STANDARD TECHNICAL SPECIFICATION FOR MAIN PLANT PACKAGE

SECTION- 5

(ELECTRICAL WORKS)

5.1 GENERATOR

One number turbo-generator set with all auxiliary systems and accessories shall be supplied for each unit.

5.1.1 Type

3-phase, horizontal mounted, 2-pole cylindrical rotor type, directly driven by steam turbine running at rated speed conforming to IEC-60034-1, 60034-3 or other equivalent international standards.

5.1.2 Rating

i)	Rated Output	500MW (589MVA) or …… MW (…. MVA)[1] Generator and its excitation system shall have capability to at least match the declared maximum continuous rated output of the associated steam turbine (for the secondary cooling water temperature of 39^0C) Also the generator and its excitation system shall be capable of continuous stable operation without any excessive temperature rise at the peak output of the associated steam turbine under VWO and HP heater out condition, etc. as available for the secondary cooling water temperature of 39^0C.
ii)	Power Factor	0.85 (lag)
iii)	Terminal voltage	18 to 24 KV
iv)	Frequency	50 Hz
v)	Speed	3000 rpm

[1] To be indicated by purchaser as applicable

vi)	Short circuit ratio	Not less than 0.48 (without negative tolerance)
vii)	Efficiency	> 98%

5.1.3 System of Cooling

i)	Stator winding	Closed loop system using deminerlised water flowing through the hollow conductors.
ii)	Rotor winding	Directly cooled by hydrogen
iii)	Stator core	Cooled by hydrogen flowing through the radial and axial ventilating ducts.
iv)	Configuration for hydrogen cooling	Generator to be designed for hydrogen pressure as per manufacturer's practice. The shaft mounted propeller type fans on one or both sides to facilitate circulation of hydrogen inside the machine. Hydrogen to be cooled by coolers using demineralised water mounted in the stator body.

5.1.4 Insulation

	Stator and Rotor windings	Class 155 (F)

5.1.5 Temperature Limits

i)	The maximum temperature limits of generator windings :	
	a) Maximum temperature of stator core (measured by thermometer)	120^{o} C
	b) Maximum temperature of stator winding (measured by RTD)	120^{o} C
	c) Maximum temperature of rotor winding (measured by Resistance method)	As per IEC-60034-1
	d) Maximum temperature at slip rings (measured by thermometer)	120^{o} C

ii)	Generator derated capability (MVA output and stator current)	
	a) When the temperature of cooling water entering hydrogen coolers or the temperature of hydrogen exceeds from rated temperature by 0^o to 15^oC.	Bidder to furnish
	b) When the temperature of demineralised water at inlet of stator winding exceeds from rated temperature by 0^o to 5^oC.	Bidder to furnish

5.1.6 Operational Requirements

i)	Voltage variation	(±) 5% of rated value at rated power and rated power factor.
ii)	Frequency variation	(-) 5 to (+) 3% of 50 Hz at rated power and rated power factor.
iii)	Combined voltage and frequency variation	5% (absolute sum)
iv)	Operating range	MVA for short duration and time period at 110% rated voltage shall be specified by the bidder.
v)	Power factor variation	0.85 (lag) to 0.95 (lead)
vi)	Operation under unbalanced load	Capable of operating continuously with a negative sequence current of 8% of the rated current. The maximum current in any of the phases not to exceed the rated current.
vii)	Operation under unsymmetrical short circuit	Capable of withstanding during any transient unsymmetrical short circuit condition, negative sequence current I_2 expressed in per unit of rated current for duration of 't' sec. such that the value of I_2^2 t is not less than eight (8).
viii)	Voltage waveform	The voltage waveform shall be approximately close to a pure sine wave under all conditions of loading

		within the tolerance limits specified in the relevant standards. The balanced and residual telephone harmonic factor (THF) to be within limits specified in IEC-60034-1.
ix)	Short circuit withstanding capacity	Capable of withstanding of 3-phase short circuit at the generator terminals when operating at rated MVA and power factor with 5% over voltage for a period of not less than 3 seconds. However, the generator to be subjected to withstand test as per clause no. 8.7 of IEC-60034-1.
x)	Line charging capability (MVAR)	Not less than 35% of the rated MVA at zero power factor leading.
xi)	Capacity with one hydrogen cooler out of service	Capable of delivering at least two third of the rated MVA
xii)	Generator neutral earthing	Non-effectively earthed neutral system. Neutral to be earthed through a distribution transformer loaded with a resistor.
xiii)	Generator capability diagrams	Bidder to submit the capabilities of the generator at different p.f. (lead and lag) and also at varying hydrogen pressures, clearly indicating the operating limits.
xiv)	Impulse level and surge protection	Impulse level as per IEC-60034,Pt.15 Surge arrestor of suitable rating to be provided for the surge protection of the generator winding. The surge capacitors also to be included.
xv)	Harmonics	Voltage and current harmonics not to exceed the limits as per IEEE-519.

5.1.7 Design and constructional features

i)	**General**	a) All components to be designed to avoid resonance at any of the frequency in the operating range and their multiples.

		b) All components requiring inspection and maintenance to be designed for easy access and replacement.
ii)	**Stator Body**	
	a) Enclosure	To withstand without any residual deformation, any internal hydrogen explosion.
	b) Handling	4 no. of trunions to be provided for handling the stator by means of crane. Bidder to clearly bring out in the proposal, the features provided in the generator body construction to enable generator stator to be lifted/ dragged.
	c) Transportation	The bidder to furnish details of the type of inland transportation (rail or road) of generator stator body upto the project site.
	d) Manholes	At suitable locations with proper sealing arrangements etc. to facilitate the inspection of back of the core, end winding area and terminal connections
iii)	**Stator Core**	
	a) Material	High permeability, low loss, cold rolled silicon sheet steel segmental punchings.
	b) Core assembly	Assembled on core bars in an interleaved manner. To rest on flexible support system such that radial and tangential magnetic vibration of the stator core due to electro magnetic loading transmitted to the outer frame is minimum.
	c) End packets	Adequately strengthened to minimise the magnetic vibration due to end leakage flux. Fastening elements used in generator to be non - magnetic and be used with proper locking arrangement.

