



5.9 415V SWITCHGEARS AND NON-SEGREGATED PHASE BUS DUCT, DC BOARDS

All 415V switchgears (i.e Power control centres (PCCs), Motor control centres (MCCs)), 415V non-segregated phase bus duct, Emergency Power and Motor Control Centres (EPMCC) and DC Boards for unit auxiliaries shall be provided.

5.9.1 Codes and Standards

The equipment, materials and service shall conform to the following standards :-

IS : 5	Colours for ready-mixed paints and enamels.
IS: 694	PVC insulated cables for working voltages upto and including 1100V
IS : 722	AC Electricity Meters
IS : 1248	Electrical Indicating instruments
IS : 13947 Part 1	Degree of protection provided by enclosures for low voltage Switchgear and Control gear
IS : 13947Part-2 / IEC-60947	AC Circuit Breakers
IS : 2551	Danger Notice Plates
IS : 2629	Hot dip galvanising
IS : 2705	Current Transformers
IS : 13947Pt 4,Sec-1 (IEC-60947)	Contactors and motors starter for voltages not exceeding 1000 V AC or 1200 V DC
IS : 3043	Code of practice for earthing
IS : 3072	Code of practice for installation and maintenance of Switchgear
IS : 3156	Voltage Transformers
IS : 3202	Code of practice for climate proofing of electrical equipment
IS : 3231	Electrical relays for power system protection
IS : 13947	Air-Break Switches, air break disconnectors, air Break disconnector and fuse combination units for voltages not exceeding 1000V AC or 1200 V DC.
IS : 13947 Pt. - I IEC -60947	General Requirements for Switchgear and Control gear for voltages <1000 V
IS : 5082	Wrought Aluminium and Aluminium alloys for electrical purposes.
IS : 6005	Code of practice of phosphating of iron and steel
IS:13947 Pt.-5 Sec.1, IEC-60947	LV switchgear and Control gear Control current devices and switching element
IS : 8623(3 parts) / IEC-60439	Specification for factory built assemblies of Switchgear and Control gear for voltages upto and including 1000V AC and 1200V DC
IS : 8686	Static Relays
IS : 13703/ IEC-60269	HRC Cartridge fuses
IS : 10118 (4 parts)	Code of practice for selection, installation and maintenance of switchgear and control gear
IS : 11171	Specification for dry type transformers



IS : 11353	Guide for uniform system of marking and identification of conductors and apparatus terminals
IS : 12021	Specification of control transformers for switchgear and Control gear for voltage not exceeding 1000V AC
IS:8084	Interconnecting bus bars for AC voltage above 1KV upto and including 36KV.
Updated upto:1992	
ANSI C37:20	Switchgear Assemblies including Metal enclosed Bus.

5.9.2 Technical parameters

i) The switchgears shall be indoor, metal clad having following features :

Circuit Breakers	air break, three pole, spring charged, horizontal drawout type, suitable for electrical operation
Switchgear	Fully drawout type, single front
MCC/ VDDC	Fully drawout type, single front
ACDB/ DCDB	Fixed type, single front

ii) System parameters

1) Nominal system voltage	415VAC	220V DC
2) Highest system voltage	433V	240V DC
3) Voltage variation	(±) 10%	190 – 240V DC
4) Rated frequency	50 Hz	--
5) Frequency variation	(+) 3 to (-) 5%	--
6) System earthing	solidly grounded	Unearthed
7) Maximum system fault level	50kA for 3 seconds	25kA for 1 second

5.9.3 Automatic Reserve Closure (ARC) - ARC to the reserve supply source shall be provided for 415V unit essential service and other critical switchgears.

5.9.4 Emergency PMCC (EPMCC)

One no. Emergency PMCC to cater power supply to important emergency load/ motors for safe shut-down of unit including 220V battery chargers shall be provided for each unit. It will have four (4) incoming supply feeders to it with circuit breakers at sending and receiving end of these supply feeders. The main incoming supply shall be from respective 415V PCC of the unit. The reserve supply with ARC shall be from respective 415V station PCC and other two reserve supplies shall be from diesel generating sets (one from dedicated DG set of the unit and other from common stand-by DG set). In case of failure of main incoming supply to the EPMCC, the reserve incoming supply shall be switched ON automatically and in case of total failure of AC supply of the power station, the supply from dedicated DG set shall be switched ON automatically. In case of failure of dedicated DG set, the stand-by DG set shall be switched ON.

5.9.5 Metering

The energy meters shall be provided on LV side of each incoming transformer feeder of 415V buses as per the Central Electricity Authority (Installation and Operation of Meters) Regulations, 2006 and its amendments.

Energy accounting and audit meters shall be of accuracy class not inferior to 1.0S as per CEA regulations. The accuracy class of CTs and VTs shall not be inferior to that of associated meters. In case, numerical relays having built-in features of energy measurement of requisite accuracy are provided in switchgear, separate energy meter is not necessary.

5.9.6 General technical particulars

- a) **Temperature rise** - The temperature rise of the horizontal and vertical bus bars and main bus link including all power draw out contacts when carrying 90% of the rated current along the full run shall in no case exceed 55⁰C with silver plated joints and 400C with all other types of joints over an ambient of 50⁰C.
- b) **Breakers**
 - i) Breakers shall have anti-pumping feature.
 - ii) The incomer and bus coupler breakers for switchgear shall be electrically operated with over current releases or relays.
 - iii) Breakers shall have inherent fault making and breaking capacities. They shall have shunt trip coils. In case releases are offered, the same shall have contact for energisation of lockout relay. All breakers shall have built in interlocks for equipment and personnel safety.
 - iv) Paralleling of two supplies shall be avoided by interlocking except for switchgear where auto-changerover is provided. Breaker contact multiplication, if required, shall be through latch relay.
 - v) Mechanical tripping shall be through red 'Trip' push button outside the panels for breakers, and through control switches for other circuits.
 - vi) Provision of mechanical closing of breaker only in 'Test' and 'Withdrawn' position shall be made. Alternatively, mechanical closing facility should be normally inaccessible, accessibility rendered only after deliberate removal of shrouds. It shall be possible to close the door with breaker in test position.
 - vii) Clear status indication for each circuit shall be provided through lamps, switch positions or other mechanical means.
 - viii) Supervision relay shall be provided for trip coil monitoring.



c) Switches, Contactors and Fuses

- i) Incomers for MCCs and DBs rated upto 630A could be load break isolators.
- ii) Motor starter contactors shall be of air break, electromagnetic type suitable for DOL starting of motor, and shall be of utilisation category AC-3 for ordinary and AC-4 for reversing starters. DC contactor shall be of DC-3 utilisation category.
- iii) Fuses shall be HRC type with operation indicator. Isolating switches shall be of AC 23A category when used in motor circuit, and AC 22A category for other applications. Fuse switch combination shall be provided wherever possible.
- iv) Isolating switches and MCCBs shall have door interlocks and padlocking facility.

d) Panels

- i) All switchgears, MCCs, DBs, panels, modules, local starters and push buttons shall have prominent engraved identification plates.
- ii) Local push button stations shall have metal enclosure of die cast aluminium or rolled sheet steel of 1.6mm thickness and shall be of DOP IP55. Push buttons shall be of latch type with mushroom knobs.
- iii) Where breaker/starter module front serves as compartment cover, suitable blanking covers, one for each size of modules per switchboard shall be supplied for use when carriage is withdrawn.
- iv) All non-current carrying metal work of boards/panels shall be effectively bonded to earth bus of galvanised steel, extending throughout the switchboard/ MCC/ DB. Positive earthing shall be maintained for all positions of chassis and breaker frame.
- v) Suitable trolley arrangement shall be provided for breaker/starter modules. Two trolleys per switchgear room shall be provided so that top most breaker module of all types, sizes and rating can be withdrawn on trolley and lowered for maintenance purpose.
- vi) The incoming connection to transformer of more than 1000kVA and inter-connecting sections between switchboards shall preferably be of bus ducts. The bus duct enclosure shall be made of minimum 3mm thick aluminium alloy. The section of the bus duct should have adequate strength to withstand internal and external forces resulting from the various operating conditions. Aluminium sheet hood shall be provided for outdoor bus duct enclosure joints to provide additional protection against water ingress. The bus duct top shall be sloped to prevent retention of water. The bus duct shall have DOP of IP55.



- vii) It should be possible to carryout maintenance on a feeder with adjacent feeders alive.

e) Relays and Meters

- i) All numerical relays, auxiliary relays and devices shall be of types, proven for the application; satisfying requirements specified elsewhere and shall be subject to Purchaser's approval. Numerical Relays shall have appropriate setting ranges, accuracy, resetting ratio, transient overreach and other characteristics to provide required sensitivity to the satisfaction of the Owner. All the numerical relays shall have communications on two ports, local front port communication to laptop and a second port on IEC 61850 port to communicate with the data concentrator through LAN and Ethernet switches.
- ii) The Numerical relays shall have communication, Metering and monitoring facility. The Numerical relays shall be networked through Data Concentrators of the main plant to HMI and further integrated to DDCMIS/ DDCMIS system. All the feeders shall be remote controlled from DDCMIS/ PLC and from the switchgear.
- iii) All relays and timers shall be rated for control supply voltage as mentioned elsewhere under parameters and shall be capable of satisfactory continuous operation between 80-120% of the rated voltage. Making, carrying and breaking current ratings of their contacts shall be adequate for the circuits in which they are used. Interrogation voltage for the binary inputs shall be suitably selected to ensure avoidance of mal operation due to stray voltages.
- iv) The protective relays shall have at least 10 no. potential free contacts (Programmable) Auxiliary relays shall have contacts as required. Relay output contacts shall be suitable for directly wiring in the breaker closing and trip circuit operating from 220V DC control voltage.
- v) Relays shall be suitable for efficient and reliable operation of the protection scheme. Necessary auxiliary relays, timers, trip relays, etc. required for complete scheme, interlocking, alarm, logging, etc. shall be provided. No control relay, which shall trip the circuit breaker when relay is de-energized, shall be employed in the circuits.
- vi) Relays shall be flush mounted on the front with connections at the rear shall be draw-out or plug-in type/ modular case with proper testing facilities. Provision shall be made for easy isolation of trip circuits for testing and maintenance.
- vii) Relays shall be provided with self reset contacts except the trip, lockout relays and interlocking (contact multiplication) relays which shall be manual reset type



- viii) Auxiliary relays shall be provided in the trip circuits of protections located outside the board, such as buchholz relay, temperature indicators, fire protection, etc.
- ix) Suitable measures shall be provided to ensure that transients present in CT and VT connections due to extraneous sources in 400kV system do not cause damage to static circuit.
- x) Only DC/ DC converters shall be provided in the solid state devices/ relays wherever necessary to provide a stable auxiliary supply for relay operation
- xi) Control circuits shall operate at suitable voltage of 110V AC or 220V DC. Necessary control supply transformers having primary and secondary fuses shall be provided for each MCC, 2 x 100% per section. However the breakers shall operate on 220V DC. The auxiliary bus bars for control supply shall be segregated from main bus bars. The control supplies shall be monitored.
- xii) Contractor shall fully co-ordinate overload and short circuit tripping of breaker with upstream and down stream breakers/ fuses/ MCCBs motor starters. Various equipments shall meet requirement of Type-II class of coordination as per IEC.
- xiii) All relays and timers shall operate on available DC supply and not have any inbuilt batteries. They shall be provided with hand-reset operation indicator (flags) or LEDs with push buttons for resetting.
- xiv) All meters/ instrument shall be flush mounted on front panel, at least 96 mm² size with 90⁰ linear scales and accuracy class of 2.0.
- xv) All motors of 30kW and above shall have an ammeter. Bus-section shall have bus VT, voltmeter with selector switch, and other relay and timers required for protection. Adequate control and selector switches, push buttons and indicating lamps shall be provided. Thermostatically controlled space heaters with switches shall be provided to prevent condensation.
- xvi) All motors are required to have an emergency stop push button near the motor.
- xvii) In case of remote controlled breaker panels, following shall be provided :

Each feeder shall have local/ remote selector switch. Closing from local shall be possible only in test position whereas closing from remote shall be possible in either service or test position. Tripping from local shall be possible only when local/ remote selector switch is in local position. Tripping from remote shall be either breaker in service position or selector switch being in remote position.



- xviii) Suitable self powered transducers as per IS : 12784 Part - I for feeding signals to panel mounted electrical meters (ammeters, voltmeters, VAR meters and watt meters etc.) and DCCMIS shall be provided.

Transducers shall be tested as per IEC:600298 or impulse test etc and short circuit withstand capability as per ANSI C 37.90a, 1989

Transducers shall be provided with two decoupled 4-20mA output signals, one for meter and one for DDCMIS. Current limiting features shall be provided for all the transducers.

- xix) Transducers

- a) Current transducers

- Input	0-1 A (CT secondary)
- Rated frequency	50 Hz
- Output	4-20 mA (2 Nos. decoupled) for meter/ DDCMIS
- Accuracy	0.5%

- b) Bus voltage transducers

- Input	110V, 50 Hz (from VT secondary)
- Output	4-20 mA (2 Nos. de-coupled)
- Accuracy	0.5%

- xx) Necessary hardware shall be provided in the switchgear panel like coupling relays (24VDC with maximum burden of 2.5VA), auxiliary relays in addition to current/ bus-voltage transducers (4-20 mA, dual output) etc. to effect interlocks, exchange information/ status and exercise control from remote.

- f) The motor feeders for the following essential auxiliaries shall have contactors with delayed drop- out feature adjustable up to three seconds.

- i) Seal air fans
- ii) Ignitor air fans
- iii) Scanner air fans
- iv) Stator water cooling pump
- v) Barring gear/ Jacking oil pump/ Auxiliary oil pump
- vi) Lubricating oil pumps of various unit auxiliaries
- vii) Hydrogen seal oil pump
- viii) Centrifugal fan of hydrogen seal oil pump
- ix) Lubricating oil system vapour fans
- x) Bearing cooling water pumps
- xi) AC emergency lubricating oil pumps/Auxiliary lubricating oil pumps



- xii) Air Pre- heaters
- xiii) Control air compressors and Service air compressors
- xiv) Any other drive recommended by Boiler, Turbine and Generator manufacturer

5.9.7 Protection

i) 415V AC and 220V DC Incomers

- a) Time graded short circuit protection on incoming supply feeder circuit breakers to main switchgears (PCCs and MCCs)
- b) Instantaneous over-current protection on all outgoing feeders
- c) Under- voltage protection for 415V bus
- d) Sensitive earth fault detectors shall be provided in DC system to annunciate earth faults

ii) 415 Volts motor feeders

- 1) Contactor controlled motor feeders (Motors up to 200 kW)
 - i) Instantaneous short circuit protection on all phases through HRC cartridge type fuses rated for 80 kA rms (prospective breaking capacity at 415V).
 - ii) Thermal overload protection
 - iii) Single phasing protection for motors protected by fuses
- 2) Breaker controlled motors feeders (motors rated above 200 kW)
 - i) Instantaneous short circuit protection on all phases
 - ii) Overload protection on two phases
 - iii) Over load alarm on third phase
 - iv) Earth fault protection
 - v) Under voltage protection
 - vi) Hand reset lockout relay with a blue lamp for monitoring

5.9.8 Design and constructional features

- a) All 415V switchgears, AC and DC distribution boards (DBs), etc shall have following features :



- i) Shall be of metal enclosed, indoor, floor mounted and free standing type.
- ii) All frames and load bearing members shall be fabricated using mild steel structural sections or pressed and shaped cold rolled sheet steel of thickness not less than 2mm.
- iii) Frame shall be enclosed in cold rolled sheet steel of thickness not less than 2mm (CR). Doors and covers shall also be of cold rolled sheet steel of thickness not less than 1.6 mm. Stiffeners shall be provided wherever necessary. Removable gland plates of thickness 3mm (hot/cold rolled sheet steel) or 4 mm (non-magnetic material) shall be provided for all panels.
- iv) For motors above 160kW, remote controlled electrical circuit breakers, and for smaller motors, switch-fuse contactor feeders shall be provided. The other outgoing feeders would be switch-fuse units or moulded case circuit breakers.
- v) The switchboards/ MCC/ DBs of 1600A and above rating shall be of DOP IP42 and of IP52 for less than 1600A rating.
- vi) All 415V switchgears, MCC's, AC and DC distribution boards etc. shall be painted by powder coating process.

Paint shade for complete panels excluding end covers shall be RAL9002 and RAL5012 for extreme end covers of all boards.

- vii) Minimum air clearance in air between phases and phase-earth shall be 25 mm for busbars and cable terminations. For all other components, the Clearances shall be at least 10mm. Wherever above is not possible except for horizontal and vertical busbars, insulation shall be provided by anti tracking sleeving or barriers. However for horizontal and vertical busbars, clearances specified above shall be maintained even when busbars are insulated/ sleeved. In case of DCDBs/ fuse boards, the busbar system shall be insulated or physically segregated with barriers to prevent interpole short circuit.
- viii) All current and voltage transformers as required for metering and protection specified shall be completely encapsulated, cast resin insulated type. Incomers from transformers shall have CTs for transformer Restricted Earth Fault (REF) protection. All current and voltage transformers as required for metering and protection specified shall be completely encapsulated cast resin insulated type. Incomers from transformers shall have CTs for transformer restricted earth fault protection. The accuracy shall be as follows:

	<u>CTs</u>	<u>VTs</u>
Protection	5P20	3P
Metering	1.0	1.0
REF	PS	



- b) Indicating lamps shall be cluster LED type.

5.9.9 Spare feeders - 20% spare feeders with atleast one of each type and rating shall be provided in each switchgear.

5.9.10 415V Non-segregated phase busduct

- i) The section of three phase and neutral metal enclosed non segregated phase bus duct shall be rectangular. The design of the bus duct enclosures shall be of sturdy construction such that it will withstand the internal or external forces resulting from the various operating conditions.
- ii) The entire bus duct shall be designed for dust, vermin and weather proof construction. A suitable aluminium sheet flange-protection hood shall be provided to cover all outdoor bus duct enclosure joints to facilitate additional protection against rain water ingress. All horizontal runs of bus duct shall have a suitable sloped enclosure top to prevent retention of water for both indoor and out door portion of bus ducts. Bus duct enclosure shall have a degree of protection of IP-55.
- iii) The inside of the bus enclosure may be treated with black paint to enable efficient heat dissipation. The matt paint used shall be suitable for temperature experienced during continuous loading of the bus conductor.
- iv) Enclosures shall be provided with flanged ends with drilling dimensions to suit the flanges at the switchgear and transformer terminals.
- v) The synthetic/ neoprene gaskets shall be provided so as to satisfy the operating conditions imposed by temperature, weathering, durability etc. Flange gaskets shall be provided at the equipment terminal connections.
- vi) Necessary earthing arrangement as applicable shall be provided with clamps to receive station earthing bus. This shall be a GI strip of adequate size, continuously running along the busduct and shall be earthed at both ends. Bus duct enclosures shall be bolted type.
- vii) The material of the conductor shall be aluminium. The bus bars shall be rated in accordance with the service conditions and the rated continuous and short time current ratings.
- viii) All steel structures required for bus duct support shall be hot dip galvanised.



ix) **Technical Data**

a)	Type	Non-segregated
b)	1 minute power frequency withstand voltage	2.5 kV
c)	Maximum short circuit withstand current	45kA/ 50kA for 1 second
d)	Momentary dynamic current withstand	94.5/ 105kA (Peak)



5.10 POWER AND CONTROL CABLES

All 11kV, 3.3kV, 415V power cables, control cables and DC cables required to connect unit auxiliaries shall be supplied.

