A	
9	Limiting surge current	A	
10	Limiting peak repetitive reverse voltage	V	
11	Limiting peak non repetitive reverse voltage	V	
12	Normal forward current	A	
13	Maximum forward voltage drop	V	
14	Threshold voltage	V	
15	Calculated differential forward resistance	m-Ohm	
16	Maximum reverse current	A	
17	Nominal DC reverse voltage	V	
18	Maximum allowable rate of rise of forward current	A	
19	Maximum allowable rate of rise of applied forward voltage	V	
20	Break down voltage	V	
	Characteristics		

SN	Description	Unit of Measurement	Manufacturer's Data
21	Forward current vs forward voltage drop characteristics		
22	Maximum allowable case temperature vs limiting average forward current characteristics		
23	Maximum allowable ambient temperature vs limiting average forward current characteristics		
24	Maximum allowable forward current during intermittent operation vs duty ratio for natural cooling characteristics		
25	Forward overload current vs duration of natural cooling characteristics		
26	Limiting forward overload current vs duration for natural cooling characteristics		
27	Transient thermal resistance vs time characteristics		
28	Overall thermal resistance vs time for natural cooling characteristics		
29	Max reverse charge vs decay of forward current characteristics		
	Thermal Data		
30	I ² t rating	A ² s	
31	Max. junction temp	C	
32	Operating temp. range	C	
33	Storage temp. range	C	
34	Thermal resistance		
a	Junction to case	K/W	
b	Case to ambient	K/W	
35	Normal housing temp.	C	
	Operational characteristics		
36	Load vs loss characteristics		
37	Current vs voltage forward characteristics		
38	Current vs voltage reverse characteristics		
	Mechanical Data		
39	Weight of cell without sink		
40	Weight of heat sink		
41	Type of attachment of heat sink to cell		
42	Max fixing torque		
43	Shock resistance cell		
44	Noise level		
a	at rated voltage at no load		
b	At 110% rated voltage at no load		
c	at max at no load		

SN	Description	Unit of Measurement	Manufacturer's Data
B	Detailed Particulars of Rectifier Assembly		
1	Makers name		
2	Country of manufacture		
3	Governing specification / standard		
4	Manufacturers type, designation		
5	Rated direct current	A	
6	Rated direct voltage	V	
7	Rated output	Kw	
8	Class of rating		
9	Overload capacity		
10	Regulation characteristics including inherent regulation		
11	Efficiency vs load characteristics		
12	Power factor vs load characteristics		
13	Telephone harmonic factor	%	
14	Harmonic voltage magnitude	V	
15	Pulse number		
16	Rated AC voltage	V	
17	No of phases		
18	Type of connection		
19	Total number of cells per assembly	Nos	
20	No of arms		
21	No of cells per arm in series		
22	No of cells per arm in parallel		
23	Cooling arrangement		
24	Minimum clearance between live parts and earth		
a	DC side		
b	AC side		
25	DC attenuation equipment		
26	Overall dimensions of the rectifier cubicle		
a	Length	Mm	
b	Height	Mm	
c	Breadth	Mm	
27	Noise level		
a	at rated voltage at no load	dB	
b	At 110% rated voltage at no load	dB	
c	at max at no load	dB	

15.4.9

TEST SHEET FOR RECTIFIER

Table 15.7: Test Sheet for Rectifier (EN 50327 & EN 50328)

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Insulation test	X	X	X	X	
Light load and functional test	X	X	X	X	
Load test	X	X			
Power loss determination by measurement	X	X	X		
Temperature rise test	X				
Checking of auxiliary devices	X	X	X		
Checking the properties of the control equipment	X	X	X		
Checking the protective devices	X	X	X		
Verification of degree of protection	X				
Overcurrent capability test		X	X		
Short time withstand current test	X				
Interlocking		X	X	X	
Visual inspection		X	X	X	
Rectifier-Transformer combined short-circuit test				X [#]	
Frame Leakage Protection				X	
SCADA Test			X	X	
Rated current Test	X	X			
# - Combined short circuit shall be carried out at Third Rail at site in accordance with clause 7.7 of EN 50327 (latest)					

15.5 RECTIFIER TRANSFORMER

15.5.1 SCOPE

- 15.5.1.1 This specification applies to indoor dry type Rectifier Transformer used in unattended Traction Substation for stepping down the incoming voltage of 33 kV to feed the silicon rectifier diode meant for supplying traction load at 750 V DC. It shall meet the technical requirements as specified herein. The Rectifier Transformer shall be manufactured for traction power system of UP Metro Rail Corporation Ltd, Lucknow Project. The scope of work includes design, supply, installation, testing and commissioning of Rectifier Transformer along with accessories
- 15.5.1.2 The Rectifier Transformer offered shall be complete in all parts and accessories necessary for their efficient performance / operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.
- 15.5.1.3 The total load requirement for the Traction load is being met through installation of two rectifier transformers of rating 2 x 2850kVA at all traction substations in the Corridor. At depot traction substations, rectifier transformers shall be of 3 x 2850 kVA capacity.

15.5.2 SPECIFICATIONS

15.5.2.1 The transformer shall, unless otherwise specified conform to IEC 60076/IEC 60146/EN50329 or latest and I.E. Rules, applied in the manner altered amended or supplemented by these specifications, wherever applicable. In all cases, latest revision to this specification referred to above shall apply.

15.5.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with approval of Employer.

15.5.3 RATINGS

15.5.3.1 The rating mentioned in this specification is the expected requirement. The other indicated in Table 15.8;

Table 15.8: Rectifier Transformer Rating

SN	Description	Rectifier Transformer Rating
1.	Type	Three phases, cast resin dry type, Aluminum wound step down, indoor installation for feeding to 12 pulse silicon rectifier assembly with two parallel type six pulse converters.
2.	Configuration	Dd0-Dy5
3.	Rated input voltage	3 Ph, 50 Hz, 33 kV AC
4.	Rated output voltage	LV1 -585 V AC, 3-phase LV2 - 585 V AC, 3-phase
5.	Nominal rated power Primary	2850 kVA
6.	Nominal rated power secondary	LV1:- 1425 kVA LV2:- 1425 kVA
7.	Winding Material	Aluminum/Aluminum
8.	%age Impedance	HV/(LV1+LV2): - 9% (2850kVA base)
9.	Over load capacity	Class VI EN 50329, a. 100% continuous b. 150% for 2 Hrs. (after a) c. 300% for 1 min (after a)
10.	Tap changer	Off Load
11.	Tappings	33 kV +/- 2 x 2.5% Off circuit tapping to be provided to give the rated voltage on the secondary for primary voltage variation of (+) 5% and (-) 5% in steps of 2.5 %. The tapings shall be on HV sides and capable of carrying full load current and overloads as specified.
12.	Rated short circuit withstand rating for HV winding	25 kA for 3s
13.	Insulation class	HV:- F Class LV1, LV2 :- H Class
14.	Cooling	AN
15.	Temperature rise	The temperature rise of windings and core shall not exceed the permissible values as per IS 11171/IEC 60076-11/EN 50329.

SN	Description	Rectifier Transformer Rating
16.	Insulation rated voltage	HV:- 36/95/200 kV (OV3, EN 50329, Table B.1) LV:- 1.2/3.6/8 kV (OV3, EN 50329, Table B.1)
17.	Protection Class	IP 3X
18.	Coupling Factor (as defined in EN50329, 1.3.16 & 4.1)	≤ 0.2
19.	E/C/F class	E2/C2/F1

15.5.3.2 Environmental and Climatic Data

15.5.3.2.1 The environmental and climatic data in Lucknow are provided in General Specifications.

15.5.3.2.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

15.5.3.3 Transformer Losses

15.5.3.3.1 The transformers shall be designed for minimum losses and efficiency level as described.

SN	Rectifier Transformer Rating	No-Load Losses (kW) (at ambient temperature)	Load Losses (kW) (at 95° C)
1.	2850 kVA	Max 4.80 kW	Max 12.00 kW

15.5.3.3.2 DELETED

15.5.3.3.3 DELETED

15.5.3.3.4 Submittals

The submittals shall have the following details

- i. Description of equipment
- ii. Arrangement drawings
- iii. Details of interconnection
- iv. Wiring diagrams & cable termination details
- v. Schematic diagrams
- vi. Elevation drawings
- vii. Temperature rise data
- viii. Production test data
- ix. Surge arrester details
- x. Bill of material
- xi. Certified copies of factory tests in accordance with referenced standards

15.5.4 CONSTRUCTION FEATURES

- 15.5.4.1 It is envisaged that the Rectifier Transformer shall be designed for 33 kV cable connections from the top for at grade/elevated/UG corridor stations. In stations and depots, the 33kV cable connections shall be from -Bottom. However, other arrangement shall also be acceptable subject to the conditions elaborated elsewhere in these specifications. The transformer construction shall take into account physical and thermal stresses on the termination bushings created by the cable termination and provide for flexible links if required. The noise level shall not exceed 68 dB in accordance with NEEMA TR-1.
- 15.5.4.2 **Core & Windings**
- 15.5.4.2.1 The core shall be built up of cold rolled grain-oriented steel conforming to relevant IEC/EN. All lamination used for stacking the core shall be leveled, free from waves, deformation, scaling of core painting insulation or signs of rust. The core shall be electricity connected to the core clamping frame for providing earthing to drain off any electrostatic potential that may built up.
- 15.5.4.2.2 Each of the core bolts and parts of the core clamping framework shall be insulated from the core laminators and tested after completion of the core assembly to with stand an AC pressure of 2 kV AC r.m.s. for a duration of 1 minute. All parts of the core shall be of robust design capable of withstanding shocks to which they may be subjected to during lifting transportation installation, and services.
- 15.5.4.2.3 The HV winding shall be so designed, as to facilitate better heat dissipation and withstand mechanical forces. A metallic electrostatic shield shall be provided between high voltage and low voltage windings. The windings and connectors of the transformer shall be brazed to withstand shocks which may occur during transportation or due to switching and other transient conditions during service.
- 15.5.4.2.4 Aluminium terminal bars shall be provided as same as of winding material. The windings shall be so designed as to be magnetically balanced with respect to one another, thus reducing to a minimum mechanical stress under short circuit conditions
- 15.5.4.2.5 The transformer shall be mounted on four bidirectional type flanged wheels for forward and cross wise movement on 1000 mm gauge rails with locking arrangement after installation.
- 15.5.4.3 **Tap Changer**
- 15.5.4.3.1 The transformer shall be fitted with externally operated off circuit links for varying its effective transformation ratio covering the specified voltage range as per ratings specified above table.
- 15.5.4.3.2 The off circuit tap changing links shall be so arranged as to facilitate its operation from ground level. Tap position indicating arrangement shall be provided.
- 15.5.4.3.3 The transformer shall be of the rated kVA without exceeding the rated temperature on any taping at a voltage $\pm 5\%$ of the rated voltage of that tapping. Each tap shall also be capable of withstanding a voltage of 10% above the rated voltage of the tap when the transformer is not loaded.

15.5.4.4 **Terminal Arrangement**

15.5.4.4.1 The terminal arrangement for high voltage side shall be suitable for XLPE cables with FRLS outer sheath for elevated Section and FRLSOH for Underground section.

15.5.4.4.2 The terminal arrangement on 585-585 V side shall be suitable for connection to the silicon rectifier through sandwiched bus duct of Aluminum with suitable bi-metallic accessories. All the LV connections shall be brought to top with suitable supported busbars.

15.5.4.5 **Transformer Cubicle**

15.5.4.5.1 Transformers shall be installed in dismountable cubicle, of wire-mesh type with adequate sizing of the sheet metal. Alternatively, the transformers may be supplied in a cubicle with enclosure having a degree of protection of not less than IP31 and without any HV portions exposed. The door shall be provided with a mechanical system interlock, to ensure that it is possible to open the door only when the protection circuit breakers on the HV side as well as LV side of the transformer are in 'Open' position. The cubicle shall provide protection against direct contact with the power transformer. It shall include connections for the MV lines from the protection bay and connections for the low voltage circuit.

15.5.4.5.2 Two doors containing two windows to allow observation of the transformer accessories shall be provided in the front face. These doors shall be closed and locked to prevent access to the transformer while either the MV or the LV side is live. Consequently, ventilation louvers shall be installed at the bottom of the front doors and in the bay rear panel and roof. A metal sheet shall be installed at 10 to 15 cm from the top grating to provide protection against any falling water. Cable arrangement shall facilitate the exchange of the either of the two Transformers without any difficulty; i.e. the cables shall be laid along each side and connected to the transformer in such a way that it will not block the passage for removal of any of the transformer during service. Suitable cable sealing arrangements with grommets to be ensured after installation.

15.5.4.6 **Fittings & Accessories**

15.5.4.6.1 Winding temperature indicator with alarm and trip arrangement shall be provided. The device shall have two thresholds (alarm and tripping). Sensors shall be located on the upper part of the secondary windings. Each phase of LV winding should have 2 PT-100 sensors 2 spare temperature sensors with wiring shall be provided.

15.5.4.6.2 Following accessories shall be provided:

- a) Installed on rollers with locking arrangement after installation
- b) Lifting rings
- c) Nameplate-2Nos.
- d) Grounding Terminal
- e) Clamps shall be provided inside the enclosure for formation of horizontal & vertical earthing ring
- f) Limit Switches 2 Nos. for enclosure Doors

g) Danger Plates as per safety rules

15.5.4.7 **Painting**

15.5.4.7.1 All steel surfaces shall be painted which shall be suitable for polluted atmosphere and has to comply with IEC 60721-2-5 standard. After baring of all metal surface an Intel two coat of rust proofing and anti-corrosive paint shall be applied then they will be covered with three coated of glossy oil & weather resistance non fading paint. The total thickness should not be less than 120µm and withstand 120°C.

15.5.4.7.2 Contractor shall ensure to touch up the painting for the small damages during the transportation and erection work.

15.5.4.8 **Nuts & Bolts**

15.5.4.8.1 The threads and hexagons of all nuts, bolts and stud shall confirm to relevant IS or BS. No bolt or stud shall project through its nut(s) more than 6mm (or) four threads, except when otherwise approved for terminating stud/bolts. If bolts and nuts are so placed that they are inaccessible by means of ordinary spanners, suitable special spanners shall be provided free of cost. All terminals should be provided with suitable cadmium plated and passivated high tensile steel hard wares facilitate cables termination.

15.5.4.9 **Labels**

15.5.4.9.1 Description labels of non-corrosive material or vitreous enameled iron plate (preferably SS) shall be of approved design and material that will ensure permanence of lettering. The finish shall be such that provides dazzle free look from the reflected light. The color used shall be permanent and non-fading. All the screws used for fixing the labels shall be of brass or with steel screws, which have received an approved rust preventive treatment.

15.5.5 **SAFETY FEATURES**

15.5.5.1 The design shall incorporate / provide full perception for safety of all those working personal associated with maintenance of the Transformer.

15.5.5.2 The following safety features shall be provided as a minimum:

15.5.5.2.1 Transformers shall be fitted with a temperature protection system that allows winding temperatures to be monitored. This shall consist of two sensors placed on each low-voltage winding, i.e. three alarm sensors and three trips out sensors. 2 spare temperature sensors with wiring shall be provided. An indicator shall be installed on the front door of the bay to indicate continuously the winding temperature. The device shall monitor the temperature of all three windings. It shall produce have two stage alarm & trip feature. At stage 1 it shall initiate an alarm. At stage 2 it shall trip the Circuit Breaker.

15.5.5.2.2 The transformer cubicle door shall be provided with a mechanical system interlock, to ensure that it is possible to open the door only when the protection circuit breakers on the HV side as well as LV side of the transformer are in 'Open' position.

15.5.6 **TYPE AND ROUTINE TESTS**

15.5.6.1 Type tests are to be carried out on the prototype equipment in accordance with governing IEC/EN or IS standards and the provision contained in this specification.

- 15.5.6.2 If prototype test confirming to this specification has already been conducted and certificate issued after conducting type test by recognized laboratories then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the Contractor for consideration.
- 15.5.6.3 All routine tests like separate source voltage withstand test, winding resistance measure, transformation ratio measure, no-load loss, current measure and coupling checking as per IEC 60076, IEC 60146 and EN 50329 are to be conducted on each transformer in presence of Engineer.
- 15.5.6.4 Test on insulation: The test consists of applying DC high voltage (2500 V or 5000 V) with the help of a motor driven megger, continuously between winding and earth, and measure insulation resistance at the end of 10 second and 60 seconds. The polarization ratios R60/R10 and R600/R60 should not be less than 1.4 and 1.2 respectively. (R10, R60 and R600 are the insulation resistance values after 10 seconds, 60 seconds and 600 seconds respectively).
- Contractor shall submit and rectifier-rectifier transformer interface study in compliance with specifications/Employer's requirement during detailed design stage
- 15.5.7 GTP FOR RECTIFIER TRANSFORMER**
- 15.5.7.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 15.5.7.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.9: GTP for Rectifier Transformer

SN	Description	Unit	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Relevant Specification		
4	Vector group		
5	Input voltage	kV	
6	Rated Output voltage (No load)	V	
7	Nominal rated power	MVA	
8	Impedance	%	
9	Winding		
10	Method of cooling		
11	Overload capacity		
12	Tap changer		
13	Current rating		
a	100 % - Continuous	A	
b	150% for 2 Hrs	A	
c	300% for 1 minute	A	
14	Rated temperature rise under normal operating condition over ambient of	°C	

SN	Description	Unit	Manufacturer's Data
	50 °C		
15	Temperature rise of winding over a maximum ambient after		
a	50% overload for 2 hours after continuous operation at full load	°C	
b	200% overload for 1 min. after continuous operation at full load	°C	
16	Specified interval of time between two successive overloads of the following types after continuous working at full load at maximum ambient temperature		
a	150% overload for 2 hours	Minute	
b	300% overload for 1 min	Minute	
17	Existing current referred to HV & 50 Hz at		
a	80% rated voltage	A	
b	100% rated voltage	A	
c	110% rated voltage	A	
18	Power factor of excitation current at 100% rated voltage and 50 Hz	%	
19	Iron loss at 50 Hz (refer to ITT for capitalization of losses)		
a	90% rated voltage	kW	
b	100% rated voltage	kW	
c	110% rated voltage	kW	
20	Copper loss (75 °C) at rated voltage (refer to ITT for capitalization of losses)	kW	
21	Resistance voltage (75 °C) at full load condition of HV & LV	%	
22	Reactance voltage (75 °C) at full load	%	
23	Impedance voltage (75°C) at full load	%	
24	Resistance of HV and LV (75°C) at full load	%	
25	Regulation at 50% overload at power factor		
a	PF = 1	%	
b	PF = 0.8	%	
26	Efficiency at power factor		
a	PF = 1		
b	PF = 0.8		
	a) 100% load	%	
	b) 75% load	%	
	c) 60% load	%	
	d) 50% load	%	

SN	Description	Unit	Manufacturer's Data
	e) 25% load	%	
27	Withstand time without injury with dead short circuit at the terminal	Sec	
28	Thermal time constant of windings or ideal time	Min	
29	Details of core construction		
a	Type of core		
b	Flux density at rated voltage and 50 Hz		
c	Flux density at 110% rated voltage and 50 Hz		
d	Thickness of iron stampings	Mm	
e	Exciting VA per kg of iron	VA	
f	Insulation between core lamination	MΩ	
g	Type of joints between core limb and yoke		
h	Bolt insulation flash over voltage	kV	
30	Details of windings		
a	Type of winding		
b	Current density on HV & LV windings	A/mm ²	
c	Insulation on the conductor	MΩ	
d	Type of joints in windings, if any		
e	Insulation withstand strength of winding with 1.2/50 μs wave	kV	
f	Applied voltage test	kV	
g	Induced voltage test	kV	
h	Estimated switching surge withstand	kV	
31	Tap changer		
a	Type		
b	Number of plus and minus taps		
c	Voltage of different taps		
32	% age impedance at		
a	Lowest tap		
b	Highest tap		
c	Normal position		
33	Weight		
a	Core and winding	Kg	
b	Total	Kg	
34	Dimensions		
a	Length	Mm	
b	Width	Mm	
c	Height	Mm	
d	Overall transport dimensions of the largest packages	Mm	
35	Noise level		

SN	Description	Unit	Manufacturer's Data
a	at rated voltage and no load	dB	
b	at 110% of rated voltage and no load	dB	
c	at maximum over induction	dB	
36	Enclosure	IP 3X	

15.5.8**TEST SHEET FOR RECTIFIER TRANSFORMER**

Table 15.10: Test Sheet for Rectifier Transformer in accordance with IEC 60076-11, EN 50329, EN 50327

INDICATIONS	TYPE of TEST				
	Type*	Routine	Acceptance	On Site	Specials
Temperature rise*	X				
Lightning impulse withstand voltage test*	X				
Separate-source voltage withstand test	X	X	X		
Insulation resistance test	X	X	X	X	
Measurement of winding resistance	X	X	X	X	
Measurement of voltage ratio and check of phase displacement	X	X	X	X	
Measurement of no-load loss and current	X	X	X		
Measurement of short circuit impedance load loss and current	X	X			
Verification of degree of protection	X				
Partial Discharge Test	X	X			
Visual inspection	X	X	X	X	
Phase Displacement	X	X			
Measurement of coupling factor	X		X		
Measurement of Sound Level	X				
Check of digital temperature controller		X		X	
Short Circuit withstand test	X				X
Induced Over voltage Test	X	X			
Rectifier-Transformer combined short-circuit test				X [#]	
Magnetizing Current & Magnetic Balance Test		X		X	
Winding Resistance Test	X	X	X		
Insulation Resistance Test		X	X	X	
Functional Test	X	X	X	X	
Climatic Test	X				
Environmental Test	X				
* For these type tests, the contractor shall provide a report on similar equipment.					
# - Combined short-circuit shall be carried out at Third Rail at Site in accordance with Clause 7.7 of EN 50327.					

15.6**OVER VOLTAGE PROTECTION DEVICE****15.6.1****SCOPE**

- 15.6.1.1 This specification applies to indoor type negative earthing equipment ("Short Circuiting Device" or "OVPD") for 750 V DC system to be installed in the metro railway substation for control and protection against impermissible touch voltage caused by rail potential due to train operation or during short-circuits. The OVPD acts as an equipotential bonding device by connecting temporarily Running Rail to the station earth. The scope of work includes design, supply, installation, testing and commissioning of devices along with accessories. This OVPD shall be suitable for integration with existing stray current monitoring system installed at OCC & BCC, if required subject to Engineer's approval.
- 15.6.1.2 The OVPD shall be installed in all stations. At stations where ASS/TSS is available, the device shall be installed inside ASS/TSS. At other stations, the device shall be installed in ASS. The device shall be connected to negative return panel (in case it is installed in ASS/TSS) or return rail (in case it is installed in ASS) with 2R x1Cx 300 mm² copper cable.
- 15.6.1.3 The equipment offered shall be complete in all respect with all parts and accessories or materials which are necessary for efficient operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.

15.6.2 SPECIFICATIONS

- 15.6.2.1 The device shall functionally comply with EN 50122-1 & EN 50122-2 and its main components shall comply with EN 50526-2.
- 15.6.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with approval of employer.
- 15.6.2.3 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for at grade/elevated section & Fire Retardant Low Smoke Zero Halogen Type (FRLSOH) for underground section.

15.6.3 RATINGS

- 15.6.3.1 The rating mentioned in this specification is the expected requirement. The other are indicated in Table 15.11;

Table 15.11: Over Voltage Protection Device

SN	Description	Values
1	Governing Specification	EN 50122-1 EN 50122-2 EN 50526-2
2	Nominal voltage	750 V
3	Rated Insulation Voltage	1800 V
4	Rated continuous current	900 A
5	Rated short circuit withstand current	50kA for 100msec
6	Capacitive current breaking capacity of contactor at 900 V DC	900 A
7	VLD class	4.1 & 4.2 (Depot)
8	Protection Rating	IP 3X
9	Number operations of contactor	20000
10	Current sensing device	+/-1000 A (shunt 60 mV)

- 15.6.3.2 The EN 50122-1 prescribes the tolerable / safe value of running rail potential – 120 V continuous, 150 V for 5 minutes and 170 V for 1 second. In the event of running rail potential breaching these value, the OVPD shall operate and earth the return circuit (to substation earth). Resetting of OVPD after operation shall be as per the provisions of EN 50122-2. To achieve this, the OVPD shall be provided with necessary numerical relays.
- 15.6.3.3 **Environmental and Climatic Data**
- 15.6.3.3.1 The environmental and climatic data in Lucknow are provided in General Specifications.
- 15.6.3.3.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.
- 15.6.4 CONSTRUCTION FEATURES**
- 15.6.4.1 Over Voltage Protection Device shall essentially consist of following devices
- a) 1 Numerical Protection Relay compatible for SCADA communication i.e., IEC 61850 from OVPD to RTU and IEC 60870-5-104 for SCADA
 - b) 1 Voltage measuring unit
 - c) 1 Current measuring unit with associated shunt
 - d) 1 Hygro-thermostat
- 15.6.4.2 Accuracy of measurements
- 15.6.4.2.1 Voltage measurement: 0.3% of the maximum value (max value 150V)
- 15.6.4.2.2 Current measurement: $\pm 0.1\%$ of the max value for the transducer (max value 1000A)
- 15.6.4.3 The PLC shall have defined protective characteristics for DC voltages following the EN 50122-1 touch voltage limits with a margin for the closing time of the contactor. It shall be possible to define user characteristic for DC voltages. It shall be possible to continually monitor the values of rail potential, current and contactor state on the HMI mounted on the panel and at SCADA.
- 15.6.4.4 The cubicle shall have two power supply cable connections:
- a) Return circuit
 - b) Structure / substation earth
- 15.6.4.5 The OVPD shall be of metal sheet or polyester construction and shall be completely best moisture and vermin proof. This shall be supplied complete with frame work, fixing bolts, barriers, enclosures, internal wiring, cable and boxes, tables, etc. All unit of the panel shall be made rust proof by at least two coats of primary paint applied on the interior and exterior surfaces followed by a finishing coat of light blue enamel paint. However, the colour coding shall be proposed to the Employer during Detailed Design Stage for his approval.

- 15.6.4.6 The various items constituting the panel shall be neatly done and secured mounted in the panel which shall be of standard design and sufficient capacity. The copper bus bar shall be made of electrolytic high conductivity grade copper as per EN/IEC standards and the busbar shall be coated with electro tinned of suitable thickness (not less than 50 micron).
- 15.6.4.7 The cable compartment is to be so designed that sufficient space is available for termination of suitable nos. of single core cable.
- 15.6.4.8 All instruments and other electrical devices mounted on the board shall have name plates with rating; date, serial number and manufacturers name etc.
- 15.6.4.9 Protection of persons against the live part shall be ensured for the panels.
- 15.6.5 OPERATION**
- 15.6.5.1 In DC railway systems, operational and short-circuit currents can result in impermissible touch voltages between the return line and the structure earth. In that case, a OVPD is included between the return line and the structure earth for voltage limitation to prevent sustained, impermissible touch voltages. The device shall have following operating states available:
- 15.6.5.2 **Active State**
- 15.6.5.2.1 In this state the opening and closing of the contractor shall be controlled through the values of various parameters being monitored.
- 15.6.5.2.2 When touch voltages greater than the parameterized protection characteristic occur in accordance with EN 50122-1, the short-circuiting device shall short-circuit at its connection points the return circuit and the structural earth. The OVPD shall continually measure the potential between the return circuit and equipotential bonding strip inputs. If this potential exceeds one of the voltage values for the time belonging to this value, the two voltages are short-circuited by the Contactor.
- 15.6.5.2.3 If all opening conditions are fulfilled, OVPD shall go back into the open operating state automatically again, so the arising of additional stray currents is avoided. For the contactor to open, all of the following conditions shall be fulfilled:
- a) The OVPD shall be in the "Active" operating state.
 - b) The "OVPD closing delay" has expired
 - c) The current through the contactor shall be less than a preset value which is much less than the maximum breaking current
- 15.6.5.3 **Blocked State**
- 15.6.5.3.1 In this state the contactor is permanently closed. The blocked state can be cancelled with Reset command.
- 15.6.5.3.2 The device shall go into blocking mode in case of:
- a) Maximum no. of trips is exceeded
 - b) Current through the contactor is greater than the maximum breaking current for a specified time

15.6.5.4 Direct Close

15.6.5.4.1 In this state, the contactor is permanently closed through issue of a command from SCADA or locally.

15.6.5.5 Fault State

15.6.5.5.1 In this state, if a fault is active, the fault group signal is activated and the contactor closes. This state can be cancelled after the fault has been rectified through a command from SCADA or locally. It shall be possible to view 256 most recent operating and fault messages.

15.6.6 PROTECTION SYSTEM

15.6.6.1 The protection relays for the protection of return circuit shall be normally mounted on the panel. Protection relay shall be communicated with the Ethernet switch installed in NRP panel in Star topology configuration with redundant path through PRP(Parallel Redundancy Protocol) over IEC 61850 protocol.

15.6.6.2 The application, performance and testing of protection relay modules shall be in accordance with the appropriate IEC, EN standards.

15.6.6.3 Protections in Return Circuit

15.6.6.3.1 The Over Voltage Protection Device shall incorporate following protections

- a) Special over voltage relay suitable for detecting both positive and negative over voltage with respect to earth
- b) 50: Instantaneous over current

15.6.7 STRAY CURRENT MONITORING

15.6.7.1 The OVPD shall serve an additional purpose of stray current monitoring. The voltage sensed by the voltage sensing devices and the conductance of the running rail with track plinth shall be calibrated in terms of stray current in the system. These values shall be transmitted to SCADA for monitoring using the IEC61850 and 60870-5-104.

15.6.7.2 Additional, logics shall also be developed to initiate an alarm in case of failure of insulation between running rail and track plinth.

15.6.8 TYPE AND ROUTINE TESTS

15.6.8.1 Type tests shall to be carried out as per the relevant standard and certificate to be submitted for consideration.

15.6.8.2 If prototype test confirming to this specification has already been conducted and certificate issued after conducting type test by recognized laboratories then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the contractor for consideration.

15.6.8.3 All equipment shall be subjected to routine tests.

15.6.9 GTP FOR OVER VOLTAGE PROTECTION DEVICE

15.1.1.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

15.1.1.2 The list indicated below is the expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.12: GTP for OVPD

SN	Description	Unit	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Manufacturer's type designation		
4	Governing Specification		
5	Rated voltage	V	
6	Maximum permissible operating voltage	V	
7	Rated continues current	A	
8	Type		
9	Rated short time current & time	kA, Sec.	
10	Capacitive current breaking capacity of contactor at 900 V DC		
11	No of Operation of contactor		
12	Contactor Main Contracts material		
13	Type of voltage sensing devices		
14	Rating of voltage sensing device		
15	Type of Current sensing devices		
16	Rating of current sensing device		
17	Type of PLC		
18	Communication protocol of PLC		
19	Over all dimensions		
a	Length	Mm	
b	Height	Mm	
c	Breadth	mm	
20	Weight	Kg	

15.6.10 TEST SHEET FOR OVER VOLTAGE PROTECTION DEVICE

Table 15.13: Test Sheet for Over Voltage Protection Device

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Temperature rise	X				
Procedure for mechanical switching VLDs and for combine thyristor with mechanical switching device	X				
Leakage current	X	X			

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
DC withstand current	X				
Procedure to determine long term current	X				
Procedure to determine short time current	X				
Response time characteristics	X				
Lightning current withstand characteristics for VLDs expose to direct lightning strike	X				
Recovery tests	X				
Dielectric tests	X				
Triggering voltage tests		X			
Fail safe behaviour		X			
Lightning impulse withstand voltage	X				
Short circuit withstand for main & earthing circuits	X				
Protection of persons against live parts	X				
Verification of degree of protection	X				
Aux. circuits dielectric withstand		X	X		
All devices operation checking		X	X		
Wiring		X	X	X	
Function		X	X	X	
Interlocking		X	X	X	
Painting & external visual inspection		X	X	X	X
Aux. circuits insulation				X	
Insulation Resistance		X		X	
Protection Test		X	X		
SCADA Testing			X		

15.7 NEGATIVE RETURN PANEL

15.7.1 SCOPE

15.7.1.1 This specification applies to indoor type Negative Return Line Panel for connecting the running rail with the negative pole of the rectifier. The scope of work includes design, supply, installation, testing and commissioning of device along with accessories.

15.7.1.2 The equipment offered shall be complete in all respect with all parts and accessories or materials which are necessary for efficient operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.

15.7.1.3 The total load requirement for the Traction load is being met through installation of two rectifiers at all traction substations in the Corridor and at Depot ASS/TSSs.

15.7.2 SPECIFICATIONS

15.7.2.1 The device and its main components shall comply with EN 50123 or IEC 61992

15.7.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with approval of employer.

15.7.2.3 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for at grade/elevated section & Fire Retardant Low Smoke zero Halogen Type (FRLSOH) for underground section.

15.7.3 RATINGS

15.7.3.1 The rating mentioned in this specification is the expected requirement. The other indicated in Table 15.14;

Table 15.14: Negative Return Panel

SN	Description	Negative return Panel
1.	Type	Combined Negative Return Panel for 2 rectifier groups
2.	Governing Specifications	EN 50123
3.	Rated Insulation voltage	1800 V
4.	Contact resistance	<10 micro-ohm
5.	Rated continuous current	2 x 6300 A
6.	Rated short time current	125 kA for 0.25 s
7.	Operation	Offload, Motorized
8.	Insulation level	According to EN 50123/EN 50163
9.	Designed creepage length	According to EN 50123/EN 50163
10.	Dry one-minute power frequency withstand voltage	11.2 kV
11.	1.2/50 μ s dry impulse level	20 kV
12.	Main busbar	Bus bar rating- 10KA
13.	Bus bar capacity for each return line	6000 A
14.	Ingress Protection	3X

15.7.3.2 Environmental and Climatic Data

15.7.3.2.1 The environmental and climatic data in Lucknow are provided in General Specifications.

15.7.3.2.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

15.7.4 CONSTRUCTION FEATURES

15.7.4.1 The proposed Negative Return Panel shall essentially consist of a single pole disconnecting switch for each rectifier. The switch shall be manually/motorized operated and interlocked with incoming feeder.

- 15.7.4.2 The Negative Return panel shall be of heavy sheet steel construction and shall be completely best moisture and vermin proof. This shall be supplied complete with frame work, fixing bolts, barriers, enclosures, internal wiring, cable and boxes, tables, etc. All unit of the panel shall be made rust proof by at last two coats of primary paint applied on the interior and exterior surfaces followed by a finishing coat of light blue enamel paint. However, the colour coding shall be proposed to the Employer during Detail design stage for his approval.
- 15.7.4.3 The various items constituting the panel shall be neatly done and secured mounted in the panel which shall be of standard design and sufficient capacity. The copper bus bar shall be made of electrolytic high conductivity grade copper as per EN or equivalent IEC and the busbar shall be coated with electro tinned of suitable thickness (not less than 50 micron).
- 15.7.4.4 The cable compartment is to be so designed that sufficient space is available for termination of suitable nos. of XLPE insulated incoming and outgoing cable.
- 15.7.4.5 All instruments and other electrical devices mounted on the board shall have name plates with rating; date, serial number and manufacturers name etc.
- 15.7.5 OPERATION**
- 15.7.5.1 In DC railway systems, the return currents are carried back to the rectifier. The system adopted in Lucknow project (East West Corridor Phase 1 B) is a floating system in which the running rails are insulated from the track plinth. Therefore, major portion of the return current flows back to the rectifier. The connection between the negative of rectifier and the return rail shall be through Negative Return Panel.
- 15.7.5.2 The proposed Negative Return Panel shall consist of the following:
- 15.7.5.2.1 Manually/ Motorized operated single pole disconnecting switch.
- 15.7.5.2.2 Local alarm indication
- 15.7.5.2.3 ON/OFF status indication with LED's for the disconnecting switch
- 15.7.5.2.4 Interlocking of the disconnecting switch with the circuit breaker of the incoming panel
- 15.7.5.2.5 Frame Fault Protection: A current relay shall measure the current flow from the frame to protection earth and if the current exceeds the set limit (80A) then a frame fault trip shall isolate the 750VDC switchgear from all in-feeding points. The transfer trip function shall be provided such that it trips the 750VDC circuit breakers both in the traction substation and the adjacent traction substation feeders which are supplying the same section. Earth current indicators shall be installed indicating whether a rectifier or the 750VDC switchgear is faulty. Energization of the 750VDC switchgear after a frame fault trip shall be only possible when the frame fault is cleared and the 'Reset Frame Fault Trip' push button has been operated at the cubicle locally/remotely.
- 15.7.5.2.6 Current measurement and indication
- 15.7.5.2.7 Redundant Communication Switches of IEC 61850(latest) protocol for communication from different DC switchgear relay panels to RTU.

15.7.6 TYPE AND ROUTINE TESTS

15.7.6.1 Type tests are to be carried out on the prototype equipment in accordance with governing EN/IEC standards and the provision contained in this specification.

15.7.6.2 If prototype test confirming to this specification has already been conducted and certificate issued after conducting type test by recognized laboratories then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the contractor for consideration.

15.7.6.3 All isolators shall be subjected to routine tests in accordance with EN/IEC at the manufacturer's works.

15.7.7 GTP FOR NEGATIVE RETURN PANEL

15.7.7.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

15.7.7.2 The list indicated below is expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.15: GTP for Negative Return Panel

SN	Description	Unit	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Manufacturer's type designation		
4	Governing Specification		
5	Rated voltage	V	
6	Maximum permissible operating voltage	V	
7	Rated continues current	A	
8	Type		
9	Rated short time current & time	kA, Sec.	
10	Capacitive current breaking capacity at 900 V DC		
11	Operation		
12	Main Contracts		
a	Materials		
b	Is the contact silver plated if yes thickness	Mm	
c	Contact pressure	Kg	
d	Clearance between contacts when in open position	Mm	
e	Designed temperature rise with rated load	°C	
f	Contact resistance	μΩ	
13	Insulation level		
14	Anticipated life of the isolator (No of operations)		

SN	Description	Unit	Manufacturer's Data
15	Over all dimensions		
a	Length	Mm	
b	Height	Mm	
c	Breadth	mm	
16	Weight	Kg	
17	Support insulators type		
18	No. of support insulators		
19	Dry one minute 50 Hz AC withstand voltage	V	
20	Designed wreckage length		
21	Dry one minute 50 Hz AC withstand voltage	kV	
22	1.2/50 micro second dry impulse level	kV	
23	50% impulse Dry flashover voltage	kV	
24	Dry Flashover voltage	kV	
25	Puncture voltage	kV	
26	Minimum mechanical breaking load under tension.	Kg	
27	Minimum Breaking Bending Load	Kg	
28	Minimum Breaking Torsional moment	Kg	
29	Ultimate tensile strength	Kg	
30	Ultimate compressive strength	Kg	
31	Height of the operating mechanism		
32	Main bus bar		
a	Materials		
b	Size		
c	Insulating paint used		
d	Insulating paint used		
e	Lengths	Mm	
33	Busbar material		
34	Busbar capacity		

15.7.8

TEST SHEET FOR NEGATIVE RETURN PANEL

Table 15.16: Test Sheet for Negative Return Panel

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Temperature rise	X				
Verification of conformity to the manufacturing drawings and to characteristics of assembly	X	X			
Verification of measurement of resistance of main circuit	X	X			
Mechanical operation test	X	X		X	

Impulse withstand voltage test	X				
Mechanical endurance test	X				
Dielectric withstand test: power frequency voltage for main circuit	X			X	
Short circuit withstand for main & earthing circuits	X				
Aux. circuits power frequency voltage dielectric withstand test	X	X	X		
Verification of the adjustment of the relays and releases		X	X	X	
All devices operation checking		X	X	X	
Wiring		X	X	X	
Function		X	X	X	
Interlocking		X	X	X	
Painting & external visual inspection		X	X	X	X
Aux. circuits insulation				X	
Visual Inspection			X	X	X
Frame Leakage Test		X		X	
Insulation resistance test			X		
Protection Test		X	X		
Verification of the behaviour under short-time withstand current	x				
Verification of the sturdiness of the manual control device and reliability of the position indicator	x				

15.8 750 V DISCONNECTOR SWITCHES

15.8.1 SCOPE

- 15.8.1.1 This specification applies to the outdoor type, single pole and double pole air break off load motorized isolator in metal / fiberglass reinforced polyester/halogen free fire retardant resin/ flame-resistant self-extinguishing enclosures to be used at Depots, air gaps, viaducts, tunnels, unattended Traction sub-station as the DC feeder disconnecter on DC system. Double pole motorized Load Break switches are envisaged only at depot isolation. The scope of work includes design, supply, installation, testing and commissioning of device along with accessories.
- 15.8.1.2 The equipment offered shall be complete in all respect with all parts and accessories or materials which are necessary for efficient operation. All such parts and accessories shall be deemed to be within the scope of this specification whether specifically mentioned or not.
- 15.8.1.3 At some locations, these Disconnecter switches shall be installed in mid sections of viaduct and tunnel. Contractor shall ensure that the switches proposed are of such physical dimension that these can fit in the space available without infringing the structure envelope.

15.8.2 SPECIFICATIONS

- 15.8.2.1 The feeder isolator and accessories shall unless otherwise specified, conform to EN 50123 or equivalent IEC. The characteristic of the support insulators of isolator unless otherwise stand shall conform to applicable IEC.

15.8.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment proposed by the Tenderer shall be given due consideration, provided full particulars with justification thereof are furnished with approval of employer.

15.8.2.3 Internal cabling shall be Fire Retardant Low Smoke Type (FRLS) for elevated section & Fire Retardant Low Smoke zero halogen Type (FRLSOH) for Underground section.

15.8.3 RATINGS

15.8.3.1 The equipment to be supplied shall comprise of the isolator complete with mounting insulator and frame work enclosed in a metal clad enclosure. Bus bar chamber shall comprise of main bus bars, termination for connection to the isolator and the adjoining cubicles and the necessary wiring.

15.8.3.2 The rating mentioned in this specification is the expected requirement. The other particulars indicated in Table 15.17;

Table 15.17: Disconnect Switch

SN	Description	Values
1.	Type	Trackside disconnect switch/panel
2.	Governing Specifications	EN 50123
3.	Nominal Voltage	750 V DC
4.	Rated Insulation voltage	1800 V
5.	Rated continuous current	4000 A
6.	Operation	Offload, Motorised
7.	Short circuit withstand current	125kA 250 ms
8.	Dry one-minute power frequency withstand voltage	11.2 kV
9.	1.2/50 μ s dry impulse level	20 kV
10.	Main busbar	4000 A
11.	Application	Outdoor/IP 65 or above

15.8.3.3 Environmental and Climatic Data

15.8.3.3.1 The environmental and climatic data in Lucknow are provided in General Specifications.

15.8.3.3.2 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

15.8.4 OPERATION

15.8.4.1 The entire section shall be divided into various sub sections. These subsections shall be fed from different supplies. In case of failure of a particular subsection, the feed may be extended from adjacent sub section. This shall be achieved through closing of Isolator by SCADA operator.

15.8.4.2 This feature shall also be useful for maintenance purpose and line isolation in depots.

15.8.5 CONSTRUCTION FEATURES

15.8.5.1 The construction of the isolator shall be such that adequate strength and rigidity are obtained to withstand rough usage without fracture or permanent distortion.

- 15.8.5.2 The blade of the isolator shall be of electrolyte high conductivity copper and of adequate strength to withstand bending stresses, particularly at the time over load current. The copper bus bar contact shall be made of electrolytic highly conducting grade Copper as per EN/IEC Standards and bar shall be electro tinned of suitable thickness (not less than 50 micron).
- 15.8.5.3 The contacts shall be designed to carry the rated continuous shall be ensured permanent and liberal and contact area. They shall be able to withstand temperature Rise at the time of short circuit current.
- 15.8.5.4 All ferrous parts shall be hot-dip galvanized and other parts shall be substantially non-corrodible.
- 15.8.5.5 The isolators shall be provided with suitable terminal connectors to take cable terminals directly to either side (8 cables of 300 mm²).
- 15.8.5.6 The terminal connector shall be of bimetallic type to prevent electrolytic corrosion.
- 15.8.5.7 The isolator shall have the provision of manual operation from the ground level with an operating rod. The length of the rod shall be such that no infringement is permitted. The isolator panels have provision of suitable size and capacity of a space heater in each panel if required.
- 15.8.5.8 The two pole Load Break Switch (LBS) are quantified in the BoQ, which are envisaged only at depot boundaries (entry/exit). The two pole Load Break Switch (LBS) shall be used to extend both 750 V DC (+) and return (-) circuit traction power supply from mainline to depot on the need basis, generally in case of outage of Depot ASS/TSS.
- 15.8.5.9 The panel shall be mounted with indication lamps, Local/remote switch as required for the efficient operation of the same.
- 15.8.6 SAFETY FEATURES**
- 15.8.6.1 All Disconnecter switches shall be fitted with interlocking arrangement for the following.
- a) It shall not be possible to open (on load) unless the HSCB's are opened.
 - b) It shall not be possible to close the HSCB's unless the isolator is closed.
 - c) Isolator shall also have the provision of pad lock in the operating handle.
 - d) Disconnecter switches shall have voltage sensors mounted on either side. These voltages shall also be communicated to SCADA. The Disconnecter switch shall not close if voltage is higher than 50 V.
- 15.8.7 SUPPORT INSULATOR**
- 15.8.7.1 The insulators shall preferably be of solid core construction. The porcelain shall be sound, free from defects and smoothly glazed.
- 15.8.8 TYPE AND ROUTINE TESTS**

- 15.8.8.1 Type tests are to be carried out on the prototype equipment in accordance with governing EN/IEC/IS standards and the provision contained in this specification.
- 15.8.8.2 If prototype test confirming to this specification has already been conducted and certificate issued after conducting type test by recognized laboratories then fresh type test may be waived off, if it had passed the type tests earlier and no change in the design or material used have been made. Certified copies of the tests report shall be furnished by the contractor for consideration.
- 15.8.8.3 All isolators shall be subjected to routine tests in accordance with EN 50123 at the manufacturer's works.
- 15.8.9 GTP FOR 750 V DISCONNECTOR SWITCH**
- 15.8.9.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.
- 15.8.9.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.18: GTP for Disconnecter switch

SN	Description	Unit	Manufacturer's Data
1	Name of the manufacturer		
2	Country of manufacture		
3	Manufacturer's type designation		
4	Governing Specification		
5	Rated voltage	V	
6	Maximum permissible operating voltage	V	
7	Rated continues current	A	
8	Type		
9	Rated short time current & time	KA, Sec.	
10	Capacitive current breaking capacity at 900 V DC		
11	Operation		
12	Main Contracts		
a	Materials		
b	Is the contact silver plated if yes thickness	Mm	
c	Contact pressure	Kg	
d	Clearance between contacts when in open position	Mm	
e	Designed temperature rise with rated load	O C	
f	Contact resistance	Micro ohm	
13	Insulation level		
14	Anticipated life of the isolator (No of operations)		
15	Over all dimensions		
a	Length	Mm	
b	Height	Mm	

SN	Description	Unit	Manufacturer's Data
c	Breadth	mm	
16	Weight	Kg	
17	Support insulators type		
18	No. of support insulators		
19	Dry one minute 50 Hz AC withstand voltage	V	
20	Designed creepage length		
21	Dry one minute 50 Hz AC withstand voltage	KV	
22	1.2/50 micro second dry impulse level	KV	
23	50% impulse Dry flashover voltage	KV	
24	Dry Flashover voltage	KV	
25	Puncture voltage	KV	
26	Minimum mechanical breaking load under tension.	Kg	
27	Minimum Breaking Bending Load	Kg	
28	Minimum Breaking Torsional moment	Kg	
29	Ultimate tensile strength	Kg	
30	Ultimate compressive strength	Kg	
31	Height of the operating mechanism		
32	Main bus bar		
a	Materials		
b	Size		
c	Insulating paint used		
d	Insulating paint used		
e	Lengths	Mm	

15.8.10 TEST SHEET FOR DISCONNECTOR SWITCHES

Table 15.19: Test Sheet for Disconnector switch

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Temperature rise	X				
Verification of conformity to the manufacturing drawings and to characteristics of assembly	X	X			
Verification of measurement of resistance of main circuit	X	X			
Mechanical endurance test	X				
Mechanical operation test	X	X			
Lightning impulse withstand voltage	X				
Lightning impulse withstand on the isolating distance	X				

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Short circuit withstand for main & earthing circuits	X				
Protection of persons against live parts	X				
Aux. circuits dielectric withstand		X	X		
Main circuits resistance value		X	X		
Withstand voltage at 50 Hz		X	X		
Withstand voltage at 50 Hz on the isolating distance		X	X		
All devices operation checking		X	X		
Wiring		X	X	X	
Function		X	X	X	
Interlocking		X	X	X	
Painting & external visual inspection		X	X	X	X
Aux. circuits insulation				X	
Insulation Resistance		X		X	
High Voltage Test		X		X	
Frame Leakage Test		X		X	
Protection test		X	X		
Power-frequency voltage	X				
Verification of the behaviour under short-time withstand current	X				
Verification of the sturdiness of the manual control device and reliability of the position indicator	X				

15.9 CONTROL POWER SUPPLY

15.9.1 SCOPE

15.9.1.1 The specification applies to DC control power supply system (Battery, Battery Charger, and DCDB), ACDB and LV & Control Cables for installation at Traction Substation. The scope of work includes Design, supply, installation, testing and commissioning of all of the above along with accessories.

15.9.2 SPECIFICATIONS

15.9.2.1 The specifications have been defined in Chapter 14 Clause-14.4 (110 V DC control power supply system), Clause-14.5 (AC Distribution Board) and Clause-14.6 (LV Cabling and Wiring). The battery, battery charger, ACDB and DCDB shall be common for Auxiliary and Traction substations.

15.9.2.2 Any deviation from this specification intended to improve the performance, utility and efficiency of the equipment, proposed by the tenderer, will be given due consideration, provided full particulars with justification thereof are furnished with the approval of employer

15.10 DC POWER CABLES

15.10.1 SCOPE

- 15.10.1.1 This specification covers compact circular stranded copper conductor, XLPE insulated, 300 mm² flexible cables and outer sheathed cable of rated voltage grade 3.3 kV (U_m) for positive cables and 1.1 kV (U_m) for negative / return cables. DC Cables of FRLS UV ATAR (Anti Termite and Anti Rodent) Compound will be used for Elevated Stations and for Underground Stations FRLSOH ATAR compound will be used.
- 15.10.1.2 They will be installed as feeding cables between the DC-switchgear in the Traction Substations (ASS/TSS) and the 3rd rail along the line and as return current cables between the running rails and the return current cubicles in the Traction Substations (ASS/TSS). Besides they will also be used as bonding cables between the rails / tracks and also required for bridging physical gaps in third rail in mainline and depot.
- 15.10.1.3 The cable shall be used for feeding 750 Volts DC traction power to 3rd rail (Conductor Rail) at sub way from traction substation. The cables will be laid on galvanized mild steel cable supports in free air. The cable may also be laid underground at some places. The cables shall also be laid in the concrete cable trenches on the elevated viaduct portion covered with RCC slabs or exposed to direct sunlight.
- 15.10.1.4 In addition to DC power cables, copper control cables of suitable sizes and rating for inter-tripping and earthing switch interlocks shall be laid along viaduct. These control cables shall be FRLS for elevated, at-grade / depot sections and FRLSOH for underground. Separate cables for this purpose shall be used and shall not be mixed with similar cables used to 33 kV network. Contractor shall propose detailed proposal including technical particulars of these cables to Engineer for approval.

15.10.2 SPECIFICATIONS

- 15.10.2.1 The DC cables are in accordance with IEC 60502-1. The cable shall conform to IS specification No. 7098 Pt-II or latest and shall be applied in the manner altered, amended or supplemented by the latest version of these specifications and also the relevant provisions of the latest Indian electricity rules wherever applicable.

15.10.3 RATINGS

The DC Cables shall be used at different locations. The cable sizing mentioned in this specification is the expected requirement. The cables in different sections is indicated in Table 15.20.

Table 15.20: 750 V DC Cable Sizing

SN	Location	Cable Size
1.	From Transformer to Rectifier	LV Bus duct
2.	From Rectifier to Incomer HSCB Panel	6 x (1 x 300 mm ² Cu), FRLS/OH
3.	From Rectifier to Negative Return Panel	Inter-panel Bus bar
4.	From each Feeder HSCB Panel to Bypass Panel	6 x (1 x 300 mm ² Cu), FRLS/OH
5.	From Bypass Panel to each section of third rail	6 x (1 x 300 mm ² Cu), FRLS/OH
6.	From each running rail to Negative Return Panel	6 x (1 x 300 mm ² Cu), FRLS/OH
7.	From return panel to Short Circuiting device	2 x (1 x 300 mm ² Cu), FRLS/OH
8.	Connections of third rail with Disconnecter switches and across physical discontinuities in	6 x (1 x 300 mm ² Cu), FRLS/OH

SN	Location	Cable Size
	3 rd rail for electrical continuity in Main Line	
9.	Connections of third rail with Disconnectors switches and across physical discontinuities in 3 rd rail for electrical continuity in Depot	6 x (1 x 300 mm ² Cu), FRLS/OH
10.	From Depot ASS/TSS HSCB to Stinger Load Break Switch panel in Depot	6 x (1 x 300 mm ² Cu), FRLS

15.10.3.1 The Cable shall be designed for the rating and other parameters indicated in Table 15.21;

Table 15.21: 750 V DC Cable Rating

SN	Description	Cable Rating
1	Type	Cu conductor XLPE Insulated
2	Governing standards	IEC 60502-1/ IS 7098-1/IS 7098-2 as applicable
3	Conductor	Compacted Circular Stranded Copper
4	Rated insulation voltage	3.3 kV (Positive Cables) 1.1 kV (Negative / Return Cables)
5	Fire retardant property	FRLS for at grade/elevated (With UV & ATAR protection properties) FRLSOH for underground (with ATAR protection properties)
6	System	Unearthed (for Mainlines) Earthed (For Depots)
7	Short circuit Rating	42.9 kA for 1 second

15.10.3.2 Environmental and Climatic Data

15.10.3.2.1 The environmental and climatic data in Lucknow are provided in General Specifications.

15.10.3.2.2 The thermal resistivity of soil may be assumed to be 120 – 150 °C-cm/watt (for laying in ground from ASS/TSS to Third Rail / Stinger and ASS/TSS to running rails, as relevant). The Tenderer during detailed design stage shall consider the de-rating and accordingly number of runs required to be ascertained.

15.10.3.2.3 It must be noted that environmental conditions shall be very severe during construction; these conditions shall not be the cause of any alteration of equipment or material whether already installed or simply stored.

15.10.4 CONSTRUCTION FEATURES

15.10.4.1 The cable shall be manufactured by a company having ISO Accreditation for quality. The manufacturing process of XLPE cable shall consist of insulation cross linked by dry curing technology to ensure homogeneity and absence of micro voids. The cables shall be manufactured by “Wet Curing” Process.

15.10.4.2 Conductor

15.10.4.3 The copper conductor shall be of Plain Annealed EC / Oxygen free Grade, Compacted circular stranded conforming to Class 2 of IEC 60228. The Geometrical Cross-sectional area of the conductor shall be better and propositional to the specified cross-sectional area with a tolerance of - 3%.

This tolerance should be calculated only on the cross-sectional area of the conductor and not on the maximum conductor resistance requirement as per IEC 60228. By using the formula which is related to specific resistivity, the manufacturer has to prove that the conductor is not only meeting the geometrical cross sectional area requirements of Lucknow but also the resistance of copper conductor is lower than the maximum specified as per IEC 60228.

15.10.4.4 The manufacturer shall precise the characteristics of the components of the conductor:

- a) Number of wires,
- b) Diameter of wires,
- c) Copper quality

15.10.4.4.1 The maximum temperatures admissible for the conductor, as per IEC 60502-1 & 2, are as follow:

- a) Permanent service: 90°C for the conductor
- b) Short-circuit: 250°C for the conductor

15.10.4.5 **Insulation**

15.10.4.5.1 The conductor shall be provided with cross linked polyethylene (XLPE) insulation applied by extrusion. The nominal thickness of insulation shall be as per IEC 60502 / IS 7098 Part-II.

15.10.4.5.2 The Insulation shall be XLPE Complying with IEC 60502 and IEC 60811. The insulation shall have a degree of Cross- Linking, free of contaminants and air voids, heat resistant and shall be applied by the extrusion process.

15.10.4.5.3 The insulation compound shall be of high quality, heat, moisture, ozone and corona resistant. XLPE compound should be from Borealis, Sweden or NUC Japan or equivalent. The insulation shall be suitable for operation in wet or dry locations at conductor temperature not exceeding 90°C for normal operation, and 250°C for short circuit conditions.

15.10.4.5.4 The Insulation shall be applied by extrusion and vulcanized using wet curing process to form a compact homogenous body free from micro voids and contaminants.

Type of cable	Nominal Thickness of Insulation	Tensile Strength shall not be less than	Elongation Shall not be less than	Hot Set Shall not be more than %,
3.3 kV DC Cable	2.0 mm	14 N/mm ²	200 %	70%
1.1 kV DC Cable	1.8 mm	14 N/mm ²	200 %	70%

15.10.4.6 **Inner Sheath**

15.10.4.6.1 All single core DC cables should have an Inner sheathing bedding above the Insulation of FRLS ST2 Compound or FRLSZH Compound. The Thickness of the Inner sheath should not be less than 1.0 mm at any one point when checked continuously.

15.10.4.7 **Armouring**

15.10.4.7.1 All DC cables of 300 mm² Copper shall be of EC grade pure aluminium wire armored in accordance with manufacturing standards.

15.10.4.8 **Outer Sheath**

15.10.4.8.1 The outer sheath shall be extruded, FRLS / FRLSOH as defined above confirming of requirement of IEC specifications and extruded continuously. Outer sheath shall be treated with Anti Termite & corrosion Resistant Compound. Elevated cables shall be treated with UV resistant properties. DC Positive cables shall be BLACK in color and negative return cables shall be black in color.

Compound Type	Min Tensile Strength shall be..	Min Elongation % shall be.	Min Oxygen Index as per ASTM	Min Temperature Index as per ASTM.	Maximum Smoke Density As per ASTM	HCL % should be within
FRLS	12.5 N/mm ²	150%	31%	260° C	40%	20%
FRLSOH	9.0 N/mm ²	150%	31%	260° C	20%	0.5%

15.10.4.9 **External Marking**

15.10.4.9.1 The protective sheath shall carry the indications listed below, in letters and digits at least 6 mm high:

- a) designation of ownership,
- b) Meter marking
- c) Year of manufacture
- d) nature and cross-sectional area of conductors,
- e) specified cable voltage,
- f) phase numbering,
- g) manufacturer's name.

15.10.4.10 **Drum Schedule and Marking**

15.10.4.10.1 The cables shall general be supplied to length not less than 500m in each drum. The length of cable on each drum shall, however, be so adjusted that the number of joints in the feeder are minimum. Normally no joints shall be permitted in the feeder and return cables.

15.10.4.10.2 The Contractor shall, therefore, assess the actual length required for the route of laying of cable before ordering on the manufacturer. Prior approval by Engineer for the size of the cable drum, length of cable in each cable drum and number of drums is to be obtained from the purchaser before manufacture.

15.10.4.10.3 The cable shall be wound on drums of suitable sizes for easy handling and maneuvering. The drums shall be robust in construction with suitably packed and marked. The marking of the drums shall have the following information:

- a) Trade mark, if any
- b) Name of manufacturer
- c) Nominal cross-sectional area of the conductor of the cable
- d) Number of cores
- e) Type of cable and voltage grade
- f) Length of the cable on the drum
- g) Approximate gross weight
- h) Drum number according to drum schedule
- i) Direction of rolling
- j) ISI/IEC mark of inspection
- k) Year and month of manufacture

15.10.5 TESTS

15.10.5.1 750 V DC positive and negative cables for use in elevated section shall comply with tests as per IEC 60502. The DC cables for underground section shall comply with the additional following tests:

- a) Conductor resistance for full drum and Weight of conductor for one meter sample
- b) Annealing Test for Copper
- c) Tensile test for Aluminum Conductor
- d) Wrapping Test for Aluminum
- e) Impulse test for 3.3kV Cable in house
- f) Test for Thickness of insulation and Sheath
- g) Hot Set Test for Insulation
- h) Tensile and Elongation tests for Insulation and sheath
- i) High Voltage test
- j) Insulation Resistance test
- k) Armour Diameter and Resistance test
- l) IEC 332 Part 1 and 3, category A, test on single and bunched cables under fire condition.
- m) Limiting Oxygen Index of at least 31 as per ASTM D 2863
- n) A Temperature index of 260 ° C as per ASTM D 2863
- o) 3 m cube smoke emission test, when Tested in accordance to IEC 61034/BS 7622- Maximum smoke emission of 40% & Minimum Light Transmission of 60%.

- p) All Insulation is to be moisture and heat resistant, with temperature rating appropriate to the application conditions and in no case lower than 90° C.
 - q) Determination of the amount of halogen acid Gases as per IEC 754 Part 1 (maximum HCL gas shall not exceed 20% for FRLS & 0.5% for FRLSOH) and IEC 754 Part –II.
 - r) Radio very low frequency test (VLF)
- 15.10.5.2 The routine test will be conducted on sample cable drums as per provision laid down in is 7098, Pt –II -1985, IEC 60502-1 but shall not be limited to the following:
- a) Conductor resistance
 - b) High voltage test
 - c) Any other relevant test
- 15.10.5.3 The manufacturer shall conduct all the routine tests as prescribed in the standard on entire lot/ drums.

15.10.6 CABLE JOINTS & TERMINATIONS

- 15.10.6.1 The indoor/outdoor termination shall be of proven make 'Heat-shrinkable type suitable for 3.3 kV (E) grade or higher, single core, XLPE Insulated DC cables with only heat shrinkable type sleeves. Terminations with insulating tapes or any other type are not acceptable.
- 15.10.6.2 The accessories should be compatible with size of the conductor, the insulation and the voltage class of the cable. The components of the accessory shall not be affected by contact with the component materials of the cable, and shall not corrode any metal, which they come in contact. The accessory, in the assembled condition, shall be capable of operating under the normal and fault temperature conditions of the cable. Accessories offered shall be of proven design.
- 15.10.6.3 Connecting junctions shall reconstitute perfectly all elements of the DC cables, so as to obtain electrical and mechanical characteristics at least equal to those of the cable.
- 15.10.6.4 The Contractor shall submit to the client, for approval, a detailed description of the technique foreseen for execution of connections in DC lines.
- 15.10.6.5 However, maintenance and repair being able to be carried out only during a short period of time, at night, due consideration shall be given to connection processes having the following characteristics, quality being otherwise equal:
- a) quickness of execution,
 - b) possibility of replacement without having to disturb the cable,
 - c) Small bulk

15.10.7 DC CABLE INSTALLATION

- 15.10.7.1 The 750 V DC +ve cables shall be used to carry the power from Rectifier to HSCB and from HSCB to third rails. 750 V –ve DC cable shall be used to carry the return current from running rail to Rectifier. Following specifications shall be applicable for laying of 750 V DC Cables (both on mainlines and Depots):
- 15.10.7.2 **Laying**

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- 15.10.7.2.1 The cables shall be laid on suitable cable trays inside ASS/TSS. Cables shall be brought out on the track side with proper bending radius as advised by the manufacturer. Over the viaduct, the cables shall be laid on channels/pipes. Cables shall be of single piece and not joined.
- 15.10.7.2.2 The +ve and –ve cables shall be connected to third rail and running rails respectively by suitable means as advised by the third rail manufacturer. All regular fixing nuts, bolts and washers shall be stainless steel of appropriate size and torque up to value as per manufacturer recommendation. The appropriate flat stainless-steel washer shall be used between cable lug and fixing bolt head. For the purpose, the contractor shall submit a suitable termination scheme for approval. Contractor shall coordinate with track contractor for suitable termination of return cables on running rails.
- 15.10.7.2.3 All contact surfaces should be vigorously wire brushed to remove the oxide layer and coated by suitable electrolytic grease as per recommendation of third rail manufacturer. Cable connections to the third rail should not be within 500 mm of a third rail insulated support and positioned to allow for 200 mm of rail expansion with increasing temperature. Further the cable connection should not be within 300 mm of the fastenings of ramps.
- 15.10.7.2.4 Positive feed cables shall be segregated as far as possible from negative cables. In no instance positive and negative cables run in the same duct. Where cables cross under the track not in ducts, there should be a clear 25 mm gap between the top of the cable and the bottom of the rail foot. Cables shall not pass under rails at the position of breathers, insulated rail joints or fish-plated rail joints.
- 15.10.7.2.5 Bending radius of cable routing shall exceed the minimum bending radius assigned to the cable by the manufacturer.
- 15.10.7.2.6 The LKE(02)-01 shall ensure that all cabling arrangements are fully coordinated with the requirements of track work and any trackside elements of the signaling system.
- 15.10.7.2.7 Laying out of the cables can be made manually or mechanically. The mechanical devices (electric or pneumatic) used for paying out the cables shall be so constructed that they would prevent damaging the cables. Methodology for using these devices shall be submitted to the Engineer for approval.
- 15.10.7.2.8 The laying team shall be under the authority of a supervisor qualified for this type of work. All necessary precautions shall be implemented during operation to prevent any deterioration of the cable; the cable shall not be subjected to any twisting around its axis, and not be bent to a radius smaller than the minimum bending radius specified by the cable manufacturer. It shall be subjected only to the traction efforts strictly required to pay it out. In no event may the cable bear against the ground or against fixed stops; it shall rest onto rollers, situated sufficiently close to one another.
- 15.10.7.2.9 The ends of two successive reel lengths shall overlap by about two meters to enable cropping the cable ends before execution of the connection sleeves.
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15.10.7.2.10 All cables laid on channels, or on cable-tray shall carry an 8 x 5 cm PVC tag placed every 10 m and in specific locations such as connection sleeves, entry into and exit from ducts, possible pulling chambers. These tags, fastened via two clamps, shall bear the labels approved by the Employer. Tagging of cables plays a part in safety as regard identification of the cables in case of incident and shall be made very carefully and the Contractor shall be responsible for any error or for any incident subsequent to such an error. The tags shall be fastened right after the paying out of each reel.

15.10.7.2.11 Flexible conduits shall be used for laying cables on the track beds as needed which shall be as per IS:3480 (latest) along with applicable standards as required for accessories.

15.10.7.3 **DC cables entry/exit sealing at Stations & ASS/TSS**

15.10.7.3.1 All entry/exit of DC positive and negative cables are to be sealed with EPDM modules. Detailed specifications and requirements are defined in Chapter 13 of ERTS/Employer's Requirement.