iv) Stator Winding

a) Winding configuration	Stator winding consisting of three phase, double layer, short chorded, bar type winding having two parallel paths. The elementary conductors to be Roebel transposed in the slot portion.
b) Winding insulation	Epoxy thermo-setting type and rated for class 155(F). Provided with adequate protection on the winding and slots for avoiding the corona and other surface discharges.
c) Ripple springs	To be provided in stator slots.

v) De-mineralized (DM) Water Headers

a) Inlet and outlet water headers	Shall be of stainless steel
b) Insulation	The headers and header connections shall be suitably insulated from the stator body. It shall be possible to measure the insulation resistance of the stator winding after simply removing the outside water pipe connection. It shall also be possible to measure the insulation resistance between the water header and casing after disconnecting the header grounding.
c) Connection of bars	High quality heat resistant and high strength teflon (PTFE) hoses. Single pass cooling arrangement shall be preferred.

vi) Stator Winding Connection and Terminal Bushings

a) Winding	Star connected. 3 phase and 3 neutral terminals brought out. All stator terminal lead connections inside the generator to be suitably supported to contain vibration.

	b) Overhang portion of winding	Over-hang portion of the stator winding to be suitably braced and supported so as to withstand 3 phase short circuit at its terminals as stipulated in IEC-60034, when the machine is operating at rated MVA, power factor and permissible maximum over voltage.
	c) Bushing housing	Bushings to be housed in lower part of stator frame in a non-magnetic steel terminal box.
	d) Bushing material	Porcelain or epoxy based material with non-hygroscopic property. The terminal bushings to be cooled by suitable arrangement with cooling medium/ system envisaged for the generator.
	e) Terminal connectors	Silver coated copper having octagonal configuration, suitable for connection to the busduct through flexible connectors for which the operating conductor temperature shall be 105^0C.
vii)	**Rotor**	Machined from a single alloy steel forging to give the required mechanical, metallurgical and magnetic characteristics. Shall have an adequate margin between critical speed and the running speed to ensure smooth running.
viii)	**Rotor Winding**	
	a) Conductor	Coils made of hard drawn silver bearing copper.
	b) Insulation	Epoxy glass based material rated for class 155(F) insulation.
ix)	**Retaining Rings and Nuts**	
	a) Retaining rings	Machined from high strength, non-magnetic alloy steel forging, with the material specification 18Mn18Cr, resistant to stress corrosion. Floating type shrunk on the rotor body.

b) Locking nuts/ snap rings	Made of high strength non-magnetic alloy steel forging to be provided on the retaining rings to prevent any axial movement.
c) Centering rings	To be mounted at the end of the retaining rings to support it and prevent the movement of rotor winding in the axial direction due to thermal stresses.

x) Bearings

a) Type	Self-aligning type sleeve bearings either mounted on separate pedestals or on the end shields. The bearing housings and bearing shells to be of split construction. The bearing shells to be lined with tin based TG bearing.
b) Seal	Provided with Labyrinth shaft seals.
c) Jacking arrangement	The hydrostatic jacking arrangement in line with turbine bearings.
d) Bearing insulation	At least one of the bearings to be suitably insulated with arrangements to measure the insulation of the generator bearing while the machine is in operation. Insulating material to be non-hygroscopic epoxy glass laminate.
e) Bearing instrumentation	Redundant pick-ups/ transducers for bearing metal temperature, bearing drain oil temperature.

xi) Shaft Seals

a) Type	Double flow ring type, to be provided at both ends and designed in such a way that minimum oil comes in contact with hydrogen during operation to minimise contamination.
b) Sealing ring lining	The face of the sealing ring shall be lined with babbitt metal.

c) Insulation	The shaft seals and associated piping shall be adequately insulated to prevent circulation of shaft current.
xii) Hydrogen Coolers	
a) General	To be provided with 10% extra tubes. Cooler to be designed for at least 10 Kg/cm^2 gauge pressure on the gas side irrespective of a lower normal operating casing pressure.
b) Cooler tubes	Corrosion resistant with integral fins and arranged in the stator casing to avoid the direct fall of water during leakage, if any, on the winding insulation. Should be possible to clean/ plug the cooler tubes of a section with the machine under operation.
c) Water pressure in coolers	Shall be maintained below the operating hydrogen pressure in the generator casing.
d) Temperature control	To be provided with necessary control system including temperature sensing elements, control valves and devices. Also provided with adequate number of temperature and pressure gauges on inlet and outlet of cooling water, in case of water cooled machine.
xiii) Generator drying arrangement	Suitable equipments, accessories and controls shall be provided to enable drying out operation of the generator.
xiv) Instrumentation for temperature measurement	
a) Temperature detectors	Thermocouples/ Resistance temperature detectors (RTDs) of duplex 100 ohms platinum, calibrated as per DIN standard and located at points, where highest temperature likely to occur during operation. Simplex type thermo-couples/ RTDs are acceptable with double the nos.

b) Number and location	- 12 no. detectors, 4 nos. per phase and uniformly distributed along the circumference of the stator and located at the hottest possible zones viz. the point of exit of stator water from winding in a water cooled machine. - Detectors for monitoring water temperature of each winding bar in case of water cooled machine. - 12 no. detectors for stator core, out of which 6 nos. to be located in the end zones where maximum temperature are expected. - 2 no. detectors per hydrogen gas cooler section for measurement of inlet and outlet gas temperature - 2 no. detectors per hydrogen cooler section for measurement of inlet and outlet water temperature - 2 no. detectors per bearing for measurement of babbitt metal and drain oil temperature - Sets of detectors for generator shaft sealing, Hydrogen gas and Stator Water systems required for monitoring the temperature of oil, water and hydrogen at different salient locations in the system.
c) Termination of RTD leads	At terminal box after grouping of signals.
d) Location of Terminal box	Terminal box to be located at an easily accessible position to enable maintenance / testing of the devices, when the machine is under operation.
e) Terminal box construction	Dust and vermin proof with degree of protection of IP 54.

	f) Interface	All the above temperature measurement devices to be connected to Distributed Digital Control, Monitoring Information System (DDCMIS).
xv)	**On-line water temperature monitoring system for stator winding bars**	The processor shall be complete with all software and hardware required to detect any abnormalities in the temperature at any given generator operating point and shall be sensitive to generator loads, header water flows, pressure, etc. and shall be possible to exchange information with DDCMIS through suitable protocols
xvi)	**Instrumentation for vibration monitoring system**	At least 6 nos. of pickups at each end of over-hang portion of the winding to be provided, symmetrically located around the periphery with connection to 'Turbine Supervisory system'. Provision to be made to connect the same to DDCMIS. Bidder to wire up all the pickups to a junction box outside the generator casing.
xvii)	**Instrumentation for liquid leakage detector**	To be provided at all the low level points inside the generator casing including end shields along with provisions of indication and alarm during leakage of liquid in generator in case of water cooled machine.
5.1.8	**Transportation :**	Bidder shall furnish the details regarding transportation to prevent ingress of moisture during transportation and storage.