5.10.1 Codes and standards

All cables to be supplied shall conform to the latest revisions of IS or any other international standards acceptable to purchaser. Some of the Indian Standards/ IEC considered relevant to the cables are given below:

IS:1554 (Part-I)	PVC insulated (heavy duty) electric cables for working voltage up to and including 1100 V.
IS:1554 (Part-II)	PVC insulated (heavy duty) electric cables for working voltage from 3.3kV upto and including 11kV.
IS:7098 (Part-II)	XLPE insulated PVC sheathed cables for working voltages from 3.3 kV upto and including 33kV.
IS:3961	Recommended current ratings for cables.
IS:8130	Conductors for insulated electric cables and flexible cords.
IS:5831	PVC insulation and sheath of electric cables.
IS:2982	Copper conductor in insulated cables and cords.
IS:3975	Mild steel wires, strips and tapes for armouring cables
IS:5609	Specification for low frequency wires and cables with PVC insulation and PVC Sheath.
IS:6380	Spec. of elastomeric insulation of sheath of electric cables.
IS:434(I and II)	Specification for rubber insulation cables
IEC:540	The methods for insulations and sheaths of electric cables and cords (elastomeric and thermoplastic compounds).
IEC:230	Impulse tests on cables and their accessories.
IEC:60	High voltage test techniques.
IEC:287	Calculations of the continuous current rating of cables (100% load factor).
IEC:288	Nominal cross-sectional area and composition of conductor of insulated cables.
IEC:502	Extruded solid dielectric insulated power cables for rated voltages from 1.00 kV upto 30 kV.
NEMA-WC-5	Thermoplastic insulated wires and cables for transmission and distribution of electrical energy.
IEEE:383	Standard for type test for class IE electric cables, filled splices and connections for nuclear power generation stations
IEC: 332-1	Test on electric cables under fire conditions.
ASTM-D-2843	Standard test method for density of smoke from burning/ decomposition of plastics.
ASTM-D-2863	Test for determination of Oxygen Index.
IEC-754-I	Test method for acid gas generation.
IEC-331	Fire resisting characteristics of electric cables.
SVENSK Standard	SS- 4241475 Class F3
BICC Hand Book	For cables in fire regarding temperature index-chapter-6

5.10.2 Design criteria

- i) The cable shall be suitable for installation in a tropical monsoon area having a hot humid climate. The reference ambient temperature to be considered for the purpose of this specification is 50⁰C.
- ii) The derating factor for the various conditions of installation including the following shall be considered while choosing the conductor size and calculations shall be submitted for purchaser's approval:
 - a) Maximum ambient air temperature.
 - b) Maximum ground temperature
 - c) Depth of laying wherever applicable
 - d) Grouping of cables
- iii) The allowable voltage drop at terminal of the connected equipment shall be maximum 2.5% at full load while choosing the conductor size and calculations shall be submitted for purchaser's approval. In case of squirrel cage induction motors, the cable size shall be so chosen that the motor terminal voltage does not fall below 85% of the rated voltage, at the time of starting.
- iv) The maximum continuous conductor temperature and the maximum allowable conductor temperature during short circuit are to be taken as 70⁰C and 160⁰C respectively in case of PVC insulated cables and 90⁰C and 250⁰C respectively in case of XLPE insulated cables.
- v) For 415V power cables of size above 35 mm², XLPE insulated cables shall also be acceptable. The minimum size of all 11kV (UE), 3.3kV (UE) grade power cables and 415V power cables connected to circuit breakers shall be chosen taking into account the following factors:
 - a) Fault level due to system contribution.
 - b) Fault contribution of running motors.
 - c) Expected time up to which motor contribution persists.
 - d) Maximum time for fault clearance (i.e. operating time of the back up protection relays plus the time of operation of the circuit breakers).
 - e) Full load current of the circuit.
- vi) The cables shall be capable of continuous satisfactory operation under a power supply system frequency variation of (±) 5%, voltage variation of (±) 10% and combined frequency and voltage variation of 10% (absolute sum).



- vii) The cables shall in general comply with the requirements of the latest revision of IS 7098 (Part-II) for the 11 kV (UE), 3.3kV grade, XLPE insulated cables and IS-1554 (Part –I) for the LT PVC power and control cables or the relevant IEC International Standard unless otherwise specified in this specification. The design, manufacture, installation, testing and performance of the cables, shall comply with the latest revisions of IS/ IEC/ NEMA/ ASTM Standard and the most stringent conditions specified in these specification shall be applicable.

5.10.3 General technical requirements

- i) Type of cable

The cable shall be multi-core/ single core (XLPE), PVC and any polymeric/ elastomeric insulation type as specified.

- ii) Conductor

The cable conductor shall be made from standard copper/ Aluminum to form compact conductor having a resistance within the limits specified.

All the cables of size 25mm² and above shall have sector shaped conductors. The minimum no. of strands in conductor shall be 7 (seven) except as otherwise specified. Power cables shall be of stranded aluminum conductor with a minimum size 6mm² and the control cables shall be stranded copper (electrolytic) conductor with a minimum size of 2.5 mm².

- iii) Conductor Shield

The conductor having a semi-conducting screen shall ensure perfectly smooth profile and avoid stress concentration. The conductor screen shall be extruded in the same operation as the insulation, the semi-conducting polymer shall be cross-linked for XLPE cables.

- iv) Insulation

The insulation of the cable shall be extruded type and shall be designed and manufactured for the specified system voltage. The manufacturing process shall ensure that insulation shall be free from voids. The insulation shall withstand mechanical and thermal stresses under steady state and transient operating conditions. The extrusion method should give a very smooth interface between semi conducting screen and insulation. The insulation of the cables shall be of high standard quality. The minimum volume resistivity of the PVC insulation of all the PVC insulated cables shall be 1x10¹⁴ ohm-cm at 27°C and 1x10¹¹ ohm-cm at 70°C.

- v) Insulation shield

In XLPE cables, to confine electrical field to the insulation, a non-magnetic semi-

conducting shield shall be put over the insulation. The insulation shield shall be extruded in the same operation as the conductor shield and the insulation by triple extrusion/process. The XLPE cable insulation shield shall be strippable. Metallic screening as given in this specification for the various power and control and special cables shall be provided.

vi) Inner Sheath

The sheath shall be suitable to withstand the site conditions and the desired temperature. It shall be of adequate thickness and applied by a continuous process to produce a sheath of consistent quality free from all defects. PVC sheath shall be extruded.

vii) Armour

Hard drawn aluminum wire armouring/ galvanized steel tape/ wire armouring shall be used for single core and multi-core cable respectively. Cables should be un-armoured wherever indicated.

The hard drawn aluminium wire for armour shall be of H₄ grade, as per IS-8130 (having tensile strength above 150 N/mm²) The diameter of the aluminium wire shall be as per the table for the dimensions of the galvanized steel wire armour given in the relevant standard.

viii) Serving/ outer sheath

Extruded PVC serving as per IS: 5831 or as specified otherwise shall be applied over the armouring with suitable additives to prevent attack by rodent and termites. All serving must be given anti-termite treatment.

5.10.4 Constructional requirements

- i) Cable shall have suitable fillers laid up with the conductors to provide a substantially circular cross section before the sheath is applied. Fillers shall be suitable for the operating temperature of the cable and compatible with the insulating material. All materials shall be new, unused and of finest quality. Workmanship shall be neat, clean and of highest grade.
 - a) 11 kV system power cables - The cable shall be 11kV/11kV (unearthed) grade, heavy duty, stranded aluminium conductor, XLPE insulated, provided with conductor screening and insulation screening, galvanized steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC of type ST2 outer sheathed.
 - b) 3.3 kV system power cables - The cable shall be 3.3kV/3.3kV (unearthed) grade, heavy duty, stranded aluminium conductor, XLPE insulated, galvanized steel wire/ strip armoured, flame retardant low smoke (FRLS) extruded PVC of type ST2 outer sheathed.



- c) 415V system power cables - The cable shall be 1.1kV, grade, heavy duty, stranded aluminium conductor, PVC Type-A Insulated galvanized steel wire/strip armoured, flame retardant low smoke (FRLS) extruded PVC type ST1 outer sheathed.
 - d) Control cables - The cable shall be 1.1kV grade, heavy duty, stranded copper conductor, PVC Type-A insulated, galvanized steel wire / strip armoured, flame retardant low smoke (FRLS) extruded PVC of Type-ST1 outer sheathed.
 - e) Generator excitation system cables - The cables shall be 3.3kV grade, heavy duty, stranded copper conductor, insulated with heat resistant PVC of Type-C, hard drawn aluminium wire armoured, flame retardant low smoke (FRLS) extruded PVC Type-ST2 outer sheathed.
- ii) Special properties : All the above cables shall be conforming to the relevant Indian/ IEC standard in general, with the following special properties:
- a) Oxygen Index of the outer sheath shall not be less than 29, when tested as per ASTM-D-2863.
 - b) Temperature Index of the outer sheath shall not be less than 250°C, when tested as per ASTM-D-2863.
 - c) Halogen acid contents in outer sheath shall not be more than 20%, when tested as per IEC-60754.
 - d) The maximum smoke density in percent light absorption should not exceed 60% in case of PVC compound and 20% in case of fire survival cables, when tested as per ASTM-D-2843.
 - e) Swedish chimney test as per SS-4241475 class F3 and ladder test for flammability as per IEEE-383.
- iii) Fire survival cables : The cable shall be of copper conductor and comply with IEC-60331 in addition to the above requirement. Also the halogen acid contents in outer sheath shall not be more than 2% when tested and per IEC-60754 and the smoke density in percent light absorption shall not exceed 20% when tested as per ASTM-D-2843. Cables required for the following systems shall be Fire survival type :
- a) DC emergency lube oil pumps
 - b) DC seal oil pump
 - c) DC emergency lighting cables for main building.
 - d) Batteries to chargers and DC distribution boards.



- e) Turbine lub oil pumps
- f) Jacking oil pumps
- g) Emergency turbine trip by push button in control room
- h) Boiler turbine : Generator inter-trip which includes the inter connecting cables between
 - Boiler master fuel trip and turbine trip relays
 - Generator trip relays and turbine trip relays
 - Generator trip relays and 400kV circuit breaker
 - Generator trip relays and generator field breaker
 - Generator trip relays and UAT breakers

5.10.5 Identification of cores

The insulated cores of HT and LT power cables shall be identified by coloured code. The control cables shall have identification by means of indelible printing of numbers of its cores at intervals not more than 75 mm. At least 20% cores shall be kept as spares in the multi-core control cables.

5.10.6 Arrangement of cables

As far as feasible, separate cables shall be provided for circuits of different plant and auxiliaries, for circuits of different voltages, and for circuit used separately. Power, control and instrumentation circuit shall invariably be taken through different routes, which shall not be laid together on the same cable trays.

5.10.7 Drums lengths

Drum lengths of the cables shall be so chosen that straight through joints are eliminated. However, the drum lengths shall not be less than the following lengths:

- | | | |
|------|--|-------|
| i) | 11kV grade power cables | 500 M |
| ii) | 1.1kV grade power / Fire survival cables etc. | |
| | - Including and above 400 mm ² size | 400 M |
| | - Below 400mm ² size | 500 M |
| iii) | 1.1kV grade control and instrumentation cables | 1000M |

5.11 INSTALLATION OF CABLES, EARTHING SYSTEM AND LIGHTNING PROTECTION SYSTEM

The cable trays, and accessories, supports, conduits, cable glands, lugs, ferrules, tags, clamps and other accessories for installation of cables in cable galleries, trenches etc. for unit auxiliaries; earthing system network/ earth mat including interconnections; and lightning protection of main and service buildings and other tall structures shall be provided.

5.11.1 Codes and standards

All work shall be carried out as per the following standards/ codes as applicable.

IS:513	Cold rolled low carbon steel sheets and strips.
IS:802	Code of practice for the use of Structural Steel in Overhead transmission Line Towers.
IS:1079	Hot Rolled carbon steel sheet and strips
IS:1239	Mild steel tubes, tubulars and other wrought steel fittings
IS:1255	Code of practice for installation and maintenance of power cables upto and including 33 KV rating
IS:1367 Part-13	Technical supply conditions for threaded Steel fasteners. (Hot dip galvanized coatings on threaded fasteners).
IS:2147	Degree of protection provided by enclosures for low voltage switchgear and control gear
IS:2309	Code of Practice for the protection of building and allied structures against lightning.
IS:2629	Recommended practice for hot dip galvanising of iron and steel
IS:2633	Method for testing uniformity of coating on zinc coated articles.
IS:3043	Code of practice for Earthing
IS:3063	Fasteners single coil rectangular section spring washers.
IS:6745	Methods for determination of mass of zinc coating on zinc coated iron and steel articles.
IS:8308	Compression type tubular in- line connectors for aluminium conductors of insulated cables
IS:8309	Compression type tubular terminal ends for aluminium conductors of insulated cables.
IS:9537	Conduits for electrical installation.
IS:9595	Metal arc welding of carbon and carbon manganese steels- recommendations.
IS:13573	Joints and terminations for polymeric cables for working voltages from 6.6kv upto and including 33kv performance requirements and type tests.
BS:476	Fire tests on building materials and structures
IEEE:80	IEEE guide for safety in AC substation grounding
IEEE:142	Grounding of Industrial and commercial power systems
DIN 46267	Non tension proof compression joints for Aluminium conductors.
DIN 46329	Cable lugs for compression connections, ring type, for Aluminium conductors
VDE 0278	Tests on cable terminations and straight through joints
BS:6121	Specification for mechanical Cable glands for elastomers and plastic insulated cables.

5.11.2 Design and Constructional Features

i) Inter Plant Cabling

Interplant cabling for main routes shall be laid along overhead trestles/duct banks. However, from tap-offs, same can be through shallow trenches. In case of Duct banks, pull-pits shall be filled with sand and provided with a PCC covering. Directly buried cables, if essential, shall not have concentration of more than 4 cables in one route.

ii) Transformer yard

In transformer yard area, cables shall be laid in RCC concrete trenches with RCC covers. The main cable routes coming out from Main plant building and crossing the Transformer yard shall be laid in overhead trestles/ duct banks. Minimum clear height of trestle shall be 3 m and for Rail/road crossing, it shall be as per rail/road crossing norms.

iii) False floors are not to be provided for cabling purpose.

iv) Cable entry : Cable entry from outdoor underground/ cable routes to the buildings, if any, shall be above the finished floor level of the building.

v) Trenches : PCC flooring of built up trenches shall be sloped for effective drainage with sump pits and sump pumps.

vi) No sub zero level cable vault/ trenches shall be provided below control building/ switchgear rooms in main plant areas.

5.11.3 Equipment Description

i) **Cable trays, fittings and accessories**

a) Cable trays shall be ladder/perforated type as specified complete with matching fittings (like brackets, elbows, bends, reducers, tees, crosses, etc.) accessories (like side coupler plates, etc. and hardware (like bolts, nuts, washers, GI strap, hook etc.) as required. Cable tray shall be ladder type for power and control cables and perforated for instrumentation cables.

b) Cable trays, fittings and accessories shall be fabricated out of rolled mild steel sheets free from flaws such as laminations, rolling marks, pitting etc. These (including hardware) shall be hot dip galvanized as per relevant IS.

c) Cable trays shall have standard width of 150 mm, 300 mm and 600 mm and standard lengths of 2.5 metre. Minimum thickness of mild steel sheets used for fabrication of cable trays and fittings shall be 2 mm. The thickness of side coupler plates shall be minimum 3 mm .



- d) Cable troughs shall be required for branching out few cables from main cable route. These shall be U-shaped, fabricated of mild steel sheets of minimum thickness 2 mm and shall be hot dip galvanized as per relevant IS. Troughs shall be standard width of 50 mm and 75 mm with depth of 25 mm

ii) Support system for cable trays

- a) Cable tray support system shall be pre-fabricated.
- b) Support system for cable trays shall essentially comprise of the two components i.e. main support channel and cantilever arms. The main support channel shall be of two types: i) having provision of supporting cable trays on one side and ii) having provision of supporting cable trays on both sides. The support system shall be as follows :
- Cable supporting steel work for cable racks/cables shall comprise of various channel sections, cantilever arms, various brackets, clamps, floor plates, all hardwares such as lock washers, hexagon nuts, hexagon head bolt, support hooks, stud nuts, hexagon head screw, channel nut, channel nut with springs, fixing studs, etc.
 - The system shall be designed such that it allows easy assembly at site by using bolting. All cable supporting steel work, hardwares fittings and accessories shall be prefabricated factory galvanized.
 - The main support and cantilever arms shall be fixed at site using necessary brackets, clamps, fittings, bolts, nuts and other hardware etc. to form various arrangements required to support the cable trays. Welding of the components shall not be allowed. However, welding of the bracket (to which the main support channel is bolted) to the overhead beams, structural steel, insert plates or reinforcement bars will be permitted. Any cutting or welding of the galvanized surface shall be brushed and red lead primer, oil primer and aluminium paint shall be applied.
 - All steel components, accessories, fittings and hardware shall be hot dip galvanized after completing welding, cutting, drilling and other machining operation.
 - The main support channel and cantilever arms shall be fabricated out of minimum 2.5 thick rolled steel sheet conforming to IS.
 - Cantilever arms of 300 mm, 600 mm and 750 mm in length are required. The arm portion shall be suitable for assembling the complete arm assembly on to component constructed of standard channel section. The back plate shall allow sufficient clearance for fixing bolt to be tightened with tray in position.



iii) Pipes, Fittings and accessories

- a) Pipes offered shall be complete with fittings and accessories (like tees, elbows, bends, check nuts, bushings, reducers, enlargers, coupling caps, nipples etc.) The size of the pipe shall be selected on the basis of maximum 40% fill criteria
- b) GI Pipes shall be of medium duty as per IS:1239.
- c) Duct banks shall be high density PE pipes encased in PCC (10% spare of each size, subject to minimum one) with suitable water-proof manholes.