15.10.8 **CONTROL CABLES**

15.10.8.1 Along the viaduct and tunnel, control cables for inter-tripping and earthing switch interlocks shall be required to be installed.

15.10.8.2 Inter-tripping cables shall be of fiber optical, armoured and FRLS/FRLSOH type.

15.10.8.3 33kV pilot wire cable shall be considered for inter-tripping between ASS/TSS.

15.10.8.4 These cables shall be suitable protected and laid according to applicable standards and code of practice.

15.10.9 **GTP FOR DC POWER CABLES**

15.10.9.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

15.10.9.2 The list indicated below is minimum requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.22: GTP for DC Cables

SN	Description	Unit of measurement	Manufacturer's data
1.	Name of the manufacturer		
2.	Country of manufacture		
3.	Relevant Specification		
4.	Manufacturer's type designation		
5.	Voltage Grade	kV	
6.	Size of cable & Type	mm ²	
7.	Rated system voltage	V DC	
8.	Rated continuous current		
a.	In air (at ambient temp.)	A	
b.	In ground (at ground temp. 30°C)	A	
c.	In duct (at ground temp. 30°C)	A	
9.	Max permissible current:-		
a.	At 90 °C (Continuous Rating)	A	

SN	Description	Unit of measurement	Manufacturer's data
b.	At 130 °C (Emergency rating)	A	
c.	At 250 °C (Short circuit rating)	A	
10.	Permissible current of overload current in case of emergency overload	Hours	
11.	Short circuit rating for one second	kA	
12.	Permissible interval of successive emergency overloads at 130 °C	Min	
13.	Group rating factor		
14.	Minimum permissible bending radius	m	
15.	Conductor		
a.	Type		
b.	Size (Nominal)	mm	
c.	No. of strands (Nominal)	Nos.	
d.	Nominal Dia. Of each strand	mm	
e.	Shape of conductor		
f.	Conductor material as per IEC 60228		
16.	Insulation		
a.	Type		
b.	Thickness (Nominal)	mm	
c.	Tolerance on thickness	mm	
d.	Core Colour		
17.	Armour		
a.	Material		
b.	Thickness (Nominal & Minimum)	mm	
18.	Outer Sheath		
a.	Material		
b.	Thickness (minimum)	mm	
c.	Colour		
d.	Short Circuit rating	kA	
19.	No. of voids per cubic inch of insulations		
a	Voids between 2 and 3 mils	Nos.	
b	Voids larger than 3 mils	Nos.	
20.	No. of contaminations per cubic inch of insulation		
a	Contaminations between 2 & 7 mils		
b	Contamination larger than 7 mils		
21.	FRLS/OH Properties		
a.	Oxygen Index		
b.	Temperature Index		
c.	Smoke Emission		
d.	Acid Gas Generation (HCL)		
e.	Flame Propagation on cables		
22.	Approx. Overall diameter of cable	mm	
23.	Tolerance on overall dia.	mm	
24.	Weight		
a.	Approx. Weight per meter	Kg/mtr.	
b.	Gross weight of drum including cable	Kg	
25.	Physical data (Material used, dimensions in mm/ nos. and source of raw material		

SN	Description	Unit of measurement	Manufacturer's data
	to be indicated)		
a.	XLPE insulation		
b.	Inner sheath (nominal and max thickness)		
c.	Armour (nominal & minimum)		
d.	Outer sheath (nominal and minimum)		
e.	Conductor		
f.	Filler		
g.	Copper tape		
h.	Core identification tape		
26.	Jointing		
a.	Type of jointing recommended		
b.	Name of manufacturer of jointing kit		
c.	Permissible temp rise of joint, if any		
d.	Brief process of jointing		
27.	Termination (Indoor / outdoor)		
a.	Type of termination recommended		
b.	Name of manufacturer of termination		
28.	Overall dimension of the covering / box of joints, if applicable		
a.	Length	mm	
b.	Width	mm	
c.	Height	mm	
29.	Brief process of manufacture indicating the method of cross-linking and type of curing		
30.	Safe Pulling Force	kN	
31.	Drum Details		
a.	Drum material used		
b.	Standard Drum length with tolerance	Mtr.	
c.	Overall Quantity Tolerance		
32.	Max. DC Conductor Resistance at 20 deg. C	Ohm/kM	
33.	Approx. AC resistance at 90 deg. C	Ohm/kM	
34.	Star reactance per phase at 50Hz	Ohm/kM	
35.	Capacitance per phase at 50Hz	μF/kM	
36.	Sequential Length Marking		
37.	Embossing details		

15.10.10 LV BUS DUCT / DC Cable**15.10.10.1 SCOPE**

15.10.10.1.1 This specification is intended for design, manufacture, supply, testing, transporting to site of 700 V, 3-phase, 50 Hz sandwich bus duct with aluminium bus conductors / DC cable suitable for 1600 A continuous current rating and short time overload rating similar to rectifier i.e., 150% for 2 Hrs – 2400 A (during interval of 3 h) & 300% for 1 min – 4,800 A (1 min during an interval of 30 min) as per specifications for the connection between secondary of traction transformer to rectifier. The equipment to be offered under this specification shall be of proven design by and duly type tested in accordance with relevant IEC produced from a manufacturing facility and in commercial operation for at least five years in similar project. Contractor shall submit the necessary design document of Bus duct / DC cable to meet the above requirement for the approval of Engineer.

15.10.10.2 **CODES AND STANDARDS**

15.10.10.2.1 The equipment specified in this specification shall be designed, manufactured and tested in accordance with latest relevant Indian standards or IEC codes. In the event of any contradiction between this specification and IS/IEC codes then the more stringent of the two shall govern.

IS 8084 –	1976 Interconnecting bus bars for AC voltages above 1 kV
IS 8623-2	Factory built assemblies requirements of bus bar trunking system
IEC 61439 (Part-2)	Particular requirements of bus bar trunking systems.(IEC 61439 – 1 & 6)

15.10.10.3 **DESIGN AND CONSTRUCTION REQUIREMENTS**

15.10.10.3.1 General

The busbar trunking system, both feeder and plug-in, shall have sandwich construction. All busbar trunking products and fittings (straight length, elbow, tees, flanged ends, cable tap box and circuit breaker, etc.) shall be in accordance with IEC 61439-6: 2012 or UL857 and from the same manufacturer as the busbar trunking system. The degree of protection of the busbar trunking system should be IP54 in accordance to IEC 60529. Rated operation voltage of the busbar trunking is 1000 V. 3 – Phase, 3 Wire. The earth busbar must be one continuous piece without bolting on housing. The ampere ratings, approximate footage, fitting, plug-in units etc. are shown on the plan.

15.10.10.3.2 Quantities specified in the BoQ are indicative only. The same are subjected to change during detailed design. The bus duct shall be supplied:

- in straight run,
- 90-degree bends,
- Aluminium flexible connections at transformer end and copper flexible connections at rectifier end
- Phase cross over chamber,
- Suitable bimetallic connections wherever required
- Wall sealing unit etc. as required.

- 15.10.10.3.3 The bus duct shall be indoor type, Aluminium bus duct, totally dust and vermin proof with adequate supports from ceiling, wall, floor etc. The bus duct shall be complete with all accessories made out of reinforced angle iron sheet steel. It shall be equipped with equipment flanges at transformer and switchgear end, earth bus with 75 x 10 mm GI flat / strip. Bus duct shall be measured along the centre line of bus duct between tips of equipment flanges. All other materials required shall be included as per standards and as required.
- 15.10.10.3.4 The earth bus bars shall be provided along with bus duct enclosure with one end tapped from MDB switch and other end to transformer with proper flexible connections at either ends. The bus duct shall be supported by angle iron from ceiling / wall such that weight of bus duct is not transferred to the transformer or MDB. Wherever required, crossovers shall be provided for phase sequencing.
- 15.10.10.4 **Bus Bars**
- 15.10.10.4.1 Bus bars shall be made of high conductivity electrical grade aluminum alloy. Plating on Aluminum Conductors shall be used to prevent surface oxidization, ensuring minimum contact resistance, prevention of fretting corrosion.
- 15.10.10.4.2 Bus bars shall be of adequate size to withstand the system fault current for the specified time duration i.e. 16 kA for 1 second. Contractor shall submit the busbar sizing calculations for short circuit withstand capability and maximum temperature, rise indicating the de-rating factors clearly for the approval of Engineer.
- 15.10.10.4.3 Bus bars shall be designed for bolted connections throughout the run. There shall be no bolts passing through the bus bars/conductors of the busway system.
- 15.10.10.4.4 Flexible connections shall be provided between bus sections to allow for expansion and contraction of the conductor. Aluminium flexible connections shall also be provided at all equipment terminations.
- 15.10.10.4.5 Bus bars shall be colour coded / taped with red, yellow and blue as applicable for easy identification.
- 15.10.10.4.6 Each busbar / conductor shall be insulated with Class F rated (155°C) polyester film/epoxy in two layers. Considering importance of insulation material, UL / Equivalent Authority Certified & Listed Insulation Material shall only be used. Considering environment friendly norms, all insulation materials shall be halogen free and RoHS compliant.
- 15.10.10.4.7 The temperature rise at any point of the busbar trunking enclosure shall not exceed 55-degree Centigrade rise above ambient temperature while in operation at rated current.
- 15.10.10.5 **Joints**
- 15.10.10.5.1 The busbar trunking joint shall be of the one-bolt type which utilizes a high strength steel bolt(s) and Belleville washers to maintain proper pressure over a large contact surface area.

- 15.10.10.5.2 The bolt shall be torque indicating and at earth potential. Each joint shall have nut retainer to ensure proper alignment of joint and positioning of joint bolt.
- 15.10.10.5.3 The bolt shall have two-headed design to indicate adequate torque level, once it is applied by wrench. Tightening of bolt shall be possible by a standard long handle wrench.
- 15.10.10.5.4 Access shall be required to only one side of the busbar trunking for tightening joint bolts.
- 15.10.10.5.5 It shall be possible to remove any joint to allow electrical isolation or physical removal of a busbar trunking length without disturbing adjacent elements / busbar trunking lengths.
- 15.10.10.5.6 Joint types requiring holes in conductors are not acceptable.
- 15.10.10.5.7 Joint Insulator Plates shall be flame retardant and shall have adequate RTI (Relative Temperature Index)
- 15.10.10.5.8 Each Joint side plate shall have specially molded covers (acting as sealants) to provide adequate protection against dust ingress for entire service life desired from system. Systems using neoprene gaskets, calking to attain desired level of ingress protection will not be acceptable. The busbar trunking joint shall be of the one-bolt type which utilizes a high strength steel bolt(s) and Belleville washers to maintain proper pressure over a large contact surface area.
- 15.10.10.5.9 The joints shall be designed to withstand vibrations caused by transformers.
- 15.10.10.5.10 All matching flanges, seal-off bushings, fittings, hardware and supports required for termination of bus duct at switch gears, transformers shall be supplied.
- 15.10.10.6 **Supports**
- 15.10.10.6.1 Hanger spacing shall not exceed manufacturer's recommendations.
- 15.10.10.7 **Name Plate**
- 15.10.10.7.1 Suitable name plate shall be provided for each piece equipment for easy identification of bus duct.
- 15.10.10.8 **Paint finish**
- 15.10.10.8.1 The outside surface finish shall be epoxy based Pebble grey shade RAL 7032. (ANSI 49 Grey). Insulation shall be original MYLAR from Du Pont, Class F and shall have UL certification for RTI and flame rating.
- 15.10.11 TESTS (BUS DUCT)**
- 15.10.11.1 The busbar, of full range and each rating, should pass full type tests specified in IEC 61439-6:2012.
- 15.10.11.2 The whole busbar trunking system shall be capable of withstanding the short circuit of the electrical installation without damaging the electrical, mechanical and thermal stress under fault condition at a service voltage of 1000V 50Hz. The minimum rated insulation voltage shall be 1000V.

15.10.11.3 The voltage drop (input voltage minus output voltage) specified shall be based on the busway operating at full rated current and at stabilized operating temperature in 50 °C ambient. The three-phase, line to line voltage drop shall not exceed 3.4 volts per hundred feet at 80% power factor and assuming concentrated load at the far end. The line-to line voltage drop of busway run shall not exceed 2.5% of rated voltage.

15.10.11.4 The above test requirement is applicable under continuous rating of 1600 A only and not applicable for overloading.

15.10.12 DESIGN / DOCUMENTS SUBMISSIONS

15.10.12.1 The following drawings / designs documents shall be furnished by the Contractor:

15.10.12.2 Busbar sizing calculations for (i) continuous current carrying capacity,(ii) temperature rise and (iii) short circuit withstand capacity.

15.10.12.3 Layout of individual bus duct set along with bill of material

15.10.12.4 Detailed fabrication drawings.

15.10.13 PACKING AND DISPATCH

15.10.13.1 All equipment covered under this specification including all accessories shall be properly packed and delivered at site in order to prevent any damage during transit and in storage at site.

15.10.14 GTP FOR BUS DUCT

15.10.14.1 The Contractor shall submit the following minimum details in technical proposal and at the time of vendor approval. The material shall be procured by the Contractor only after the particulars have been approved by the Engineer.

15.10.14.2 The list indicated below is expected requirement of details to be provided by the Contractor and it is not exhaustive. The Contractor shall provide additional relevant details, if any.

Table 15.23: GTP for Bus Duct

SN	Description	Unit	Values
1	Make		
2	Applicable Standard		
3	System nominal voltage	Volt	
4	System frequency	Hz	
5	Number of phases		
6	Current rating	A	
a.	Continuous – 100%	A	
b.	Over load – 150% for 2 hours	A	
c.	Over load – 300% for 1 minute	A	
8	Deleted		
9	Insulation level		
a.	1-minute dry power frequency withstand voltage	kV rms	
b.	Impulse withstand voltage		
10	Short time rating (symmetrical kA for 1 second)	kA	
11	Cooling		
12	Design ambient temperature	°C	

SN	Description	Unit	Values
13	Location		
14	Degree of protection		
15	Maximum temperature rise (over 50°C ambient)		
a.	Bus conductor	°C	
b.	Bus enclosure and support structure	°C	
16	Material		
a.	Busbar		
b.	Enclosure		
17	Constructional features		
a.	Busbar joints		
b.	Flexible / expansion		
	i. Material		
	ii. Type		
	iii. Short circuit & continuous rating		
c.	Cover over chamber		
18	Enclosure joints		
19	Disconnecting link		
20	Ground bus		
21	Grounding terminal		
22	Paint finish		
a.	Inside		
b.	Outside		
c.	Coating thickness		
23	Applicable standards		
24	Acceptance tests		
25	Application clearance		
26	Creepage distance		
27	Seal off bushing at wall entries		
28	Insulators non-hygroscopic FRP/SMC with high anti-tracking index		
29	Inspection		

15.10.15

TEST SHEET FOR BUS DUCT

Table 15.24: Test Sheet for Bus Duct

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Visual test	X	X		X	
Strength of Materials & Parts	X				
Degree of Protection	X				
Impulse Voltage Test	X				
Clearance Check	X	X	X		
Creepage distance	X				
Protection against electric Shock & Integrity of protective CKT	X		X		
Temperature-Rise Test	X				

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Short Circuit Withstand Test	X				
Resistance to flame propagation	X				
Fire Resistance in building Penetration	X				
Dielectric Test	X	X	X		
Mechanical operation	X			X	X
Insulation Resistance Test for enclosure circuit		X	X	X	
Dimension Checks		X	X	X	
Bolt and nut tightness of Housing		X	X		
Overall Appearance Check		X	X	X	X

15.11 Third Rail Short Circuit Device (Motorized)

15.11.1 SCOPE

15.11.1.1 Scope of work shall include design, supply, install, test and commission the Third Rail Short Circuit & Earthing Device connected between the third rail and running rail including the necessary cables, cable terminations, cable terminals, cable terminal cover and running rail connections as indicated in the table below for Lucknow Metro Project:

15.11.2 SYSTEM FEATURES

- 15.11.2.1 The switchboard will be installed in ASS/TSS room or at trackside in Mainline and at trackside locations in Depot for the operation within the minimum and maximum temperature admissible for itself. The location shall be subject to Employers approval.
- 15.11.2.2 The type of flooring and consequently how the equipment is fastened to the floor, will be detailed by the traction contractor or will submit shop drawing for mounting installation details for Employer's approval.
- 15.11.2.3 For installation in trackside locations Suitable pedestal structure/foundation or suitable support structure must be provided to support the weight of the complete switchboard. Also suitable arrangement for accessing/operating the panel to be provided.
- 15.11.2.4 The contractor shall provide the necessary support to ensure that the proposed panel is appropriately and adequately supported.
- 15.11.2.5 Insulated pad shall be provided between floor and the switchboard in order to get proper functioning of the Earth Fault Relay 64.
- 15.11.2.6 Switchboard shall be capable of carrying rated current continuously without exceeding 45 deg C rise over 50 deg C ambient temperature external to the enclosure. The design shall take into account of the temperature in Lucknow and the effect upon temperature within the enclosure.

- 15.11.2.7 Motor Mechanism shall be operated on 110V DC Power Supply. The motor capacity shall be sized to overcome the initial stiffness of the operating mechanism due to non-operation for prolong period. Power cable shall be sized to consider voltage drop and surge current due to motor starting.
- 15.11.2.8 The switchboard shall be able to operate manually during control supply failure. The operating handle shall be complete with suitable torque limiter/tightener for local manual operation of the switch.
- 15.11.2.9 The enclosure of the switchboard shall have provision to clearly display the physical switch position.
- 15.11.2.10 Switchboard shall be provided with electro-mechanical interlock actuated by voltage measuring relays connected to the 3rd rail side to prevent operation when the relay is energized. The sensing circuit of the relay shall normally be isolated from the third rail when the switch is in the "off" position.

15.11.3 GENERAL ELECTRICAL CHARACTERISTICS

- 15.11.3.1 The main electrical characteristics of switch-disconnector are listed here below:

Table 15.25: Electrical Characteristics

Sr. No.	Description	Rating
1	Nominal voltage U_n	750 V DC
2	Maximum permanent voltage U_{max1}	900 V DC
3	Maximum non permanent voltage U_{max2}	1000 V DC
4	Rated insulation voltage U_{nm}	1800 V
5	Rated impulse voltage U_{ni} <ul style="list-style-type: none"> to earth and between the poles Across the isolating distance 	15 kV 18 kV
6	Power frequency withstand voltage <ul style="list-style-type: none"> against earth and between the poles across isolating distance auxiliary circuits 	6,9kV 8,3kV 2kV
8	Short time withstand current 250 ms	50 kA
9	Peak short-circuit current I_{ss}	70kA
10	Making capacity	50 kA
11	Rated auxiliary power supply	110±15%VDC 230 ± 15%VAC
12	Protection degree of switchboard	IP31 for Indoor IP 65 for Outdoor
13	Over voltage category	OV4
14	Pollution degree	PD4
15	Incoming/Outgoing Cables	Top Cable Entry for Mainline Panels Bottom for UG Depot /outdoor locations.
16	Accessibility	Front

Sr. No.	Description	Rating
17	Design Life	> 30 years
18	Operation	Remote/Local & Manual

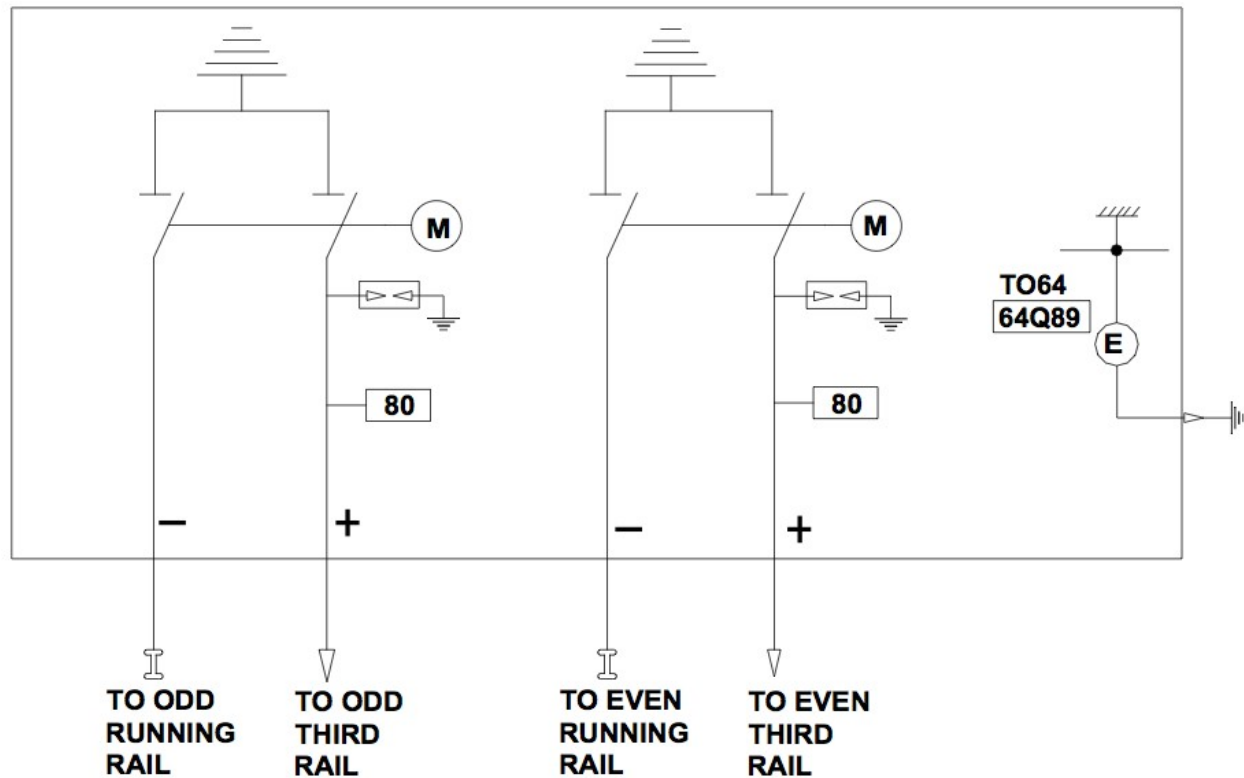
15.12 DESCRIPTION OF THE EARTHING SWITCHBOARDS IN MAINLINE (ASS/TSS)

15.12.1 DC Earthing disconnector includes the following main components:

- a) 02Nos. two pole disconnectors motorized operated
- b) 02Nos. Voltage Presence relays (80)
- c) 02Nos. Surge Arresters (SA)
- d) 01No. Earth Fault relay (TO64)

15.12.1.1 The 110VDC for auxiliary circuits of the switchboard shall be supplied by DCDB unit of the Mainline ASS/TSS.

Figure 1.1: Typical DC Earthing Disconnecting Switchboard Schematic for 2P



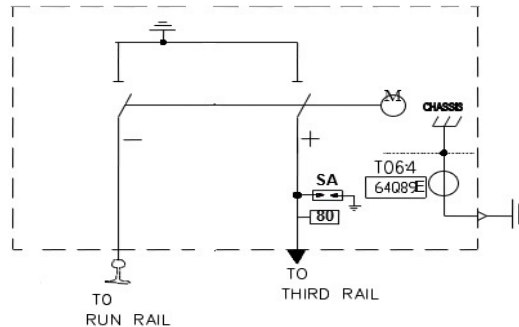
15.13 DESCRIPTION OF THE EARTHING SWITCHBOARDS IN DEPOT (TRACKSIDE)

15.13.1 The DC earthing disconnector includes the following main components:

- a) 01No. Two pole disconnectors motorized operated

- b) 01No. Voltage Presence relays (80)
- c) 01No. Surge Arresters (SA)
- d) 01No. Earth Fault relay (TO64)

Figure 1.2 –Typical DC Earthing Disconnecting Switchboard Schematic for 2P



- 15.13.1.1 The 110VDC for auxiliary circuits of the switchboard shall be supplied by DCDB unit of the Depot ASS/TSS or Nearby AC/DC Distribution Box.

15.14 CONSTRUCTION CHARACTERISTICS

- 15.14.1.1 Proper eyebolts and base pallets are provided for lifting and moving inside the substation.
- 15.14.1.2 The cable inputs are through a special bolted removable gland plate.
- 15.14.1.3 The disconnecter position shall be visible from outside on the front face.
- 15.14.1.4 The main following command and controls are provided in panels Low Voltage cubicle:
- a) Remote/Local key selector switch
 - b) Local control push buttons for motorized disconnecter
 - c) 2 Nos. LEDs signaling the disconnecter position
 - d) 1 No. LED signaling line voltage presence of 3rd rail
 - e) 1 No. LED for voltage presence diagnostic relay
 - f) 1 No. LED for auxiliary power voltage presence
 - g) 1 No. Auxiliary voltage main switch
- 15.14.1.5 All internal components are accessible and removable from the front panel. The segregation of the busbar compartment from disconnecter is made by reinforced fiberglass barriers with anti-dust vertical walls.
- 15.14.1.6 The earthing of the doors will fulfil the IEC 50123-6 requirements, in particular the doors will be bonded with flexible copper braids of proper length so as not to interfere with their opening.
- 15.14.1.7 The movable contacts will consist of a series of independent multiple contacts with Motor Mechanism which will determine action of the contact in the opening and closing operations.
- 15.14.1.8 The operation of the earthing switch shall be also possible by an emergency manual control, if the motor cannot be operated.

- 15.14.1.9 Normally the electrical and manual control mechanisms are interlocked with the voltage detector device, so it is possible to close it only in case of absence of voltage on the third rail.
- 15.14.1.10 A key shall be also provided to lock the earthing disconnecter in both open and closed position (maintenance key), with auxiliary contact to cut power for the motor control.
- 15.14.1.11 The emergency manual control shall be provided with an electrical lock and a push-button to allow its (electrical interlock with voltage detector included).

15.15 INTERLOCKS

- 15.15.1.1 The switchboard compartments shall be fitted with proper safety interlocks (where possible mechanical type), to prevent operations or operation sequences that could compromise the reliability of the switchboard and the safety of operational and maintenance personnel.
- 15.15.1.2 For motorized disconnecter at least the following interlocks must be provided:
- a) Key lock of the disconnecter in open position with maintenance key removed to inhibit any operation including emergency ones.;
 - b) Key lock of the disconnecter in closed position with maintenance key removed to inhibit any operation including emergency ones.;

15.16 COMMAND AND CONTROL

- 15.16.1.1 All input and output has to be connected to the terminal block of the switchboard. A PLC/RTU and the relevant network switch located inside ASS/TSS can be used to remote command and control.
- 15.16.1.2 Command and control are possible for the Motorized SCD by remote control:
- a. from SCADA OCC
 - b. from RTU cabinet located in ASS/TSS
- 15.16.1.3 Manual Operation from the front panel of the disconnecter using the local selector switch.

15.17 MAIN CHARACTERISTICS OF SWITCHBOARD COMPONENTS

15.17.1 SURGE ARRESTOR

- 15.17.1.1 The surge arrestors (zinc-oxide type) are provided on outgoing connections at line side.
- 15.17.1.2 The surge arrestors selected are specifically for DC traction application and are equipped with anti-explosion protection.

15.17.2 VOLTAGE PRESENCE DETECTOR

- 15.17.2.1 The Voltage Presence Detection device is constituted of two galvanically isolated units.
- 15.17.2.2 The first unit is powered by auxiliary Low Voltage, while the second unit is self-powered by the line under control.
- 15.17.2.3 No operation of OFF LOAD disconnectors shall be allowed with voltage presence even on one side only.

15.17.3 SPACE HEATERS

- 15.17.3.1 The heaters inside the cubicles are armored type with steel shell pre-set for fixing and equipped with thermostat.
- 15.17.3.2 Main characteristic of the heaters are:
- Voltage supply 230 VAC
 - Power 40 / 60 W
 - Quantity 1 piece/panel
- 15.17.4 INTERNAL LIGHTING**
- 15.17.4.1 The internal lighting is operated by a two-position selector switch placed on the door of the switchboard.
- 15.17.4.2 Main characteristic are:
- Voltage supply 230 VAC
 - Power >20 W
- 15.17.5 STRUCTURE**
- 15.17.5.1 The structure of each panel is fully modular prefabricated and shall allow a comfortable and easy access to the internal apparatus through the front only.
- 15.17.5.2 The mechanical design of the complete structure shall consider the mechanical stress due to handling and transportation and the electromechanical stress generated by fault conditions.
- 15.17.5.3 The structure components shall be made of steel sheets (or equivalent) properly shaped and flanged in order to meet the here above strength.
- 15.17.5.4 Each switchboard shall be provided with a synoptic mimic on the own front showing the incoming and outgoing direction of the power cables and the 750VDC busbars way.
- 15.17.6 Protection degree**
- 15.17.6.1 For indoor apparatus the protection degree shall be IP3X (whichever side measured); with door open the protection degree shall be IP20 in respect to each live part.
- 15.17.7 Earth conductor**
- 15.17.7.1 The dimensioning of the main earth conductor shall withstand the maximum admissible short time current regarding to the cubicle in which it is installed.
- 15.17.7.2 The switchboard earth system shall be made using a copper flat type and it will be marked by means of a yellow/green adhesive tape.
- 15.17.8 Insulated conductors**
- 15.17.8.1 The insulated conductors shall be fire retardant, low-smoke and halogen free type for UG Stations and FRLS for Elevated and at Grade.
- 15.17.9 Painting**
- 15.17.9.1 They shall be painted with powder paint with a minimum thickness of 50 micron. The color will be specified in the order.
- 15.17.9.2 The paint shall be thermosetting type based on epoxy resin and selected segments with lighting and heat heating resistance.

15.17.10 Number Plate

15.17.10.1 At front panel a plate in compliance with EN-50123-6 section 7 subclause 7.2 shall be applied.

15.17.10.2 All plates shall be in English language.

15.17.11 LV cable

15.17.11.1 Each terminals shall be identified by means of a proper permanent mark.

15.17.11.2 The terminals shall be suitable for 4 mm² wires connections.

15.17.11.3 The terminals shall be polyamide modular type, with anti-loosening screws embedded or insulated head type to avoid accidental contacts and shall be marked according to drawings.

15.17.11.4 The wiring of auxiliary circuits shall have a path separate respect to the main circuit. The inner cables shall be fire retardant, low-smoke and halogen free type for UG Stations and FRLS for Elevated and at Grade. Each wire shall be properly marked at both ends and shall be equipped with crimped terminal lugs.

15.17.11.5 The auxiliary circuits wiring shall be protected by proper plastic ducts with removable cover or conduit pipes, earthed if running nearby live conductors at 3 kV.

15.17.11.6 The terminal board for low voltage cables shall be provided with a 20% of Spare terminals.

15.17.12 Power Cables

15.17.12.1 The Power busbar shall be sized to connect the 1C X 300 sq.mm Cu cables at 1.8/3.3kV , No. of runs will be defined during construction stage.

15.17.12.2 The connection terminals shall be suitable for connecting all the necessary cables requested for feeding the third rail.

15.17.12.3 The connection wire between the voltage presence sensor and the switch-disconnector shall be with double or reinforced insulation.

15.17.13 Auxiliary Power Supply

15.17.13.1 110VDC or 230VAC (50Hz) \pm 15%

15.17.14 Test Sheet

15.17.14.1 Test Matrix is described as below:

Table 15.26

INDICATIONS	TYPE of TEST			
	Type	Routine	On site	After Shipment
Visual and Dimensional check		X		
Serial number and labels check		X	X	
IP protection degree check	X			
Internal components check		X		
Wiring check		X		
Insulation test of power circuit		X		
Insulation test of auxiliary circuit		X		
Complete functional check		X	X	

INDICATIONS	TYPE of TEST			
	Type	Routine	On site	After Shipment
Making capacity test current	X			
Behavior under short-time withstand current test	X			
Over Temperature Test	X			
Mechanical endurance test	X			
Electrical endurance test	X			
Dielectric test	X			

15.18 Inverter for Reversible ASS/TSS

15.18.1.1 Scope

15.18.1.2 The scope of work includes Design, Supply, installation, testing and commissioning of IGBT based inverter along with Transformer (if required) and associated Switchgear at suitable locations at which maximum regeneration energy is available.

15.18.1.3 Inverter Configuration shall be submitted by contractor for the approval of Employer during detail design Stage.

15.18.1.4 Inverter location shall be submitted for the approval of Employer during design stage with minimum of two locations. The location of inverter shall be considered such that the maximum regenerated energy can be fed back. If in case additional inverter location is required, then that will be subject to approval of Employer based on simulation studies submitted by contractor and extra cost for additional inverter shall be paid by Employer.

15.18.1.5 Specification (Indicative Only)

15.18.1.5.1 This is a generic preliminary specification giving the general requirement allowing the deployment of a reversible traction substation.

15.18.1.5.2 The reversible converter units shall be designed to work in parallel/replace the diode rectifier units in order to supply traction system and to recover the braking energy.

15.18.1.6 Introduction

15.18.1.6.1 Figure 1 presents the general architecture of the reversible substation.

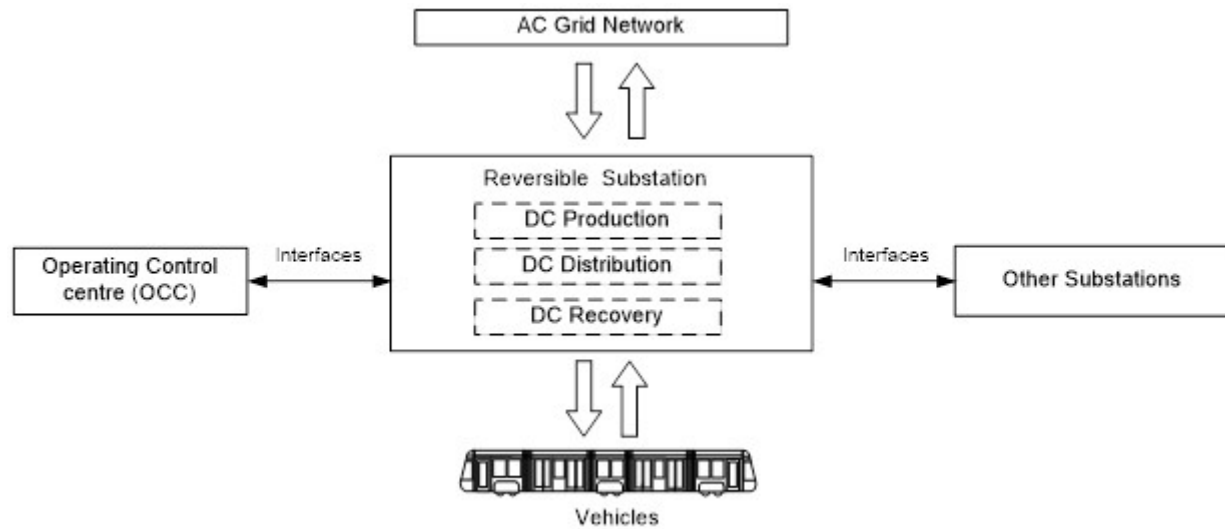


Figure 1: General Architecture of the Reversible Traction Substation

- 15.18.1.7 The minimum requirements for these reversible converters are indicated here after.
- 15.18.1.7.1 AC incoming equipment
- 15.18.1.7.2 Bus bars and bus connections will be designed to withstand, without damage, the thermal and mechanical stresses occurring during the specified load cycle and the rated short-circuit current. Bus bars will be made of rigid copper or aluminium.
- 15.18.1.7.3 AC High Voltage Distribution
- 15.18.1.7.4 In each substation, the AC distribution will be achieved with AC Switchgear. The board will consist of an assembly of circuit breakers and disconnecting switches cubicles.
- Incoming cubicles which will include each a Low Voltage Circuit Breaker (LVCB)
 - One metering cell which will include a High Voltage disconnecting switch and a fuse
 - One Traction Group Protection cubicles which will include a High-Speed Circuit Breaker (HSCB with DS)
- 15.18.1.7.5 Each cubicle will be fed with an 110Vdc voltage supply for control purpose and 230Vac for lighting and heating.
- 15.18.1.7.6 Main Electrical characteristics for all equipment
- 15.18.1.7.7 Cubicles composing the switchgear will have the following electrical characteristics:
- Rated input voltage: 33kV
 - Short-circuit withstand current: 25 kA for 3 sec
 - Rated frequency: 50 Hz
 - Number of phases: 3
 - Auxiliary voltage: 110Vdc/230Vac

- 15.18.1.7.8 Mechanical characteristics for all equipment
- 15.18.1.7.9 Cubicles composing the switchgear will have the following mechanical characteristics:
- a) Installation: Indoor type
 - b) Insulation: Air
 - c) Insulation condition: ungrounded
 - d) Cable connection: From top
 - e) Type of cooling: Natural
 - f) Protection Degree: IP3X
- 15.18.1.7.10 High Voltage Circuit breakers will have the following characteristics:
- a) Type: Fixed / Withdrawable
 - b) Insulation: Vacuum/SF6
 - c) Rated Current: 1250 A
- 15.18.1.7.11 Protection relay
- 15.18.1.7.12 The following functions shall be provided in the cubicles composing the switchgear:
- a) 86: Locking-out relay
 - b) 87L: Differential line protective relay
 - c) 27: Undervoltage protection
 - d) 50: Instantaneous Overcurrent protection
 - e) 51: Inverse time Overcurrent protection
 - f) 50N: Homopolar Instantaneous Overcurrent protection
- 15.18.1.8 DC Protection
- 15.18.1.8.1 DC protection will be composed of:
- a) One AC Filter (if required)
 - b) One reversible converter (IGBT/Thyristor bridge unit) and the DC coupling contactor and isolating switch.
- 15.18.1.9 Inverter characteristics
- 15.18.1.9.1 The proposed inverter unit will be designed to convert the 750 V DC supply to 585V AC supply converting the braking recovery energy from DC traction power to the AC network. The inverter shall consist of an AC filter, an IGBT/Thyristor bridge unit, a DC panel, sound attenuator, surge protective devices, PLC and auxiliary power source devices. The inverter cubicles will have a protection degree IP31 at least, vermin-proof, free standing, and natural air ventilated cubicle type. The efficiency of inverter mode shall be more than 95%. The power factor shall be not less than 98% at full load and at the rated voltage, during the inverter operation mode. The inverter harmonic distortion rate, in recovery mode, shall not exceed the limits recommended by the IEC applicable standard/IEEE 519/CEA Guidelines. The inverter equipment shall be designed considering:
- a) 3.3 kV insulation voltage level
 - b) protection against internal short-circuit
 - c) protection against internal and external over-voltages

-
- 15.18.1.9.2 The inverter enclosure shall be sufficiently insulated from ground (earth) to enable the proper operation of the frame earth leakage relay
- 15.18.1.9.3 The reversible converter equipment shall include:
- a) Internal busbars made of copper tinned or aluminium
 - b) Anti-condensation heaters with thermostat control for each cell of the inverter
 - c) Temperature sensors with two thresholds (one alarm and one trip). These alarms will be transmitted to the Operation Control Centre (OCC) through the Supervisory Control System(network)
 - d) The noise level at the rated value for the inverter shall be less than 75dBA at a distance of 1meter with the fans in operation.
- 15.18.1.9.4 Each door of the inverter shall be equipped with safety locks in order to avoid doors opening when parts of AC or DC voltage systems are live. These safety locks will be part of the interlocking system
- 15.18.1.9.5 Electrical and mechanical interlocking components shall be provided to ensure the safe operation of the inverter. In addition, the design of the inverter shall take into consideration the shutting down of the equipment after revenue service without having to re-energize the transformers. The inverter start-up and shut down sequences will be fully automatic for local and remote mode
- 15.18.1.10 Inverter module
- 15.18.1.10.1 The inverter module of the converter consists of IGBTs that are fired via a PWM (Pulse Width Modulation) control. It is designed to divert the excess kinetic energy released during braking to the AC network whenever the DC network is no longer receptive and with a low total harmonic distortion.
- 15.18.1.10.2 The rating at 50°C shall be 1.0 MW for continuous operation and the overloading capability shall be 150% for two (2) hours and 300% for one (1) minute of continuous operation according to Class VI of IEC 60146. The inverter will have a voltage detection type with constant or adjustable current and voltage features. The inverter shall have voltage and current detections sensors to regulate the current during inverting mode. The inverter shall have a rated voltage at rated continuous load. The continuous rating shall be defined as the output that can be delivered continuously at rated full load voltage.
- 15.18.1.10.3 The inverter shall be designed to withstand the worst-case of the fault current such as commutation fault, loss of AC supply during inverting mode, etc. The inverter shall be of IGBT type and shall withstand sustained and repetitive over-voltage from the traction network due to regenerative braking energy, as well as over voltages due to switching or other causes
- 15.18.1.11 DC switchgear
- 15.18.1.11.1 All reversible converter equipment will include the associated DC switchgear, which shall be able to withstand transient voltage equal to the maximum voltage which can transit through any DC surge arrestor device applied in either direction at rated current.
-

15.18.1.11.2 The disconnecting switches shall be mounted in a separate cell of the inverter. The HSCB/disconnecting switch shall allow electrical isolation of the inverter from the positive and negative DC traction circuit and shall be rated according to the existing system requirements. Design and construction of the negative disconnecting switch shall allow off load opening and closing using manual handle with key interlocking facility with the DC circuit breaker.

15.18.1.12 Low Voltage and Control compartment

15.18.1.12.1 The reversible converter system shall be equipped with a low voltage compartment for the control command and protective devices. Indications shall be provided on the front face of the low voltage compartment to indicate the status, alarms and faults. All indications shall be LED type. The front face of the low voltage compartments shall be equipped with:

- a) "Local/Remote" switch
- b) Green illuminated push button for start/stop (light ON = ON)
- c) Yellow "Alarm" light
- d) Red illuminated push button for fault acknowledgment (light ON = fault)
- e) Red emergency push button
- f) White DC Contactor position light (light ON = closed)
- g) Push button for testing lights

15.18.1.13 Protection of inverter system

15.18.1.13.1 The reversible converter system shall have the following protection relays and features:

Sl. No.	Fault Descriptions	Protection and Control
1	DC Output Overvoltage	Trip AC and DC breaker
2	Enclosure Frame Leakage	Trip AC and DC breaker
3	Secured Auxiliary supply Failure	Trip AC and DC breaker
4	AC Incoming Undervoltage	Trip AC and DC breaker
5	AC Incoming loss of synchronization	Trip AC and DC breaker
6	IGBT/Thyristor Temperature Failure (2 levels)	Level 1: Alarm Level 2: Trip AC and DC breaker
7	Cubicle Temperature Failure (2 levels)	Level 1: Alarm Level 2: Trip AC and DC breaker
8	AC Incoming Overvoltage	Alarm
9	IGBT/Thyristor Overcurrent	Trip AC and DC breaker
10	IGBT/Thyristor Overload	Trip AC and DC breaker

15.18.1.13.2 The protections and faults signal shall be sent to OCC through Ethernet fiber optic network and to the local human machine interface located in the substation control cubicle. The inverter shall be protected and coordinated between the ac and dc circuit breakers. Instantaneous and timed over current protection shall be provided to trip ac side as well as dc side on transformer internal fault, converter/inverter fault and DC switchgear fault.

15.18.1.13.3 Frame leakage protection

15.18.1.13.4 The inverter frame shall be insulated from the mechanical structure earth (general earth) and connected to ground via the frame leakage protection relay. Any detection of frame leakage shall trip and lock out the respective AC and DC breakers. The trip signal shall be sent to OCC

15.18.1.14 Control and monitoring for reversible converter system

15.18.1.14.1 The following control and information shall be sent to the HMI (local) and OCC (distance):

Table 15.27

Sl. No.	Items	Function description
1.	Operation control	Start / Stop / Alarm-Fault reset
2.	Alarms and faults	Current active Alarm and Fault
3.	Measurement	AC: Voltage and Current DC: Voltage, Current and Power
4.	Event Record	Operation information (start / stop / event) Historical Alarm and fault Historical consumed and recovered Energy
5.	Settings	Rectifier working voltage Inverter voltage regulation

15.18.1.15 Technical particulars of reversible converter

15.18.1.15.1 Technical particulars of reversible converter shall be provided as follows:

Table 15.28: Technical Particulars

Sl. No.	Items	Inverter Mode	Remarks
1.	Type	Reversible Converter	
2.	Rated voltage	750Vdc	
3.	Maximum voltage	900 V	
4.	Rated capacity	1000 kW (approx.)	
5.	Efficiency	95%	
6.	Type of cooling	Natural air or ventilated	
7.	Overload duty	150% 2 hours; 300% 1 minute	
8.	Withstand voltage	Main circuit : AC 3kV /1 minute Aux. Circuit : AC 2kV	
9.	Setting for voltage regulation	No load voltage Full load voltage	(VO) (V100)
10.	Setting for operation value	760-850V	1V step
11.	Voltage accuracy	±2%	
12.	Response time (ON)	1.5ms	
13.	Rated frequency	50Hz	
14.	Allowable frequency range	±2%	
15.	Power factor	>98%	At rated load
16.	Displacement power factor	>98%	At rated load
17.	THD for AC current	<5%	At rated load

Sl. No.	Items	Inverter Mode	Remarks
18.	Auxiliary power supply	110Vdc 230V 3ph 50Hz	

Location of Inverter: The location of inverter shall be considered randomly at two locations in the corridor, each such that the maximum regenerated energy can be fed back.

CHAPTER 16: THIRD RAIL SYSTEM

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CHAPTER – 16

THIRD RAIL SYSTEM

16.1 INTRODUCTION

16.1.1 GENERAL

- 16.1.1.1 The third rail system shall be installed on the side of the electrified tracks to supply the electrical traction power from the traction power substations to the rolling stock.
- 16.1.1.2 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in chapter-2 & Chapter 19 along with clause wise compliance and suggest similar or better design for the approval of Employer.
- 16.1.1.3 The traction power shall be transferred via the vehicle collector shoes by contacting the surface of the contact rail from underneath. The third rail shall be made of an aluminium body designed for a nominal current of 4500A and a stainless steel contact path for current transfer to the collector shoes.
- 16.1.1.4 The proposed conductor rail shall be designed for a 1000 V DC and withstand transient voltage up to 3000 V. The third rails shall be manufactured in standard lengths such as 15m length, which shall be joined together by special splice joints.
- 16.1.1.5 The third rail is kept in defined positions on the concrete support/rail sleeper and is insulated from ground by an insulated support system. The normal support spacing is of the order of 5m.
- 16.1.1.6 In order to compensate for temperature-dependent rail expansion, expansion joints assemblies shall be installed according to a calculated distance, which depends on the ambient temperature and heat rise.
- 16.1.1.7 At the mid-span between two expansion joints, an anchor assembly shall be mounted to avoid unidirectional creeping of the rail caused by thermal expansion. Cable terminal shall be used to bring power to the conductor rail and can be easily adapted to the cable lugs and to the cable section used by the power supply.
- 16.1.1.8 A Ramp-Ramp assembly shall be used in order to separate the different power sections along the track.
- 16.1.1.9 Different kind of ramps shall be used on turnouts, Station Entry/Exit and Depots or where needed in order to bring affects a smooth transfer of collector shoe to conductor rail.
- 16.1.1.10 The conductor rail shall be installed on trackside at the specified distance to the track centerline / top of the rails. In the double-track line, the conductor rail shall be installed between both tracks in order to leave sufficient space for walkways.
- 16.1.1.11 In stations, it is necessary for safety reasons to install the conductor rail on the side of the track opposite to the platform edge. Also at turnouts the conductor rail shall change sides

suitably, as per the third rail design.

16.1.2 COMPONENTS

16.1.2.1 The Third Rail system consists basically of the following main components:

- a) Conductor Rail
- b) Splice Joint assembly for third rail
- c) Expansion Joint
- d) Anchor Assembly
- e) Power Feed Assembly
- f) Ramp
- g) Support Assembly
- h) Protective Cover system

16.1.3 STINGER SYSTEM

16.1.3.1 In the main workshop areas, for the purpose of safety of working personnel, a system called stinger system shall be installed. The conductor rails shall be installed on the gantry of the buildings and vehicles are powered through flexible cables.

16.1.4 SECTIONING PLAN

16.1.4.1 Mainline Sectioning plans for both the depots are depicted in the drawings of tender documents.

16.2 THIRD RAIL SYSTEM SPECIFICATIONS

16.2.1 SCOPE

16.2.1.1 This Specification applies to the third rail system for the Lucknow Metro Rail Project. The third rail system at 750 V DC shall be utilized for transporting the power to rolling stock. The third rail system shall be of the bottom contact type in which vehicle-mounted current collection shoes press upwards onto the underside of the conductor rail.

16.2.1.2 The Contractor's Scope of Work includes design, interface, procurement/supply, installation, testing and commissioning of the complete third rail system for mainline and depots. Necessary interface with track work contractor for third rail pedestal layouts, crossovers, installation of insulated rail joints, DC cable crossings beneath the tracks and along, alignment of third rail with respect to track, testing and commissioning of third rail system. Supply and installation of HDPE pipes for cable crossings shall be under the scope of LKE(02)-01 Contractor. Contractor shall interface with track contractor for installation of HDPE pipes. Installation and connection of all DC cables shall be carried out by LKE(02)-01 Contractor.

16.2.1.3 The design, interface, procurement, installation, testing and commissioning of stinger system shall be under the Scope of the LKE(02)-01 Contractor, in addition to procurement, supply, testing and commissioning.

- 16.2.1.4 All components of the same pattern should be interchangeable. The use of interchangeable components shall be maximized in the design.
- 16.2.1.5 The Contractor shall submit valid type test certificates for the components proposed for the third rail system.
- 16.2.1.6 The designated supplier shall submit drawings / specifications / manuals to describe the component, to explain the installation and maintenance and to calculate the maximum section lengths considering the ambient temperatures as well as the heating of the rail by flowing current.
- 16.2.1.7 LKE(02)-01 Contractor shall submit the feasibility report before procurement of third rail components which includes detailed study of alignment with the third rail, crossovers, curves, gap study, interfaces, depot and mainline separation etc., for mainline and depot.
- 16.2.1.8 Mainline tracks are floating & Depot tracks other than workshop, inspection lines, wash plant and pit wheel lathe tracks (which are earthed) only are also floating. To separate these, one Insulated Rail Joints (IRJ) are used. LKE(02)-01 Contractor will give the location of the IRJs to the track Contractor. The supply & erection of IRJ is in the scope of Track contractor.

16.2.2 THIRD RAIL SYSTEM

- 16.2.2.1 Electric power shall be supplied to the trains by means of a conductor rail known as third rail. The conductor rail shall be installed on trackside at the specified distance to the track centerline / top of the rails. In the double-track line, the conductor rail shall be installed between both tracks in order to leave sufficient space between for walkways. In stations, it is necessary for safety reasons to install the conductor rail on the side of the track opposite to the platform edge. Contractor shall be liable to adhere to the project Schedule of Dimensions (SOD).
- 16.2.2.2 The nominal traction power supply voltage is 750 V DC, which shall be transferred to the traction vehicles via conductor rails and current collector shoes placed at defined positions on the traction vehicles.
- 16.2.2.3 The collector shoes shall contact the conductor rails from underneath.
- 16.2.2.4 Power for tracks inside the workshop building shall be provided via stinger installations. Stinger cables, attached to contact trolleys, provide power from overhead conductor rails. The installation and commissioning of the stinger system inside the workshop building shall also be under the Scope of the work of LKE(02)-01 Contractor.
- 16.2.2.5 The conductor rail and all connected parts are kept within a defined space constraint to prevent anything coming into contact by a passing train. The track contractor has not been finalized so far. The following specifications have been proposed for the track contract subject to confirmation:

Table 16.1: Track Structure Parameters

Description	Elevated and at-grade sections
-------------	--------------------------------

	Ballasted	Ballast-less (DFF)
Track Laying Gauge	1435mm	
Rail Type		
Main Line	UIC 60 Head hardened (1080)	
Depot	UIC 60 (880)	
Rail Profile	UIC 60	
Inclination of Rail	1 / 20	
Rail Seat Spacing, Main line (straight)	650 mm \pm 10 mm	650 mm \pm 10 mm
Curve sharper than 400 m radius	650 mm \pm 10 mm	650 mm \pm 10 mm
Sleeper Spacing, depot	650 mm \pm 20mm	
Ballast Cushion		
Main line		
Depot	250 mm	
Standard Rail Length	13m - Depot, 18m – Mainline	
Rail Panel Lengths	Long welded rails – 360 mtrs (depot & Mainline)	
Minimum Radius of Curvature	120m-main line 90m-depot	120m
Minimum Turn Out Radius. Main Line	140 m	
Minimum Turn Out -Depot	1 in 7	
Minimum Turn Out Main line	1 in 7	
Maximum Cant Permissible in curves	125 mm	
Maximum Cant Deficiency Permissible	100mm	
Maximum Permissible Cant Gradient	1 in 440	
Turn-out Speed in Turn-out (Main line)	45 km/h	
Turn-out Speed: Scissors (Main line)	45 km/h	
Turn-out Speed: In Depots	25 km/h	
Maximum Gradient (Main Line)	4% (compensated)	
Minimum vertical curve radius crest	1500m	
Maximum track axle load (AW4)	15 tons	
Widening of track Gauge on curves	Up to 9 mm	

16.2.2.6

The following details are 'standard' and the Contractor shall conform this by interface with the Rolling Stock supplier.

Table 16.2 Current Collection System

System Particulars	For all sections and depots
Supply Voltage System	750 V DC (Floating negative system at mainline and negative earthed system at depots)
Type of Current collection	Through Third Rail (Inverted Rail) in all sections.

System Particulars	For all sections and depots
Current Collection	Through current collector shoes mounted on the driving cars.
Height of Current collecting surface of the conductor rail from rail level	148 mm nominal
Distance between Centre line of the Conductor rail and track centre	1485 mm
Nominal voltage	750 V DC
Minimum voltage	500 V DC
Maximum voltage	900 V DC
Occasional maximum voltage	950V DC
Occasional maximum voltage during regenerative braking	1000 V DC
Flood Proofing	The traction equipments mounted on the under-frame will be designed to permit propulsion of the train at 10 km/h through water up to a depth of 75mm above rail level. The traction equipment shall be made splash proof in accordance with International Standards

16.2.2.7 The limit of the space envelope is known as the structure gauge of the conductor rail. No portion of the conductor rail system i.e. rails, supports, covers or ramps ends, will lie outside the structure gauge.

16.2.2.8 The position of the conductor rail contact face is 148 mm above the level of the running rails measured from the gauge face of the nearer running rail to the conductor rail centre line and 1485 mm horizontal measured from the centre of track to the conductor rail centre line. The tolerance of installation of the rails is typically ± 3 mm horizontally and +10mm vertically. (Latest SOD to be followed).

16.2.2.9 At ramp ends, where the train pickup shoes are required to run onto the rail, the rail is typically raised by 85-90mm and forms a smooth transition back to the normal rail position. Ramp height to be defined by LKE(02)-01 Contractor based on the gap study considering the rolling stock and track parameters during design phase in compliance with project SOD.

16.2.2.10 At defined locations it is required to interrupt the conductor rail. This applies to turnout locations but also at locations where the conductor rail changes to the other side of the track, at level crossings, in the depot area and last but not least at locations where two different feeding sections must be separated.

16.2.3 RATINGS

16.2.3.1 The third rail system shall match the following rating requirements:

Table 16.3: Third Rail

SN	Description	Rating
----	-------------	--------

SN	Description	Rating
1	Rated voltage	750 V DC
2	Maximum operating voltage	900 V DC
3	Minimum operating voltage	500 V DC
4	Designed voltage of conductor rail	1000 V DC
5	Withstand capacity to transient faults	3000 V DC
6	Nominal current rating of the conductor rail at 50 °C (without exceeding 40 °C heat rise)	4500 A
7	Short circuit withstand capacity	50 kA for 1 sec
8	Design life	30 years min.
9	Nominal Resistance at 15 °C	7 milliohm per km Max
10	Thickness of stainless steel in conductor rail	6 mm Nominal
11	Adhesive strength (Aluminium / stainless steel)	> 60 kN

16.2.4 COMPONENTS

16.2.4.1 The conductor rail system, also called third rail system, consists basically of the main components described in Clause 16.1.2.1 above. Details of these components are provided hereunder.

16.2.4.2 Conductor Rails

16.2.4.1 The conductor rail shall be manufactured of an aluminum alloy body designed for a nominal current of 4500 A and utilized with a stainless-steel wearing face. Tenderer may propose a proven design meeting the specified requirements and parameters. The junction bond strength shall be not less than 70 N/mm². Alternatively, 90 mm piece of conductor rail shall withstand 60 kN force without damage.

16.2.4.2 The conductor rails shall be rated at a nominal resistance of max. 0.007 Ω / km at a current of 4500 A. Rails shall be preferably supplied in lengths of 11m to 15m with pre-drilled holes for splice joints. The typical configuration of the conductor rail shall be – Aluminum: EN-AW 6101B & Stainless Steel: 1.4016, X6Cr17, 17% Chromium or equivalent to match the industry standards acceptable to project requirements. In any case the stainless steel shall have minimum 16% Chromium. The stainless-steel strip thickness at the contact surface shall be nominal 6 mm.

16.2.4.2.1 The process used for the composition of conductor rail shall preferably ensure no gaps remain between the head of the aluminum section and the stainless-steel wearing strip. Preferably there shall be no gaps between the head of the aluminum section and the stainless-steel wearing strip. The interface resistance between steel and aluminum shall not exceed **30** μΩ. Conductor rail is intended to be used up to complete worn-out of stainless steel without any delamination of the remaining stainless-steel strip. The same to be demonstrated by LKE(02)-01 Contractor during type/factory tests.

16.2.4.2.2 The conductor rails shall be indelibly marked for life to be traceable to batch and date of manufacture.

16.2.4.2.3 Conductor rails shall be designed to not exceed 40°C heat rise above ambient of 50°C at 4500 A continuous current (with air circulation).

- 16.2.4.2.4 Rail can be installed without pre-bending on curves of radius 100m or greater (value to be confirmed by the manufacturer). For curves under this radius the rails shall be pre-bended using a three-point bender without any distortion in the profile.
- 16.2.4.2.5 The conductor rail shall be sectioned at traction substations, crossovers, turnouts, and in the depot to enable sections of the track to be isolated, whilst permitting reversing of trains in the event of an accident, fault, and/or for operational flexibility.
- 16.2.4.2.6 The LKE(02)-01 Contractor shall develop detailed feeding and sectioning arrangements in the mainline and depot consistent with the operational and maintenance requirements, using the alignment drawings and the system single line diagrams included in the Contract Drawings as a guide.
- 16.2.4.2.7 Conductor rails shall be designed for a maximum operating temperature of 90⁰ C.

16.2.4.3 Splice Joint Assemblies

- 16.2.4.3.1 The conductor rails (including ramps and expansion joints) shall be designed for joining end to end through a bolted connection incorporating aluminum splice plates. The unprotected parts remaining after installation shall be painted with the appropriate paint in order to avoid any corrosion. The splice plates shall be of sufficient length and designed to provide sufficient cross section area to maintain the electrical and mechanical properties of the conductor rail across the joints. The lengths and the cross-sectional areas of the splice plates shall be such that the electrical resistance across a joint shall be not higher than that of an equivalent length of un-jointed conductor rail.
- 16.2.4.3.2 The splice plates shall be designed to carry 4500 A continuously with a maximum heat rise of not more than 40°C above 50°C ambient. The splice plates shall be manufactured from a similar aluminum alloy to that of the conductor rail and designed to clamp tightly into the web area of the rails using a taper on upper and lower edges.
- 16.2.4.3.3 Fastenings shall be with not less than four Huckbolts made of Aluminum or high tensile carbon steel with Zinc plating.
- 16.2.4.3.4 The splice plates shall be pre-drilled with no directional constraints.
- 16.2.4.3.5 The tolerances of the rail and cap ensure that the completed joint has an accurate and smooth transition between rail ends. On assembly the maximum step will be 0.2 mm. Should a step across a joint be greater than 0.2mm the Contractor shall apply an abrading/grinding process or similar operation on the installed joint to provide a smooth connection. The assembled joint shall have a maximum of 2 mm gap between rail ends.
- 16.2.4.3.6 The conductor rails shall be predrilled. During assembly, no-oxide grease or zinc-loaded contact grease shall be applied at the interfacing surface of splice plate and third rails to achieve minimum contact resistance across the joint and prevent any corrosion.
- 16.2.4.3.7 The gap between the edge of splice plate and third rail installation support shall be not less than 200mm, to allow for temperature dependent third rail expansion.
- 16.2.4.3.8 The splice joint shall be included in a short circuit test and comparison load test of a

representative setup of rail, support and insulators undertaken in the laboratory.

16.2.4.4 **Expansion Joints**

- 16.2.4.4.1 Thermal movement (expansion and contraction) of the conductor rails, due to change in ambient temperature, heat rise of conductor created by electrical load, solar radiation and guide way movement, shall be taken care of by the provision of sliding expansion joints at defined intervals. This shall be pre-assembled unit typically 4-5m in length. The assembly shall allow free mechanical movement and shall have overlapping ends ("make-before-break" basis) so that the collector shoes on the trains shall cross the gap without impact or damage. The longitudinal movement shall be 150mm or 2x100 mm.
- 16.2.4.4.2 Every expansion joint shall be factory made from a length of conductor rail, which shall be cut symmetrically about its centre with one or more oblique cuts, which both allow the specified relative movement and provide the specified electrical continuity.
- 16.2.4.4.3 The expansion joints shall be delivered as pre-assembled in the factory, to achieve high-quality conditions.
- 16.2.4.4.4 Calculation and test documents shall be provided to prove that the expansion joints correspond to the local conditions. An adjustment list shall be delivered with the installation documents showing the temperature-dependent elongation gap to be established in the expansion joint.
- 16.2.4.4.5 Electrical continuity across the sliding surface shall be maintained by a copper rolling shunt designed to carry 4500 A. This provides a low resistance path across the joint and has no sliding surface to cause difficulty. The electrical resistance of the expansion joint shall be less than $35\mu\Omega$ per expansion point at 15°C. Bi-metallic strips shall be used between the copper shunt and the aluminum to prevent electrochemical corrosion. When assembled, the electrical resistance across the joint shall be similar to plain rail. Current shall not flow through the splices used for expansion compensation. Meaning that the electrical and the mechanical function of the EJ must be independent each other. The heat rise of the expansion joint shall not exceed 40°C above 50°C ambient temperature.
- 16.2.4.4.6 Particular attention shall be made to reduce wear and to maintain a good vertical offset between two pieces of conductor rail.
- 16.2.4.4.7 The expansion joint shall be protected by a special GRP (tunnel) or UPVC (outside) cover in the shunt area.
- 16.2.4.4.8 All electrical bolted connections within the joint assembly shall be made using an acid free petroleum jelly or other suitable contact grease.
- 16.2.4.4.9 To provide extra support in the expansion joint area, it may be necessary to move adjacent insulator supports closer together than at standard rail joints. The expansion joints shall be placed exactly between the two third rail supports. These shall be installed typically in a distance of 2.80 m with the joint at mid span. The next consecutive supports shall be spaced in standard lengths.
- 16.2.4.4.10 The design shall minimize electrical arcing that characteristically occurs at these

transition points and shall meet the same electrical and mechanical requirements as the balance of the system. Consequently, it shall be manufactured from the same material as the conductor rail.

- 16.2.4.4.11 The spacing of expansion joints on the track shall be determined by calculating the expansion of the aluminium rail over the extremes of temperature possible in service. The minimum shall be defined as the lowest ambient temperature defined on site (refer to GS). The maximum shall be the highest ambient temperature recorded, plus an allowance for current heating by the train, and for the effects of solar radiation. Expansion joints shall be placed in such a manner that the maximum movement in each is not exceeded.
- 16.2.4.4.12 In order to prevent electrochemical corrosion, all fastening items shall be made of stainless steel and brass.
- 16.2.4.4.13 The expansion joint shall be easily and quickly removable and replaced as a unit. The expansion joint shall be suitable for pressure washing in situ for the removal of contaminants.

16.2.4.5 Conductor Rail Ramps

- 16.2.4.5.1 The intent of ramp assemblies is to evenly engage and disengage the contact shoes during rail transitions.
- 16.2.4.5.2 Entry and exit ramps shall be provided at turnouts and at other locations where a gap in the conductor rail is necessary. Such ramps shall also be provided at all electrical disconnecting points or at changes of the third rail installation from one side of the track to the other as required.
- 16.2.4.5.3 The end of every rail conductor rail section is provided with a ramp to allow the train pickup shoes to run onto or off the rail section. It shall consist of a piece of conductor rail shaped so as to guide the shoes down to the normal contact level as smoothly as possible and avoid any loss of contact between shoe and rail as this is achieved. The design of the ramp assembly shall be to provide a smooth engagement of the collector shoe during transition. The ramp shall serve to channel the collector into position.
- 16.2.4.5.4 The rails forming the ramps shall be made of conductor rail material and machined and formed into the required curved profile. The profile shall be defined by the performance of the vehicle shoe-gear. Therefore, the Contractor shall closely interface with Rolling Stock Contractor for achieving the design of ramps. Alternatively, feasibility of steel ramp to be checked by the Contractor by taking arcing and wear of current collector shoe into consideration.
- 16.2.4.5.5 This profile shall be defined by the performance of the vehicle shoe gear, so that the shoes are guided onto the conductor rail with minimum impact and without bounce. The transition between the angle and the straight portion of the ramp shall be a gentle curve. The extreme end of the ramp shall have an upwards curving end piece to deflect any badly-adjusted shoes without damage to the ramp end.

- 16.2.4.5.6 The conductor rail ramps shall be of two types:
- a) Typically, 5.0m to 5.5m for high speed ramp (upto 90 kmph) used on the main lime (slope 1/50)
 - b) Typically, 3.0m to 3.3m for low speed ramp (up to 35 kmph) used in depot area (slope 1/30)
- 16.2.4.5.7 Each Ramp type shall also have a safety slope at its end.
- 16.2.4.5.8 The maximum speed rating for the ramp design shall be defined by reference to the shoe gear performance. In the same way, the geometry of the ramp, including the entry height, comes from the shoe design and the vehicle movements. The ramp design must be the result of interface agreements between the vehicle manufacturer, Power Supply Contractor and the Trackwork Contractor.
- 16.2.4.5.9 The ramps shall be delivered as factory-fitted unit with the all parts and components to splice with the regular conductor rail. It shall be supported by two brackets and insulators of same types as used on plain line but raised in height and shall be connected to the conductor rail by using a splice assembly through a Huckbolts connection. The ramp throat shall be 130 mm above surface of conductor rail at the end of the ramp.
- 16.2.4.5.10 The ramps shall not have any specific direction and the connection with the conductor rail shall be similar to the connection of two conductor rail pieces.
- 16.2.4.5.11 The ramps shall be covered with standard cover of suitable length. For conductor rail ramps only, mechanical test are required. The Contractor shall provide respective test procedures.
- 16.2.4.5.12 Specific attention is needed during manufacturing to guarantee the slope of the ramp according to the requirement in order to keep the safety component. The ramp end of the rail is raised above the nominal rail height by an amount shown on the structure gauge drawing, but the overall height at the ramp end must lie within the normal structure gauge of the third rail system.