5.2 GENERATOR AUXILIARY SYSTEMS

The generator auxiliary system comprising of gas system, seal oil system, stator water cooling system and excitation system shall be provided with all accessories.

5.2.1 Gas system

i)	Description	Each generator to be provided with H_2 and CO_2 gas supply system including gas manifolds, CO_2 heating system, hydrogen pressure regulator, inter-connecting piping, fittings, valves, gauges, thermometers, pressure transmitters and other instruments, control and annunciation panels etc.
ii)	Requirement of gas cylinders	Requirement for one start-up and one shut-down of a unit plus those required to be connected on manifolds of both the units plus total requirements for 7 (seven) days consumption of both the units to be furnished.
iii)	Purity	The system to be suitable for purity of hydrogen from 97-99%.
iv)	Piping and valves	Seamless steel tubes to be used for piping. Valves to be of glandless diaphragm type, wherever possible.
v)	Purging	During purging, filling and emergency operating conditions, the gases to be expelled to the atmosphere (outside the TG hall) through a manually operated vent valve.
vi)	Hydrogen safety relief valve	To be provided at hydrogen manifold
vii)	Hydrogen driers	2x100% duty to maintain the H_2 inside the machine dry at operating pressure. Gas circulation at standstill: To run the gas system for short time shut down of generator for which gas circulation arrangement through drier, piping valves and accessories along with required control equipment shall be provided.

viii)	Reactivation of desiccant type dryer	The design of the drier to be such that it is possible to reactivate the drying medium in situ after isolation from the generator casing and connecting it to atmosphere. For controlling the time/ regime of reactivation, suitable thermometers, thermostats, timers etc. with a local control panel to be provided.
ix)	Valve inter-locking	3-way valve used along with the drier for interconnecting the H_2 and air line (as applicable) preferably have mechanical inter-locking, such that closing of the H_2 side port is positively ensured before opening of the air side port.
x)	On-line dew point measurement	On-line dew point monitoring system to be provided across the inlet and outlet lines to the drying system along with alarm/ annunciation in case of high moisture content in the generator casing H_2.
xi)	Gas Analyser	To be provided with thermal conductivity/ gas density based type to continuously analyze the gas discharged from the casing during purging and also analyze samples of the casing H_2 during normal operation. The analyzer to measure the gas purity under the following three conditions : a) Normal percentage of purity of H_2 in air in the generator casing. Purity range to include a low purity alarm. b) Percentage of H_2 in CO_2 leaving the casing when H_2 is being admitted or expelled. c) Percentage of air in CO_2 leaving the casing when CO_2 is being admitted or expelled.
xii)	Local Control Panel :	To be provided with all necessary switches, lamps, indicators, power supplies etc. along with the instruments, necessary outputs to DDCMIS.

xiii)	Portable gas analyzer	Similar as detailed above under clause "Gas Analyzer" to be provided for supervision of the gas purging operation.
xiv)	H_2 pressure and purity	To be monitored in DDCMIS and to be annunciated.

5.2.2 Seal Oil System

i)	General	A complete seal oil supply and control system including AC and DC motor operated pump sets, cooler, filters, pressure regulators, oil tanks, de-gasification tanks, regulating and control valves, gauges, thermometers and other instruments, interconnecting piping including hangers and supports, valves and control/ annunciation panel complete with all interlocking relays to be provided. Blowers for venting out H_2 gas liberated from oil to be provided suitably mounted at places where such gas accumulation is likely to occur.
ii)	Number of pumps	2x100% AC motor driven pumps. 1 no. 100% DC motor driven pump.
iii)	Pump starting interlock	Auto starting of stand-by seal oil pumps to be interlocked with seal oil pressure.
iv)	Emergency condition	During short time emergency, which may arise due to non-availability of both AC and DC pumps, unit may be tripped and seal oil supply for such coasting down period shall be from a suitable arrangement from lubrication oil system or a damper tank.
v)	Pipes	Seamless steel piping to be used in the system.
vi)	Seal oil pressure	The seal oil pressure to be maintained at a pressure suitably in excess of the generator casing H_2 pressure. The differential pressure to be kept constant, once set at the time of commissioning, at all H_2 pressures and all regimes of generator operation. The pressure regulator or the regulating valve used for the purpose to be of adjustable type.

		The seal oil system to be designed, such that it is possible to run the machine at no load in air medium at a slightly positive air pressure without any modification in the system.
vii)	Oil level gauge	For alarm/ annunciation of high and low levels, switches to be fitted in the tank and adequate contacts to be provided for annunciation.
viii)	Hydraulic sealing arrangement	Necessary hydraulic sealing arrange-ment to be provided in H_2 side oil discharge line, to prevent circulation of gas due to any possible difference of heads developed by fans mounted at the end of the generator rotor.
ix)	Coolers	2x100% duty seal oil coolers along with necessary 3-way valves for isolating or bringing one cooler in service to be provided. Coolers to be of shell and tube type suitable for using DM water of condensate quality.
x)	Cooler tube redundancy	Seal oil coolers to be designed to have 15% excess tube surface area over and above designed tube surface area required for the rated load conditions, while maintaining the design pressure drop on cooling water side.
xi)	Water pressure	Oil pressure in the cooler to be greater than water pressure under all operating conditions.
xii)	Filters	Suitable filters of 2x100% duty to be provided. Possible to carry out cleaning and maintenance of any cooler and filter, when the machine is in operation.
xiii)	Temperature/ Flow Measurement	Temperature gauges and flow meters to be provided at all appropriate locations.
xiv)	Pressure gauges and switches	Pressure gauges and switches to be provided at least at the following locations: a) At the inlet and outlet of pumps b) At the outlet of the cooler

		c) At the inlet and outlet of the pressure regulators and filters. d) At the oil supply header.
xv)	Control and monitoring	Bidder to offer proven micro-processor/ PLC based controller. System to be controlled from Man Machine Interface and Plant Information System (MMIPIS) as part of turbine control system at unit control room (UCR). In addition to the remote control and monitoring, local control and monitoring for this system to be realized in the local panel mounted near these systems as per manufacturer's standard. Local panel to be provided with all necessary instrumentation and alarms. Outputs to be provided for alarm to DDCMIS
xvi)	Remote Recording	Seal oil differential pressure to be recorded in DDCMIS.