iv) Junction boxes

- a) Junction Boxes with IP:55 degree of protection, shall comprise of a case with hinged door constructed from cold rolled sheet steel of minimum thickness 2 mm. Top of the boxes shall be arranged to slope towards rear of the box. Gland plate shall be 3 mm thick sheet steel with neoprene/synthetic rubber gaskets. All junction boxes shall be of adequate strength and rigidity, hot dip galvanized as per relevant IS, and suitable for mounting on wall, columns, structures etc. The boxes shall include brackets, bolts, nuts, screws M8 earthing stud etc. required for installation
- b) Terminal blocks shall be 650 volts grade, rated for 10 Amps and in one piece moulding. It shall be complete with insulating barriers, Klip-on-type terminals and identification strips. Marking on terminal strip shall correspond to the terminal numbering on wiring diagrams. It shall be Elmex type CSLT-1 with insulating material of Melamine conforming to ESI Standard 12.1 or equivalent. Terminal block shall be suitable for terminating 2 wires of 2.5mm² on both sides arranged to facilitate easy termination

v) Terminations and straight through joints

- a) Termination and jointing kits for 11kv/ 3.3 kV grade XLPE insulated cables shall be of proven design and make which have already been extensively used and type tested. Termination kits and jointing kits shall be pre-moulded type, tapex type or heat shrinkable type. 11kV/ 3.3kV grade joints and terminations shall be type tested as per IS:13573. Critical components used in cable accessories shall be of tested and proven quality as per relevant product specification/ ESI specification. The kit shall be complete with the aluminium solderless crimping type cable lugs and ferrule as per DIN standard.
- b) Straight through joint and termination shall be capable of withstanding the fault level for 11 kV and 3.3kV system.

c) 1.1 kV grade straight through joints shall be of proven design.

vi) Cable glands

Cable shall be terminated using double compression type cable glands. Cable glands shall conform to BS:6121 and be of robust construction capable of clamping cable and cable armour (for armoured cables) firmly without injury to insulation. Cable glands shall be made of heavy duty brass machine finished and nickel chrome plated. Thickness of plating shall not be less than 10 micron. All washers and hardware shall also be made of brass with nickel chrome plating. Rubber components shall be of neoprene and of tested quality. Necessary cable dimensions shall be furnished to the successful bidder.

vii) Cable lugs/ ferrules

Cable lugs for power cables shall be Aluminium solderless crimping type conforming to IS:8309 suitable for aluminium compacted conductor cables. Cable lugs and ferrules for control cables shall be tinned copper conforming to IS:8309. The cable lugs for control cables shall be provided with insulating sleeve and shall suit the type of terminals provided on the equipments.

viii) Trefoil clamps

Trefoil clamps for single core cables shall be pressure die cast aluminum or fibre glass or nylon and shall include necessary fixing accessories like G.I. nuts, bolts, washers, etc. Trefoil clamps shall have adequate mechanical strength to withstand the forces generated by the system short circuit current of 105kA peak.

ix) Cable clamps and straps

The cable clamps required to clamp multicore cables on vertical run shall be made up of Aluminium strip of 25x3 mm size. For clamping the multicore cables, self-locking, de-interlocking type nylon clamps/ straps shall be used. The clamps/ straps shall have sufficient strength and shall not get affected by direct exposure to sun rays and outdoor environment

x) Receptacles

Receptacles boxes shall be fabricated out of MS sheet of 2mm thickness and hot dipped galvanized or of die-cast aluminium alloy of thickness not less than 2.5 mm. The boxes shall be provided with two nos. earthing terminals, gasket to achieve IP55 degree of protection, terminal blocks for loop-in loop-out for cable of specified sizes, mounting brackets suitable for surface mounting on wall/ column/ structure, gland plate etc. The ON-OFF switch shall be rotary type heavy duty, double break, AC23 category, suitable for AC supply. Plug and Socket shall be shrouded Die-cast aluminium. Socket shall be provided with lid safety cover. Robust mechanical interlock shall be provided such that the switch can be put ON only when the plug is fully engaged and plug can be withdrawn only when the switch is in OFF position. Also cover can be opened only when the

switch is in OFF position. Wiring shall be carried out with 1100 V grade PVC insulated stranded aluminium/ copper wire of adequate size. The Terminal blocks shall be of 1100V grade.

xi) Galvanizing

- a) Galvanizing of steel components and accessories shall conform to IS:2629 and IS:2633. Additionally galvanizing shall be uniform, clean smooth, continuous and free from acid spots
- b) The amount of zinc deposit over threaded portion of bolts, nuts, screws and washers shall be as per IS:1367. The removal of extra zinc on threaded portion of components shall be carefully done to ensure that the threads shall have the required zinc coating on them as specified

xii) Welding

The welding shall be carried out in accordance with IS:9595. All welding procedures and welders qualification shall also be followed strictly in line with IS:9595

5.11.4 Installation

i) Cable tray and support system installation

- a) Cables shall run in cable trays mounted horizontally or vertically on cable tray support system which in turn shall be supported from floor, ceiling, overhead structures, trestles, pipe racks, trenches or other building structures. All cable trays shall be in vertical configuration in boiler and ESP areas.
- b) Horizontally running cable trays shall be clamped by bolting to cantilever arms and vertically running cable trays shall be bolted to main support channel by suitable bracket/ clamps on both top and bottom side rails at an interval of 2000 mm. For vertical cable risers/shafts cable trays shall be supported at an interval of 1000mm. Fixing of cable trays to cantilever arms or main support channel by welding shall not be accepted.
- c) The cantilever arms shall be positioned on the main support channel with a minimum vertical spacing of 300 mm unless otherwise indicated in the relevant tray layout drawings
- d) All cable way sections shall have identification, designations as per cable way layout drawings and painted/stenciled at each end of cable way and where there is a branch connection to another cable way. Minimum height of letter shall be not less than 75 mm. For long lengths of trays, the identification shall be painted at every 10 meter. Risers shall additionally be painted/ stenciled with identification numbers at every floor.



- e) In certain cases it may be necessary to site fabricate portions of trays, supports and other non standard bends where the normal prefabricated trays, supports and accessories may not be suitable. In such cases the Contractor shall fabricate at site suitable sections of trays, supports and accessories to make the installation complete for the specific purpose after obtaining Project Manager's prior approval, which shall be neat in appearance and shall match with the prefabricated sections in the dimensions. They shall be applied with one coat of red lead primer, one coat of oil primer followed by two finishing coats of aluminium paint.

ii) Conduits/ Pipes/ Ducts installation

- a) All openings in the floor/ roof/ wall/ cable tunnel/ cable trenches made for conduit installation shall be sealed and made water proof.
- b) GI pull wire of adequate size shall be laid in all conduits before installation. Metallic conduit runs at termination shall have two lock nuts wherever required for junction boxes etc.
- c) Conduit runs/sleeves shall be provided with PVC bushings having round edge at each end. All conduits/ pipes shall have their ends closed by caps until cables are pulled. After cables are pulled, the ends of conduits/ pipes shall be sealed with Glass-wool/ Cement Mortar/ Putty to prevent entrance of moisture and foreign material
- d) Exposed conduit/ pipe shall be adequately supported by racks, clamps, straps or by other approved means. Conduits / pipe support shall be installed square and true to line and grade with an average spacing between the supports as given below, unless specified otherwise

Conduit/ pipe size (dia)	Spacing
Upto 40 mm	1.0 m
50 mm	2.0 m
65-85 mm	2.5 m
100 mm	3.0 m

iii) Junction boxes installation

Junction boxes shall be mounted at a height of 1200mm above floor level or as specified in the drawings or as decided by Project Manager and shall be adequately supported/mounted on masonry wall by means of anchor fasteners/ expandable bolts or shall be mounted on an angle, plate or other structural supports fixed to floor, wall, ceiling or equipment foundations.

iv) Cable installation

- a) Cable installation shall be carried out as per IS:1255 and other applicable standards. Cable drums shall be unloaded, handled and stored in an approved manner on hard and well drained surface so that they may not sink. In no case shall be drum be stored flat i.e. with flange horizontal. Rolling of drums shall be avoided as far as possible. For short distances, the drums may be rolled provided they are rolled slowly and in proper direction as marked on the drum. In absence of any indication, the drums may be rolled in the same direction as it was rolled during taking up the cables. For un-reeling the cable, the drum shall be mounted on suitable jacks or on cable wheels and shall be rolled slowly so that cable comes out over the drum and not from below. All possible care shall be taken during unreeling and laying to avoid damage due to twist, kink or sharp bends. Cable ends shall be provided with sealed plastic caps to prevent damage and ingress of moisture.
- b) While laying cable, ground rollers shall be used at every 2 metre interval to avoid cable touching ground. The cables shall be pushed over the rollers by a gang of people positioned in between the rollers. Cables shall not be pulled from the end without having intermediate pushing arrangements. Pulling tension shall not exceed the values recommended by cable manufacturer. Selection of cable drums for each run shall be so planned so as to avoid using straight through joints. Care should be taken while laying the cables so as to avoid damage to cables.
- c) Cables shall be laid on cable trays strictly in line with cable schedule furnished.
- d) Power and control cables shall be laid on separate tiers. The laying of different voltage grade cables shall be on different tiers according to the voltage grade of the cables. In horizontal tray stacks, HT cables (11kV) shall be laid on topmost tier and cables of subsequent lower voltage grades on lower tiers of trays. Single core cable in trefoil formation shall be laid with a distance of four times the diameter of cable between trefoil center lines and clamped at every two metre. All multi-core cables shall be laid in touching formation. Power and control cables shall be secured fixed to trays/ support with self locking type nylon cable straps with de-interlocking facilities. For horizontal trays arrangements, multi-core power cables and control cables shall be secured at every five meter interval. For vertical tray arrangement, individual multi-core power cables and control cables shall be secured at every one meter by nylon cable strap. After completion of cable laying work in the particular vertical tray, all the control cables shall be binded to trays/ supports by aluminium strips at every five meter interval and at every bend.
- e) Bending radii for cables shall be as per manufacturer's recommendations and IS:1255.



- f) Where cables cross roads/rail tracks, the cables shall be laid in hume pipe/ PVC pipe.
- g) Joints for less than 250 Meters run of cable shall not be permitted.
- h) In each cable run some extra length shall be kept at suitable point to enable one LT (415V system) / two HT (11kV, 3.3kV) straight through joints to made, should the cable develop fault at a later stage. Control cable termination inside equipment enclosure shall have sufficient lengths so that shifting of termination in terminal blocks can be done without requiring any splicing.
- i) Wherever few cables are branching out from main trunk route troughs shall be used.
- j) The installation work shall be carried out in a neat workman like manner and areas of work shall be cleaned of all scraps, water, etc. after the completion of work in each area every day. RCC/ Steel trench covers shall be replaced after the installation work in a particular area is completed or when further work is not likely to be taken up for some time.
- k) **Separation** - At least 300mm clearance shall be provided between :
- HT power and LT power cables,
 - LT power and LT control/ instrumentation cables,
- l) **Segregation**
- Segregation means physical isolation to prevent fire jumping.
 - All cables associated with the unit shall be segregated from cables of other units.
 - Interplant cables of unit critical drives shall be segregated in such a way that not more than half of the drives are lost in case of single incident of fire. Power and control cables for AC drives and corresponding emergency AC or DC drives shall be laid in segregated routes. Cable routes for one set of auxiliaries of same unit shall be segregated from the other set.
- m) Minimum number of spare cores required to be left for interconnection in control cables shall be as follows :

No. of cores in cable	No. of spare cores
2C, 3C	NIL
5C	1
7C-10C	2
14C and above	3

n) **Cable fire sealing**

Wherever the cables pass through walls/ floors, fire proof cable penetration seals rated for two hours shall be provided. This shall be by suitable block system using individual blocks with suitable framework or by silicon RTV foaming system. In case foaming system is offered, damming board, if used, shall not be considered for fire rating criteria. Any of the system offered shall be of proven type as per BS:476 (Part-20) or equivalent standard.

o) **Directly buried cables**

- Cable trenches shall be constructed for directly buried cables. Construction of cable trench for cables shall include excavation, preparation of sieved sand bedding, riddled soil cover, supply and installation of brick or concrete protective covers, back filling and compacting, supply and installation of route markers and joint markers. Laying of cables and providing protective covering shall be as per IS:1255.

- RCC cable route and RCC joint markers shall be provided wherever required. The voltage grade of the higher voltage cables in route shall be engraved on the marker. Location of underground cable joints shall be indicated with cable marker with an additional inscription "Cable Joint". The marker shall project 150 mm above ground and shall be spaced at an interval of 30 meters and at every change in direction. They shall be located on both sides of road crossings and drain crossings. Top of cable marker/joint marker shall be sloped to avoid accumulation of water/dust on marker.

p) Cable tags shall be provided on all cables at each end (just before entering the equipment enclosure), on both sides of a wall or floor crossing, on each duct/conduit entry, and at every 20 meters in cable tray/trench runs. Cable tags shall also be provided inside the switchgear, motor control centers, control and relay panels etc. where a number of cables enter together through a gland plate. Cable tag shall be of rectangular shape for power cables and control cables. Cable tag shall be of 2 mm thick aluminum with number punched on it and securely attached to the cable by not less than two turns of 20 SWG GI wire conforming to IS:280. Alternatively, cable tags made of nylon, cable marking ties of 'TY-CAB' or equivalent type with cable number heat stamped on the cable tags may also be provided.

q) While crossing the floors, un-armoured cables shall be protected in conduits upto a height of 500 mm from floor level if not laid in tray.



v) Cable terminations and connections

- a) The termination and connection of cables shall be done strictly in accordance with cable termination kit manufacturer instructions, drawings etc. Cable jointer shall be qualified to carryout satisfactory cable jointing/ termination.
- b) Work shall include all clamps, fittings etc. and clamping, fitting, fixing, plumbing, soldering, drilling, cutting, taping, preparation of cable end, crimping of lug, insulated sleeving over control cable lugs, heat shrinking (where applicable), connecting to cable terminal, shorting and grounding as required to complete the job.
- c) The equipment will be generally provided with undrilled gland plates for cables/ conduit entry. The Contractor shall be responsible for punching of gland plates, painting and touching up. Holes shall not be made by gas cutting. The holes shall be true in shape. All cable entry points shall be sealed and made vermin and dust proof. Unused openings shall be effectively sealed by 2mm thick aluminium sheets.
- d) Control cable cores entering control panel/ switchgear/ MCCs etc. shall be neatly bunched, clamped and tied with self locking type nylon cable ties with de interlocking facility to keep them in position.
- e) The panels where a larger number of cables are to be terminated and cable identification may be difficult, each core ferrule shall include the complete cable number as per the drawings. The ferrules shall be indelible interlocking type and shall fit tightly on cores. Spare cores shall have similarly ferrules with a suffix letter 'S' alongwith cable numbers and coiled up after end sealing.
- f) All cable terminations shall be appropriately tightened to ensure secure and reliable connections.

5.11.5 Earthing system

- i) Earthing system shall be in strict accordance with IS:3043 and Indian Electricity Rules/ Acts.

Earthing system will be designed considering suitable corrosion allowance based on earthing conductor material and type of soil, for a service life of at least forty (40) years for maximum fault current or system fault current of 40kA whichever is higher for 1 second. The minimum rate of corrosion of earthing conductor shall be considered as 0.12mm per year while determining the conductor size.

- ii) The earth conductors shall be free from pitting, laminations, rust, scale and other electrical, mechanical defects.



- iii) The material of the earthing conductors shall be as follows :
- a) Conductors above ground level and in built up trenches - Galvanized steel
 - b) Conductors buried in earth - Mild steel
 - c) Earth electrodes - Mild steel rod
- iv) The sizes of earthing conductors for various electrical equipments shall be as below:

<u>Equipment</u>	<u>Earth conductor buried in earth</u>	<u>Earth conductor and in built-up trenches</u>
a) Main earth grid	40 mm Ø MS rod	65x12mm GS flat
b) 11kV switchgear/ equipment		65X12MM GS flat
c) 3.3 kV switchgear/ 415V switchgear/ Transformers		50X6MM GS flat
d) 415V Motors		
- above 125 kW		50 x 6mm GS flat
- 25 kW to 125 kW		25 x 6mm GS flat
- 1kW to 25 kW		25 x 3mm GS flat
e) Control panel/ desk		25 x 3 mm GS flat
f) Push button station/ Junction Box		8 SWG GI wire
g) Columns, structures, cable trays and bus ducts enclosures		50x6mm GS flat
h) Crane, rails, rail tracks and other non-current carrying metal parts		25x6mm GS flat

- v) Metallic frame of all electrical equipment shall be earthed by two separate and distinct connections to earthing system, each of 100% capacity, Crane rails, tracks, metal pipes and conduits shall also be effectively earthed at two points. Steel RCC columns, metallic stairs, and rails etc. of the building housing electrical equipment shall be connected to the nearby earthing grid conductor by one earthing ensured by bonding the different sections of hand rails and metallic stairs. Metallic sheaths/screens, and armour of multi-core cables shall be earthed at both ends. Metallic Sheaths and armour of single core cables shall be earthed at switchgear end only. Every alternate post of the switchyard fence shall be connected to earthing grid by one GS flat and gates by flexible lead to the earthed post. Railway tracks within the plant area shall be bonded across fish plates and connected to earthing grid at several locations. Portable tools, appliances and welding equipment shall be earthed by flexible insulated cable.
- vi) Each continuous laid lengths of cable tray shall be earthed at minimum two places by GS flats to earthing system, the distance between earthing points shall not exceed 30 metre. Wherever earth mat is not available Contractor shall do the necessary connections by driving an earth electrode in the ground.



- vii) Neutral connections and metallic conduits/ pipes shall not be used for the equipment earthing. Lightning protection system down conductors shall not be connected to other earthing conductors above the ground level.
- viii) Connections between earth leads and equipment shall normally be of bolted type. Contact surfaces shall be thoroughly cleaned before connections. Equipment bolted connections after being tested and checked shall be painted with anti corrosive paint/compound.
- ix) Suitable earth risers shall be provided above finished floor/ ground level, if the equipment is not available at the time of laying of main earth conductor.
- x) Connections between equipment earthing leads and between main earthing conductors shall be of welded type. For rust protection the welds should be treated with red lead compound and afterwards thickly coated with bitumen compound. All welded connections shall be made by electric arc welding.
- xi) Resistance of the joint shall not be more than the resistance of the equivalent length of conductors.
- xii) Earthing conductors along their run on columns, walls, etc. shall be supported by suitable welding/ cleating at interval of 1000mm and 750mm respectively.
- xiii) Earth pit shall be constructed as per IS:3043. Electrodes shall be embedded below permanent moisture level. Minimum spacing between electrodes shall be 600mm. Earth pits shall be treated with salt and charcoal if average resistance of soil is more than 20 ohm metre.
- xiv) Earthing conductor shall be buried at least 2000mm outside the fence of electrical installations. Every alternate post of the fences and all gates shall be connected to earthing grid by one lead.

5.11.6 Lightning Protection System

- i) All lightning protection installation work shall be in accordance with the Indian Electricity Rules and IS Code of Practice for the Protection of Buildings and allied Structures against Lightning (IS : 2309).
- ii) Lightning protection system shall comprise vertical air terminations, horizontal air terminations, down conductors, test links and earth electrodes.
- iii) Air terminations, down conductors and test links shall be of galvanized steel conductors and earth connection below ground level shall be of mild steel rod.
- iv) For tall buildings and structures, early streamer emission (ESE) type air terminal systems such as marketed by Heary Brothers (USA) are preferred.