16.2.4.6 **Anchor Assemblies**

- 16.2.4.6.1 The anchor assembly is mounted at the mid span between two expansion joints with the purpose to avoid unidirectional creeping of the rail caused by thermal expansion.
- 16.2.4.6.2 The anchor assembly shall be designed to fix, with respect to the guide way, the midpoint between expansion sections. The assemblies will be necessary for each third rail section between expansion joints. The anchor design shall be based on the same profile as that of the aluminum splice plates to ensure the high adhesion in the web of the conductor rail with no corrosion.
- 16.2.4.6.3 The Anchor Assembly shall consist of two pair of aluminium blocks (same as aluminium splice plates) or stainless-steel blocks set at each side of the insulator jaw. Each block shall be drilled by one hole. The anchor blocks shall be firmly fitted onto the conductor rail by mean of Huckbolts. The anchorage shall be capable of withstanding an 'along track' load of 2 kN minimum without failure.

- 16.2.4.6.4 Assemblies of lengths of rails are retained in position and prevented from moving longitudinally by the use of rail anchors. Normally these anchors shall be located at the mid-point of rail lengths, between expansion joints, but there may be occasions when anchors are needed at other places, for example near cable terminals (typically 22.5m from cable terminal).
- 16.2.4.6.5 The anchor must be strong enough to withstand all the likely forces from normal expansion and contraction of the rails in service. In the event of overload, for instance from a seized expansion joint or insulator, the anchor shall be designed to move and ease the load in the rail.
- 16.2.4.6.6 Anchors shall be designed to locate against a support bracket so that if overload occurs, the bracket may deflect and indicate the fault.
- 16.2.4.6.7 Tests shall be carried out on the mechanical and electrical properties to prove the quality of the arrangement. The Contractor/supplier shall submit respective test programs.
- 16.2.4.6.8 The Contractor shall submit design calculations required to identify locations for the midpoint anchor placement to ensure proper thermal movements. The type of design shall be easy to install, offers a positive lock on the rail, and to be easily adjusted to any point on the system. Special care shall be taken to identify for midpoint anchor placement to ensure the proper thermal movements. The movements shall be calculated and to be made available, along with graphical presentation for approval of the Employer.

16.2.4.7 **Power Feed Assembly**

- 16.2.4.7.1 The Power Feed Assembly consists of cable terminals that are arranged on the conductor rail located in accordance with the plans of the traction power supply. At intervals along the conductor rails, it is necessary to connect cables, particularly near ramps and at substation feeding points. It shall be the responsibility of the Contractor to lay and connect the cables connections at all such places.
- 16.2.4.7.2 Feeding points shall consist of two aluminium blocks and associated Huckbolts, firmly connected to the third rail. One aluminium block is the same as used for splice joints and the other one has a specific extrusion plate that is dedicated for cable lug fastening. It should be possible to arrange the plate in shape, which suits the incoming cable lugs. Power Feed Plate must be a single aluminium profile, welding must be avoided.
- 16.2.4.7.3 The entire assembly shall be able to withstand the effect of vibration leading to fatigue and loosening and be suitable to carry the current without undue resistance or temperature rise. The calculations for deflection due to power feed terminals shall be submitted by the Contractor.
- 16.2.4.7.4 All feeding points shall be pre-drilled having no direction restrictions to facilitate onsite installation. For installing the feed assembly, drilling on the conductor rail shall be done through a manufacture-recommended template.
- 16.2.4.7.5 Cable terminals shall be designed to carry safely the full rail current without overheating. They shall allow sufficient room for easy connection of the cables. They shall be suitable

for the termination of up to three 300 mm² copper cables. It should be possible to install two or three feed assembly in the same area in order to connect additional cables. Contact clamping faces of aluminum and copper components must be cleaned and greased as for bolted joints.

- 16.2.4.7.6 Each feeding point shall be suitable for the necessary number of lugs, to be determined and confirmed by dedicated studies. If cables are made of copper, it will be necessary to use special bi-metallic lugs to avoid corrosion between aluminium and copper.
- 16.2.4.7.7 The electrical resistance of the terminal plate to the cable joint shall not exceed 5.0×10^{-6} ohm. The compression cable lugs for the DC cable to the third rail shall be of tinned plated copper and suitable for the size of conductor used.
- 16.2.4.7.8 The feeding point connector plates shall be sized to accommodate the highly flexible incoming cables. These cables shall be attached to the conductor rails in such a manner, and shall be of sufficient lengths so that they do not hinder the natural longitudinal movement of the rail and shall not exert any lateral stress on the conductor rail.
- 16.2.4.7.9 The special cover using the same profile as the standard cover shall be used to avoid any contact with the power feeds components. The cover shall be readily removable for inspection of the cables.
- 16.2.4.7.10 A current heating test and a geometric test for the feeding points with the cable terminal assemblies shall be performed.
- 16.2.4.7.11 The Contractor shall submit design calculations of power feed determining the sag on account of weight of the cables and other acting forces.

16.2.4.8 Conductor Rail Supports

- 16.2.4.8.1 The Contractor shall design / specify the support to meet the requirements of a heavy-duty service, with adequate insulation of the conductor rails from its ground support under all operating and environmental conditions and also allowing the conductor rail to move within the temperature-dependent elongation. The support insulator assembly shall also be designed to support and locate the conductor rail with reference to the running rail. The Contractor shall furnish complete design calculations in this regard.
- 16.2.4.8.2 In the sections of non-ballasted track construction (mainlines), the third rail insulated supports shall be fastened to the track slab / plinth with bolted construction by using plastic dowel inserts. In the sections of ballasted track construction (e.g. Depots) the third rail insulating support shall be fastened to the running rail support sleepers with bolted construction by using plastic dowel. The third rail mounting system shall be of proven design with objective evidence of its ability to withstand the long-term static, forces developed during short-circuit and dynamic loading imposed by the passage of contact shoes.
- 16.2.4.8.3 The Contractor shall design / specify the support to meet the requirements of a heavy-duty service, allowing the conductor rail to move within the temperature-dependent elongation. The loss / mechanical failure of a single insulated support shall not cause the

third rail system to fail to meet the mechanical support requirements.

- 16.2.4.8.4 The conductor rails shall be supported by special rail supports, placed along the tracks in defined consecutive distance of the 5 m and adjusted according to the defined height and distance of the conductor rails with respect to the top of the running rails. Contractor shall submit the support spacing calculation and explore the possibility of increasing the spacing between supports.
- 16.2.4.8.5 Third rail supports shall consist of an insulator with a bracket. The insulator provides the mechanical connection between the conductor rail and the concrete surface of the track. It shall be designed to adequately insulate the conductor rails from earth under all specified operating and environmental conditions.
- 16.2.4.8.6 Conductor rails shall be supported at intervals, which are sufficiently small to ensure that nowhere will the conductor rail deflection exceed the limit defined by the Suppliers Performance Specification, taking into account the locations of expansion joints and ramps.
- 16.2.4.8.7 The conductor rail support assembly shall allow for adjustments to be made at both the time of installation and during service. The available adjustment range shall be $\pm 20\text{mm}$ vertically and $\pm 10\text{mm}$ horizontally.
- 16.2.4.8.8 The support assembly must withstand all the static, dynamic and vibration loads which are imposed on the third rail in service and provide the necessary electrical isolation between the third rail and the surrounding track work. The assembly should be capable of withstanding the static loads from the conductor rails and also any shocks, dynamic loads, vibration or short circuit forces likely to be encountered in the environment of track-work.
- 16.2.4.8.9 The support assembly shall be constructed of mild steel or composite material and be attached to track plinth or sleeper. Alternatively, GRP support assembly shall also be acceptable for which the proposed assembly shall be service proven and minimum 5 years in operation in an under running metro system.
- 16.2.4.8.10 At the upper end of the support bracket a molded insulator shall be attached which shall support a cast steel fastener/fix and mobile claw to hold the conductor rail in place. The brackets and fastenings shall be adjustable vertically and horizontally in order to position the conductor rail to the tolerance specified. Consideration must be given to the tolerance and quality of the sleeper ends and slab in providing the required adjustment. Any screws or bolts used to make the adjustment shall be of high-quality stainless steel. After the final adjustment, there shall be sufficient margin to further lower the conductor by at least 20mm to allow for running and conductor rail wear at some future date in the life of system.
- 16.2.4.8.11 Support Assembly: The bracket is an interface between the guide way and the insulator. It shall hold and locate the conductor rail with reference to the running rail. The bracket shall allow the adjustment of conductor rail position, laterally and vertically. The lateral adjustment shall be made by using steel washers behind insulator. The vertical adjustment shall be made by using a screw system. The design shall make the

adjustment the easiest and the safe.

- 16.2.4.8.12 All steel parts of the bracket assembly shall be hot dip galvanized with a minimum Zinc thickness of 70µm min and 85 µm average or stainless steel.
- 16.2.4.8.13 To the extent possible, a minimum number of designs of brackets shall be achieved to match with various track design scenarios of Ballast less track plinth, Ballast less track slab or PSC sleeper ballasted track.
- 16.2.4.8.14 Clamps (Jaws): The clamps are composed of two half clamps made of cast copper aluminium alloy alternatively cast stainless steel clamps may be accepted subject to its provenness and it is designed to withstand the fault force. The half clamps shall be locked together on rail with two stainless steel pins or by minimum one M8 screw. The mechanical properties, such as Tensile Strength, Yield Point, Elongation and Hardness etc. of the clamps shall be according to NF A 53-709 and is not subject to corrosion. Special plastic bearings shall be inserted on the clamp under the rails and on lateral sides to minimize friction thus allowing the conductor rail to expand and contract freely without damaging the insulator or the conductor rail. Alternatively cast stainless steel clamps may be accepted subject to its provenness and Contractor providing all relevant details.
- 16.2.4.8.15 The Contractor shall submit the proposal for clamps and accessories, along with properties as per standards and the operation service reference, for the approval of the materials by the Employer.
- 16.2.4.8.16 The clamp shall be fastened on the composite body of the insulator through one stainless steel M16 bolts and three centering pawls or by 3 M10 screws.
- 16.2.4.8.17 The rated insulation voltage required as a minimum for a section is equal to the highest working voltage appearing within the section or produced by adjacent sections. Long-term stresses shorter than 5 minutes (e.g. U_{max2} as defined in EN 50163) may be taken into account case by case, considering in particular the interval between such stresses.
- 16.2.4.8.18 Degree of pollution class to be considered as per EN 50124-1 is PD4B.
- 16.2.4.8.19 Insulator shall be fastened to brackets with stainless steel screws. The insulators shall be designed to withstand mechanical forces due to the weight of the rail and a 150 kg load applied on the rail. The material used shall be fire retardant, self-extinguishing and non-burning.
- 16.2.4.8.20 Insulators shall be of a material with a resistance to fatigue cracking and suitable for a tropical climate and a high resistance to ultraviolet rays. The surface finish of the insulator shall have high surface tracking resistance.
- 16.2.4.8.21 The insulator shall be manufactured with a high creepage distance (not less than 140 mm). They shall have a minimum of 100 Mega ohms apparent DC insulation resistance under 1000 V, measured in dry and clean conditions between the conductor rail and the mounting base of the insulator on the concrete slab track bed.
- 16.2.4.8.22 The insulators shall withstand 15kV industrial frequency voltage in dry conditions for one

minute. The voltage being applied between mounting studs and the rail position shall not cause any flashover.

- 16.2.4.8.23 The insulators immersed under 610 mm water during 24 hours and thoroughly dried shall have a minimal 100 M ohms apparent DC insulation resistance under 1000 V, measured in dry and clean conditions between the insulator rail and the mounting bolt on the bracket.
- 16.2.4.8.24 The insulators shall withstand 5 kV industrial frequency voltage in wet conditions for one minute. The voltage being applied between mounting studs and the rail position shall not cause any flashover.
- 16.2.4.8.25 The insulator shall possess adequate dielectric strength. It should have no arcing at 10 kV in dry condition and 5 kV in wet condition. It shall not flashover at 15 kV under dry impulse (1.2/50 μ s, 10 positive and 10 negative pulses).
- 16.2.4.8.26 The assembly of insulator and inserts shall be suitable for the atmospheric and climatic conditions in Lucknow.
- 16.2.4.8.27 Electrically the insulator shall be capable of withstanding all likely over-voltages due to switching or short circuits on the Metro System.
- 16.2.4.8.28 The insulator body shall be designed and manufactured with smooth contoured edges to eliminate high stress concentrations. It shall withstand mechanical forces due to the weight of the rail and a 150kg load standing on the rail as well as fault forces.
- 16.2.4.8.29 Clamps shall consist of two halves clamps made of cast copper aluminum alloy or cast stainless steel. They should be designed to withstand fault forces. Half clamps shall be locked together on the rail with two stainless steel pins. Plastic bearings shall be inserted on the clamps to allow the conductor rails to expand and contract freely without damaging the insulator or conductor rail.
- 16.2.4.8.30 All insulators shall be stamped with the manufacturer's logo and a manufacturing date.

16.2.4.9 Protective Covers & Fasteners

- 16.2.4.9.1 The entire conductor rail, including all ramps, expansion joints and cable terminals shall be covered by an insulated protective cover to protect against the weather and to avoid unintentional contact by staff working/walking on the line. Each cover system shall be designed for high standards of electrical performance, fire and smoke properties, and long life. The covers shall be colored yellow or Grey, it shall be decided during detailed design stage.
- 16.2.4.9.2 For outdoor applications insulated unplasticised Polyvinyl Chloride (UPVC) molded/extruded material shall be installed to cover all conductor rails. In tunnel Sections, the cover material shall be of GRP materials. They shall have a high capability to withstand fire in accordance with NF F 16-101 and UV compliant suitable for local atmospheric conditions and to be tested in accordance with IEC, EN, NE etc.,
- 16.2.4.9.3 Permanent self-adhesive labels shall be affixed to the top surface of the cover, at

intervals not exceeding 5 m, displaying an electric flash symbol and "Danger" sign. The label shall be suitable for outdoor use in the Lucknow environment and legible for at least five years after installation.

- 16.2.4.9.4 These covers (both UPVC and GRP) shall be capable of supporting 150 Kg weight at mid-span.
- 16.2.4.9.5 Dielectric strength of UPVC and GRP shall be such that it should have no arcing at 10 KV in dry condition and 5 KV in wet condition. They shall not flashover at 15 KV under dry impulse (1.2/50 μ s, 10 positive and 10 negative pulses).
- 16.2.4.9.6 The covers shall be fastened to the conductor rail by means of spacers in a way that accidental removal is not possible.
- 16.2.4.9.7 Design of cover fastener shall be made in such a manner that the cover fasteners are locked on the conductor rail feet to prevent movement of the protective cover supports during operation.
- 16.2.4.9.8 The protective covers shall be supported by cover support block (cover fastener) from the conductor rail.
- 16.2.4.9.9 At ramp ends, the nylon cover spacers shall be specially adapted to ensure that no part of the conductor rail assembly infringes the structure gauge. By selecting the manufacturing tolerances, the protective cover shall be connected to the cover supports so that additional screws or other fastenings are not required.
- 16.2.4.9.10 The individual cover sections shall be joined together without leaving any gap and that under regular operation a disconnection of such joints is not possible. The cover supports shall be connected to the conductor rails by clamping.
- 16.2.4.9.11 The distance holders shall also be made of the same materials.
- 16.2.4.9.12 The Contractor as a part of detailed design shall submit properties of the UPVC and GRP, fire properties, electrical properties, mechanical properties etc., in accordance with applicable EN/ASTM/IS standards. In addition, Contractor shall also delivery documents lists showing tests, methods of testing to explain the test results and the test results.

16.2.5 DESIGN CALCULATIONS

- 16.2.5.1 The Contractor shall submit calculations proving that the systems / system components work in the intended ways and that their design complies with the specified performance.

16.2.5.2 Technical Calculations

- 16.2.5.2.1 The Contractor shall calculate all electrical and mechanical criteria, which may affect the conductor rail. Respective reports shall be issued and supported by graphic demonstrations for better understanding. Some of the calculations are listed below but not be limited to:
- a) Electrical resistance of the conductor rail considering defined temperatures
 - b) Conductor rail elongation and consequences for expansion joint installation /

- adjustment
- c) Delamination test results of conductor – demonstration of usage of conductor rail up complete wear out stainless-steel surface (up to 0 mm)
- d) Partition of current between aluminum profile / steel Strip
- e) Influence of temperature on electrical resistance
- f) Nominal continuous DC current rating at ambient Temperature
- g) Peak and short circuit current
- h) Peak current load
- i) Short circuit current
- j) Conductor Rail deflection due to Power feed
- k) Bracket Support Spacing Calculation
- l) Bracket Loading Calculation

16.2.5.2.2 The Contractor shall submit calculations and sketches covering the planning parameters for the conductor rail on site, which concern mainly calculations for various gaps, to be installed in the conductor rail system.

16.2.5.2.3 The Contractor shall consider the rolling stock and train configurations, system component characteristics (i.e. ramps, turnouts) and safety regulations (separation of feeding sections, wash equipment, cross ways etc.).

16.2.5.2.4 The results shall be demonstrated with reports, supported by respective graphs and sketches.

16.2.5.2.5 In detail, but not limited to, the following documents / sketches / drawings / explanations shall be prepared:

- a) Gap types to be used based on train configuration but also placement of current collector shoes at individual cars.
- b) Minimum / maximum gap length in tangent tracks and at turnouts of different types
- c) Ramp conditions, like pickup situation with new / worn wheel conditions
- d) Minimum possible conductor rail section considering one single car conditions
- e) Clearance gauge of a support with respect to the vehicle outline and its movements during operation

16.2.6 STINGER EQUIPMENT

16.2.6.1 The third rail system as used for traction power supply along the electrified tracks shall be replaced in train inspection tracks inside the workshop by ceiling conductor rails. The power will be provided to the vehicles by cables with special contacts simply known as stingers.

16.2.6.2 The power supply from the suspended rail to the vehicle shall be made via a current collecting trolley, which itself can be switched on and off through control supply. A two button control pendant suspended from the trolley shall be used to switch the trolley on and off. This trolley, running on the I-profiled MS gantry beam, shall be equipped with a current sensing device and shall be provided with a strain relieved dropper cable fitted with a special plug. This plug shall be fitted with an auxiliary contact such that the plug can only be made live when it is correctly inserted into the train socket.

- 16.2.6.3 The inspection tracks inside the workshop shall be provided with individual stinger lines. The other depot tracks shall be equipped with regular conductor rail equipment.
- 16.2.6.4 The Contractor shall submit calculations proving that the systems / system components work in the intended ways and that their design complies with the specified performance.
- 16.2.6.5 **Conductor**
- 16.2.6.5.1 The conductor rail shall be of V-profile (100), capable for a continuous current load of at least 800 A. The conductors shall comply with DIN 1025 or equivalent standards.
- 16.2.6.5.2 The conductor rail (both power and control) shall be “V” shaped self-guiding contact surface, capable for a continuous current load of at least 800 A. The conductors shall be high conductivity rolled copper section, with properties conforming to BS 2870: 1980 Grade C101.
- 16.2.6.5.3 Provision shall be made for electrical power connections to the conductor bars. The power feed connection points shall be fully protected to IP2X rating and capable of being connected by the use of cable lugs.
- 16.2.6.5.4 The conductor rail sections (both power and control) shall normally be delivered in individual lengths of about 4.5m which shall be assembled mechanically and electrically to form a continuous stringer runway. The conductor rails (both power and control) including the joints shall be provided with strong, rigid extruded PVC insulating covers (providing protection to IP2X along the length). PVC end covers shall be provided at the ends. Power feed shall be provided to transfer power to stringer system through flexible cables.
- 16.2.6.5.5 The lengths of conductor bars (both power and control) shall be joined by a purpose made bolted joint which shall be of sufficient cross section to carry the rated current and provide structural stiffness whilst ensuring mechanical and electrical integrity.
- 16.2.6.6 **Suspension**
- 16.2.6.6.1 The stringer's conductor rail (both power and control) shall be anchored to the I-profiled MS gantry beam through purpose made suitable hanger clamps designed for 1000 V. The insulators shall ensure sufficient insulation of the 750 V DC against parts / components that are not used for current supply. The anchoring shall be carried out in such a way to prevent movement along its length under the influence of frictional forces from the current collecting device and the effects of continued thermal expansion and contraction. The anchoring device shall not puncture the insulating cover. Hangers shall be installed at sufficient intervals to ensure a secure assembly, whilst taking consideration of movement along the length of the system caused by expansion / contraction due to temperature change. The final suspension is part of the final design stage and requires coordination with the civil contractors and those responsible for the workshop / depot design. Interfaces with other services within the depot area shall be cleared during the design stage. This applies in particular to cranes operating in the depot in close distance to the stringer arrangements.

- 16.2.6.6.2 All current carrying equipment shall be capable of carrying current up to the maximum requirement without detrimental effect. Provision shall be made for thermal expansion of the conductor bars by means of expansion sections. These shall be supplied in lengths identical to standard lengths of conductor bars. Expansion sections shall have no external cables.
- 16.2.6.6.3 Provisions shall be made to install stingers that are totally enclosed in metal housings or shall be utilized with a protective cover along the stinger. In particular cases it may be necessary to install the stinger line underneath working platforms or crane rails.
- 16.2.6.7 **Impact Bumper**
- 16.2.6.7.1 Impact bumpers shall be provided to serve as travel limits for the current collection trolleys.
- 16.2.6.8 **Current Collector Trolley**
- 16.2.6.8.1 The current collector trolleys shall be fabricated from steel sections and supported by four wheels with precision bearings to provide mobile support for tandem 250 A parallel arm current collectors and dropper cable and plug. The trolley shall be equipped with a pair of status beacons, which indicate whether the trolley is on or off. Traction supply shall automatically cut off when the plug is not fitted to the car or not properly fitted.
- 16.2.6.8.2 The dropper cable from the trolley to the plug shall include a suitably rated frangible link. Indicator lights shall be incorporated into the dropper assembly which shall provide a red display when the train plug is passing current and a white display when the train plug is not passing current. The lights shall be located within 1m of the train plug and shall provide continuous illumination over at least 1.5m of the total length of the dropper.
- 16.2.6.8.3 The current collecting device shall have a contact shoe made from a sintered copper graphite material and shall be of an articulated spring loaded design to provide all degrees of freedom necessary to maintain contact between its contact shoe and the conductor bar surface. The collectors shall have tolerance for movement - ± 80 mm (vertical) & ± 25 mm (horizontal) for 750V dc traction supply and +80mm / -20mm (vertical) & ± 60 mm (horizontal) for control supply.
- 16.2.6.8.4 A tow rope to allow the trolley to be pulled along the system either by an operated or the train shall also be provided.
- 16.2.6.8.5 Two adequate cables to the cable connection adapter will affect the current collection. At least two trolleys per stinger line shall be provided to allow power supplies to one train.
- 16.2.6.8.6 The main electrical connections shall be made in a steel junction fastened to the trolley. A woven steel cable stock shall support the weight of the cable and plug and a polyester low rope shall be provided to allow towing of the trolley power supplies to two train units.
- 16.2.6.9 **Indicator Lamps**
- 16.2.6.9.1 For reasons of safety it shall be necessary to equip stingers along determined distances

of the line with special indicator lights, showing whether the stingers are energized or not.

16.2.6.10 Emergency Conditions/Installation Conditions

- 16.2.6.10.1 The Contractor shall provide all control circuits and facilities required to switch off all stinger lines together in case of emergency.
- 16.2.6.10.2 The Contractor shall submit an emergency philosophy, explaining step by step, based on defined scenarios, the actions necessary to work safely with the system.
- 16.2.6.10.3 The same applies for the installation of the stinger lines. The Contractor shall submit an instruction manual to explain the steps to install the stinger equipment properly.

16.2.7 MOUNTING ARRANGEMENT

- 16.2.7.1 Typical mounting arrangements for the third rail system have been shown in the tender drawings part of tender documents. The arrangements are typical. The Contractor shall propose the arrangements to be used at different locations depending upon site conditions and track configuration for approval by the Engineer.
- 16.2.7.2 The Contractor may propose a mounting arrangement different from the arrangements shown in tender drawings. However, the arrangement should be based on established practices and in use in a Metro Systems. Depending upon the merits of the proposal, the Engineer may accord approval for the arrangement.

16.2.8 INSTALLATION

- 16.2.8.1 The installation of the conductor rail assembly on the mainlines and depots shall be carried out by LKE(02)-01 Contractor. For installation works, LKE(02)-01 Contractor shall closely interface with the Track Contractor for the required pedestals for installations of brackets/sleepers, crossing of DC cables below the tracks, pedestals for disconnection switches, third rail alignment, testing and commissioning in mainline and depots.
- 16.2.8.2 The stinger system in the workshop, however, shall be installed by the LKE(02)-01 Contractor.
- 16.2.8.3 LKE(02)-01 Contractor shall design and finishing requirements for installation of third rail bracket pedestal and shall be handed over to Track work Contractor for construction. LKE(02)-01 Contractor shall supervise the casting of pedestals and witness the pullout tests to verify the requirement as per the design document.
- 16.2.8.4 The LKE(02)-01 Contractor shall prepare an installation manual covering all aspects of the installation. It shall also incorporate the recommendations of the manufacturer.
- 16.2.8.5 The Contractor shall procure adequate number of sets of manufacturer's recommended tools, jigs, equipment etc., for the installation of third rail system. The number of sets to be procured should be adequate to achieve to meet the works program.
- 16.2.8.6 The Contractor shall supply new sets of such spares as provided in Chapter- 9 of this Technical Specifications.

- 16.2.8.7 Contractor shall also procure adequate number of sets of manufacturer's recommended special tools for installation of the third rail. The number of sets handed over should be adequate to achieve to meet the works program.

16.3 COMPONENTS' TEST REQUIREMENT

16.3.1 GENERAL

- 16.3.1.1 The various components of the third rail system and stinger system shall be subjected to type tests, routine test, site test etc.
- 16.3.1.2 Since there is no international or national standard for third rail systems, the test requirements shall be developed in consultation with the manufacturers and as adopted by other metro systems.
- 16.3.1.3 The Contractor shall submit a comprehensive plan and program for type tests and other tests for items of third rail and stinger system assembly to the Engineer for approval. The plan and program shall consist of the minimum tests as detailed in subsequent clauses.

16.3.2 CONDUCTOR RAILS

16.3.2.1 Development / Type Tests

- 16.3.2.1.1 Adhesive Strength
- 16.3.2.1.1.1 The adhesive strength between aluminium and stainless steel of the conductor rail shall be demonstrated. For the test, one sample piece of minimum 90 mm in length shall be cut out of the center of a standard length conductor rail. The test piece shall be suitable clamped and a force applied normal to the stainless steel as recommended by the manufacturer. The test shall be classified as passed only if no de-lamination of the steel from the aluminium body of the rail is noted under a minimum 60 kN force.
- 16.3.2.1.2 Dynamic Loading
- 16.3.2.1.2.1 The Contractor shall supply documentation that demonstrates that the shear strength / connection at the interface between the aluminium and stainless steel remains sufficient during the service life of the conductor rail under all dynamic loadings to be expected.
- 16.3.2.1.3 Delamination Test
- 16.3.2.1.3.1 Conductor rail is intended to be used up to complete worn-out of stainless steel without any delamination, same to be demonstrated by machining down the entire stainless steel strip. No debonding or delamination between steel strip and aluminum body to be observed.
- 16.3.2.1.4 Plastic Deformation
- 16.3.2.1.4.1 A length of rail shall be deformed to simulate the forming of ramp ends. The bonding / connection between the aluminium body and the stainless wearing surface shall not be

reduced by bending to a radius of 1000 mm.

16.3.2.1.5 Electrical Resistance

16.3.2.1.5.1 The resistance of a standard conductor rail length and that of two standard rail lengths connected together with a splice-joint assembly shall be measured. The resistance of the joint shall not exceed that of an equal length of un-joined rail. This DC resistance value shall not exceed $7.0 \mu\Omega/\text{m}$ at 15°C .

16.3.2.1.6 Contact Resistance

16.3.2.1.6.1 The contact resistance at the aluminium and stainless-steel joint shall not exceed $30\mu\Omega$ over the series of measuring points, at a minimum 5 per 15 meter length.

16.3.2.1.7 Temperature Rise

16.3.2.1.7.1 The temperatures at five equally spaced locations along two standard rail lengths, connected together with a splice-joint assembly, shall be measured after application of the specified continuous and peak currents. The continuous current shall be applied for four hours and the peak for 1 minute. The temperature rise shall not exceed 40°C above an ambient temperature of 50°C .

16.3.2.1.7.2 A current heating test shall be performed for the feeding points with the cable terminal assemblies.

16.3.2.1.8 Corrosion Resistance

16.3.2.1.8.1 The corrosion resistance shall be proven by a neutral salt spray as per DIN EN ISO 9227 for 1000h under 35°C . The contact resistance at the aluminium and stainless-steel joint of the conductor rail sample shall not exceed $30 \mu\Omega$ after the test.

16.3.2.1.8.2 Short Circuit Withstand

16.3.2.1.8.3 A standard length of the conductor rail shall be mounted on the support insulator assemblies and alongside the normal running rails. A short circuit test shall be performed by passing an (alternating) current of 125 kA down the conductor rail and back along the adjacent running rail, the current pulse lasting for 0.20 seconds. The maximum permanent deflection of the supports shall be not more than 5mm and there shall be no permanent deformation of the rail between supports.

16.3.2.2 **Routine Tests**

16.3.2.2.1 Visual Examination

16.3.2.2.1.1 A visual examination shall be done before deliveries.

16.3.2.2.2 Dimensional Checks

16.3.2.2.2.1 The most important dimensions of the conductor rail shall be checked on a random basis before deliveries.

16.3.2.2.3 Adhesive Strength

- 16.3.2.2.3.1 One rail per 100 rails shall be subject to an ultrasonic examination to ensure the absence of any voids in the aluminium to steel interface. The Employer may require more frequent testing if voids are found in the test rails.

16.3.3 SPLICE JOINTS

- 16.3.3.1 The type test requirements of splice joints shall be covered under the type tests of conductor rails (electrical resistance, temperature rise and short circuit withstand tests).
- 16.3.3.2 The Contractor shall submit a test program to carry out the performance tests of the splice arrangement concerning the mechanical and electrical properties.
- 16.3.3.3 The routine tests shall include visual examination and dimensional checks on a random basis before deliveries.

16.3.4 EXPANSION JOINTS ASSEMBLY

16.3.4.1 Development Testing

- 16.3.4.1.1 One complete expansion joint shall be set up and supported by the normal insulated support assembly. The contact surfaces across the gap shall be aligned. One end shall be fixed and the other repeatedly extended by the full length of the gap and then returned to normal position. The joint shall be capable of withstanding 15000 such cycles without maintenance.
- 16.3.4.1.2 At the end of the test the flexible shunt should not show any signs of buckling, cracking, increase in resistance or other deterioration, and there should be no wear debris produced from the shunt, which would collect on the fishplates.
- 16.3.4.1.3 At the end of the cycling test, the vertical distance between the contact surfaces across the gap shall not exceed 0.5mm.
- 16.3.4.1.4 The test shall be completed before proceeding with expansion joint installation.

16.3.4.2 Routine Tests

- 16.3.4.2.1 Every complete expansion joint shall be inspected to ensure that it has the required movement. Every expansion joint shall be measured for resistance by the use of a micro ohmmeter or alternative method. The resistance of the conductor rails including the shunt shall be measured and shall be within the required limits (i.e. not exceeding 35 $\mu\Omega$ per 4 meter or per EJ).
- 16.3.4.2.2 In addition, visual examination and dimensional checks shall be performed on a random basis before deliveries.

16.3.5 ANCHOR ASSEMBLY

16.3.5.1 The type test shall include mechanical loading. A worst-case load shall be applied on the anchor blocks after they are mounted on a piece of conductor rail, and there shall be no deformation and no fracture of the anchor blocks.

16.3.5.2 The routine test shall include visual examination and dimensional checks and shall be performed on a random basis.

16.3.6 POWER FEED ASSEMBLY

16.3.6.1 The power feed terminal assembly shall be subjected to a current heating test using continuity cables. The temperature under maximum operating conditions shall not exceed 90°C.

16.3.6.2 An electrical resistance test for checking the resistance between terminal plate to the cable joint. The resistance shall not exceed 5 $\mu\Omega$.

16.3.6.3 The routine test shall include visual examination and dimensional checks.

16.3.7 RAMPS

16.3.7.1 The Contractor shall design the ramp profiles by mathematical simulation followed by laboratory testing, with a view to:

- a) Minimizing the ramp length by optimizing the ramp angle for the applicable design speeds taking into account the mass / spring / damper properties of the current collection shoe; and
- b) Minimizing arcing (or minimizing the frequency of ramp renewals due to arcing) which occurs when a current collection shoe which is drawing current becomes isolated from the supply

16.3.7.2 The Contractor shall propose their research and development proposals as part of their tender submissions.

16.3.7.3 For conductor rail ramps, only mechanical tests are required. The routine test shall include visual examination and dimensional checks. The Contractor shall provide respective test procedures.

16.3.8 SUPPORT ASSEMBLY

16.3.8.1 Support Assembly Development Testing

16.3.8.1.1 The Contractor shall demonstrate by laboratory testing of his proposed design that:

- a) Adequate fatigue endurance will exist in the support arm and all components; and
- b) Sufficient resilience in the fastening between the conductor rail and the support claw will be sufficient to avoid accelerated component wear.

16.3.8.1.2 The support assembly shall be easy to adjust both vertically and horizontally and be able to maintain that adjustment without further checking.

16.3.8.1.3 The Contractor shall provide test programs showing test procedures, relevant test

standards and explaining test results were also the mechanical stability of the rail and the supports for short circuit currents shall be verified by carrying out a short circuit type test.

- 16.3.8.1.4 The necessary tests related to the anchor assemblies shall be carried out on the mechanical properties to proof the quality of the arrangement. The Contractor/supplier shall submit respective test programs.

16.3.8.2 Support Assembly Routine Testing

- 16.3.8.2.1 The quality of welds shall be checked by visual inspection on each item and by nondestructive liquid penetrate test on samples.

- 16.3.8.2.2 Visual examination and dimensional checks shall be performed. The electrical resistance of the insulators shall be checked on a random basis. The measured value shall not be less than 100 mega ohm.

16.3.8.3 Insulator Development Testing

- 16.3.8.3.1 Ten insulators shall each be immersed in tap water at room temperature for 24 hours and then removed and dried thoroughly. The insulator electrical resistance shall be measured. Electrical resistance (dry) shall not less than 100 mega ohm.

- 16.3.8.3.2 The insulator compound shall be non-porous and be limited to a weight increase of 0.3% maximum in 24h at 23°C as per ASTM D570.

- 16.3.8.3.3 Dielectric Strength: Ten insulators shall each be tested in accordance with ASTM D 149 Method A Short Time Test. A 60 Hz AC voltage shall be applied for 1 minute between top and bottom in air at ambient temperature and humidity, increasing at approximately 1000 volts per second up to 15 kV rms. There shall be no flashovers and the insulators shall not break down during the time the 10000 volts are applied.

- 16.3.8.3.4 After the dry test, the insulators shall be subjected to the alternating voltage of 5 kV rms for one minute at 60 Hz or 72 sec. at 50 Hz while experiencing artificial rain (3mm per min). There shall be no flashovers.

- 16.3.8.3.5 Dry Impulse: Ten insulators shall each be subjected to 20 impulses of 15kV crest, 1.2/50 μ s pulse, 10 pulses in positive and 10 pulses in negative direction, in dry conditions. They shall not break and there shall be no flashovers on any one insulator during the complete test.

- 16.3.8.3.6 Ageing Simulation: Ten insulators shall each be heavily grit blasted to remove the surface layer, then immersed in tap water at 50 °C for 2 hours and cooled for 6 hours at room temperature. This heating / cooling cycle shall be repeated a total of 10 times. After this artificial ageing process, the insulators shall be subjected to the electrical resistance, dielectric strength and dry impulse tests, specified herein, and all pass the requirements of each test.

- 16.3.8.3.7 Insulator Molding Compound Properties: The support insulator molding material shall be tested by an independent laboratory to demonstrate compliance with the requirements. The results of these tests shall be submitted for acceptance by the Employer.

- 16.3.8.3.8 Mechanical Loading: The expected worst case static and dynamic loading in both vertical (downwards and upwards) and horizontal (parallel and perpendicular to the rail) direction shall be determined by analysis. Destructive and non-destructive loading tests shall be performed on 3 and 5 complete support insulator assemblies respectively to demonstrate the capability of the support assembly to withstand the expected loading.

16.3.8.4 Insulator Routine Tests

- 16.3.8.4.1 Each insulator shall be inspected for:
- Uniform surface with no visible cracks, hollows, inclusions or surface defects, the insulators showing any of these defects shall be rejected.
 - Important dimensions of the insulator
 - Molding protrusions on edges of surface of the molding shall not exceed 2mm above the general surface level.
 - Electrical resistance of each insulator shall be measured at room temperature and under dry conditions, and it shall be not less than 100 mega ohms.
 - From each batch of 1000 insulators, 3 shall be cut along the shortest internal path and the cross-section studied. There shall be no voids in the cross-section greater than 2 mm diameter and no significant accumulation of such voids, which might lead to internal breakdown. There shall also be no internal cracks.

16.3.9 PROTECTIVE COVERS

16.3.9.1 Development Testing

- 16.3.9.1.1 A standard length of cover shall be assembled onto the conductor rail to form a normal assembly arrangement and a 1500 N load applied via a pad 30 mm in diameter for UPVC cover and a pad of 100 mm for GRP cover and shall be maintained for five minutes and then removed. For GRP cover test Rubber pads have to be placed in between the Ø100mm pad and the cover top surface. There shall be no permanent deformation or cracking of the cover, and the cover shall remain fastened to the rail with the whole assembly intact.
- 16.3.9.1.2 Dielectric Strength: A standard length of cover shall be assembled onto the conductor rail to form a normal assembly arrangement and a thin metal foil (approximately 120 mm by 120 mm) shall be attached closely to the top surface. Connections shall be made from this foil and the conductor rail to a voltage source. The dielectric strength tests similar to the ones specified for the support insulator shall then be performed under both dry and wet conditions. There shall be no flashovers during the tests.
- 16.3.9.1.3 A short length of cover shall be immersed in acetone for 30 minutes and then inspected. No de-lamination shall be visible in the specimen.
- 16.3.9.1.4 The protective cover material shall withstand the following test voltages, which are related to a rated voltage of 750 V dc.
- | | | |
|-----|-----------------------------------|--------------------------------|
| a) | Power frequency withstand voltage | 5 kV for wet and 10 kV for dry |
| b) | Impulse withstand voltage | |
| i. | Lower impulse level | 13 kV |
| ii. | Upper impulse level | 15 kV |

- 16.3.9.1.5 The Contractor shall submit with the delivery documents lists showing tests, methods of testing and explain the tests results and the resulting consequences.

16.3.9.2 Routine Tests

- 16.3.9.2.1 Lengths of protective cover shall be inspected for general conformity to this Specification to the acceptance of the Employer. There shall be no measurable de-laminations or voids.

16.3.10 STINGER SYSTEM

- 16.3.10.1 The Contractor shall indicate development / type tests and routine tests for stinger system on the similar lines as for third rail system and undertake all the tests.

16.4 INSTALLATION AND SYSTEM ACCEPTANCE TESTS

16.4.1 GENERAL

- 16.4.1.1 Contractor shall develop and submit the detailed installation plan, hold points, check points, tests involved etc., for Engineer's approval. Installation and system acceptance tests plan shall be in accordance with the design requirements and comply to system acceptance requirements.
- 16.4.1.2 Contractor shall responsible for transportation to site and installation, testing and commissioning of third rail system, for which Contractor shall interface with Track Contractor, Station Contractor, Viaduct Contractor, Depot Contractor and other designated contractors of the Project. All the tools, jigs, equipment, fixtures etc., required for transportation of material, installation, testing and commissioning is under the scope of LKE(02)-01 Contractor.
- 16.4.1.3 The LKE(02)-01 Contractor shall submit a comprehensive system acceptance test plan to the Engineer for approval.

16.4.2 STRUCTURE GAUGE

- 16.4.2.1 The conductor rail and all connected parts shall be kept within a defined space constraint to prevent anything coming into contact with passing trains. The limit of this space envelope is known as the Structure Gauge of the conductor rail. No portion of the conductor rail system – rails, supports, covers or ramp ends – shall lie outside the structure gauge.
- 16.4.2.2 Position of the conductor rail contact faces is 148mm above the level of the running rails, and 1485 mm measured from the center of track to the conductor centerline. The tolerance of installation of the 3rd rail shall be no more than typically +/- 3mm (as per sod) horizontally and +10mm vertically.
- 16.4.2.3 The position of the conductor rail and the structure gauge shall be unchanged on curves.

- 16.4.2.4 At ramp ends, where the train pickup shoes are required to run onto the rail, the rail shall be typically raised by 90mm, and shall form a smooth transition back to the normal rail position.

16.4.3 INSTALLATION TOLERANCES

- 16.4.3.1 The height of the conductor rail wearing surface above the plane containing the crowns of the two running rails shall be within +/- 3mm of the nominal dimension, and variations in elevation shall not exceed 1mm per meter.
- 16.4.3.2 The lateral offset of the conductor rail from the gauge corner of the running rail shall be within ± 5 mm of the nominal dimension.

16.4.4 SPLICE JOINTS

- 16.4.4.1 The Huck bolts shall be assembled using the manufacturer's specified tooling and procedures.
- 16.4.4.2 Before assembling the fish plated joints, the contact faces of rail and fishplates shall be thoroughly wire brushed and coated with a layer of No-Oxide or zinc-loaded contact grease to achieve minimum contact resistance across the joint and prevent any corrosion.
- 16.4.4.3 The tolerances of the rail and cap shall ensure that the completed joint has an accurate and smooth transition between rail ends. On assembly the maximum step shall be no more than 0.2mm.
- 16.4.4.4 The assembled joint shall not have more than 2mm gap between rail ends.
- 16.4.4.5 The gap between the edge of splice plate and third rail installation support shall be not less than 200mm, to prevent temperature dependent third rail expansion.

16.4.5 ACCEPTANCE TESTS

16.4.5.1 Commissioning and Acceptance Tests

- 16.4.5.1.1 For integrated tests between the Contractors, the Track Contractor and the Rolling Stock supplier refer to Clause 7.11 of chapter 7 of this Volume.
- 16.4.5.1.2 Once the system of conductor rails has been installed, it is necessary to confirm that the installation has been correct dimensionally; that it is continuous and able to provide the required power; and that it is safely isolated from the ground. These checks are normally made at the conclusion of several km of tracks, and between successive substations so that the whole power loop may be tested at one time.

16.4.5.2 Electrical insulation

- 16.4.5.2.1 Sections of track shall be individually raised in voltage by connecting a flash tester between the running rails and the conductor rail, each completed length of third rail shall be connected to a high voltage supply and the rail raised in potential to 3000 volts relative

to local earth and maintained at this figure for 15 minutes. The leakage current at the start and finish of the test shall be recorded. Any faults discovered in the insulation shall be rectified.

16.4.5.2.2 Third rail electrical insulation resistance test shall be conducted at intervals of every 5 support brackets interval. The following electrical resistance shall be measured:

- a) Between third rail and running rail
- b) Between third rail and cover
- c) Between third rail and support bracket

16.4.5.2.3 The resistance shall be measured and recorded. The indicative resistance shall be 1 MΩ for 100 m section.

16.4.5.2.4 At the conclusion of these tests the conductor rail may be considered as complete and ready for conducting integrated tests with Rolling Stock supplier and the Track Contractor under the supervision of the Contractor.

16.4.5.3 **Line Electrical Resistance**

16.4.5.3.1 When the rail and all fittings are installed, including expansion joints and continuity cabling, the end-to-end resistance of the system shall be checked to confirm its compliance with the overall system requirements.

16.4.5.4 **Electrical Continuity**

16.4.5.4.1 A low voltage source of current (minimum 100 A) shall be set up and current passed along sections of the completed conductor rail. The voltage drop along the rail shall be checked and the resistance of the rail calculated and compared with the prescribed line resistance. There shall typically be a correction applied for the local temperature of the rails, because of the temperature coefficient of resistance, and allowance may be made for cables, which are not in the direct length of the system. The result shall then be compared with the Specification. If errors are found they shall be corrected at this stage.

16.4.5.5 **Electrical Proving**

16.4.5.5.1 Before measuring the line resistance, it is necessary to check that the individual switches are in the correct position and that the cables are connected correctly to the track. This shall normally be undertaken by measuring continuity of track sections as the various switches are operated. Details of this process shall be worked out by the Contractor and submitted to Engineer for approval. A detailed integrated tests plan between the Contractor, the Track Contractor and the Rolling Stock supplier shall be prepared with the Rolling Stock supplier in the lead role.

16.4.6 **SPECIAL TOOLS**

16.4.6.1 **Special tooling for installation and maintenance**

16.4.6.1.1 The installation and maintenance of the power rail system is a specialized process, requiring knowledge of mechanical assemblies, civil engineering practices, and basic

electricity. Certain tooling shall be supplied to assist in the work, consisting of the necessary jigs and tools to complete the tasks efficiently and correctly.

16.4.6.2 All the tools, jigs, equipment, fixtures etc., required for installation, testing and commissioning of third rail and stinger system is under the scope of LKE(02)-01 Contractor.

16.4.6.2.1 The following are the minimum tools to be procured to meet the installation programme and maintained with Contractor for installation of third rail and stinger system

- a) Conductor rail structure gauge tool: Used to ensure the power rail or its components do not infringe the structure gauge
- b) Cover Tool: Used to aid installation of the conductor rail cover
- c) Track installation gauge: Used to check the position of the conductor rail relative to the gauge face of the running rail
- d) Insulator Setting Jig: Used to set the height of the insulators
- e) Cable Terminal Drill Jig: Used to as a guide to drill the power rail prior to cable terminal installation
- f) Mid-Point Anchor Drill Jig: Used to drill connections for the midpoint anchors
- g) Ramp Cover Cutting Template: Used as a guide when trimming the corner angles of the power rail cover at ramps
- h) Insulator Cover Cutting Template: Used as a guide when cutting the conductor rail cover at ramp insulator covers.
- i) Any other tools required for completion of job

16.4.6.2.2 The following is a list of jigs and other tools to be procured to meet the installation programme and maintained with Contractor for installation of third rail and stinger system:

- a) Jigs for casting the third rail bracket in mainline
- b) Jigs for casting PCC sleepers for depots
- c) Jigs for drilling conductor at cut ends and cable terminal locations
- d) Jigs for installing conductor rails
- e) Disc cutter or saw with clamp and guide fixture for cutting rail
- f) Cable lug crimping tools
- g) Gauge for checking the position of conductor rails
- h) Installation tooling for Huck bolts
- i) Voltage measuring devices

16.4.6.2.3 The Contractor shall supply all the special tools and jigs as required to complete the installation of Third rail system. For the avoidance of doubts, two sets of all the tools specified under Clause 9.3, as a minimum but not limited to, please refer Chapter-9 of Technical Specification. These shall be supplied in advance as per the installation programme.

16.4.7 PORTABLE SHORT-CIRCUITING DEVICE (SCD) & VOLTAGE TESTING DEVICE

16.4.7.1 The Contractor shall design and supply portable short circuiting devices as well as the voltage tester to facilitate connection of third rail sections to the running rails when necessary for trackside safety. It is intended that such short circuiting devices shall normally be used in pairs and deployed at both ends of an area where electrical

protection is required.

16.4.7.2 The short-circuiting devices shall be of proven design and certified to be short circuit proof without endangering the operator when applied in error to a live third rail. Portable SCD shall be of proven make and Contractor shall submit the detailed engineering and test certificates for Engineer's approval.

16.4.7.3 The rating of portable SCD is 100 kA for 35 ms. Quantity to be supplied is as per BoQ. SCDs shall be of proven make and shall be in service in metro/railway applications.

16.4.7.4 Contractor shall supply portable voltage testing device suitable for testing the presence of voltage in third rail before applying portable SCD. Portable voltage testing device shall be of proven design and certified for the required insulation. Portable SCD are meant for testing the voltages even in live third rail without endangering the operator when applied during rainy conditions. Portable voltage testing device shall be of proven make and Contractor shall submit the detailed engineering and test certificates for Engineer's approval.

16.4.8 750 V DC SHORE SUPPLY

16.4.8.1 LKE(02)-01 Contractor shall design and supply 750 V DC Shore Supply to facilitate connection at the Workshop Bay in Depot. Adequate Length of the cable to be considered and necessary arrangement to be ensured and interlocking with Rolling stock to be explored.

16.4.9 TEST SHEET FOR THIRD RAIL & ITS ACCESSORIES

Table 16.4 Test sheet for Third Rail & its Accessories

INDICATIONS	TYPE of TEST				
	Type	Routine	Acceptance	On site	After Shipment
Adhesive Strength	X	X	X		
Dynamic Loading	X				
Delamination Test	X				
Plastic Deformation	X		X		
Electrical Insulation Resistance	X	X	X	X	
DC Resistance	X		X	X	
Contact Resistance	X		X		
Temperature Rise	X				
Corrosion Resistance	X				
Short Circuit Withstand	X				
Visual Examination		X	X		X
Dimensional Checks		X	X	X	
Mechanical Tests	X			X	
Gauge Measurement				X	
Dielectric Strength	X				
Power Frequency Withstand Voltage	X				
Impulse withstand voltage	X				
Electrical Continuity				X	
HV Test			X		
Ultrasonic Examination	X	X			

CHAPTER17: EARTHING, BONDING, STRAY CURRENT CONTROL AND EMC REQUIREMENTS

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CHAPTER - 17

EARTHING & BONDING, STRAY CURRENT
CONTROL & EMC REQUIREMENTS**17.1 EARTHING, BONDING, STRAY CURRENT CONTROL& EMC
REQUIREMENTS****17.2 SCOPE**

17.2.1 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in chapter-2 along with clause wise compliance and suggest similar or better design for the approval of Employer.

17.2.2 This Specification applies to earthing, bonding, stray current management system and EMC requirements for Lucknow Metro Rail Project (East West Corridor- Phase 1 B).

17.2.3 The Contractor Scope of Work includes engineering, supply, installation, testing and commissioning of earth cable for the earthing and bonding of structure earth terminals, running rails (as relevant) and equipment on entire section. The connection at the interface point of viaduct sections shall also be the responsibility of LKE(02)-01 Contractor.

17.2.4 The running rail on the main line section shall be kept floating (unearthed) to minimize the stray currents to structures. However, in depot area, earthed system has been adopted for workshop and Inspection bay lines whereas rest part of depot is floating. The entire earthing and bonding for the power system installations inside depot shall be the responsibility of the LKE(02)-01 Contractor.

17.2.5 LKE(02)-01 Contractor shall be the custodian of earthing, bonding, stray current control and validation of EMC requirements of the entire system. He shall suitably interface with all relevant designated contractors and ensure implementation of the Earthing, Bonding, stray current control measures and EMC requirements as per the relevant specifications and design. Interface responsibilities with other Contractors, have further been defined in Chapter-3.

17.3 SPECIFICATION / STANDARDS

17.3.1 The earthing, bonding and stray current protection system shall be conforming to the following specifications:

Table 17.1: Specifications

SN	Specification No.	Description
1	EN 50122-1	Railway applications (fixed installations) protective provisions relating to electrical safety & earthing
2	EN 50122-2	Railway applications (fixed installations) protective provisions against the effects of stray currents caused by dc traction system
3	EN 50122-3	Railway Applications – Fixed Installations – Electrical Safety, Earthing and the Return Circuit - Part 3: Mutual Interaction of A.C. and D.C. Traction Systems
4	EN 50310:2011	Application of equipotential bonding and earthing in buildings with information technology equipment
5	IEC 60364-5-54:2011	Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors
6	IEC 60364-5-54:2011	Selection and erection of electrical equipment - Earthing arrangements, protective conductors and protective bonding conductors
7	IEC 60364-4-41: 2005	Low-voltage installations – Part 4-41: Protective Provisions – Protection Against Electric Shock
8	IEC 62305-1:2010	Protection against lightning – Part 1: General principles
9	IEC 62305-2:2010	Protection against lightning – Part 2: Risk management
10	IEC 62305-3:2010	Part 3: Physical damage to structures and life hazard
11	EN-50162:2004	Protection against corrosion by stray current from direct current systems
12	UIC 605	“Protection from Corrosion – Measures to be taken on direct current catenaries to reduce the risk on adjacent piping and cable systems”
13	IEC 61000-5	Electromagnetic Compatibility (EMC)
14	IEEE 80-2013	Substation Earthing
15	BS 7671	Requirements for Electrical Installations
16	IEC 60364-1	Electrical Installations of Buildings
17	IEC/TS 61312-2, Edition 1.0 (1999-08)	Protection against lightning electromagnetic impulse (LEMP) – Part 2: Shielding of structures, bonding inside structures and earthing
18	IEC 61024	Protection of structures against lightning
19	IEC 61936	Power Installations exceeding 1kV
20	BS 7430	Code of Practice for Earthing
21	IS 3043	Code of Practice for Earthing
22	NBC	National Building Code
23	NEC 2011	National Electricity Code (India) - 2011

17.4

REFERENCE DRAWINGS

17.4.1

The reference drawings are enclosed with the Tender Document for the reference as Volume 5.

17.4.2 LKE(02)-01 Contractor shall develop policy and approach for earthing, bonding, lightning protection and stray current corrosion control based on those drawings and this specification. The LKE(02)-01 Contractor shall coordinate its strategy and designs for earthing, bonding, lightning protection and stray current corrosion control with the designated contractors.

17.5 **EARTHING& BONDING STRATEGY**

17.5.1 The purpose of Earthing & Bonding Strategy is to define the requirements for the earthing and bonding of the electrical power supply systems throughout the network to ensure, as far as practically possible:

- a) The safety of operating personnel and other persons from electrical shock
- b) The minimum of electrical interference between the electrical power supply and other electrical and electronic systems
- c) The minimum of disturbance to existing statutory services and parts of the Lucknow Metro network system due to any electrolytic corrosion effects arising from dc traction currents flowing to and from the general body of the earth.

17.5.2 Floating system (i.e. traction system with floating negative) has been adopted for all sections of mainline of the Lucknow Metro East West Corridor (Phase 1 B).

17.5.2.1 The running rails shall be adequately insulated as per EN 50122-2. The recommended conductance per unit length for elevated/underground section for single is $100 (\Omega\text{-km})^{-1}$ (0.01 S/km) for a new track measured under dry conditions.

17.5.2.2 Structural earth conductor, 2 x 185 mm² Aluminium shall be provided along the viaduct and all the metallic parts of equipment, cable sheath, viaduct reinforcement, signal posts, ASS/TSS earth mats, viaduct pillar etc. shall be connected to structural earth (SE) cable with 120 mm² Aluminium cable or 70mm² Copper cable.

17.5.2.3 The continuity of the reinforcement's bars of the viaduct as well as track slabs shall be ensured along with a tapping point for connection with SE cable in order to ensure the longitudinal connectivity in accordance with EN 50122-2.

17.5.2.4 A provision shall be made to earth the running rail i.e. negative bus, in case of rail potential being higher than limits prescribed (120V) in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing Over Voltage Protection Device (OVPD) at every station and physically located in ASS/ASS+TSS. In case the station has a TSS, the device shall be provided in the TSS. Whereas in case, the station doesn't have a TSS, the device shall be provided inside ASS.

17.5.2.5 In addition, OVPD for continuously monitor the running rail potential with respect to earth, which is an input for Stray Current Monitoring System (SCMS) at OCC, an indirect way of measurement of stray currents along the mainline.

- 17.5.3 A mix of earthed and floating negative system has been adopted for Depot area. In depots, system shall be as follows:
- 17.5.3.1 A separate ASS+TSS shall be provided for the depot so as to facilitate isolation of depot traction supply from mainlines in order to prevent the leakage of return currents to depot area.
- 17.5.3.2 An earthed negative system shall be provided for Depot workshop, Inspection bay lines, pit wheel lathe and washing plant. For the remaining part of Depot shall be provided with floating return.
- 17.5.3.3 The tracks of depot area shall also be isolated from mainline through insulated rail joints (IRJ). Remotely operated double pole disconnecting switches shall be provided to feed power from mainline to depot in case of failure of Depot TSS.
- 17.5.3.4 A provision shall be made to earth the running rail i.e. negative bus, in case of rail potential being higher than limits prescribed (120V) in relevant standard (EN 50122-1) in order to ensure safety of personnel. This will be achieved by providing Over Voltage Protection Device (OVPD) at every station and physically located in ASS/ASS+TSS.
- 17.6 **GENERAL REQUIREMENTS FOR EARTHING AND BONDING**
- 17.6.1 **EARTHING CONDUCTORS**
- 17.6.1.1 The earthing conductor (GI strips) joins the installation / equipment earthing terminal to the earth electrode. It is a vital link in the protective system, so care must be taken to see that its integrity will be preserved at all times.
- 17.6.1.2 Where the final connection to the earth electrode or earthing terminal is made there must be a clear and permanent label "SAFETY ELECTRICAL CONNECTION – DO NOT REMOVE". GI strips with a minimum cross-sectional area of as per calculation.
- 17.6.1.3 Earthing conductors, as well as protective and bonding conductors, must be protected against corrosion.
- 17.6.1.4 A main earth terminal or bar must be provided for each installation to collect and connect all protective and bonding conductors. It must be possible to disconnect the earthing conductor from this terminal for test purposes, but only using a tool.
- 17.6.2 **TREATMENT OF AC POWER SUPPLIES**
- 17.6.2.1 The general policy to be followed is to provide an earth mat for each substation. The earth mats at each substation and other locations, which are multiple interconnected by bonding connections, cable sheaths, cable armoring to adjacent earth mat to form an incidental earth mat embracing the whole of the network system.

- 17.6.2.2 The armoring of incoming 33 kV power supply cables shall not be connected to the Lucknow Metro (East West Corridor Phase 1 B) Network substation earthing system. However, there shall be provision to do so conveniently on a temporary basis. The armoring shall be connected to earth on RSS end.
- 17.6.3 TREATMENT OF DC POWER SUPPLIES
- 17.6.3.1 The DC main traction systems i.e. main line and depot form two entirely separate systems, in so far as they are not normally interconnected with any earth electrodes or earth systems as discussed above. The running rails of the two systems and hence dc negative bus bars are separated by insulated rail joints at the depot entrance. Enclosures, which are an integral part of the traction system, shall be insulated from the ground and are bonded directly to the running rails. Certain structures (e.g. trackside isolator cabinets and signaling equipment) in close proximity to the track but which cannot be insulated from the ground are bonded to the track system via devices which are only effective for traction fault currents or currents flowing into the track e.g. over voltage protection devices (OVPD).
- 17.6.3.2 Because the traction system is not bonded to any earth electrodes, the track, and any structures bonded thereto may be at a potential relative to the earth system and any structure bonded thereto.
- 17.6.3.3 The exception to the above is the traction return system within the depot workshops, which is insulated from the main line return system and fed from a dedicated Rectifier, and deliberately earthed to the depot earthing system. Hence, within this workshop area, metal work adjacent to the vehicles is to be bonded directly to the local traction return / earth system, without insulation from the earth.
- 17.7 **EARTHING OF POWER SUPPLY SYSTEMS**
- 17.7.1 EARTH SYSTEMS FOR RSS
- 17.7.1.1 The RSS shall be provided with earth mats by Power Supply Contractor. The equipment to be installed by LKE(02)-01 Contractor shall provide the required earth terminal, MET connections.
- 17.7.2 EARTH SYSTEMS FOR ELEVATED/UNDERGROUND SUBSTATIONS (ASS OR ASS+TSS AS APPLICABLE)
- 17.7.2.1 Each substation shall be provided with earth mats installed and commissioned by E&M Contractor (designed by LKE(02)-01 Contractor), of resistance less than 1 ohm, and connected to the substation earthing system through two "Principal Connection" links by means of GI strips with a minimum cross-sectional area of 50x10 mm each or equivalent.
- 17.7.2.2 Supply, installation, testing and commissioning of earth mat/pits at ASS/TSS shall be under the scope of E&M Contractor based on the design and supervision of LKE(02)-01 Contractor. LKE(02)-01 Contractor shall witness the final testing and commissioning of earth mats/pits installed by E&M Contractor.

- 17.7.2.3 Connections from earth mats/pits and up to MET of ASS, ASS+TSS is under the scope of E&M Contractor. Earthing & bonding connections from MET to the respective equipment supplied by LKE(02)-01 Contractor shall be under the scope of LKE(02)-01 Contractor. Contractor shall interface with station/finishing/E&M and other designated Contractors for the same.
- 17.7.2.4 The substation earthing system shall be compliant with IEEE 80, IS 3043, IEC 60364-1 (2001-08) and IEC 61312-2 (1999-08) or BS 1013.
- 17.7.3 EARTHING FOR DISTRIBUTION SYSTEMS
- 17.7.3.1 Supplies at 415/230 Volts, or 110 volts are made available for depot and station equipment, and, where applicable, trackside equipment. These supplies are derived from 415 V star-connected 3-phase supplies, the star point of which is to be bonded to the substation earthing system. Continuity of this earth connection to the point of supply is provided by the cable sheath / armouring. All locations receiving such supplies, which are remote from the earth system of any traction or distribution substation shall be earthed.
- 17.7.3.2 The star point of the 415 V secondary winding of the services transformer will be connected to the protected earth bar of the 415 V switchboard (to be provided by the E&M Contractor). The protected earth bar shall be connected to the neutral bar via a neutral link in the switchboard. The neutral bar of the transformer is to be solidly earthed, via a bolted link to the earth system.
- 17.7.3.3 E&M Contractor is responsible for measurement of soil resistivity of Stations/installations and accordingly design the earthing/earth mats/earth pits to cater the requirement of Earthing and Bonding in compliance with the applicable standards, codes, manuals etc., In this regard, LKE(02)-01 Contractor shall interface with E&M Contractors, Station Contractors, Signaling, Telecom and other designated Contractors of the Project. Detailed interfaces required are articulated in Chapter 3.
- 17.7.4 SYSTEM EARTHING
- 17.7.4.1 33 kV Recieving supplies
- 17.7.4.1.1 The method of earthing of 33 kV, 3-phase supplies from UPPTCL shall be coordinated and installed by LKE(02)-01 Power Supply Contractor for 33 kV power supply receiving, construction and commissioning of 33 kV RSS.
- 17.7.4.2 33 kV supplies
- 17.7.4.2.1 The 33 kV, 3-phase, 3-wire supplies from the 33 kV RSS, which have the star points of the secondary windings, shall be earthed to the Lucknow Metro (East West Corridor Phase 1 B) RSS earth system via 19 Ω neutral grounding resistor (NGR) to limit the earth fault current to a value compatible with the system earthing resistance.
- The above work shall be executed by LKE(02)-01 Contractor, shall also interface for integration, fault level and insulation coordination requirements.

- 17.7.4.3 415 V supplies
 - 17.7.4.3.1 The star point of the 415V secondary winding of the auxiliary transformer shall be solidly earthed, via a bolted link to the earth system by LKE(02)-01 contractor.
- 17.7.4.4 230V supplies
 - 17.7.4.4.1 The 230V supplies are taken from one phase and the neutral of the above 415V supplies. The neutral shall be earthed by E&M Contractor.
- 17.7.4.5 750V DC Traction Supplies
 - 17.7.4.5.1 The 750V main line system negative pole is not to be connected directly to earth, whereas the depot workshops negative pole (with dedicated rectifier) is to be deliberately earthed.
- 17.7.4.6 110V DC supplies
 - 17.7.4.6.1 Both poles of the 110V battery supplies used for control panel supply in the substations (ASS, ASS+TSS) and elsewhere in connection with the power supply system are to be insulated from earth.
- 17.7.5 EQUIPMENT EARTHING (NOT TRACKSIDE)
 - 17.7.5.1 This section refers to the treatment of metal enclosures or supporting metal work for the equipment associated with the power supply systems, except for the trackside equipment.
 - 17.7.5.2 Earthing and bonding of electrical equipment is required to reduce the effects of interference, and to ensure the personnel safety of the public, operational and maintenance staff. Where there is a conflict between these requirements, personal safety is always to take precedence.
 - 17.7.5.3 33 kV cables
 - 17.7.5.3.1 The earthing of screens and armoring of all 33 kV cables shall be earthed as per the requirement. Contractor shall calculate and submit the sheath voltage value based on the drum lengths, interstation distances etc., during detailed engineering stage for Engineer's approval. Remedial action suitable for the required sections shall also be proposed for limiting the sheath voltage rise above 65 volts as per IS 3043/IEEE 575. Exception may be made at the extreme ends of the system to avoid any circulating currents detected in service.
 - 17.7.5.3.2 Means shall be provided for disconnecting the screen ends, individually, from earth for testing purposes.
- 17.7.5.4 750V DC Cables
 - 17.7.5.4.1 750V DC cables armouring shall not be connected to any earth. Where cleats, conduits or ducts are used with such cables, they are to be in non-metallic material. Positive and negative DC traction cables are to be run in separate ducts from each other and kept physically separate wherever practicable.

17.7.5.5 Other Power Supply Cables

17.7.5.5.1 This section covers the cables for the distribution of 415/230V ac supplies and 110V dc supplies.

17.7.5.5.2 The armoring of multi-core cables (e.g. 3 phase or twin and earth etc.) shall be earthed at both ends via an earth terminal provided with the gland, or via the metalwork of the cable box and structure to the earth bar or terminal of the equipment at which the cable is terminated.

17.7.5.5.3 Exceptions will be where the equipment at each end does not share the same earth system. For example, the DC switchgear for which the enclosures are insulated from the substation earth and connected to it via a leakage current measuring shunt. In this case the armoring will be earthed only at the distribution board end. Single core cables are to be earthed in a similar manner but at one end only.

17.7.5.6 33 kV switchgear

17.7.5.6.1 All AC switchgear shall be earthed directly to the substation earthing system.

17.7.5.7 750V DC switchgear

17.7.5.7.1 Each 750V dc switchboard shall be fitted with an earth bar running the full length of the switchboard and all components of the metal-clad enclosures shall be bonded to the internal earth bar. The circuit breaker trucks themselves are to be fitted with scraping contacts to provide the necessary earthing connections. The whole switchboard including earth bar shall be insulated from ground and the earth bar of the switchboard connected to the substation earth bar via dc shunt for leakage current measuring.