5.2.3 Stator Water Cooling System

i)	General	Cooling to be provided with a closed loop stator water cooling system. System to include but not be limited to the following:
	a) Primary water tank	One (1) no. mounted on anti-vibration pads and covered by the generator cladding. The empty space in primary water tank may be filled with N_2 to minimise water evaporation. Bidder to indicate and provide devices to detect, trap, monitor and release the H_2 that leaks in to the stator water cooling system, to a safe place outside the building through suitable safety valves.
	b) Make up water	Make-up water for primary water system to be tapped-off from condensate extraction pump discharge header (before and after the condensate polisher) and from DM water make-up line to the condenser. The level in the tank to be maintained by means of suitable valves in the make up line.
	c) Water to water heat exchangers	2x100% capacity water to water heat exchangers to be designed to accept

		secondary DM water (condensate quality). The system to be so designed that the pressure of primary DM water inside the cooler is always greater than that of secondary DM water (condensate quality). The exchanger to be designed to have 10% excess tube surface area over and above the designed surface area required for the rated load condition, while maintaining the design pressure drop on cooling water side.
	d) Filters	2x100% capacity fine wire mesh filters with magnet bars of unlimited life for removal of all magnetic particles. Permanent magnet bars to be protected by sleeves of stainless steel. Possible to clean easily the ferro-magnetic particles adhering to the magnet bars during capital maintenance.
	e) Circulating water pumps	2x100% capacity AC motor driven. Standby pump to cut in automatically in case the working pump fails or the pressure of circulating water drops below a certain preset value.
	f) De-mineraliser	One (1) mixed bed demineraliser (MBD) of adequate capacity to maintain the required quality of water. MBD to remain continuously in service in order to retain high purity of stator cooling water with its associated electrical resistivity. Bidder to indicate the capacity of MBD necessary to maintain the quality of water at the desired level for a time duration of six (6) months or more. It shall be designed that the MBD could be taken out of service for refilling without untoward effect on the system, which could necessitate load reduction/ rejection.
	g) Piping	Set of stainless steel piping including hangers and supports, valves and other fittings for the complete water system.
ii)	Instrumentation	Following minimum instrumentation to be provided : a) Set of conductivity meters in the main

		water circuit and after the demineraliser. b) Set of flow switches (at least 2 nos.) to monitor low distillate condition and flow transmitters / meters for primary water to stator winding and main bushing, make up water etc. c) Sets of pressure gauges at the inlet and outlet of stator water filters, differential pressure switches for the filters, differential pressure gauge across stator winding and pressure transmitters as required. d) Set of resistance temperature detectors/ indicators for primary water before and after the generator winding, bushing and cooler. Vapour filled temperature detectors shall also be provided to give signals for high temperature e) Set of dial type thermometers for cooling water at the inlet and outlet of the cooler. f) Water level gauge, transmitters, level switches for high and low level alarms and other accessories for primary water tank.
iii)	Control and monitoring	Bidder to offer proven micro-processor/ PLC based controller. System to be controlled from Man Machine Interface and Plant Information System (MMIPIS) as part of turbine control system at Unit Control Room (UCR). In addition to the remote control and monitoring, local control, monitoring and alarms for this system to be realized in the local panel mounted near these systems as per manufacturer's standard. Local panel to be provided with all the necessary instrumentation and alarms. Outputs to be provided for alarm to DDCMIS

iv)	On-line monitoring System for water quality	Required for ensuring a corrosion free operation to be provided along with stator water system.
v)	Stator coolant flow recorder	To be monitored in DDCMIS

5.2.4 Generator Excitation System

i) General

a) The generator shall be provided with 'Static Excitation System' or 'Brushless Excitation System' along with 'Automatic Voltage Regulator' to meet the requirement specified herein. The excitation system offered shall be of proven design and have a satisfactory field service record on machines of similar size and construction incorporating the type of excitation.

b) Stability studies, both dynamic (long duration, transient) and steady state, shall be carried out to evaluate various parameters of the excitation system, e.g. response time, response ratio, ceiling voltage, loop gains, power system stabilizer (PSS) parameters etc., so as to meet the operational requirements of the grid particularly on loading side as the power station is connected to the grid by long transmission lines.

The purchaser will furnish all information/ data necessary to carry out the stability studies to the contractor at detail engineering stage

c) The excitation system shall have matching characteristics suitable for satisfactory parallel operation with other generators in the plant

d) The necessary inputs and interface equipment shall be provided with Generator Excitation and Automatic Voltage Regulator for hooking up with Turbine Automatic Run-up system and Electro Hydraulic Governing System.

ii) Design and Construction

a) When the generator is subjected to a sudden loss of rated output at rated power factor, the system shall be capable of restoring the voltage within 2% of the nominal preset value within negligible time

b) The excitation system shall have 2x100% channels including independent AVRs, power converters and controls. The controls shall have two independent controllers, one for each channel with hot stand-by facility. Each shall be equipped for Auto Operation with the facility for selecting either channel in Auto or Manual mode

c) Each excitation system channel shall be designed to continuously carry at least 110% of the rated machine excitation current at the rated output of the machine and higher currents for short time duty. Short time duty as mentioned above shall be on MCR base as per clause 1.14 of part III in VDE 530. The rated voltage shall be atleast 110% of the machine excitation voltage

d) Excitation system response time shall be less than 0.5 sec as per IEEE 421 A

e) Excitation response ratio shall be greater than 2.

f) Excitation system ceiling voltage shall be greater than 1.5 times rated load excitation voltage

g) Each excitation system channel shall be capable of supplying without damage to any of the components, the field forcing voltage and current of the system for a period of 10 seconds without exceeding the limits of temperature for rectifier junction and sink, when the equipment starts at normal operating temperature

h) Rectifier transformer overload protection shall be provided in case of static excitation system.

iii) Automatic Voltage Regulator (AVR)

a) The excitation system shall be designed in such a manner that due to any fault in AVR firing circuit pulse transformer, rectifying elements in any channel etc. excitation system shall be available with its full capacity. All rectifying elements shall have over voltage and short circuit protection

b) Two numbers fully equipped automatic channels having independent inputs and automatic changeover shall be provided. Either channel shall be capable of being the main or standby. Either channel shall be capable of being selected as manual also.

c) Automatic voltage regulators shall be either of solid state based type or microprocessor/ PLC based as per manufacturer's standard and having negligible time delay suitable for a large interconnected system.

d) Input to AVR shall be through current transformer secondary 5A and voltage transformer secondary 110V phase to phase.

e) Characteristics

- Auto control range of generator operation shall be (±)10% in all modes of voltage level adjustments.