- v) Lightning protection conductors/ air termination rods and circumferential bands provided at the top portion of chimney stack shall be lead coated in order to avoid melting by exposure to hot flue gases.
- vi) Horizontal air termination flats provided on top of boilers, main plant building, pump houses and other buildings shall be laid such that no part of the roof shall be more than 9 meters
- vii) Conductors of lightning protection system shall not be connected with conductors of earthing system above ground level.
- viii) Down conductors shall be cleated on outer side of building wall at 1000 mm interval or tack welded to outside of building columns at 1000 mm interval.
- ix) Down conductors shall be connected to separate earth electrodes through test points located at height of above 1000 mm above ground level. These earth electrodes shall in turn be connected to earth mat at two points.
- x) Lightning protection conductors shall not pass through or run inside GI conduits.
- xi) All metallic equipments on roof and exposed steel works within the vicinity of 2000 mm from lightning protection conductors in air shall be bonded to conductors of lightning protection system.
- xii) Lightning protection system shall have as few joints as possible and avoid sharp bends. Down conductors shall have, as far as possible, no joint except at test point and end termination.
- xiii) Termination at the metallic equipments on roof should be made by suitable nuts, bolts, pressure washers and bitumen washers with good electrical conductivity.
- xiv) All lightning protection conductors shall be exposed to atmosphere unless specifically mentioned.



5.12 DC STORAGE BATTERY

DC battery is required for certain essential unit auxiliaries, control supply for switchgear/control panels, emergency lighting etc. As such 2x100% sets of 220V of either Lead-Acid Plante or Nickel-Cadmium Battery banks catering to 100 percent unit and station load shall be provided for each unit.

5.12.1 Codes and Standards

All batteries shall be as per the following standards and codes:

(a) Lead –Acid Plante Battery

IS : 266	Specification for sulphuric acid
IS : 1069	Specification for water for storage batteries
IS : 1146	Specification for rubber and plastic containers for lead acid storage batteries
IS : 1652	Specification for stationary cells and batteries, lead acid type (with plant positive plates).
IS : 3116	Specification for sealing compound for lead acid batteries.
IS : 8320	General requirements and methods of tests for lead acid storage batteries
IS : 6071	Specification for synthetic separators for lead acid batteries

(b) Nickel-Cadmium Battery

IS : 10918	Specification for vented type Nickel Cadmium Batteries.
IS : 1069	Quality tolerances for water for storage batteries

5.12.2 Technical particulars

- i) The ampere-hour capacity of the DC storage battery shall be based on half an hour supply to the essential auxiliaries.
- ii) The permissible voltage variation for 220V battery shall be from 190V to 240V.
- iii) To cater to the electronic and microprocessor loads of the C&I system, suitable UPS/ Battery back-up system shall be provided.

iv) Battery Ratings

a) For Lead Acid Plante type Battery

- | | |
|--|---|
| - Battery Voltage | 220V |
| - Battery type | Stationary Lead Acid Plante high discharge type |
| - Capacity for ten(10) hour rate to 1.85V/ cell at 27 ⁰ C any time during the entire duty cycle | As per system requirement |



- Nominal discharge voltage/ cell 2.0V
- Float Voltage 2.2V/ Cell

- b) For Ni-Cd Type Battery
 - Battery Voltage 220V
 - Battery type Stationary Ni- Cadmium Pocket Plate High discharge type (KPH)
 - Capacity for five(5) hour rate to 1.14V/ Cell at 27⁰C any time during the entire duty cycle As per system requirement
 - Nominal discharge voltage/ cell 1.2V
 - Float voltage 1.42V/ Cell

- v) The unit auxiliaries for which emergency power supply from the DC storage battery is required are listed below:
 - Minimum emergency lighting system for reduced illumination during failure of main power supply.
 - Hydrogen seal-oil system.
 - TG bearing oil system (emergency lubricating oil pump)
 - Auxiliary control supply for 11kV unit and station switchgears and 3.3kV and 415V unit switchgears
 - Electrical protection system.
 - Turbine DC Jacking oil pumps (for main turbine and BFP turbine)
 - Any other emergency load considered necessary.

5.12.3 General Technical Requirements

5.12.3.1 Lead -Acid Plante Battery

i) Equipments

- a) DC Batteries shall be stationary lead acid Plante positive plate type conforming to IS:1652. The battery shall be high discharge performance type. For the purpose of design an ambient temperature of 50⁰C and relative humidity of 85% shall be considered.
- b) DC Batteries shall be suitable for standby duty. The Batteries shall normally be permanently connected to the load in parallel with a charger and shall supply the load during emergency conditions when AC supplies

are lost. Batteries shall be suitable for a long life under continuous float operations and occasional discharges. The batteries shall be boost charged at about 2.7 volts per cell maximum and float charged at about 2.2 V/cell.

ii) Construction Features

a) Containers

Containers shall be made of transparent glass, hard rubber, suitable robust, heat resistance, leak proof, non absorbent, acid resistant, non-bulging type and free from flaws, such as wrinkles, cracks, blisters, pin holes etc. Electrolyte level lines shall be marked on container in case of transparent containers. Float type level indicator shall be provided in case of opaque containers. The stem portion of the float should be long enough to prevent falling of the float inside the container even if there is no electrolyte in the container. The marking for the electrolyte level should be for the upper and lower limits. The material of level indicator shall be acid proof and oxidation proof. Container shall be closed/sealed lid type. Lid and sealing compound shall be non-cracking type. The container made of hard rubber and plastics shall be type tested as per IS:1146. All type tests shall be carried out for sealing compound as per IS:3116.

The pole sealing arrangement should be such that no acid particle get entrapped due to acid creep as a result of capillary action and it should be possible to remove and refix the sealing to carry out the maintenance.

b) Vent Plugs

Vent plugs shall be provided in each cells. They shall be anti-splash type, having more than one exit hole shall allow the gases to escape freely but shall prevent acid from coming out. The design shall be such that the water loss due to evaporation is kept to minimum. In addition the ventilator shall be easily removed for topping up the cells and of such dimensions that the syringe type hydrometer can be inserted into the vent to take electrolyte sample.

c) Plates

The plates shall be designed for maximum durability during all service conditions including high rate of discharge and rapid fluctuations of load. The construction of plates shall conform to latest revisions of IS: 1652 as applicable.

The separators shall maintain the electrical insulation between the plates and shall allow the electrolyte to flow freely. Separators should be suitable for continuous immersion in the electrolyte without distortion. The positive and negative post shall be clearly marked.



d) Sediment Space

Sufficient sediment space shall be provided so that cells will not have to be cleaned during normal life and prevent shorts within the cells.

f) Cell Insulator

Each cell shall be separately supported on PVC/ porcelain/ hard rubber insulators fixed on the racks with adequate clearance between adjacent cells. Minimum distance between adjacent cells shall be more than the buldge allowed for two cells in accordance with IS:1146.

g) Electrolyte

The electrolyte shall be prepared from battery grade sulphuric acid conforming to IS:266 and distilled water conforming to IS:1069. The cells shall be shipped dry uncharged. The electrolyte shall be supplied separately.

h) Connectors and fasteners

Lead or Lead coated copper connectors shall be used for connecting up adjacent cells and rows. Bolts, nuts and washers shall be effectively lead coated to prevent corrosion. The thickness of lead-coating of connectors should not be less than 0.025 mm. The lead coating thickness shall be measured in accordance with APPENDIX F of IS:6848 (latest edition). All the terminals and cells inter-connectors shall be fully insulated or have insulation shrouds. End take off connections from positive and negative poles of batteries shall be made by single core cables having stranded aluminium conductors and XLPE insulation. Necessary supports and lugs for termination of these cables on batteries shall also be supplied by the contractor. All connectors and lugs shall be capable of continuously carrying the 30 minutes discharge current of the respective Batteries and through fault short circuit current which the battery can produce and withstand for the period declared.

i) Battery racks

Wooden racks/ Steel Racks with anti-corrosive epoxy paint for all the batteries shall be provided. These racks shall be made of good quality first class seasoned teak. They shall be free standing type mounted on porcelain/ hard rubber/ PVC pads insulators. Batteries shall preferably be located in the single tier arrangement. However, batteries having a complete cell weight of lower than 50 Kg could be located in the double tier arrangement. The batteries rack and wooden support for cable termination shall be coated with three (3) coats of anti-acid paint of approved shade. Numbering tags, resistant to acid, for each cell shall be attached on to the necessary racks. The bottom tier of the stand shall not be less than 150 mm above the floor. Wherever racks are transported in



dismantled condition, suitable match markings shall be provided to facilitate easy assembly.

j) Manufacturer's Identification systems

The following information shall be indelibly marked on outside of each cell.

- Manufacturer's name and trade marks
- Country and year of manufacture.
- Manufacturer type designation.
- AH capacity at 10 hour discharge rate.
- Serial number

5.12.3.2 Nickel-Cadmium Battery

i) Equipments

- a) DC Batteries shall be stationary Nickel Cadmium Pocket plate type (KPH) conforming to IS:10918. The batteries shall be high discharge performance type as specified. For the purpose of design an ambient temperature of 50⁰C and relative humidity of 85% shall be considered.
- b) DC batteries shall be suitable for standby duty. The batteries shall normally be permanently connected to the load in parallel with a charger and shall supply the load during emergency conditions when AC supplies are lost. Batteries shall be suitable for a long life under continuous float operations and occasional discharges. The batteries shall be boost charged at about 1.54 to 1.7 volts per cell maximum and float charged at about 1.42 V/cell.

ii) Construction Features

a) Containers

Containers shall be made of polypropylene plastic material. Containers shall be robust, heat resistance, leak proof, non absorbent, alkali resistant, non-bulging type and free from flaws, such as wrinkles, cracks, blisters, pin holes etc. Electrolyte level lines shall be marked on container in case of translucent containers.

b) Vent Plugs

Vent plugs shall be provided in each cells. They shall be anti-splash type, having more than one exit hole shall allow the gases to escape freely but shall prevent alkali from coming out. The design shall be such that the water loss due to evaporation is kept to minimum. In addition the ventilator shall be easily removed for topping up the cells and of such dimensions that the syringe type hydrometer can be inserted into the vent to take electrolyte samples.



c) Plates

The plates shall be designed for maximum durability during all service conditions including high rate of discharge and rapid fluctuations of load. The construction of plates shall conform to latest revisions of IS:10918.

The separators shall maintain the electrical insulation between the plates and shall allow the electrolyte to flow freely. Separators should be suitable for continuous immersion in the electrolyte without distortion. The positive and negative terminal posts shall be clearly marked.

d) Sediment space

Sufficient sediment space shall be provided so that cells will not have to be cleaned during normal life and prevent shorts within the cells.

e) Cell Insulator

Each cell shall be separately supported on PVC/porcelain/hard rubber insulators fixed on to the racks with adequate clearance between adjacent cells. Minimum distance between the adjacent cells shall be more than the buldge allowed for two cells in accordance with IS:1146.

f) Electrolyte

The electrolyte shall be prepared from battery grade potassium hydroxide conforming to BS:1069.

The cells can be shipped either in charged condition or in dry condition

Necessary electrolyte for make-up shall be supplied separately.

g) Connectors and Fasteners

Nickel coated copper connectors shall be used for connecting up adjacent cells and rows. Bolts, nuts and washers shall be effectively Nickel coated to prevent corrosion. The thickness of Nickel coating of connectors should be not less than 0.02 mm. All the terminals and cells inter-connectors shall be fully insulated or have insulation shrouds. End take off connections from positive and negative poles of batteries shall be made by single core cables having stranded aluminium conductors and XLPE insulation. Necessary supports and lugs for termination of these cables on batteries shall also be supplied by the contractor. All connectors and lugs shall be capable of continuously carrying the 30 minutes discharge current of the respective batteries and through fault short circuit current which the battery can produce and withstand for the period declared. Contractor shall furnish necessary sizing calculations to prove compliance to the same. Suitable number of Inter-rack connectors



shall be supplied by the Bidder to suit the battery room layout during detailed engineering.

h) Battery racks

Mild steel racks for all the batteries shall be provided. They shall be free standing type mounted on porcelain/ hard rubber/ PVC pads insulators. Batteries shall preferably be located in the single tier arrangement. However, batteries having a complete cell weight of lower than 50 Kg could be located in the double tier arrangement. The batteries racks and supports for cable termination shall be coated with three (3) coats of anti-alkali paint of approved shade. Name plates, resistant to alkali, for each cell shall be attached on to the necessary racks. The bottom tier of the stand shall not be less than 150 mm above the floor.

Wherever racks are transported in dismantled conditions, match markings shall be provided to facilitate easy assembly.

i) Manufacturer's Identification system

The following information shall be indelibly marked on outside of each cell.

- Manufacturers' name and trade marks
- Country and year of manufacture.
- Manufacturer type designation.
- AH capacity at 5 hour discharge rate.
- Serial number



5.13 BATTERY CHARGER

2x100% float cum boost charger shall be provided for each unit battery bank as described in clause no. 5.12. In addition one no. spare float cum boost charger shall also be provided for each unit battery bank.

5.13.1 Codes and Standards

Battery chargers shall be as per the following standards and codes :

ANSI-C 37.90a	Guide for surge withstand capability tests
IS:5	Colours for ready mix paints.
IS : 694	PVC Insulated Cable for working voltages upto and including 1100V
IS : 1248	Specification for Direct acting indicating analogue electrical measuring instruments.
IS:13947 Pt-1	Degree of protection provided by enclosures for low voltage switch gear and control gear.
IS : 13947	Specification for low voltage switch gear and control gear
IS : 3231	Electrical relays for power system protection.
IS : 3842	Application guide for Electrical relays for AC System
IS : 3895	Mono-crystalline semi-conductor Rectifier Cells and Stacks
IS : 4540	Mono crystalline semi-conductor Rectifier assemblies and equipment.
IS:6005	Code of practice for phosphating of Iron and Steel
IS:6619	Safety Code for Semi-conductor Rectifier Equipment.
IS:6875	Control switches (switching devices for control and auxiliary circuits including contactor relays) for voltages upto 1000 VAC or 1200VDC
IS : 9000	Basic environmental testing procedures for electronic and electrical items.
IS:13703	Low voltage fuses for voltages not exceeding 1000 V AC, 1500VDC.
EEUA-45D	Performance requirements for electrical Alarm Annunciation system

5.13.2 Technical Particulars

- i) Battery Charger for Lead Acid Plante Type Battery :

The Batteries shall be Trickle charged at 2.15 to 2.25 Volts per cell. All chargers shall also be capable of Boost Charging the associated D.C. Battery at 2.0 to 2.7 Volts per cell at the desired rate. The Chargers shall be designed to operate, as mentioned above, at an ambient air temperature of 50°C.

- ii) Battery Charger for Nickel-Cadmium Type Battery :

The Batteries shall be Trickle charged at 1.4 to 1.42 Volts per cell. All chargers shall be capable of Boost Charging the associated D.C. Battery at 1.53 to 1.7 Volts per cell at the desired rate. The Chargers shall be designed to operate, as mentioned above, at an ambient air temperature of 50°C.

5.13.3 Interlocks - Necessary interlock shall also be provided to avoid accidental boost mode operation when loads are connected to the bus.



5.13.4 General Technical Particulars

5.13.4.1 Battery Charger for Lead Acid Plante Type Battery

- i) The Battery Chargers as well as their automatic regulators shall be of static type. Battery chargers shall be capable of continuous operation at the respective rated load in Trickle mode i.e. Trickle charging the associated DC lead-acid Batteries while supplying the DC loads.
- ii) Battery Chargers shall have a selector switch for selecting the battery charging mode i.e. whether Trickle or Boost charging.
- iii) All Battery Chargers shall be provided with facility for both automatic and manual control of output voltage and current. A selector switch shall be provided for selecting the mode of output voltage/current control, whether automatic or manual. Means shall be provided to avoid current/voltage surges of harmful magnitude/ nature which may arise during changeover from Auto to Manual mode or vice-versa under normal operating condition.
- iv) Soft start feature shall be provided to build up the voltage to the set value slowly within fifteen seconds. The chargers shall have load limiters which shall cause, when the voltage control is in automatic mode, a gradual lowering of the output voltage when the DC load current exceeds the load limiter setting of the Charger. The load limiter characteristic shall be such that any sustained overload or short circuit in DC system shall neither damage the Charger nor shall it cause blowing of any of the charger fuses. The Charger shall not trip on overload or external short circuit. After clearance of fault, the Charger voltage shall build up automatically when working in automatic mode.
- v) When on automatic control mode during Trickle charging, the Charger output voltage shall remain within $(\pm)1\%$ of the set value for AC input voltage variation of $(\pm) 10\%$, frequency variation of $(+3/ -)5\%$, a combined voltage and frequency variation of 10% (absolute sum) and a continuous DC load variation from zero to full load. Uniform and stepless adjustments of voltage setting (in both manual and automatic modes) shall be provided on the front of the Charger panel covering the entire Trickle charging output range specified. Stepless adjustment of the load limiter setting shall also be possible from 80% to 100% of the rated output current for Trickle charging mode.
- vi) During Boost charging, the Battery Chargers shall operate on constant current mode (When automatic regulator is in service). It shall be possible to adjust the Boost charging current continuously over a range of 50 to 100% of the rated output current for Boost charging mode. The charger output voltage shall automatically go on rising, when it is operating on boost mode, as the battery charges up. For limiting the

output voltage of the charger, a potentiometer shall be provided on the front of the panel, whereby it shall be possible to set the upper limit of this voltage anywhere in the output range specified for boost charging mode. All voltage and current setting potentiometers shall be vernier type.

- vii) Energising the Charger with fully charged battery connected plus 10% load shall not result in output voltage greater than 110% of the voltage setting. Time taken to stabilise, to within the specified limits as mentioned elsewhere, shall be less than fifteen seconds.
- viii) Momentary output voltage of the Charger, with the Battery connected shall be within 94% to 106% of the voltage setting during sudden load Change from 100% to 20% of full load or vice-versa. Output voltage shall return to, and remain, within the limits specified as mentioned elsewhere in less than 2 seconds after the above mentioned change.
- ix) The Charger manufacturer may offer an arrangement in which the voltage setting device for Trickle charging mode is also used as output voltage limit setting device for Boost charging mode, and the load limiter of the trickle charging mode is also used as Boost charging current setting device.
- x) Suitable filter circuits shall be provided in all the Chargers to limit the ripple content (peak to peak) in the output voltage to 1% irrespective of the DC load, even when they are not connected to a battery.
- xi) The DC System shall be ungrounded and float with respect to the ground potential when healthy. An earth fault relay shall be provided by the Employer in the DC distribution board for remote annunciation.

5.13.4.2 Battery Charger for Nickel-Cadmium Type Battery

- i) The Battery Chargers as well as their automatic regulators shall be of static type. Battery chargers shall be capable of continuous operation at the respective rated load in Trickle mode i.e. Trickle charging the associated DC Nickel-Cadmium Batteries while supplying the DC loads.
- ii) Battery Chargers shall have a selector switch for selecting the battery charging mode i.e. whether Trickle or Boost charging.
- iii) All Battery Chargers shall be provided with facility for both automatic and manual control of output voltage and current. A selector switch shall be provided for selecting the mode of output voltage/ current control, whether automatic or manual. Means shall be provided to avoid current/ voltage surges of harmful magnitude/ nature which may arise during changeover from Auto to Manual mode or vice-versa under normal operating condition.