17.7.5.7.2 Each 750V dc switchboard shall be fitted with low impedance earth fault protection equipment combined with an inter-tripping scheme, incorporating a current-measuring device around the single connection to the substation earth connection. The scheme shall be arranged to initiate a local mass trip of all dc and associated ac circuit breakers and to inter-trip corresponding dc feeder breakers at adjacent substations. In order to ensure correct operation, only the manufacturer's nominated earthing terminal shall be connected to the substation earthing system. All other metallic earthing connections, including fortuitous connections such as cable trays and armoring are to be avoided.

17.7.5.8 415 V and 230V switchgear

17.7.5.8.1 All metallic components of the cubicles are to be bonded to an earth bar or terminal which shall be connected to the substation earth system.

17.7.5.9 Battery equipment

17.7.5.9.1 All metallic components of metal stands and cubicles for battery chargers to be bonded to an earth bar or terminal which is to be connected to the earth system. However, batteries and dc distribution switchboards are to be isolated from earth.

- 17.7.5.10 Traction Transformers & Rectifiers
- 17.7.5.10.1 All electrically separate parts of each transformer core are to be bonded together and the core as a whole is to be insulated from the enclosure / tank. An accessible removable link is to be provided between the core and the enclosure / tank for earthing the core for core testing.
- 17.7.5.10.2 All metallic components of control compartments are to be bonded to an earth terminal or bar, which is to be connected to the enclosure. The enclosure is to be connected to the substation earth system with a suitable fault rated earth connection.
- 17.7.5.10.3 All metallic components of the traction rectifier are to be bonded to an earth terminal or bar, which is to be connected to the rectifier enclosure. The enclosure shall be insulated from ground and the earth bar of the Rectifier Panel shall be connected to substation earth bar via frame leakage relay.
- 17.7.5.11 33 kV/ 415 V auxiliary transformers
- 17.7.5.11.1 All electrically separate parts of the core are to be bonded together, and the core as a whole is to be insulated from the rest of the transformer and its enclosure. An accessible, removable link is to be provided between the core and the enclosure. All other parts of the transformer and its enclosure are to be connected to the substation earthing with a suitable fault rated earth connection.
- 17.7.5.12 Marshaling Panels
- 17.7.5.12.1 All metallic components of each cubicle are to be bonded to an earth terminal or bar, which is to be connected to the earth system.
- 17.7.5.13 Negative Bus bars (750V dc traction system)
- 17.7.5.13.1 A negative busbar, insulated from earth and mounted within a sheet steel enclosure, shall be provided at each mainline traction substation for the purpose of providing a connection point for all rectifier negative cables and outgoing negative feeder cables to the track. The structural and other metallic parts of the enclosures for each negative bus-bar shall be bonded to an earth terminal, which is to be connected to the substation earth system via dc shunt for leakage current measuring.
- 17.7.5.13.2 The negative busbars (running rails) shall be connected to the substation earth system through over voltage protection device (OVPD). The OVPD essentially comprises of:
- a) Instantaneous type voltage sensing relay
 - b) Electromagnetic contactor operated by 110V dc actuated by the action of the voltage sensing relay

- 17.7.5.13.3 The voltage-sensing relay shall continuously monitor the voltage between the negative busbar to which traction return circuit is connected, and the main earth. When the voltage so monitored exceeds the setting value of the relay in accordance with EN 50122-1, the relay initiates the operation of the contactor so as to connect the negative bus to the earth. Upon removal of this excessive voltage, the system will itself reset to normal status.
- 17.7.5.13.4 If the OVPD has operated, it shall automatically reset after a maximum of 10 seconds. Should the high rail potential equal to or above 120V persist, then the OVPD shall cycle for three auto-reclosures until it locks to the closed position. When the cause is remedied, the OVPD can be reset manually.
- 17.7.5.13.5 The OVPD shall be designed to operate under the highest envisaged value of current under fault conditions. Once closed, it shall not open until this current has reduced to a safe value lower than the rated breaking current of the device.
- 17.7.5.14 Instruments, relays, communication device, Control Switches and other Electrical Components
- 17.7.5.14.1 All metallic cases and frames of instruments, relays, control switches and other electrical components mounted on control panels or in cubicles are to be connected to the earth bar or terminals of the cubicle in which the component is mounted.
- 17.7.5.15 Ancillary Equipment
- 17.7.5.15.1 Cubicles, cabinets, racks and panels are to be provided with a copper earth bar having a suitable cross-sectional area for the possible fault current, placed at a convenient position within the equipment. All metal parts, other than those forming part of an electrical circuit, are to be earthed by connection to the earth bar.
- 17.7.5.15.2 When apparatus or instruments are accommodated on panel cubicle doors or swinging frames, flexible cable or braid is to be used for earthing these items; the door hinges shall not be acceptable as means of earthing this part of the equipment.
- 17.7.5.15.3 Except where otherwise approved, a stud type terminal of diameter not less than 12mm, or a taped boss of equivalent size, shall be provided on the outside of each cubicle or structure for the purpose of making the connection to earth. This terminal shall be connected to the substation earthing system.
- 17.7.6 TRACK AND TRACKSIDE EQUIPMENT
- 17.7.6.1 Traction Return Running Rails (main Line)
- 17.7.6.1.1 The running rails, where used for traction return purposes in main line shall be free of any direct connection to earth or earthed structures.
- 17.7.6.1.2 The rails forming the return current path shall be nominally insulated from earth in order to discourage stray currents. A system shall be provided for monitoring the level of stray currents. This system allows for nominated metalwork to be bonded together and connected to an along-track stray current collection cable.

- 17.7.6.1.3 All main line rails are nominally insulated from the earth, using insulating rail fastening components. Acceptable minimum values for insulation (in terms of conductance per meter) for various track forms are given in Table 1 of EN 50122-2. The insulation level between the under-track structure and the rails shall be no less than 2.0 ohms per km of single track under normal operating conditions. The insulation level of each section shall be tested, on completion of the track works for the section, and the results recorded. Values less than this, but of the same order may be accepted by the Engineer under exceptional conditions. The above track insulation level shall be maintained through points and crossing work. All the work related to track insulation shall be in scope of track work contractor.
- 17.7.6.1.4 Both running rails per track on the Main line are to be used for traction return purposes, and cross-bonded to other tracks. Each traction return rail is to be electrically bonded longitudinally at each joint (other than welded joints) except where insulated joints are required for segregation between, running lines, depot, depot / workshop building tracks or for segregation from non-electrified tracks. These continuity bonds and bonds across expansion joints and discontinuities such as insulated rail joints provided for track insulation testing are to be in duplicate and fault rated for the anticipated traction return currents.
- 17.7.6.2 Traction return Running Rails (Depot Workshop)
- 17.7.6.2.1 The negative return rails for the depot are electrically isolated from rest of the system by means of insulated rail joints to ensure that any stray currents due to unavoidable earthing of the depot track are closely contained in its geographical area, and not propagated to the main traction return system. The arrangement also simplifies the ac/dc protection and touch potential limitation arrangements. Hence only within the workshop area are the ac and dc earthing systems intentionally interconnected.
- 17.7.6.2.2 Within the depot workshop area, metalwork, which is in proximity of shore supply leads, down shop conductors and shoe gear, is to be electrically continuous and bonded to the traction return rail and hence earth.
- 17.7.6.3 750V Isolators / Disconnection Switches
- 17.7.6.3.1 The metal clad enclosures for the 750V dc main line isolators are to be provided with a substantial, stainless steel stud terminal to which all parts of the enclosure, internal and external supporting steelwork and metal parts of the operating handle shall be bonded. The metal clad enclosure shall be bonded by, fault rated, bonding cable, to the 'trunk earth' cable or 'structure earth' where one is provided e.g. in the viaduct sections. Where no trunk earth cable or structure earth is accessible within 4 meters, the enclosure shall be insulated from earth and bonded to the nearest running rail.
- 17.7.6.3.2 All 750V dc isolators are motorized, using an LV ac power supply and controlled over the SCADA system. The sheath of the LV ac supply cable shall not be connected to any part of the isolator cabinet. The dc multi-core control cable sheath shall not be connected to any part of the isolator cabinet. The isolator cabinet shall be connected to the trunk earth cable as for any other trackside isolator cabinet.
- 17.7.6.3.3 The incoming LV ac supply shall be segregated from the general body of the cabinet and equipment in the cabinet by means of an isolating transformer.

17.7.7 CLEARANCE TO EARTHED EQUIPMENT & STRUCTURES

17.7.7.1 No part of any structure or other equipment, which is connected to an earth system, is to be closer than 2.0m from the mainline or any part of any equipment solidly bonded to the main line, or traction return rail, or the vehicle static envelope, without providing protection against dangerous step potential. Examples of such equipment are; sump pumps, walkways, metallic station structures etc.

17.7.7.2 Where this separation cannot be met owing to limitations of trackside space, the provisions for earthed metallic structures within 2m of the vehicle static envelope will apply. To meet the provisions, the bare trunk earth cable will be connected to the running rails at stations through short circuiting device. The touch potential of the trunk earth being controlled in this way, the metal enclosures of all the equipment within the 2.0m limit will be bonded to the trunk earth cable.

17.8 EARTHING OF COMMUNICATION AND CONTROL SYSTEMS**17.8.1 GENERAL**

17.8.1.1 There are several separate sub-systems which collectively form the control and communications system, equipment, enclosures and mountings associated with these subsystems are distributed throughout at trackside, stations and depot locations.

17.8.1.2 The equipment, enclosures and mountings associated with the control and communications system are not anticipated to be located within 2m of any part of the system that is intentionally connected to the traction return system. Earthing of the control and communications system will thus be by conventional methods to the protected earth of the distribution switchboard.

17.8.1.3 Should it become necessary, during construction, to locate any item of equipment associated with the control and communication system within 2m of a part of the system that is connected to the traction return system then additional protective measures shall need to be adopted such as application of self-restoring spark gap. The equipment enclosure shall be earthed to the SE cable.

17.8.1.4 The provisions of this Clause 17.8 are for general understanding of LKE(02)-01 Contractor and shall be used for developing detailed earthing and bonding strategy. The actual work for the implementation of this strategy shall be undertaken by the respective contractors.

17.8.2 TRACKSIDE EQUIPMENT**17.8.2.1 Station Locations**

- 17.8.2.1.1 At each station a UPS and UPS distribution switchboard will be provided by a designated contractor. Each item of control and communication equipment that is connected to a 230V single phase supply derived from this source shall have its earth terminal directly connected to the main protected earth terminal at the distribution board by an appropriate protective conductor. All metalwork (including enclosures, mountings etc.) associated with an item of control and communications equipment that is not intended to carry current is to be bonded to the earth terminal within the equipment enclosure.
- 17.8.2.1.2 Alternatively, if the design of the equipment requires, a direct earth cable, to the station earth mat principal earth connection, may be provided.
- 17.8.2.2 Trackside Locations
 - 17.8.2.2.1 Control and communication equipment at trackside locations, e.g. points machines, are to derive their power supply from the UPS of the nearest station or the depot as appropriate. Each item of control and communications equipment that is connected to a 230V single phase supply derived from this source is to have its earth terminal directly connected to the main system earth cable running between the earth systems of successive substations.
 - 17.8.2.2.2 All metalwork (including enclosures, mountings etc.) associated with an item of control and communications equipment that is not intended to carry current e.g. signal lamp enclosures, shall be bonded to the main system earth cable running between the earth systems of successive service substations.
- 17.8.2.3 Substation locations
 - 17.8.2.3.1 Control and communication equipment, housed within or immediately adjacent to substations, are to derive their power supply by dedicated feed from the UPS of the station or depot as appropriate. Each item of control and communication equipment that is connected to a single-phase supply derived from this source is to have its earth terminal directly connected to the protective earth terminal at the distribution board.
 - 17.8.2.3.2 All metalwork (including enclosures, mounting etc.) associated with an item of control and communication equipment that is not intended to carry current shall be bonded to the equipment earth terminal. The earth terminal of the distribution board shall be connected to the distribution board protective earth.
- 17.8.3 DEPOT EQUIPMENT
 - 17.8.3.1 The depot equipment comprises all control and communications equipment contained within the depot building and that located in the stabling yard and mounted on the depot buildings.
 - 17.8.3.2 Signaling and telecommunication room

17.8.3.2.1 Equipment contained within the signaling and communications is to be fed from the UPS distribution board, installed complete with protective devices and earth terminal. Power distribution to the various items of ancillary equipment and cubicles is by means of several ring main circuits. Each circuit contains a dedicated protective conductor (separate conductor or cable armoring) connected to the protected earth terminal at the distribution switchboard. All items of control and communication equipment are to have a direct connection between the equipment earth terminal and the circuit protective conductor.

17.8.3.3 Other Depot Locations

17.8.3.3.1 Control and communication equipment, located externally or on depot buildings, is to derive its power from the control center UPS. Internal earthing of the equipment will be to a dedicated earth terminal connected to the enclosure. Where the equipment is outside the 2m limit to the vehicle static envelope an earthing circuit for the metallic enclosure will be provided back to the protected earth of the distribution switchboard. Where the equipment is within the 2m limit the enclosure will be earthed to the depot system earth. The touch potential of this earth system will be controlled by strategically situated voltage limiting devices as per requirements.

17.9 **EARTHING OF OTHER METALLIC STRUCTURES**

17.9.1 GENERAL

17.9.1.1 Other metallic structures comprise those structures, which do not form part of the power supply or communication and control systems. This includes sections of viaduct / tunnel with concrete linings, the reinforcing in concrete construction, pipes for other services and fixtures and fittings in buildings and stations. Lightning protection of structures and buildings is also included in this section.

17.9.1.2 As a rule, no part of any earthed metallic structure is to be closer than 2m from the main line rails, any metalwork bonded to the rails, or the static envelope of the vehicle themselves. This, however, does not apply in the depot workshop, where the track is deliberately earthed.

17.9.1.3 The fundamental point of difference between the principles of earthing applied to the ac and dc traction systems dictates the application of self-restoring spark gap or over voltage protection device:

- a) The ac systems are generally arranged to operate with their neutrals earthed, and with associated metallic enclosures also connected to earth, by conventional methods.
- b) The dc main line traction system is not earthed deliberately at any point and is indeed insulated to in order to control stray currents and mitigate their effects on buried metalwork.

17.9.1.4 This principle entails that the ac earthing system must not be permanently connected to the dc traction return system, as it would create a dc earth leakage path.

- 17.9.1.5 As the dc main line negative return system is not deliberately earthed, it can attain unacceptable step and touch voltages with respect to ac earthing systems, and the loop resistance introduced can render dc earth faults difficult to detect and interrupt. Hence, over voltage protection devices (OVPD's) at stations (in TSS or ASS), shall be used for either or both of the following purposes:
- a) To hold the touch or step voltage to an acceptable level (normally during dc fault clearance); the devices shall be fitted where deliberately earthed metalwork is closer than 2m to the traction return rails, or vehicle static envelope. 'Deliberately earthed' is defined as being connected to earthing of a power system.
 - b) To convert a dc earth fault into a detectable 'positive-to-negative' fault; the devices shall be fitted where earthed metalwork is vulnerable to contact from the 750V dc supply.
- 17.9.1.6 The self-restoring properties of high voltage limiting devices avoid a permanent leakage path for limited faults whereas a latched contactor needs to be manually reset or a whole device needs to be physically replaced.
- 17.9.1.7 The provisions of this Clause 17.9 are for general understanding of LKE(02)-01 Contractor and shall be used for developing detailed earthing and bonding strategy. The actual work for the implementation of this strategy shall be undertaken by the respective contractors. For the avoidance of doubt, the scope of LKE-1B Contractor does however include SE Cable, connection to viaduct, track slab structure for the compliance with this Clause 17.9.
- 17.9.2 UNDERGROUND STRUCTURES
- 17.9.2.1 Reinforced Concrete Track Slab
- 17.9.2.1.1 The reinforced track slab shall form a single continuous structure by interconnecting all track plinths, viaduct and other metallic structure of each track. At each link position one side of the link will be connected to a structure earth conductor.
- 17.9.2.2 Exposed Structural Steelwork
- 17.9.2.2.1 All exposed structural steelwork shall be bonded to the nearest local earth system. The bonding shall be by bare copper strip or other approved conductor, and / or the structural steelwork itself provided any joints are electrically continuous or are bridged by a bonding conductor.
- 17.9.2.3 Pipe work
- 17.9.2.3.1 Pipe work shall be bonded to the local earth systems of the locations through which the pipe work passes and all joints between individual lengths of pipe are to be electrically continuous or bridged by a bonding conductor.
- 17.9.2.3.2 Pipe work shall be bonded to all adjacent exposed structural steelwork and other metalwork such as walkways, cable and pipe supports etc. either directly or, where there is a local earth system, via the bonding to the local earth system of both pipe work and the structural steelwork.

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- 17.9.2.4 Steelwork in Tunnels
- 17.9.2.4.1 All steelwork in tunnels forming walkways and supports for pipes, cable trays and racks shall be bonded and earthed to the nearest trunk earth cable in both directions by bare copper strip or aluminium conductor.
- 17.9.2.4.2 Small isolated metallic components need not be earthed e.g. individual metallic cable cleats, fixing bolts for plastic cable cleats.
- 17.9.3 OVER GROUND STRUCTURES
- 17.9.3.1 Depot building frames and structural steelwork
- 17.9.3.1.1 This clause covers the structural steel frames of depot and workshop buildings, and similar structural steelwork.
- 17.9.3.1.2 The frames of all buildings and other structural steelwork are to be bonded to the local earth system unless all parts of the frame or structure are completely encased in concrete, masonry or other non-metallic cladding.
- 17.9.3.1.3 Where a local earth system is not provided under the provisions, such a system is to be provided for the purposes of this Clause in those locations where accidental contact with the traction system is possible. Such an earth system is to have an overall resistance not exceeding 10 ohms between any point of the earthed frame or structure and the general body of the earth.
- 17.9.3.1.4 In the case of the building structure of the depot workshop, where the traction return system is deliberately earthed, the structure E&M service and traction earthing systems are all to be interconnected.
- 17.9.3.1.5 Depot Fencing
- a) Metallic fencing within 2.0 meters of the track or any part of any structure or other equipment which is connected to it shall be earthed to the depot earth system.
 - b) Each separate section of fencing shall be separately earthed.
 - c) All gate posts are to be bonded to each other across the gate opening by an underground conductor, and the gates themselves bonded across the hinges.
- 17.9.3.2 Viaduct
- 17.9.3.2.1 Single track U-girders are pre-manufactured structures having structural rebars and pre-tensioned strands embedded in the concrete. As both are exposed to stray currents, both shall be bonded together and be connected to the structure earthing system. This can only be done before concreting. Pre-tension strands are not allowed to be welded and can therefore only be bonded using mechanical connectors.
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- 17.9.3.2.2 Upon erection the individual segments shall be linked together via Aluminium SE conductor that shall run longitudinally. The Structure Earth (SE) conductor shall be of Aluminium 185 mm² size and shall be provided on both sides of the viaduct. All the terminal connections emerging from pier heads, viaduct segments at pier locations shall be bonded with SE cable via 120 mm² Aluminium cable or 70mm² copper cable. The SE cable shall link the individual segments by connection bar, aluminium clamp, fixing bolts etc. All exposed material shall be of anti-corrosion type. This SE cable shall be connected to the earth mesh at each TSS/ASS.
- 17.9.3.2.3 The following parts of the system shall be bonded to the SE cable as per the plan proposed by LKE(02)-01 and approved by Engineer:
- a) Metal parts (other than current carrying parts) including conduits, raceways, distribution boards, mechanical items etc.
 - b) Panel boards body
 - c) Earth terminal of socket outlets
 - d) Signal posts
 - e) Viaduct / station structure reinforcement
 - f) Track slab reinforcement (used for stray current collection)
 - g) Connection of the viaduct / station reinforcement to structure earth cable shall be made with 120 mm²aluminium cable.

17.10 STATION/BUILDING LIGHTNING PROTECTION

- 17.10.1 The need for lightning protection for individual buildings shall be assessed in accordance with IE Rules, IS 3043, IEEE 80:2013, IEC 61024-1, National Building Code or National Electricity Code. Where lightning protection is found to be necessary, it shall be provided in accordance with this Standard.
- 17.10.2 Metal roofing shall be multiple bonded into the metal of the building structure.
- 17.10.3 Cables with metal sheaths and other metallic services entering the building are to be bonded to the structure at the point of entry and to any electrodes provided for lightning protection, if not already adequately bonded via the local earth system.
- 17.10.4 Execution and implementation of lightning protection shall be in scope of E&M Contractor; however, LKE(02)-01 Contractor shall interface with E&M Contractor for the earth mat design integration (considering the input from E&M Contractor).

17.11 VIADUCT LIGHTNING PROTECTION

- 17.11.1 The need for viaduct lightning protection shall be assessed in accordance with IE Rules, IS 3043, IEEE 80:2000, IEC 61024-1, National Building Code or National Electricity Code. Where lightning protection is found to be necessary, it shall be provided in accordance with this Standard.

17.11.2 LKE(02)-01 Contractor is responsible engineering and implementation of viaduct lightning protection. For viaduct lightning protection, the handrail on top of the parapet/ or any other alternate arrangement to be provided by LKE(02)-01 contractor with no additional cost and pier reinforcement/galvanized steel shall be provided at pier locations and connected to SEC. In case of hand rail, LKE(02)-01 Contractor shall interface with hand rail contractor/civil contractor for ensuring the continuity of hand rail and wherever the hand rail is discontinuous, shall be bridged with 120 mm²Aluminium cable or 70mm² copper cable.

17.11.3 After completion of works, Contractor shall test for continuity of handrail with earth in accordance with the standards

17.12 SIZES OF EARTH CONNECTION

17.12.1 For the sake of clarity, the reference sizes of various earth connections for ASS and TSS equipment are provided in the table below:

Table 17.2: Earth Connection Sizes

SN	From MET to:	Size
1	Traction transformer body/enclosure	50 x 10 mm GI strip
2	Auxiliary transformer body / enclosure	50 x 10 mm GI strip
3	Auxiliary transformer neutral	50 x 10 mm GI strip
4	33 kV switchboard	50 x 10 mm GI strip
5	ACDB enclosure	25 x 3 mm GI strip
6	DCDB enclosure	25 x 3 mm GI strip
7	Battery	25 x 3 mm GI strip
8	Battery charger	25 x 3 mm GI strip
9	RTU	Min. 50 sqmm copper cable or equivalent
10	ETS	25 x 3 mm GI strip

17.12.2 LKE(02)-01 contractor shall submit the sizing of all the earth strip/flat to be used for equipment earth connection to the METs for Engineer's approval based on the suitable current rating.

17.12.3 All equipment shall be connected to MET through twin connections (each from separate MET to the extent possible). Contractor shall interface with E&M and civil/finishing contractors during detailed engineering stage for the same.

17.13 STRAY CURRENT CORROSION CONTROL

17.13.1 The scope of work includes Design Review, Supply, Installation, Testing and Commissioning of dc stray current corrosion control and monitoring measures on the system and protective provisions relating to electrical safety and earthing.

17.13.2 Contractor shall develop a philosophy for stray current corrosion control for the Lucknow Metro network in accordance with internationally recognized practices.

- 17.13.3 DC traction supplies and negative return paths through the running rails for the main line tracks shall be isolated from each other with insulated rail joints in order to minimize the stray currents.
- 17.13.4 The LKE(02)-01 Contractor shall coordinate with the civil/track contractors regarding the installation of stray current collector mats as part of civil works, and shall coordinate designs for such stray current collector mats, elevated structures, etc.
- 17.13.5 The LKE(02)-01 Contractor shall provide performance requirements for stray current control and shall provide all monitoring equipment within DC traction substations.
- 17.13.6 The LKE(02)-01 Contractor shall provide all facilities necessary for the control and monitoring of stray current in accordance with its strategy for earthing, bonding, lightning protection and stray current corrosion control.
- 17.13.7 The following Specifications shall be followed in addition to the National Codes of practices on earthing, and the Employer's safety documentation. The track bonding shall also conform to these specifications:
- a) EN 50122-1. Railway applications: Fixed Installation
Part-1: Protective provision relating to electrical safety and earthing.
 - b) EN 50122-2. Railway Applications: Fixed Installations
Part-2: Protective provisions against the effects of stray currents caused by dc traction systems.
- 17.13.8 In all cases of protective provisions, those against electric shock shall have precedence over effects of dc stray currents, as stipulated in above-mentioned Specifications.
- 17.13.9 Design Review criteria and performance specification
- 17.13.9.1 General Requirements
- a) In design review, construction and operation of the elevated/UG Metro Corridor the rules relating to electrical safety and protective provision against dc stray currents shall be followed.
 - b) The Contractor shall review the design of the entire system of earthing, bonding, and connections of return current circuit, means of measuring of track voltages and leakage currents, determination and calculation of safe touch and step potentials, measurement of voltage of Structural Earth (SE) against reference electrodes and location of reference electrodes and Over Voltage Protection Device (OVPD). The design review shall also include the construction details and methods to be followed by other Contractors, e.g., Elevated Viaduct/Underground Tunnel and Station Contractors, Contractors, Track Contractors, S&T Contractors etc. so that their entire work is rendered safe for both the protection aspects of electrical safety and stray dc currents. The Contractor shall interface with other Contractors in this regard. The interface responsibilities are already defined in Chapter 3 of this Particular specification.
- 17.13.9.2 Floating Traction System Earthing

- a) There shall be no direct connection of any metallic structure to the return circuit. All metallic structures (e.g. signal posts, cable sheaths, cable hangers, metallic pipes, metallic body of equipment, current collection mat if provided, etc.) shall be connected to a separate earth bus running longitudinally on both sides of the Viaduct / tunnels. This earth bus, called Structural Earth (SE), shall be solidly connected to the earth mass at Stations and Piers.
- b) The traction return current circuit shall run floating (isolated from earth). The return current circuit shall be connected to Earth through over voltage protective device (OVPD) with remote indication and protective measures. The OVPD shall solidly connect the track return circuit to earth when rail potential increases beyond unsafe values in accordance with EN 50122-1.
- c) OVPD shall be located at all passenger stations (irrespective of TSS or not) and housed ASS, ASS+TSS room. The arrangement shall ensure that the rail potential does not exceed the threshold voltage limits in the vicinity of stations and maintenance area in the Depot. To keep the rail potential in the Depot within safe limits, additional OVPD with remote indication shall be provided at the Depot TSS.
- d) The traction rectifier and dc switchgear at each TSS shall be insulated from earth and connected to substation earth through an earth leakage relay.
- e) The operation of OVPD shall be automatic so that in case the high difference in potential subsides and current flow reduces to safe limits within 10 seconds, the OVPD shall reset with opening of the earthing contact and remote indication to OCC and the concerned adjacent TSS

17.13.9.3 Laying of tracks

- a) The Track Work Contractor shall insulate tracks from the concrete mass of the ballast less support by use of insulation pads and insulated fastenings ensuring that the track conductance is within the limits prescribed in the governing specifications.
- b) The tracks shall have effective water drainage and adequate clearance between running rails and ballast in the Depot. The engineering drawings for stray current control and longitudinal connectivity shall be issued by LKE(02)-01 Contractor.
- c) LKE(02)-01 Contractor shall interface with Track Contractor and monitor the track laying work.

17.13.9.4 Track bed/plinth construction

- a) The track bed reinforcements shall be welded to form a continuously conductive welded mass. External connecting terminals at pier/expansion joints shall be provided by Track Contractor.

- b) The Contractor shall connect the reinforcement to the Structure Earth (SE) cable at suitable intervals. Contractor shall consider the reinforcement connectivity required with reinforcement mesh as well as the Structure Earth (SE) to ensure that the installation meets the 200mV criteria stipulated in governing specifications.

17.13.9.5 Stray Current monitoring equipment

- 17.13.9.5.1 A new & functional SCMS shall be installed at OCC. OVPD signals from every station shall be connected real-time to the Central Evaluation Computer (CEC) at OCC through RTU (FO network) for monitoring.

17.13.9.6 Special arrangements for Depot

- 17.13.9.6.1 At depot separate TSS shall be provided. The depot traction supply system shall be isolated from the main line traction supply system and tracks shall also be isolated through insulated rail joints. Remote operated sectionalizing switches shall be provided to feed power from depot to main line and vice-versa in case of TSS failure.

- 17.13.9.6.2 The running rails shall serve as a return path for traction current to flow back to negative bus of TSS. All the running rails that are connected to the negative bus shall be protected against the following:

- a) Touch voltage of running rail
- b) Earth fault of Third Rail current collection system that results in the over voltages of running rail

- 17.13.9.6.3 Contractor shall provide special measures for safety of persons in the depot. For this purpose, the depot tracks may require to be insulated from main line tracks through insulated rail joints (IRJs) with provision of switches to bridge the IRJ to allow passage of return current.

- 17.13.9.6.4 IRJs in running rails shall supplied and installed by Track Work Contractor. LKE(02)-01 Contractor is responsible for engineering the requirement and location of IRJs in interface with track work, signaling, rolling stock and other designated contractors.

17.13.9.7 System Earthing and DC stray current control

- 17.13.9.7.1 The Contractor shall review the detailed design of the System earthing and dc stray current control and submit a detailed report and the integrated earthing and bonding and stray current protection measures drawing for review and approval of the Engineer. On receipt of no objection, the details shall be entered in the interface protocol to ensure that the approved measures in the design are implemented by the other concerned Contractor such as Civil, Track, Signal, and Depot Contractors.

- 17.13.9.7.2 Contractor shall develop method statements for measurements like continuity/integration test, conductance measurement etc., and submit for Engineer's approval. Conductance shall be witnessed by LKE(02)-01 Contractor and maintain the records of all tests conducted and submit to Engineer after completion of works.

17.13.10 Baseline stray current Survey

17.13.10.1 On completion of the entire work by all Contractors and prior to commencement of services, baseline stray current surveys shall be performed, as required, to produce a documented reference for future investigations. Initial survey shall be conducted prior to the start of revenue service. The survey shall include, but not be limited to, the following activities:

- a) Soil and ground water corrosive characteristics shall be determined and documented. Structure to soil voltage measurements shall be made to establish locations, sources and polarities of existing stray currents.
- b) Recording charts shall be obtained to determine the effects and magnitude of stray currents, if present, on existing utility installations.

17.13.10.2 The Engineer will carry out regular stray current monitoring and analysis after the start of revenue service, and comparisons will be made against the baseline survey reference data and analytical results. During Defects Liability Period the Contractor will assist in monitoring and analyzing these stray currents.

17.13.11 Review of Stray Current Control measures

17.13.11.1 The Contractor may also review the requirements and offer a full integrated scheme for best safety and corrosion control from stray currents.

17.14 ELECTROMAGNETIC COMPATIBILITY (EMC) REQUIREMENTS**17.14.1 GENERAL**

17.14.1.1 The requirements stated below shall be read in conjunction with the EMC Requirements in the General Specification.

17.14.1.2 The Contractor shall prepare and submit for review by the Employer an EMC Control Plan which shall, based upon a top-down approach, define the EMC philosophy, activities, means of control for the design processes and EMC submissions to be supplied to demonstrate compliance with the Technical Specification (TS) and other document of this tender.

17.14.1.3 The EMC Control Plan shall identify a comprehensive list of specifications, standards, method statements and procedures to be submitted to the Engineer for review. The EMC Control Plan shall also include a programme that shall identify the dates for EMC submissions. The EMC Control Plan shall include an initial list of design documentation, test specifications and test reports with a single paragraph description of each document to indicate compliance with the Specification. The EMC Control plan shall include a definition and description of the process and methods used for Verification and Validation that the Works will achieve the required EMC parameters in all respects.

17.14.1.4 The EMC Control Plan shall include measures to reduce conducted, induced, and radiated emissions, especially the levels of harmonic, to acceptable values as specified by the relevant international standards.

- 17.14.1.5 The Contractor shall co-ordinate the levels of interference emissions and susceptibility of all equipment, which are to be designed, manufactured, supplied and installed by the Contractor and its sub-contractors and suppliers. The Contractor shall designate a person as point of contact to deal with EMC matters. Details of the nominated person and any subsequent change of the nominated person shall be subject to review by the Engineer.
- 17.14.1.6 The Contractor shall liaise and co-ordinate with all Other Contractors in the exchange of EMC data and related equipment performance characteristics and advise the Engineer when any such information is requested from any Other Contractor. A copy of all EMC related information exchange shall be sent to the Engineer for review.
- 17.14.1.7 The Contractor is required to conduct type tests as well as full EMC tests. Tests to be conducted shall include but not limited to the following standards:
- a) Overall compliance:
- EN50121-1
 - EN50121-2
 - EN50121-5
 - EN50123
- b) Specific standards:
- i) Immunity
 - Electrostatic discharge IEC 61000-4-2
 - Radio frequency fields IEC 61000-4-3
 - Power frequency magnetic field IEC 61000-4-8
 - Pulse magnetic field IEC 61000-4-9
 - Damped oscillatory magnetic field IEC 61000-4-10
 - ii) Emission:
 - Radiated emission EN50121-5
 - Conducted emission EN50121-4
 - IEC61000-2-6/
 - IEC61000-3-2/
 - IEC61000-3-3/
 - IEC61000-3-4
- 17.14.1.8 The Contractor shall ensure that all electrical and electronic apparatus are designed and constructed to operate without degradation of quality, performance or loss of function in the electromagnetic environment of the Project. The Contractor shall ensure that the specified electromagnetic compatibility (EMC) requirements are adequate. Any shortcomings shall be made known to the Engineer immediately and recommendations for corrective action formulated.

- 17.14.1.9 Examples of EMC tests and their respective test levels extracted from selected international standards are given in Table of this Specification. However, this table is by no means exhaustive and the Contractor shall refer to the respective standards for further information.
- 17.14.1.10 EMC type testing shall be carried out on all equipment identified in the design stage, which require attention regarding EMC.
- 17.14.1.11 All tests shall be conducted at severity levels specified by EN50121 and/or those imposed by the Employer, whichever are more stringent.
- 17.14.2 INTRA-SYSTEM EMC
- 17.14.2.1 The Contractor shall ensure that all intra-system EMI are taken care of through proper design and other special measures. All major sub-systems shall be tested for emissions and immunities in accordance with the appropriate international standards for equipment operating in railway or similar industrial environment. Examples of these international standards are given in, but not limited to Table 17.4: of this Specification. Where testing is not applicable due to factors such as size of sub-system or availability of test facilities, letter of no objection shall first be obtained from the Employer for waiver of such tests.
- 17.14.3 INTER-SYSTEM EMC
- 17.14.3.1 The Contractor shall ensure that all equipment is designed and constructed in accordance with the latest issues or versions of internationally recognized EMC standards, including but not limited to EN50082, EN50121, EN50123, EN50155, IEC60571 and IEC6100 or equivalents, to ensure proper functioning. Consideration shall be given to the EMC of the complete Lucknow Metro Rail Project.
- 17.14.4 SAFETY-RELATED SYSTEM INTERFERENCE
- 17.14.4.1 Special attention shall be given to the interference with safety-related operations. Special tests shall be designed to ensure that the emissions whether conducted, induced, or radiated conform to the specific requirements of the safety-related systems. Adequate safety margins between the immunity levels of these safety-related systems and the emission levels of other electrical and electronic equipment shall be adopted. Measures shall be taken to reduce the levels of the unwanted emissions.
- 17.14.4.2 The Contractor shall also provide computations on the expected conducted and radiated emissions from the power supply system due to electrical fault, load fluctuations, and/or system imbalance. Their effects on the safety-related equipment, especially the probabilities of leading to an unsafe operation shall be determined. An appropriate technical construction file suitable for safety audit shall be developed to demonstrate EMC compliance.
- 17.14.5 NON-SAFETY RELATED SYSTEMS INTERFERENCE

- 17.14.5.1 The Contractor shall take appropriate measures to ensure that EMC is achieved between the power supply equipment and all other system equipment. The traction and auxiliary transformers shall be designed with attention to the suppression of harmonic voltages as applicable.
- 17.14.5.2 The harmonic voltages of the system output with one or both loop in operation and under the worst loading condition, harmonic voltage/current shall not exceed the values as specified by the latest version of the relevant International Standards.
- 17.14.5.3 All radiated emissions, either via the power cables, rectifiers, transformers or any other system components, shall be minimized such that they conform to the appropriate international standards. Special reference shall be made to the compliance of EN 50121-5, EN 50123, and IEC 61000-2.
- 17.14.5.4 All power cables shall be properly shielded where applicable, not only to reduce radiated emissions from the cables, but also to reduce the possibility of the cable picking up unwanted RF noise. Reference shall be made to IEC 61000-4-6 and IEC 61000-4-16.
- 17.14.5.5 The Contractor shall ensure that all conducted emissions, including but not limited to harmonics, shall not interfere with telephone, communications, supervisory and control, automatic fare collection, train protection and control, and other MRTS equipment either via the rectifier transformer to the primary 33kV system or via the rectifier to the DC traction power system. Reference shall be made to EN 50121-5, EN 50123, IEC 61000-2.
- 17.14.5.6 The Contractor shall also co-ordinate with other contractors whose equipment are connected to the power supply system and are likely to inject unwanted emissions into the power supply system to reduce such emissions. Reference shall be made to EN 50121-2, EN 50121-4, EN 50121-5, IEC 61000-3 and IEC 61000-4-7.
- 17.14.6 ENVIRONMENT EMC
- 17.14.6.1 The Contractor shall ensure that radiated emissions from the power supply cable are maintained at an internationally acceptable level, the Contractor shall also ensure that the power cables are protected from RF radiations from All India Radio (AIR), Doordarshan, Bharat Sanchar Nigam Limited (BSNL), etc.
- 17.14.7 INSTALLATION AND MITIGATION GUIDELINES
- 17.14.7.1 IEC 61000-5 series of guidelines shall be observed wherever applicable.
- 17.14.8 EARTHING
- 17.14.8.1 An earthing system shall be provided throughout the system, as described elsewhere in this Specification, to ensure personnel safety and protection of installations against damage. It shall also serve as a common voltage reference and to contribute to the mitigation of disturbances.

- 17.14.8.2 To achieve the primary goal of assuring personnel safety and damage control, a low impedance path shall be made available to the large current generated due to lightning or power system fault. The potential differences (touch and step voltages) between any two points shall be as low as possible. Safety considerations also require the chassis or enclosure to be earthed to minimize shock hazards to passengers and Employer's staff.
- 17.14.8.3 To achieve the secondary goal of providing protection for sensitive and interconnected electronic and electrical systems, earthing shall be provided to minimize the noise voltage generated by currents from two or more circuits flowing through a common earth impedance and to avoid creating earth loops susceptible to magnetic fields and differences in earth potential.
- 17.14.8.4 Earthing shall be in place also to accomplish the following minimum requirements:
- a) Protect personnel and equipment from electrical hazards, including lighting, where practical.
 - b) Reduce potential to system neutrals.
 - c) Reduce or eliminate the effects of electrostatic interference and electromagnetic interference arising from within the Metro Rail System.
 - d) Provide a single-point earthing method for all equipment enclosures, cabinets, drawers, assemblies and sub-assemblies.
 - e) Provide a clean zero-volt reference point for signals in computer and related equipment.
- 17.14.9 BONDING
- 17.14.9.1 Bonding all exposed metallic parts of all equipment and connecting them to the earthing network is a way for meeting safety requirements and to minimize noise voltages due to potential differences. The Bonding shall be provided throughout the system, as described in earlier clauses of this specification.
- 17.14.9.2 Direct bonding shall be used wherever practical. Where indirect bonding via bonding strap is used to connect two isolated items, the bond shall satisfy the following minimum requirements and prevailing international standards, for example, IEC 61000-5-2.
- a) Low bonding resistance from DC to at least 2 GHz.
 - b) Low bonding inductance from DC to at least 2 GHz.
 - c) Proper bonding procedure, including appropriate surface treatment before and after the bonding process, is adopted.
 - d) Proper use of bond material to minimize electrolytic corrosion.
- 17.14.10 CABLING

17.14.10.1 The cables used shall be adequately protected against external interference. Additional protective measures, including but not limited to the use of metallic conduit, armour, ferrite choke, EMI filters shall be used to reduce such external interference wherever required. Covered conduit is preferred.

17.14.10.2 A cable routing plan shall be planned by the Contractor to minimize likelihood of coupling between parallel cables. The Contractor shall refer to guidelines recommended by IEC 61000-5-2 wherever possible. The Contractor shall submit a cable routing plan for review by Engineer and issue of No Objection in respect of EMC requirements.

17.14.11 IMMUNITY LEVELS AT VARIOUS POWER PORTS

Table 17.3: IMMUNITY LEVELS AT VARIOUS POWER PORTS

Test	Severity Level
Enclosure port	
RF field	800-1000 MHz, 20 V/m, 80%AM 1kHz
RF field - pulse modulated	900 MHz, 20 V/m, 50% duty cycle, PRF 200 Hz
Power frequency magnetic field	50 Hz, 100 A/m
Electrostatic discharge	6 kV contact, 8 kV air
RF common mode	0.15-80 MHz, 20 V, 80%AM at 1kHz source impedance 150 ohms
Fast transients	2 kV, 5/50 Tr/Th nanoseconds, PRF 5 kHz
Port for process, measurement and control lines, and long bus and control lines	
RF common mode	0.15-80 MHz, 20 V, 80%AM at 1kHz source impedance 150 ohms
Fast transients	4 kV, 5/50 Tr/Th nanoseconds, PRF 5 kHz
Transients common/diff modes	1.2/50 Tr/Th μ sec, 2 kV (c), 1 kV (d)
Power frequency	150 V rms
Power frequency common mode	650 V rms
DC input and DC output power ports	
RF common mode	0.15-80 MHz, 20 V, 80%AM at 1KHz source impedance 150 ohms
Fast transients	4 kV, 5/50 Tr/Th nanoseconds, PRF 5 kHz
Transients common/diff modes	1.2/50 Tr/Th μ sec, 2 kV (c), 1 kV (d)
AC input and AC output ports	
RF common mode	0.15-80 MHz, 20 V, 80%AM at 1kHz source impedance 150 ohms
Fast transients	4 kV, 5/50 Tr/Th nanoseconds, PRF 5 kHz
Transients common/diff modes	1.2/50 Tr/Th μ sec, 2 kV (c), 1 kV (d)
Earth port	
RF common mode	0.15-80 MHz, 20 V, 80%AM at 1kHz source impedance 150 ohms

17.14.12 TYPICAL INTERNATIONAL STANDARDSON EMC

Table 17.4: TYPICAL INTERNATIONAL STANDARDS ON EMC

Standard Ref.	Title
2004/40/EC	EU directive on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (electromagnetic fields)
ICNIRP Recommendations	ICNIRP 'Guidelines for Limiting Exposure to Time Varying Electric, Magnetic and Electromagnetic Fields', Health Physics, April 1998, Vol.74, No. 4
EN 50121-1	Electromagnetic Compatibility – Part 1: General
EN 50121-2	Electromagnetic Compatibility – Part 2: Emission of the Whole Railway System to the Outside World
EN 50121-5	Electromagnetic Compatibility – Part 5: Emission and Immunity of Fixed Power Supply Installations and Apparatus
EN 50122-1	Railway applications - Fixed installations - Electrical safety, earthing and the return circuit - Part 1: Protective provisions against electric shock
EN 50388	Railway applications - Power supply and rolling stock – Technical criteria for the coordination between power supply (substation) and rolling stock to achieve interoperability
EN 50163	Railway applications - Supply voltages of traction systems
EN 50371	Generic Standard to Demonstrate the Compliance of Low-Power Electronic and Electrical Apparatus with the Basic Restrictions Related to Human Exposure to Electromagnetic Fields (10 MHz–300 GHz) — General Public
EN 50174-2	Cabling installation-Installation practices inside buildings
EN 50174-3	Cabling installation-Installation practices outside buildings
EN 62305	Protection against lightning
IEEE C95.1-2005	Standard for safety levels with respect to human exposure to electromagnetic fields 3 kHz to 300 GHz
IEEE C95.6-2002	Standard for Safety Levels with Respect to Human Exposure to Electromagnetic Fields, 0 - 3 kHz
IEEE 1143-1994	Guide on Shielding Practice for Low Voltage Cables
IEEE 142-2007	Recommended Practice for Grounding of Industrial and Commercial Power Systems
IEEE 525-2007	Guide for the Design and Installation of Cable Systems in Substations
EN61000-6-4	Electromagnetic compatibility (EMC). Generic standards. Emission standard for industrial environments
EN61000-6-3	Electromagnetic compatibility (EMC). Generic standards. Emission standard for residential, commercial and light industrial environments
EN61000-6-2	Electromagnetic compatibility (EMC). Generic standards. Immunity for industrial environments
EN61000-6-1	Electromagnetic compatibility (EMC). Generic standards. Immunity for residential, commercial and light industrial environments

Standard Ref.	Title
EN 61000-2-2	Electromagnetic compatibility (EMC) Part 2-2: Environment – Compatibility levels for low-frequency conducted disturbances and signaling in public low-voltage power supply systems
EN 61000-2-4	Electromagnetic compatibility (EMC) – Part 2-4: Environment – Compatibility levels in industrial plants for low-frequency conducted disturbances
EN 62040-2	Uninterruptible power systems (UPS) – Part 2: Electromagnetic compatibility (EMC) requirements
IEC 61936-1	Power installations exceeding 1 kV a.c. – Part 1: Common rules (Basic rules for electromagnetic compatibility of control systems)
EN 60034-1	Rotating electrical machines – Part 1: Rating and performance 13: Electromagnetic compatibility
EN 60255-26	Measuring relays and protection equipment – Part 26: Electromagnetic compatibility requirements

17.15 PLATFORM INSULATION MEMBRANE

- 17.15.1 Power Supply Contractor shall be responsible for supply, laying and testing of Electrical Insulation Membrane required at station platforms to mitigate the accessible touch voltages.
- 17.15.2 Platform insulation shall be installed and embedded in to the station platforms to protective the passengers from touch potentials and to prevent passengers getting a shock while boarding or de-boarding from the train when one part of the body is in contact with the train and other on the platform which is at earth potential. Since the main lines are at floating potential, a person may get a shock on account of difference in potential.
- 17.15.3 In order to increase the resistance between passengers and the ground (platform), platform insulation membrane also known as electrical insulation membrane (EIM) shall be embedded within the platforms. EIM shall be in the form of plain sheets, which shall be embedded into the platform.
- 17.15.4 EIM shall be laid up to not less than 2.0m from the edge of the platform and the platform side opening shall be finished with suitable and aesthetic insulation material. EIM shall be laid with suitable solvent based primer and overlap of 10 % i.e., 100 mm. In future, there may be a requirement for installing the platform screen doors or gates, same to considering in the detailed engineering stage.
- 17.15.5 The membrane shall rise vertically up to the floor level. This is very important, otherwise the concrete will by-pass the insulation. It is to note that concrete is a more or less good conductor depending on its moisture content.
- 17.15.6 PSD Contractor shall ensure to maintain the insulation from the platform floor/concrete and shall ensure that at no point other than the fixing points for the PSD installation shall affect the insulation membrane. Necessary interface as and when required with any other agency shall be ensured by power supply Contractor.

- 17.15.7 EIM shall be of heavy duty, cold applied and self-adhesive membrane HDPE film and rubber bitumen compound nominal 1.5 mm thick and 1.1 m wide. The EIM shall be designed for the rating and other parameters indicated in Table 17.5:

Table 17.5: EIM Specifications

Performance	Description	Governing Specification	Requirement	
			Unit	Electrical Insulation Membrane
Volume Resistivity	Resistance to electrical current	ASTM D 257	$\Omega\text{-c m}^2$	Min. 1×10^{13}
Tensile Strength	Resistance to tension	ASTM D-638	kN/m ²	Min 40,000
Elongation	Stretch ability	ASTM D638	%	Min 300
Puncture Resistance	Resistance to puncture	ASTME-154-88	N	Min 490
Tear Resistance	Resistance to failure under tension	ASTM D 624	N/mm	Min 44

- 17.15.8 Contractor shall submit the type test reports of EIM confirming the above requirements. The list indicated above is minimum requirement of details to be provided by the Contractor and it is not exhaustive. Contractor shall submit the detailed GTP of EIM as part of Technical proposal and during vendor approval.

- 17.15.9 Contractor shall interface with station/finishing contractors for floor finishing for installation of EIM and the required coordination for during and after installation tests.

- 17.15.10 After installation, Contractor shall demonstrate a minimum platform to earth resistance 10 k Ω and 30 k Ω over a 300 x 300 mm area at 250 V DC under damp and dry conditions respectively.

17.16 CROSS BONDING

- 17.16.1 In order to contain the running rail voltages in accordance with EN 50122-1, track cross-bonding are to be provided. The interval of track cross-bonding is detailed in tender drawings Volume 5 of Tender documents. However the interval and locations of track cross bonding to be Verified and Confirmed by LKE-1B Contractor.

- 17.16.2 LKE(02)-01 Contractor shall develop detailed engineering drawings for installation of track cross bonds. LKE(02)-01 Contractor shall coordinate with track contractor for CAD welding in the running rails.

- 17.16.3 LKE(02)-01 Contractor shall interface, if & when needed, with signaling and track contractors for installation of track cross bonds.

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CHAPTER – 18 SCADA

18.1 Broad Scope

18.1.1 General

18.1.1.1 The scope of work comprises of design & verification of the preliminary design to ensure that it meets the operational, functional, performance, RAMS requirement as defined in Chapter-2 and Chapter-19 along with clause wise compliance and suggest similar or better design for the approval of Employer.

18.1.1.2 This Specification applies to the design and engineering, manufacture, supply, erection, testing and commissioning of the Supervisory Control and Data Acquisition (SCADA) System for the East West Corridor (Phase 1 B) of Lucknow Metro Rail Project:

- **East West Corridor** : Charbagh to Vasantkunj (incl. Vasantkunj RSS)

18.1.1.3 Integrated OCC for E-W corridor & N-S corridor & BCC for E-W corridor at Vasantkunj Depot RSS/AMS including upgradation of existing N-S corridor SCADA system. The works to be executed under the package include the design and engineering, manufacture & development, supply, installation, integrating, upgradation (Existing N-S corridor SCADA system) testing, commissioning, supply of contract spares, operation and maintenance manuals, training, as-built documentation, coordination with other designated contractors, maintenance support during warranty / Defect Liability Period and AMC for the SCADA System.

The integrated Operation Control Centre (OCC) shall be located at Metro Bhawan building nearby Sachivalaya UG station. BCC for E-W corridor will be installed in Vasantkunj Depot RSS/AMS.

18.2 Standards

The design and installation of SCADA system shall be based on this particular specification (PS) and based upon best engineering practices. However, the following IEC/EN/ISO/Indian equivalent standards form the guiding principle for design, manufacturing, installation and testing of SCADA system.

Table 18.1: List of Standards

[IEC 61508]	Functional safety of electrical/electronic/programmable electronic safety related systems
[EN 50126]	Railway applications – The specification and demonstration of Reliability, Availability Maintainability and Safety (RAMS) [IEC 62278 series]
[EN 50122-2]	Railway Applications – Fixed installation Electrical safety, earthing and the return circuit Part 2: Provision against the stray currents caused by DC traction
[IEC 62128-2]	Railway Applications – Fixed installation Electrical safety, earthing and - Part 2: Provision against the stray currents caused by DC traction
[IEC 60850]	Railway Applications - Supply Voltages of Traction Systems
[IEC 62443-5]	Industrial communications networks – Network and System Security – Security for industrial automation and control systems – Part 5: Technical security

	requirements for industrial automation and control systems
[IEC 62236]	Railway Applications – Electromagnetic Compatibility
[EN 50121]	Railway applications - Electromagnetic compatibility
[EN 50011]	Limits and methods of measurement of radio disturbance characteristics of industrial, scientific and medical radio frequency equipment
[IEC 61000-4]	Series of standards - Electromagnetic compatibility – Generic standards – Testing and Measurement Techniques
[IEC 60870-2-1]	Tele-Control equipment and systems- Operating conditions – Power Supply and electromagnetic compatibility
[IEC 60870-2-2]	Tele-Control equipment and systems- Operating conditions – Environmental Condition.
[IEC 60870-3]	Tele-Control equipment and systems – interfaces (electrical characteristic)
[IEC 60870-4]	Tele-Control equipment and systems – Performance Requirement
[IEC 60870-5-101]	Tele-control equipment and systems- Transmission protocols - Companion standard for basic tele-control tasks
[IEC 60870-5-103]	Tele-control equipment and systems- Transmission protocols - Companion standard for the informative interface of protection Equipment
[IEC 60870-5-104]	Tele-control equipment and systems- Transmission protocols - Network access for IEC 60870-5-101 using standard transport Profiles
[IEC 61850]	Series of Standards - Communication networks and systems in Substations
[IEEE 802 series]	Local Area Network
[IEC 61131-3]	Programmable Controllers – Programming Language
[IS:6911-1992]	Specification for Stainless Steel and Strip
[IEC 60297]	Specification for 19-inch rack
[IEC 60529]	Degree of protection provided by enclosures (IP Code)
[IEC 62040]	Specification for UPS
[IEC 60146]	Specification for Semiconductor Converter
[IS 694]	PVC Insulated cables for working voltages up to and including 1100 Volts.
[IS 1554-Part I]	PVC Insulated Cable (Heavy Duty) Electric Cables

[IEC 60255-5]	Insulation coordination for measuring relays and protection equipment – Requirements and tests
[IEC 60255-21]	Vibration, shock, bump and seismic tests on measuring relays and protection equipment
[IEC 60255-22]	Measuring relays and protection equipment - Part 22-5: Electrical disturbance tests
[BS 6651]	Lightning Protection
[IEC 61643]	Components of low-voltage surge protection devices
[IEC 61312]	Protection against lightning electromagnetic impulse
[IEC 61024]	Protection of structure against lightning
[IS 3043-1987]	Code of Practice for Earthing
[EN 50122-1]	Railway applications - Fixed installations - Protective provisions relating to electrical safety and earthing
[BS 7671-2001]	Requirement for wiring Installation, IEE Electrical Wiring Regulations 17th Edition.
[IEC 61000-4]	Series of standards - Electromagnetic compatibility – Generic standards – Testing and Measurement Techniques
[IEC 61000-6-1]	Immunity standard for residential, commercial and light-industrial environments
[IEC 61000-6-2]	Immunity standard for Industrial environments
[IEC 61000-6-3]	Emission standard for residential, commercial and light-industrial environments
[IEC 61000-6-4]	Emission standard for Industrial environments
	Cyber security Guidelines issued by GOI (Government of India)

18.3 Purpose of SCADA System

18.3.1 General

18.3.1.1 The purpose of the SCADA system is to monitor and control the Auxiliary and Traction power supply installations, Depots and Two RSS at N-S corridor & One AMS at E-W corridor under Lucknow Metro Rail Project. There are two types of power requirement for the metro rail system.

- a) **Auxiliary Power:** The auxiliary power supply network transforms 132kV/220 KV supply into 33kV by means of step down transformer for N-S corridor. For East -West corridor 33 KV supply is received directly from DISCOMat Vasantkunj Depot RSS/Auxiliary Main Substation (AMS). Then distributes the 33kV via ring main network through adequate protection and cable to the auxiliary sub-stations/ Auxiliary cum Traction substation (ASS or ASS cum TSS) located at stations/depot, which feeds in 415V supply to the electrical and electromechanical installations (which are not included into SCADA under this specification). In case of emergency, power outage at Vasantkunj Depot RSS/AMS, the power shall be fed from N-S corridor. SCADA in current scope shall cater the control and monitoring requirement up to 415 V LT Transformer breaker level only.
- b) **Traction Power:** For powering the rolling stock. This power shall be fed through OHE at 25 KV AC in North south corridor and through third rail at 750V DC level in East West corridor.

18.3.1.2 This Power Demand shall be met through power supply networks (Receiving/Distribution of the 33kV power respectively) created across the corridors. The 33kV supply at the RSSs/AMS shall be distributed to the Lucknow Metro Rail network through a ring main feeder cable network. Power supply at 33kV is distributed to various traction substations as well as auxiliary substations located in stations, by means of a 33kV ring main feeder network.

18.3.1.3 This mainly consist of followings

- a) 33kV HT cables from RSSs/AMS to Auxiliary Substations and Traction Substations.
- b) 33kV HT cable network connecting various ASSs/TSSs.
- c) 33kV/ 415V Auxiliary Substation at Stations and Depots for feeding power to Main Distribution Board for auxiliary power supply system.
- d) 33kV AC / 750V DC Traction Substation at Stations and Depots for feeding power to third rail system.
- e) 750V DC Cable connections from TSS to Third Rail and return cables from running rails to the negative bus in TSS.
- f) Third Rail system operating at 750V DC for feeding power to Rolling Stock.
- g) Emergency Trip System (ETS).
- h) Stray Current Protection and Control Devices.
- i) 220, 132kV HT feeders from RSS to Traction/ Auxiliary Transformer for North south corridor
- j) 132 KV/220 KV/33 KV power cables transporting power from UPPTCL to RSS/AMS.
- k) 25kV AC Traction Substation equipment's, FP, SS, SSP & SP.

18.3.1.4 The entire power supply network shall be distributed over a long stretch along the metro corridor. Thus, for supervision and control of this power supply network, an effective SCADA system shall be established, which shall fulfil the following main requirements of Power System Management:

- a) **Supervisory Function**
 - To monitor the condition of the power supply network at workstation console as well as video display terminals
 - To detect any change in the status of power supply network
 - To monitor and record several electrical analogue parameters (voltage, power, current etc.)

- To monitor and record energy consumption data (Active Power, Reactive Power, Total Energy, Maximum Demand Import, Frequency, Power Factor). Create daily report in various configuration (for Receiving Substation).
- To detect any fault in power supply network and notify the operator
- b) **Control Function**
 - To control the individual equipment
 - To energize or de-energize the different electrical sections of the auxiliary network in case of demand
 - To energize or de-energize the different electrical sections of the traction network in case of demand of traffic operator or maintenance staff
 - To isolate the faulty section in the event of a fault in traction network
 - To provide assistance in restoring services
 - To operate the system in such a manner to arrange alternative feeds from the healthy system
- c) **Diagnostic Function**
 - To records log of events in chronological order
 - To provide assistance tools for analyzing normal operation features (trends & reports)
 - To provide analysis of sequence of events.
 - To print a pre-determined log of events and data
- d) **Maintenance Function**
 - To identify and communicate the fault and faulty section to concerned maintenance staff
 - To issue and cancel the blocks on individual equipment's and system for maintenance
 - To restore the entire system after attending to faults

18.4 Brief Description of SCADA System

18.4.1 General

- 18.4.1.1** The Power supply equipment shall be located in unmanned switchgear room and normally remotely controlled & monitored by Traction power controller from the Operational Control Centre (OCC).
- 18.4.1.2** For this purpose, a SCADA system designed to supervise, control and acquire various data from the "Controlled Stations" along the line, such as Receiving Substations/Auxiliary Main Substation, Traction Substations, Auxiliary Substations, Depots, track way equipment's etc. along with upgradation of existing SCADA system of N-S corridor shall be envisaged, that allows the power controller to remotely observe and control the appropriate power system facilities.
- 18.4.1.3** The SCADA system shall consist of group of equipment's distributed over the various locations. It shall essentially consist of following:

- Master Station Equipment or Operational Control Centre/Backup Control Centre Setup
- Remote Terminal Units
- Communication Network (To be provided by S&T contractor)

- 18.4.1.4** The Power Controller shall be stationed at Operational Control Centre (OCC) and Backup Control Centre (BCC) and is required to carry out the main functions identified in clause 18.3.1.4.
- 18.4.1.5** The OCC shall consist of Main Control room i.e. OCC theatre room, SCADA Equipment/ Server room, Telecom equipment room, Uninterrupted Power Supply (UPS) & Battery room. Operator Workstations and Visual Control Panel (VCP)/ Large Video Display Screen (LVDS) shall be installed at the OCC theatre room, whereas other equipment shall be installed at their respective rooms. Video walls of the LVDS shall be supplied and installed by the signalling contractor. SCADA contractor shall interface with signalling contractor for configuration of video walls and display of SCADA HMI and LVDS
- 18.4.1.6** The back up control (BCC) facilities for East West Corridor shall be accommodated ~~set up~~ at Vasantkunj Depot RSS/AMS itself ~~AMS~~.
- 18.4.1.7** A Power Controller shall be stationed at this Back up control centre (BCC). He shall be able to execute all functions entitled to Power Controller at OCC when authorized by Power Controller of OCC or upon failure of OCC. Suitable control logic shall be implemented in SCADA to avoid any conflicting command to power equipment.
- 18.4.1.8** RTUs shall be installed in all ASSs and ASS cum TSS along the E-W corridor and in Vasantkunj Depot RSS/AMS. The RTU shall include CPU module, Communication module, digital input/output modules, analogue input modules, transducers, communication switch, interposing contactors, power supply units, surge arrestors and other items necessary for its proper functioning. At some elevated and underground stations, ASS/TSS are housed in a single room. Therefore, at those elevated and underground stations, Single RTU shall be provided for ASS cum TSS room. Design of RTU shall ensure that I/O modules of each ASS/TSS functions are separated / independent.
- 18.4.1.9** All the RTU's in East West Corridor and North South Corridor of Lucknow Metro shall communicate with SCADA Servers at OCC and BCC over specified communication network on IEC 60870-5-104 protocol through OFC backbone network to be provided by designated Telecom contractor.
- 18.4.1.10** The communication between OCC/BCC and RTU at controlled stations shall be achieved through OFC network to be provided by designated tele-communication contractor. The SCADA contractor is required to interface with designated telecom contractor to ensure the provision of necessary channel requirement.

- 18.4.1.11** Both Receiving Substations (RSS) of North South corridor and Vasantkunj Depot RSS/AMS shall communicate with OCC and respective BCC over IEC 60870-5-104 protocol data through designated ports in RSS/AMS RTU over fiber optic network backbone by designated telecom contractor. Dedicated Intelligent Electronic Devices (IEDs) or bay controller (IEC 61850 compatible) shall be provided at RSS for control, monitoring & protection of RSS equipments. RTU in redundant configuration shall be provided at each RSS/AMS. Each IED shall communicate with RSS/AMS RTU over dual network of IEC 61850 protocol. Each RTU shall have redundant communication ports for simultaneous reporting to at least 4 (four) control centres/masters. Each RTU shall have necessary communication ports with provision of redundant ports: -
- To transmit RSS/AMS data to OCC over IEC 60870-5-104 protocol
 - To transmit RSS/AMS data to BCC over IEC 60870-5-104 protocol
 - To transmit RSS/AMS data (analogue data, metering data and CBs Operating Status only) to UPPTCL State Load Dispatch Centre (SLDC) through wireless communication over Web network with Firewall protection for the purpose of remote viewing only, if required. No control shall be possible from SLDC. Any modem or wireless communication device and Firewall for external interface shall be supplied by SCADA contractor.
 - To transmit RSS/AMS data from RSS/AMS RTU to Local Workstation directly over Ethernet.
- 18.4.1.12** Deleted.
- 18.4.1.13** SCADA system proposed for EW corridor shall be smoothly integrated & commissioned with existing North South corridor SCADA system at OCC and respective BCC including SAS at both RSS(TPNR RSS & MSPA RSS) for seamless operation.
- 18.4.1.14** Any addition/modification/upgradation at hardware level as well Software level (at each level and layer) required for integration of North South Corridor and East-West corridor SCADA will be covered.
- 18.4.1.15** The contractor shall submit detailed design, implementation scheme, upgradation and Integration philosophy for successful integration of SCADA System.
- 18.4.1.16** All the other items as required for successful commissioning and integration with the existing SCADA system at OCC & BCC as per Chapter-18 part (II) as well as all other relevant clauses of GS and ERTS.
- 18.4.1.17** The integration of East West corridor will involve updation of base line in the existing ~~SCMS~~ SCADA software if required. The contractor shall interface with the track contractor to ensure satisfactory track conductance as per EN standard.

18.5 Scope of Work

18.5.1.1 Scope of Supply and Service

The Scope of Work shall essentially consist, but not limited to the following

- a) All equipment related to SCADA in the Main Control Centre i.e. OCC (including power and communication cabling works, servers, networking devices, workstations, monitors etc.).
- b) At OCC, a dedicated BASE and FE server shall be provided for each corridor i.e. for North south corridor and East West corridor.
- c) All equipment related to SCADA System in the each BCC (including power and communication cabling works, servers, networking devices, monitors etc.).
- d) Control and monitoring equipment (including RTUs, control cabling etc.) at ASSs, TSSs, Vasantkunj Depot RSS/AMS and RSSs (MSPA RSS & TPNR RSS).
- e) Control voltage sources and associated control cabling.
- f) Deleted
- g) Stray Current Monitoring system including central evaluation unit, Stray Current Monitoring System Software and integration into SCADA system at OCC only. The field side measuring equipment shall be provided by traction power supply contractor.
- h) Integration of Emergency Trip System (ETS) with RTU and SCADA system. ETS Boxes in field shall be provided by traction power supply contractor.
- i) Complete Engineering of SCADA HMI, Installation of RTUs and equipments at OCC/BCC and Integrated Testing & Commissioning entire SCADA system.
- j) Supply of Spare and Tools.
- k) Training & O&M Manuals and Troubleshooting Manuals, Functional Philosophy, Test Reports (Type Test, FAT, Acceptance Test, Integrated Test etc.).
- l) Interface with telecom contractor for necessary channel requirement for communication between SCADA equipment in OCC/BCC and RTU.
- m) Interface with Signaling contractor for the requirement of Visual Control Panel (VCP) or Large Video wall for Traction SCADA at OCC and Uninterrupted Power Supply (UPS) load for Traction SCADA equipments at OCC.
- n) DLP / Warranty for complete SCADA system for both corridor (N-S & E-W), SCMS, RTUs and all equipment supplied under this contract for 2 years.
- o) Comprehensive AMC of Complete SCADA System for both corridor (N-S & E-W) for 3 Years (after DLP period)
- p) Any other equipment and works for meeting the requirements of this specification.
- q) Design, supply, installation, testing and commissioning of communication equipment (Ethernet switches, routers, gateway, firewall for secure wireless communication if required) and data processing and viewing equipment (servers, workstations if required) for control and monitoring from centralized OCC at Lucknow. Contractor shall submit detailed design for the approval from Employer.

18.5.2 Scope of Comprehensive AMC

- 18.5.2.1** Comprehensive Annual Maintenance Contract shall be considered in the scope of SCADA contractor for 3 years after 2 years of DLP for all SCADA Hardware and software equipments including OCC/BCC/RSS/Stations equipments i.e. servers, workstations, SCMS etc. and all the RTUs and associated components etc.

The contractor will execute the work i.e. Round the Clock Manning of SCADA Server Room at OCC/BCC for Troubleshooting, Maintenance and Breakdown Support of SCADA System at OCC and BCC during CAMC.