- Frequency range of operation shall be 47.5Hz to 51.5Hz.

- Accuracy at which generator voltage to be held shall be better than 0.5% generator terminal voltage.

- Range of transformer drop compensation shall be 0 to 15%.

- Maximum change in generation voltage when AVR is transferred from auto to manual under all conditions of excitation. shall be less than 0.5%.

- Manual control range shall be 70% of no load to 110% full load excitation.

f) Technical features -

The AVR shall be provided with minimum following features :

- Maximum and minimum excitation limiter.	To keep field excitation within the specified limit.
- Channel reference control	Either motorised rheostats or microprocessor control.
- Ramp generation circuit	To enable gradual rise of reference signal applied to the comparator circuit to avoid sudden voltage build up.
- Rotor earth fault detection	Two stage rotor earth fault unit for continuous monitoring along with alarm and trip contacts.
- Transformer drop compensation	Suitable feedback proportional to transformer drop to be provided for compensation.
- Rotor angle limiter	A rotor angle limiter shall be incorporated in the system. This shall enable to keep the angle between the direct axis of the machine and network vector within the set reference value as determined by stability, by adjusting the excitation.
- Stator current limiter	The stator current limiter shall act immediately in under-excited range. The time delay in over-excited range shall enable a temporary overloading of the machine.
- Rotor Current limiter	The regulator shall act with time delay, so that the regulation dynamics are not impaired in case of a fault.
- Voltage/ frequency (V/F) limiter	To limit the ratio of generator voltage and frequency at all operating conditions to such a value that the maximum generator transformer core flux density does not exceed the value specified.
- Automatic change-over from Auto-1 to Auto-2 or vice versa	To be possible in case of trouble in the running channel.

- Automatic change-over from Auto to Manual	Automatic change over shall be possible from Auto to Manual in case of : - Generator protection circuit operation i.e. after field forcing and over excitation condition with a time delay. - Loss of terminal voltage feedback by way of any of the VT fuse blowing up. - Faulty over excitation condition. - Loss of automatic channel reference signal - Power supply failure in the automatic channel - Manual intervention

iv) Power system stabilizer (PSS)

a) The excitation system shall be provided with power system stabilizer for achieving the dynamic stability of the system under most stringent conditions of operation in the phase of disturbance created by short circuits conditions, load rejections, switching on/ off of transmission lines.

b) The power system stabilizer should have adoptable settings, which should automatically adjust to system reactance. In other words the system should provide automatic and continuous measurement of system reactance and power system stabilizer setting must continually adjust itself for any changes in the system reactance so as to provide required dynamic stability margins.

v) Specific Technical Requirements for Static Excitation System :

a) General

The excitation system to be provided with the following :

–Rectifier transformer.
–Thyristor convertor alongwith gate firing circuits
–Voltage Regulator (Auto, Manual)
–Field Flashing system along with transformer and rectifier
–Field Circuit Breaker along with field discharge resistor
–Interconnecting cables/ busbars between different equipment / panels of the system.

b) Rectifier transformer

Type	Indoor, epoxy moulded dry type, 3 phase step down transformer with class F insulation complete with

		flanges and terminal lugs for connection to the generator terminals through isolated phase bus ducts.
	Temperature rise	70^0C over an ambient temperature of 50^0C.
	Fault rating	Withstand through fault current for the time duration equal to de-excitation time of the generator field current for such faults under AVR/ manual operation.
	Housing	Sheet steel cubicle
	Protection	A set of CTs to be provided in the primary of rectifier transformer for overload protection. Hot spot temperature measurement in each limb of the transformer alongwith indication as well as alarm and trip contacts shall be provided.
c)	Power Thyristor Convertor	
	Type	Fully controlled three phase, full wave bridge type facilitating fast and high ceiling performance. Suitable to ensure trouble free service of the cells under all fault conditions.
	Protection	The thyristors shall be selectively protected against over- loads by ultra high speed fuses. Suitable lamps indication shall also be provided to indicate the defective 'thyristor'.
	Gate Firing Circuit	The firing circuit shall have the following essential features : – It shall produce a gate pulse for every thyristor once in a cycle. – It shall be able to shift the gate pulse in the time over a range of about 150 electrical degrees under a signal from the regulator.

– It shall provide a linear relationship between the regulating inputs volts and rectifier output.

– firing circuit shall have negligible time lag.
– it shall fire the thyristors correctly for any situation of input voltage, depression or unbalance coupled with high or low field currents.

Pulse Transformer

There shall be a pulse transformer between the individual gates of the parallel connected thyristors and between the main current circuit and the control circuit.

Their amplitudes shall be depending upon the trigger characteristics, approximately (+) 3 to (+) 20V peak against cathode.

d) Field Flashing

The initial field flashing shall be from the station's 415V auxiliary AC supply. Suitable rectifier filters, etc. required for converting this ac supply to the required DC supply shall be housed in the excitation system cubicle. Suitable protection interlock with desired time delay shall be provided so that when the AC terminal voltage of the generator is built up to the required level for the main excitation rectifier system to take over, the field flashing circuit is switched off.

In case the main excitation system fails to take over after a predetermined time of field flashing, the field breaker should trip automatically. An annunciation for field flashing failure/ main field breaker trip due to field flashing failure shall be incorporated.