- iv) Soft start features shall be provided to build up the voltage to the set value slowly within fifteen seconds. The chargers shall have load limiters which shall cause, when the voltage control is in automatic mode, a gradual lowering of the output voltage when the DC load current exceeds the load limiter setting of the charger. The load limiter characteristic shall be such that any sustained overload or short circuit in DC system shall not damage the charger, nor shall it cause blowing of any of the charger fuses. The charger shall not trip on overload or external short circuit. After clearance of fault, the charger voltage shall build up automatically when working in automatic mode.
- v) When on automatic control mode during Trickle charging, the Charger output voltage shall remain within (\pm)1% of the set value for AC input voltage variation of (\pm)10%, frequency variation of (+)3 to (-)5%, a combined voltage and frequency (absolute sum) variation of 10% and a continuous DC load variation from zero to full load. Uniform and stepless adjustments of voltage setting (in both manual and automatic modes) shall be provided on the front of the Charger panel covering the entire Trickle charging output range specified. Stepless adjustment of the load limiter setting shall also be possible from 80% to 100% of the rated output current for Trickle charging mode.
- vii) During Boost charging, the Battery Chargers shall operate on constant current mode (When automatic regulator is in service). It shall be possible to adjust the Boost charging current continuously over a range of 50 to 100% of the rated output current for Boost charging mode. The charger output voltage shall automatically go on rising, when it is operating on boost mode, as the battery charges up. For limiting the output voltage of the charger, a potentiometer shall be provided on the front of the panel, whereby it shall be possible to set the upper limit of this voltage anywhere in the output range specified for boost charging mode. All voltage and current setting potentiometers shall be vernier type.
- viii) Energising the Charger with fully charged battery connected plus 10% load shall not result in output voltage greater than 110% of the voltage setting. Time taken to stabilise, to within the specified limits as mentioned elsewhere shall be less than fifteen seconds.
- ix) Momentary output voltage of the Charger, with the Battery connected shall be within 94% to 106% of the voltage setting during sudden load Change from 100% to 20% of full load or vice-versa. Output voltage shall return to, and remain, within the limits specified as mentioned elsewhere in less than 2 seconds after the above mentioned change.
- x) The Charger manufacturer may offer an arrangement in which the voltage setting device for Trickle charging mode is also used as output voltage limit setting device for Boost charging mode, and the load limiter of the trickle charging mode is also used as Boost charging current setting device.



- xi) Suitable filter circuits shall be provided in all the Chargers to limit the ripple content (peak to peak) in the output voltage to 1% irrespective of the DC load, even when they are not connected to a battery.
- xii) The DC System shall be ungrounded and float with respect to the ground potential when healthy. An earth fault relay shall be provided by the Employer in the DC distribution board for remote annunciation.

5.13.4.3 Printed Circuits Boards (PCB)

PCB shall be made of glass epoxy of 1.6 mm thick, fire resistant, bonded with 99.8% pure copper foil, free of wrinkles, blisters, scratches and pinholes. The contact surface of the edge connectors of the PCBs shall be plated with hard gold to a minimum thickness of 5 microns. Component identification shall be printed on PCB by silk screen method. All PCBs shall be tropicalised and masked.

5.13.4.4 Contactors

All Battery Chargers shall have an AC contactor on the input side. It shall be of air break type and suitable for continuous duty. The operating coil shall be rated for 415 Volts AC.

5.13.4.5 Thermal Overload Relay

A thermal overload relay incorporating a distinct single phasing protection (using differential movement of bimetal strips) shall also be provided for the AC input. The relay shall trip the above contactor.

5.13.4.6 Rectifier-Transformers and Chokes

The rectifier transformer and chokes shall be dry and air cooled (AN) type. The rating of the rectifier-transformers and chokes shall correspond to the rating of the associated rectifier assembly. The rectifier-transformers and chokes shall have class-B insulation with temperature rise limited to class-A insulation value.

5.13.4.7 Rectifier Assembly

The rectifier assembly shall be full wave bridge type and designed to meet the duty as required by the respective Charger. The rectifier cells shall be provided with their own heat dissipation arrangement with natural air cooling. The rectifier shall utilise diodes/ thyristors and heat sinks rated to carry 200% of the load current continuously and the temperature of the heat sink shall not be permitted to exceed 85°C absolute duly considering the maximum charger panel inside temperature. The Contractor shall submit calculations to show what maximum junction temperature will be and what the heat sink temperature will be when operating at 200% and 100% load current continuously duly considering the maximum surrounding air temperature for these devices inside the charger panel assuming air ambient temperature of 50°C outside the panel. Necessary surge

protection devices and rectifier type fast acting fuses shall be provided in each arm of the rectifier connections.

5.13.4.8 Instruments

DC voltmeter, DC ammeter and AC voltmeter in 96 mm square shall be provided for all Chargers. The instruments shall be flush mounted type, dust proof and moisture resistant. The instruments shall have easily accessible means for zero adjustments. The instruments shall be of 1.5 accuracy class.

5.13.4.9 Air Break Switches

All Chargers shall have AC input and DC output switches of air break, single throw, load break and fault make type. The contacts of the switches shall open and close with a snap action. Switches shall be rated for 120% of the maximum continuous load. 'ON' and 'OFF' position of the switch shall be clearly indicated.

5.13.4.10 Control and Selector Switches

Control and selector switches shall be of rotary stay-put type with escutcheon plates showing the functions and positions. The switches shall be of sturdy construction and suitable for mounting on panel front. Switches with shrouding of live parts and sealing of contacts against dust ingress shall be preferred. The contact ratings shall be atleast the following :

- Make and carry continuously – 10 Amps.
- Breaking current at 220 V DC – 0.5 Amp. (inductive)
- Breaking current at 240 V AC – 5 Amp. At 0.3 p.f.

5.13.4.11 Fuses

Fuses shall be of HRC cartridge fuse link type. Fuses shall be mounted on fuse carriers which are mounted on fuse bases. Wherever it is not possible to mount fuses on fuse carriers, fuses shall be directly mounted on plug in type bases. In such cases one insulated fuse pulling handle shall be supplied for each charger. Kick-off fuses (trip fuses) with alarm contacts shall be provided for all DC fuses.

5.13.4.12 Indicating Lamps

Three (3) indicating lamps shall be provided to indicate AC supply availability. The indicating lamp shall be of panel mounting, filament type low wattage or LEDs and capable of clear status indication under the normal room illumination. The lamps shall be provided with series resistors (non-hygroscopic) preferably built in the lamp assembly and replaceable from front. The lamp covers shall be preferably screwed type, unbreakable and moulded from heat resistant material



5.13.4.13 Blocking Diode

Blocking diode shall be provided in the output circuit of each Charger to prevent current flow from the D.C. Battery into the Charger.

5.13.4.14 Annunciation System

Following annunciations shall be provided for local and remote indications in all chargers :

- a) AC supply failure
- b) Rectifier fuse failure
- c) Surge circuit fuse failure
- d) Filter fuse failure
- e) Load limiter operated
- f) Charger trip
- g) Battery on Boost
- h) Battery on Boost

5.13.4.15 Name Plates and Marking

The name plates shall be made of non-rusting metal/3 ply Lamicoid and shall have black back-ground with white engraved letters and secured by screws. These shall be provided near top edge on the front as well as on rear side of Charger. Name plates with full and clear inscriptions shall also be provided on and inside the panels for identification of the various equipments.

5.13.4.16 Construction

- i) The Chargers shall be indoor, floor mounted, self supporting sheet metal enclosed cubicle type. The Contractor shall supply all necessary base frames, anchor bolts and hardware. The Charger shall be fabricated using cold rolled sheet steel shall not less than 1.6 mm and shall have folded type of construction. The panel frame shall be fabricated using cold rolled sheet steel of thickness not less than 2.0 mm. Removable undrilled gland plates of at least 3.0 mm sheet steel and lugs for all cables shall be supplied by the Contractor. The lugs for cables shall be made of electrolytic copper with tin coat. Cable sizes shall be advised to the Contractor at a later date for provision of suitable lugs and gland plates. The Charger shall be tropicalised and vermin proof. Ventilation louvers shall be backed with fine brass wire mesh. All doors and covers shall be fitted with synthetic rubber gaskets. The Chargers shall have hinged



double leaf doors provided on front and/or backside for adequate access to the Charger internals. All the Charger cubicle doors shall be properly earthed. The degree of protection of Charger enclosure shall be atleast IP-42.

ii) All indicating instruments, control and selector switches and indicating lamps shall be mounted on the front side of the Charger. Design of panels shall be based on the following dimensions.

a)	Overall height	Maximum 2350 mm
b)	Operating handles (highest and lowest positions reached by operator's hands),	Maximum 1800 mm Minimum 350 mm
c)	Doors and panel handles and locks	Maximum 1800 mm Minimum 300 mm

iii) Electronic equipments shall be of modular design consisting of plug in modules in standard 19 inches metallic racks with metallic card guides. The cards should be provided with proper handles. Card to card wiring should be preferably through a mother board. Unplanned jumpering and track modifications are not permitted. Mechanical interlocks to prevent wrong insertion of cards should be provided. Each card shall have its junction and test points identified. Maintenance aids such as extension printed wiring boards and jumper leads shall be provided.

iv) The layout of Charger components shall be such that their heat losses do not give rise to excessive temperature within the Charger panel surface. Location of the electronic modules will be such that temperature rise of the location, in no case, will exceed 10°C over ambient air temperature outside the Charger.

v) Each Charger panel shall be provided with an illuminating lamp and one 5 Amp. Socket. Switches and fuses shall be provided separately for each of the above.

vi) Painting

Treatment as per IS:6005. Two coats of lead oxide primer followed by powder painting with final shade of RAL9002 for complete panel except end covers and RAL 5012 for end covers.



5.14 CONTROL, METERING AND PROTECTION

Following shall be included in the scope of the bidder:

- i) Complete control, operation and metering requirements for the following :
 - Generator, generator transformer, unit auxiliary transformers and associated circuit breakers
 - 11kV incomers, tie feeders and outgoing transformer, supply feeders of unit and station switchgears
 - 3.3kV incomers, bus-coupler feeders and outgoing transformer, supply feeders of unit switchgears and incomers of station switchgears
 - 415V incomers and bus-coupler feeders of unit and station switchgears
 - Diesel Generator sets
- ii) Protection and relay panels for generator, generator transformer and UATs including relay test kit

5.14.1 Codes and Standards

IEEE: Std. C37.111	Standard common format for transient data exchange (COMTRADE) for power systems
IEEE Std. C37.90.2	Standard for withstanding capability of relay systems to radiated electromagnetic interference from transceivers
ANSI/ IEEE C37.90	Relays and relay systems standard associated with electric power apparatus
ANSI/ IEEE C37.93	Power system protective relay applications of audio tones over telephone channels
IS: 3231	Electrical relays for power system protection
IS: 8686	Specification for static protective relays

5.14.2 Control Requirements

- i) Operators work station (OWS) along with thin film transistor (TFT) and keyboard etc. shall be located in unit control room and shall be provided for operation, control and interlocking of the following :
 - Generator, generator transformer, unit auxiliary transformers and associated circuit breakers
 - 11kV incomers, tie feeders and outgoing transformer, supply feeders of unit and station switchgears
 - 3.3kV incomers, bus-coupler feeders and outgoing transformer, supply feeders of unit switchgears and incomers of station switchgears
 - 415V incomers and bus-coupler feeders of unit and station switchgears
 - Diesel Generator sets



ii) General Technical Description

a) Generator

The generator and auxiliary systems shall be controlled from OWS located in unit control room through DDCMIS. All necessary control, interlock, indication, metering and annunciation shall be provided. These controls shall be in addition to local control panels for generator auxiliary systems.

The synchronization of the 400kV Generator transformer circuit breaker shall be performed through auto-synchronizer in DDCMIS. The manual synchronizing shall also be provided in the generator metering panel.

b) Auxiliary power distribution system

The control, monitoring, metering as required for the electrical auxiliary power distribution system comprising of 11kV, 3.3kV, 415V circuit breakers and unit auxiliary transformers, 11kV/3.3kV, 3.3kV/415V auxiliary service transformers within the power block including ESP switchgear shall be performed.

c) Diesel Generator set

The remote control of DG set shall be provided in addition to those provided in associated automatic mains failure (AMF) panels.

5.14.3 Metering

i) Generator

The ammeters, voltmeters, MW meter, MVAR meter, frequency meter, power-factor meter, energy meter (MWH) meter, MVARH meter, exciter field voltage and exciter field current meters including necessary transducers shall be provided in the generator metering panel located in unit control room.

The energy meters mentioned above shall be used for energy accounting and audit purposes and shall be located at a point after the generator stator terminals and before the tap-off to UATs and shall comply with the requirements of CEA regulations on Metering.

The digital indication for the above meters shall also be provided.

ii) 11kV, 3.3kV incomers, tie feeders and outgoing transformer, outgoing supply feeders.

The digital indication of Ammeter, kW meter and kWh meter located on the respective switchgears and bus voltages shall be provided.



- iii) 415V Incomer and bus-coupler feeders and Diesel Generator sets

The digital indication of Ammeter, kW meter and kWh meter located on the respective switchgears and bus voltages shall be provided.

5.14.4 Protection and Relay Panels

5.14.4.1 General requirements

i) Panels

- a) The panels shall be free standing, floor mounting type and completely metal enclosed. Cable entries shall be from bottom.
- b) The panels shall have removable gland plates with glands made of brass and suitable for armoured cables
- c) All equipment mounted on front and rear side of the panels shall have individual name plates with equipment designation engraved. Each panel shall also have circuit/ feeder designation name plate.
- d) Each panel shall be provided with a 240V AC fluorescent lighting fixture controlled by door switch as well as a 5A, 240V AC switch-socket unit.
- e) Voltage circuits for protection and metering shall be protected by fuses. Suitable fuse failure relays shall be provided to give an alarm for voltage circuits of protection/metering. Voltage selection scheme based on relays shall be provided for meters wherever possible.
- f) The DC supplies at the individual relay and protection panels shall be monitored by suitable relays and failure of DC supplies shall be annunciated.

ii) Relays

- a) The protective relays shall be numerical type. All relays, auxiliary relays and devices shall be of reputed make and types proven for the application and shall be subject to purchaser approval. The relays and timers shall have appropriate setting ranges, accuracy, resetting ratio, transient over-reach and other characteristics to provide required sensitivity to the satisfaction of the owner.
- b) Relays shall be suitable for efficient and reliable operation of the protection scheme. Necessary auxiliary relays, timers, trip relays, etc. required for complete scheme, interlocking, alarm, logging, etc. shall be provided. No control relay, which shall trip the circuit breaker when relay is de-energized, shall be employed in the circuits.

- c) Relays shall be flush mounted on the front with connections at the rear shall be draw-out or plug-in type/ modular case with proper testing facilities. Provision shall be made for easy isolation of trip circuits for testing and maintenance.
- d) Relays shall be provided with self reset contacts except the trip, lockout relays and interlocking (contact multiplication) relays which shall be manual reset type
- e) Auxiliary relays shall be provided in the trip circuits of protections located outside the board, such as buchholz relay, temperature indicators, fire protection, etc.
- f) Suitable measures shall be provided to ensure that transients present in CT and VT connections due to extraneous sources in 400kV system do not cause damage to static circuit.
- g) Only DC/ DC converters shall be provided in the relays, wherever necessary to provide a stable auxiliary supply for relay operation
- h) All relays shall have hand-reset flags or other means for ready visual indication of their operation and also of the faulty phase.
- i) The numerical relays shall have continuous self-monitoring and cyclical test facilities. The internal clock of the system shall be synchronized through the GPS Time Synchronizing System.
- j) Each numerical relay shall have a serial interface on the front for local communication to a PC and Printer. Facilities shall be provided to access each discrete protection function including modification in relay settings and monitoring of the relay from a HMI or a separate protection. The printout of all settings, scheme logic, event records etc. shall be accessible through the HMI. The display of various measured parameters during normal as well as fault conditions on a segregated phase basis shall be provided. LEDs and a backlit LCD screen shall be provided for visual indication and display of messages related to major trips/ alarms. Necessary multilevel password protection shall be provided.
- k) The sampling rate of analog inputs, the processing speed and processing cycle of digital values shall be selected to achieve the operating times of various protection functions specified. In case all protection functions specified do not have as a part of the standard numerical relay, separate discrete numerical relays can be provided.
- l) The numerical relays shall be provided with built-in disturbance recording facility. The output shall be available in IEEE/ COMTRADE format and shall be compatible with the dynamic relay test kit.

- m) The manufacturer of the numerical protection system shall carry out the complete engineering, testing and commissioning on site of the protection equipment including the associated relays and protection panels. The testing and commissioning protocols for the numerical protection systems offered shall be approved by the purchaser before commissioning on site.
- n) The numerical relays offered shall have self-diagnostic features to reduce the down time of the relay and to provide useful diagnostic information upon detection of an internal fault so as to speed up the maintenance. The necessary support documentation explaining in detail the self-diagnostic features of the numerical relays shall be furnished for the purchaser's use.

5.14.4.2 Protection

- 1) Protection Philosophy
 - The protection and control equipment and circuitry, shall be provided with two independent channels with reliable protection systems with separate DC supplies, separate CT/ VT cores and separate cables and hand-reset trip relays to obtain 100% reliability. The DC supplies to these protections shall be monitored.
 - Associated trip relays of the two systems shall be separate having sufficient number of contacts for all the functions.
 - Each protection system shall energize both trip coils of the circuit breaker.
 - The total critical fault clearance time from fault initiation in any part of the system shall be 80ms for phase to phase fault in the generator-transformer unit and for phase to phase and phase to earth faults in the 400kV system inter-connection.
 - Protective relay system shall be provided to protect the Electrical equipments from faults, overloading and abnormal operating conditions.
- 2) Each generator, generator transformer and unit auxiliary transformer etc. shall be provided with microprocessor based protection system comprising of the following protections :
 - i) Generator
 - a) Differential current protection (87)
 - b) Inter-turn fault protection (where split winding in stator is provided) if six neutral terminals are available (87TG)



- c) 100% stator earth fault protection (64G)
- d) Loss of field protection (40) (to be duplicated)
- e) Back-up impedance protection (21)
- f) Negative sequence current protection (46)
- g) Reverse power protection (32) (preferably of 3-phase power relay)
- h) Low forward power interlock (37) (preferably of 3-ph. power relay)
- i) Rotor earth fault Protection:
 - First stage (alarm) (64F1)
 - Second stage (trip) (64F2)
- j) Over voltage protection (59)
- k) Generator pole slipping protection (98)
- l) Synchro-check relay (25)
- m) Under-frequency protection (based on manufacturer's recommendations, under-frequency relays with timers set at prescribed values connected to alarm and trip (81).
- n) Stand by stator earth protection (64G2)
- o) Overload (51)
- p) Overheating (windings and/ or bearings) (49)(annunciation only)
- q) Over fluxing protection in addition to all aforecited protections (99) (to be duplicated)
- r) Accidental back energisation protection
- s) Voltage balance scheme for blocking voltage dependent protection, in case of VT-fuse failure (60)

In case digital multifunctional generator protection system (MGPS) is provided, the protections shall be duplicated. Each MGPS shall be preferably provided with individual inputs from CTs and VTs and connected to the independent set of hand-reset trip relays, such that one set is always available in case of testing and mal-operation of other set. Any protection, which is not a part of MGPS, separate discrete protection shall be provided as per the above table. The MGPS shall preferably have continuous self-monitoring and testing facilities.