Preventive maintenance of OCC & BCC servers & software including FE Servers and Base Servers including SCADA Softwares & licenses. TPC workstations, engineering workstation and any other workstation related to SCADA including its softwares & licenses, LIUs and FO/Communication cabling between server room to TER as well as OCC.

All other Software including OS, time sync and updation of patches in firewall and antivirus (as per NCIIPC Guidelines) are also included in scope of work.

Extension of warranty of servers & workstations after the expiry of existing warranty is in the scope of Contractor. Contractor should have support from OEMs of hardware & software installed at Lucknow metro site for rectification/replacement of servers & workstations.

In case of failure of any hardware part in the scope of this contract, Contractor shall replace the hardware with new one or get it repaired from OEM/Authorized service center. Nothing shall be paid extra. In this regards, the contractor have to be ensured minimum nos of spares availability at site during AMC & DLP.

- 18.5.2.2** During the AMC period for 3 years, daily maintenance or preliminary check of the SCADA equipment and assessment of daily reports shall be conducted by the SCADA contractor in co- ordination with UPMRC's staff as per the check list and recommendation covered in maintenance manual.
- 18.5.2.3** All other weekly/monthly/yearly maintenance or as required shall be performed by the SCADA contractor or OEM of SCADA equipment in co- ordination with UPMRC's.
- 18.5.2.4** Contractor shall submit the detailed Maintenance Plan covering preventive maintenance and predictive maintenance schedule, Maintenance Spare requirement, along with details of how the maintenance to be carried and tools required for the same. This Maintenance Plan shall be submitted before Testing and Commissioning stage.
- 18.5.2.5** The responsibility for employer's staff and contractor's staff during AMC period is as below.

- 18.5.2.5.1 All the maintenance activities shall be performed by the Contractor in presence of the Employer's staff. In case of any breakdown in the SCADA system, the contractor's staff shall report to the employer's staff and shall perform the breakdown maintenance immediately to restore the system.

Table 18.2: Responsibility of Staff

S. No.	Job	Employer Staff	Contractor/OEM Staff
1	Daily Preliminary Check	X	√
2	Weekly Maintenance	X	√
3	Monthly Maintenance	X	√
4	Half Yearly Maintenance	X	√
5	Yearly Maintenance	X	√

6	Breakdown Maintenance	X	√
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If the contractor fails to perform preventive maintenance activity strictly as per the maintenance schedule or skips/delays any schedule activity due to shortage of spares/Contractor's Engineer or any other reason, then a penalty of one thousand Rupees per day shall be deducted. The contractor shall therefore complete all maintenance activities as per the maintenance schedule and shall also submit the relevant service reports pertaining to the preventive maintenance activity carried out during the period of contract. If the contractor does not submit the service reports duly verified by the UPMRC representative, then also the above penalty clause shall prevail.

18.5.2.5.2 BREAKDOWN MAINTENANCE:

A failures/ breakdown shall be registered to the Contractor's representative when any defect is noted by the concerned Site in charge of Lucknow Metro.

The scope of Breakdown Maintenance shall include the attending/rectification of the breakdown and failures occurring in the system at any time during 24 hrs x 365 days inclusive of all Sundays & Holidays.

All the breakdowns of SCADA system which may lead to disruption of train services and failure of any FE server and base server shall be considered as major breakdown. All other remaining breakdowns shall be treated as minor breakdowns.

Minor Breakdown: Minor failures/defects occurring in the system during operation which include repairing/replacement (if required) of defective items with spare parts/Components shall be done by the contractor within the time specified as follows:

Response Time (Max) : 30 minutes

Rectification Time (Max) : 5 days

Action Taken Report: 48 hours

Major Breakdown: Major failures/defects taking place in the system which cover all type of Breakdown of the Major Equipment and which includes Repair/Replacement of Assemblies, Sub-Assemblies, and Components etc. as a whole shall be attended and rectified within the time frame specified as follows:

Response Time (Max) : 30 Minutes

Rectification Time (Max) : 02 Hours

Action Taken Report: 48 hours

The contractor shall be responsible for ensuring prompt & proper attention to break downs/failures along with undertaking detailed root-cause analysis of the break down/failure, so that appropriate corrective measures are taken to prevent their recurrence in future.

For meeting above contractual stipulations, register will be kept at OCC/BCC to record date/time of failure and date/time of rectification with joint signatures of UPMRC representative and Contractor representative. The period of breakdown/failure for the particular system (major or minor) shall commence from time of occurrence of break down/failure and will continue till the closure of complaint is verified as 'attended' by the Lucknow metro site in-charge.

18.5.2.5.3 Penalty Description

For Minor Breakdown

- i. For more than 4 hours- Rs.2,000.00
- ii. For more than 24 hours- Rs. 2,000.00 for every period of 24 hours for which the equipment is out of service after.

For Major Breakdown

- i. For more than 2 hours- Rs.3,000.00
- ii. For more than 24 hours – Rs 3,000.00 for every period of 24 hours for which the equipment is out of service after.

For complete OCC/BCC failure

- i. For more than 2 hours- Rs. 10,000.00/ incident
- ii. For more than 2 times in a month- Additional Rs. 10,000.00/ per such occurrence

For any non-compliance of UPMRC cybersecurity policy by Contractor's Engineers- Rs.50,000.00 per such occurrence.

18.5.2.6 Deployment Of Staff During DLP and AMC Period

The Contractor's deployment of man-power shall be such that the contractor man-power should be available round the clock (24x7) at OCC. From OCC Contractor's Engineer will also do health check-up of BCC through existing RDP interface. If breakdown occurs at BCC, Contractor's Engineer shall immediately move to BCC from OCC. Transportation from OCC to BCC is in the scope of contractor. Nothing shall be paid extra.

The contractor shall deploy minimum 4 nos of SCADA engineers (OEM Certified) including rest or leave reliever at Lucknow metro site. Roster of these Contractor's Engineers shall be in such a way so as to achieve round the clock manning of OCC or BCC as per requirement. Contractor engineer shall leave the server room only when his reliever reports in server room of OCC/BCC. Quarterly attendance report shall be prepared jointly by UPMRC and Contractor representative. Within 15 days from the date of issue of LOA, The Contractor shall submit bio-data of OEM certified SCADA Engineers (Manning team) along with competency check-sheet as certified by OEM and verified by UPMRC as per mentioned below:

18.5.2.6.1 Checklist for Contractor's Engineer to be deployed for Working on SCADA System

S.No.	Having Knowledge and Tested for following	Yes/No	Remarks
1	B.Tech in Electrical/Electronics/Computers (IT)		
2	Minimum 2 years working experience in SCADA System installed in Lucknow metro		
3	Servers, Workstations and Network Devices and other hardware devices in- stalled in Lucknow metro		
4	SCADA Architecture and Network configuration and troubleshooting		
5	LVDS Software configuration and trouble- shooting		
6	Server Database & Picture modification and troubleshooting		
7	Basic RTU and Logics configuration and troubleshooting		
8	Operations & Maintenance related to Hardware & Software installed at Lucknow metro site		
9	Communication protocols such as Serial, Modbus, IEC101, IEC101, IEC104 etc.		
10	Data Analysis of packets captured through protocol testers		
11	Failure analysis and Report Generation		

We have tested Sh. for his knowledge on the above aspect & found satisfactory. We recommend him for working on SCADA System at OCC & BCC of UPMRC.

This is the minimum requirement and needs to be enhanced if considered necessary without financial implications.

The deputed engineers' leave shall be sanctioned with a suitable replacement .

If any lag is observed in round the clock manning requirement at OCC/BCC or not fulfilling the minimum attendance requirement at Lucknow metro site for at least 24hrs x No. of days in respective quarter, two hundred rupees per hour penalty shall be imposed

18.5.2.6.2 Spares and T&P kept by contractor at Lucknow metro site

Contractor shall provide all the spares and T&Ps to maintain equipments mentioned under the scope of work as mentioned below. Spare parts should be labeled & tested by contractor.

S.N.	Spare Item	Quantity	Remarks
1	Workstation	1 No.	
2	KVM Extender	1 No.	
3	KVM Switch	1 No.	
4	Network Switch	1 No.	
5	Firewall	1 No.	
6	Patch cord	5 Nos.	
7	LAN cable	5 Nos.	
8	Panel Cooling Fan	2 Nos.	
9	Display Cable compatible with Server and Workstations	2 Nos.	
10	2 TB SSD	2 Nos.	

List of T&P to be maintained by Contractor

S.No.	T&P Item	Quantity	Remarks
1	LAN Tester	1 No.	
2	DVD Writer	1 No.	
3	Multimeter	1 No.	
4	Laser Light	1 No.	
5	Blower	1 No.	
6	Vacuum Cleaner	1 No.	
7	Screwdriver set	3 No.	
8	LAN Cable Crimping Tool	2 No.	

Consumable items other than the listed Spares and T&Ps such as cable management accessories, connectors, fiber cleaning wipes, fiber cleaning solutions, dust caps, screws, nut & bolts, labeling tapes, tags, insulation tapes etc. shall also be under scope of Contractor.

18.5.2.6.3 Software Support:

During the contract, the contractor shall render all support and undertake appropriate remedial action for satisfactory performance of software installed in the SCADA System or any of its component(s)/sub-component(s).

The contractor should notify the employer about any patches or fixes available to correct or patch faults. Additionally, contractor should inform about effects of such patches or fixes on existing system.

18.5.2.7 Maintenance Regimes

18.5.2.7.1 The Contractor shall produce a maintenance regime for the equipment that shall comprise two constituent parts, corrective and routine/preventative maintenance.

18.5.2.7.2 Routine/preventative maintenance shall be non-intrusive to the day-to-day operation of the train service and be capable of being pre-planned in advance of the work.

18.5.2.7.3 Corrective maintenance shall be available 24 hours per day, able to respond to all foreseeable circumstances.

18.5.2.7.4 The maintenance regime shall cover all parts and equipment of the SCADA system designed, installed and commissioned by the Contractor.

18.5.2.7.5 The Contractor shall take into account the requirements of the operations and maintenance when determining and proposing its maintenance regime. The contractor shall submit the maintenance regime to the Engineer in charge for approval.

18.5.2.8 Scope and Hours of Coverag

18.5.2.8.1 Deleted.

18.5.2.8.2 Deleted

18.5.2.8.3 Deleted

- 18.5.2.8.4 All elements of First Line preventative maintenance shall be carried out and completed during non-traffic hours without interrupting train services.

Power Supply System Description

18.5.3 Source of Power Supply

18.5.3.1 Power Supply System configuration for the East West Corridor & North- South corridor of Lucknow Metro Rail can be referred in single line diagrams in Volume 5: Tender Drawings

18.5.3.2 132kV/220 KV Power at RSS is supplied from the nodal power supply authorities (DISCOM) for N-S corridor. The 132kV/220kV power is transformed to 33kV at RSS by means of step down power transformer. For E-W corridor 33 KV power would be supplied from the nodal power supply authorities (DISCOM). The power at 33kV level from the 33kV switchgear at RSS/AMS is transmitted to the Auxiliary and Traction Substations located along the corridor, in the premises of passenger stations and depots, through duplicate feeders made up of 33kV insulated cables. In case of emergency, power outage at Vasantkunj Depot RSS/AMS, the power shall be fed from N-S corridor.

18.5.3.3 The 33kV power is transformed to 415V power by means of 33kV/415V dry type transformers installed in the Auxiliary Substations, for meeting the electrical power requirement of various Electrical, Signalling and Electro-mechanical installations in passenger stations and along the line.

18.5.3.4 The 33kV power is transformed to 750VDC power by means of 33kV/750V DC dry type rectifier transformers and rectifier set installed in the TSS's.

18.5.3.5 Details of various corridors are as under:

Table 18.3: Details of Corridors

Corridor	Stations	RSS/AMS	ASS	ASS cum TSS	Depot
E-W Corridor Charbagh to Vasantkunj	<ul style="list-style-type: none"> 05 Nos. Elevated 7 Nos. Underground 	1	7	6	1(Vasantkunj)

18.5.3.6 Details of East West Corridor (Charbagh to Vasantkunj) are as under:

Table 18.4: Details of East West Corridor

S. No.	Station Name	Station Type	Category	RTU type	No. of RTU
1	Charbagh	Underground	ASS	Type-3	1
2	Gautam Buddha Marg	Underground	ASS cum TSS	Type-4	1
3	Aminabad	Underground	ASS	Type-3	1
4	Pandeyganj	Underground	ASS cum	Type-4	1

			TSS		
5	City Railway Station	Underground	ASS	Type-3	1
6	Medical Chauraha	Underground	ASS cum TSS	Type-4	1
7	Chowk	Underground	ASS	Type-3	1
8	Thakurganj	Elevated	ASS cum TSS	Type-2	1
9	Balaganj	Elevated	ASS	Type-1	1
10	Sarfarazganj	Elevated	ASS	Type-1	1
11	Musabagh	Elevated	ASS cum TSS	Type-2	1
12	Vasantkunj	Elevated	ASS	Type-1	1
13	Vasantkunj Depot	At Grade	ASS cum TSS	Type-5	

Details of different RTU types and categories are as under

Table 18.3: Details of different RTU Types

Station Type	RTU Type
Elevated ASS	Type 1
Elevated ASS cum TSS	Type 2
Underground ASS	Type 3
Underground ASS cum TSS	Type 4
Depot ASS cum TSS	Type 5
RSS/AMS	Type 6

18.5.4 Auxiliary Power Supply

18.5.4.1 The various electrical and electro-mechanical installations in passenger stations and depots are required to be provided with electrical power at 415V 3-phase. For this purpose, each passenger stations and depot is provided with Auxiliary Sub-station (ASS). ASS receive power at 33kV level through redundant Auxiliary Feeders networks. The 33kV power is transformed to 415V power by means of 33kV/415V dry type transformers of suitable capacity installed in the ASS's. 415V power is further distributed within station through multiple LV main and sub-distribution boards (DBs). 415V DBs are not in scope of this work package.

18.5.5 Traction Power Supply

18.5.5.1 The rolling stock is required to be provided with traction power at 750V DC for E-W corridor. For this purpose, Traction Substations (TSS) are provided in multiple passenger stations and depot along the corridor. TSS receive power at 33kV level through redundant traction feeder networks. The 33kV power is transformed to 750VDC power by means of 33kV/750V DC Dry type rectifier transformers and rectifier of suitable capacity installed in the TSS's. 750V DC power then transported to third rail through High-Speed Circuit Breakers (HSCB) and DC cables.

18.5.6 Third Rail System

- 18.5.6.1** The Electric power is supplied to the rolling stock by means of a conductor Rail known as third Rail. The conductor Rail shall be installed on trackside at the specified distance to the track centreline / top of the Rails. In the double-track line, the conductor Rail shall be installed between both tracks in order to leave sufficient space between for walkways. In stations, it is necessary for safety reasons to install the conductor rail on the side of the track opposite to platform edge.
- 18.5.6.2** The nominal traction power supply voltage is 750V DC, which shall be transferred to the traction vehicles via conductor Rails and current collector shoes placed at defined positions on the traction vehicles
- 18.5.6.3** Power of tracks inside the workshop building and Inspection Bays shall be provided via stinger installations. Stinger cables, attached to contact trolleys, provide power from overhead conductor rails.

18.6 SCADA System Overview

- 18.6.1** Description
- 18.6.1.1** The SCADA system provides the highest level of observation control and command of the Power Supply system. It is an operational nerve centre which allows the power controller to get a real time status of the installations, to make relevant measurements, and to take the appropriate actions during the normal operation as well as during unusual occurrences when efficiency and swift responses are required. Thus
- SCADA system shall provide all possible facilities for real-time monitoring of complete power supply installation from a centralized location i.e. OCC/BCC.
 - It shall help Operation Team (Power Controllers) in making most suitable decisions during normal operation as well as during failures and shall ensure transmission of corresponding control command to the equipment on the corridor.
 - It shall also help Operation team in analyzing power supply installation's performance and undertaking improvements. It shall also help in diagnosis of a failure, post occurrence.
- 18.6.1.2** The SCADA equipment at OCC/BCC, here after called as "Master Station Equipment" and the SCADA equipment for integration of field signal at various controlled stations (RSS, TSS, ASS & RSS/AMS etc.) is called Remote Terminal Unit (RTU). The RTUs and Master Station are interconnected through a communication channel.
- 18.6.1.3** Thus, the SCADA system is primarily comprised of below listed sub system.
- a) Field Control & Monitoring Devices
 - b) Master Station Equipment
 - c) Communication network (to be provided by Telecom)
- 18.6.2** Field Control & Monitoring Devices

- 18.6.2.1** To achieve the functionality of data acquisition, the power supply installations such as Receiving Substation (RSS), Traction Substation (TSS), Auxiliary Substation (ASS) and Depots etc. shall be provided with control & monitoring devices, which shall be interfacing with controlled equipment's for necessary field data collection and data transfer to Operation Control Centre & Backup Control Centre simultaneously. These control & monitoring devices shall comprise of Remote Terminal Unit (RTU).
- 18.6.2.2** The interface between RTU's and controlled equipment's shall be hardwired by logical interface (i.e. DI, DO), Analog interface (4/20 mA) from transducers or digital communication interface i.e. RS232, RS485, IEC 61850 for IEDs/Relays etc.
- 18.6.2.3** The RTU's shall have provision to communicate with relays/IEDs of AMS/RSS over IEC 61850 protocol.
- 18.6.2.4** The RTU's shall also have provision to communicate with one and multiple control centres over specified protocol.
- 18.6.2.5** The RTU's shall support peer to peer communication for implementation of logic and field side automation.
- 18.6.2.6** The key functions of RTUs are as indicated below.
- Provision to fully integrate control and monitoring signals of various electrical and mechanical devices at controlled station
 - Provision to communicate with at least four Master Station Equipment
 - Accept and execute command from OCC/BCC/Locally
 - Perform control priority checks & provide control conflicts data
 - Retrieve equipment status upon cold start
 - Store and execute operational logic and control function as per system operational requirement
 - Perform self-diagnostics in the background and indicate hardware failures
 - Provision of data storage
 - Provision for RTU's configuration setup and management locally as well as remotely from Master System Equipment
 - Accept real time synchronization signal from control centre
 - Local time management if time sync from Master System Equipment is not available
 - Provide auxiliary power to actuators etc. if connected
- 18.6.2.7** The RTU generally comprised of followings.
- RTU Panel complete with internal wiring
 - Processor/CPU Card, Power Supply Card, Communication cards etc. All applicable Input-Output modules & Transducers etc.
 - Power Supply Converter & subsequent distribution inside panel
 - Any Networking Switch, LIU, Routers etc. if required.
 - Panel Lighting, enclosure heater etc.
- 18.6.2.8** Any key components of RTU like CPU card, Power Supply Card, Communication Card, Power Supply Converter etc. shall be considered in dual redundant and auto changeover configuration. Network Switch shall also be provided in dual redundant configuration.
- 18.6.3 Master Station Equipment**

18.6.3.1 The Master Station Equipment is set of devices, software's, functional modules, and assemblies that are necessary to implement the polling & supervisory functions over remotely located controlled stations / apparatus. The equipment includes the interface with the communication channel but does not include the interconnecting channel. Master station also includes consoles that provides facilities for observation and control of the system.

18.6.3.2 Master Station Equipment for Lucknow Metro Rail project (Phase 1B) shall comprise of minimum following functions:

- Centralized Data Acquisition, Control and Monitoring function with provision of Hot-Standby Servers and Operator Terminal for display of information to Power Controllers and shall be also used to issue control operations.
- Centralized Data storage and Archival System with interconnected external back-up storage device.
- Provision of LAN with applicable network protection to fully interconnect all devices, modules of SCADA system.
- Provision of large video display screen for displaying power overview line diagram (to be provided by Signaling contractor).
- Provision of Master clock interface over Network Time Protocol (NTP) with suitable interface provision with telecom system.
- Provision of data logging or printing devices.
- Provision of Power supply distribution and UPS for fail safe system operation. UPS load for Traction SCADA equipments at OCC shall be provided by Signaling contractor in S&T UPS system.
- Provision of suitable furniture and Rack with access control for smooth and secure SCADA system.

18.6.3.3 The Master Station Equipment shall be setup inside OCC and BCC.

18.6.4 Communication Network

18.6.4.1 The RTU's at "Controlled Stations / Power Supply Installation" along the corridor, shall require to be exchange data with SCADA system at OCC/BCC over specified communication network.

18.6.4.2 The communication between OCC/BCC and RTU at controlled stations shall be achieved through OFC network to be provided by designated telecom contractor. The SCADA contractor is required to interface with designated telecom contractor to ensure the provision of necessary channel requirement.

18.6.5 General Architecture of SCADA system

18.6.5.1 SCADA system shall have two Control Centres: Main Operational Control Centre and Backup Control Centre.

18.6.5.2 All the RTU at stations, substations or depots shall communicate with Main & Backup control centres directly, through a redundant fiber optic communication network over telecom communication backbone (not under the scope of this contract).

18.6.5.3 Relay & Protection Panel – The Numerical relays shall be communicating with RTU over IEC 61850 protocol. The relays data shall be collected by RTU and transmitted to SCADA server in OCC/BCC. The Relay & Protection Panel shall be supplied and installed by traction power supply contractor. Interfacing with the power supply contractor/UPMRCL shall be done for relays protocol compatibility.

- 18.6.5.4** The SCADA system at the integrated control centres shall communicate and control all RTUs along the corridor. The SCADA system at the integrated control centres shall consist of dedicated redundant Hot-Standby SCADA Servers for each corridors (i.e N-S corridor & E-W corridor), which shall be installed at integrated Control Centres to communicate with RTUs along the corridor.

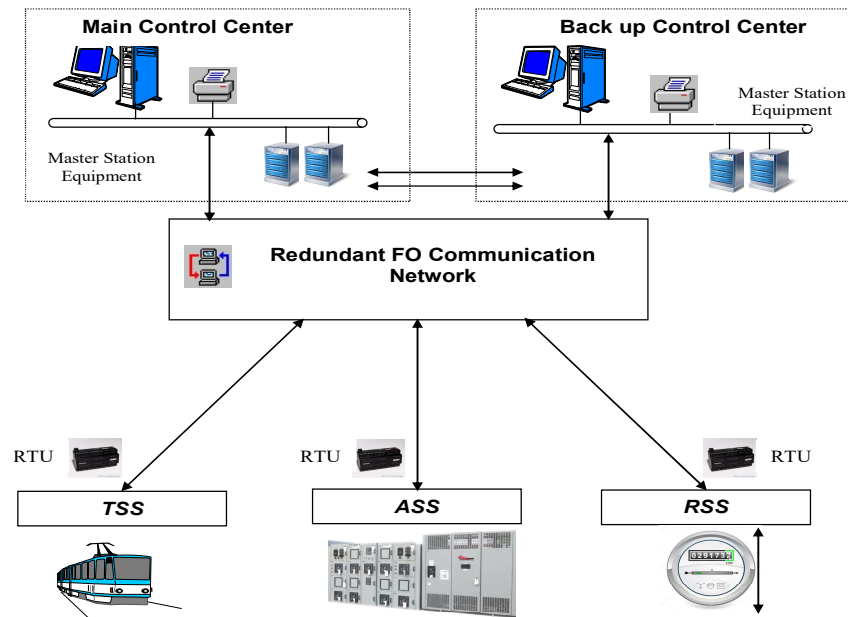


Figure-1 General Arrangement of SCADA System

- 18.6.5.5** The dedicated SCADA Communication Server (for eachcorridor i.e East West corridor and North South corridor)) shall be provided in hot-standby arrangement at OCC. Whereas at BCC of East West Corridor the SCADA Communication Server shall be provided as a non-redundant standalone system and upgradation of BCC for N-S corridor as per existing architecture.
- 18.6.5.6** The dedicated SCADA Database cum Application Server (for each corridor i.e East West corridor and North South corridor) shall be provided in redundant Hot-standby configuration complete with necessary database software at OCC. Whereas at BCC of East west Corridor the SCADA Database cum Application Server shall be provided as a non-redundant standalone system and upgradation of BCC for N-S corridor as per existing architecture.

- 18.6.5.7** An engineering server shall be provided at OCC only for each corridor, which shall serve as development & maintenance machine for SCADA HMI engineering, RTU Configuration, Parameters downloading to RTU through RTU's configuration file (with password protection), Testing and other development and maintenance purpose. Any new development from engineering machine shall be deployed on main server only after appropriate quality check, integrated testing, verification and validation by appropriate employer personnel. Any work-in progress work in engineering server shall not affect the functioning of main server.
- 18.6.5.8** Deleted
- 18.6.5.9** The Stray current monitoring system (SCMS) including central evaluation unit, Stray Current Monitoring System Software shall also be provided at OCC only.
- 18.6.5.10** Auto application backup management shall be configured to handle accidental system recovery or data loss with implementation of online or offline backup management policies.
- 18.6.5.11** Four Operator Workstations each with dual 24" LED monitors shall be provided in OCC theatre room only.
- 18.6.5.12** Suitably sized Large Video Display Wall/System shall be provided by Signalling Contractor for Traction SCADA at OCC only.

All the equipments related to SCADA System in the Backup Control Centre (BCC) at Transport Nagar Depot (including power and communication cabling works, servers, networking devices, monitors etc.) for the control & monitoring of traction and auxiliary power supply of North South Corridor including TPN depots and both the RSSs (TPNR RSS & MSPA RSS) are already available and are in service

- 18.6.5.13** Backup Control Centre (BCC) for E-W corridor shall be located at Vasantkunj Depot RSS/AMS. All equipments related to SCADA System in the BCC (including power and communication cabling works, servers, networking devices, monitors etc.) for the control & monitoring of traction and auxiliary power supply of E-W corridor including Vasantkunj depot RSS/AMS shall be installed in Vasantkunj depot RSS/AMS.
- 18.6.5.14** One no. Disturbance Recorder (DR) workstation with 24" LED display incl. fault analysis and relay configuration software is installed in each existing RSS of N-S corridor and one no. Disturbance Recorder (DR) workstation with 24" LED display incl. fault analysis and relay configuration software to be installed at Vasantkunj depot RSS/AMS of E-W corridor by the contractor with facility of its Remote Desktop at OCC & BCC.
- 18.6.5.15** Deleted
- 18.6.5.16** Each RSS/AMS RTU shall be provided with dual redundant Ethernet switches to transmit RSS/AMS data to OCC/BCC over IEC 60870-5-104 protocol.

- 18.6.5.17** The data exchange between the electronic devices on bay and station level shall take place via the communication infrastructure. This shall be realized using fiber-optic cables, thereby guaranteeing disturbance free communication. The fiber optic cables shall be run in GI conduit pipes. Data exchange is to be realized using IEC 61850 Communication standard with a redundant managed switched Ethernet communication infrastructure which shall be supplied by Traction contractor. Traction contractor shall also supply fiber optic patch cables inside GI flexible conduit from CRP panels to Ethernet Switches for establishing dual LAN over IEC 61850. Ethernet switches complying to IEC 61850 shall also be installed in RSS RTU.
- 18.6.5.18** One no. Workstation with 24" LED display shall also be provided by Traction contractor in the RSS/AMS of East West Corridor as an O&M (Operation & Maintenance) workstation/system which shall be connected on a separate office LAN by designated Telecom contractor or UPMRC O&M.
- 18.6.5.19** SCADA server and SCADA software shall be sized and suitably licensed for the control & monitoring requirement of EAST-West Corridor & North south corridor and its future expansion shall be included. The SCADA software shall be supplied with the license of minimum 70 RTUs and 45000 I/Os shall be included.
- 18.6.5.20** The requirement of Input Output signal points for traction power supply equipment under this project shall be incorporated in detailed design of server and SCADA software.
- 18.6.5.21** SCADA system shall support multi-protocol environment i.e. IEC 60870-5-101, IEC 60870-5-103, IEC 60870-5-104, MODBUS and OPC DA/UA protocols.

18.6.6 Control Philosophy

As explained in last section, the control & monitoring of Power Supply Equipment's shall be implemented from Operation Control Centre and Back-up Control Centre.

Following levels of controls shall be possible from SCADA system:

- Centralized Control from OCC/BCC for entire corridor
- Local mode from the equipment
- Local control from RSS

18.6.6.1 Centralised Control from OCC/BCC

- 18.6.6.1.1** It shall be possible to control the all-power supply equipment (switchgears, motorised isolator and relay resetting etc.) at RSS/AMS, TSS, ASS, Depot, Trackway etc. along the metro lines, from the OCC as well BCC. The Power Controller in OCC shall have primary control over the complete power supply network and all the activities with respect to operation of power supply and supervision of maintenance (scheduled or breakdown) etc. shall be managed from this location.
- 18.6.6.1.2** In the event of major incidents which cause a temporary unavailability of the main OCC, the SCADA system shall be fully operable remotely by SCADA equipment installed inside the BCC. The control shall be possible from BCC only when automatic control is transferred to BCC from OCC in case of failure of respective SCADA servers at Main OCC and when operator manually transfer the control to BCC from Main OCC.

18.6.6.2 Local mode from the equipment

- 18.6.6.2.1 It shall be possible to operate the equipment's locally from the control panels by selecting the local / remote selector switch in the Control Panel/equipment. This selection shall be logged in the event list by SCADA system.
- 18.6.6.2.2 Such control shall only be possible after taking "Permission for Local Operation" from the Traction Power Controller. This shall be also logged in the event list by SCADA system. SCADA system shall ensure that no operation is performed without authorization from Operator. However, a bypass switch (for SCADA permissive command) shall be provided in the RTU for equipment local operation in case of communication link failure between Control Centre and RTU.

18.6.6.3 Local control from RSS

- 18.6.6.3.1 Each RSS shall be provided with Local Workstation to carry out the local control & monitoring function of RSS in case of emergency.
- 18.6.6.3.2 The Local Workstation shall allow to operate in case of disturbances such as failure of control centre or RSS communication failure with control centre or manual control transfer from OCC.
- 18.6.6.3.3 In case control authorization is at OCC, then control of RSS equipment shall be blocked at RSS local workstation. In case of manual control transfer from OCC, control of RSS equipment shall be blocked at OCC.

18.6.7 Control Transfer Management

- 18.6.7.1** To avoid possibility of control from multiple locations, a method of control transfer logic shall be implemented in SCADA system at various control points (OCC/BCC, RSS, RTU, Equipments) considering the above control philosophy & confirming to operational requirement of metro lines of Lucknow Metro Rail Project (Phase 1B).
- 18.6.7.2** This is to ensure the smooth and safe operation of SCADA system with applicable safety interlocks and to avoid conflicting control action from multiple control locations.
- 18.6.7.3** In case of RSS communication failure with OCC, the control shall be transfer to BCC/respective RSS.
- 18.6.7.3.1 Traction Power controller shall have the authority to give permission to RSS operator for the operation of the RSS equipment.
- 18.6.7.3.2 There shall be a provision of taking the control transfer from RSS Local workstation only through a specific User login ID and password which shall not be shared with the RSS operator and shall be available in RSS in a packed envelope.

18.7 Design and Functional Requirement**18.7.1 General Requirement**

- 18.7.1.1** The SCADA system shall be constructed with modern techniques in accordance with internationally recognized standards and designed for safe and efficient operation. All materials and equipment to be supplied shall be of a proven design and the major core components of the SCADA System shall have a Service Life of at least fifteen years.
- 18.7.1.2** The Contractor shall ensure that the SCADA system is designed to accommodate the ambient conditions under which the SCADA is required to operate. In addition, the Contractor shall ensure that condensation does not form in a manner detrimental to the durability or operability of any part of the SCADA system.
- 18.7.1.3** The SCADA system shall be designed to achieve high system availability and to ensure that any single point failure of SCADA network equipment shall not cause a reduction in SCADA system performance. Redundancy shall be incorporated, where failures cannot be tolerated particularly when associated with safety critical systems.
- 18.7.1.4** The remote terminal units shall be configured to enable logical and sequential functions to be carried out locally, without reference to any servers and/or workstations. The SCADA system shall be capable of transmitting the results of such operations to the main servers for data storage, although the remote terminal units shall also have the capability of storing data.
- 18.7.1.5** SCADA equipment that is not desk-mounted or otherwise free-standing shall be housed in line-replaceable plug-in modules, rack mounted in accordance with DIN standards.
- 18.7.1.6** The racking shall be enclosed within suitable cabinets to suit the climatic conditions of the installation. The arrangement of the SCADA equipment within the cabinets shall be such that all routine maintenance can be carried out through hinged access doors or removable covers, and where possible from the front.
- 18.7.1.7** The design of the cabinets shall ensure adequate ventilation and air circulation without permitting the entry of vermin. Cable entries shall be closed and made vermin proof, by means of non-magnetic, fire-barrier plates. All SCADA equipment shall be identified with permanently affixed labels, written in English.
- 18.7.1.8** All SCADA equipment shall operate satisfactorily in the very high "electrical noise" environment normally associated with electrified mass transit railways due to electrical and magnetic fields created by traction supplies. Equipment shall be immune to the effects of conducted and radiated electrical and magnetic interference. The RTUs shall comply to environment condition prevailing in Lucknow region and in general shall comply to the following environmental requirements:
- a) EMC Immunity: As per IEC 60870-2-1 Level 3 or 4
 - b) EMC Emission: As per IEC 60870-2-1 Class A
 - c) Temperature: -10 to 55 deg C as per IEC 80870-2-2
 - d) Humidity: 5 to 95% as per IEC 80870-2-2
- 18.7.1.9** All SCADA equipment shall be fully protected against the effects of power surges and transients in power, signal and communication cables.

- 18.7.1.10** The SCADA equipment shall be fully protected against the effects due to lightning strikes in accordance with the requirements of an internationally recognized standard and the Contractor's approved Earthing Policy.
- 18.7.1.11** All surge suppression equipment shall be self-contained and self-resetting. The suppression equipment shall be selected to ensure that the let-through voltage does not exceed the absolute maximum voltage specified for the particular equipment being protected. Signal cables from external sensors at risk from the effects of lightning shall have surge suppressers fitted at both ends of each cable and shall be installed and connected in accordance with the manufacturer's recommendations.
- 18.7.1.12** The Contractor shall provide portable programming devices / Laptops, including all the associated software, to enable the maintenance personnel to test or interrogate items of the SCADA equipment locally, i.e. without using the SCADA communication network.

18.8 SCADA Functions

The following functionalities are to be achieved by the SCADA system proposed to be installed at Main & Backup OCC:

- Remote monitoring: The remote monitoring functions covers the monitoring of equipment status as per the IO list enclosed in section 18.22.
- Remote control: The SCADA system shall provide facility to open /close the breakers, interrupters etc. as per the IO list in section 18.22.
- In case of an emergency or abnormal situation, the Power Controller shall be able to control the various items of equipment, typically:
 - Isolation of the faulty sections or circuit
 - Restoration of the normal configuration after the fault has been remedied.
- Tele-measuring: The voltage and currents measurements as per IO list referred in section 18.22, shall be covered in scope of the RTU. The RTU shall be provided with necessary analogue input modules to receive the 4 to 20 mA signals from the transducers.
- Logics & Interlocking
- Transfer, to handle the opening/closing of switchgears in bridges.

18.8.1 Remote Monitoring

- 18.8.1.1** The system shall collect and transmit remote monitoring information from the field supervised equipment to the work stations.

- 18.8.1.2** In normal operation, the Power Controller shall be able to monitor the status of the RSS/AMS equipments, HV, traction and auxiliary supply equipment. The Power Controller shall receive alarms relating to different events and alarms on equipment, e.g. low level or loss of voltage on 33kV system, 25 kV AC Traction system, 750V DC System, 33kV cables and 415V Transformer CB's.

- 18.8.1.3** The SCADA software shall be designed with necessary process display screen to provide a graphical depiction of the power supply network for the Metro Corridors. This shall include the Receiving Substation, Auxiliary Main Substation, Auxiliary Substation, Traction Substation, Local Auxiliary power distribution for Main Line and Depot etc. Two separate views for complete Traction Line & Auxiliary Line shall also be designed.
- 18.8.1.4** The SCADA System shall collect the operator's request and field information changes. Any change on the field or any operator request shall be processed as an event. The SCADA System may generate additional events resulting from the processing of the field information and/or operator request. All events processed by the SCADA System shall generate an update of the related dynamic display objects and also be recorded in logging list. The logging list shall contain all the events in chronological order that occurred within a certain period of time. All the events shall have a time stamping of 1 msec. Furthermore, alarm types events shall be recorded in the alarm list and generate an alarm procedure initialization.
- 18.8.1.5** The event logging system of SCADA remote monitoring system shall support the following features and options:
- a) Historical Storage of events with facility to retrieve the same later
 - b) Configurable layout: columns, fonts, toolbars, Colouring, and so on.
 - c) Configurable scrolling behavior
 - d) Configurable presentation modes: log mode /event mode, latest at top/bottom
 - e) Updating/Frozen presentation modes.
 - f) Easy navigation through scrolling, go to date, time filters.
 - g) Filtering (By Station, Device, and Period etc.)
 - h) Extensive filtering that can be stored and easily called up later
 - i) Multiple station filtering to filter out more than one location simultaneously.
 - j) Find, Sorting by column
 - k) Exporting data to other Windows applications like MS Excel etc.
 - l) Printing
 - m) Commenting of events by operator
- 18.8.1.6** The SCADA System shall be able to handle various types of alarms, typically:
- a) Alarm generated due to change in field information.
 - b) Alarm generated due to fault in SCADA system equipment and communication link.
 - c) Alarm generated due to loss of communication of RSS with OCC/BCC
- 18.8.1.7** The details of the individual parameters to be monitored is provided in the section "Input/Output Requirement" in this specification.
- 18.8.1.8** Followings are important sub-functions of Remote Monitoring that SCADA system must support.
- a) Network Colouring
 - b) Event Management
 - c) Alarm Management
- 18.8.2** Network Colouring

- 18.8.2.1** The SCADA software proposed shall support necessary busbar colouring feature by which the dynamic status of the bus bar can be depicted during charged and uncharged conditions. The busbar colouring shall be provided for the overall feeding diagram, auxiliary and traction over view diagram etc.
- 18.8.2.2** Auxiliary Network: The colour of each loop in ASS overview diagram and the busbar colouring shall be done based on the breakers and interrupter status. In addition, the status of 415V Transformer LV breakers in Main LV Distribution Board shall be depicted in suitable distinct colour.
- 18.8.2.3** Traction Network: The colour of each loop in 33kV distribution diagram for traction supplies and the busbar colouring shall be done based on the breaker status. Colouring of 750V DC third rail sections shall be done based on the voltage of third rail coming from DC PTs. When the voltage of section is > 550 V DC, it shall be shown in green colour. When the voltage of section is > 250 V DC and < 550 V DC, it shall change to orange colour and when section voltage is less than 250 V DC; its colour shall change to red colour. However, this design requirement of third rail section coloration shall be finalized at the design stage.
- AC Traction Network: The colour of each loop in 25kV distribution diagram for traction supplies and the busbar colouring shall be done based on the breaker status. Colouring of 25kV AC sections shall be done based on the voltage coming from PTs which are as follows:
- | | |
|---------------------------|--------|
| ≥ 18.5 kV- | Green |
| > 7.5 kV & < 18.5 kV- | Orange |
| < 7.5 kV- | Red |
- 18.8.2.4** The busbar coloration of RSS/AMS/ASS/ASS cum TSS network shall be done based on breaker status and based on voltage values coming from PTs of incoming & outgoing bays.
- 18.8.2.5** Equipment, other than Battery Charger: Normally all power equipment reflecting in various screens shall be in green colour unless and otherwise any alarm, blocking and communication fail event is associated with the equipment. Close and Open State shall not be considered as an alarm state for a switchgear and in both cases, it shall be shown in Green colour. In case of occurrence of other alarms its colour shall change to Red.
- 18.8.2.6** **Battery Charger:** The status of battery chargers shall be indicated in SCADA as per follows – Green (healthy and in service), Yellow (healthy and standby) and Red (defective).
- 18.8.2.7** **Alarm Status:** Normally all devices shall show in green colour, unless and otherwise any alarm associated with the device appears from field or it is blocked by the Power Controller. In case of alarm occurrence colour of device shall change to red.
- 18.8.2.8** **Blocking Status:** In case of operator blocks control of any device or section, colour of the blocked device shall change to brown.
- 18.8.2.9** **Communication Failure:** In case of communication failure of an installation, all equipment of the installation shall change to pink colour.
- 18.8.3** **Event management**

- 18.8.3.1** The system shall collect the Power Controller's requests and field information changes. Any change in the field or any operator request shall be processed as an event. The SCADA system may generate additional events resulting from the processing of field information and / or operator requests.
- 18.8.3.2** The SCADA system shall record any events caused by faults, malfunctions, warnings or alarm information generated automatically by the selected equipment. A central recording system shall be provided to record the following events, including but not limited to:
- a) Change of state of remote terminal unit input parameters
 - b) Events designated as alarms
 - c) Faults
 - d) Control actions
 - e) Text entered by operations personnel
 - f) System generated messages, e.g. equipment malfunction
- 18.8.3.3** Deleted
- 18.8.3.4** Deleted
- 18.8.3.5** Events shall be given an order of priority to allow events to be classified, sorted and filtered. Subject to the requirements of the approved operations plan, events shall be classified as:
- a) **Emergency** - this type of fault shall require instant attention in order to minimize interruption of the normal operation or the risk of injury to personnel or passengers and shall be classified as an Alarm
 - b) **Urgent** - this type of fault shall require reasonably prompt, but not instant attention in order to minimize interruption of the normal operation and shall be classified as an Alarm and
 - c) **Non-urgent** - this type of fault shall be dealt with in a more convenient manner while more urgent events are dealt with first. This type of event shall not directly result in any degradation of the normal operation. These need not be configured as alarms. These are to be recorded in event list only.
- 18.8.3.6** The event records shall be available as a text table, with each event classified by its priority level and shall be tagged with details of the date and time at which the event occurred. Additionally, the operations personnel identification code shall be recorded for each event that is initiated by the operations personnel. Each event shall be highlighted until acknowledged by the operations personnel. All events shall continue to be displayed in the automatic event log after acknowledgement and after the fault has been satisfactorily rectified in the equipment which generated the event.
- 18.8.3.7** All data messages transmitted through the SCADA network shall be tagged with the time at origin to an accuracy of at least 1 millisecond and shall be sorted and logged in time tagged order on the central database.

- 18.8.3.8** Each SCADA workstation shall be capable, at any moment in time, of sorting and filtering events in accordance with their priority to the level required by the operations personnel. A facility shall also be provided to enable a summary printed event record report to be prepared, listing not only the current active events, but also any events, including faults and alarms, reported and/or cleared during the period since the previous summary report. The event records shall also be able to be interrogated in a structured manner to determine the trends and associations between different events based on association by location, time or equipment type. All data records associated with the day's railway service once stored within the central database shall be collated, sorted and accessible within one minute of a request being issued by any workstation in the SCADA system.
- 18.8.3.9** The logging list shall have various filter facilities to enable the Power Controller to display different format of events. The filter keys shall typically include:
- a) location
 - b) equipment group
 - c) time period
 - d) event category
 - e) other options
- 18.8.3.10** Any combination of the filter keys shall be possible. When a filter is applied to the logging list, a specific display shall be presented to the operator to avoid confusion.
- 18.8.3.11** In the event that a particular incident gives rise to numerous SCADA events, then the SCADA workstations shall be capable of displaying either all such events or only the most all-encompassing event. In the event that the most all-encompassing event is chosen to be displayed, all the associated events shall still be recorded with the most all-encompassing event.
- 18.8.3.12** The SCADA system shall produce regular automatic reports of the overall power system reliability indices with faults categorized by system (e.g. feeders, HV Power etc.) and by location (e.g. TSS, ASS etc.).
- 18.8.3.13** All databases established within the SCADA system shall be accessible for maintenance and exporting of data as required by the Engineer/UPMRC. This requirement shall also include any database used to configure the graphics used on the workstation VDUs. The Contractor shall supply the necessary database tools, manuals, documentation and training required to enable the maintenance and exporting of such data to be performed.
- 18.8.4 Alarm management**

- 18.8.4.1 Alarm Procedure:** The purpose of the alarm procedure is to draw the Power Controller's attention and ensure that the information is taken into consideration, whatever activity being performed when the procedure is initiated. The alarm procedure shall generate a specific visual effect and audible warning on the operator workstation. The activation of the audible warning shall be configurable for major alarms. It shall be possible to disable the audible alarms by user for identified conflict alarms in SCADA system. Equipment having alarm shall blink in red colour and upon acknowledgment blinking shall stop. Disable of specific alarm of any equipment or multiple equipment or any specific signal shall not disable the complete or part or group or equipment alarm other than intended alarm disable condition. Alarm procedures may be generated in case of 'Alarm appearance' and 'Alarm disappearance'.
- 18.8.4.2** Alarms shall be generated in case of any change from "normal" to "alarm" ("Alarm appearance") value of a monitored state. The processed alarm shall be considered as an alarm appearance event and shall generate an alarm.
- 18.8.4.3** Similarly, alarms shall be generated in case of changes from "alarm" to "normal" ("Alarm disappearance") value of a monitored or processed alarm. This shall happen whenever a reconfiguration action is required from the operator in order to continue operation. The alarm procedure shall ensure that the operator is informed of the alarm disappearance so that he may restore normal configuration and continue operation.
- 18.8.4.4 Alarm List:** All alarm appearance events shall generate a record in the alarm list. The alarms can be removed from Alarm List if the alarm is not present anymore or the alarm has been acknowledged by the operator. Alarm disappearance events, which generate an alarm procedure, shall also generate a record in the alarm list. This record shall only be erased by the SCADA system when the concerned operator has acknowledged the alarm disappearance. All alarms which appear in the SCADA screen shall be logged in the log mode and shall not be erasable.
- 18.8.4.5** The SCADA system shall be able to handle various types of alarms, typically:
- a) **Monitored alarm:** - Shall be directly linked with the value of a field-monitored alarm.
 - b) **Complex alarm:** - Shall be the result of processing the values of one or more field events. This shall be in the nature of derived (computed) alarms to be defined during engineering.
 - c) **Conflicting alarm:** - Shall apply to a processed status resulting from several distinct field monitored states, when the sources give inconsistent information e.g. inconsistent inputs resulting from chattering of breakers or non-zero voltage/current appearing on SLD when corresponding breaker is in open state.
 - d) **Control failure alarm:** - When performing such remote control, the SCADA system shall check the correct monitored or processed status change. If this event does not occur after a predefined time, the SCADA system shall generate a Control failure alarm.
 - e) **Uncontrolled state change alarm:** - If a monitored or processed status associated to such remote-control changes without previous control action from the operator or the system, an uncontrolled state change alarm shall be generated.
- 18.8.4.6 Alarm Classification for Display**

- a) This classification shall be programmed in the OCC and the local equipment, but can be easily modified and reloaded in the OCC as well as in local equipment.
- b) All alarms shall be classified into four levels of priority. Each level of priority shall be segregated and characterized by a distinguishable colour and a display attribute (flashing, ...) that are the same on all the Workstations and the screens of the system:

Level 0:- used for non-severe alarms and events cases that do not need any acknowledgement from a Power Controller; it appears on the relevant view, then disappears when it disappears on site, without any Power Controller action;

Level 1:- used for non-severe alarms and events cases that however need acknowledgement from Power Controller. It appears flashing on the Workstation. The Operator acknowledges it, and then it is displayed as fixed. When it disappears on site, it disappears also on the Workstation without any other action from the Power Controller.

Level 2:- used for alarm cases that are self-maintained by the equipment, and then need an erasing control to stop the alarm signaling. The alarm is maintained active until the Power Controller sends an erasing control order that resets the alarm bit if the RTU input is back to the normal state. The alarm appears flashing on the Workstation. When the Power Controller acknowledges the displayed alarm, the alarm becomes fixed. When the RTU input goes back into its normal state, the erasing control becomes possible from the OCC;

Level 3:- used for severe alarms that are not self-maintained by the equipment and need acknowledgements after both appearing and disappearing of the alarm. The alarm is maintained active until the Power Controller sends an acknowledgement control. After disappearing of the alarm, i.e. when the input comes back to the normal state, it is also necessary to send an acknowledgement control. The alarm appears as flashing. When the Power Controller acknowledges the alarm, it becomes fixed if the RTU input is always in alarm state. When the alarm disappears, following acknowledgement or return of the RTU input to its normal state, it is displayed in flashing with a different colour. The operator then has to acknowledge the alarm again.

- c) The alarms and events as classified above shall appear in a display window. These shall be displayed on a priority basis. When there are several alarms or events of the same priority, the system shall establish another priority between them: the older they are, the lower is their priority.
- d) Event for an alarm acknowledgment by an operator shall be logged in the event list with details of that alarm (equipment under alarm, alarming state, date & time of alarm generation), date & time of alarm acknowledgment, operator ID shall be logged.

18.8.4.7 Audio Visual Alarm

- a) Generation of alarm shall lead to an audio-visual signal for the Power Controller. The signals shall be generated in such a manner that it immediately draws the attention of the Power Controller.

- b) There shall be different categories of audible alarms easily distinguishable by separate tones or sounds for events classified as emergency, urgent and non-urgent.
- c) A mute facility shall be provided to silence an individual or group of alarm. Once the event causing the alarm has been acknowledged, the alarm shall be muted. It shall be possible to acknowledge alarms individually or in groups from the alarm display page. When the status of an alarm returns to normal condition, a return-to-normal message to this effect shall be generated.
- d) The nature of all audible alarms shall be accompanied with a corresponding message, providing details of the alarm, which is presented on the workstation display. When an alarm is initially received a corresponding visual flashing indicator shall appear on the display. Once the alarm has been acknowledged the flashing indicator shall transfer to a permanent illumination.
- e) In the event of multiple events initiating audible alarms, only one alarm shall be broadcast at any time. The highest category of alarm shall always take priority, even in the event that a lower priority alarm is already being broadcast. Once the higher category has been acknowledged and muted, the next lowest category of alarm shall initiate the alarm broadcast.
- f) To avoid unnecessary and nuisance alarms or alarms generated by testing or chattering of a signal, a facility shall be provided to enable alarm blocking/filtering to inhibit particular or global alarms, from any workstation. Inhibited alarms shall activate an appropriate message, detailing the non-alarmed/blocked parameters and the remote terminal units affected. Blocking of an individual update, control, alarm and event for the various data base points shall be provided.
- g) Audible warning cancellation: The possibility of implementing an 'audible warning cancellation' facility shall be provided. When an alarm procedure has been initialized, this facility shall allow the Power Controller to stop the audible warning prior to alarm acknowledgement. The audible warning cancellation shall have no other consequence on the alarm procedure (the visual warning shall remain until alarm acknowledgement) and shall not interfere with the management of the alarm list. It shall also be possible to mute or cancel the audible warning of an individual alarm. Once the audible warning of higher category alarm has been cancelled, the next lowest category of alarm shall initiate the audible alarm broadcast.

18.8.5 Remote Control

18.8.5.1 The SCADA System shall transmit and execute predefined commands from the work stations to the field supervised equipment.

18.8.5.2 In normal operation, the Power Controller shall be able to control / operate the 220kV /132 KV /33 KV RSS/AMS equipments, traction and auxiliary supply equipment's e.g. 33kV system , 25 KV AC traction system & 750V DC System, etc..

18.8.5.3 Controls may be generated by Power Controller or the system and executed by the system. The Power Controller shall be able to take actions wherever and whenever required. In case of an emergency or abnormal situation, the Power Controller shall be able to control the various items of equipment, typically: isolation of the faulty sections or circuit, restoration of the normal configuration after the fault has been remedied.

18.8.5.4 The various outputs have been indicated in the section "Input/Output Requirement" in this specification. Following control functions shall be necessarily available in the SCADA:

- a) The SCADA system shall provide facility to open /close the breakers. It shall be guided by Remote / Manual control selection at the equipment. In case of remote selection, operation can be done from SCADA. In case of manual selection, the operation from SCADA shall be inhibited.
- b) It shall be possible to control the breakers and interrupter via Power Controller request or via automatic control procedures. The control functions shall be Close/Open of the equipment's as per IO Lists. The operator initiated Open/Close control functions shall be possible using Select- Check – Execute sequence.
- c) Control command logging: The SCADA system shall log the control operations by the operators in the event list so that any closing opening other than issued by the operator from SCADA can be differentiated from the event list.
- d) Authorization for Local Operation: In order to facilitate local maintenance of the equipment and to prevent unauthorized local operations, authorization for Local operation shall be provided by way of Access Control Rights so that the field operator can carry out operation of the power equipment only after the above permission is granted from the Control Centre. SCADA system shall ensure that no operation is performed without permission from the OCC. Further, even after granting the permission of local operation, the events and parameters shall continue to be monitored.
- e) Remote control inhibition management- Alienation of Power Supply Equipment: The Power Controller shall be able to inhibit /block the equipment control from SCADA system. This blocking action shall be available in the blocking list. The control inhibition/ control blocking shall be possible individually for each equipment being processed. The Power Controller shall be possible to cancel the blocking also. The user performing the blocking / deblocking shall be logged in the event list along with the details such as identity of the Power Controller who alienated the equipment, identification of the alienated equipment, its status when it has been alienated, time at which alienated, identity of the Power Controller that de-alienated the equipment, its status when it has been de-alienated, and corresponding time.
- f) This means that once the equipment is alienated, the “remote control inhibition” shall prevent any Power Controller from sending a remote control to that particular equipment. The SCADA System shall handle, for each controllable item of equipment, a control status, which is a combination of:
 - Local / remote operation,
 - Remote control inhibition.

18.8.5.5 The SCADA System Power Controller shall have access to a list showing all remote-control inhibitions currently active.

- a) To alienate equipment, the OCC Power Controller shall have proper level of access rights to de-alienate the equipment. An equipment alienated by a Power Controller can be de-alienated by a new Power Controller on condition that he has the same level of access rights
- b) An alienated equipment is displayed in the colour corresponding to its status (red, green or blue), and is accompanied with a special alienation symbol.

18.8.5.6 The blocking and deblocking actions shall be available in the SCADA system in the form of blocking list for Identification of the blocked equipment, status of equipment when it has been alienated, time of blocking.

18.8.5.7 Two types of control function as under are possible in the SCADA system:

- Manual control function: - Means the operator has to handle the switching sequence. In this scenario operator has to do the operation by manual judgement as per operational guide line from available SCADA HMI function. However, during this mode of operation, applicable pre-configured interlocks shall be in place.
- Automatic control function: - Means the switching sequences are controlled by the programmed function and / or hardwired control sequence interlock of devices itself. The pre-configured control sequence as applicable for emergency tripping, CTO etc. are example of such control mode. Such automatic operation as or when required or recommended through operational guide line shall be operator initiated or controlled to avoid any unwanted operation. Applicable alarm or operator alert shall be configured in SCADA application.

18.8.6 Logics & Interlocking

- 18.8.6.1** To improve the overall power availability, two separate incoming feeds are connected to different sources. In case of outage of a source, appropriate switching shall execute so that the other one supply feeds the power.
- 18.8.6.2** In case of power failures, the system redundancies shall be operated to restore power to the system. There shall be a provision to operate these redundancies and interlocks through automatic mode or through manual mode.
- 18.8.6.3** In automatic mode, the complete sequence shall be designed and operated in an appropriate manner to ensure safety of equipment and personnel.
- 18.8.6.4** In manual transfer mode, it can be transferred with breaking or transfer without breaking. In transfer with breaking the faulty switchgear is opened first and the other one is then closed. In transfer without breaking mode the operator selects the switchgear to be opened and closes the one in parallel. The electronic device implements the sequence with the appropriate time out.
- 18.8.6.5** In case of a breaker or any equipment operation is interlocked, the SCADA software shall be having the feature of displaying that particular device on the HMI with a tag, crossing line or in a specific colour showing that the device is interlocked. SCADA software shall also provide the feature of enabling/disabling the remote operation of the interlocked devices. In addition to this, execution of any forced remote operation of an interlocked device shall be possible from a separate command window. It shall also display a warning message indicating that the device is interlocked and shall ask for an additional confirmation of the operator before executing the command.
- 18.8.6.6** It shall be possible to read all interlocking conditions in a separate pop-up window which are currently prevailing for an interlocked device.
- 18.8.6.7** The Remote Monitoring of CBs and Isolators shall be doubled and complemented: two bits: bit 1 and bit 0. Once received a test of verification shall be carried out; if not correct, an alarm shall be shown. The value « 1 » represents the active position (effective position).

- 18.8.6.8** The Remote Monitoring of other equipment is simple and not complemented. The value « 1 » represents the active position, except for: bus-bars, and 3rd Rail, for which the value « 1 » represents absence of voltage.
- 18.8.6.9** The following interlocks mainly to be provided but not limited to:
- a) Breaker – Isolator interlocking: It shall not be possible to operate Isolator when consecutive Breaker is in Close condition and Breaker operation shall not be possible when Isolator is in Open condition.
 - b) 33kV ASS Ring Network Interloop Interlocking: When Potential Transformer of consecutive loop is showing voltage, extending power from one loop to other shall not be possible.
 - c) (n-1) interlocking in 33kV network loops.
 - d) 2/3 interlocking at RSS/AMS incomer, 415 V LT incomer of ASS LT.
- 18.8.6.10** The Contractor shall implement any other additional logics or interlocking as required for power supply system security and suggested by Engineer in Charge during implementation stage.
- 18.8.7 Tele Measuring**
- 18.8.7.1** In the power system, some of the data needs to be measured and monitored like Voltage, Current, Frequency, Power factor, consumption of energy for receiving substation, traction and auxiliary services. Dedicated equipment picks up the relevant information and in turn delivers to the local RTU which translates them into a digital value to be sent to OCC and BCC.
- 18.8.7.2** The voltage and currents measurement requirements are indicated in IO Requirement Section in this specification. The list shall be covered in scope of the RTU. The RTU shall be provided with necessary analogue input modules to receive the 4 to 20 mA signals from the transducers of equipment like PTs. The transducers required at RTU end shall be in the scope of the SCADA Contractor.
- 18.8.7.3** This information shall be recorded and used for several purposes among which statistics, consumption supervisory, etc. are few examples.
- 18.8.7.4** The measuring functions shall sum the integrated power consumption of the various equipment (RSS/AMS, TSS, and ASSs), and current values or voltage values on several parts of the network.
- 18.8.7.5** The energy (i.e. kWh, kVAh, pf) shall be measured for each equipment supplying the network i.e.
- a) Each 220/132/33 kV incoming at RSS/AMS
 - b) Each 220/132/33 kV outgoing feeder
 - c) Each 33kV CB feeding power to auxiliary transformer in ASS
 - d) Each 33kV CB feeding power to rectifier transformer in TSS
- 18.8.7.6** The measuring of maximum demand shall be made at a cyclic interval of time. The measurement shall be done through latest digital signal processing-based multifunction meters.
- 18.8.7.7** Voltage & Current shall be measured at following points.

- a) Each 220/132/33 kV incoming from PSA,
- b) 33kV at RSS/AMS, ASS and TSS level
- c) 750VDC/25 KV AC at TSS level

18.8.7.8 The analogue value shall be updated in every 1 seconds or when crossing a set threshold range. For 750 V DC voltage, 5% threshold range shall be configured in SCADA. They shall be displayed on the Operator Workstation. It shall be possible in SCADA to configure different limit ranges for measurement analogue values. Alarm shall be generated in case of normal limit/range violation with different alarm colour and priority for different limit ranges (normal, warning etc.). Suitable provision shall be made in the system to define two level of alarm on either side of the value or which shall be user defined for each measurand.

18.8.7.9 Energy values from energy meters of the RSS/AMS have to be hooked up to main OCC and BCC.

18.8.8 Information Search & Retrieval (IS&R) and Report Generation

18.8.8.1 A data and software storage system (archives) with removable storage media facilities shall be provided at the OCC & BCC for the historical storage of database records and software.

18.8.8.2 IS&R function shall provide for periodic history of analogue and status data. History shall take place in standard RDBMS package like MS SQL Server, Oracle etc. IS&R shall support archival of history data in external mass storage media. The archived data shall be retrievable on demand for analysis.

18.8.8.3 Web based reporting function shall support following types of reports based on data availability:

- a) Standard substation parameters like MW, MVAR, Amp, Voltage etc.
- b) Frequency / voltage band violation report
- c) Energy exchange report
- d) Substation energy balance report
- e) Reliability Indices
- f) Equipment operation report
- g) Hardware Status report
- h) Additional user configurable report

18.8.8.4 These reports shall be available on shift / daily / monthly and yearly basis on query. It shall be possible to export the generated reports into MS excel. The reports shall be based on time-related follow-ups of process, metered, entered or calculated data. The data for the reports shall be stored in real time. Report data is collected and calculated cyclically or triggered by events. The most common method is to fetch raw data from the process, and thereafter to scale and store it in the report database. All the events / reports shall be automatically written in text files and stored on hard disk in the reports folder of the application. Periodic backups of reports shall be possible. The measurement reports shall support the following time related reports:

- a) Hourly report (time resolution: 3 minutes)
- b) Daily report (time resolution: 15 minutes)
- c) Daily report (time resolution: 30 minutes)
- d) Weekly report (time resolution: 1 day)
- e) Monthly report (time resolution: 1 day)
- f) Yearly report (time resolution: 1 month)

- 18.8.8.5** The external network attached storage system shall utilize optical disc technology, which shall allow the data to be indexed and shall allow random and sequential searches. Each data storage facility shall have a capacity adequate to hold all operational and user programmable software as well as data records generated over the previous minimum period of 30 days without the replacement of storage media. All data records generated within the minimum 30 days period shall be available for recovery from any Control Centre workstations. Retrieval of such data shall not degrade the performance of the SCADA system.
- 18.8.8.6** An automatic alarm shall be triggered at the OCC Workstation in the event that the accumulated data and software is stored for more than a pre-defined period (maximum seven days) without being backed up. The bulk data storage system shall have sufficient capacity to provide a master historical data storage of all software and recorded data for the entire SCADA system. All software files contained within the SCADA workstations shall be able to be up-loaded to the OCC for historical data storage.
- 18.8.8.7** The historical data storage system shall index the storage media to enable rapid retrieval of data by date and time and be capable of event searches based on selectable criteria.
- 18.8.8.8** Printers that are connected to the Master Stations shall be used for printing of reports.
- 18.8.9** **Operational Aids**
- 18.8.9.1** Various functions shall be provided in the system to assist the Power Controller for operation. Some of the features are as follows, but not limited to:
- 18.8.9.2** Log on: Before commencing work on a workstation, Power Controller identification to the system shall be required. Log on window with password protection shall be provided for the purpose. After suitable display prompts, the Power Controller shall enter his / her name, password, and validate them, system access shall be granted to the authorized sessions.
- 18.8.9.3** Log off: The Power Controller shall log off to end a working session on a workstation. After the current operator has logged off and with no other Power Controller logged on, no supervisory, control, monitoring or other action on the SCADA system shall be possible from the workstation. Log on/Log off the operator working session by power controller shall be logged in the event list with details such as date & time, operator Id, device Id on which an operator has log on/log off.
- 18.8.9.4** Filing
- 18.8.9.5** Accountings
- 18.8.9.6** Reports as described above

- 18.8.9.7** Trends: The SCADA shall support trends for performing time related follow up of process data on historical as well as real time basis. The trends shall be possible for both digital as well as analogy parameters. The trend shall support a maximum of 10 trend parameters in a single trend window. However multiple such trend windows can be open to display all the analogue parameters. The trends shall be possible in both graphical and tabular forms which shall share the same database. The X-axis and Y-axis of the graphs shall be configurable in scale. It shall be possible to have different scan time variable in single display. The trend display shall support the following features:
- a) Support of Graphical or tabular view modes with zooming facility
 - b) Shall support Scrolling with scroll bars and panning
 - c) Configurable axes, line properties and legend
 - d) Update interval of 2-10 seconds
 - e) Trends for calculation formulas; direct, mean, sum and difference shall be possible
 - f) Shall have Printout option
 - g) Depiction of Update/Frozen modes
 - h) Facility to copy to clipboard and export to CSV File
- 18.8.9.8** Find, sorting by column, Copy/Paste of events to other windows application
- 18.8.9.9** Printing
- 18.8.9.10** Commenting of events by operator
- 18.8.9.11** Search with a provision of easy sorting through several criterion
- 18.8.9.12** Inhibits and tags
- 18.8.10** **Calculated Data**
- 18.8.10.1** It shall be possible to define the calculations on real-time data and historical data, periodically and on request. The results shall be incorporated into the database as calculated data available for display & report generation.
- 18.8.10.2** The user shall be able to define calculated analogue values using database points as the arguments and mathematical functions as the operations. Functions such as addition, subtraction, multiplication, division, maximum value, minimum value, average, count, square root, etc. shall be provided.
- 18.8.11** **Trending**
- 18.8.11.1** Trend displays shall enable the user to select real-time and historical data for trending on graphical displays and for tabular displays. In graphical trending it shall be possible to assign minimum 10 number of tags to a single window for trending. However multiple such trend windows can be open to display all the analogue parameters.
- 18.8.12** **Redundancy**

- 18.8.12.1** In order to ensure adequate safety and reliability for the operation, SCADA equipment mainly (SCADA servers, all network devices, key components of RTUs) shall be fully duplicated for redundancy. Such redundancy shall be achieved such that one of the units may be taken out of use without loss of overall functionality. An indication shall be available to the operating personnel of the status of all redundant equipment showing as a minimum the following states:
- a) in use;
 - b) hot standby;
 - c) initializing;
 - d) failed;
 - e) available isolated (cold standby); and
 - f) Unavailable (disconnected).
- 18.8.12.2** Once a failed unit has been repaired it shall be possible to re-connect and restart the unit at any time without any interruption to the rest of the SCADA system. The unit shall then update itself to the current state of the SCADA system without other manual intervention and without a change in functionality (other than incorporating the actual unit or providing the availability of a system hot standby).
- 18.8.12.3** Operations personnel shall be provided with a clear understanding of the actual status of all SCADA equipment and transmission paths at all times. A facility shall be provided in the OCC to enable the operations personnel to activate an operational changeover between an on-line and hot standby unit at any time without any disruption to the operation or functionality of the SCADA system.
- 18.8.12.4** At BCC, SCADA servers shall be provided in Non-redundant standalone configuration.

18.9 SCADA Software Requirement

The technical features of the SCADA software shall meet the following minimum technical features:

18.9.1 Acquisition of measurands

- a) The SCADA system shall be capable of acquiring measurands i.e. analogue inputs from the RTUs including transients.
- b) Software shall have capability for Analogue value scaling, processing and conversion to engineering values, limit settings of parameters.
- c) Software shall be fully configurable to analyze the analogue data received from RTU e.g. energy parameters (active, reactive and apparent power & energy), voltage, current and power factor in the form of displays (graphs as well as tabular), trends (graphs as well as tabular), alarms (frequency of alarms and switching trends in graphs as well as tabular form) to operator in case of set limit violations and historical interpretations.
- d) Software shall also be able to analyze the transient analogue data for detection of faults and their corrective measures
- e) There shall be facility to transfer the data to spreadsheet applications like MS-Excel in .xml formats.