All the components of field flashing system shall be continuously rated irrespective of its short time duty requirement so as to guard against any failure in case of it's prolonged mal-operation.

e) Field Application and Suppression Arrangement

Field breaker : The generator field breaker shall be of DC, multi pole air break type, suitable for operation from local panel and also from DDCMIS/ OWS. The breaker shall have arc quenching arrangement for both the main poles as well as the discharge contacts. Breaker shall be designed to carry currents for continuous as well as short time duty of the excitation system. Breaking current capacity of the breaker shall match with the fault level at the output DC bus. Discharge contacts shall be rated to discharge the field energy corresponding to the highest field current which may come during its entire operating range. The breaker shall be complete with control switches, indication lamps, local/ remote selector switch, etc.

Discharge resister : Non-inductive for quick discharge of inductive energy and thereby controlling the voltage across the field.

Option : Separate breakers for field application and suppression may also be considered if it is manufacturer's standard arrangement.

Interlocks : Suitable interlock shall be provided to prevent closing of the field breaker unless the regulator reference signal is at/ near the minimum setting and minimum machine speed of 95% is attained. Adequate number of normally open and normally closed field circuit breaker auxiliary contact for remote position indication and interlocking with generator and field flashing circuit shall be provided.

vi) Specific Technical Requirements for Brushless Excitation System :

a) General

The complete equipment shall be mounted on a bed plate and enclosed by suitable exciter cover. The system shall consist of :

- Permanent Magnet Generator (PMG) type pilot exciter.
- Voltage Regulator (AVR, MVR along with rectifier bridges for PMG)
- Field Circuit Breaker along with field discharge resistor
- Rotating rectifier bridges
- Brushless AC Main Exciter

- Complete instrumentation and protection system
- Inter-connecting cables between different components of the system.

b) Pilot Excitation System

- The pilot exciter shall be revolving field, rectifier assembly and excitation control equipment. The rotor shall be magnetized and stabilized by the Manufacturer to give stable magnetisation characteristic during operation.

- The stator winding shall be of class-155(F) insulation or better, suitable for operation at 50^0C ambient temperature. The machine shall be fitted with fans for self ventilation.

- Converter Assembly of pilot excitation system, thyristor gate firing system and pulse transformer etc. shall be of similar design as specified under static excitation system.

c) Brushless AC Main Exciter

Armature : This shall be of rotating armature, 3-phases, star connected, feeding current to the rotating diodes mounted on the exciter shaft.

Armature core : The armature core shall be made from silicon sheet lamination to reduce eddy losses and shall be suitably varnished on both sides.

Exciter enclosure and support : The exciter shall be totally enclosed, self ventilated, frame supported on the generator foundation having journal bearings.

Heat exchanger : Integrally mounted air to water heat exchangers. The heat exchangers shall be designed for DM water (condensate quality). Sizing criteria for the heat exchanger shall be similar as for generator mounted hydrogen cooler.

Insulation : The stator and rotor winding insulation shall be of class-155(F) with the temperature rise limited to class-130(B) limits of IEC-60034.

Overhang conductor : The armature conductor in the overhang portion shall be adequately held to withstand the electro-dynamic forces during field forcing condition. Rotor winding retaining ring shall be made up of stress corrosion resistant material.

d) Rotating Rectifier Assembly

- The rectifier assembly made of silicon diodes shall be arranged as two distinct rings with opposite polarity diodes on respective rings.

- The diodes shall be connected in a conventional three arm full wave rectifier bridge. Rectifier assembly shall have one complete bridge as redundant. Alternatively a single three phase rectifier bridge having at least one redundant parallel branch in each of the six arms of the bridge may also be considered.

Rectifier assembly shall have same requirements as regards the component features and rating as detailed out for the thyristor assembly.

- Diodes shall be cooled by forced air circulation by means of fans mounted on the main exciter.

- Each diode shall be provided with a fuse together with visual indication in the event of diode failure.

- The output from the rectifier shall be fed to the generator field through the bore of the rotor shaft and necessary plug in type of shaft connection. The axial copper connector shall be designed such that it shall be possible to disconnect this connector at the point where the exciter shaft couples to the generator so that, if necessary, the generator and exciter can be tested individually.

e) Field application and suppression arrangement — As detailed out in 'Static Excitation System'

f) Instrumentation and Protection

The system shall generally include, but not be limited to, the following :

- Suitable twin resistance temperature detectors for measuring hot and cold air temperature of exciter with necessary provisions for protection tripping/ interlocks.

- Dial type thermometers for measuring the inlet and outlet temperature of water to the air coolers.

- Pressure gauges at the inlet and outlet of water to air coolers.

- Instruments and devices for the measurement of rotor winding temperature.

- Stroboscope or suitable alternative device for detection of faulty rotating diode element.

- Suitable arrangement for exciter field suppression.

A pair of auxiliary slip rings shall be provided to give access to the rotor circuit allowing an earth fault detector circuit to be connected.
For all alarms in the system, contact shall be taken from the pressure switches temperature switches etc. provided at suitable points. The system shall be provided with transmitters for the indicators/ recorders.

5.3 GENERATOR ISOLATED PHASE BUS DUCTS (IPBD) AND NEUTRAL GROUNDING EQUIPMENT

Generator isolated phase bus duct between generator terminals to generator transformer and tap-off to unit auxiliary transformers shall be provided.

5.3.1 Codes and standards

The design, manufacture, erection, testing and performance of IPBD shall comply with the latest edition including amendments of the following standards.

Standard	Description
IS:2062	Steel for General Purpose Specification
IS:1367	Hot dip galvanized coatings on fasteners
IS:2099	Bushings for alternating voltage above 1000V
IS:13947Part 1	Low voltage switchgear and Control gear.
IS:2544	Porcelain post insulator for voltages above 1000V
IS:2633	Methods of testing uniformity of coating on zinc coated articles
IS:2705	Current transformers
IS:3070 Part III	Lightning Arresters
IS:3151	Earthing Transformers
IS:3156	Voltage Transformers
IS:4759	Hot dip zinc coating on structural steel and allied products
IS:5082	Wrought aluminum and aluminum alloy for electrical purposes.
IS:8084	Interconnecting busbars for AC voltages above 1 kV upto and including 36 kV.
IS:9431	Specification for indoor post insulators of organic material for systems with nominal voltages greater than 1000 volts upto and including 300 kV.
IEEE:32	Neutral Grounding Devices
IEC:60726	Dry type power transformers
C37.20a, 37, 20b, ANSIC37.20 C37.20c, (IEEE-27)	Switchgear assemblies including metal enclosed bus
ANSI C37.24	Effect of solar radiation on outdoor metal enclosed switchgear
ANSI,C 37.23 (IEEE-298)	Calculating losses in isolated Phase Bus.
BS:3816	Cast epoxide resin insulating material for electrical application at power frequency