- ii) Generator Transformer
 - a) Overall differential current protection covering the Generator zone also (87OA)
 - b) Time graded IDMT type back up non-directional over current protection in all phases on HV side (51)
 - c) Restricted earth fault protection (87NT)
 - d) Over- fluxing protection (99) (to be duplicated)
 - e) Neutral over-current protection against sustained external system earth faults (51 NT)
 - f) Buchholz protection (annunciation and trip) (63)
 - g) Winding temperature high for annunciation and trip (49T)
 - h) Oil temperature high (annunciation and trip) (49Q)
 - i) Pressure relief valve trip (PRV)
 - j) Generator Transformer differential protection for single phase bank (87T)
 - k) Overhead line connection differential protection(87L) (For 3 single phase banks, if 87L includes HV winding, separate 87NT is not mandatory)
 - l) Pole discrepancy protection of the breaker if single pole breakers are used (162)
 - m) Breaker (HV) back-up protection (protection against breaker failure) (50Z)
- iii) Unit Auxiliary Transformer
 - a) Differential current protection (87)
 - b) Restricted earth fault protection for LV winding in case of low resistance grounding (87N)
 - c) Back-up over- current protection on primary side (51)
 - d) Back-up earth fault protection for low/ high resistance grounding (LV side)



- e) Winding temperature high (annunciation and trip LV side breaker) (49T)
- f) Oil temperature high (annunciation and trip the LV side breaker) (49Q)
- g) Buchholz protection (annunciation and trip) (63)
- h) Pressure relief valve trip (PRV)

5.14.5 Generator Disturbance Recorder (DR)

- a. One no. microprocessor based Disturbance Recorder (DR) shall be provided for each generator to record graphic form of instantaneous values of voltage and current in all three phases and neutral, open and closed positions of relay contacts and breaker during disturbances.
- b. It shall have the facility for slow and fast scan to record transient and dynamic performance of the system.
- c. Both slow and fast scan facility shall have atleast 8 analog and 16 digital inputs.
- d. The slow scan facility shall be provide with the following minimum features
 - The input shall be MW, MVAR, field voltage, frequency and generator terminal voltage etc. Any transducers, if required for interfacing, shall be provided.
 - It shall be suitable to record the frequency excursions and response of generator field and governor control on system fluctuations.
 - It shall have options to select the scan rate in the range having a min. of 10Hz suitable to facilitate capture of low frequency waveforms in the range of 0.5 - 3Hz.
 - The non-volatile memory shall be suitable for recording for a minimum of 15 minute at scan rate corresponding to selected pre-fault zone of recording.
- e. The fast scan facility shall be provide with the following minimum features
 - The input shall be voltages and current etc. Any transducers, if required for interfacing, shall be provided.
 - It shall have scan rate of 1000Hz or better for sampling each of the analog channel having fundamental frequency of 50Hz. The frequency response for these channels shall be DC on the lower side to 500Hz or better on the upper side. Any interposing devices provided shall be suitable for this frequency response.



- The pre and post fault recording time shall be atleast 200 ms and 5s respectively.
- f. All external and internal faults in the DR equipment such as power supply fail, printer faults, paper exhausting, processor failure, memory failure etc. are to be indicated by means of light emitting diodes on the front of the panel of restitution unit. The DR shall be provided with a MMI (man machine interface) through a PC with VDU, keyboard and printer.
- g. The internal clock of the system shall be synchronized through the GPS. The output shall be in IEEE/ COMTRADE format. The format shall be compatible for dynamic protection Relay Test Kit Necessary interfacing and software for analysis shall also be provided.
- h. The amplitude resolution of the analog channels shall not be less than 16 bit and event resolution for digital channels shall be 1ms or better.

5.14.6 Electrical Control Board :

- a. One no. 'Electrical Control Board' (ECB) shall also be provided in the Central Control Room with minimum control and indication facilities for various equipments described below, as a back-up to Operator Work Station/ CRT keyboard (OWS) for both units and station supply. ECB shall be Simplex panel in mosaic grid configuration.
- b. Semaphore indicators shall be provided for isolators, earth-switches of 400kV system associated with generators. Further, control and indication of the important but not limited to the followings breakers shall also be provided:
 - i. Generator Transformer breaker (at 400kV), field breaker for both units including manual synchronizing facilities, governor and excitation control.
 - ii. Incoming and Tie breakers of 11kV, 3.3kV and 415V Unit Switchgears including Unit Emergency Switchgears of both units.
 - iii. Incoming and Tie breakers of 11kV, 3.3kV and 415V Station Switchgears.
 - iv. Emergency Diesel Generator sets
- c. Relevant Mimic shall be provided to cover the above 400kV, 11kV, 3.3kV and 415V system. Mimic shall be atleast 3 mm thick and 10 mm width and colour coded.
- d. The analogue meters for the following shall also be provided on ECB:
 - i. Generator current, voltage, MW, MVAR, power-factor, frequency, field current, field voltage, etc.
 - ii. Bus voltages for 400kV, 11kV, 3.3kV and 415V system

- iii. Incoming current and wattage
- iv. Emergency Diesel Generator set parameters
- v. DC system voltages
- e. Annunciation system with sufficient no. of window facia shall also be provided. Annunciation system shall be solid state type. Minimum 20% annunciation channels and window facia shall be provided as spare.
- f. Suitable arrangement shall be provided for the auto, manual synchronization consisting of synchroscope, voltmeters, frequency meters, lamps/ LED's, check synchronizing relays etc. for generators and other breakers where ever necessary.
- g. Necessary control switches, selector switches, lamps/ LED's, push buttons, auxiliary relays etc. shall be provided for completeness of the schemes.
- h. Suitable engraved/ painted name plates shall be provided for component identification.

5.14.7 Relay Test Kit for generator protection

Relay test kit shall comprise the following :

- i) One dynamic portable relay test system based on type Multi-Amp. PULSAR Cat. 10 E3T3N or equivalent with 3 current and 3 voltage modules allowing dynamic and steady state testing capabilities.
- ii) The DR recording of the generator in standard IEEE COMTRADE or EMTP simulations shall be compatible for transient testing of protections with this test system. Required software for steady state/ dynamic testing of the protection relays shall also be supplied.
- iii) Other auxiliary items like phantom loads, etc. shall also be supplied as required for protection relay testing.
- iv) One portable over-current relay testing equipment with a timing of 0-10 sec. Voltage rating shall be 200-250V and output current range shall be 0.05 to 200A.
- v) Test plugs for modular protections and two relay tool kits.



5.15 ELECTRICAL LABORATORY AND TESTING EQUIPMENT

The following minimum electrical laboratory and testing instruments shall be provided complete with necessary hardware and software and other accessories such as mains cables, calibration leads, clamps, connectors, operating manual, calibration certificate etc.

5.15.1 Auxiliary Power Supplies

The test equipments shall be suitable for working on the following auxiliary power supplies :

- i) 3 phase, 4 wire, 415V, 50Hz solidly earthed system with $\pm 10\%$ voltage variation, $\pm 5\%$ frequency variation and 10% combined voltage and frequency variation
- ii) 220V, 2 wire, DC system with floating neutral and (+)10% to (-)15% variation.

5.15.2 List of Minimum Requirements (for two units)

<u>Item No.</u>	<u>Description/Specification</u>	<u>Purpose</u>	<u>Quantity</u>
i)	Portable 5kV Digital Automatic Insulation Tester Complete with test leads, mains lead, carrying case, PC down load software, instruction manual, test/ calibration certificate etc. Measuring Ranges :	For checking the insulation level and polarising index of electrical equipments	Two (2)
a)	Resistance	: <100 kilo ohm - > 1 Terra ohm	
b)	Current	: <100 pico A - > 5 mA	
c)	Test Voltages	: 500, 1000, 2500 and 5000V	
d)	Accuracy	: Better than 2%	
e)	Test Time	: Adjustable <15 Sec. -> 10 minute	
f)	Display	: LCD 3½ digit with analog bargraph for Resistance, test voltage, current, PI	
g)	Data storage capacity	: >75 Values	
h)	Power Supply	: 240V, 50 Hz and rechargeable dc battery	



- i) MMI : Via RS232
- j) Printer/PC interface: Via RS232C
- k) Safety Standard : IEC 1010-1
- l) EMC Standard : EN50081-1 and EN 50082-1

- ii) **Portable HV Decade Resistance Box. In Polystyrene case with lid and carrying handle** For testing and calibration of insulation testers. One (1)
 - a) Overall range : 1 kilo ohms to 1 Terra ohms
 - b) Resolution : 1k Ohms
 - c) Accuracy : 0.1% - 2%
 - d) Connection : Shielded Plugs with 1 Metre cable

- iii) **Portable HV AC Test Set comprising** For checking the high voltage with-stand level of electrical equipments viz, transformers, switchgears, cables, motors/ generators etc. One (1)
 - a) An epoxy cast, single phase, 50-200kV/240V, 5kVA (continuous) and 10kVA (5minute) rated low discharge transformer with maximum discharge level of 1 PC mounted in a steel tank fitted with swivel cast or wheels, HV bushing.

A control unit with microprocessor based automatic control, programming key pad
 - b) LCD display analog ammeter and voltmeter with 2% accuracy trip push button, safety protections etc.

A zero interlock circuit shall be provided to prevent energization of HV output on less voltage control is set to zero.
 - c) Necessary power and metering cables, removable earth link fuses etc. shall be provided.

- iv) **Automatic Capacitance and Tan-Delta Test Set (Schering Bridge) with oil resistivity test cell.** For monitoring the condition of insulation of electrical equipments One (1)
Fully automatic, microprocessor-based, accurate ac voltage bridge.



-
- a) Input : 120/240V, 50 Hz
- b) Output : 0-12kV, 100 mA (Cont.), 200mA (15 min)
Extendible to 4A with resonating inductor
- c) Capacitance : 1.6 pF to 8 ∞ F (with 100pF std. capacitor)
- d) Measurement : with $\pm 0.02\%$ to $\pm 0.05\%$ accuracy and
0.0001 pF resolution
- e) Tan-delta : 1×10^{-6} to 9.999 with accuracy $\pm 0.5\%$ and
 1×10^{-6} resolution
- f) Capacitive current : 0-5A
- g) Measurement
oil test cell : 2.5 kV(RMS), 150°C, 100 cm³, 100 pF
- h) Display : Large graphic TFT (4-5 digit)
Test voltage, frequency, capacitance,
Tan-delta
- i) Interface : RS232 for Printer 1 PC
- v) **Portable Transformer Oil Breakdown Test Set** To test the dielectric strength of transformer oil. One (1)
Fully automatic, microprocessor. Complete with transportation trolley oil test vessel with electrodes, PTFE agitator/lift-off sticks, gap-gauges, mains cable, operation manual calibration certificate, warranty certificate etc.
- a) Test Voltage : 0-100kV (RMS)
- b) Accuracy : $\pm 2\%$ of reading
- c) Switch-off response : < 4 mA
current.
- d) Switch-off response : < 6 mS
time
- e) Rate of rise of : 0.5/1/2/3/5KV per sec.
- f) Test voltage : Manual/Auto adjustable
- g) Display : Alpha numeric LCD



- h) Interface : RS 232, RS232C
- i) Standard : IEC 156, ASTM D877
ASTM D1816, BS 5874, IEC 1010-1
- vi) **Portable Karl-Fischer Test Set** To measure the One (1)
Coulometric test set for oils with specific percentage of moisture
gravity ranging from 0.6 to 1.4, with a contamination of
built-in printer transformer oil.
- a) Titration Method : Coulometric, Karl-Fischer
- b) Display : 40 character alpha numeric backlit LCD
- c) Sample Volume : 0.1, 0.2, 0.5, 1.0, 2.0, 5.0, 10.0 ml
- d) Sp. Gr. range : 0.6 to 1.4 in 0.01 steps
- e) Moisture range : 1 ppm – 100%
- f) Measuring range : 1 μ g – 10 mg water
- g) End point detection : ac polarization
- h) End point indication : Visual display/ printout/ acoustic beep
- i) Titration speed : 2 mg/ minute maximum
- j) Maximum current : 400 mA
- k) Drift compensation : Automatically controlled
- l) Start delay : 10 seconds
- m) Stirrer speed : Microprocessor-controlled
- n) Accuracy : $\pm 3 \mu$ g to $\pm 0.5\%$
- o) Calculation mode : Volume/ density or weight/ weight
- p) Printer : High Speed Thermal
- q) Power supply : 90-264V ac, 12V dc rechargeable battery



vii) 3-phase Portable Transformer Turns Ratio and Vector Group Meter One (1)

Fully automatic, microprocessor based having automatic tap changer control with internal chip card reader and built-in keyboard. In a robust mobile case having following features:

- a) Ratio Range : 0.75 to 10000
- b) Ratio accuracy : $\pm 0.1\%$ to $\pm 0.3\% \pm 1$ digit
- c) Measuring voltage : 63.5V to 240V
- d) Frequency range : 45-55 Hz
- e) Phase angle range : $\pm 90^0$
- f) Phase angle : $\pm 0.1^0 \pm 2$ digit accuracy
- g) Magnetising current : <1 mA - >500 mA
- h) Magnetising Current: Better than $\pm 2\%$ accuracy
- i) Measuring time : 5-20 seconds
- j) Data storage : > 200 sets of measurement
- k) Display : Backlit LCD 256 x 128 pixels
- l) Data displayed : Vector group, phase, tap position, ratio, Ratio deviation, phase angle, phase angle Deviation, mag. Current, pass-fail result
- m) Interface : RS232C, printer port
- n) Accessories : Windows compatible software for control Via PC

HV/LV cables, mains lead, clamps,
Operating Manual, guarantee certificate



- viii) Portable Digital DC Resistance Meter** For simultaneous measurement of HV and LV winding resistance and check on OLTC operation One (1)
- Dual channel, direct-reading ohm meter; having a safe discharge circuitry and in-built printer with date and time stamping, software for remote PC control heavy duty connecting cables, clamps, operating manual, test/ calibration certificate and transportable case.
- a) Measuring ranges
- | <u>Nominal Range</u> | <u>Resolution</u> |
|----------------------|-------------------|
| 0- 2 m Ohm | micro Ohm |
| 0- 20 m Ohm | 1.0 micro Ohm |
| 0- 200 m Ohm | 10 micro Ohm |
| 0- 2 Ohm | milli Ohm |
| 0-20 Ohm | milli Ohm |
| 0-200 Ohm | 10 milli Ohm |
- b) Accuracy : 0.1% of reading over entire range
- c) Exctn. Current : 0.1 – 25A with compliance open circuit voltage of 100V
- d) Display : 4½ digit backlit LCD
- e) Data Storage : Upto 700 measurements
- f) Interface for remote control : RS232
- ix) Portable High Current Digital Micro Ohm Meter** For measuring contact resistance of circuit breakers, isolators, busbars etc. One (1)
- Suitable for carrying out measurements in charged EHV (>400kV). Supplied with built-in charger, mains lead, operating manual, test/calibration certificate, mounted in a light weight portable case with clip-on clamps and voltage leads for 4-wire measurement system. Having following features :
- a) Measurement ranges :
- 0.01 – 100 micro ohm
- 0.1 – 600 micro ohm
- 1.0 – 6000 micro ohm



10.0 – 60000 micro ohm

0.1 – 600 m ohm

0.02 1.0 – 6000 m ohm

- b) Resolution : 0.01 micro ohm to 1.0 m Ohm
- c) Accuracy : (\pm) 0.2% --- (\pm) 0.5%
- d) Display : with 4 digit LED or LCD (backlit)
- e) Data Storage : > 300 readings
- f) Interface : RS232
- g) Test Current : Upto 200A

**x) Portable Primary and Secondary Current Injection Test Kit One (1)
with Separate Control and Loading Units**

- a) Control Unit
 - Current Output : 0-25A/0-50A (cont.)
0-50A/0-100A (upto 5 min)
 - Voltage Output : 0-230V
 - Current and Voltage measurement : By true RMS, 4 digit digital meters with $\pm 0.6\%$ accuracy (+6 digit)
 - Timing Units : For ON and OFF
 - Range : 0 – 1000 Sec.
 - Resolution : 1 m sec.
 - Accuracy : $\pm 0.1\% + 2$ digits
 - Power supply : 230V $\pm 10\%$, 45-551/2, 1-phase
 - Display : LCD/ LED
- b) Loading Unit
 - Ranges : 0-500A/0-1000A/0-2000A/0-3000A



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- | | | | |
|-------------|--|--|---------|
| xi) | Portable Automatic Earth Tester

Microprocessor-controlled, user-friendly, with self-diagnostic features and alpha-numeric display, re-chargeable battery. Mounted in a robust case and provided with hammer and 4 GI spikes and 50M long cable on a cable winder. | For measuring earth electrode resistance and soil resistivity using Warner 4-terminal method. | One (1) |
| | a) Earth resistance range | : 0-20 k Ohms (Auto ranging) with 1 M Ω resolution and 60.5% 62 digit accuracy | |
| | b) Test frequency | : 100-160 Hz in 0.5 Hz steps | |
| | c) Test current | : 50 mA | |
| | d) Maxm output voltage: | <50V (RMS) | |
| | e) Maxm. Interference | : 40V peak to peak (50 Hz) | |
| | f) Display | : 3½ digit Alpha numeric LCD | |
| | g) Standards | : IEC 1010-1, EN 50081-1, EN 50082-1 | |
| xii) | Portable Three Phase Universal Protective Relay Test Set

Microprocessor-based user-friendly with digital signal processing.

Having large LCD display with programmable menu. Having programmable output current and voltage waveforms and phase angles. Having following additional features and specifications : | For testing various types of electro-mechanical, static and microprocessor based protective relays, MCCBs etc. | One (1) |
| | a) Input power | : 90-250V, 1 Ph, 50 Hz | |
| | b) Outputs | : One ac Current 0-100A
One ac Voltage 0-300V
One ac Voltage/Current, 0-240V/ 0-2.5A | |
| | c) Output frequency | : Selectable from 16.66 Hz – 300 Hz | |



- d) Output AC voltage : 0-360 deg. independently controlled phase shift
- e) Reading accuracy : $\pm 1\%$ for AC/DC Volts, Current
 ± 0.5 deg. In phase angle
 $\pm 0.02\%$ in power factor
 $\pm 1.5\%$ in active/reactive power
 $\pm 0.005\%$ in time
- f) Memory : Non volatile RAM
- g) Interface : RS port for PC and parallel printer port

xiii) Precision Digital Multimeter

One (1)

7½digit precision multi-meter for calibration of voltage/ current sources, decade resistance boxes, frequency sources with a large 24-digit vacuum fluorescent display, a bar-graph function allowing user programming of high and low pass/ fail limits, audible and visual indication of component specification and Auto Dynamic Filter (ADF) to enable automatic selection of suitable filter.