18.9.2 Acquisition of tele signals

- a) The software shall support the acquisition of tele-signals (bi-state devices) for each RTU.

- b) There shall be dependent and independent points in the power supply system. For example, if a feeder Circuit Breaker Trips, there shall be associated tele-signals for catenary and 230 V AC fail. All such events shall be reported by RTU to OCC/BCC with time stamp.

18.9.3 Execution of tele-commands

- a) The Software shall be capable of issuing tele-commands to open or close a switching device. All the commands shall follow select – check – execute and report back execution procedure.
- b) Operator shall be able to cut off power to a sub-sector by selecting it and giving the command. The system shall open all the associated switching devices automatically in appropriate order with confirmation for each device as an event.
- c) Option to abort a command shall be available with the operator before giving the confirmation.
- d) All the operator commands shall be logged as events (with operator Id indicating the power controller who has executed the command) after a control command is issued by the operator, and if the command is not executed, then a message shall be displayed indicating reason(s) for it.
- e) The tele-command once selected, if not sent to RTU due to communication failure or otherwise, shall be aborted after a predefined period and shall not remain in queue.

18.9.4 Process Displays

- a) The SCADA software shall support flexible process displays for continuous & effective monitoring at OCC & BCC for the RSS/AMS, Traction & Auxiliary Power equipment on the power supply network of the LucknowMetro Rail.
- b) The process display feature shall facilitate depiction of Single Line Diagrams with flexible choice of colors for the process objects and backgrounds. The Process Displays shall support zooming & panning facility. The process display features shall be flexible enough to build the complete Traction network and the auxiliary network as a single Display with facility to navigate using mouse from one end of the network to the other. It shall also be possible to zoom portions for picture for getting a magnified view of the Single Line Diagram.

18.9.5 Alarm Management

18.9.5.1 Alarm Management System to alert Power Controllers & maintenance staff during equipment malfunctions or any other system alarms likely to cause disruption to operation of the railways. The alarm management function shall support:

- a) Two types of Alarm List templates
- b) User friendly filters, Alarm List setting tool for colors and text layout
- c) Updating / frozen presentation modes
- d) Alarm acknowledgement, Alarm reset function
- e) Authorization support
- f) Help in all dialogs
- g) Visible Alarm Class
- h) Locate Object
- i) Column sort, Find, Fields indicating the number of active and unacknowledged alarms
- j) Field indicating the use of filters
- k) Field indicating the current presentation mode
- l) Current / total page number indication on both lists

18.9.6 Event Logging System

18.9.6.1 Event Logging System for displaying and logging sequence of event recording with 1 millisecond resolution for the various field inputs configured at the RTU. The Event List contains the following features and options:

- a) Historical storage of events with facility to retrieve the same later
- b) Configurable layout: columns, fonts, toolbars, colouring and so on
- c) Configurable colouring of events
- d) Configurable scrolling behavior
- e) Configurable presentation modes: log / event order, latest at top / bottom
- f) Updating / frozen presentation modes
- g) Easy navigation through scrolling, go to date, time filters and so on
- h) Extensive filtering that can be stored and easily called up later
- i) Multiple station filtering to filter out more than one location simultaneously
- j) Find, sorting by column, copy / paste of events to other windows applications
- k) Printouts
- l) Commenting of events by Power Controllers

18.9.7 SCADA Software configuration

18.9.7.1 The software shall provide menu driven and user-friendly configuration. The configuration shall define the various devices, their attributes and the traction system specific details. The configuration of the software shall be carried out to cover all details/address/nodes of traction supply operation e.g. Interlocking, locked out signals, protection relays & elements, alarms with attributes, power blocks, parameter settings and display/picture screen properties etc.

18.9.8 Test Procedure & Diagnostics

- a) The software shall support basic test procedure and diagnostic checks for RTU as per IEC 60870-5-104 & basic standards of IEC 60870-5 series. As in IEC 60870-5-104, there is no periodic polling for Class1/Class2 event from the master and all events shall be reported by exception from the RTU. The only periodic poll from the master shall be the general interrogation, at intervals not exceeding 10 minutes. Apart from this, master shall send a TESTFR packet 10-15 seconds, to check the health of the RTU and communication media.
- b) SCADA application software shall have minimum following inherent features to check its own sub functions and report status to the operator:
 - Operating Status & Online (Hot)/standby /offline state of SCADA server/communication front ends.
 - State of all RTUs.
 - State of printers.
 - Connection & Operating status of all the operator workstations.

- Diagnostics shall use standard OS tools to be provided as part of the administrator tools.

18.9.9 Communication Failures

- 18.9.9.1** Time out of the RTU and the cyclic redundancy check (CRC) errors shall be progressively counted and displayed in a tabular report as “Communication failures” for each RTU. The tabular report shall be generated at 04:00hrs every day for the preceding calendar day of 24 hours.

The communication failure/restoration shall appear in MMI within 0-45 seconds.

- Connection status of all the operator workstation
- Communication as well as health status of energy meter and numerical relay.

18.9.10 Hot-Standby Redundancy

- a) Switch over to hot-standby systems
 - Hot standby systems shall be designed to improve the reliability of SCADA system by having back-up machines that automatically takes over when the primary fails.
 - The standby systems for the main server shall ensure that there shall be no loss of data, alarms, event etc. due to the failure of primary server and data shall be updated normally after the failure occurs.
- b) Switch over of cold-standby systems
 - In the event of failure of primary server, the system shall ensure that the stand by server computer system automatically takes over including the data acquisition and the communication with RTUs over the existing channels. In any case the changeover from main to standby computer shall not take more than 30 secs from the point of view of SCADA system working. The failure of primary server shall be displayed on all HMI's along with suitable alarm indication.
 - The system shall be configured on dual Ethernet LAN wherein each computer and server shall have two LAN interfaces. From each computer, one LAN interface shall be connected to first network switch and the second interface to the other switch. After achieving this connectivity, it shall be ensured that any failure of one LAN interface of computer, any one LAN wire, any one LAN switch shall not cause permanent break in LAN connection between any two machines. In any such condition, the system shall be able to restore alternate LAN route within 30 seconds. None of the equipment shall be declared offline/disconnected during LAN failure. Server hot standby switch over shall not be initiated due to a single LAN card failure.

18.9.11 Data logging and Reports generation:

- a) All alarms and events shall be logged by the system. Average, minimum and maximum values of selected analog parameters shall be stored. The duration of this logging shall be settable and logged data shall be stored automatically with date (year, month and day) and time (hours and minutes) stamp in a file. The software shall be capable of generating different types of reports.
- b) Some of the reports which may be required are: -

- Summary of circuit breaker's tripping during a specified period including the relay(s) which caused the tripping;
- Power block availed report;
- Event and their durations during the month when the voltage went beyond permissible levels at the RSS, TSS& ASS respectively; & parameters of excesses
- Duration during the month when the current exceeded nominal full load capacity of the transformer;
- Energy data interpretation, MD violation.
- Morning reports of all the abnormal incidences in the last 24 hours.
- Generation of reports for the downtime of the servers.

- The SCADA software shall support configuration of time related measurement reports
- Reports shall be defined based on historical data as well as real time .
- Reports shall be generated in .CSV, .TXT or any other suitable format and displayed on user screens.
- The contents of reports shall be defined from the engineering workstation.
- Support both single-point-in-time and time-range reports.
- Allow for scheduling reports at specific times, periodically, upon operator request, or event-initiated.
- Allow for customization of report content, format, and layout.
- Enable filtering of data to generate specific reports.
- Implement a system for archiving reports for future reference.
- Integrate the reporting system with other applications for further analysis or visualization.

18.9.12 Tabular displays, Current & Historical trends diagrams/ graphs:

- a) The software shall be capable of providing tabular display of data of a controlled station e.g. equipment status, alarms and measurands.
- b) The time versus value plot of measurands in a separate colour including the arithmetic values on the measurands such as multiplication shall be displayed in a trend diagram. The trending shall include both historical trending and dynamic trending of current data.
- c) The dynamic (current values) trending shall update at an interval of 2-10 seconds and shall be logged for 24 hours. For historical trend, average value of data shall be logged at the interval of 5 min duration.
- d) It shall be possible to store historical data of 5 years. If required a separate server may be provided at backend to store historical data.
- e) However, all data shall be accessible from the main screen where operator normally watch the recent data.

18.9.13 Measurement Reports

The SCADA software shall support configuration of time related measurement reports as detailed in Clause 18.9.8.

18.9.14 Printers

- a) The SCADA software shall support a minimum of two data-logging laser printers connected on SCADA LAN. It shall be possible to display status of each printer in SCADA.

18.9.15 Help functions

- a) On-line help and tutoring guide shall be provided for all major functions in the HMI using the HELP option. The help option shall guide the operator for any specific help for carrying out certain tasks.

18.9.16 Safety Tagging

- a) Tagging facility with addition of note marker shall be provided on each item / equipment for operator to put his comment and inhibit the command for that equipment.
- b) Note marker shall be possible for any alarms, equipment status including manually operated isolators, measurands and limit-settings, through keyboard.
- c) This note shall be saved even on the condition of change over and change of operator.
- d) The operator shall be able to give some specific instructions to the shift operator using this functionality.
- e) This shall be logged in the event list with date & time, operator Id who is putting or deleting the note and that particular equipment Id.
- f) After this note has been enabled, issuing of command shall not be possible from any operator or other control rooms until this note has been over-ridden by the chief SCADA operator.
- g) The note shall not be lost on system restart or any such scenario.
- h) Tag can appear near to any breaker/device symbol. Tagging facility shall be configurable for multiple states of an equipment such as L/R Status, MTR Status etc. Upon resetting of the status tag shall automatically disappear.

18.9.17 Breaker Operation Counter

The system shall monitor operation counter of the breakers. The operation counter shall segregate normal operations and fault tripping after analyzing the associated trip relay data. It shall generate alarms after a predefined limit of normal & fault operations is reached.

18.9.18 Block/Un-block control for devices

Facility shall be provided to block / un-block a control point (circuit breaker, interrupter and other controllable equipment or a set of controlled equipment at the controlled station). The block or unblock command shall disable/enable control operations from the OCC. The blocked condition of any equipment or a set of equipment shall be suitably indicated on the monitor. It shall also be possible to block / un-block the control/update/event/alarm of an individual signal or I/O point of any controlled equipment of the installation.

18.9.19 Blocking List

The SCADA software shall support feature of Blocking List which shall depict the prevailing blocking status of update, Control, Alarm and event for the various data base points along with the name of the Signal text used in the SCADA system.

18.9.20 Screen Design & Real Time Display

- a) The MMI screen shall generally comprise of title bar, menu bar, tool bars, status bars etc. for real time depiction & control of traction power system. This interface shall provide for all interactions between the operator and the SCADA system.
- b) The MMI shall have features for alerting the operator with audio/visual supports on occurrence of critical alarms and events.
- c) Full graphic, coloured displays of controlled stations shall be provided by the software. The display shall include ON/OFF status of equipment, (such as feeder CB trip, AC and DC voltage fail/low, RTU fail, communication fail, machine down etc.), alarms, measurands and names of the controlled stations.
- d) There shall be facility for viewing display of full section, suitably condensed to fit screen size. This condensed picture shall be displayed on the MMI when called by the operator. Condensed diagram shall have fewer details as compared to the normal display but operator shall be able to control any of the devices and accept / acknowledge any alarm. The display shall support decluttering, zooming and panning through mouse.

18.9.21 Bus Bar Coloring

- a) The SCADA software proposed shall support necessary busbar colouring feature by which the dynamic status of the busbar can be depicted during charged and dead (discharged) conditions.
- b) The bus bar coloring shall be provided for the overall feeding scheme, 33kV distribution scheme, ASS over view diagram, Traction Over view Diagram, Traction individual screens.
- c) Earthed equipment, blocked equipment, faulty equipment, faulty status, communication failures shall be displayed in separate colors.
- d) The colouring shall be provided on all screens (overview / individual or sub-picture) at all the times.
- e) It shall be possible to give a specific colour to any section based on an intelligent rule.

18.10 Power Block Management System

18.10.1 Power Block Identification

18.10.1.1 Power block for maintenance or inspection shall be granted by the power controller in the OCC/BCC after identification of both the persons granting the block i.e. (the controller and the authorized person requesting the block through a system of passwords & interlocks). The block shall not be cancelled & section is energised unless the block is cancelled by the person who has taken the block. In case a tele-command is attempted for energising the device/ section under block, the command shall be aborted, and a warning/hazard message shall be generated at OCC/BCC and at RTU end (in case command executed locally from RTU).

18.10.2 Granting the power block

18.10.2.1 The software shall have facility to select the device/section to be brought under power block and kept under, power block or to be taken out of power block.

18.10.2.2 It shall be possible to select a number of circuit breakers/ Interrupters required to be operated for making a section dead and a group command shall possible to be issued. The system shall be open all devices, which are put under power block by the operator. The operation shall be confirmed for each device as an event. Predefined sequences shall be configured and saved for granting power block.

18.10.2.3 Operator shall be able to cut off power to a sub-sector by selecting it and giving and confirming the command. The system shall open all the associated switching devices automatically with confirmation for each device as an event.

18.10.2.4 The operator shall have to enter the details of the power block like the operator's code number, and time duration of power block. All power block details like operator's identity, time of imposition and section shall be recorded along with system time.

When a device/section is under power block, it shall not be possible to operate/charge it, unless the power block is first cancelled from the OCC/BCC. In case a telecommand is attempted, a failure message shall be given to the operator.

18.10.3 Cancelling the power block

18.10.3.1 On receiving the authorisation of the field supervisor having been granted power block, the operator shall select the devices or the section on which the block has to be cancelled and give power block cancellation command. With this the power block of the devices/section shall be removed.

18.10.3.2 It shall be possible to display or print the information of all power block details giving clear details regarding operator's identity, time of imposition and its cancellation. Power block details shall be stored in the database for later use.

Message pad: One page shall be provided for the operator to record/add important messages. They can also be edited and removed by the operator. The messages will be retained by the system even if the MMI is shutdown. When it is brought up again, the last entered message shall be viewable by the operator. The messages entered in hot system shall be automatically replicated to Standby system when SCADA failover takes place

There shall also be a facility to put "REMARKS "notes on MIMIC to any Equipment, Parameters, and interconnections.

18.11 Emergency Tripping System

18.11.1 General

18.11.1.1 Objective of Emergency Tripping System (ETS) is to achieve an electrical tripping scheme to de-energize the third rail section during emergency conditions. Upon activation of ETS, ETS shall proceed through a pre-determined programme of operation of circuit breakers and relevant interrupters to de-energize the third rail sections.

18.11.1.2 The Traction and power supply contractor's scope of work includes engineering, supply, installation, testing and commissioning of ETS, control & power cabling and integration with SCADA system and signalling system separately.

18.11.1.3 Every ETS Box is consists of a unit which is fire protected and with a breakable glass, containing the emergency push button. ETS boxes shall be cabled to the nearest SCADA RTU through armoured cables for digital input signal of the ETS push button and ETS activation.

- 18.11.1.4** The digital input signal of the ETS activation shall be sent to signalling system also so that upon ETS activation and de-energization of the third rail section, the rolling stock in the de-energized section shall be provided an input for the application of Emergency braking by signalling system in order to stop. The Signalling contractor shall coordinate with Traction power supply contractor for the necessary interface in order to achieve the required functionality with complete testing in all terms.
- 18.11.1.5** Emergency Trip System (ETS) shall be provided at each end of the station platforms, SCR, Cross passage in tunnels, TSS and in depots as per the requirement of NFPA 130.
- 18.11.2** Specifications
- 18.11.2.1** The ETS shall be provided in accordance with NFPA-130 (Fire Protection Standards for fixed guide wall transit system).
- 18.11.2.2** Emergency Tripping System (ETS) is to achieve an electrical tripping scheme to de-energise the third rail section during emergency conditions. ETS consists of ETS boxes, its interconnection with tripping circuit of feeder HSBC, hardwired inter-tripping function between adjacent stations, and interface with SCADA system and signalling system. Upon activation of any of the ETS box at a particular station following sequence of operation shall follow.
- All feeder HSCBs of that particular station shall trip. This shall be achieved through hardwired logic circuit implemented between ETS boxes and feeder HSCBs.
 - Tripping of these feeder HSCBs shall activate the hardwired inter-tripping function between the particular station and its adjacent stations (TSS). Accordingly, all the respective HSCBs feeding the affected particular section shall trip.
 - SCADA shall monitor operation of ETS activation, tripping of feeder HSBC (and its status) due to ETS activation and tripping of feeder HSCBs (and its status) due to inter-tripping.
 - In the event of HSCBs failure of open on account of failure of inter-tripping or any other reason a back-up logic shall be built in SCADA at OCC and BCC, which shall activate after definitive time delay (to be decided in consultation with Engineer during detailed engineering stage) and a trip command shall be generated from OCC/BCC for all the feeder HSCBs connected with affected section.
- 18.11.2.3** The Traction contractor shall develop a detailed implementation logic and submit for Engineer's approval.
- 18.11.2.4** The ETS unit shall be a highly visible, vandal-resistant wall-mounted stainless-steel emergency phone station with built-in flashing LED blue light and lighted faceplate. The LED blue light shall be of continuously lit type. Under any emergency conditions person/passenger shall push the button or for any other de-energising make a request call to OCC. Telephone is a hot line telephone with heavy-duty handset supplied by Telecom Contractor. ETS unit shall be connected with Fire Survival Cable up to the equipment where the hardwired logics are built.
- 18.11.2.5** The ETS unit shall be constructed of minimum 12-gauge #4 vertical brushed marine grade 316 stainless steel. Unit shall be designed to withstand prolonged exposure to harsh environments. The finish shall be uniform and free of visible defects.

18.11.2.6 The blue light shall be a 7.8-watt high efficiency, all-LED construction light. The unit shall retain 70% of its initial lumens after 50,000 hours of operation. The unit shall lit at all times. The blue light shall have a rating of 209 lumens (peak). The unit shall have a concealed ultra-bright LED assembly to illuminate the emergency phone faceplate at all times. LEDs shall have a lifetime of 100,000 hours.

18.11.2.7 Each ETS box shall have minimum cable entry/exit for:

- a) Power supply Cable
- b) Control Cable of fire survival type to RTU
- c) Telephone Cable

18.11.3 Features

18.11.3.1 Some Particular features of ETS station are as follows: -

- a) Fire Protected Cover
- b) Heavy duty telephone hand set
- c) Blue locations – indicating light and emergency push button
- d) Wall mounted ETS Box of approximate dimension 500 x 350 x 225 mm (Height x Width & depth)
- e) There shall be no infringement of ETS Boxes with the moving dimensions of the Rolling Stock.

18.11.4 Installation and Operation

18.11.4.1 ETS Boxes shall be placed at the following locations:

- a) End of each Platforms
- b) Station Control Room (SCR)
- c) Cross passage in tunnels
- d) Traction Sub-Station (TSS)
- e) Depot

18.11.4.2 The ETS cable system being an item of vital nature shall be protected from physical damage and shall be capable of withstanding temperature upto 950° C for three hour and in that condition does not support combustion as provided as per NFPA-130. (Category C BS 6387).

18.11.5 Types of ETS

Four types of Emergency Trip Stations (ETS) are proposed:

- 18.11.5.1** Type 1: The Emergency Trip System shall be used for switching off the DC Traction Power Supply on the main line of the particular sections near the ETS in case of urgently needed access to the track. Type 1 ETS shall be provided with heavy duty telephone hand set provided by telecom contractor.
- 18.11.5.2** Type 2: Type 2 is similar to Type 1 and provided at the cross passage in tunnels.
- 18.11.5.3** Type 3: The Emergency Trip shall be used for immediately switching off the DC Traction Power Supply in the depot area (including at Depot Road crossings to tracks & at critical locations in Depot) in case of electrocution incident or imminent danger thereof.
- 18.11.5.4** Type 4: The Emergency Trip shall be used for immediately switching off the DC Traction Power Supply of the stinger in the workshop area in case of electrocution incident or imminent danger thereof. All stingers shall be switched off by hard wired relay control.
- 18.11.6** Locations of ETS

The Emergency Trip Stations shall be located at:

Table 18.4: Location of ETS

Type	Location
Type 1	ETS at the ends of the platform and in SCR shall be combined with a direct line telephone to the Engineering Controller within the OCC and a blue light
Type 2	At Cross passage in tunnels
Type 3	At depot road crossings to the tracks
Type 4	Inside the Workshop for each track which is equipped with a Stinger

- 18.11.6.1** Type 1 ETS shall be combined with a direct line telephone to the TPC within the OCC and a blue light.
- 18.11.7** Functions of the Emergency Trip Stations (ETS)
- The Emergency Trip Station fulfils the requirements in the depot area and of station conditionally on the line. The following functions of the ETS are envisaged:
- 18.11.7.1** Type 1–ETS at platform ends of stations and in SCR:
- Type 2 – ETS at Cross passage in tunnels:
- Equipped with a mushroom shaped button that only can be released using a key.
 - The mushroom shall be inside the clear protective cover such as glass/polycarbonate with breakable tie to avoid unintentional operation by personnel at platforms and cross passage in tunnels.

- c) Activating an ETS at station platforms and cross passage in tunnels will send an individual Signal to feeder HSCBs/SCADA thereby tripping the Supply to the relevant feeding circuit breaker Station TSS as per logic defined in Clause 18.12.2.2.
- d) Trip signals will be sent to SCADA indicating an ETS has been activated.
- e) Together with the above mentioned the "yellow" indication light at the activated ETS will be turned on to indicate de-energized status.
- f) It is only possible to re-energize the tripped sections if the ETS has been reset by the key.

18.11.7.2 Type 3– ETS in Depot / trackside:

- a) Equipped with a mushroom shaped button that only can be released using a key.
- b) Activating an ETS shall send a signal to feeder HSCBs/SCADA thereby tripping the Supply to the relevant feeding circuit breaker Station TSS as per approved logic.
- c) A combined signal shall be sent to SCADA indicating an ETS has been activated.
- d) The position contacts (Open) of the circuit breaker together with the aux. contacts in the activated ETS shall turn on the "yellow" light at the relevant ETS indicating the de-energized status and showing which ETS has been used.

18.11.7.3 Type 4– ETS in Depot / Workshop:

- a) Equipped with a mushroom shaped button this only can be released using a key.
- b) Activating an ETS shall send a signal to feeder HSCBs / SCADA thereby tripping the Supply to the relevant feeding circuit breaker Station TSS as per approved logic defined. (MC in Workshop TSS/Stinger).

18.12 Remote Terminal Unit (RTU)

18.12.1 Hardware Requirement

The RTU at each ASS/TSS/RSS shall have as a minimum following configuration:

18.12.1.1 The Central processing unit shall have 32-bit microprocessor and shall have a dedicated peripheral bus controller for handling the IO functions. The CPU shall have minimum 128 MB of RAM and minimum 256 MB of SD Flash Memory to store archived data. The processor speed of the CPU shall be minimum 512 MHz. RTU shall have an internal clock with the stability of 50 PPM. The CPU module shall have non-volatile memory. CPU modules shall be provided with redundant hot-standby configuration. Operating status and Hot-standby status of each CPU module shall be remotely monitored at OCC/BCC.

18.12.1.2 RTU shall communicate with various peripherals. The RTUs shall support the following serial & Ethernet ports requirements:

- a) It shall have necessary communication ports for communication with at least 4 (four) control centres over IEC 60870-5-104 protocol.

- b) It shall have min. 4 nos. of 10/100 Base T Ethernet Ports for communication with OCC/BCC over IEC 60870-5-104 protocol.
- c) It shall have necessary communication ports for communication with both AC & DC numerical relays/IEDs on IEC 61850 protocol with provision of redundant ports and communication modules.
- d) It shall support data acquisition from Energy meters on MODBUS protocol on one port.
- e) The RTU shall have one suitable communication port which can be used for local configuration purpose.
- f) Each RSS/AMS RTU/gateway shall have necessary redundant communication port for transmit RSS data (analogue data, metering data and CBs Operating Status only) to UPPTCL SLDC through wireless communication over Web network with Firewall protection for the purpose of remote viewing only, if required. Any modem or wireless communication device and Firewall for external interface shall be supplied by SCADA contractor.
- g) The RTU shall be provided with necessary Ethernet Port for interfacing with the SCADA Ethernet Switches & Telecom equipment which shall be installed at Telecom Equipment Room (TER) at each station by the Telecom Contractor. Necessary communication interface and connection equipment between TER and the SCADA RTU shall be under the Scope of the SCADA Contractor.
- h) The OFC cables, converter or any other equipment required for terminating at the Telecom equipment would be in the Scope of the SCADA Contractor.

18.12.1.3 There shall be three types of I/O Modules connected to CPU:

18.12.1.4 Digital Input Modules: It shall have 16 optically isolated channels per modules and shall support time stamping with time resolution of 1 ms with buffering up to 3 changes. The digital input module shall support configuration of inputs for the Single Indications, Double Indications & Digital Measurements. The digital input module shall support the programmable parameters like

- a) Bounce Filter (Suppression Time),
- b) settling time for reliable digital measurand value,
- c) chatter suppression,
- d) suppression of intermediate position,
- e) Configurable with / without time tagging and configurability of message transmission priority.
- f) The digital input module shall also have the feature of indication processing of
 - group or common alarms shall be configurable from individual alarms by Boolean operations,
 - acquisition of events in chronological order with a time resolution of 1 msec and
 - buffering up to 3 changes per input.

18.12.1.5 Analogue Input Modules: Analogue input modules shall have 8 channels per modules and shall support 16-bit A/D conversion. It shall support unipolar and bipolar measured values with accuracy ≤ 0.1 % of full scale. Input shall be 4 to 20 mA bipolar or live zero. They shall also support programmable parameters like

- a) live zero conversion coefficient,
- b) cyclic transmission or threshold value,
- c) forced zero point conversion coefficient,
- d) limit values,
- e) smoothing factor,

- f) threshold values,
- g) cyclic duration and
- h) Priority of transmission.

18.12.1.6 Digital Output Modules: The Digital Output module shall support a minimum of 16 digital output channels per module. The output module shall support features like

- a) select before execute,
- b) priority of transmission,
- c) cyclic duration,
- d) release disconnection delay time at response indications and
- e) Duration of output pulse.

The RTU at each ASS/TSS/RSS/AMS shall have as a minimum following configuration:

18.12.1.7 There shall be a facility of remote programming for remote download of database for configuration or any modification purposes at OCC/BCC.

18.12.1.8 The critical components of RTU's like CPU card, Power Supply card, Communication card, Power Supply Converter, networking switch etc. shall be provided with dual redundant configuration.

18.12.1.9 One overview picture shall be developed in SCADA to show the status of CPU module, Communication module and each I/O module. Failure of any module shall be communicated to OCC/BCC so that timely rectification can be done.

18.12.1.10 RTU modules like CPU module, Communication module, I/O modules, Power supply modules, Diode coupler, Ethernet Switch etc. shall be provided with inbuilt LED indicators to monitor at RTU level the healthiness status, any fault status, error status, communication fault status, hot-standby status of respective module, individual communication port/link status of respective networking switches etc.

18.12.2 Communication Requirement

18.12.2.1 All the RTUs shall be linked to the OCC as well as to the BCC. The RTUs shall have provision for direct communication over 10/100Mbps LAN and RTUs shall support minimum four (4) communication ports. Connectivity to multiple control centre in future shall be possible.

18.12.2.2 All the RTUs shall have dual – redundant managed Ethernet switches for communicating to OCC/BCC over redundant FO communication backbone system provided by S&T.

18.12.2.3 RTU shall support communication over following protocols:

- a) IEC 60870-5-104 for communication with Control Centre.
- b) IEC 60870-5-103 Protocol for communication with Relays.
- c) IEC 61850 for communication with Relays/IEDs, Stray Current Device etc.
- d) MODBUS for communication with Energy Meters.

18.12.3 Functional Requirement

- 18.12.3.1** RTUs shall be intelligent, fully autonomous in operation and modular in construction. Remote terminal units shall be configured to suit the input/output requirements of the selected equipment they are connected to.
- 18.12.3.2** RTUs shall be suitable for floor mounting and shall be suitably robust. Remote terminal units shall be, as far as possible, of the same make and type and individual components shall be interchangeable between remote terminal units.
- 18.12.3.3** Remote terminal units shall be capable of being fully interrogated or reconfigured from portable test equipment.
- 18.12.3.4** It shall be possible to disable a RTU locally to allow maintenance or reconfiguring of the remote terminal unit without affecting other parts of the SCADA system. When disabled or enabled, a change of status condition shall be recorded as an event.
- 18.12.3.5** RTUs shall operate correctly in conjunction with independent safety systems, such as hard wired safety circuits for over temperature trips, over pressure trips, electrical interlocks on equipment, etc. Neither normal operation nor failure of the SCADA equipment connected to such systems shall prevent the correct and timely operation of such systems.
- 18.12.3.6** The memory of the RTUs shall be sized, in addition to holding all necessary programs and data, to store up to minimum 2,000 ~~4500~~ data points in the event of a SCADA communications failure. Operation of the remote terminal units or any other part of the SCADA system shall not be adversely affected as memory utilization increases to the maximum.
- 18.12.3.7** All recorded events shall be tagged with the date, real time, in hours, minutes and seconds, and milliseconds for high resolution events, and location of the event. The data shall be stored on non-volatile read-write memory, in a first in first out (FIFO) manner, such that the data shall overwrite the earlier recorded data. Access to stored data in a RTU shall be restricted by means of security codes. Portable computer based plug-in devices / Laptops shall be provided to read and evaluate stored data. Such reading process shall not erase or corrupt stored data.
- 18.12.3.8** RTUs shall be provided with a clock which shall support time synchronization from master station via periodically initiated synchronization messages of communication protocol. The SCADA system shall also initiate time synchronization messages when the communication with the RTU is restored after a communication failure. RTUs shall be provided with dedicated back-up power for the clock, so that in the event of a RTU suffering a power failure, the clock shall keep updating the time.
- 18.12.3.9** The RTU has to program for several logic functions which are required for the metro power supply distribution application. Hence the RTUs offered shall support PLC programming facility as per IEC 61131-3 standards (or latest version). Necessary programming tool shall be offered.
- 18.12.3.10** RTUs shall be compatible with the input/output signals from selected equipment. Power supplies contained within the remote terminal unit shall be available for the interrogation of volt-free contacts of the selected equipment.

- 18.12.3.11** Each RTU shall be supplied complete with 20% spare I/O signals capacity or min. 1 spare card of each type complete with RTU internal wiring and termination for handling additional input and output signals. Expansion by at least 50% of the initial capacity shall be possible simply by adding more input/output modules and reconfiguring the software. A further 100% expansion shall be possible by adding additional interfacing equipment in additional cabinets, etc. and reconfiguration of the software. Each RTU shall be supplied with min. 2 spare DIN Rails or mounting channels for mounting of I/O modules, MCBs, Terminal blocks etc. Each RTU should be supplied with licensed logic development software.

18.12.3.12 Parameter Downloading to RTU

The OCC/BCC software shall be capable of parameter downloading to the RTU in line with IEC 60870-5-104 & other basic standards of IEC 60870-5 series Some configurable parameters are as under

The SCADA software shall be capable of parameter downloading to RTU.

- i. Dead band settings for RBE (Report by Exception) of an Analogue value
- ii. Closed Loop Action settings for under voltage tripping

The above should be configurable through RTU's configuration file. The file can be Downloaded from OCC & BCC as well as locally to the RTU with password protection.

The RTU address shall be configurable. The RTU address should not be lost in case of power swings or surges It shall be possible for the UPMRC to reconfigure the address for the remote station. (The manufacturer shall train the UPMRC in the setting. configuring of the RTU's)

It shall be possible to configure and record selected set of analog parameters at a duration of 1 second. This function once enabled shall function continuously, and provide automatic retrieval at OCC/BCC of the recorded data. The data transfer can take place in buffered fashion, such that normal functions are not affected.

All switching station CPU, Power Supply, DI, DO, AI and any other module required for functioning of the RTU shall be interchangeable with changing the address to use the CPU at other RTU in case of failure and non-availability of spare CPU to restore the RTU .

The RTU shall be configurable to report analogue & status changes by exception to OCC/BCC However, RTU shall also support periodic reporting of analogue data and periodicity shall be configurable from 1 sec to 15 minutes. The dead-band for reporting Analogue value by exception shall be settable from 1% to 10% of the maximum measuring range. In addition, analogue values shall also be reported to Master station by exception on violation of a defined threshold limit. The threshold values are to be configured in the RTU so that any sudden variation in analogue value, like crossing a limit, or a significant change in the value is reported spontaneously to SCADA

The CPU if any manual intervention after restoration of power failure or communication failure or internal faults. All restarts shall be reported to OCC/BCC over the IEC 60870-5-104 protocol.

RTU shall be capable of being reconfigured (under password control locally from the laptop/portable programing device and from the Central Master Station by using RTU Maintenance Software. SCADA vendor shall furnish authentic copies of RTU Firmware in CD/DVD to the purchaser. Documents regarding file formats shall be submitted along with designs/drawings of SCADA to UPMRC for approval.

The RTU shall have self-monitoring/diagnostic for fault conditions. This shall provide various details such as, defective cards I/O cards, host lines, device status, command supervision etc. The RTU should generally support the test procedures as per standard IEC 60870-5-104. SCADA vendor shall submit the details of specific diagnostic function UPMRC at the time of design document and drawing approval. The RTU shall also support SNMP protocol to allow monitoring of the RTU modules and other diagnostic information from a Network Management System.

18.12.4. Environment Condition

The RTU hardware shall specifically meet the environmental condition of Lucknowregion and in general follow environmental requirements:

- a) EMC Immunity: As per IEC 60870-2-1 Level 3 or 4
- b) EMC Emission: As per IEC 60870-2-1 Class A
- c) Temperature: -10 to 55 deg C as per IEC 80870-2-2
- d) Humidity: 5 to 95% as per IEC 80870-2-2

18.12.5 RTU Panel

18.12.5.1 The RTU panel shall be of IP54 protections class and shall comply with EMC Immunity and emission as per IEC 60870-2-1.

18.12.5.2 The RTU panel which houses RTU hardware mainly consisting of the CPU & IO racks and power supplies, switches, interface converters etc. All panels shall provide enough space to house main and redundant components and shall be of IP54 protection class or higher for indoor panels and of IP55 protection class or higher for outdoor ones. For outdoor applications, the RTU exterior shall be epoxy based polyester powder coated or of SS-304 stainless steel grade.

18.12.5.3 RTU panels shall be having dual access i.e. front and rear access. All the CPU cards, I/O racks, I/O modules, power supply cards, converters, switches, LIU box etc. shall be mounted and installed on the front side of the RTU. All the terminal blocks, AC/DC cables, field interface C&M cables and wiring shall be located on the rear side of the RTU panel.

18.12.5.4 The designated station contractor shall provide individual earth terminal for the RTU's. RTU's shall be connected by the Traction contractor to this Earth. Traction contractor shall interface with station contractor for earthing requirement of RTUs. Kindly refer Chapter 3 of Tender Specifications for detailed SCADA interface requirements.

18.12.5.5 The Traction SCADA contractor shall submit the RTU General Arrangement drawings and wiring scheme to the Engineer in charge for approval.

18.12.5.6 Earthing link from MET & communication link with nearest TER shall be provided by Traction SCADA contractor.

18.12.6 Terminal Boards

18.12.6.1 Disconnecter type screwless spring cage clamp type terminal boards and Fuse terminal boards with LED indicator shall be used for ease in trouble shooting.

- 18.12.6.2** Terminal boards for receiving control & monitoring cables and AC, DC supply cables laid by other contractors from their equipment's to RTU shall be located in the RTU in such a manner that the other contractor can terminate & connect the cables in the TB without unlocking / opening the main door of RTU. TB shall have a separate lockable door with cable run ways for laying the incoming / outgoing cables neatly inside the RTU and suitable provisions for cable entry inside the enclosure.

In case of failure of CPU/PSU the redundant module will take care without interrupting the functionality of SCADA, and an alarm for the failed module shall be generated in the OCC/BCC and logged as to RTU shall have feature to monitor status of all IEDs connected to it from OCC/BCC. RTU shall be compatible to work with any make of master (SCADA server).

The redundant CPU shall have capability of synchronizing their states in order to maintain the most recent copy of the process state such as, I/O states, SoE in both CPUs. In the event of a switchover of CPUs, the newly promoted active CPU should have the most recent state as was before the switchover.

18.12.6.3 Protection against Surges

- The power supply unit/DC-DC converter of RTU shall have internal protections against under voltage, over voltage, overload and short circuits in addition to adequate protection against surges and lightening in compliance of IEC 60870-2-1, & IEC 60364-5-53 as applicable.
- Surge Protection Device of Class D type shall be provided in RTU for protection of RTU against switching surges travelling through communication line as per IEC 61643-21.

18.12.6.4 Cyber Security

- RTU shall support RBAC (Role based access control) according to IEC 62351-8
- Proper Encryption in the field data (data from RTU to OCC/BCC) shall be implemented as per IEC 62351 Standards as applicable.
- Proper Security measures and policies for handling unused communication port shall be taken.
- The firmware integrity verification (digitally signed firmware) shall be carried out prior to the firmware update.
- A patch management policy shall be adopted which shall be based on established standards like CLC/TS 50701. Enterprise patch management system shall be implemented as per IEC 62443-2-3 as applicable.
- Multi-level authorization shall be implemented for the firmware update operation as per patch management policy.
- The opening/closing of RTU door shall be stored as an event.
- RTU shall communicate with white listed SCADA servers only. Requests from unauthorized systems/IP shall be rejected and logged by the RTU
- All connection requests received by the RTU shall be logged using external protocol analyzer including connection acceptance and rejection.
- Access to RTU via its configuration software shall be protected using username/password combination. Facility to have multiple users with different access rights shall be possible.
- Access to RTU via its configuration software shall be archived and shall be stored in RTU as an event.

- It shall be possible to enforce configuration software access, only after appropriate access from SCADA software
- RTU shall prevent execution of unauthorized third-party applications

18.12.7 Transducer for Analogue Measurement

18.12.7.1 The RTUs shall acquire analogue signals like voltages and currents from the transducers, if required, via 4 to 20 mA analogue. The transducers at RTU end would be supplied by the SCADA contractor, if required, under Power supply contract. There shall be dead band of 0.5 kV for voltage measure of PT to reduce data traffic & loading of server, if required.

18.12.8 Test Sheet of RTU

18.12.8.1 The test sheets include Type Test, Routine Test, Acceptance Test and Integrated Test. The test shall be performed in accordance with the IEC standards mentioned in test sheet.

18.12.8.2 The tests defined in the sheet are indicative. The Contractor shall carry out all the tests and checks required for guaranteeing the engineer in charge of the satisfactory construction and the satisfactory operation.

18.12.8.3 The Contractor shall put in place a full testing program to demonstrate that all the requirements of the specification are met.

18.12.8.4 The Contractor shall develop Type Test, Routine Test, Acceptance Test and Integrated Test plan including details of all testing activities as specified, to verify the system in all modes of operation and with all necessary interfacing requirements. Test programs, methods and results shall be documented and submitted to the Engineer in charge for necessary approval.

Table 18.7: Test sheet of RTU

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	Integrated Testing
Dry Heat Test as per IEC 60068-2-2	X			
DampHeat Test as per IEC 60068-2-30	X			
Cold Test as per IEC 60068-2-1	X			
Temperature Change Test as per IEC 60068-2-14	X			
Vibration Test as per IEC 60068-2-6	X			
Series of Electromagnetic Compatibility Tests as per IEC 61000-4	X			
Series of Operating Conditions – Power Supply and Electromagnetic Compatibility Tests as per IEC 60870-2	X			
Degree of protection provided by enclosures (IP Code) as per IEC 60529	X			
Visual / Physical Inspection as per approved drawing		X	X	
Panel Paint shade and Thickness		X		
General Arrangement, Bill of material and Layout check as per approved drawing		X	X	
Electrical wiring check as per approved		X	X	

INDICATIONS	TYPE of TEST			
	Type	Routine	Acceptance	Integrated Testing
drawing				
System start-up and Power Supply Test		X	X	
Modules Redundancy check		X	X	
I/O and Functionality Test through simulator software		X		
Communication Test through Protocol simulator software		X		
Panel Earthing Test			X	
Power Supply Test			X	
RTU Communication Link Test			X	
I/O Signal Local Testing with power supply equipment			X	
I/O signal and functionality Test Integrated with SCADA and power supply Equipment				X
License for RTU			X	

18.13 Communication Network

18.13.1 Description

18.13.1.1 The integrated OCC/BCC (respective corridors) shall communicate with the East West corridor and existing North South corridor RTUs over IEC 60870-5-104 protocol via communication channel to be provided by designated telecom contractor/Telecom department.

18.13.1.2 The SCADA nodes (servers or RTUs) shall be connected to the telecom equipment installed at respective TER room via Ethernet interface. Necessary Managed Ethernet Switches or Routers or any other interfacing equipment wherever required shall be provided by the SCADA/Power supply contractor.

18.13.1.3 The OFC required for connection between the RTU/Servers and the Telecom Equipment Room at stations/OCC/BCC shall be under the scope of this Contract. Each cable shall be armoured type, FRLS in Elevated sections and FRLS0H in Underground sections with 100% redundancy.

18.13.2 Communication with Control Centre

18.13.2.1 The RTU shall be provided with necessary Ethernet Ports for interfacing with the Station Telecom Rack installed at TER room in stations. The SCADA contractor is required to connect RTU to station TER and SCADA Servers to CER/TER at OCC/BCC. The necessary cable (optical or copper as required), converters and other equipments, shall be in scope of SCADA contractor.

- a) The SCADA Contractor shall coordinate with the Telecom Contractor for the finalization of communication architecture according to the specifications set forth in this document as well as in the relevant functional specifications and system requirements.

- b) In order to achieve requested response times, the transmission network shall provide a dedicated bandwidth for the SCADA system. Telecom Contractor shall provide minimum 2 nos. fixed bandwidth (10/100 Mbps, as required) optical Ethernet ports in telecom rack at each RSS, station, depot, OCC & BCC TER for SCADA communication over transparent and dedicated TCP/IP link.
- c) The designated Telecommunication Contractor shall lay optical fiber along the corridor, on which different RTUs shall be connected. It shall be noted that the medium is outside the Scope of Supply of the SCADA Contractor. However necessary Ethernet switches, media converter, network router, FO termination box, FO patch cables, FO cables upto TER and other equipment required for connection to TER at each RSS, station, depot & CER/TER to OCC/BCC shall be under the scope of SCADA/Power supply contractor.
- d) LIU (Light Interface Unit) boxes at both ends shall be provided by SCADA contractor who shall interface with Telecom contractor for placement of LIU inside telecom rack at each TER/CER.

18.13.2.2 Each RTU shall be provided with dual redundant managed ethernet Switches each with min. 6x 10/100 Base Tx RJ45 ports and 2x 100/1000 Base FxFO ports.

18.13.2.3 SCADA contractor shall interface with telecom contractor and supply communication ethernet switches & other accessories for communication of RTU to TER compatible with the type of FO ports provided by telecom contractor in TER of each RSS, station, depot, OCC & BCC.

18.13.2.4 Telecom contractor shall also provide 100 Mbps or as required dual direct link connectivity between OCC & BCC.

18.13.3 SCADA Control Centre Network

18.13.3.1 The SCADA Servers, Workstations, Video Control Panel and other SCADA equipment etc. at control centres shall be connected over dual LAN to be setup by SCADA contractor. The required LAN switch/ routers and firewalls to achieve this shall be in scope of SCADA contractor. All the Ethernet switches at OCC/BCC shall be managed ethernet switches. In case of loss of any workstation, server, printer or any OCC/BCC SCADA equipment, an alarm shall be generated.

18.13.3.2 SCADA contractor shall supply and lay dual redundant armoured fiber optic cable from SCADA communication equipment installed in SCADA server rack at SCADA server room up to TER at OCC/BCC. FO cable splicing, jointing and patching shall be done by SCADA contractor.

18.13.3.3 Dual redundant armoured fiber optic cable from SCADA server room to OCC/BCC theatre room for communication in between SCADA servers and operator workstations shall be provided by SCADA contractor.

18.13.3.4 Any interface with external network or web network at OCC/BCC/RSS/AMS shall be achieved through Firewall/L3 Router. The Firewall settings and network configuration shall be validated from the OEM or manufacturer of the Firewall/L3 Router which shall be involved during design, configuration and commissioning phase. Firewall settings should be provided to UPMRCL along with O&M and troubleshooting manual.

18.13.4 Time Synchronization

- 18.13.4.1** The SCADA servers shall be synchronized with Lucknow Metro Rail Master clock which in turn shall synchronize the RTU's with the required periodicity.
- 18.13.4.2** The accuracy and resolution of the time stamping is very critical for analysing the events that occurs across various stations. To achieve this RTU shall be provided with clock which shall support time synchronization from master station via periodically initiated synchronization messages over IEC 60870-5-104 communication protocol.
- 18.13.4.3** Apart from periodically synchronizing the RTUs, the SCADA servers shall synchronize the RTU during start-up or after recovering from communication failure. The SCADA system shall also initiate Time Synchronization messages when the communication with the RTU is restored after a communication failure. If RTU loses time synchronization, event shall be generated for loss of synchronization at OCC/BCC.
- 18.13.4.4** The SCADA servers shall acquire the time synch messages over NTP protocol via TCP/IP link at OCC/BCC through the ports provided by telecom contractor.
- 18.13.4.5** RTU shall be provided with dedicated back-up power for clock, so that in the event of RTU getting off due to power failure, the clock shall be updating the time. When communication with an RTU is interrupted, all data from that RTU shall be marked with invalid time till the time synchronization with the RTU is established again.
- 18.13.4.6** All relays shall be synchronized by RTU using IEC 60870-5-103 or IEC 61850 communication protocol.

18.14 Master Station Equipment

18.14.1 Description

- 18.14.1.1** The Master Station Equipments shall be installed in OCC and BCC.
- 18.14.1.2** The SCADA contractor shall assess the requirement of the Master Station Equipment (including the networking & communication cabling) for achieving the desired functional & performance characteristic of SCADA system and submit the Engineer for the approval.
- 18.14.1.3** The SCADA contractor shall offer servers/software with latest technology prevailing in similar industry and launch date of model and key components shall not be older than one year from date of supply.

18.14.2 Hardware Configuration

The minimum configuration for various data processing equipment are as follows.

18.14.2.1 Server

Table 18.8: Details of Server

S. No.	Item	Description
1	Processor	PowerEdge R470 Server, Enterprise Processor: Intel Xeon 6 Performance

2	Main Memory (RAM)	64 GBM DDR-5 Memory Type & Speed: DDR5- RAID Configuration RAID 1
3	Hard Disk	2*1 TB SSD, Raid-1
4	Input Output Device	KVM Switch with LCD Display
5	Ethernet Ports (LAN)	2*10/100/1000 mbps LAN Ethernet Ports onboard, 3*Dual Port 10/100/1000 mbps Ethernet Card.
6	DVD-R Drive	16x DVD +/-RW ROM, SATA, Internal with double layer write capability.
7	Ports	4*USB, 2*Serial and 1*VGA Port onboard. 1*HDMI Port onboard 1*USB Keyboard and Optical Mouse. 1*Audio port 1*TPM Module Min. 4 nos. USB ports and 1 no. On-board USB port for installing hard license (if required)
8	Operating System	Windows Server Std 2022 (64 Bit) or latest
9	Power Supply	Redundant Power Supply
10	Server Type	Rack Mountable
11	Form Factor	1U or 2U
12	EMI immunity	As per IEC 801

18.14.2.2 Workstation**Table 18.9: Details of Workstation**

S. No.	Item	Description
1	Processor	i9 processor with 14 th generation CPU or latest
3	Main Memory (RAM)	Minimum 32 GB
4	Auxiliary Memory (SSD)	2x1 TB -Ent.24x7-7K-SSD
5	DVD-R Drive	SATA 16x Super Multi DVD Drive
6	Graphics Card	ATI/NVIDIA graphics controller with 4 GB RAM Dual Output
7	Ethernet Ports (LAN)	2x Onboard 10/100/1000 mbps Ethernet ports 3xDual Port 10/100/1000 mbps Ethernet card
8	Key Board	Standard Wireless QWERTY Keyboard

9	Mouse	Wireless Optical Scroll Mouse
10	Monitor	<p>Dual 24 inch LED display for all Operator Workstation & Training Workstation</p> <p>Native Resolution 1920 x 1200 at 60 Hz</p> <p>Aspect Ratio Widescreen – 16:9</p> <p>Colour Support 16.7 Million colors</p> <p>Brightness 350 cd/m² (typical)</p> <p>Screen Coating 44% Haze with 2H hardness</p> <p>Input Connection Min 1 x HDMI 1, 1 x VGA, 1 x USB 3.0, 1 x DVI, 1 x DP</p> <p>Tilt Swivel -170° to + 170°</p> <p>View Adjustment Tilt -5° to + 30° vertical</p> <p>Height Adjustable up to 4.72 in (12.0 cm)</p> <p>Pivot Rotation 90° to portrait</p> <p>Energy Class Class B</p>
11	DVD-R Drive	16x DVD +/-RW ROM, Internal with double layer write capability.
12	Ports	Min. 4 nos. USB ports and 1 no. On-board USB port for installing hard license (if required), 1*HDMI Port, 1*VGA Port
13	Interface	2 x DVI, 2 x VGA, 2 x DP or mini DP
14	Operating System	Windows 11 pro 64 bit or latest
15	Form Factor	Tower Type
16	EMI immunity	As per IEC 801

18.14.2.3 Ethernet Switch

Servers and peripheral devices shall be connected to each other on a dual local area network (LAN). Managed Ethernet Switches shall be provided for this purpose and shall have the following characteristics:

- a) Shall preclude LAN failure if a server, device, or their LAN interface fails.
- b) Shall allow reconfiguration of the LAN and the attached devices without disrupting operations.
- c) Shall be either controlled LAN such as Token passing or uncontrolled LAN such as CSMA/CD
- d) Shall support VLAN.
- e) Shall support spanning tree protocol support for redundant backbone connections and loop-free networks
- f) Shall have sufficient ports of 10/100 Mbps and 10/100/1000 Mbps Tx and 100/1000 Base X FO ports with spare ports of each type for respective switch as per detail design requirement.
- g) Ethernet switch provided at SCADA server room at OCC shall be Layer-2, managed switch with min. 24 nos. 10/100/1000 Mbps Tx RJ45 ports and 4 nos. 100/1000 Base X FO ports.
- h) Ethernet switch provided at OCC theatre room shall be Layer-2, managed switch with min. 8 nos. 10/100/1000 Mbps Tx ports and 2 nos. 100/1000 Base X FO ports.

- i) Ethernet switch provided at SCADA control room at BCC shall be Layer-2, managed switch with min. 16 nos. 10/100/1000 Mbps Tx RJ45 ports and 4 nos. 100/1000 Base X FO ports.
- j) Shall have dual redundant power supply.
- k) As or when required in compliance to latest network security guide line for SCADA system.

18.14.2.4 Firewall/L-3 Router

- 18.14.2.4.1 The SCADA LAN shall be provided with redundant firewalls/L-3 routers in order to deploy different security settings for access control in SCADA LAN. One set of redundant firewalls shall be provided, between SCADA dual LAN and external system interface. Each Firewall shall be a Layer-3 switch with security feature.

Each Firewall shall be rack mount Firewall system with following features.

- a) Data encryption supported DES (56 BITS) 3des (168 bits) and hashing algorithm like MD5 and SHA-1.
 - b) Shall have NERC, CIP, CERT-In compliance.
 - c) It shall have minimum 8 nos. Ethernet 10/100/1000 Mbps ports and minimum 4 nos. 100/1000 Base X FO Ports with spare ports of each type.
 - d) Shall support Layer-3 routing.
 - e) Support NAT and PAT
 - f) Filtering of packets based on Source address, Destination address, Protocol type, User, Port number
 - g) Denial of service prevention
 - h) Stateful packet inspection
 - i) Detailed system logging and accounting feature
 - j) No. of concurrent TCP Session supported shall be more than 5000
 - k) Capability of working in Hot-standby mode, VRRP
 - l) Radius Integration
 - m) Assigning zones to virtual and physical interfaces
 - n) Assigning firewall policies between zones, physical interfaces and virtual interfaces
 - o) Web based management interface
 - p) Definition updates for software patches up to DLP period.
 - q) Shall have dual redundant power supply
- r) RJ45 Ports 128 GB SSD onboard storage service (OT dashboards and compliance reports, OT applications and service detection, OT vulnerability correction, OT virtual patching, OT signatures-Application control and IPS rules)

18.14.2.5 Colour Printer

Table 18.10: Specifications of colour Printer

S. No.	Item	Description
1	Resolution	600 X 600 dots per inch
2	Print Speed Mono/Colour	A4 Mono 20 PPM / colour 20 PPM A3 Mono 15 PPM / colour 15 PPM
3	First Page Out	Less than 30 Secs

4	Duty Cycle	10000 per month
5	Interface	USB 2.0, 10 Base-T/100-Base-TX
6	Network Port Feature	SNMP enabled with network interface, security features and remote monitoring function
7	Paper Size	A3, A4
8	Paper Weight	80 to 160gsm
9	Duplex Printing	Built In Duplex Printing
10	Input Tray	250 sheets
11	Output Tray	250 sheets
12	Output Tray Page Orientation	Landscape and Portrait

18.14.2.6 KVM Switch & LCD Display

Table 18.11: Specifications of KVM Switch & LCD Display

S. No.	Item	Description
	KVM Switch:	
1	Computer Connections	16
2	Port Selection	OSD, Hotkeys, Push buttons
3	Console Port Connectors	1 x SPHD – 18 Male (Yellow)
4	KVM Port Connectors	16 x SPHD – 15 Female (Yellow)
5	FW Upgrade Connector	1 x RJ-11 Female (Black)
6	Power Connector	1 x DC Jack
7	Switches Port	16 x Pushbuttons
8	Key Board / Mouse Emulation	PS/2, USB
9	Scan Interval	1-255 Second
	KVM LCD Console:	
1	KVM Port Connectors	1x SPHD – Female (Yellow)
2	Power Connectors	1 x 3-prong AC socket
3	LCD Adjustment Switches	4 x Pushbuttons
4	Reset Switches	1 x semi-recessed Pushbuttons

5	Power Switches	1 x Rocker
6	Key Board / Mouse Emulation	PS/2, USB
7	Screen / Display Area	17" LCD
8	Display Screen Resolution	1920 x 1080
9	OSD Control	Yes, 4 buttons and 10 controls
10	Colour Support	16 Million
11	Contrast Ratio	700:1
12	Aspect Ratio	4:3
13	Tilt Angle	0 – 140°.

18.14.2.7 Central Backup Unit

18.14.2.7.1 An external network attached storage facility with removable storage media shall be provided at the OCC& BCC for the historical storage and backup of database records and software.

18.14.2.7.2 Each storage facility shall have a capacity adequate to hold all operational and user programmable software as well as data records generated over the previous minimum period of 30 days without the replacement of storage media.

18.14.2.8 Visual Control Panel

18.14.2.8.1 Designated Signalling contractor shall supply, install & commissioning of the Large Video Wall or LVDS (70" cube, Full HD, Laser light source) with Base Stands at OCC combined for Signalling and Traction SCADA system.

18.14.2.8.2 Signalling contractor shall allocate and provide min. 5 nos. of cubes (5 x 1 matrix – 1 row high and 5 columns wide) for each corridor (N-S corridor & E-W corridor) to Traction SCADA system for display of Traction and Auxiliary power network overview of Lucknow Metro.

18.14.2.8.3 Signalling contractor shall allocate and provide separate/dedicated Dual Redundant Display Wall Controllers for the LVDS cubes of Traction SCADA system.

18.14.2.8.4 Signalling contractor shall also provide support to Traction SCADA contractor for the maintenance of its allocated cubes and controllers from the supplier during DLP & AMC period and in case of any failure.

18.14.2.8.5 Traction SCADA contractor shall separately supply and lay power cables for its each LVDS cubes and redundant display wall controllers.

- 18.14.2.8.6 Traction SCADA contractor shall coordinate with Signalling contractor and UPMRC O&M for any fault rectification or maintenance support of its allocated cubes and controllers from the supplier during DLP and AMC period.

18.14.2.9 UPS & BATTERIES

- 18.14.2.9.1 Traction contractor shall interface with designated S&T contractor for the requirement of Uninterrupted Power Supply (UPS) feeder for Traction SCADA system at OCC.
- 18.14.2.9.2 Traction contractor shall provide the Load requirements of Traction SCADA system at OCC to the S&T contractor.
- 18.14.2.9.3 Designated S&T contractor shall supply, install & commissioning of the UPS & Batteries combined for Signalling and Traction SCADA system catering the load requirements of Traction SCADA system also at OCC.
- 18.14.2.9.4 S&T contractor shall allocate and provide the power supply feeder (3-Ph O/P supply, Ph-N: 240 V AC) at UPS output to Traction SCADA system.
- 18.14.2.9.5 Traction contractor shall also supply and lay the power supply feeder cable from S&T UPS room to the SCADA ACDB in SCADA server room and further power supply distribution to all SCADA equipments at OCC.

18.15 SCADA System Security

18.15.1 Description

The SCADA system shall support following security provisions

- a) Identification and Authentication
- b) Role Based Access Control
- c) Media Control
- d) Security from Malicious Code

18.15.1.1 Identification and Authentication

- 18.15.1.1.1 The workstations, servers and other resources shall have a restricted access to data and system.
- 18.15.1.1.2 To restrict access the SCADA system, each person accessing the system shall be required to initially log-in using some form of security access code. All logging activities shall be recorded including time of action, terminal and user.

18.15.1.2 Role Based Access Control

- 18.15.1.2.1 Besides access codes the system's 'Area of Responsibility' function shall govern the limits of access for each individual user. The access codes shall be assigned to individual persons based upon, as a minimum, the following access levels:
- a) Read all data: - All views shall be available, but controls are not allowed.

- b) Read all data and equipment control facilities. All views along with control and monitoring shall be available.
- c) Facilities as in (b) above, with access to modify certain (non-critical) SCADA parameters;
- d) Full SCADA system access: -Shall be the authorized person/administrator with full access including maintenance and software upgrade.
- e) Maintenance: -Can access any of the maintenance functions but not operational functions.
- f) Training: - Can access any of training related functions

18.15.1.2.2 Separate user groups and their passwords for traction power operators shall be defined within the system based on these access levels.

18.15.1.2.3 It shall be possible to modify the access security features and user rights only from the highest access level i.e. administrator level only. In the event that no activity at a particular workstation has been detected by the SCADA system following a pre-defined period, access to the SCADA system from such a workstation shall be denied and the Power Controller shall be required to again log-in using the normal procedure.

18.15.1.2.4 The Power Controller shall log off to end a working session on a workstation. After the current operator has logged off and with no other Power Controller logged on, no supervisory, control, monitoring or other action on the SCADA system shall be possible from the workstation.

18.15.1.2.5 Any workstation shall not permit log on of more than 1 user at a time.

18.15.1.2.6 The action of all log-in and log-out operations of the SCADA system, as well as any configuration changes to the system, shall be recorded by date, time and the user's security access code as an event record.

18.15.1.3 Media Control

18.15.1.3.1 Use of External Media on any of system component (server, workstations etc.) shall not be allowed on SCADA system

18.15.1.3.2 There shall be means to indicate & give alarm in case an intrusion event occurs either through a connection or a peripheral device.

18.15.1.4 Security from Malicious Code and Intrusion

18.15.1.4.1 The Servers, Workstations etc. shall be provided with proper application (Anti-virus, Intrusion Detection system etc.) to prevent propagation of malicious code by any Media or on Network.

18.15.1.4.2 There shall be no remote/email/internet access, user access codes/passwords in the master station software and hardware so that any possibility of a cyber-intrusion or attacks is eliminated. Reasonable precaution, by way of installing fire-wall, and blocking ports for connecting external devices like pen drives, CD drives etc. shall be ensured.

18.15.2 Firewall in Network Architecture

- 18.15.2.1** The SCADA network shall be separate from the corporate network. The nature of network traffic on these two networks is different: Internet access, FTP, e-mail, and remote access will typically be permitted on the corporate network but should not be allowed on the SCADA network. Rigorous change control procedures for network equipment, configuration, and software changes may not be in place on the corporate network. By having separate networks, security and performance problems on the corporate network should not be able to affect the SCADA network.

18.16 User Interface

18.16.1 General concept of the workstation screens

- 18.16.1.1** The display of views, controls and the event resolution shall be possible from the same screen.
- 18.16.1.2** The screens shall be organized into different sections for processing the Power Controller activity information. There shall be no overlap between the various sections at any time that may obscure vital information.
- 18.16.1.3** The active sections shall have dynamic information displayed. Each active section shall manage and update the alarms, processing and controls that shall be displayed in it. Every status change shall be shown within the active sections and the relevant display updated.
- 18.16.1.4** Each view shall display the necessary tools and options for the processing or management of events.
- 18.16.1.5** Any section of the screens displaying text shall have scrolling abilities. The management of any overflows of alarms and various data, i.e. when the number of alarms exceeds the capacity of the section on the screen, shall use these scrolling facilities.

18.16.2 Typical Workstation Screen Design

18.16.2.1 Alarm List (AL)

- 18.16.2.1.1** The alarm list may show detailed alarms in comprehensible text format with the date and time of their occurrence. They shall be displayed in chronological order, commencing with the most recent.
- 18.16.2.1.2** A scrolling facility shall enable the Power Controller to scan the list.
- 18.16.2.1.3** Each alarm in the list shall be displayed with different colour or shape attributes according to the alarm level and acknowledgement status.
- 18.16.2.1.4** The alarm list shall have various filter facilities to enable the Power Controller to display different format of events.
- 18.16.2.1.5** The Power Controller shall be able to print the alarm list.

18.16.2.2 Logging List (LL)

- 18.16.2.2.1 The logging list shall show detailed events in comprehensible text format with the date and time of their occurrence. They shall be displayed in chronological order.
- 18.16.2.2.2 A scrolling facility shall enable the Power Controller to scan the list.
- 18.16.2.2.3 The logging list shall have various filter facilities to enable the Power Controller to display different format of events.
- 18.16.2.2.4 The filter keys shall typically include location, equipment group, time period, event category (ordinary event, minor and major alarm ...) and other options.
- 18.16.2.2.5 Any combination of the filter keys shall be possible.
- 18.16.2.2.6 Each event in the list shall be displayed with different colour attributes according to their category
- 18.16.2.2.7 The Power Controller shall be able to print the logging list or the filtered logging list.

18.16.2.3 View Selection

- 18.16.2.3.1 A view selection bar may be permanently displayed on each screen to allow the Power Controller to select various available images.
- 18.16.2.3.2 Some detailed images may not be selectable from the view selection bar but be selected directly from other displays.

18.16.2.4 Graphic Display

- 18.16.2.4.1 The graphic display shall display images as requested by the Power Controller.

18.16.2.5 Control facilities

- 18.16.2.5.1 Equipment control may be managed by designating the equipment on the screen.
- 18.16.2.5.2 This action may open a dialogue box requiring the Power Controller to select one possible control mode for the equipment, setting remote control inhibition on the equipment and cancelling remote control inhibition on the equipment.
- 18.16.2.5.3 After selecting the control action, the Power Controller shall either validate or cancel the action. If validated, the control action shall be performed.

18.16.3 SCADA Views

- 18.16.3.1** The Contractor shall design specific views which shall be designed in such a manner that it gives an easy control and accessibility to the relevant operators. The views shall be submitted to the Engineer for their approval. The views related to RSS, ASS, TSS, RSS/AMS, Depot, 3rd Rail System etc. shall be designed as per the single line diagram of each location showing the switchgear status and measured values. One common alarm status HMI window of each equipment of a location shall be designed for each RSS, ASS, TSS, Depot, 3rd Rail system views.

The view at BCC should be same as the views at the integrated OCC SCADA.

- 18.16.3.2** The auxiliary overview and traction overview of both the corridors shall be designed to be display on the visual control panel.

18.17 Performance Requirement

The performance of the system must enable the Power Controller to operate the line under satisfactory conditions. More precisely, the following targets must be reached.

18.17.1 Transfer time

- 18.17.1.1** The display of each critical system shall require rapid updates of the workstation displays of the status and event data, together with a rapid response by the SCADA System to control inputs. The status of any circuit breaker trip, protecting any Safety Critical equipment etc., shall also be identified on the workstations at OCC and BCC and recorded in the event record, within 1 second in normal condition and within 2 seconds in avalanche conditions of its occurrence. Similarly, activation of a control command shall reach any critical system in no more than 2 seconds.

- 18.17.1.2** The SCADA systems shall continue to be able to function without degradation of performance of system, shall there be a mass tripping of equipment at multiple RSS, ASS, TSS or avalanche breakdown of power supply network. The OCC/BCC SCADA system shall continue to function normally in such an event without any software hanging and system restart.

18.17.2 System Capacity

- 18.17.2.1** The processing power of the servers, workstations, remote terminal units, and all the relevant peripherals of the system shall be designed to guarantee that SCADA System shall cope with all situations and allow the operator to manage all the events he is in charge to supervise. SCADA server and SCADA software shall be sized and suitably licensed for the control & monitoring requirement of East West corridor and North South corridor separately and its future expansion shall be included. The SCADA software shall be supplied with the license of minimum 70 RTUs and 45000 I/Os shall be included.

18.17.3 Start-up Time

- 18.17.3.1** Complete SCADA system with servers, workstations, and full communication with all RTU's shall be ready within 3 minutes of a cold restart of complete system. All software shall automatically start up on system restart and system shall be ready for the operator after entering the password.

18.17.4 Hot-Standby Changeover Time

- 18.17.4.1** In case of failure of Main system, the complete SCADA system shall switch to standby system with full communication with all RTU's and HMI on Workstations within not more than 30 Seconds without requirement by Power Controller to re-login into the standby system.

18.17.5 Chronological analysis

- 18.17.5.1** In order to analyse afterwards a sequence of events with an acceptable accuracy the number of data samples must be sufficient. Therefore, every alarm or event is dated with a precision of 0.001s i.e. 01 (one) ms (day and time: hours, minutes, seconds, tenths of second) by the RTU that receives it from an equipment, or by the computer that generates it if no RTU is involved in this alarm or event: this date is called the « origin » date of the alarm or event. Each alarm or event existing in the whole system is designed to be sent to the OCC and the BCC.

- 18.17.5.2** The sequence of events shall be logged and presented in event list or alarm list strictly in chronological order.