5.3.2 General Technical Requirements

i) The IPBD will serve as an interconnection between generator, and its associated generator transformer banks and unit auxiliary transformers.

ii) The bus duct will be installed partially indoor and partially outdoor and shall be suitable for hot, humid and tropical atmosphere. However, cubicles for neutral grounding, voltage transformers and surge protection equipment will be installed indoors.

iii) The portion of the bus duct at the generator end will be subject to vibrations. Bus duct enclosure shall not be bolted with generator. A slit of 10–20 mm shall be kept between enclosure and generator flange. Suitable covering shall be provided on the slit to allow escape of hydrogen and avoid dust entry inside the common chamber.

iv) The following calculations for main run delta and tap-off run bus duct shall be furnished.

a) Temperature rise at rated current considering effect of solar radiation.
b) Conductor size
c) Guaranteed KW losses in conductor and enclosure
d) Supporting span
e) Dynamic and static forces transferred to TG foundation.

v) Generator transformers and unit auxiliary transformers shall be placed on the rail track. The bus duct and supporting structure shall be designed in such a way so as to permit transformers removal, after opening the terminations, but without dismantling bus duct run or supporting structure.

5.3.3 Equipment Description

5.3.3.1 The bus duct shall be of standard size as per IS-8084 and shall be isolated phase, continuous (bonded enclosure), natural air cooled and positive pressure type.

5.3.3.2 The layout of the bus duct and number of flexible, bolted and welded joints shall be provided as per requirement.

5.3.3.3 Technical parameters

i) General

a) Rated maximum Voltage(r.m.s)	To suit generator voltage
b) No. of phases	3
c) Frequency	50 Hz
d) Neutral grounding	Non-effectively grounding
e) Insulation level	
- 1 minute dry power frequency withstand	55 kV
- 10-sec wet power frequency withstand	55 kV
- Impulse withstand (1.2/50 micro second wave)	125kV (peak)
- Creepage distance	480mm (minimum)

ii) Generator Busduct

a) Type	Isolated phase, continuous self cooled, pressurized type
b) Service	Indoor/ Outdoor
c) Rating	

	Continuous	Symmetrical SC kA rms	Momentary peak kA
- Main run		-----As per system requirement-----	
- Delta run		----------do--------	
- Tap-off for UAT, VT and SP Cubicle and NG cubicle		----------do--------	

d) Permissible temperature rise for
- Bus conductor 55^0C
- Bus enclosure 30^0C

iii) Current Transformer

a) Type	Epoxy cast resin, ring type
b) Service	Indoor
c) Mounting	Within bus enclosure
d) Other ratings	Accuracy Class
- Low forward power relay, acceptance testing, energy accounting, audit meters	0.2
- Reverse power relay, AVR, EHG and other measurements	0.5

Note : CTs for energy meters for Energy Accounting and audit purpose shall be located at a point after the generator stator terminals, and before the tap-off to the UATs.

iv) Lightning arrester

a) Type	Gapless type for rotating machine protection
b) Service	Indoor
c) Rated voltage	As per generator voltage
d) Nominal discharge	10 KA
e) Power frequency spark over voltage	Surge protection of the generator having power frequency one minute high potential test voltage at works of 2U+1kV and BIL of 4U + 5 kV (peak), where U is the line to line voltage.

v) Voltage Transformer

a) Type	Epoxy cast-resin drawout
b) Service	Indoor
c) Rated Voltage	
- Primary	Generator voltage in kV/√3 V
- Secondary	110 / √3 V

d) Winding connection

- Primary	Grounded Wye
- Secondary	Grounded Wye

e) Insulation Class — E or better

f) Over voltage Factor

- Continuous	1.2
- 30 seconds	1.9

g) Other ratings

	Accuracy Class	VA burden
- Protection	3P	100
- Automatic Voltage Regulator (AVR)/ Electro Hydraulic Governor (EHG)/ Synchronization and other measurements	0.5	100
- Acceptance testing, energy accounting and audit meters	0.2	100

vi) Neutral grounding transformers

a) Type	Cast iron insulated self cooled
b) Service	Indoor
c) Phase	Single
d) Voltage ratio	22 kV/ 220 V
e) Rated Output	175 kVA
f) Duty Time rating	5 minutes
g) Insulation class	Class F or better
h) Maximum Temperature	90^0C rise above 50^0C ambient

vii) Neutral Grounding Resistor

a) Type	Grid Type
b) Material	Punched Stainless Steel
c) Service	Indoor
d) Resistance	As per system requirement
e) Current	---------do--------
f) Voltage	250 Volt
g) Duty (Time rating)	5 minutes
h) Maximum temperature rise	300^0C above 50^0C ambient

viii) Surge Capacitors — 0.125 micro-farad/ Phase, 24 kV Class.

5.3.3.4 The maximum temperature of the bus conductor and enclosure shall be as defined in the technical parameters when operating at maximum ambient temperature and carrying rated current continuously. For outdoor portions the effect of solar radiation shall also be considered. The bidder shall furnish calculation for temperature rise taking effect of solar radiation into consideration.

5.3.3.5 The bus ducts shall be capable of withstanding the mechanical forces and thermal effects of three phase short circuit currents, mentioned in the technical parameters, without any damage, deformation or deterioration of material.

5.3.4 Temperature rise

For continuous operation at rated current under specified site conditions, the temperature rise shall not exceed the limits as defined under technical parameters.

5.3.5 Enclosure

i) Each phase shall be enclosed in a weather proof, dust tight, non-magnetic metal (aluminum alloy) enclosure. The enclosure shall be designed for welded connection.

ii) Filtered drain tapping with dual stop cocks shall be provided for drainage of condensate at the lowest point and at such other locations where accumulation of condensate can be expected. In particular a drain valve shall be provided at the lowest point of transformer end termination. The contractor shall be required to add drainage points if required during installation.