- a) Input Power : 110/220/240V AC 50 Hz
- b) DC Voltage Measurement Range : 3 MV to 10 kV with resolution of 10 nV and accuracy of ± 12 ppm + 6 digits
- c) DC Current Measurement Range : 3 μ A to 30A
Resolu. : 10 pA
Accu. : ± 75 ppm + 10 digits
- d) Resistance Measurement : 30 meg ohm to 1 G ohms
Resolu. : 10 n Ohm
Accu. : ± 200 ppm + 6 digits
- e) Frequency Measurement : 1 Hz to 100 K Hz
Resolu. : 1Hz
Accu. : ± 10 ppm + 1 digit
- f) AC Voltage Measurement : 3m V to 3 KV
Resolution : 100 nV
Accuracy : $\pm 0.05\%$ + 40 digits
- g) AC Current Measurement : 3 Micro Amp to 30A
Resolution : 100 pA
Accuracy : $\pm 0.1\%$ + 80 digits



- h) Capacitance Measurement : 0-300 Microfarad
Resolution : 1pF
Accuracy : $\pm 0.2\% + 20$ digits

Special Features : Self Test, Diode/ Zener Test, Maximum/ Minimum functions, continuity testing AC/ DC coupled facility count down and sample beep on long filter periods.

xiv) Portable Digital Frequency Meter One (1)

Rugged, high accuracy portable frequency meter/calibrator in a dust-tight, water resistant case. Having LCD display complete with test leads, carrying case, 9V battery and instruction manual.

- a) Ranges : 0-100 KHZ / 0-1000 Hz
b) Resolution : 1 KHZ / 0.1 Hz
c) Accuracy : $\pm 0.1\%$ FS ± 1 LSD
d) Step Size : 10% of range
e) Scroll Size : 0.1% of range
f) Input : 1V to 100V p-p
g) Output : 5V p-p Square Wave
h) Maxm. load : 5 mA

xv) Digital Sound Level Meter One (1)

Condenser type microphone, frequency and time weighting functions, AC and DC outputs supplied with 9V battery and calibration screw driver.

xvi) Digital Tachometer One (1)

Non-contact photo electric optical type. Having features such as reading hold, memory recall and low battery indication.

- a) Range : 10-100,000 RPM
b) Resolution : 0.1 RPM to 1 RPM
c) Accuracy : $\pm 0.1\%$ ± 1 digit to $\pm 0.15\%$ ± 1 digit
d) Display : 5 digit LCD
e) Optical Range : Upto minimum 300 mm



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- xvii) Cable Fault Locator** One (1)
- Working on pulse reflection (echo) technique. Capable of discriminating between inter-core and core to earth fault with facility to detect high resistance faults (>10 ohms) complete with surge generator, acoustic receiver, input filters, head phones etc.
- a) Input : 240V, 1 phase, 50 Hz
- b) Range : 10 nano sec. To 2000 ns
- c) Impedance range : 25 ohms to 100 ohms
- d) Surge Generator : 15kV, 100 mA, <512 joules,
capacity 10-20 pulses per minute
- e) Display : Backlit LCD
- xviii) Portable Hand held SF₆ Gas Leakage Detector** One (1)
(wth audio-visual indication)
- Sensitivity : 3 to 5 ppm
- xix) Portable Hand held Hydrogen Gas Leakage Detector** One (1)
(wth audio-visual indication)
- Sensitivity : 50 to 100 ppm
- xx) Portable Vacuum Tester** One (1)
- For testing the condition of vacuum in medium voltage switchgear with automatic discharging facility and high voltage screened cable and over load/over voltage protection
- a) Display : Digital display of applied voltage in kV and leakage current in mA. Red and green indications for defective and acceptable chambers
- b) Resolution : 0.1 kV and 0.01 mA
- c) Input : 240V AC, 50 Hz
- d) Output : 0-60 kV DC Adjustable
0-9.99 mA Adjustable
- e) Loading time : Upto 30 seconds
-



xxi) Portable Light Intensity Meter One (1)

With selenium photocell, 2 metres lead and filters.

- a) Ranges : 0-15/30/100/300/1000/3000 lux
- b) Accuracy : $\pm 4\%$ of full scale

xxii) Portable Circuit Breaker Motion Analyser One (1)

For analyzing performance of SF6/Vacuum/air circuit breakers upto 400kV

Microprocessor-based capable of measuring, recording and printing opening/ closing times and velocity, coil currents, dynamic contact resistance of main/aux. and arcing contacts, pole discrepancy etc.

The instrument shall have user-friendly menu driven software for easy operation and reduced set up time. It shall have communication ports for downloading of data from memory on to a PC. It should have a built-in DC battery and printer. Other specifications shall be as follows :

- a) Input Supply : 110-240V, 50Hz with built-in DC battery backup with charger
- b) Current injection : upto 100A DC
- c) Timing Range : 0-9.99 S. with a resolution of 0.1mS and accuracy of $\pm 0.01\%$
- d) Number of channels : 12 analog, 24 digital
- e) Display : 16 character alphanumeric LCD

xxiii) Generator On-line Partial Discharge Real Time Monitoring System Two (2)

To detect and monitor partial discharge activity in generator stator windings and vibrations in generator end windings by acoustic sensors. To generate alarms in case of excessive partial discharge or end winding vibrations. Should have the capability to acquire partial discharge patterns and determine PD quantities as apparent charge, quadratic rate and average discharge current for each phase.

Standalone type with facility for storage of trend data and patterns. With facility to download patterns and trends on to PC or LAN; visualization software and automatic report generation. Having noise suppression circuitry for input and signal transfer.



The surge capacitors connected on the line Terminals of the generators shall be used as PD sensors. Necessary surge capacitor connection kit shall be included and the instrument shall be compatible with surge capacitors of 0.25 micro farads/ 24Kv supplied with the generators

The instrument shall be in 19” rack-mounted design. Housed in a wall-mounting IP65 case. Other specifications as below :

- a) PD Input : 4 channels, 0-30 V rms
- b) Frequency Ranges : 0.3 MHz - About 10 M Hz
- c) Acquisition Software : Standalone C-based
- d) Evaluation Software : Standalone Java based
- e) Data Storage : Upto 48 values per channel 1 Pattern per day
- f) Visualisation : Web server with standard web-browser and Windows based internet capable software
- g) Communication : 100 M Bit Ethernet interface with TCP/ IP protocol and fibre-optic communication.

xxiv) Interfacial Tension Meter for Transformer Oil One (1)

Motorised operation using a Platinum Iridium Ring. In dust tight IP55 enclosure

- a) Range : 0-90 Dynes/per cm.
- b) Zero Drift : < 0.1 Dynes/m in 24 Hours
- c) Resolution : 0.05 Dynes
- d) Accuracy : ± 0.5 Dynes/cm

xxv) Portable, Hand-held Thermal Imaging Camera One (1)

Having voice recording and alarm facility, double ocular view finder and clear CCD lens, multi-spot (Minimum 4) temperature measurement and High End image analysis software capable of generating wizard guided reports and trend analyses etc. Battery operated.



-
- a) Temperature Range : -10°C to 2000°C
- b) Detector Type : Uncooled Focal Plane Array
- c) Thermal Sensitivity : 0.08°C @ 30°C
- d) Frame Rate : 50 Hz
- e) Field of View : $20^{\circ} \times 20^{\circ}$
- f) Spectral Response : 8 to 14 microns
- g) Battery Operation : For atleast 2-hours
- xxvi) Portable High Voltage/Live Line Detector** Two (2)
- Electronic type, giving audio-visual indication for presence of voltage/charge. Having in-built self-diagnostic check feature. Insulating stick shall be class 'F' insulated.
- Range : Upto 300 kV
- xxvii) Tong Testers**
- Digital clamp-on volt-ammeters
Ranges :
- a) 0-5/ 25A, 0-60/ 300/ 600V Three (3)
- b) 0-1/ 5A, 0-60/ 300/ 600V Three (3)
- c) 0-10/ 30/ 300/ 1000A, 0-60/ 300/ 600V Three (3)
- xxviii) Portable Phase Sequence/Continuity Indicators** Three (3)
- To indicate phase continuity and phase rotation sequence of 3-phase power circuits. Complete with colour-coded and insulated 1 Metre long fused leads with boot-protected alligator clips and carrying case.
- Having an impact resistant plastic body with encapsulated circuitry incorporating neon indicators for phase continuity and phase sequence.
- Rated 100-600V, 40-60 Hz
- xxix) Relay Tool Kit** Two (2)
- Comprising following minimum tools :
- a) Spring setting tool
- b) Inspection mirror and torch
- c) Ring spanners
- d) Box spanners



- e) Burnishing tool
- f) Contact pressure gauge
- g) Factor gauges
- h) Test plugs with link plugs
- i) Screw drivers
- j) Nose pliers
- k) Scissors

xxx) HV Discharge Rod and Portable Earthing Equipment Two (2)

Class 'F' insulated. Having non-linear carbon film resistor with negative temperature co-efficient. Non-hygroscopic

- a) Dimensions : ID 25 mm
OD 31 mm
Length 1250 mm (main rod and each extension)
Total Length : 6 metres
- b) Discharge hook: 100 mm dia
12.5 mm dia copper rod
- c) Earth lead : Flexible braided copper
- d) Voltage rating : Upto 400 kV

xxxi) Hot Sticks (Live/ Dead Line Tester) Two (2)

Class 'F' insulated, upto 400kV, extendible from 1.25 metre to 6.0 metres with inbuilt self-check feature. Contact or proximity type in a special carrying case.



5.16 EMERGENCY DIESEL GENERATING SETS

One number DG set complete with Automatic Mains Failure (AMF) panel and other accessories shall be provided for each unit. In addition, one number common stand-by DG set shall also be provided.

5.16.1 Codes and Standards

IS:10000, BS:5514 and as per standard practice of diesel engine manufacturer's association of USA	Diesel engine
IS : 4722 / IEC - 60034	Generator
IS : 3977	Diesel oil system

5.16.2 Design Requirements and Sizing Criteria

- a) AMF (Automatic Mains Failure) Diesel Generator Sets capable of starting and picking up the load within 30 seconds shall be provided for power supply to the following :
 - i) Barring gear motors of turbo-generator sets and BFP turbine
 - ii) Seal oil system comprising of (AC seal oil pump, Re-circulating seal oil pump and seal oil vacuum pump)
 - iii) Air pre-heaters lubricating oil pumps
 - iv) Jacking oil pumps for main turbine and for BFP turbine
 - v) Main oil tank vapour extractors
 - vi) Turbine gear oil pump.
 - vii) Turbine Auxiliary oil pump (AOP)
 - viii) Stator water cooling pumps.
 - ix) Bearing chamber exhaust fans for hydrogen.
 - x) Lubrication oil systems for BFP, ID, FD and PA fans.
 - xi) Seal air fans.
 - xii) Elevators.
 - xiii) Air pre-heaters lubricating oil pumps.
 - xiv) Battery chargers for 220 volts and other DC system



- xv) Emergency lighting for reduced illumination (This shall cover 20% of fixtures in the main plant building and switchyard control building).
 - xvi) 220 volts control supply.
 - xvii) Scanner air fans.
 - xviii) Emergency service cubicle.
 - xix) HP and LP bypass auxiliary PRDS oil supply motors.
 - xx) Instrumentation and data acquisition system.
 - xxi) Standby air conditioner for control room and control equipment room, if required.
 - xxii) Mill inching motor.
 - xxiii) Mill lube oil pumps.
 - xxiv) BFP oil tank vapour extractors.
 - xxv) DM make up pumps
 - xxvi) Condenser vacuum breaker valve.
 - xxvii) BFP vacuum breaker valve.
- b) The sizing of DG set shall be based on the actual loads thrown on DG sets after the emergency and not the algebraic sum of all connected loads. The minimum capacity of diesel generating set shall be 1250kVA for 500MW unit (or ...kVA for ...MW unit)⁸. There will be three (3) no. DG sets, one for each unit and one common standby.
- c) Wherever DG set is started with DC motor, separate automobile type battery with charger shall be provided for starting.

5.16.3 Installation

The generating set shall be installed indoor/ inside weather proof enclosure.

5.16.4 Critical speed

Critical speed of DG shall not be lesser than 120% of the normal speed.

⁸ To be indicated by purchaser as applicable



5.16.5 General Technical Requirements

i) Starting and Control

- a) The DG Set shall have integrated control with automatic starting sequence from the manually initiated command from a single push button. It shall also have auto initiation through a 'No volt relay' and Auto position of auto/manual selector switch. The DG set shall also issue automatic closing command to its breaker on achieving rated voltage and frequency on its terminals.
- b) The starting time required from the initiating signal until the operating speed and voltage is attained and the engine and generator are ready to take load, shall not be greater than 30 seconds. Three attempt starting facility shall be provided using two impulse timers and a summation timer. The DG shall be capable of being stopped manually from remote and local. Interlock shall be provided in DG control panel to prevent shutting down operation as long as the circuit breaker at its generator output is closed.
- c) If electrical self starting system is provided, the source of energy shall be batteries backed up by battery chargers.
- d) If compressed air starting is provided, 2x100% air compressors to meet the entire compressed air requirement of the diesel generating set with one number electric motor driven and another with diesel engine driven with manual cranking system shall be provided. Air receiver shall be provided with necessary piping, fitting and instrumentation.
- e) The starter motor shall conform to IS : 4722.
- f) Suitable thermal insulation together with jackets shall be provided on all exposed hot pipes and equipment to limit the surface temperature to 60⁰C.

ii) Battery and Battery charger

- a) The battery shall conform to the requirements of IS:7372. A suitable battery charger using semiconductor rectifier shall be provided to recharge the battery within 10 hours. The minimum voltage at the end of load cycle shall not be less than 1.75 volts/ cell.
- b) The battery or compressed air system for starting the engine shall be capable of performing six (6) normal starts without recharging or refilling. In any case, continuous cranking for at least one minute shall be possible.

5.16.6 Diesel Engine**i) Type**

Stationary type, 4-stroke with Vertical in line or 'V' type cylinder arrangement and turbo charged and water cooled.

ii) Rating

a) Electrical output	As per design calculation for emergency duty application
b) Ambient temperature	50 ⁰ C
c) Relative Humidity	85%
d) Noise level at works at one metre distance from DG set	105 dB sound pressure
e) Noise level at ½ metre distance from DG acoustic enclosure	Room shall be acoustically treated for 25dB insertion loss
f) Fuel	All types of diesel fuel available in India
g) Maximum speed	1500 rpm
h) Duty	12 hours continuous running, of which one hour at 10% overload at rated speed
i) Governor	Electronic A1 type as per BS:5514
j) Vibrations	Maximum 250 microns peak to peak with anti-vibration pads
k) Starting	Electrical self starting or by compressed air
l) Fuel service tank	990 litres
m) Air intake system	Dry type air filter suitable for site conditions.
n) Cooling	Air cooled/ Forced water cooled.

iii) Constructional features

- a) Diesel engine shall be mounted on visco damper type vibration dampening system and shall be complete with integral air intake through dry type air filters and exhaust systems, metering facility, speed regulation system, fuel injection system, lube oil system, primary cooling water system along with necessary filters, silencers, ducts, piping and fittings, valves, instruments, etc.
- b) The generating unit shall be complete with all auxiliaries and its performance, torsional vibration, materials and workmanship, etc. shall be in accordance with the standard practices of diesel engine manufacturer's association in USA, IS-10000, BS-5514 or equivalent. The engine shall be properly balanced so as to transmit only small unbalanced forces to the foundation.

iv) Diesel oil system

- a) The diesel oil system as provided shall be complete with duplex type filters, hoses, piping, fittings, relief valves, supports, control and instrumentation and all other accessories to make it complete.
- b) The fuel consumption of the engine at full and three quarters of its rated power output shall be indicated.
- c) A day oil tank of 990 litres fuel capacity shall be provided, mounted on fabricated steel platform. The tank shall be complete with level indicator marked in litres, two nos. of level switches, filling inlet with removable screen, an outlet, a drain plug, an air vent and necessary piping. The fuel tank shall be painted with oil resistant paint. All pipe joints shall be brazed/ welded.

v) Lubricating oil system

- a) Automatic pressure lubrication shall be provided by a shaft driven gear type pump through an oil cooler and fine mesh filters to the end bearing, camshaft bearings, camshaft chain and gear drives, governor, air starting, distribution, auxiliary drive gears etc.
- b) If pre-lubrication is required before starting of the DG set, than one (1) no. electrically operated and one (1) no. standby DC operated lube oil pump shall also be provided for the purpose.
- c) All necessary accessories like pressure gauges, temperature and oil level indicators, pressure relief valves, bypass valves, pressure switches for alarm and control shall be furnished together with all inter connecting piping, fittings, supports, valves, etc.

vi) Cooling system

Totally air cooled type DG sets are preferable. However, in case jacket water cooling system is offered, the same shall be in closed cycle and have radiator located in front of the engine with a fan driven mechanically from the engine shaft. Forced water circulation by means of pump driven by the engine shaft shall be employed. As an alternative to radiator located in front of the engine with a fan driven mechanically from the engine shaft, separately located radiator (which will be located outside the DG room) with motor driven fan by 415V DG MCC directly fed from alternator terminals. The radiator tube shall be of copper with sufficient transfer area. Heat exchanger/ cooling tower arrangement shall also be acceptable.

vii) Governing system

- a) The governor shall be electronic A1 type as per BS-5514

- b) The governor shall have necessary characteristics to maintain the speed substantially constant even with sudden variation in load. However a tripping shall be provided even if speed exceeds the maximum permissible limit.
- c) A mechanical over-speed trip device shall be provided to automatically shut-off fuel in case the speed exceeds 110% of the rated value.

viii) Ancillary equipment - The following minimum equipments shall be provided :

- a) Flywheel
- b) Fuel piping
- c) Tachometer/RPM indicator
- d) Lubricating oil cooler (if applicable)
- e) Exhaust silencer and piping
- f) Fuel and lubricating oil filters, air filters.
- g) Temperature gauges for water and lubricating oil and pressure gauges for lubricating oil.
- h) Hand barring gear.
- i) Necessary foundation bolts and base channels for the engine, alternator, fuel service tank and for all other equipment included in this package.
- j) Base frames
- k) Platforms and hand railing and access ladder (if applicable)
- l) Starting equipment
- m) Protective equipment preferably in the form of fuel cut-off solenoid and suitable relays to protect the engine against low lubrication pressure.
- n) Lifting attachment for lifting the complete set or the engine alternator separately.
- o) Radiator/ Heat Exchanger.