18.17.6 Usable Service Life

- 18.17.6.1** The SCADA software shall be supplied with perpetual license, and the usable service life of SCADA software and it's enabling IT environment (OS, Database Software and any other software required for installation of SCADA software) shall be minimum 15 years from date of supply. All materials and equipment to be supplied shall be of a proven design and the major core components of the SCADA system shall have a Service Life of at least fifteen years.

18.17.7 Interoperability

- 18.17.7.1** The SCADA System selected shall support integration of RTU of other make and model over IEC 608705-104. It shall also be capable to exchange information with other SCADA system over IEC 60870-5-104, OPC DA/UA and other standard communication protocols.

18.18 INTERFACE REQUIREMENT

It shall be the responsibility of Traction Contractor to interface with all the agencies involved in the project for the successful completion of all activities assigned to the Contractor. SCADA contractor shall be required to do the necessary interface with the following contractors but not limited to.

- 18.18.1** Interface with Depot Civil contractor & integrated OCC/Metro Bhawan Building Civil Contractor
- 18.18.2** Interface with Depot E&M contractor & integrated OCC/Metro Bhawan Building E&M Contractor
- 18.18.3** Interface with Signalling contractor
- 18.18.4** Interface with Telecom contractor
- 18.18.5** Interface with Station E&M contractor

Kindly refer Chapter 3 of Tender Specifications for detailed Interface Requirements.

18.19 Installation Requirement**18.19.1** Description

18.19.1.1 The SCADA equipment shall be of modular in construction to facilitate maintenance, repair and replacement of parts.

18.19.1.2 Cabinets and racks when fully assembled shall not be filled to greater than 80% of their capacity at the completion of the Works.

18.19.1.3 Outdoor equipment shall be sealed against the ingress of dust, moisture and vermin to a minimum rating of IP55 in accordance with EN 60529. The Indoor Panels shall have rating of IP54.

18.19.2 RTU Manufacturing

18.19.2.1 All components used shall be purchased from suppliers complying with internationally authorize quality assurance and reliability certification procedures.

18.19.2.2 All components shall be identified either by carrying a manufacturer's designation or part reference number or unique value in a standard format.

18.19.2.3 Adjustable controls shall be provided with locking devices to prevent inadvertent movement. Test points shall be clearly labelled as such in English and any test points involving Safety Critical functions shall be protected against unauthorized access.

18.19.2.4 Plugs and sockets shall incorporate mechanical locking features to hold both parts together and protect against vibration and shock. Mechanical coding or barriers shall be provided to prevent a plug or socket being incorrectly connected.

18.19.2.5 Each wire shall be labelled, consistent with the circuit or handbook/drawing designation, such that it may be uniquely identified.

18.19.2.6 Each wire connecting the remote terminal units to the selected equipment shall carry a unique identification, which shall also be clearly shown on the interface drawings.

18.19.3 Server Rack Specification

18.19.3.1 Rack shall be of All Steel Construction and powder coated finish.

18.19.3.2 All SCADA servers or any communication equipments shall be installed in standard 19" rack complying with IEC 60297-3 at SCADA server room with redundant power supply system and protection from UPS distribution board.

18.19.3.3 Rack shall be designed with redundant power strips with applicable electrical protection, inbuilt protection MCBs arrangements to safeguard different IT equipments.

18.19.3.4 Rack design shall enable shipping of the rack in (CKD) Completely Knock Down condition. Typically, the frame and other structural members are bolted together to offer such flexibility of the product. Design shall permit an easy assembly of the racks at site as per the requirement at site. Complete flexibility shall be available with regards to the internal mountings in every rack.

- 18.19.3.5** Front and rear frame shall be rigidly fastened together with the help of side mounting channels or depth sections to ensure perfect square-ness of the internal mounting space. Furthermore, the said structure comprising of frames and mounting channels shall rest positively fastened onto the Plinth of box like Configuration. Thus, ensuring the higher level of Rigidity of the Basic rack skeleton while effectively distributing and transferring the entire load to integrated Plinth.
- 18.19.3.6** Mounting rails (for Standard 19" mounting) shall be made up of steel. (Minimum 2.0mm thickness) Recessing of these Front & Rear 19" mounting rails shall be completely flexible within the entire depth of the rack. These mounting rails shall also have an extra internal web for increasing rigidity and to facilitate mounting of the shelves and other required accessories conveniently.
- 18.19.3.7** Integral Plinth shall have provision for Cable Entry on rear and two sides along with cable entry gland plate on the top face of the Plinth. Minimum opening of this top gland plate on the plinth shall be at least 300mm x 300mm with separate opening for electrical / power cables entry. Solid bottom panel with provision of front and rear cable entries through bottom cable entry removable gland plate.
- 18.19.3.8** The rack shall have provision to mount castors (4 Nos.) and Levelling Feet – (4 Nos.) simultaneously. This is required for the facility of moving the rack while installation process and then resting the same rigidly at the final location. When the rack is resting on the levelling feet, castors shall not touch the ground surface.
- 18.19.3.9** Side Panels shall be easily removable type along with the provision for locking. Ideally, the panels shall have latching arrangement to facilitate easy removal and putting back the panel along with locks for the security purpose.
- 18.19.3.10** It shall also be possible to open the front and rear door by 180 Degrees to ensure proper approach to front of rack. It shall have the provision of unique key lock for restricted access control.
- 18.19.3.11** Rear door shall be completely perforated to facilitate the air circulation at the maximum without offering any resistance to the same. Ideally, it shall be possible to remove it easily and shall have unique key lock for the security purpose and restricted access control.
- 18.19.3.12** Top roof shall be well ventilated, especially with ventilation provided on the vertical side of the roof. This shall greatly enhance the hot air outflow while in operation. Roof shall also have provision to mount the cooling fan trays. It shall be possible to mount at least 4 nos. of 90 CFM cooling fans on this roof.
- 18.19.3.13** Two vertical cable managers to be provided at the rear of the rack in the form of Cable Trays. These trays shall offer the maximum flexibility by way of the cable dressing and routing provision.
- 18.19.3.14** Panel lighting provision with LED light connected with door limit switch mounted on the top to provide indoor working LUX level.
- 18.19.3.15** All panel entries shall be blockable with metallic covering plates and it shall be vermin proof.

18.19.3.16 Contractor shall ensure the provision of free space inside the rack and shall submit the general arrangement drawing to Engineer in charge for approval.

18.19.4 Installation & Control Cabling of RTU

18.19.4.1 Traction contractor shall finalize the space requirement for SCADA equipment in RSS/ASS/TSS/Depot. It shall ensure the provision of necessary I/O contacts in ASS/TSS equipments and wire all the I/O contacts (as per approved I/O list) from equipment end to the designated TBs in RTU.

18.19.4.2 Traction contractor shall interface with Station/Depot E&M contractor to ensure the provision of necessary I/O contacts for SCADA RTU interface for control & monitoring of 415 V LV panels (415 V transformer level breaker) from OCC/BCC.

18.19.4.3 Traction contractor shall ensure that all Energy Meters are provided with RS485 or TCP/IP port for communication with SCADA over MODBUS Protocol and shall connect & communicate meters with RTU over MODBUS protocol.

18.19.4.4 Traction contractor shall lay redundant communication cables for AC/DC relays/IEDs signals communication up to the RTU over IEC 61850 protocol.

18.19.4.5 All SCADA cables, except power supply cables, shall be terminated in order of their core number on combined terminal/disconnection or terminal/fuse links. Each wire shall be capable of being disconnected and isolated without removing the wire itself. Such terminations shall be easily accessible for inspection and test and shall be identified with the designation of the circuit it carries.

18.19.4.6 All multi-core SCADA cables shall have 10% of their cores (with a minimum of 2 cores), as spares.

18.19.4.7 Cable terminals and busbars carrying voltages exceeding 50 volts shall be uniquely identified and protected against accidental contact by persons, test equipment or other unintended physical contact.

18.19.4.8 Traction contractor shall modify/reconfigure RTUs at ASS1 and ASS2 of Sachivalaya underground station as well as at Charbagh metro station to accommodate changes made in 33kV switch gear for feeding 33kV to new ASS or ASS cum TSS at integrated OCC/Metro Bhawan.

18.19.5 Furniture

18.19.5.1 The Contractor shall consider suitable and aesthetically designed furniture at OCC and BCC for all SCADA servers display console, server room printer at SCADA Server room. The servers shall be housed in separate cabinets to prevent dust and they shall have easy access for the cables. The furniture for Power controller and operator workstations at OCC theatre room shall be provided by control centre contractor. The SCADA contractor shall interface with control centre contractor and shall submit the requirement of necessary power supply switch sockets & cooling fans along with the provision of cut out on bottom plate for cable entry inside the furniture. The Contractor shall submit proposal for furniture type and design to Engineer for approval.

- 18.19.5.2** The supply of furniture in RSS/AMS control room at each RSS shall be under the scope of Traction contractor.
- 18.19.6 Power Supply**
- 18.19.6.1** The designated contractor shall install DCDB, ACDB, Inverter, battery and battery charges of appropriate capacity and shall provide spare connections at DCDB, ACDB for SCADA-RTU at each RSS/AMS/ASS/TSS/Depot. Traction Power supply contractor shall ensure the provision at DCDB for dual feeders of 110 V DC supply and single feeder of 230 V AC supply from ACDB for SCADA RTU power supply.
- 18.19.7** Interconnection with OCC/BCC
- 18.19.7.1** SCADA contractor shall coordinate with station building contractor for requirement of cable route and support for RTU communication with TER at stations. The designated station / E&M contractor shall provide cable route and install support (metallic cable tray, conduit etc.) for RTU communication from RTU panel to Telecom Equipment Room at stations.
- 18.19.7.2** SCADA contractor shall coordinate with Depot E&M contractor for the requirement of cable route and cable tray support for connectivity between various SCADA equipment and power distribution to SCADA equipment located in designated rooms at OCC/BCC. Kindly refer Chapter 3 of Tender Specifications for detailed interface requirements.
- 18.19.8 Power supply distribution in OCC/BCC**
- 18.19.8.1** Equipment contained within the OCC/BCC shall be fed from the UPS distribution board, installed complete with protective devices and earth terminal. There shall be separate AC power distribution boards for SCADA equipment in SCADA server room and Theatre room at OCC. There shall be separate AC power distribution boards for SCADA equipments in BCC at RSS/AMS Control room. Power distribution to the various items of ancillary equipment and desks shall be by means of several ring main circuits. Each circuit contains a dedicated protective conductor (separate conductor or cable armouring) connected to the protective earth terminal at the distribution switchboard. All items of control and communication equipment shall have a direct connection between the equipment earth terminal and the circuit protective conductor.
- 18.19.8.2** The distribution board shall comply with the relevant Indian Standards and shall comply to the I.E. Rules with ingress protection rating of IP 41.
- 18.19.8.3** The Distribution Board (DB) shall comprise of the following accessories of suitable rating, but not limited to:
- a) One nos. 230 V, MCB/ MCCBs.
 - b) Bus bar chamber with copper bus of adequate size.
 - c) Ammeters, Voltmeter
 - d) Single Pole or Double Pole MCBs for distribution (with min. 2 nos. spare MCBs of each type)
 - e) Indication lamps.
 - f) Outgoing feeders as per requirement

- 18.19.8.4** The distribution boards shall be of heavy sheet steel construction and shall be completely dust, moisture and vermin proof. These shall be supplied complete with frame work, fixing bolts, barriers enclosure, internal wiring cable end boxes, labels etc.
- 18.19.8.5** The distribution boards shall be suitable for wall mounting.
- 18.19.8.6** Bus bars of the DB shall be electrolytic copper with heat shrinking sleeves. Internal cabling/wiring shall be FRLS-0H wiring of suitable sizing shall be selected to carry the full load current. MCBs shall be selected for providing discrimination between incoming and outgoing feeders.
- 18.19.8.7** All units of the distribution boards including supporting frames shall be made rust proof.
- 18.19.8.8** The busbars shall be supported on LT porcelain insulators. Busbar chambers shall be made of heavy sheet and shall be provided with detachable covers at both ends and suitable opening on top as well as at the bottom to enable installation of incoming and outgoing feeders.
- 18.19.8.9** The circuit breaker, changeover switch shall be arranged neatly and mounted on the panel which shall be of standard design and provided within a hinged cover to facilitate inspection.
- 18.19.8.10** The various items constituting the distribution board shall be neat and secured on a channel from framework designed for wall mounting. The indicating lamps shall be of the low watt consumption and which shall be interchangeable and replaceable on front of the panel.
- 18.19.8.11** Suitable markings for identification of circuits shall be provided on the distribution panels. Suitable name plates shall also be provided.
- 18.19.9 Earthing of SCADA Equipment**
- 18.19.9.1** The SCADA contractor is required to interface with the designated station/depot E&M contractor for earthing requirement of SCADA equipments at field and OCC/BCC.
- 18.19.9.2** The Traction Power supply contractor shall ensure dual Earthing arrangement and shall connect SCADA equipment RTU, Server rack, ACDB etc. with MET as per approved schematic. The cable required for this connection shall be under the scope of Power supply contractor. Kindly refer Chapter 3 of Tender Specifications for detailed interface requirements. Testing & Acceptance
- 18.19.10 Network Management System (NMS)**
- The Contractor shall provide a network management system software for following management functions:
- (a) Configuration Management
 - (b) Fault Management
 - (c) Performance Monitoring
- This system shall be used for management of communication devices and other IEDs in

the system. The NMS shall monitor all the devices and report if there is any fault in the monitored devices.

18.19.10.1 An NMS shall also be provided at OCC by SCADA contractor for monitoring the status, performance, statistics, errors and alarms of all switches, routers and all other active nodes of SCADA dedicated FO network system for both corridors (N-S Corridor & E-W corridor).

18.19.10.2 NMS shall be a set of dedicated server and a network management software. The NMS shall have simple browser-based user interface to provide all the required information of SCADA dedicated network nodes. The NMS shall not impact the availability and performance of SCADA system.

18.19.10.3 The NMS software shall perform but not limited to the following features.

Centralized web-based management of all network nodes and IP networks

Auto discovery of device links and services and representation on a network map. NMS shall have the polling system by which devices shall be discovered using ICMP pings. Logs can be received, status can be detected, and a topology map shall be created. Performance data shall be regularly polled by NMS of all discovered devices.

Real time monitoring and notification of events, alarms and thresholds. NMS shall continuously monitor the network and reports or trigger events for any changes and abnormal traffic conditions it detects. It shall allow the users to define their own customized threshold rules.

Continuous collection of traffic statistics for analyses and reporting. Reports allow a network operator to assess the current and historical health of a network. These reports provide the tools needed to pro-actively detect issues and correct them before an outage or unacceptable network latency occurs. Statistics shall be available for printout.

NMS shall support remote monitoring of the network and shall monitor network traffic for abnormal behaviour such as a rapid rise or fall in throughput.

NMS shall provide flexible, browser-based mapping of network entities. It can automatically map and lay out a selected set of devices, save and restore custom map views, perform live map updates, display map updates in real time and more.

- a) Icon specific to each device type
- b) Hierarchical views of devices
- c) Grouping of multiple objects under a single icon
- d) Color coded representation of each node and link status
- e) Graphical representation of bandwidth used between ports.
- f) Network monitor gage (for overall usage of network bandwidth)
- g) Capability for getting detailed information by clicking on desired device icon

18.19.10.4 The minimum technical specifications of NMS hardware server shall be as follows.

S. No.	Item	Description
1	Type	19" 4U RACKMOUNTABLE INDUSTRIAL PC
2	Processor	Intel Core I9, 14th Gen CPU or higher
3	Main Memory (RAM)	64GB DDR5 Memory
4	Hard Disk	1*2TB SATA SSD. (RAID 5 controller)
5	Ethernet Ports (LAN)	2*10/100/1000 Mbps dual Ethernet Port expandable up to four.
6	DVD-R Drive	16x DVD +/-RW ROM, SATA, Internal with double layer write capability.
7	Power Supply	1*500-Watt Dual Power Supply.
8	Form Factor	1U or 2U
9	Number of USB Ports	4*USB, 2*Serial, 1*VGA, 1*DP & 1*HDMI Port onboard. 1 no. USB port on board for installing hard license (if required)
10	Operating System	Windows-11 Pro. 64 Bit O.S. or latest / LINUX
11	EMI immunity	As per IEC 801

18.20 Testing & Acceptance

18.20.1 General Requirements

18.20.1.1 The Contractor shall carry out all the tests and checks required for guaranteeing the engineer in charge of the satisfactory construction and the satisfactory operation of all SCADA installations.

18.20.1.2 The Contractor shall put in place a full testing program to demonstrate that all the requirements of the specification are met.

18.20.1.3 The Contractor shall develop an Integrated Testing & Commissioning Plan including details of all testing activities as specified, to verify the system in all modes of operation and with all necessary interfacing requirements. Test programs, methods and results shall be documented and submitted to the Engineer in charge for necessary approval.

18.20.1.4 Kindly refer chapter 7: Testing and Commissioning of Tender specifications for detailed requirements.

18.20.2 Tests

All the tests shall be carried out by the Contractor and shall be witnessed by the Engineer in charge.

18.20.2.1 Type Test

- 18.20.2.1.1 Type Tests shall be performed prior to full production and before FAT.
- 18.20.2.1.2 Type Tests shall be used to confirm that the proposed equipment is fit for purpose in the environmental conditions specified, design and meets the requirements of the Specification.
- 18.20.2.1.3 The Contractor shall provide detailed Type Test specifications in respect of tests to be performed for the equipment.
- 18.20.2.1.4 Type tests shall be carried out on the prototype in accordance with provisions contained in governing specifications. If type test conforming to this specification has already been conducted and a valid type test certificate is available, fresh type test shall not be required if it had passed the type tests and no change in design or material used have been made. Certified copies of type test report shall be furnished along with the Tender submission or at the time of vendor approval.
- 18.20.2.1.5 For any item that the Engineer does not agree to waive Type testing for, the Contractor shall propose the body who shall undertake the Type Testing (which may in certain circumstances be the Contractor). The Engineer may specify which authority shall witness and approve the results of the Type Testing.

18.20.2.2 Factory Acceptance Test

- 18.20.2.2.1 The manufacturing phase of the SCADA system equipments shall be concluded by the factory acceptance test (FAT) at supplier's premises. The purpose is to ensure that the Contractor has interpreted the specified requirements correctly and that the FAT includes checking to the degree required by the user. The general philosophy shall be to deliver a system to site only after it has been thoroughly tested and its specified performance has been verified, as far as site conditions can be simulated in a test lab. If the FAT comprises only a certain portion of the system for practical reason, it has to be assured that this test configuration contains at least one unit of each and every type of equipment incorporated in the delivered system. Engineering work shall be completed by the time of FAT.

18.20.2.3 Acceptance Test

- 18.20.2.3.1 Tests shall be carried out during erection/commissioning of the equipment at site on the complete system in the presence of the employer's representative to check the proper erection and successful commissioning of the equipment. These tests shall be carried out to check the compliance of the SCADA system with the stipulations made in the specification/drawings.

18.20.2.4 Integrated Testing & Commissioning

- 18.20.2.4.1 Integrated Testing of SCADA system shall be carried out from OCC and BCC on fully interconnected SCADA system with power supply equipment and communication network. In Integrated Testing, both functional and performance test shall be conducted. Additionally, point to point testing of each I/O signals shall be also carried out.
- 18.20.2.4.2 All the defects and shortfalls in the Contractor's system discovered in the course of integrated testing and commissioning shall be made good and retested to the satisfaction of the Engineer.
- 18.20.2.5** The contractor shall submit the Type test reports, FAT reports, Acceptance test reports and Integrated testing & commissioning reports to the Engineer in charge for approval.
- 18.20.3 Document Submission Schedule**
- 18.20.3.1** The contractor shall follow the design development process in line with industry best practices and shall minimum need to create the following documents
1. Software Quality Assurance Plan for SCADA
 2. SCADA System Architecture Description
 3. SCADA Functional Design Specification
 4. SCADA Interfacing Design Specification
 5. SCMS System / Functional Design Specification
 6. Hardware Specification for Master Station Equipment
 7. Hardware Specification for RTU and its accessories
 8. HMI Display Design Specification
 9. General Arrangement Drawing for RTU and Server Racks
 10. Schematic and Wiring (internal and communication) Drawing for RTU and Server Racks
 11. IO List
 12. Automatic Operation and Safety Design Specification covering logics and interlocks and other safety feature and automization to be implemented in SCADA system.
 13. SCADA Software configuration
 14. Installation Plan
 15. Test Specification
 16. SCADA System Backup and Restoration Manual also covering information retrieval and report generation
 17. Maintenance Plan and Schedule
 18. DLP Management Plan
 19. AMC Management Plan
 20. List of Minimum Onsite AMC Spares and Consumables
 21. Final Design Specification and as build drawings (covering all design documents & drawings as above)
 22. SCADA Software User Manual
 23. SCMS Software User Manual
 24. Operation and Maintenance Manual for SCADA
 25. Operation and Maintenance Manual for SCMS
 26. A write-up explaining the principal of operation of the equipment.
 27. Any other details considered necessary for the proper understanding of the system.

28. Detailed step by step procedure for operation, maintenance and repairs of the system and individual equipment indicating procedure for trouble shooting, measurement of various signals at different points and diagnostic checks to be adopted for repairs at site.
29. Licensed copies of CD/DVD of SCADA application and peripheral software along with write up on software features, instructions for configuration, working of software and procedures for taking out report and data in the form of instruction manual/guide. The SCADA software licence should also be handed over to UPMRC. Whenever updated the same should be advised or made available on line.
30. All test report with sign and stamp.

18.21 Input / Output Requirement

18.21.1 Description

18.21.1.1 This Specification defines the Input/output requirements for the SCADA system. The list is indicative and not exhaustive. The I/O list is typical equipment wise signal list and shall be applicable for all similar type of power supply equipments. The contractor shall consider all I/O signals for the equipments at all ASS/TSS/RSS/Depot. The Contractor shall prepare a comprehensive list of Input/output for each of the monitored/controlled equipment and submit for approval by the Engineer.

18.21.1.2 The typical requirement for the various equipments have been indicated below:

Table 18.12: Typical Requirement of various Equipments

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
132KV GIS									
1		CB Open Status	DI			IEC61850	P1	Open	Intermediate/ Faulty
2		CB Close Status	DI			IEC61850	P1	Close	Intermediate/ Faulty
3		CB Open Command		DO		IEC61850			
4		CB Close Command		DO		IEC61850			
5		86A Trip Reset Command		DO		IEC61850		Reset	
6		86B Trip Reset Command		DO		IEC61850		Reset	

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
7	SF6 Circuit Breaker/Bay	Scada Permissive	DI			IEC61850	P1	Banned	Permitted
8		Scada Permissive Command		DO		IEC61850			
9		86A Relay Supervision	DI			IEC61850	P3	Healthy	Unhealthy
10		86B Relay Supervision	DI			IEC61850	P3	Healthy	Unhealthy
11		86A Relay Operated	DI			IEC61850	P3	Normal	Operated
12		86B Relay Operated	DI			IEC61850	P3	Normal	Operated
13		Line VT Metering/Protection Core MCB Status	DI			IEC61850	P2	Normal	Trip
14		CB Trouble Close Block	DI			IEC61850	P2	Normal	Operated
15		CB Spring Status	DI			IEC61850	P2	Charged	Discharged
16		DS/ES Control Dc Mcb	DI			IEC61850	P2	Normal	Trip
17		Spring Charge Motor Running Timeout	DI			IEC61850	P3	Normal	Operated
18		DS/ES Motor DC MCB	DI			IEC61850	P2	Normal	Trip
19		LCC I/C AC MCB	DI			IEC61850	P1	Normal	Trip
20		CB Motor MCB	DI			IEC61850	P3	Normal	Trip
21		L/R Switch Position In LCC	DI			IEC61850	P1	Remote	Local
22		CB N/M Switch In	DI			IEC61850	P1	Normal	Maintenance
23		Interlock Switch In	DI			IEC61850	P2	Normal	Bypass
24		CB TC-1 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
25		CB TC-2 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
26		CRP DC-1 Supply Status	DI			IEC61850	P2	Normal	Fail

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
27		CRP DC-2 Supply Status	DI			IEC61850	P2	Normal	Fail
28		Inter Trip Sent	DI			IEC61850	P2	Normal	Send
29		Inter Trip Received	DI			IEC61850	P2	Normal	Receive
30		96 Trip Relay Status	DI			IEC61850	P3	Normal	Operated
31		Inter Trip From Bcu	DI			IEC61850	P2	Normal	Received
32		DC-1 Distribution MCB Status	DI			IEC61850	P2	Normal	Trip
33		DC-2 Distribution MCB Status	DI			IEC61850	P2	Normal	Trip
34		LCC I/C DC MCB	DI			IEC61850	P3	Normal	Trip
35		Loss Of Signal & Alarm MCB	DI			IEC61850	P1	Normal	Trip
36		Differential LDCM-1 Status	DI			IEC61850	P1	Normal	Fail
37		Differential LDCM-2 Status	DI			IEC61850	P1	Normal	Fail
38		BCU Status	DI			IEC61850	P2	Normal	Fail
39		Fuse Fail Alarm	DI			IEC61850	P2	Normal	Operated
40		Time Synch Status	DI			IEC61850	P1	Normal	Fail
41		CB Manual Open	DI			IEC61850	P1	Normal	Open
42		CB Manual Close	DI			IEC61850	P1	Normal	Close
43		Ethernet Switch MCB Status	DI			IEC61850	P1	Normal	Trip
44		CB Spring Charging Motor Protection	DI			IEC61850	P2	Normal	Operated
45		CB Control Voltage Mcb	DI			IEC61850	P2	Healthy	Unhealthy
46		Emergency Puch Button Optd	DI			IEC61850	P3	Normal	Operated
47		Hand Crank Cover Open	DI			IEC61850	P2	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
48		I/O Rack Relay Unhealthy	DI			IEC61850	P2	Healthy	Unhealthy
49		SF6 Pressure Rising	DI			IEC61850	P3	Normal	Operated
50	Bus Bar	BB DC-1 Supply Status	DI			IEC61850	P2	Normal	Fail
51		BB DC-2 Supply Status	DI			IEC61850	P2	Normal	Fail
52		BB Ac Supply Status	DI			IEC61850	P1	Normal	Fail
53		Rph BBP Supervision	DI			IEC61850	P3	Healthy	Unhealthy
54		Yph BBP Supervision	DI			IEC61850	P3	Healthy	Unhealthy
55		Bph BBP Supervision	DI			IEC61850	P3	Healthy	Unhealthy
56		BB Relay Communication Status	DI			IEC61850	P2	Healthy	Unhealthy
57		BB Relay Faulty	DI			IEC61850	P3	Healthy	Unhealthy
58		BB Open CT Alarm Zone-1	DI			IEC61850	P3	Normal	Operated
59		BB Open CT Alarm Zone-2	DI			IEC61850	P3	Normal	Operated
60		Open CT Alarm	DI			IEC61850	P3	Normal	Operated
61	Bus PT	BPT LCC I/C AC MCB	DI			IEC61851	P1	Normal	Trip
62		BPT LCC I/C DC MCB	DI			IEC61852	P2	Normal	Trip
63		BUS1 VT MCB	DI			IEC61853	P2	Normal	Trip
64		BUS2 VT MCB	DI			IEC61854	P2	Normal	Trip
65		BPT ES MOTOR DC MCB TRIP	DI			IEC61855	P2	Normal	Trip
66		BPT DS/ES CONTROL DC MCB	DI			IEC61856	P2	Normal	Trip
67		BPT INTERLOCK STATUS	DI			IEC61857	P2	Normal	Bypass
68		BPT LOSS OF SIGNAL ALARM MCB	DI			IEC61858	P1	Normal	Trip
69	Protection	Differential Relay	DI			IEC61850	P2	Healthy	Unhealthy

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
		Communication							
70		Differential Relay Status	DI			IEC61850	P2	Normal	Faulty
71		Differential Protection Status	DI			IEC61850	P3	Normal	Operated
72		Distance Protection Operated	DI			IEC61850	P3	Normal	Operated
73		Over Voltage Alarm	DI			IEC61850	P2	Normal	Operated
74		Under Voltage Alarm	DI			IEC61850	P2	Normal	Operated
75		O/C Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
76		E/F Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
77		BCU Communication	DI			IEC61850	P2	Healthy	Unhealthy
78		Power Swing Detected	DI			IEC61850	P3	Healthy	Unhealthy
79		LBB Protection Status	DI			IEC61850	P3	Normal	Operated
80		BCU Status	DI			IEC61850	P2	Normal	Faulty
81		Switch On To Fault	DI			IEC61850	P2	Normal	Operated
82		REV Power Operated	DI			IEC61850	P3	Normal	Operated
83		32 REV Power Relay Unhealthy	DI			IEC61850	P2	Healthy	Unhealthy
84		Differential 2Nd Harmonics Blocked	DI			IEC61850	P2	Normal	Operated
85		Differential 5Th Harmonics Blocked	DI			IEC61850	P2	Normal	Operated
86		HV REF Protection	DI			IEC61850	P3	Normal	Operated
87		LV REF Protection	DI			IEC61850	P3	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwire d Signal / Soft Signal		Normal State	Alarm State
88		Tank E/F Protection Trip	DI			IEC61850	P3	Normal	Operated
89		Thermal Over Load Level-1 Alarm	DI			IEC61850	P1	Normal	Operated
90		Thermal Over Load Level-2 Alarm	DI			IEC61850	P2	Normal	Operated
91		Thermal Over Load Level-3 Alarm	DI			IEC61850	P3	Normal	Operated
92		Hv Standby E/F Protection Trip	DI			IEC61850	P3	Normal	Operated
93		Over Excitation Alarm	DI			IEC61850	P1	Normal	Alarm
94		Trafo HV Sef Protection Operated	DI			IEC61850	P3	Normal	Operated
95		Trafo LV Sef Protection Operated	DI			IEC61850	P3	Normal	Operated
96		Bus Bar Protection Differential (R/Y/B)	DI			IEC61850	P3	Normal	Operated
97		96 Trip Relay Operated (R/Y/B)	DI			IEC61850	P3	Normal	Operated
98		Dead Zone Operated	DI			IEC61850	P3	Normal	Operated
99		Bus Bar Protection Out Of Service	DI			IEC61850	P3	Normal	Operated
100		Bus Bar Protection Zone-2 Out Of Service	DI			IEC61850	P3	Normal	Operated
101	Isolator/Disc onnector	Isolator Open Status	DI			IEC61850	P1	Open	Intermediate/ Faulty
102		Isolator Close Status	DI			IEC61850	P1	Close	Intermediate/ Faulty
103		Isolator Open Command		DO		IEC61850			
104		Isolator Close Command		DO		IEC61850			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
105	Earthing Switch	Earth Switch Open Status	DI			IEC61850	P1	Open	Intermediate/Faulty
106		Earth Switch Close Status	DI			IEC61850	P1	Close	Intermediate/Faulty
107		Earth Switch Open Command		DO		IEC61850			
108		Earth Switch Close Command		DO		IEC61850			
109	Gas compartment	SF6 Gas Pressure Stage 1 Alarm	DI			IEC61850	P2	Normal	Alarm
110		SF6 Gas Pressure Stage 2 Alarm	DI			IEC61850	P3	Normal	Alarm
111		SF6 Gas Pressure Trip Lockout	DI			IEC61850	P3	Normal	Operated
112		Other Signals From Protection Relays Through Communication Link As Per The Protection Scheme	DI			IEC61850	P2	Normal	Operated
113		Other Signals From Metering Relays Through Communication Link As Per The Protection Scheme	DI		AI	IEC61850	P1		
114		Transducer Signal			AI	IEC61850			
115	Measurement	R Phase Current			AI	IEC61850			
116		Y Phase Current			AI	IEC61850			
117		B Phase Current			AI	IEC61850			
118		R-Y Voltage Phase			AI	IEC61850	P1	Normal	High/Low
119		Y-B Voltage Phase			AI	IEC61850	P1	Normal	High/Low
120		B-R Voltage Phase			AI	IEC61850	P1	Normal	High/Low
121	Metering	Active Power			AI	IEC61850			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
122		Reactive Power			AI	IEC61850			
123		Apparent Power			AI	IEC61850			
124		Frequency			AI	IEC61850	P1	Normal	High/Low
125		Energy Kwh			AI	IEC61850			
126		Energy Kvah			AI	IEC61850			
127		Energy Kvarh			AI	IEC61850			
128		Maximum Demand			AI	IEC61850			
129		Power Factor			AI	IEC61850			
Power Transformer									
1	Power Transformer (132/33kv)	Tap Raise		DO		IEC61850		Updated	
2		Tap Low		DO		IEC61850		Updated	
3		Trafo Oti Alarm	DI			IEC61850	P2	Normal	Alarm
4		Trafo Oti Trip	DI			IEC61850	P3	Normal	Trip
5		Trafo Buchholz Alarm	DI			IEC61850	P2	Normal	Alarm
6		Trafo Buchholz Trip	DI			IEC61850	P3	Normal	Trip
7		Trafo Osr Protection	DI			IEC61850	P3	Normal	Trip
8		Trafo WTI Alarm	DI			IEC61850	P2	Normal	Alarm
9		Trafo Wti Trip	DI			IEC61850	P3	Normal	Trip
10		Trafo Oil Level Low Alarm	DI			IEC61850	P2	Normal	Alarm
11		Trafo OLTC Prv Protection	DI			IEC61850	P3	Normal	Trip
12		OLTC L/R Switch Status	DI			IEC61850	P1	Remote	Local
13		Rtcc Auto/Manual Switch	DI			IEC61850	P1	Auto	Manual
14		OLTC DC Supply Status	DI			IEC61850	P2	Healthy	Unhealthy
15		OLTC AC Supply Status	DI			IEC61850	P2	Healthy	Unhealthy
16		OLTC Stuck	DI			IEC61850	P3	Normal	Alarm
17		OLTC In Lower Limit	DI			IEC61850	P1	Normal	Reached
18		OLTC In Upper Limit	DI			IEC61850	P1	Normal	Reached

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwire d Signal / Soft Signal		Normal State	Alarm State
19		OLTC Status	DI			IEC61850	P2	Healthy	Unhealthy
20		PN Isolator Status	DI			IEC61850	P1	Close	Open
21		SN Isolator Status	DI			IEC61850	P1	Close	Open
22	Measurement	Tap Position			AI	IEC61850	P1	Real Time Value	Reached Higher
23		OLTC Temperature			AI	IEC61850	P1	Normal	High
24		HV Winding Temperature			AI	IEC61850	P1	Normal	High
25		LV Winding Temperature			AI	IEC61850	P1	Normal	High
26		Oil Temperature			AI	IEC61850	P1	Normal	High
GSS									
1	Circuit Breaker	CB Open Status	DI			IEC61850	P1	Open	Intermediate/ Faulty
2		CB Close Status	DI			IEC61850	P1	Close	Intermediate/ Faulty
3		CB Stuck Alarm	DI			IEC 61850	P1	Normal	Alarm
4		CB Trip Circuit Unhealthy	DI			IEC 61850	P1	Normal	Unhealthy
5		Master Trip Relay Circuit Unhealthy	DI			IEC 61850	P1	Normal	Unhealthy
6		Master Trip Relay Operated	DI			IEC 61850	P2	Normal	Operated
7		Under Voltage Alarm	DI			IEC 61850	P2	Normal	Alarm
8	Protection	Relay Faulty	DI			IEC 61850	P2	Normal	Faulty
9		Dist. Protection Operated	DI			IEC 61850	P3	Normal	Operated
10		O/C Protection Operated	DI			IEC 61850	P3	Normal	Operated
11		E/F Protection operated	DI			IEC 61850	P3	Normal	Operated
12		Relay Faulty	DI			IEC 61850	P2	Normal	Faulty
13		Dir. O/C Protection Operated	DI			IEC 61850	P3	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
14		Dir. E/F Protection Operated	DI			IEC 61850	P3	Normal	Operated
15		Other Signals From Protection Relays Through Communication Link As Per The Protection Scheme	DI			IEC61850	P2	Normal	Operated
33KV AIS									
1	Vaccum Circuit Breaker/Bay	CB Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
2		CB Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
3		CB Open Command		DO		Hardwired			
4		CB Close Command		DO		Hardwired			
5		Trip Reset Command		DO		IEC61850		Reset	
6		Scada Permissive	DI			Hardwired	P1	Banned	Permitted
7		Scada Permissive Command		DO		Hardwired			
8		Trip Relay Supervision	DI			IEC61850	P3	Healthy	Unhealthy
9		Trip Relay Operated	DI			IEC61850	P3	Normal	Operated
10		PT MCB status	DI			Hardwired	P2	Normal	Trip
11		CB Position	DI			Hardwired	P1	Service	Test
12		CB Spring Status	DI			Hardwired	P2	Charged	Discharged
13		110V DC control supply status	DI			Hardwired	P2	Normal	Trip
14		L/R Switch	DI			Hardwired	P1	Remote	Local

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
		Position							
15		CB TC-1 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
16		CB TC-2 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
17		Pilot wire communication	DI			IEC61850	P2	Normal	Fail
18		Time Synch Status	DI			IEC61850	P1	Normal	Fail
19		Ethernet Switch MCB Status	DI			Hardwired	P1	Normal	Trip
20		Bus PT status	DI			Hardwired	P1	Normal	Unhealthy
21		IRF Healthy	DI			IEC61850	P2	Healthy	Unhealthy
22		CB Ready to close	DI			IEC61850	P1	Healthy	Unhealthy
23		Master trip relay circuit unhealthy	DI			IEC61850	P3	Healthy	Unhealthy
24		CB Stuck alarm and trip	DI			IEC61850	P3	Normal	Operated
25		CB Trouble close block	DI			IEC61850	P2	Normal	Operated
26		Relay L/R status	DI			IEC61850	P2	Remote	Local
27	Sub Station Transformer (33/0.415KV)	Trafo WTI Alarm	DI			Hardwired	P2	Normal	Alarm
28		Trafo WTI Trip	DI			Hardwired	P3	Normal	Trip
29		Trafo door status	DI			Hardwired	P2	Close	Open
30	Protection	Differential Relay Communication status	DI			IEC61850	P1	Healthy	Unhealthy
31		Differential Relay Status	DI			IEC61850	P2	Normal	Faulty
32		Differential Protection	DI			IEC61850	P3	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
		Status							
33		Over Voltage Alarm	DI			IEC61850	P2	Normal	Operated
34		Under Voltage Alarm	DI			IEC61850	P2	Normal	Operated
35		O/C Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
36		E/F Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
37		O/C & E/F Relay Communication	DI			IEC61850	P1	Healthy	Unhealthy
38		O/C & E/F Relay Status	DI			IEC61850	P2	Normal	Faulty
39	Earthing Switch	Earth Switch Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
40		Earth Switch Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
41		Earth Switch Open Command		DO		Hardwired			
42		Earth Switch Close Command		DO		Hardwired			
43	Measurement	R Phase Current			AI	IEC61850			
44		Y Phase Current			AI	IEC61850			
45		B Phase Current			AI	IEC61850			
46		R-Y Voltage Phase			AI	IEC61850	P1	Normal	High/Low
47		Y-B Voltage Phase			AI	IEC61850	P1	Normal	High/Low
48		B-R Voltage Phase			AI	IEC61850	P1	Normal	High/Low

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input			Normal State	Alarm State
49	Metering	Active Power			AI	IEC61850			
50		Reactive Power			AI	IEC61850			
51		Apparent Power			AI	IEC61850			
52		Frequency			AI	IEC61850	P1	Normal	High/Low
53		Energy Kwh			AI	IEC61850			
54		Energy Kvah			AI	IEC61850			
55		Energy Kvarh			AI	IEC61850			
56		Maximum Demand			AI	IEC61850			
57		Power Factor			AI	IEC61850			
58		Other Signals From Protection Relays Through Communication Link As Per The Protection Scheme	DI			IEC61850	P2	Normal	Operated
59		Other Signals From Metering Relays Through Communication Link As Per The Protection Scheme	DI		AI	IEC61850	P1		
33KV GIS									
1	SF6 Circuit Breaker/Bay	CB Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
2		CB Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
3		CB Open Command		DO		Hardwired			
4		CB Close Command		DO		Hardwired			
5		Trip Reset Command		DO		IEC61850		Reset	
6		Scada Permissive	DI			Hardwired	P1	Banned	Permitted

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
7		Scada Permissive Command		DO		Hardwired			
8		Trip Relay Supervision	DI			IEC61850	P3	Healthy	Unhealthy
9		Trip Relay Operated	DI			IEC61850	P3	Normal	Operated
10		PT MCB status	DI			Hardwired	P2	Normal	Trip
11		CB Position	DI			Hardwired	P1	Service	Test
12		CB Spring Status	DI			Hardwired	P2	Charged	Discharged
13		110V DC control supply status	DI			Hardwired	P2	Normal	Trip
14		L/R Switch Position	DI			Hardwired	P1	Remote	Local
15		CB TC-1 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
16		CB TC-2 Supervision	DI			IEC61850	P2	Healthy	Unhealthy
17		Pilot wire communication	DI			IEC61850	P2	Normal	Fail
18		Time Synch Status	DI			IEC61850	P1	Normal	Fail
19		Ethernet Switch MCB Status	DI			Hardwired	P1	Normal	Trip
20		CB SF6 pressure Low	DI			Hardwired	P3	Normal	Operated
21		CB SF6 pressure High	DI			Hardwired	P3	Normal	Operated
22		Bus compartment SF6 pressure Low	DI			Hardwired	P3	Normal	Operated
23		CB Ready to close	DI			IEC61850	P1	Healthy	Unhealthy
24		Master trip relay circuit unhealthy	DI			IEC61850	P3	Healthy	Unhealthy
25		CB Stuck alarm and trip	DI			IEC61850	P3	Normal	Operated
26		CB Trouble close block	DI			IEC61850	P2	Normal	Operated
27		Relay L/R status	DI			IEC61850	P2	Remote	Local
28	Sub Station	Trafo WTI Alarm	DI			Hardwired	P2	Normal	Alarm

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
29	Transformer (33/0.415KV)	Trafo WTI Trip	DI			Hardwired	P3	Normal	Trip
30		Trafo door status	DI			Hardwired	P2	Close	Open
31	Protection	Differential Relay Communication	DI			IEC61850	P1	Healthy	Unhealthy
32		Differential Relay Status	DI			IEC61850	P2	Normal	Faulty
33		Differential Protection Status	DI			IEC61850	P3	Normal	Operated
34		Trafo LV REF	DI			IEC61851	P3	Normal	Operated
35		Over Voltage Alarm	DI			IEC61850	P2	Normal	Operated
36		Under Voltage Alarm	DI			IEC61850	P2	Normal	Operated
37		O/C Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
38		E/F Protection Trip (Dir/Non Dir/Instat)	DI			IEC61850	P3	Normal	Operated
39		O/C & E/F Relay Communication	DI			IEC61850	P1	Healthy	Unhealthy
40		O/C & E/F Relay Status	DI			IEC61850	P2	Normal	Faulty
41		IRF Healthy	DI			IEC61850	P2	Healthy	Unhealthy
42		REF Relay Status	DI			IEC61850	P2	Normal	Faulty
43	Isolator/Disc onnector	Isolator Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
44		Isolator Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
45		Isolator Open Command		DO		Hardwired			
46		Isolator Close Command		DO		Hardwired			
47	Earthing Switch	Earth Switch Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
48		Earth Switch Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
49		Earth Switch Open Command		DO		Hardwired			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
50		Earth Switch Close Command		DO		Hardwired			
51	Measurement	R Phase Current			AI	IEC61850			
52		Y Phase Current			AI	IEC61850			
53		B Phase Current			AI	IEC61850			
54		R-Y Voltage Phase			AI	IEC61850	P1	Normal	High/Low
55		Y-B Voltage Phase			AI	IEC61850	P1	Normal	High/Low
56		B-R Voltage Phase			AI	IEC61850	P1	Normal	High/Low
57	Metering	Active Power			AI	IEC61850			
58		Reactive Power			AI	IEC61850			
59		Apparent Power			AI	IEC61850			
60		Frequency			AI	IEC61850	P1	Normal	High/Low
61		Energy Kwh			AI	IEC61850			
62		Energy Kvah			AI	IEC61850			
63		Energy Kvarh			AI	IEC61850			
64		Maximum Demand			AI	IEC61850			
65		Power Factor			AI	IEC61850			
66		Other Signals From Protection Relays Through Communication Link As Per The Protection Scheme	DI			IEC61850	P2	Normal	Operated
67		Other Signals From Metering Relays Through Communication Link As Per The Protection Scheme	DI		AI	IEC61850	P1		
33KV Control Relay Panel									
1	33kV Control	Local/Remote in Local	DI			Hardwired	P1	Remote	Local

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwire d Signal / Soft Signal		Normal State	Alarm State
2	Relay Panel	Permission for Local Control	DI			Hardwired	P1	Banned	Permitted
3		Signals from Transducers			AI	Hardwired			
4		Other Signals from metering relays through communication link as per the protection scheme	DI			IEC 61850	P2		
5		Other Signals from protection relays through communication link as per the protection scheme	DI			IEC 61850	P2	Normal	Operated
33KV Vacuum Interrupter									
1	33 KV Vacuum Interrupter	Local/Remote in Local	DI			Hardwired	P1	Remote	Local
2		Permission for Local Control	DI			Hardwired	P1	Banned	Permitted
3		110V DC Control Voltage Fail	DI			Hardwired	P2	Normal	Fail
4		Close Indication	DI			Hardwired	P0	Close	
5		Open Indication	DI			Hardwired	P0	Open	
6		Vacuum or SF6 Gas Pressure Low Alarm all stages for individual compartment	DI			Hardwired	P2	Normal	Low
7		SF6 Gas low pressure auto trip alarm all stages for individual compartment	DI				P2	Normal	Trip
8		IT in Test/Service	DI			Hardwired	P2	Service	Test
9	IT Trip Circuit Unhealthy (Individual trip	DI			Hardwired	P3	Normal	Unhealthy	

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
		circuit status)							
10		Spring Discharged	DI			Hardwired	P1	Charged	Discharged
11		Open Command		DO		Hardwired			
12		Close Command		DO		Hardwired			
13		SCADA Permissive for Local Control		DO		Hardwired			
14		Other Signals from metering relays through communication link as per the protection scheme	DI			IEC 61850	P2		
15		Other Signals from protection relays through communication link as per the protection scheme	DI			IEC 61850	P2	Normal	Operated
750V DC									
1	High Speed DC Circuit Breaker	Local/Remote in Local	DI			IEC 61850	P1	Remote	Local
2		Permission for Local Control	DI			IEC 61850	P1	Banned	Permitted
3		110V DC Control Voltage Fail	DI			IEC 61850	P2	Normal	Fail
4		Open Command		DO		IEC 61850			
5		Close Command		DO		IEC 61850			
6		Lockout Relay Reset Command		DO		IEC 61850			
7		SCADA Permissive for Local Control		DO		IEC 61850			
8		HSCB in Test/Service	DI			IEC 61850	P2	Service	Test
9		Close Indication	DI			IEC 61850	P1	Close	Intermediate/ Faulty

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
10		Open Indication	DI			IEC 61850	P1	Open	Intermediate/ Faulty
11		HSCB Trip Circuit Status	DI			IEC 61850	P2	Normal	Unhealthy
12		HSCB Spring Status	DI			IEC 61850	P1	Charged	Discharged
13		Overcurrent Reverse Relay	DI			IEC 61850	P2	Normal	Operated
14		Under Voltage Relay	DI			IEC 61850	P2	Normal	Operated
15		Over Voltage Relay	DI			IEC 61850	P2	Normal	Operated
16		HSCB Stuck Alarm	DI			IEC 61850	P2	Normal	Alarm
17		Inst. Over Current	DI			IEC 61850	P2	Normal	Operated
18		Frame Fault Relay	DI			IEC 61850	P2	Normal	Operated
19		DC Over Current Trip Release	DI			IEC 61850	P2	Normal	Trip
20		Time Delayed Over Current	DI			IEC 61850	P2	Normal	Trip
21		Current Measurement			AI	IEC 61850			
22		Voltage Measurement			AI	IEC 61850			
23	DC Short Circuiting Device	Permission for Local Control	DI			IEC 61850	P1	Banned	Permitted
24		110V DC Control Voltage Fail	DI			IEC 61850	P2	Normal	Fail
25		Close Indication	DI			IEC 61850	P1	Close	Intermediate/ Faulty
26		Open Indication	DI			IEC 61850	P1	Open	Intermediate/ Faulty
27		Open Command		DO		IEC 61850			
28		Close Command		DO		IEC 61850			
29		SCADA Permissive for Local Control		DO		IEC 61850			
30		Voltage			AI	IEC 61850			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
31		Current			AI	IEC 61850			
32		Other Signals from protection relays through communication link as per the protection scheme	DI			IEC 61850	P2	Normal	Operated
33		Other Signals for stray current monitoring through communication link as per the protection scheme			AI	IEC 61850			
34	DC Load Break Switch	Permission for Local Control	DI			IEC 61850	P1	Banned	Permitted
35		Local/Remote in Local	DI			IEC 61850	P1	Remote	Local
36		110V DC Control Voltage Fail	DI			IEC 61850	P2	Normal	Fail
37		Close Indication	DI			IEC 61850	P1	Close	Intermediate/ Faulty
38		Open Indication	DI			IEC 61850	P1	Open	Intermediate/ Faulty
39		Open Command		DO		IEC 61850			
40		Close Command		DO		IEC 61850			
41		SCADA Permissive for Local Control		DO		IEC 61850			
42	Disconnecto r Switch / Isolator	Close Indication	DI			Hardwired	P1	Close	Intermediate/ Faulty
43		Open Indication	DI			Hardwired	P1	Open	Intermediate/ Faulty
44		Open Command		DO		Hardwired			
45		Close Command		DO		Hardwired			
46	Bus Voltage	Voltage R-Y			AI	IEC 61850			
47		Voltage Y-B			AI	IEC 61850			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
48		Voltage B-R			AI	IEC 61850			
49	CT	Current R			AI	IEC 61850			
50		Current Y			AI	IEC 61850			
51		Current B			AI	IEC 61850			
52	Earth Switch	Open Indication	DI			Hardwired	P1	Close	Intermediate/ Faulty
53		Close Indication	DI			Hardwired	P1	Open	Intermediate/ Faulty
54	Aux Transformer In ASS	Winding Temp High Alarm	DI			IEC 61850	P3	Normal	Alarm
55		Winding Temp High Auto Trip Alarm	DI			IEC 61850	P3	Normal	Trip
56		Transformer Door Open	DI			IEC 61850	P3	Normal	Alarm
57	Rectifier Transformer In TSS	Winding Temp High Alarm	DI			IEC 61850	P3	Normal	Alarm
58		Winding Temp High Auto Trip Alarm	DI			IEC 61850	P3	Normal	Trip
59		Transformer Door Open	DI			IEC 61850	P3	Normal	Alarm
60	Rectifier	Diode Over Temp Alarm	DI			IEC 61850	P2	Normal	Alarm
61		Diode Over Temp Trip	DI			IEC 61850	P2	Normal	Trip
62		Diode Failure Relay Status	DI			IEC 61850	P2	Normal	Faulty
63		Door Relay Status	DI			IEC 61850	P3	Normal	Faulty
64		Frame Fault Relay	DI			IEC 61850	P3	Normal	Faulty
65		Fuse Fault Relay	DI			IEC 61850	P3	Normal	Faulty
66	Negative Return Panel	Close Indication	DI			IEC 61850	P1	Close	Intermediate/ Faulty
67		Open Indication	DI			IEC 61850	P1	Open	Intermediate/ Faulty
68		Open Command		DO		IEC 61850			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
69		Close Command		DO		IEC 61850			
70		LOCAL/REMOTE STATUS	DI			IEC 61850	P1	Remote	Local
71		Equipment Status	DI			IEC 61850	P3	Remote	Local
72		FLR Protection				IEC 61850	P3	Normal	Alarm
73		Closing Interlock				IEC 61850	P1	Ok	Not ok
74		Permit to Operate ND	DI			IEC 61850	P1	Banned	Permitted
75		Inter Trip Out (HSCB No.)	DI			IEC 61850	P3	Normal	Operated
76	Motorized SCD	Close / Open Indication	DI			Hardwired	P1	Close/Open	Intermediate/Faulty
77		Local/Remote Indication	DI			Hardwired	P1	Remote	Local
78		Permission for Local Control	DI			Hardwired	P1	Banned	Permitted
79		110V DC Control Voltage Fail	DI			Hardwired	P2	Normal	Fail
80		SCADA Permissive for Local Control		DO		Hardwired			
81		Close / Open Command		DO		Hardwired			
82	Disconnecto r Switch (Depot TSS)	Disconnecto r Close/Open Indication	DI			Hardwired	P1	Close/Open	Intermediate/Faulty
83		Local/Remote Mode	DI			Hardwired	P1	Remote	Local
84		Left Side of D/S Energized	DI			Hardwired	P2	Normal	Alarm
85		Right Side of D/S Energized	DI			Hardwired	P2	Normal	Alarm
86		D/S Fault	DI			Hardwired	P2	Normal	Faulty
87		Permission for local control	DI			Hardwired	P1	Banned	Permitted
88		110V DC Control voltage fail	DI			Hardwired	P2	Normal	Fail
89		Disconnecto r (Open/Close)		DO		Hardwired			

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
		Command							
90		SCADA Permissive for Local Control		DO		Hardwired			
91	Protection	EQUIPMENT STATUS	DI			IEC 61850	P2	HEALTHY	UNHEALTHY
92		FLR PROTECTION	DI			IEC 61850	P3	NORMAL	OPERATED
93		CLOSING INTERLOCK	DI			IEC 61850	P0	OK	NOT OK
94		VOLTAGE DETECTION ELEMENTRY SECTION NO.	DI			IEC 61850	P0	LIVE	DEAD
95		VOLTAGE DETECTION ELEMENTRY SECTION NO.	DI			IEC 61850	P0	LIVE	DEAD
91	Off Load Manual Disconnecto r Switch (Depot TSS)	Disconnecto r Close/Open Indication	DI			Hardwired	P1	Close/ Open	Intermediate/ Faulty
92	OVPD	EXTERNAL CLOSING		DO		Hardwired	P0	Open	Close
93		OVPD OPEN COMMAND		DO		Hardwired		Open	
94		OVPD CLOSE COMMAND		DO		Hardwired	P0	Close	
95		RESET COMMAND		DO		Hardwired	P0	-	Reset
96		LOCAL/REMOTE STATUS	DI			Hardwired	P1	Remote	Local
97		OVPD OPEN STATUS	DI			Hardwired		Open	
98		OVPD CLOSE STATUS	DI			Hardwired	P2	Close	
99		PERMIT TO CLOSE	DI			Hardwired	P0	Banned	Permitted
100	Protection	OVPD LOCK OUT & CLOSE	DI			IEC 61850	P3	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
101		OVPD trip	DI			IEC 61850	P3	Normal	Operated
102		Umax+	DI			IEC 61850	P3	Normal	Operated
103		Umax++	DI			IEC 61850	P3	Normal	Operated
104		Service maintenance status	DI			IEC 61850	P1	Normal	Maintenance
105		CURRENT LEVEL- (50 THRESHOLD)	DI			IEC 61850	P2	Normal	Operated
106		Lockout operated	DI			IEC 61850	P2		
107		VOLTAGE LEVEL- (50 THRESHOLD)	DI			IEC 61850	P2	Normal	Operated
108		VLD protection detection	DI			IEC 61850	P3	Normal	Operated
109		Anti pumping	DI			IEC 61850	P3	Normal	Operated
110	Measurement	VOLTAGE			AI	IEC 61850	P2	-	-
111		CURRENT			AI	IEC 61850	P2	-	-
112	IGBT Inverter	Thyristor Fuse (97) Status	DI			IEC 61850	P3	Normal	Blown
113		Inverter Material Status	DI			IEC 61850	P1	Normal	Fault
114		Inverter Operation Status	DI			IEC 61850	P1	Normal	Fault
115		Synchronization Transformer Fuse Status	DI			IEC 61850	P3	Normal	Blown
116		Door Status	DI			IEC 61850	P1	Close	Open

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
117		LOCAL/REMOTE STATUS	DI			IEC 61850	P1	Remote	Local
118	Measurement	Coil Stage 1 Temperature			AI	IEC 61850	-	Normal	Alarm
119		Coil Stage 2 Temperature			AI	IEC 61850	-	Normal	Trip
120		Inverter Stage 1 Temperature			AI	IEC 61850	-	Normal	Low
121		Inverter Stage 2 Temperature			AI	IEC 61850	-	Normal	High
415V LT CB									
1	415V CB	CB Open Status	DI			Hardwired	P1	Open	Intermediate/ Faulty
2		CB Close Status	DI			Hardwired	P1	Close	Intermediate/ Faulty
3		CB Open Command		DO		Hardwired			
4		CB Close Command		DO		Hardwired			
5		110V DC Control volt	DI			Hardwired	P1	Normal	Fail
6		Trip relay operated	DI			Hardwired	P2	Normal	Operated
7		L/R Switch position	DI			Hardwired	P1	Remote	Local
8		CB Position	DI			Hardwired	P1	Service	Test
9		Spring Discharged	DI			Hardwired	P1	Charged	Discharged
10		Auto/Manual Indication	DI			Hardwired	P1	Auto	Manual
11		Auto Manual Command		DO		Hardwired			
12		Scada Permissive	DI			Hardwired	P1	Banned	Permitted
13		Scada Permissive Command		DO		Hardwired			
14	Protection	Thermal Overload protection	DI			Hardwired	P2	Normal	Operated
15		Under voltage trip	DI			Hardwired	P2	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwire d Signal / Soft Signal		Normal State	Alarm State
16	Measurement	R Phase Current			AI	Modbus			
17		Y Phase Current			AI	Modbus			
18		B Phase Current			AI	Modbus			
19		R-Y Voltage Phase			AI	Modbus			
20		Y-B Voltage Phase			AI	Modbus			
21		B-R Voltage Phase			AI	Modbus			
22	Metering	Active Power			AI	Modbus			
23		Reactive Power			AI	Modbus			
24		Apparent Power			AI	Modbus			
25		Frequency			AI	Modbus			
26		Energy Kwh			AI	Modbus			
27		Energy Kvah			AI	Modbus			
28		Energy Kvarh			AI	Modbus			
29		Maximum Demand			AI	Modbus			
30		Power Factor			AI	Modbus			
ETS									
1		ETS Operated (Individual for all ETS)	DI			Hardwired	P3	Healthy	Operated
Battery Charger									
1	Battery Charger	Charger Status	DI			Hardwired	P1	Main	Standby
2		Float/Boost	DI			Hardwired	P1	Float	Boost
3		Input MCB Trip	DI			Hardwired	P2	Normal	Trip
4		AC Fail	DI			Hardwired	P2	Normal	Fail
5		Charger Fail	DI			Hardwired	P2	Normal	Fail
6		Battery Low	DI			Hardwired	P2	Normal	Alarm
7		DC Under Voltage	DI			Hardwired	P1	Normal	Alarm
8		DC Over Voltage	DI			Hardwired	P2	Normal	Alarm
9		Output MCB Trip	DI			Hardwired	P2	Normal	Trip
10		Ready for changeover	DI			Hardwired	P2	Normal	Fail
11		Battery reverse polarity	DI			Hardwired	P2	Normal	Alarm
12		DC Earth Leakage	DI			Hardwired	P2	Normal	Alarm
13		DC Fail	DI			Hardwired	P2	Normal	Fail
14		AVR channel fail	DI			Hardwired	P2	Normal	Fail

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
15		Charger Trouble	DI			Hardwired	P2	Normal	Alarm
16		Charger Voltage			AI	Hardwired			
ACDB & DCDB									
1	ACDB	Lack of 415V	DI			Hardwired	P1	Normal	Alarm
2	DCDB	Lack of 110V	DI			Hardwired	P2	Normal	Alarm
3		L/R Switch position	DI			Hardwired	P1	Remote	Local
4		Bus under voltage	DI			Hardwired	P2	Normal	Operated
5		Breaker position indicator	DI			Hardwired	P1	open/ close	Intermediate/ Faulty
6		Breaker command		DO		Hardwired			
UPS									
1	UPS	Common Alarms	DI			Hardwired	P2	Normal	Operated
2		Bypass frequency out of range	DI			Hardwired	P1	Normal	Operated
3		Load on Bypass	DI			Hardwired	P1	Normal	Operated
4		Inverter Overload	DI			Hardwired	P1	Normal	Operated
5		Low Battery	DI			Hardwired	P2	Normal	Operated
RTU									
1	RTU	RTU Power Supply 1 Status	DI			Hardwired / Internal	P2	Normal	Unhealthy
2		RTU Power Supply 2 Status	DI			Hardwired / Internal	P2	Normal	Unhealthy
3		RTU Panel Door Status	DI			Hardwired	P1	Normal	Open
4		RTU SCADA Permissive Switch Status	DI			Hardwired	P1	Remote	Local
5		SCADA FO cable	DI			Internal	P2	Normal	Unhealthy
6		RTU DC-DC Converter	DI			Hardwired	P2	Normal	Unhealthy
7		DO MCB Status	DI			Hardwired	P2	Normal	Trip
8		RTU communication status	DI			Internal	P3	Running	Suspended

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwire d Signal / Soft Signal		Normal State	Alarm State
9		RTU CPU Module, Communication Module, I/O Module, Power supply module Status	DI			Internal	P2	Normal	Faulty
10		RTU Reset / Restart Command		DO		Internal			
Energy Meters									
1	Energy Meters	Voltage, Current, Power, Frequency, Energy, Maximum demand etc.			AI	Modbus			
Other Miscellaneous I/O									
1	Server panel	Server Panel Control supply MCB	DI			Hardwired	P2	Normal	Trip
2		Server Panel Ethernet switch MCBs status	DI			Hardwired	P2	Normal	Trip
3	Networking Panel	Gateway-1 AC Supply	DI			Hardwired	P1	NORMAL	UNHEALTHY
4		Gateway-2 AC Supply	DI			Hardwired	P1	NORMAL	UNHEALTHY
5		DC-1 Supply	DI			Hardwired	P2	NORMAL	ALARM
6		DC-2 Supply	DI			Hardwired	P2	NORMAL	ALARM
7		AC Supply	DI			Hardwired	P1	OFF	ON
8	Ethernet switches	RSS all ethernet switch ports status	DI			Hardwired	P1	Normal	Unhealthy
9	Gas flooding system	Gas flooding system status (All equipments)	DI			Hardwired	P1	Normal	Operated

S.N.	Device	Event Description	Event Type			Signal Interface Type	Alarm Class	Event Text	
			Digital Input	Digital output	Analog Input	Hardwired Signal / Soft Signal		Normal State	Alarm State
10	Other	Other signal from FACP, AHU, Air Conditioning panel & Main gate	DI			Hardwired	P1	Normal	Operated

- Signals list are not limited to mentioned in above list and may be modified as per installed system specification with the consent of UPMRC.

18.22 Stray Current Monitoring System

18.22.1 Description

18.22.1.1 The Stray current monitoring system shall be supplied at OCC under this contract for the Esar West Corridor.

18.22.1.2 The operation of DC traction systems requires suitable measures to prevent corrosion caused by stray currents on railways and non-railway installations. This function is forming a part of the remote monitoring of

- Negative Earth Panel
- Short Circuiting Device

18.22.1.3 Stray current monitoring consists of two functions

- Supervision of status of short-circuiting devices & Negative relay panel at all TSSs /ASSs and raising an alarm if the device has been activated.
- Supervision of stray current along the line, which is not measured directly but monitoring system shall be based on comparison of normal system's values (reference values) with actual reading of track potentials. In case of earth failure or increase of stray current, this system shall provide alarms to SCADA to be displayed at the HMI.

18.22.2 Stray Current Protection & Control

18.22.2.1 In DC traction system, the running rails are used to carry the traction return current, back to the Traction Substations. It is essential to ensure that the return current does not stray into the earth and as far as possible is wholly returned to the traction substation.

18.22.2.2 Despite the precautionary measures adopted, it is quite possible that some current may find its path into the earth and this current, termed as "stray current", shall be detected and monitored.

- 18.22.2.3** Thus, a Remote monitoring system shall be provided, to continuously acquire track-to-earth potentials from multiple measuring points along the entire alignment, namely TSS and passenger stations.
- 18.22.2.4** The values of track-to-earth potentials shall be displayed at a central evaluation unit located at the OCC only, to enable a good overview of track potentials (in a safe voltage limit) and stray current danger for the entire network.
- 18.22.2.5** Suitable algorithms shall be developed to evaluate the measured data against reference values to determine whether track potential shifts are caused by a change in operating conditions or a failure in the track to earth insulation.
- 18.22.2.6** The central evaluation unit shall be capable of displaying mean values of the track voltage versus time and the track voltage versus distance over a selected time interval, alert against any abnormal conditions associated with track to earth insulation failures and provide essential information to allow maintenance personnel to locate possible track to earth fault.
- 18.22.3 Stray Current Monitoring System**
- 18.22.3.1** Stray current cannot be measured directly. The stray current monitoring system based on comparison of normal system's values (reference values) with actual reading of track potentials (Voltages between return line L- and earth) at all TSSs of the complete system during operation. The actual data usually are taken from the over voltage devices mounted inside short-circuiting device and transmitted to SCADA. The system is able to localize earth leakages.
- 18.22.3.2** Track potential values shall be provided via. RTU to SCADA. At central evaluation unit an additional standard interface (like ODBC, OPC etc.) shall be provided to channel those potential values to the stray current monitoring system.
- 18.22.3.3** Output information of the stray current monitoring systems normal/abnormal shall be fed back into SCADA to be monitored at HMI.
- 18.22.3.4** Messages from supervision of status of over voltage devices as well as the stray current monitoring system shall be handled as alarms due to change of field information.
- 18.22.4 Main Components**
- 18.22.4.1 Voltage Limiting Device (VLD)**
- 18.22.4.1.1 This device collects information about the voltages between return line and earth (structure earth) at several measuring points along the tracks to be monitored during railway operations. The measured values are represented and evaluated in order to locate any insulation deficiencies. VLD shall be supplied by respective power supply contractor.
- 18.22.4.2 Communication**
- 18.22.4.2.1 The measured values are transmitted from the Short-circuiting Devices to the central evaluation unit via RTU and telecom communication network.
- 18.22.4.3 Central Evaluation Unit**

18.22.4.3.1 The Central Evaluation Unit is a PC/server with latest configuration, on which SCMS shall be installed and implemented. The specification of SCMS server shall be similar to the SCADA server as mentioned in clause 18.15.2.1. It shall be connected to field devices through SCADA communication network and would acquire measured value.

- a) The 2-layer architecture shall be provided for SCMS at OCC. The data collection & processing shall be done in master layer to be located in SCADA server room and display layer (client) shall be provided to TPC WS in OCC theatre room.
- b) The data exchange between SCADA system and SCMS over IEC 60870-5-104 or OPC DA protocol or any other standard open protocol.
- c) The system shall support sampling rate max. 1 measure/ sec.
- d) The system shall time Synchronized with SCADA server.
- e) The time stamping of stray current data shall be done at field side either IEDs or RTUs.