5.16.7 Generator

- i) The generator shall be of totally enclosed or screen protected drip proof and self air cooled type. The generator shall be driven by the diesel engine specified above and shall match the same in all respects. The generator shall conform to IS-4722, IEC-60034.
- ii) AC generator shall be supplied along with excitation system, AVR and include all necessary auxiliaries.
- iii) The Generator shall be star connected, 3-phase, 50Hz synchronous generator and shall have a continuous rating. The operating conditions shall be as follows:
 - a) Voltage 415V
 - b) Frequency 50Hz (+3 to -5%)
 - c) Power factor 0.80



- iv) The generator stator and rotor windings core insulation and all connections including main and neutral leads shall have class-F or better insulation.
- v) Resistance element temperature detector shall be installed at the following locations :
 - a) 6 nos. duplex or 12 nos. simplex RTD's in stator windings.
 - b) 1 no. RTD element in each bearing.
- vi) Suitably rated 240V, single phase, 50Hz, space heaters located in lower part of alternator shall be provided to maintain the internal temperature above the dew point to prevent moisture condensation on the insulation when the set is not running.
- vii) Separate terminal boxes shall be provided for phase and neutral side of leads. The terminal boxes shall be dust proof, weather proof phase segregated double walled (metallic as well as insulated barriers) having degree of protection of IP-54 as per IS: 13947.
- viii) The terminal box shall be of sufficient size to conveniently terminate the size and number of cables. Suitable tinned copper pads shall be provided for power cable termination along with all necessary hardware and cable lugs. For single phase cables gland plate shall be of nonmagnetic material and shall be removable type. The necessary CT's for differential protection shall be provided on neutral side.
- ix) Alternator vibration level shall not exceed the values as defined in IS:12075. Alternators in case driven by diesel engine shall be able to withstand vibration level of 9 mm/sec. as per BS 5000 Part III,

5.16.8 Excitation system

The generator shall be provided with complete excitation system capable of supplying the excitation current of the generator under all conditions of output from no load to full load and capable of maintaining voltage of the generator constant at any value with (\pm)10% of the rated voltage. It shall be possible to set the same from remote also. The type of insulation of the armature field winding of the exciter shall be class-B and the temperature shall not exceed the values specified in IEC-60034 Part-I for different parts. The excitation system shall be of static excitation system/ brushless excitation system/ any other modern excitation system.

5.16.9 Automatic Voltage Regulator (AVR)

- i) The regulation system shall be provided with equipment for automatic and manual control. Necessary equipment shall be furnished for the following:
 - a) To prevent automatic rise of field voltage in case of failure of potential supply.
 - b) To initiate transfer from automatic to manual control of excitation on fuse failure in the generator potential signal.



- ii) The regulator shall regulate from generator current and potential signals.
- iii) The above equipment shall be housed in self standing sheet metal cubicle, and shall be completely tested and wired.
- iv) The regulation equipment shall function correctly between the frequencies 47.5Hz and 51.5Hz and shall ensure a voltage variation not more than (\pm) 1% of the set point in steady operating condition between no load to full load.

5.16.10 Protection

- a) Differential Protection (87) – Three Pole
- b) Reverse Power Protection.
- c) Overload Alarm on one phase
- d) Earth Fault Detection Relay (64)
- e) Voltage controlled over current relay
- f) Generator under/over voltage Protection
- g) Hand Reset/ Lockout Relay.

5.16.11 Metering - The following minimum meters shall be provided.

- a) 3 no. AC ammeters of suitable range.
- b) 1 no. AC Voltmeter of suitable range with selector switch.
- c) 1 no. Wattmeter
- d) 1 no. Watthour meter having accuracy of 1.0 class.
- e) 1 no. frequency meter
- f) 1 no. Power Factor meter.

5.16.12 Diesel Generator Control Panel

- i) One local control panel with provision for local starting shall be provided which shall incorporate all controls required for starting, monitoring, regulating and stopping DG set. It shall be equipped with all necessary instrumentation to provide adequate surveillance of DG set under all operating conditions including 'Standby'. The local control panel shall be of robust construction, floor mounting, free standing type made of 2.0 mm thick cold rolled sheet steel. Neoprene gaskets shall be provided between all openings and joints. The control panels shall have IP-52 degree of protection as per IS:13947 Part-I.
- ii) All cables shall have bottom entry. Separate cable chamber shall be provided in the control panel for all incoming and outgoing cables.
- iii) A tinned copper/ aluminium bar of adequate dimension shall be provided for earth connection complete with nuts and bolts as required for external connection to earth grid.
- iv) The final paint shade shall conform to shade grey RAL 9002. The identification tag shall be white in colour shade RAL 9010.



- v) CT shorting links, test terminal blocks etc. shall be provided. All the equipment mounted inside the control panel shall be identified by lamicoid labels/ stenciling by paint.
- vi) Panel shall be provided with panel illumination lamp operated by the door switch and thermostat-controlled space heater.
- vii) The manual control of the engine speed and generator voltage shall be provided through suitable Raise/ Lower control switches on the local control panel and remote.
- viii) The following tripping and alarms shall be provided:
- Fail to start (Alarm)
 - Overload (Alarm)
 - Cooling water pressure low (Trip)
 - Lube oil pressure inadequate (Trip)
 - Over Speed (Trip)
 - High cooling water temperature (Trip)
 - Abnormal voltage (under and over voltage) (Alarm).
 - Charger ON/OFF (Alarm)
 - Fuel level low in day tank (Alarm and Trip)
 - High lube oil temperature (Trip)
 - Low air pressure in receiver (Alarm)
 - Alternator stator temperature high (Alarm)
 - Electrical protective relays operated (Trip)
- ix) Necessary pressure switches, level switches, thermostats, flow switches, auxiliary relays, etc. required for the above alarm and annunciation system shall be provided.
- x) The following minimum instruments shall be mounted on each engine:
- Thermometers for lube oil temperature.
 - Pressure gauges for lube oil, fuel oil and air starting systems.
 - Differential pressure gauges across strainers and filters
 - Speed indicator
 - Exhaust pyrometers with temperature switch.
 - Level switches for alarm and trip in day fuel oil tank.

5.16.13 Sound proofing system

- i) The sound proofing system shall be designed to achieve a minimum 25dB insertion loss/ maximum sound level at ½ metre distance from enclosure/ acoustically treated room as per State Pollution Control Board norms. The ventilation system shall be of adequate design to ensure no deterioration in performance of DG.



- ii) The sound absorptive layer shall comprise of bonded type mineral wool/ glass wool of adequate thickness and density to comply the design requirements.
- iii) The exposed surface of lining inside room/ enclosure shall be retained in place by a adequately thick CRCA/ aluminium perforated sheet (not less than 0.8mm). Absorptive lining shall be provided between the perforated sheet and absorbing material. Necessary acoustic sealing shall be done in the panels/ modular unit joints.
- iv) All hardware of mild steel shall be electro-galvanised.
- v) The door design shall be generally compatible to the enclosure design/ acoustic treatment of room. The bonded mineral wool slab of adequate thickness shall be used. The door shall be provided with heavy duty hinges and handles. The sealing shall be done with neoprene/ silicon rubber gasket to avoid leakage of noise. The size of the door shall be as per the room design/ functional requirements.
- vi) Acoustic treatment of DG room shall be done. The following requirements shall be complied in case of acoustic treatment:
 - a) The acoustic treatment of wall, ceiling and other opening shall be done using galvanised steel sections. The framework shall be fixed on wall/ ceiling using expansion fasteners.
 - b) Bonded mineral wool slab of required density and thickness shall be used for sound absorptive layer. This shall be concealed with perforated aluminium/ CRCA sheet. Suitable lining shall be provided between the bonded wool and perforated sheet.
 - c) Necessary acoustic sealing shall be done in the panel joints.
 - d) In rolling shutter area, removable type of acoustic paneling shall be done to facilitate maintenance.
- vii) Ventilation system of adequate capacity shall be provided. The system shall comprise of tubular axial flow fans for air intake and air exhaust. The ventilation shall be design to ensure required air flow rate as per manufacturer recommendations, after providing necessary acoustic treatment/ silencers in air flow path. The ventilation system shall be design to prevent leakage of sound and maintain required room temperature for comfortable working in the area not to deteriorate performance of DG.
- viii) The construction of ventilation duct shall be similar to that of the enclosure/ room acoustic treatment
- ix) The exhaust air from radiator shall be discharge through modular duct duly/ insulated of adequate size. The duct cross section shall be 1.5 times the cross-section of the radiator (radiator X-section is approximately 2mx2m).



5.17 ELECTROSTATIC PRECIPITATOR

5.17.1 General

- i) For the purpose of design of equipment, an ambient temperature of 50°C and relative humidity of 95% shall be considered. The equipment shall operate in a highly polluted environment.
- ii) All equipments shall be suitable for 415V, 50Hz AC supply with voltage variation of (±)10%, frequency variation of (+)3% to (-)5% and combined voltage and frequency variation of 10%.
- iii) All the equipment, material and systems shall conform to the latest edition of relevant national and international Codes and Standards, especially the Indian Statutory Regulations.
- iv) Paint shade shall be as follows :
 - a) TR set : Blue RAL 5012 (Legend in Block letters)
 - b) Motors : Blue RAL 5012
 - c) Panels : Front and rear panels in Grey (RAL9002). End panel sides in blue (RAL 5012)
- v) Technical requirements of ESP Electrical equipment like motors, cables, ACP/MCC etc., which are not covered in the following clauses, shall be as per previous subsections.

5.17.2 Transformer Rectifier (TR) sets

- i) Codes and standards - Transformers shall conform to IS:2026. All other equipment/ accessories shall conform to relevant Indian Standards. Equipment conforming to equivalent International Standard like IEC shall also be acceptable. The transformer oil shall meet the fire safety requirement specified in paragraph 450-23 of National Electrical Code.

- ii) Equipment Description

Type : Silicone oil filled, free standing transformer rectifier assemblies in steel housing with HV disconnect and ground switch for each section of the ESP field. The sets shall be mounted on top of precipitator.

Tank : Welded type construction. Tank cover shall be sloped to prevent retention of water and shall be provided with bi-directional skids, lifting lugs and four jacking pads.

Core : High grade non aging cold rolled grain oriented silicon sheet steel laminations.



	Winding	Electrolytic grade copper.
	Oil	The transformer oil shall be non toxic and shall have high flash point (above 300 ⁰ C) sealed type construction without breather.
	LT Connection	Cable
	Cable box	Degree of protection IP:54
	Bushings	Made of porcelain.
	Marshalling box	Degree of protection IP-54, provided with thermostatically controlled space heaters.
	TR set controller panel	Provided with isolating switch, power contactor, thermal overload relay, fuses for protection of Silicon Controlled Rectifiers etc.
iii)	Fittings	
	Temperature Indicator	Dial type oil temperature indicators with alarm and trip contacts.
	Drip trays	To contain total volume of cooling fluid.
	Drip trays	To be connected to a separator chamber through drain pipes. The separator chamber located at ground level to be sized to contain oil from drainage of any two TR sets.
	Pressure relief device	Spring loaded type.
	Oil level indicator	Magnetic with low level alarm contact
	Oil level gauge	Prismatic/ toughened glass.
	Buchholz relay	Double float type with alarm and trip contacts
iv)	Operating Conditions	
	Operation of precipitator shall not be affected when one rectifier unit is taken out of service.	
	Flux Density	Flux density not to exceed 1.9 Wb/ m ²
	V/F	Designed for 1.1 continuous.
	Noise Level	Not to exceed the values specified in NEMA-TR-1
	Protection	Suitability for working under transient sparking conditions and occasional short circuit load. Protection against surge, excess temperature rise and under voltage to be provided.
	Maximum temperature rise	Winding : 55 ⁰ C Oil : 50 ⁰ C

5.17.3 ESP Insulators

High voltage insulator shall be located outside the gas stream, suitably housed in the insulator compartments to facilitate maintenance when the precipitators are on load. Each insulator compartment shall be provided with insulator heaters or hot air ventilation system to avoid moisture condensation on insulators. In case of hot air system, it shall include fans, air filters, heaters etc.

The insulator compartment shall be provided with thermal insulation. The compartment shall be designed such as to prevent ingress of flue gas into compartments.

Insulators for supporting emitting frame and roof bushing shall be of porcelain suitable for long life, in ESP internal environment (highly polluted with flue gas temperature of 200⁰C and going upto 300⁰C for 5 minutes). Rated voltage for the insulators shall be such that AC rms one minute dry power frequency withstand voltage shall be 1.5 times the DC maximum operating voltage as per relevant IS.

5.17.4 ESP earthing shielding and Safety interlocks

- i) Earthing and shielding
 - a) A complete earthing system with double path to the ground for all equipment and ESP structure shall be furnished. Each casing shall be provided with two earthing pads located on diagonally opposite corners of each casing. The pad surfaces shall be tinned, drilled and shall be connected to earthing mat by 50x6 galvanised steel flats.
 - b) Manual safety earthing switches shall be furnished so that individual equipment can be grounded during maintenance. All access doors, gas distribution baffles or perforated plates located in the inlet or outlet nozzles of the precipitators shall have ground straps connected to the precipitators casing if they are not welded permanently to the casing.
- ii) Safety Interlocks
 - a) A full proof manual key sequence type interlock system for the safety of operating personnel from contacting energised high voltage equipment shall be provided. Key interlocks shall be provided such that for a particular ESP casing any TR set cannot be energised until all insulator housing compartments, disconnect switch boxes, casing inspection doors are locked and emitting and collecting electrode rapping motors are prevented from energisation. It shall also prevent opening of any inspection door unless all TR sets of that stream are de-energised and all HV disconnect switches are opened to earthed position. Rapping motors operation shall be prevented under this condition unless interlock is specifically defeated for testing.
 - b) Key interlock system shall be simple, robust, weather proof construction suitable for outdoor mounting.



5.17.5 ESP Control system

The control system shall be designed for automatic and manual local/ remote operation. ESPs serving one boiler shall be provided with a complete control system consisting of microprocessor based Electrostatic Precipitator Management System (EPMS), TR set controllers, rapper controllers, communication controllers, hopper heater controls, insulator heaters and pressurization system controls and all other controls required for safe, efficient and reliable operation.

- i) Electrostatic Precipitator Management System (EPMS) : The EPMS shall be connected to the Transformer Rectifier Set Controllers (TRC) and Rapper Controllers (RPC) through duplicate data highway. However, any other standard, proven system of communication through balanced current loop is also acceptable. EPMS shall accept the feed back analog signals like Boiler Load Index and Output from opacity monitors, process these signals and issue control parameters to the TR Controllers and Rapper Controllers. It shall also control, monitor and display the status of each stream i.e. status of TR Controllers, Rapper Controllers, hopper heaters, hopper levels, insulator heaters/pressurization air blowers etc.
- 1) The EPMS shall include, but not be limited to, the following features :
 - a) A PC based master controller with non-volatile memory and report storage capabilities for a period of 6 months.
 - b) TR set controllers and Rapper Controllers.
 - c) High resolution 21" colour CRT.
 - d) Communication ports and protocol for data transfer between EPMS Master control unit and the TRC/ RPC/ other controllers.
 - e) Keyboard for operator interface.
 - f) Color inkjet printer for alarms and reports
 - g) Facility for Auto operation of ESP with Energy Management
 - h) Necessary Input/ Output points for interfacing with distributed digital controls and Management information system (DDCMIS).
 - i) Self surveillance and self diagnostic features.
- 2) The EPMS display unit shall display at least the following :
 - a) A summary of the status of all the controllers.
 - b) A summary of the readings of all the TR sets.



- c) A summary about each TRC i.e., settings, limits, voltage and current readings, alarms and the controller status.
- d) A summary of each RPC i.e. controller status, rapping frequency, alarms and indication of the rapper being operated.
- e) Status reading Energy Management System such as charge ratio of each field etc.
- f) Necessary alarms as decided during detail engineering stage.
- g) Status of hopper level, hopper heaters and insulator heater/blower
- h) ESP TR set power supply status and alarm
- i) Potential free contact for ESP trouble shooting etc. as required shall be provided.

The PC based master controller i.e. operating and monitoring station together with 21" colour CRT, keyboard and colour inkjet printer shall be located in the unit control and equipment room/ programmer's room for each unit. Necessary links with the DDCMIS shall be provided so that all the functions of the master controller can be performed from operator's work station of DDCMIS.

- ii) TR set controllers : Each Transformer rectifier set shall be provided with a separate microprocessor based controller (TRC) for regulation and control of the electric power input to electrostatic precipitator fields. It shall be designed for minimum charge ratio of 1:99. It shall automatically optimise the charge ratio and maintain the spark rate at a suitable level for variations of gas temperature, dust composition, gas flow etc. It shall regulate the rectifier in such a way, that the current through the electrostatic precipitator is corrected as the conditions for sparking are changed. It shall be able to monitor filter functioning and shall give an alarm when values are lower or higher than preset values. It shall automatically regulate the charge ratio of each field/ TR set based on V-I characteristics of the respective electrical fields. It shall have alternative arrangement of optimising the charge ratio based on Opacity Monitor signal also. The controller shall have proven noise immunity and shall be suitable for ESP application. It shall be capable of maintaining the optimum voltage and current in ESP under all regimes of boiler operation.

The system shall have the following minimum features :

- a) Display unit for :
 - All the operating values like field DC voltages and currents
 - Spark rate
 - Semi pulse current limit
 - Voltage low limit



- Charge ratio
 - All other adjustable parameters and limits
- b) Keys for operator interface and potentiometers local control and adjustments.
- c) Serial communication with protocol for communicating to EPMS.
- d) Local/ Remote selection.
- e) Spark counter.
- f) Alarms as mentioned below
- TR set oil level low.
 - TR set temperature high.
 - AC current high.
 - Low DC voltage.
 - High DC voltage.
 - Back corona.
 - Management command failure.
 - TR set buchholz / PRV trip
 - TR set buchholz alarm
- iii) Rapper Controller (RPC)

Each stream of ESP shall be provided with a separate, microprocessor based Rapper Controller (RPC). However, any other proven standard design of rapper controller integral to TR set controller is also acceptable. It shall have proven noise immunity and shall be suitable for ESP application. It shall control the sequence and frequency of operation of the rapping mechanisms of collecting and discharge electrodes of the different fields of the precipitator. The unit shall control and survey the operation of rappers in the ESP. It shall start and stop the rappers as programmed and shall give an alarm if a rapper fails. It shall be possible to start or stop manually each rapper, without interfering with the other rappers from the controller. The operation status of each rapper shall be indicated with LEDs on the rapper controller panel.

It shall be possible to change the three timings (viz. start time, repetition time and run time), intensity (if applicable) and frequency of rapping independently for each rapper, without need for opening the panel or any alternation in programme. The range of rapping frequency available shall be upto 24 hrs. Additionally, the rapper controller shall have at least 50 no. pre-programme sequences of rapping stored in its memory so that the operator can select any of them according to his judgment or the controller itself can choose them based on feedback from boiler load.

In case one separate rapper controller is provided for each stream, one standby working rapper controller shall be provided so that in case of failure of any one



of the working rapper controllers, the standby controller shall immediately and automatically take over the control functions of this rapping without affecting the operation of ESP.

The system shall have the following minimum features :

- a) Display of all adjustable parameters, rapping modes, time settings and intensity of rapper/ group and rapper status, rapper alarm and controller alarms.
- b) Key board for operator interface.
- c) Local/ remote selection: In local mode all commands and adjustments shall be from RPC. In remote mode all commands and adjustments shall be from EPMS.
- d) Communication port with protocol for communicating with EPMS.
- e) Remote on/ off capability from EPMS.
- f) The controller address (field programmable), logic programmes and other adjustable parameters shall be stored in non-volatile memory and shall not be affected by power loss.