18.22.4.4 Stray Current Monitoring Software

18.22.4.4.1 The system shall be suitable for the monitoring of a typical Metro line, including multiple measurements points installed in traction sub-station or passengers' stations. The system shall have minimum following function.

- a) Data acquisition via the IEC60870-5-104 network.
- b) Support sampling rate max. 1 measure/ sec.
- c) Shall store and compute the data and issue an alarm in case of abnormal condition that could create a risk of stray current leakage.
- d) Archiving with multi-level data compression
- e) Representation of the track potentials at all measuring points
- f) Instantaneous values as a time characteristic
- g) Average values and averages of the absolute value as short-term and long-term averages
- h) Representation of average values as a time characteristic or at a line location
- i) Location of insulation deficiencies
- j) Reference value recording
- k) Automatic analysis

18.22.4.4.2 To locate insulation deficiencies SCMS compares the current measured values with previously recorded reference values. If the track potentials exceed the tolerance range with respect to certain criteria, a message shall be generated. The location of the suspected insulation deficiencies can be pinpointed by means of integrated analysis functions.

18.22.5 Functional Requirement

18.22.5.1 Continuous monitoring of traction negative voltage during operation

18.22.5.1.1 The SCMS includes the following functions:

- a) Set up of network lines & stations, up to 10 lines and 60 control points
- b) Data acquisition and transmission through the communication network
- c) Determination on data reference

- d) Integration of specific algorithm depending on type of network
- e) Supervision of status of VLD at all stations and alarm if the device has operated
- f) Permanent automatic analysis of recorded values realized by the Central Evaluation Unit plus alarm in case stray current increases.
- g) Localization of the detected fault
- h) Manual analysis of recorded values possible
- i) Archiving of the measured values into CEU
- j) Export of the measured and recorded values
- k) Communication with SCADA system

18.22.5.1.2 The SCMS can adapt to either an existing or a new network.

18.22.5.2 Data Acquisition

18.22.5.2.1 The Stray Current Monitoring System can be connected directly to the main SCADA system data transmission network or a separate network to gathers the value of the track – earth voltage of each sensor installed in each of the VLD.

18.22.5.2.2 The most suitable communications protocols are IEC61850 (inside the sub-station) and IEC60870-5-104 (at the OCC level).

18.22.5.3 Displaying, archiving and analysing track potential via central evaluation device

- a) Instantaneous values as a time characteristic
- b) Average values and averages of the absolute value as short-term and long-term averages
- c) Representation of average values as a time characteristic or at a line location
- d) Shall store and compute the data and issue an alarm in case of abnormal condition that could create a risk of stray current leakage.

18.22.5.4 Calculation & Visualization

18.22.5.4.1 Mean values of each voltage are calculated based on an adjustable time lag for each measuring point. The software shall permit:

- a) Short-term mode: representation of mean values and mean of the absolute values with a mean value window adjustable from 1 to 60 minutes
- b) Long-term mode: representation of mean values and mean of the absolute values with a mean value window adjustable from 1 to 7 days

18.22.5.4.2 The following data shall be represented on the screen:

- a) Instantaneous rail – earth voltage versus time in with a sample of 2 seconds.
- b) Mean values/Mean of absolute values of the Rail – earth voltage versus location on the line.
- c) Mean values/Mean of absolute values of the Rail – earth voltage versus time.

- 18.22.5.5** During the testing stage of the project, measurements shall be done in order to define the reference values of the rail – earth voltage. During this phase, measurements shall be performed on site and are computed in order to define the reference profile of the line.
- 18.22.5.6** During the operational stage, each mean value of the rail – earth voltage is compared to the values of the reference profile. According to defined settings, this can generate an alarm when it shall violate the set limits.
- 18.22.5.7** Archiving Function
- 18.22.5.7.1 The last 16 weeks or time defined by Engineer instantaneous values shall be archived. The mean values of the voltage are archived during minimum 5 years or defined by Engineer.
- 18.22.5.8** Interface with SCADA system and push the various alarm generated by SCMS system for display to TPC WS and record in SCADA alarm list.

18.23 UPMRC officials Training-

- i. The vendor shall submit training program of UPMRC staff at site or at suitable location at own cost. The training shall broadly cover following aspects but not limited to:
 - a. Identification of various cards & components of RTU.
 - b. Erection, commissioning and wiring of RTU and troubleshooting of the RTU.
 - c. Configuration of addresses of RTU, future expansions of the RTU and setting up of additional tele signals and telecommands.
 - d. Using the test instruments to check the communication cable performance parameters.
 - e. Training in operation of OCC software and MMI display functions.
 - f. Training in configuration of SCADA software, changing the setting of the software, generating various reports etc.
 - g. Training in Industrial Control System (ICS) Firmware Security and in following secure practices such as password protection etc., as per CLC/TS 50701 and IEC 62443-2-1.
 - h. Formatting of hard disk, loading of the Operating system, loading of the basic SCADA application software and taking back up of files.
 - i. Operation & maintenance instructions recommended by OEMs of different SCADA sub-systems.
 - j. Training in configuration of network equipments such as switches, routers, GPS and firewall.
 - k. Any other training requirement shall be specifically mentioned by UPMRC.
 - l. Develop comprehensive training modules that cover SCADA system operations, alarm management, troubleshooting, safety protocols, and emergency response procedures.
 - m. Provide detailed user manuals, quick reference guides, and checklists to support daily operations and troubleshooting.
 - n. Training in understanding of protocols and data flow through various protocols.
 - o. Training of Network Management System.

CHAPTER-18(II)

Up-gradation of existing SCADA System (Make-ABB) installed at BCC server room, TPNR RSS & MSPA RSS of Lucknow Metro

1 Scope of Work:

The Scope of works shall include the following “Up-gradation works of SCADA System (Existing Make-ABB) installed at BCC server room, TPNR RSS & MSPA RSS of Lucknow Metro” but not limited to -

- The Contractor shall execute the work as defined herein. The work shall be carried out as per specified guidelines and as per directions of UPMRC/GC.
- The scope shall also include the installation, commissioning and testing of system including required engineering and configuration support regarding strengthening and upgradation of existing SCADA server.
- Complete signals of system will be checked from server room (OCC/BCC) as well as from RSS by UPMRC/GC. UPMRC/GC will assist in Simulation of these signals from field during site testing.
- The Contractor will provide the details and it's Function (if required) for any new software .
- Supply of Antivirus Software with validity of at least 03 years (suitable for upgraded SCADA system) and to be updated periodically.
- The contractor will provide classroom training at site to UPMRC staff and will further provide training at factory (if required) as per directions of UPMRC.
- After upgradation, existing hardware shall be compatible and functional with upgraded SCADA system.
- Windows version shall be upgraded with latest version.
- Upgraded windows, softwares and other related software keys / licenses should have lifetime validity for up-graded version.
- All Software patches updation during Warranty/DLP period to be ensured.
- The new software/License must be compatible to existing system.
- The server software license shall be at least 25000 database I/O's and 4 Lines.
- The contractor will provide CD/DVD/Pen Drive containing licence.
- The contractor will provide technical support regarding hardware / software / firmware etc, whenever required, during DLP / Warranty period.
- The contractor will upload licence key in UPMRC's laptop/desktop, as applicable, after up-gradation of software.
- The SCADA contractor shall offer servers with latest technology prevailing in similar industry and launch date of model and key components shall not be older than one year from date of supply.
- After successful installation and commissioning items as defined herein and scope of work , testing shall be carried out to ensure the working of complete function of SCADA system.
- All such tools and tackles etc. required for work execution shall be arranged by contractor at own cost.

- The contractor will have to ensure availability of spare parts at least for 10 years which is proposed to install. Supply of spare parts and necessary software upgrades on versions and window version will be provided during DLP periods.
- The work execution purely depends upon availability of power block / required clearance, the contractor has to adjust their plan of execution accordingly inclusive night hrs working. Nothing shall be paid extra on this account and no claim shall be entertained.
- The contractor will provide a Dual Power Supply scheme for server and other associated hardware.
- The contractor will have to provide one (1) no. Laptop (RAM-16GB, SSD-1 TB with latest windows) with pre installed all diagnostics tools/software/firmware etc.
- The contractor will have to provide two (2) nos. SSD external drive (2 TB) for backup of servers.
- Provision of Spare capacity to be provided in software for remote desktop connection in view of future extensions.
- The contractor will provide a user authentication scheme and role based access control with password for all remote PC.
- Server changeover through KVM switch should be applicable with press scroll lock twice.
- Dismantling of existing panel & Erection of new panel.
- Supply, Laying, Splicing and Terminating of all cables.
- Testing, Commissioning and Installation of PC's.
- Any FO cable, LIU or other hardware required for upgradation of existing SCADA system will be provided by the contractor at own cost.
- All the hardware and software shall be in compliance with cyber security guidelines (latest) issued by Govt. Cyber security features shall be implemented as per latest cyber security policy and guidelines. The confirmation certificate to be provided by the contractor with OEM after completion of work.
- Proposed technical solution shall be in compliance with IEC62443-2-4 security levels and address the System hardening (Windows & Existing SCADA user credential, disabled unused ports, removed unused programs, etc.), Antivirus software, Firewall, Patch Management as applicable for OCC& BCC. OEM's certification to be provided after completion of work.
- Scada license for Front end server (FES) will be configured with 5% additional data points/signals over and above the existing count provided by UPMRC/GC.
- Factory Inspection Test (FAT) of offered equipment shall be conducted at factory premises/any authorized institution/Lab. UPMRC/GC may send its representative to witness FAT.
- The offered equipment shall comply with operational temperature of 0-40 deg. C.
- The contractor shall submit the Method statement, testing and quality plan for the upgradation of existing SCADA server at BCC, TPNR RSS & MSPA RSS comprising of Installation, Testing and Commissioning procedure along with the necessary drawings as per requirement.
- During commissioning of systems, it shall be ensured that transfer of existing SCADA database to new systems shall be done as per approved architecture and certificate shall be submitted to UPMRC/GC that no addressing and logic change have been done except required configurations to migrate old database to new systems.

- Testing of new systems shall be done as per existing testing protocol as mentioned in IEC therein. Necessary testing & commissioning reports shall be submitted by the contractor to UPMRC/GC.
- OEM manuals (02 copies) of offered equipments covering datasheet, trouble-shooting and maintenance aspects to be provided to UPMRC/GC.
- 01 week training of UPMRC staff at OEM training centre is included in the scope of work at contractor's own cost. However, all the to and fro charges including boarding and lodging charges shall be arranged by UPMRC.
- The contractor shall have to provide new hardware and software or associated accessories like cables, switches, MCBs, Junction Boxes etc. which is necessary for upgradation at their own cost which is not mentioned herein.
- The contractor may also deploy multiple teams on various sites if required, to execute the work within stipulated time on each day for which power block shall be arranged by UPMRC.
- The work shall be carried out during revenue hours as well as non-revenue hours as per requirement. The time for actual work may be less than the power block/permit to work duration. No compensation/extra payment shall be made in this account.
- There may be cases when the scheduled permit to work may be cancelled even after contractor manpower reaches the site of work & no work may be performed. No compensation shall be paid for such cases.
- The contractor team shall be equipped with necessary communication facility at site of work. There should be at least one Engineer who will control his man-power & obtain necessary instruction from UPMRC's Engineer at site of work.
- The warranty/Defect Liability Period for upgraded system shall be same as mentioned in SCC/GCC.
- During warranty, rectification of items shall be arranged by contractor within 24 hours from the date of reporting failure to firm.

The contractor has to provide up-gradation of SCADA System (existing Make-ABB) installed at BCC sever room, TPNR RSS & MSPA RSS of Lucknow metro at their own cost as mentioned in table given below:

.2 Technical Specification

(A) Technical Specification of TPNR RSS

Sl. No.	Details of Software/ hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (Inst.)	Qty (Req.)
1	19" Rack Mountable Server for SAS	Make- Portwell Laxsons, Processor: Intel Xeon CPU E3-1220 V2 @ 3.10GHz, 64 bit RAM: 8 GB DDR3	Make-Any Make 19" Rack mountable industrial PC, 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base 64GB DDR5 RAM. 2*1TB SSD, RAID-1.	2	2

Sl. No.	Details of Software/hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (Inst.)	Qty (Req.)
		HDD: (SAS-1: 500GB SATA, SAS-2: 1 TB SATA) 1*DVD-RW Drive. 2*10/100 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100 mbps Ethernet Card. 6*USB, 2*Serial and 2*VGA Port, 2*HDMI Port, 1*Audio port 1*USB Keyboard and Optical Mouse. 1*500-Watt single Power Supply. OS: Windows 8.1pro (SAS1), 10pro (SAS2)	2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 4*USB, 2*Serial and 1*VGA Port onboard. 1*HDMI Port onboard 1*USB Keyboard and Optical Mouse. 1*Audio port 1*DVD-RW Drive. 1*TPM Module 1*Dual Power Supply. 1*Windows-Server Std. 2022 64-Bit O.S. or latest		
2	19" Rack Mountable DR Server	DR server Make- Portwell Laxsons, Processor: Intel Core i7-2600 CPU @ 3.40GHz, 32 bit RAM: 4 GB DDR3 HDD: 500GB SATA 1*DVD-RW Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100 mbps Ethernet Card. 6*USB, 2*Serial and 1*VGA Port, 1*HDMI Port 1*USB Keyboard and Optical Mouse. 1*500-Watt single Power Supply. OS: Window 7 Professional	DR cum NMS server Make-Any Make 19" 4U Rack mountable industrial PC 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base frequency. 64GB DDR5 Memory 2*1 TB SATA SSD, RAID-1. 1*DVD-RW-Drive 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 4*USB, 2*Serial and 1*VGA, 1*DP & 1*HDMI Port onboard, 1*USB Keyboard and Optical Mouse. 1*Audio port 1*TPM Module 1*Dual Power Supply. 1*Windows-11 pro. 64 bit O.S. or latest	1	1

Sl. No.	Details of Software/hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (Inst.)	Qty (Req.)
3	NMS License	Not installed	Latest NMS software license	NA	1
4	Tower type PC for O&M Work station	Make-HP, Processor: Intel Xeon CPU E3-1226 V3 @ 3.30 GHz, 64bit RAM: 4 GB HDD: 1TB SATA 1*DVD-RW Drive. 1*10/100 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100 mbps Ethernet Card. 10*USB, 2*Serial and 1*HDMI Port 1*Audio port 1*USB Keyboard and Optical Mouse. OS: Window 8.1 Pro	Make-Any make Intel Core I9, 14th Gen CPU or latest, 32GB DDR5 Memory. 2*1 TB SATA SSD, 1*DVD-RW-Drive 2*10/100/1000 mbps LAN Ethernet Ports onboard. 4*USB, 2*Serial and 1*VGA Port onboard. 1*HDMI Port onboard 1*USB Keyboard and Optical Mouse. 1*TPM Module 1*Windows-11 pro. 64 bit O.S. or latest	1	1
5	Monitor	21" LED Display Make- HP	Make-Any Make 24" monitor with keyboard and mouse FHD monitor, aspect ratio-16-9 resolution-1920x1080	4	4
6	KVM Extender	Make- Aten VGA/HDMI, Audio, RS-232, RJ-45, CPU Port USB KVM switch	Latest & compatible with server	3 set	3 set
7	Server Software Up-gradation for SAS system	Micro SCADA 9.4 Make- ABB	Make-Any make SCADA software (latest version) and compatible with existing SCADA installations of N-S corridor (i.e RTUs, cables, switches & ports etc.)	1	1
8	MS Office for O&M WS	MS Office 2013	MS Office 2022 or latest	1	1
9	Antivirus	Mcafee End point security	Make-Any make Endpoint protection client with integrity control agent for lifetime validity. Latest and Compatible with upgraded server	2	6

Sl. No.	Details of Software/hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (Inst.)	Qty (Req.)
10	Accessories	Including all cables, connectors, accessories	Including all cables (power supply & telecom cable), connectors, accessories like patch cord, JB, switches, MCBs & LIU etc to achieve the complete working of system	-	
11	Ethernet switch	HIRSCHMANN SSR40-6TX/2SFP (Product code: SPIDER-SL-40-06T1O6O699SY9HHH H) Unmanaged, 6 x 10/100/1000BASE-T RJ45 Ports, 2 x 100/1000MBit/s SFP	Make-Any make 5port 10/100/1000 Mbps RJ45 Managed Ethernet switch RS900- Ordering code : 6GK6090-0AS23-0BA0-Z A00+B00 6 Nos 10/100/1000TX	2	2
12	GPS Unit	Not installed	GPS unit consisting of a) Redundant GPS Receiver [T-GPS-300-EU or equivalent] b) Redundant GPS Antenna c) Interconnecting cable of length 50 mtrs with 2. Sertel Slave Clock (T-SL-300-100-6D or equivalent) Time Display	NA	1
13	Standalone Gateway	Not installed	19" 4U RACKMOUNTABLE INDUSTRIAL PC WITH FOLLOWING FEATURES: - Based on Intel Core I9, 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base 64GB DDR5 Memory. 2*1TB SATA SSD. 1*DVD-Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 4*USB, 2*Serial, 1*VGA, 1*DVI & 1*HDMI Port onboard. 1*USB Keyboard and Optical Mouse. 1*TPM Module. 1*Dual Power Supply.	NA	2

Sl. No.	Details of Software/hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (Inst.)	Qty (Req.)
			1*Windows-Server Std. 2022 64 Bit O.S.		
14	Software for Standalone Gateway	NA	Latest SCADA software for Gateway TRANSPORT NAGAR - RSS	NA	1
15	Firewall	Not installed	Make-Fortiwell or equivalent 10 x GE RJ45 ports (including 2 x WAN Ports, 1 x DMZ Port, 7 x Internal Ports), 128GB SSD onboard storage. OT Security Service (OT dashboards and compliance reports, OT application and service detection, OT vulnerability correlation, OT virtual patching, OT signatures - Application Control and IPS rules)	NA	2

(B) Technical Specification of MSPA RSS

SN	Details of Software/hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (ins.)	Qty (Req)
1	19" Rack Mountable Server for SAS	Make- Advantech, Processor: Intel Xeon CPU E5-1620 v4 @ 3.50GHz, 64 bit RAM: 8 GB DDR3 HDD: 1 TB SATA 1*DVD-RW Drive. 2*10/100 mbps LAN Ethernet Ports onboard. 2*Dual Port 10/100 mbps Ethernet Card. 7*USB, 2*Serial and 2*VGA Port, 1*HDMI Port, 1*Audio port	Make-Any Make 19" Rack mountable industrial PC, 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base 64GB DDR5 RAM. 2*1TB SSD, RAID-1. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 4*USB, 2*Serial and 1*VGA Port onboard. 1*HDMI Port onboard 1*USB Keyboard and Optical Mouse.	2	2

		1*USB Keyboard and Optical Mouse. 1*500-Watt single Power Supply. OS: Windows 8.1 Pro	1*Audio port 1*DVD-RW Drive. 1*TPM Module 1*Dual Power Supply. 1*Windows-Server Std. 2022 64-Bit O.S. or latest		
2	19" Rack Mountable DR Server	DR server Make- Advantech, Processor: Intel Core i5-3570 CPU @ 3.40GHz, 32 bit RAM: 8 GB DDR3 HDD: 1TB SATA 1*DVD-RW Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100 mbps Ethernet Card. 5*USB, 2*Serial and 2*VGA Port 1*USB Keyboard and Optical Mouse. 1*500-Watt single Power Supply. OS: Window 7 Professional	DR cum NMS server Make-Any Make 19" 4U Rack mountable industrial PC 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base frequency. 64GB DDR5 Memory 2*1 TB SATA SSD, RAID-1. 1*DVD-RW-Drive 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 4*USB, 2*Serial and 1*VGA, 1*DP & 1*HDMI Port onboard, 1*USB Keyboard and Optical Mouse. 1*Audio port 1*TPM Module 1*Dual Power Supply. 1*Windows-11 pro. 64 bit O.S. or latest	1	1
3	NMS License	Not installed	Latest NMS software license	NA	1
4	Tower type PC for O&M Work station	Make- Advantech, Processor: Intel Core i5-6500 CPU@ 3.20GHz, 64 bit RAM: 8 GB HDD: 1TB SATA 1*DVD-RW Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 6*USB, 2*Serial and 1*HDMI Port 1*VGA port 1*Audio port 1*USB Keyboard and Optical Mouse.	Make-Any Make Intel Core i9, 14th Gen CPU. 32GB DDR5 Memory. 2*1 TB SATA SSD, 1*DVD-RW-Drive 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 4*USB, 2*Serial and 1*VGA Port onboard. 1*HDMI Port onboard 1*USB Keyboard and Optical Mouse. 1*TPM Module 1*Windows-11 pro. 64 bit O.S. or latest	1	1

		OS: Window 8.1 Pro			
5	Monitor	21" LED Display Make- HP	Make-Any make 24" monitor with keyboard and mouse FHD monitor, aspect ratio-16-9 resolution-1920x1080	4	4
6	KVM Extender	Make- Aten VGA/HDMI, Audio, RS- 232, RJ-45, CPU Port USB KVM switch	Make-Any make Latest and Compatible with upgraded server	3 (set)	3 (set)
7	Server Software Up- gradation for SAS system	Micro SCADA 9.4 Make- ABB	Latest SCADA software and compatible with existing SCADA installations of N- S corridor (i.e RTUs, cables, switches & ports etc.)	1	1
8	MS Office for O&M WS	MS Office 2013	MS Office 2022 or latest	1	1
9	Antivirus	Mcafee End point security	Make- Any make Endpoint protection client with integrity control agent for lifetime validity Latest and Compatible with upgraded server	2	6
10	Accessories	Including all cables, connectors, accessories	Including all cables (power supply & telecom cable), connectors, accessories like patch cord, JB, switches, MCBs & LIU etc to achieve the complete working of system		
11	Ethernet switch	HIRSCHMANN SSR40-6TX/2SFP (Product code:SPIDER- SL-40- 06T1O6O699SY9HHHH) Unmanaged, 6 x 10/100/1000BASE-T RJ45 Ports, 2 x 100/1000MBit/s SFP	5port 10/100/1000 Mbps RJ45 Managed Ethernet switch RS900- Ordering code : 6GK6090- 0AS23-0BA0-Z A00+B00 or equivalent 6 Nos 10/100/1000TX	2	2

12	Standalone Gateway	Not installed	19" 4U RACKMOUNTABLE INDUSTRIAL PC WITH FOLLOWING FEATURES: - Based on Intel Core I9, 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base 64GB DDR5 Memory. 2*1TB SATA SSD. 1*DVD-Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 4*USB, 2*Serial, 1*VGA, 1*DVI & 1*HDMI Port onboard. 1*USB Keyboard and Optical Mouse. 1*TPM Module. 1*Dual Power Supply. 1*Windows-Server Std. 2022 64 Bit O.S. Without Monitor.	NA	2
13	Software for Standalone Gateway	Not installed	Latest SCADA software for Gateway MSPA RSS	NA	1
14	Firewall	Not installed	Fortinet make or equivalent 10 x GE RJ45 ports (including 2 x WAN Ports, 1 x DMZ Port, 7 x Internal Ports), 128GB SSD onboard storage. OT Security Service (OT dashboards and compliance reports, OT application and service detection, OT vulnerability correlation, OT virtual patching, OT signatures - Application Control and IPS rules)	NA	2

(C) Technical Specification of BCC

SN	Details of Software/ hardware to be up-graded	Existing Installed Version/Make details	Upgradation details required to be installed	Qty (ins.)	Qty (Req)
1	19" Rack Mountable	Make- HP, Processor: Intel Xeon CPU E5-2630 nv3 @	19" Rack mountable industrial PC, 14th Gen CPU or latest, Minimum Octa core processor base	2	2

	Server for BASE System	2.40GHz 2397MHz, Octa core 64 bit (2 Processors) RAM: 32GB HDD: 3x500GB 1*DVD-RW Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 5*USB, 2*VGA Port, 1*Dual Power Supply 1*Wired Keyboard and Optical Mouse. OS: Windows Server 2012 R2	frequency 3 GHz. Higher no. of cores minimum 2GHz base frequency. RAM: 64 GB, 2*1TB SSD – RAID-1, 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 1*HDMI Port 1*VGA Port 1* Dual power supply 1*TPM Module 1*Wired Keyboard and Optical Mouse. 4*USB ports OS - Windows Server Standard LTSC 2022 (64 Bit) or latest		
2	19" Rack Mountable Server for FE System	Make-HP, Processor: Intel Xeon CPU E5-2630 v3 @ 2.40GHz 2397MHz, Octa core 64 bit (2 Processors) RAM: 32GB HDD: (FE-1 1x500GB, 1x1TB) (FE-2 2X500GB) 1*DVD-RW Drive. 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 5*USB, 2*VGA Port, 1*Dual Power Supply, 1*Wired Keyboard and Optical Mouse. OS: Windows Server 2012 R2 standard	19" Rack mountable industrial PC, 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base frequency. RAM: 64 GB, 2*1TB SSD – RAID-1, 2*10/100/1000 mbps LAN Ethernet Ports onboard. 1*Dual Port 10/100/1000 mbps Ethernet Card. 1*HDMI Port 1*VGA Port 1* Dual power supply 1*Wired Keyboard and Optical Mouse. 1*TPM Module 4*USB ports OS - Windows Server Standard LTSC 2022 (64 Bit) or latest	2	2
3	FE & BASE Server Software Up-gradation	Micro SCADA 9.4 Make- ABB	Latest SCADA software	2	2
4	Tower type PC for EWS	Processor: Intel Xeon CPU E3-1225 V5 @ 3.30 GHz, 64bit	Engineering Workstation cum NMS Server,	1	1

		RAM: 8GB HDD: 1 TB SATA Interface Ports: 10/100/1000 Mbps dual Ethernet port, 1*serial port, 2*HDMI port, 1*VGA Port, 10- USB port, 1*USB Keyboard and Optical Mouse. OS: Windows 7 Professional	14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base, 64GB DDR5 RAM 2*1TB - SSD 2*10/100/1000 mbps Ethernet ports onboard 1*10/100/1000 mbps Dual ports Ethernet card 4*USB Ports 1*HDMI Port 1*VGA Port 1*USB Keyboard and Optical Mouse. OS: Windows 11 pro 64 bit		
5	NMS License	Not installed	Latest NMS software license	NA	1
6	Tower type PC for TPC Workstation	Processor: Intel Xeon CPU E3-1225 V5 @ 3.30 GHz, 64bit RAM: 8GB HDD: 1 TB SATA Interface Ports: 10/100/1000 Mbps dual Ethernet port, 1*serial port, 2*HDMI port, 1*VGA Port, 10- USB port, 1*USB Keyboard and Optical Mouse. OS: Windows 7 Professional	Operating Workstation Core i9, 14th Gen CPU or latest, 32GB DDR5 RAM, 1 x 1TB SSD 1*Dual power supply, 2*10/100/1000 Mbps Ethernet port onboard, 1* 10/100/1000 Mbps dual Ethernet port card, 1*serial port, 2*HDMI port, 1*VGA Port, 4-USB port, 1*USB Keyboard and Optical Mouse. 1*Windows-11 Pro. 64 Bit O.S.	2	2
7	Firewall	Make-Cisco, Memory: 50GB SSD 8*10/100/1000 Mbps LAN ports 2*serial port, 1*USB port, 1*Single power supply	Fortinet make or equivalent 10 x GE RJ45 ports (including 2 x WAN Ports, 1 x DMZ Port, 7 x Internal Ports), 128GB SSD onboard storage. OT Security Service (OT dashboards and compliance reports, OT application and service detection, OT vulnerability correlation, OT virtual patching, OT signatures - Application Control and IPS rules)	1	2

8	Antivirus	Mcafee End point security	Make-Any Make Latest and Compatible with upgraded server, lifetime subscription (Antivirus Software: Endpoint Protection Client with Integrity Control Agent)	4	8
9	Monitor	24" LED Display Make- HP	24" LED display	7	8
10	KVM Extender	VGA & USB Extension cable	KVM Extender compatible with upgraded server	NA	3set
11	MS Office for Engg. WS	MS Office 2013	MS Office 2022 or latest	1	1
12	Accessories	Including all cables, connectors, accessories	Including all cables (power supply & telecom cable), connectors, accessories like patch cord, JB, switches, MCBs & LIU etc to achieve the complete working of system		
13	Ethernet switch	CISCO, SG300-28 28-port Gigabit Managed Switch 24*10/100/1000 Ethernet ports 2*10/100/1000 SFP ports	19" Rack Mountable Managed Network Switch Hirschmann Mach Series or equivalent Copper Ports: 10/100/1000, FO Ports: 10/100/1000 MBPS SEP Module *4*M-SFP-TX/RJ45 - 1KHS001324P000 Ports Ports Density: 28TX 4xCopper 1Gbps RJ45 Dual Power Supply	2	2
14	Ethernet switch	CISCO, SG300-28 28-port Gigabit Managed Switch 24*10/100/1000 Ethernet ports 2*10/100/1000 SFP ports	Make- Any Make L2 Ethernet Switch FX06-MMST+TX10 Dual Power Supply	2	2
15	Backup recovery server/Auto tape loader	HP, LTO-8 Ultrium 30750, 300 MB/s, 8 cartridge slots, Tape size-3TB	Make- Any Make 14th Gen CPU or latest, Minimum Octa core processor base frequency 3 GHz. Higher no. of cores minimum 2GHz base	1	1

			64GB DDR5 RAM 3x 10TB 2.5" SATA SSD with RAID-5 with HOT-Swappable rack With External Raid Controller 2 X Onboard 10/100/1000 Mbps Ethernet ports 2 X Dual Port 10/100/1000 Mbps Ethernet Cards 2 X HDMI Port with Dual Monitor Capability + 1VGA Port. 4 X External USB Ports With Minimum 2Nos of USB with 3.0 3 X Internal USB Port 2 X Serial Ports (DB9) Dual power supply 1*Windows-Server Std. 2022 64 Bit O.S.		
16	Backup recovery server license	NA	Acronis Cyber Protect or equivalent- Backup Advanced Server Subscription License, lifetime validity	NA	4

CHAPTER 19: RAMS Requirement

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19 SYSTEM ASSURANCE

19.1 ACRONYMS

ACRONYM / ABBREVIATION	DEFINITION
CENELEC	European Committee for Electro-technical Standardisation
EMC	Electromagnetic Compatibility
EN	European Standard
FHA	Functional Hazard Analysis
FMECA	Failure Mode & Effect Criticality Analysis
FRACAS	Failure Reporting & Corrective Action System
FTA	Fault Tree Analysis
IEC	International Electro technical Commission
LRU	Line Replaceable Unit
MDT	Mean Down Time
MDTBSAF	Mean Down Time Between Service Affecting Failures
MTBF	Mean Time Between Failures
MTBMA	Mean Time Between Maintenance Actions
MTBSAF	Mean Time Between Service-Affecting Failures
MTTR	Mean Time To Repair
MTTRS	Mean Time To Restore Service (includes mobilisation & fault locating times)
MUT	Mean Up Time
PHA	Preliminary Hazard Analysis
RAMS	Reliability, Availability, Maintainability, Safety
RAR	Remove And Replace
RBD	Reliability Block Diagram
RMDT	Reliability and Maintainability Demonstration Test
ROD	Revenue Opening Date

19.2 APPLICABLE STANDARDS

EN 50126-1	<p>Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 1: Basic Requirements and generic process.</p> <p>It shall include all the various IEC / EN codes that cover phase-wise implementation from design, manufacture, installation, testing and commissioning and finally to operations and maintenance.</p> <p>The standard along with its Normative References shall apply as relevant.</p>
EN50126-2	Railway Applications – The Specification and Demonstration of Reliability, Availability, Maintainability and Safety (RAMS) – Part 2: System Approach to Safety
IEC 62278	<p>Railway applications - Specification and demonstration of reliability, availability, maintainability (RAMS) and its sub-documents.</p> <p>IEC 62278 defines the RAMS process based on the system life cycle and functions for managing the reliability, availability, maintainability and safety parameters of a railway system and provides guidance in defining requirements and parameters that must be demonstrated for all railway applications and all sub applications, encompassing complete railway systems right down to major sub-systems and their components including associated firmware, software and application data, at all relevant phases of the life cycle of an application.</p>
IEC 61124	Reliability Testing – Compliance tests for constant failure rate and constant failure intensity
IEC 61025	Fault Tree Analysis
MIL-HDBK-472	Maintainability Prediction and Notice 1 1984
EN 50562	Railway applications - Fixed installations - Process, protective measures and demonstration of safety for electric traction systems
IEC 61078	Reliability block diagram method

19.3 PURPOSE

The purpose of the study of railway system assurance for power supply and dc traction system for Lucknow Metro project is to demonstrate the achievement of RAMS target parameters backed up with supporting evidences in accordance with Employer's Requirements.

19.4 SCOPE

The scope of RAMS study shall involve a systems-level approach where interactions between power supply equipment including traction transformers, switchgear, auxiliary transformers, bus couplers, tap changers, load disconnect switches, motorized circuit breakers, potential transformers, current transformers, high speed dc circuit breakers, traction converter system, Over-Voltage Protection Device (OVPD)/Voltage Limiting Device (VLD)s, blue light stations, third rail conductor, conductor cover and accessories, battery chargers and battery sets, charger systems, PLC, Power System SCADA, earthing and lightning protection systems, HV/ MV / LV / DC power cables and control cables are well coordinated.

The Contractor shall implement the assurance system to ensure the Reliability, Availability, Maintainability and Safety requirements for the complete traction power supply and dc distribution system. It is important that individual sub-system RAMS parameters converge towards achievement of full system RAMS parameters.

The RAMS Study for the traction power supply system shall involve a thorough analysis using conventional techniques and using software simulation tools. Such analyses shall include but not limited to PHA, IHA, SSHA, OSHA, FHA, FMECA, RBD and FTA, in order to mitigate every single possible failure and ensure that comprehensive failure characteristics are available and found within specified target ranges. Simulation studies shall be carried in line with standard System Engineering V-Cycle principles. Stepwise compliance tables shall be prepared for each type of study and analysis, depicting impact of severity of failure of system and / or safety, the compliance standard followed and status of compliance.

FHA (top-down) and FMECA (bottom-up) studies must be carried out and the results validated. Failure Modes shall be defined and their effect and criticality (FMECA) be elaborated in the study.

Fault Tree Analysis implementing FTA logic tree in a top-down approach shall be carried out to perform system safety analysis.

19.5 ADHERENCE TO STANDARDS

The contractor shall adhere to the requirements of the standards especially EN 50126-1, while conducting their analysis and undergoing validation of achievement of RAMS targets.

Particular attention must be paid to the interaction between RAMS elements of reliability, availability, maintainability and safety, because of the fact that any shortcomings due to a mismanagement of conflicts between the elements will render the system undependable. Unless all four elements of RAMS are carefully addressed, it is impossible to achieve RAMS targets specified by any particular railway application and will cause a definite failure of the system availability.

Special attention is drawn to EN 50126-1, Section 5.6.3 and its sub-sections which illustrate the influencing factors for railway RAMS, and the checklists covering railway specific factors (5.6.3) and human factors (5.6.4).

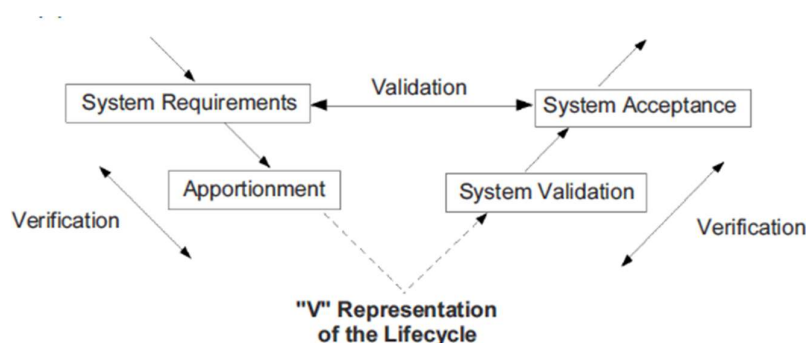
The contractor is further encouraged to enumerate the means to achieve railway RAMS requirements as detailed out in Section 5.0 of the specification EN 50126-1 and to work towards achievement and demonstration of the same, failing which, the Employer will be unable to accept the system in its final desired form.

The contractor is required to submit a detailed RAMS requirements specification and detail out the methodology to achieve those specifications, focused around failure categories for railway applications as specified in the standard. This specification shall include risk identification, analysis and mitigation steps based around the failure categories, following which an analysis of the safety integrity levels shall be carried out.

A comprehensive analysis of the system life cycle shall then be conducted starting from conceptual design and definition of system requirements, followed by implementation comprising manufacture, installation, testing, commissioning and acceptance tests, along with tabulated phase-wise tasks for RAMS for each phase.

Such an analysis shall typically be demonstrated in the form of standard System Engineering V-Model principles, with the left branch demonstrating top-down activities which the right branch of the V-Model demonstrating the implementation activities leading up to final operation of the whole system.

At each stage, the contractor is required to show the verification and validation (V&V) tasks, to pictorially depict how the right branch deliverables are linked to the specific inputs on the left branch. A snapshot as per the standard is shown below, for better understanding:



19.6 ASSUMPTIONS

19.6.1 GENERAL

The contractor is required to spell out the key assumptions for conducting these studies. Suggested general are as follows:

- The traction power supply system shall be maintained within specified input and output limits and intended use.
- Component failures shall be expected to occur randomly, and it should be possible to describe the failures with a constant rate. Both primary and cascading failures would be in the responsibility of the Contractor and shall be accounted for.
- A failure shall be regarded as a forced outage, which is an event that forces the power supply equipment to be automatically stopped via trip signal by the power supply control system or requires an unscheduled immediate power supply stop to repair the failure. It may contribute to a service affecting failure.

19.6.2 INTERNAL AND EXTERNAL INTERFACE ASSUMPTIONS

Interface with O&M

- The predictions are based on the assumption that maintenance will be performed according to the applicable O&M manuals and by staff trained according to the contract in order to minimise service interruptions.

- The OCC personnel shall initiate the necessary maintenance actions at once when a disturbance or failure is recognised in the OCC.
- All actions and precautions including provisioning spare parts and tools in order for the RAMS performance to be maintained at a high quality, shall be the responsibility of the Contractor. In fact, the contractor is required to include such factors in their calculations for availability.
- Sufficient inventory and availability of contractor's staff at site is compulsory for meeting the RAMS targets, for which the contractor shall be solely responsible, including any logistics of travel, procurement of material, storage of material, availability of appropriate tools with the contractor etc.
- The contractor shall spell out clearly in their tender as regards the methodology of repair of faulty components of the system, whether redundant or otherwise, as to whether system shutdown is required for such repairs and if so, for what durations. The contractor solely shall be responsible, should there be any unnecessary delay in repairs resulting in system and operations downtime.
- Scheduled maintenance is excluded from the availability calculations of the system as far as reasonably practicable.

Interface with Power Grid

The possible influence of failures due to the loss of AC power supply from Power Grid shall not be considered for RAMS calculations.

Interface with SCADA

Failure of the SCADA system shall be excluded only from the availability calculations of the total system. However, for reliability and maintainability purposes, failure of SCADA shall be considered.

Interface with Rolling Stock

The contractor shall include in their calculation the power consumption by rolling stock as per designed headway which is expected to remain within specified limits as governed by the rolling stock contract.

Switching times of contractor's supplied equipment, e.g. switch over to a redundant subsystem or short interruptions caused by short circuits are to be considered for the RAMS calculations of the system.

Interface with Track

The contractor shall ensure that its design is compliant with the latest Schedule of Dimensions issued by UPMRC and the track alignment data. Such dimensions must be referenced in the RAMS analysis.

The contractor shall consider in the RAMS calculations, the approved bridgeable and non-bridgeable gap analysis to prevent any service-affecting failures.

Interface with Trackside Installations

The contractor shall include in their RAMS analysis, any EMI/EMC related issues that may be causing malfunction to trackside signalling equipment such as Eurobalises, point machine controls, signal control circuits, axle counter control circuits etc.

19.7 RAM TARGETS

The Contractor shall as a minimum, meet, and if possible, try to exceed, the RAMS target requirements as specified herein. The contractor shall provide evidence of fulfilment of the stated criteria and in cases where they have not fulfilled, provide justifiable action plan to fulfil the same in line with the contract and the CENELEC / IEC / relevant specifications.

The System engineering shall be planned and managed in accordance with the above aspect as specified in the Employer's Requirements related to System Performance and System Assurance Requirements.

19.8 RELIABILITY

Impact of failures shall be minimised to achieve high reliability figures as follows:

$$R_t = e^{-\lambda t}$$

Where:

R_t = Reliability, considered as probability of performance of a system or function within a time interval t

e = Exponential

λ = Constant Failure Rate

t = Time Interval

It is to be noted that MTBF being the arithmetic mean time between failures:

$$MTBF = \frac{1}{\lambda}$$

Hence,

$$Reliability = e^{-\left(\frac{Time\ Interval}{MTBF}\right)}$$

- The reliability engineering studies to be carried out by the contractor shall satisfy the Sub-System RAM targets as per the failure categories tabled below, and the same shall be used as reference by the Contractor for the study and classify failures accordingly when performing FMECA:

FAILURE TYPE	IMPACT	EXAMPLE FAULTS	RELIABILITY OF ENTIRE POWER SYSTEM (MTBSAF)
Negligible	Delay < 2 min (Non-service-affecting)	Failure causing remotely re-settable traction power faults.	≥ 750 h
Minor	Delay < 5 min (Minor service-affecting)	Failure requiring REMOTE re-configuration of traction power system e.g. configuring supply from alternate RSS, TPS, (N-1) operation at a TPS etc.	$\geq 4,000$ h
Major	5 min \leq Delay < 30 min (major service affecting)	Failure requiring trackside action to restore power, e.g. inability to operate through SCADA remotely, manual resetting required at TPS etc.	$\geq 50,000$ h
Serious	Delay ≥ 30 min (severely service affecting)	Failure requiring engineering effort to allow trains to use section.	$\geq 120,000$ h

Power Supply and Third Rail System

The reliability for the full traction power supply system shall be designed as N-½ Scenario (for Design Year). Further, failure of a single item shall not cause failure of the entire traction power supply system.

Following are typical MTBF figures for vendor items, which the contractor must review and exceed in terms of reliability performance:

ITEM	MTBF
Circuit breaker	1 x 10 ⁵ hours;
Motorised switch	5 x 10 ⁴ hours;
Motorised disconnect	5 x 10 ⁴ hours;
Protection relay	1 x 10 ⁵ hours;
MV power cable	1 x 10 ⁵ hours;
Rectifier panels	1.47 x 10 ⁵ hours
Rectifier High Speed circuit breakers	6.34 x 10 ⁴ hours;
Feeder High Speed circuit breakers	5.71 x 10 ⁴ hours;
Bypass High Speed circuit breakers	5.4 x 10 ⁴ hours;
Over-Voltage Protection Device (OVPD)/Voltage Limiting Device (VLD)s	1 x 10 ⁵ hours;
Rectifier transformer	4.5 x 10 ⁵ hours (2.65 x 10 ⁵ hours for minor faults)
Auxiliary transformer	4.5 x 10 ⁵ hours (2.65 x 10 ⁵ hours for minor faults)
Potential transformer	4.5 x 10 ⁵ hours (2.65 x 10 ⁵ hours for minor faults)
Current transformer	4.5 x 10 ⁵ hours (2.65 x 10 ⁵ hours for minor faults)
Load break switch	1.35 x 10 ⁵ hours
Metering Unit	1.35 x 10 ⁵ hours
Dual redundant UPS	3.5 x 10 ⁴ hours
PLC	2.9 x 10 ⁴ hours
Protection Relays	2.65 x 10 ⁵ hours
Track Bypass Switch	6.9 x 10 ⁴ hours

In the case of transformer, a minor fault is defined as a fault causing loss of output capability from the transformer for less than 24 hours, a major fault being one which causes a loss for 24 hours or more.

MTBFs for protection relays shall also exceed 30 years, while those for load break switches and metering units shall exceed 15 years. These are typical values which the contractor shall review and submit for review and acceptance of the GC.

SCADA

Failure of the SCADA system shall be excluded only from the availability calculations of the total system. However, for reliability and maintainability purposes, failure of SCADA shall be considered.

The inability to perform any required function, the occurrence of unexpected event, or the degradation of performance below the specifications shall be considered as a failure. MTBF shall be the average operating time accumulated by the total population of identical items between failures.

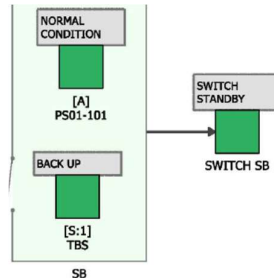
The SCADA equipment supplied under the contract shall comply with the reliability figures given below:

SCADA EQUIPMENT	MTBF (Hours)
Workstation or Programmable Logic Controller (PLC)	>2.9 x 10 ⁴ hours;
Central Control Equipment / Server	>5x10 ⁴ hours
RTUs	> 5x10 ⁴ hours
Workstations	> 5x10 ⁴ hours

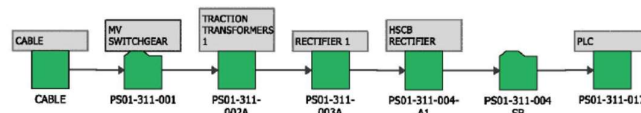
The Contractor shall take particular note of the interfaces with other contractors and shall provide full assistance in working towards complete integration of the SCADA System into the overall project.

Reliability Block Diagram

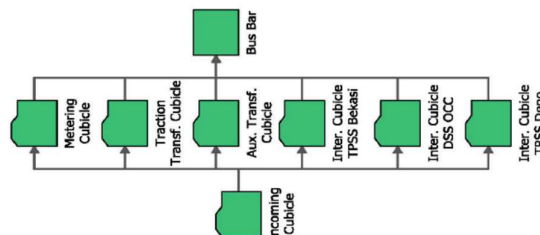
- A detailed Reliability Block Diagram (RBD) shall be developed for each critical equipment in every traction substation to demonstrate equipment functional relationships and availability and is to be developed based on the function of each equipment and its effect following a failure.
- For the purposes of study and testing, the operation hours shall be considered as 19 hours per day (05:00 to 24:00) for 7 days a week.
- A sample reliability block diagram series is shown for reference:
Power Supply System:



Normal Condition:



MV Switchgear:



Reliability Demonstration Testing (RDT)

- Reliability Demonstration Testing (RDT) shall be carried out. All plant shall be included in the RDT and shall be fully operational.
- Recommendations and conclusions of the study must be drawn up and submitted as part of submittals.
- The Contractor shall perform failure/incident data analyses, component analyses and provide corrective action designs and tests.
- The Contractor shall submit bi-weekly status reports, which shall include as a minimum a statement of failures, status of failure dispositions, and achieved MTBF for each subsystem.
- The RDT shall be carried out over a period of not less than twelve (12) months commencing during the warranty period once the equipment is suitably burned in but shall be completed a

minimum of six (6) months before the end of the warranty period. This is to ensure that the equipment is in a relatively stable condition, which shall give rise to accurate availability data.

- Simulated predictive analysis of reliability shall be carried out using modelling techniques for railway systems that would employ factor such as availability through redundancy, high quality of components to reduce failures, ruggedness of equipment to function in harsh environments (for example third rail components) etc.

19.9 AVAILABILITY

Availability follows from reliability factors and is based on the mean time between failures and mean time to restore components to put the system back on service.

$$Availability = \frac{Uptime}{Total\ Time} = \frac{Uptime}{Uptime + Downtime}$$

Considering quick repair times,

$$Availability\ \% = \frac{MTBSAF}{MTBSAF + MTTRS} \times 100\%$$

In all these mathematical relations, MTBSAF instead of MTBF and MTTRS instead of MTTR are considered because from the viewpoint of revenue service, only such failures which may contribute in combination with others to effects on revenue service, are of importance.

The Contractor shall ensure that failure of third rail system is limited to only one track of the two, so that in emergency situations, train movements can still be managed, though with reduced overall efficiency, by isolating the faulty section and reconfiguring the power supply system. Such manipulations shall be possible to control from the SCADA System at the OCC.

Since the third rail system for each track on the revenue lines are mechanically independent of the other, the overall system would be of sufficient robustness, such that any accidental impact by the rolling stock current collection shoe on the third rail shall not cause a complete shutdown of both running lines.

Line Replaceable Units (LRUs) as modular components shall be used as far as possible in order to achieve better than optimum MTTR values. The reliability of each LRU directly related to safety shall be $>10^{-9}$ failures/h, while MTTR for overall power supply equipment shall be $< 1h$.

The study shall develop a failure analysis and assessment in order to determine the correct reliability requirements applicable for each LRU.

The complete traction power supply system including the dc third rail system shall be designed to meet 99.95% service availability within 1 (one) year of ROD. The availability figures for individual SCADA subsystems viz. Software Development, Historical Record-Searching and Training Simulator shall be 99.7%.

Scheduled maintenance is excluded from the availability calculations of the system as far as reasonably practicable.

19.10 MAINTAINABILITY

Maintainability Analysis shall show that maintenance requirements are proposed such that there is no impact on train service. Such requirements may include:

- Sufficient redundancy of 1oo2 or 2oo3 for all major functions to ensure full-service availability
- convenient equipment layout
- clear physical separation between HV and MV/LV and Control panels

- modular construction for easy replaceability
- maintenance friendly equipment
- optimisation of types of components for efficient spare parts inventory
- least feasible maintenance effort and time
- easy accessibility for repairs
- simple modular design and
- quick and smart diagnosis, e.g. smart alarms in protection relays, transformer winding temperature alarms, trip signals relayed to the OCC etc.
- quick switching and isolation for easy access to maintenance staff
- isolate only the affected part of the third rail while maintaining power to unaffected sections
- diagnostics to identify short circuit in the Third Rail System and initiate a CB trip, followed by automatic check for short circuits to assist fast repair.

Since the Third Rail System cannot be a redundant system by way of nature of the application itself. It clearly necessitates different maintenance strategies to counter the downtime aspects. While focus must be given to robust mechanical design and robust manufacture and installation, it is necessary to rely on configuration such that only the affected part of the third rail system can be isolated on a particular track while the other track can be utilised to route traffic.

System Maintainability requirement shall be such that repairs are performed in no more than 60 minutes for service-affecting failures and 120 minutes for non-service affecting failures.

From the foregoing list of material to be installed in a typical TSS and third rail system, it is seen that even the maintainability of cables – ac and dc power and control – is of vital importance. While redundancy is also built in as required by the system design, it is important to note that cable damage from mechanical wear, damage and fire are common phenomena for all cables, which can happen for reasons beyond the FRLS capability of the cables. There is therefore a need to be able to isolate and repair / join / replace damaged cables as needed, in the quickest possible time, without interrupting train operations. For best reliability and availability therefore, it is important that cables are laid in proper cable ducts, cable trays, cable racks, concrete troughs etc. to prevent easy access by other systems and to prevent undue movement of cables due to moving civil structures such as viaduct girders. From a diagnostics viewpoint, if the protection system identifies a short circuit in cables, it will initiate a trip. After a circuit breaker trips an automatic check of short circuits is performed. If the short circuit still exists, the fault will be localised as accurately as possible to assist the repair team to travel to the fault quickly. This failure cable may cause a protection trip and can be monitored by SCADA, e.g. data transfer is missing.

19.11 SAFETY

Safety targets shall be analysed based on the following formula:

Accident Occurrence x Accident Severity Acceptability

Probabilities range from Frequent, Probable, Occasional, Remote, Improbable to Incredible, considering the entire alignment and number of train sets:

ACCIDENT PROBABILITY	FREQUENCY
Frequent	≥ 1 accident per 100 h
Probable	1 accident per 10^2 h < 1 accident \leq 1 accident per 10^4 h
Occasional	1 accident per 10^4 h < 1 accident \leq 1 accident per 10^5 h
Remote	1 accident per 10^5 h < 1 accident \leq 1 accident per 10^6 h
Improbable	1 accident per 10^6 h < 1 accident \leq 1 accident per 10^8 h
Incredible	1 accident per 10^8 h < 1 accident \leq 1 accident per 10^{10} h

Accident severity levels as follows shall be used to classify the consequences of accidents, for people, system and environment and evaluate and mitigate resulting risks:

HAZARD	DESCRIPTION
Catastrophic	Fatalities and / or multiple severe injuries and / or major damage to environment
Critical	Single fatality and /or severe injury and / or significant damage to environment

Marginal	Minor injury and / or significant threat to environment
Insignificant	Possible minor injury

19.12 DEMONSTRATION AND VALIDATION OF RAM TARGETS

- Contractor shall achieve Demonstration and Validation of RAM targets including RMDT within 1 years following commencement of revenue operations or DLP, whichever is later, over the full network (in km) and with both partial and full load (train sets).
- All costs for any corrective actions like redesign, repair, replacement, retrofit etc. that may be required, shall be borne by the Contractor.

19.13 FAILURE TO ACHIEVE RAM TARGET

Failure to demonstrate the minimum RAMS objectives and parameters for the traction power system, including failure to achieve full railway system level RAMS objectives and parameters that may be impacted by non-achievement of Traction power and DC system RAMS parameters, shall attract implications as follows:

- The contractor is further encouraged to enumerate the means to achieve railway RAMS requirements as detailed out in Section 5.0 of the specification EN 50126-1 and to work towards achievement and demonstration of the same, failing which, the Employer will be unable to accept the system in its final desired form.
- Notwithstanding anything mentioned elsewhere in the contract agreement, should the systems supplied by contractor fail to meet the performance parameters, both at sub-component level and sub-system level, the Employer shall have the right to withhold 10% of the total contract value as a retention sum till such parameters are achieved.
- The Contractor shall forthwith conduct restoration and / or retests and any other corrective actions to be proposed by the Contractor and approved by the General Consultant. Such tests shall continue till the entire sub-system of traction power and DC system itself and its interface parameters are demonstrated and validated strictly as required by the Employer's Requirement.
- In case of safety hazards created on account of fault of the Contractor, including but not limited to not updating hazard logs, third rail not being fully powered down before allowing detrainment, or, poor grounding related safety hazards or high touch voltage due to improper operation of Over-Voltage Protection Device (OVPD)/Voltage Limiting Device (VLD)s especially when a passenger has accidentally fallen on to or close to the third rail or any significant life-threatening faults etc., the Contractor shall be solely liable for damages and legal implications, notwithstanding any third party or other professional insurances they may have taken out, while indemnifying UPMRC from any impact of such incidences within the contractual obligation period including and up to the end of DLP.
- Should the Contractor still fail to achieve the above parameters within the maximum allowed period of three years from DLP, the Employer shall have the liberty to terminate the contract, forfeit the retention sum, encash the performance bank guarantee, and award the contract to another suitable party at the time and cost of the original Contractor, including possible debarment from participating in future tenders and contracts in any capacity, whether as a main contractor or a sub-contractor and including charging the Contractor for all costs that the Employer may have incurred on account of failure of performance parameters.

19.14 FUNCTIONAL HAZARD ANALYSIS (FHA)

Functional hazard assessment is an examination of the functional failures of the Power Supply system. The report is prepared as part of the demonstration of compliance with the applicable safety requirement as per provisions of Safety in the tender / contract.

The contractor is required to prepare sample summaries of failures conditions with varying degrees of effect, from Major up to Catastrophic, in accordance with the FHA assessment, along with detailed analysis of the failure conditions, in order to identify potential serious failure conditions when a functional failure or a malfunction occurs. Such a template would include data for each component of the TSS and DC third rail system as per table of components given above:

Defined Function	Functional Failure	Failure Mode	Indicator	Crew Action	Effect on People	Effect on System	Effect on Railway	Remarks
Protection of System from Fault occurring from incoming outgoing lines	Failed to protect system from fault	Protection Device is faulty	Local Display & SCADA	Fault Analysis, Maintenance	Potential injury, fire hazard	Potential fire hazard, loss of functionality, loss of component	Delayed headway	

Since FHA is a top-down functional approach, specific hardware failures are not to be considered at this stage which would need to be done through the FMECA which is a bottom up approach, and which will automatically validate the FHA, if done correctly. The FHA analysis is also an important analysis to be considered as part of the Standard Operating Procedures for future.

This approach will also lead to correctly building the Reliability Block Diagram. The contractor is required to adhere to these principles as guided by the EN 50126-1 and EN 50126-2.

FHA assessment will also demonstrate the impact severity of safety while designing power supply system.

19.15 FAILURE MODE, EFFECT & CRITICALITY ANALYSIS (FMECA)

In order to analyse reliability of sub-components of the TSS and Third Rail as a bottom-up approach, the contractor is required to define all Functional Failure, Failure Mode, Failure Effect, Criticality and Failure Cause of all sub-components of equipment. FMECA is used to assess the equipment with a purpose of finding out possibilities of single failure along with all the failure modes. Detail FMECA tables shall also be prepared on the same lines as prescribed above for FHA.

The Contractor shall conduct an FMECA Scenario & Safety Analysis of failure modes of the concerned sub-system / component and classify whether the severity ID can be termed SIGNIFICANT or SEVERE or NEGLIGIBLE as the case may be, as given elsewhere in this document.

Certain standard terminologies must be adhered to for the FMECA part of the study:

TERMINOLOGY	DEFINITIONS
FUNCTION IDENTIFICATION	The name of the item under analysis, together with a clear description of its function
TYPE	Type of the equipment
FUNCTION	Functions or service of the product, highlighting any modes or situation in which the function will change
OPERATIONAL MODE	Indicates the Normal / Emergency mode of operation
FUNCTIONAL FAILURE	Any failure that prevents the equipment from achieving its normal function
FUNCTIONAL FAILURE MODE	The manner in which a component could potentially fail causing a functional failure
FAILURE EFFECTS	Consequences of failure mode on the operation and functioning of equipment and the effect on overall System

SEVERITY CLASS	The consequences of a failure mode. Severity considers the worst potential consequence of a failure, determined by the degree of injury, property damage, system damage and/or time lost to repair the failure.
FAILURE CHARACTERISTIC	The traits (random, age related, etc.) and the manner is m of the failure mode
REVEALED/UNREVEALED	Visibility of the failure mode to the operator in normal operation of the equipment; Hidden - any failure which cannot be identified prior to loss of equipment functionality; Evident-any failure which can be identified prior to loss of equipment functionality
FAILURE DETECTION MEANS	Means of detection through visual or audible indication, automatic sensing devices, built-in test devices, maintenance regime, etc.
AVAILABLE CONTINGENCY/ COMPENSATING PROVISION 1st LINE OF MAINTENANCE	Describe the existing design provisions or operator actions, which can nullify or reduce the consequences of failure of an item. Include the 1 st line maintenance actions required to restore the system to a fully operational state.
DESIGN ACTION RECOMMENDATION	Indicate any recommended control measures, which might limit the effects of the failure mode or reduce failure rate. For example, addition of a redundant / standby or spare unit, increasing of inspection frequency, reducing unnecessary complexity, special procedures, etc.
REMARK	Include, if necessary, comments pertaining to or clarifying other columns in the FMECA worksheet.

Some examples of failure criteria for FMECA are given below, which can broadly be classified into the following Failure Modes:

- Loss of Function
- Erroneous Operation
- Operation without command






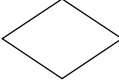
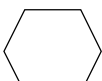


These must be detailed in the final analysis report of the contractor.

Event	Failure Criteria
Train Stops due to outage – Loss of functionality	750 V dc power supply to the Third Rail tripped on at least one track because of failure caused by TSS equipment failure; this results into incomplete trip of the trainset running on that section.
Loss of OCC functionality	Loss of communication caused by Power SCADA equipment.
Train Stops due to outage - Loss of functionality	750 V dc power supply to the third rail tripped on at least one track because of damaged dc cable or other third rail system component; this results into incomplete trip of the trainset running on that section.
Train Stops due to outage - Loss of functionality	750 V dc power supply to the third rail tripped on at least one track because of damage to ac power cables; this results into incomplete trip of the trainset running on that section.

19.16 FAULT TREE ANALYSIS (FTA)

Fault tree analysis is a method used to perform system safety analysis as a top-down approach organised as events rather than sub-systems. The focus is usually on a significant failure or a catastrophic event, which is referred to as the top event and appears at the top of the fault tree diagram. The analysis is divided into two parts, qualitative and quantitative. The qualitative analysis consists of identifying the various combinations of events that will cause the top event to occur. While quantitative analysis is used to estimate the probability of occurrence of the top event.

Symbols that are extensive used to create fault trees are as follows:

	DEFINITION
	AND gate - event can occur when all the next lower conditions are true.
	OR gate - event can occur if any one of the next lower conditions are true.
	Basic Event - event which is internal to the system under analysis, requires no further development.
	External Event -event which is external to the system under analysis.
	Transfer - indicates transfer on information from one page to another page of that same fault tree.
	Undeveloped Event - event which is not developed further because it has little impact on the top level event or because the details necessary for further event development are not readily available.
	INHIBIT gate - event can occur if a specific condition occurs. This specific condition is represented by a Conditioning Event.
	Conditioning Event - a condition which is necessary for a failure mode to occur
	Intermediate Event - output of a logic symbol.

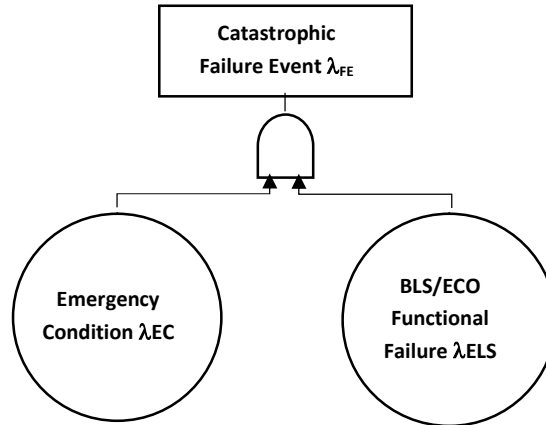
Fault Tree Analysis implementing FTA logic tree in a top-down approach shall be carried out to perform system safety analysis and evaluate and arrive at Safety Integrity Level (SIL) of all sub-system components of the traction power supply and third rail system, as per Tolerable Hazard Rate per hour and per function as defined in EN 50129 (see SIL determination table below):

Tolerable Hazard Rate per hour & per function	SIL as per EN 50129
$10^{-9} \leq \text{THR} < 10^{-8}$	4
$10^{-8} \leq \text{THR} < 10^{-7}$	3
$10^{-7} \leq \text{THR} < 10^{-6}$	2
$10^{-6} \leq \text{THR} < 10^{-5}$	1

The Contractor is required to study the following examples and carry out an analysis of the failure rate for each situation, and conduct a RAMS study to evaluate the risk:

- (i) Blue Light Station / Emergency Cut-Off system
- (ii) Over Voltage Protection Device
- (iii) Earthing Switch
- (iv) SCADA along with local RTU/Equipment etc.

By implementation of FTA logic tree for such situations, it can be seen that in case of BLS/ECO system, the function of AND Gate determines that both hazard conditions, i.e. BLS/ECO Fail and Emergency Condition, are required to cause Catastrophic Failure Event:



This relationship between the hazard rates can be expressed as:

$$\lambda_{FE} = \lambda_{EC} \times \lambda_{BLS}$$

The Contractor is now required to make their own assessment of hazard rates for all likely Emergency Conditions based on the following:

- Likely to occur several times– OCCASIONAL, hazard rate of $\lambda_{EC} = 10^{-4}$
- Likely to occur sometimes in overall Lifecycle of System – REMOTE, hazard rate of $\lambda_{EC} = 10^{-5}$
- Unlikely to occur but possible – IMPROBABLE, hazard rate of $\lambda_{EC} = 10^{-6}$

19.17 FAILURE REPORTING, ANALYSIS & CORRECTIVE ACTION SYSTEM (FRACAS)

FRACAS is a system where failures are logged and analysed. The Contractor is obliged to set up a FRACAS so as to enable a system for recording, analysing, investigating and taking corrective action on all failures.

The Contractor shall establish FRACAS during the project preliminary design phase and shall be continually maintained right up to the O&M Phase as per the obligations under the contract. All failures thus recorded shall be backward traceable so as to enable identification of the path starting from initial factory test to resolution of the fault.

FRACAS shall communicate directly with automatic built-in test equipment, maintenance management systems and other automatic systems with the ability to collect failure data directly with minimal human intervention.

Typical data that may be reported and recorded shall include:

- technical data on system
- reason for maintenance action
- type of maintenance action
- person hours and elapsed time for maintenance action
- maintenance down time
- spare parts used
- cost of spare parts
- reporting and corrective action

19.18 MAJOR DELIVERABLES

The deliverables for RAMS shall include but not limited to:

- System Assurance Plan covering RAM Plan and System Safety Plan
- RAMS Programme
- Reliability Studies and Demonstration Reports
- Availability Studies and Demonstration Reports
- Maintainability Studies and Demonstration Reports
- Safety Documents and reports (Safety Plan, PHA, SHA, SSHA)
- Preliminary Hazard Analysis Report (PHA)
- Functional Hazard Analysis Report (FHA)
- Asset Register
- Traceability Matrix
- RAMS Allocation, Modelling and Prediction
- Software Safety Analysis
- Reliability and Maintainability Demonstration Test (RMDT) Plans, procedures and reports
- Listing of functional failures for all major sub-systems
- FRACAS Procedures and Report
- Failure Modes, Effects and Consequence Analysis (FMECA)
- Quantitative Fault tree analysis (FTA)
- Event Tree Analysis (ETA)
- Human Factors analysis (HF)
- SA Status Reports
- Sub-System Safety Report and Sub-System RAM report at Preliminary and Detailed stages
- Audit Reports

19.19 SYSTEM ASSURANCE MANAGEMENT

Upon award of the Power Supply contract, the Contractor shall:

- Nominate a System Assurance Expert whose CV shall be approved by the Employer; (S)he can normally operate from the contractor's office but shall ensure a minimum of one week's attendance at site initially, during which time (s)he shall be submitting logs of work carried out for this project, which shall be demonstrated by way of deliverables. During outages however, it shall be mandatory for the SA Manager to be present at site and personally supervise the restoration / rectification and demonstration of parameters activities till satisfactory compliance is achieved. The SA Manager shall not leave station without written permission of the Employer's Representative.
- Submit an organisation chart comprising SA staff well experienced in the relevant fields of work and preferably with experience in System Assurance of Traction Power Supply Systems. The organisation chart shall clearly indicate the positions and names of persons who will be posted on-site and those working from Contractor's office;
- Ensure that the SA team is guided by the contract agreement, the SA standards and special requirements of the contract and are equipped to take decisions as far as practicable on the spot;
- Submit a System Assurance Plan in line with the contract, the relevant SA standards, Indian Metro rail standards as relevant and any special conditions of the contract and technical specifications.