5.3.6 Bus Conductor

i) The Bus Conductor shall be of high conductivity, painted aluminum alloy as per IS:5082 supported on insulators.

ii) The bus conductor shall be designed for welded connections except at equipment terminations, bolted disconnect links, and bolted flexible.

iii) Flexible connections shall be provided between bus sections to allow for expansion and contraction of the conductor. Flexible connections shall also be provided at all equipment terminations.

iv) All contact surfaces shall be silver plated. All connection hardware shall be non-magnetic and shall have high corrosion resistance.

5.3.7 Insulators

i) Bus support insulators shall be interchangeable, high strength and fine glazed porcelain manufactured by wet process, or high strength cast resin insulators.

ii) Insulator shall be mounted in such a way so as to permit its easy removal or replacement without disassembly of the bus.

iii) The conductor shall be fastened on the insulator through fixed and sliding joints so as to allow conductor expansion or contraction without straining the insulator. Positive contact shall be made between end caps of the supporting insulators and the conductors.

iv) Additional support insulators shall be provided at bend and at tap offs for withstanding all possible forces.

5.3.8 Connections and Terminations

i) All matching flanges, seal off bushings, gaskets, fittings, hardware and supports required for termination of the bus duct at Generator, Transformers and other equipment shall be furnished under the scope of this specification. Flexible connections both for conductor and enclosure shall be furnished :

a) At all equipment termination to take care for misalignment upto 25mm in all directions.

b) Between bus duct supported from building steel and that supported by turbine foundation to prevent transmission vibrations.

ii) The equipment terminal connections shall be readily accessible and shall provide sufficient air gap for safe isolation during electrical testing.

iii) If the material of bus conductor and that of the equipment terminal is different, then suitable bi-metallic connectors shall be provided by the contractor.

iv) Seal off bushings shall be provided at the generator end of the bus duct, tap off to PT cubicles and neutral grounding (NG) cubicle.

5.3.9 Grounding

i) The electrically continuous bus enclosure shall be used as the grounding bus. All parts of the bus enclosure, supporting structure and equipment frames shall be grounded to earthing mat.

ii) Duplicate bolted type ground pads shall be provided to accommodate 50x10 mm galvanized steel flats, wherever isolated phase bus duct terminates.

5.3.10 Supporting Structure

i) All supporting structure required for hanging and/or supporting the complete bus duct shall be furnished. These shall include all members, indoor/outdoor posts, bolts, shims, base plates, hangers, brackets, bracings and hardware.

ii) All bus ducts shall be adequately supported and braced to successfully withstand normal operation, vibrations, thermal expansion, short circuit forces and all specified design loads.

iii) Supports shall be designed to provide tolerance of 12mm in the horizontal and vertical directions.

iv) All steel members shall be hot dipped galvanised after fabrication. All hardware shall be of high strength steel with weather resistant finish.

v) Arrangement of support steel work shall be such as to prevent heating of structures caused by circulating currents.

vi) Hinges of all inspection covers shall be strapped across with flexible earth connections.

5.3.11 Air pressuring

i) Air pressurisation of entire bus duct installation shall be provided to keep pressure inside the bus duct 20 to 100mm water column above atmospheric pressure by clean dry air.

ii) Complete arrangement for pressurisation of bus duct with purchaser's compressed instrument air supply which shall be at 5.0 to 7.0 kg/ cm^2 shall be provided including equipment for pressure reduction, drying, bus duct internal pressure indication, dust filters control, safety valves and alarms for failure of pressurisation and excessive leakage. Air drying plants shall have 2x100% redundancy. The degree of protection for control panel shall be IP-52.

iii) To prevent ingress of foreign matter into the bus duct enclosure during plant shut down or maintenance, aluminum end caps shall be provided for the following locations :

a) Generator transformer end, and
b) Unit auxiliary transformer end

iv) One feeder of required capacity shall be made available at each control panel which shall house starters and control systems for blowers, heater, solenoid valves etc.

5.3.12 Current Transformers (CTs)

i) The current transformers shall be epoxy cast-resin, single core ring type conforming to IS;2705. It shall be mounted within the bus duct enclosure and suitable for operation at an ambient temperature existing within the bus duct enclosure which may be in range of 90^0C to 100^0C. Mounting arrangement of CT shall be so designed so as to avoid equalising connections between live conductor and CT inner surface.

ii) CT secondary leads shall be brought out through non-magnetic metallic conduits to a marshalling box (MB) with degree of protection IP-55 (IS:13947 Pt.1). The MB shall be provided with removable aluminum gland plant. The facility for shorting and grounding shall be provided at the terminal blocks.

5.3.13 Voltage Transformers (VTs) and Surge protection (SP) cubicles

i) The VT cubicles and SP cubicles shall be provided separately for each phase and shall be metalclad, dust and vermin proof, free standing, dead front assemblies housing VTs, surge capacitor, lightning arrester, fuses on LV side of VT etc.

ii) Each VT and SP cubicle shall have seal off busing at the terminations of tap-off bus duct to cubicle.

iii) Lightning arrester shall be gapless type, hermetically sealed, connected between line and ground, specifically suitable for generator.

iv) A discharge counter shall be provided for each lightning arrester. The discharge counter register shall be visible without having to open the compartment door.

v) Mineral oil filled/ Askarel filled surge capacitor shall not be acceptable.

vi) The voltage transformer shall be epoxy cast-resin type conforming to IS:3156.

vii) The voltage transformer along with secondary fuses shall be mounted on draw out type carriage. Suitable guide slots and stops shall be provided to ensure easy withdrawal and positioning. The fixed and draw out contacts of voltage transformer primary shall be tinned or silver plated.

viii) Marshalling box shall have sufficient number of terminals with 20% spare, to accommodate all VT leads.

5.3.14 Neutral Grounding (NG) Cubicle

i) The transformer and resistor shall be located in separate cubicles/compartment adjacent to each other. The cubicles shall have hinged access doors capable of being pad locked.

ii) The neutral grounding transformer shall be cast epoxy resin dry type natural air cooled single phase connected between generator neutral and ground.

iii) The loading resistor shall be formed of non-aging, corrosion resistant punched stainless steel grid element provided with necessary insulation and designed for indoor service for a temperature rise not exceeding 300^0C.

iv) All alarm, protection and indication leads shall be wired up to terminal blocks that shall be mounted in a IP:52 enclosure suitable for flush mounting and having a fully hinged cover with lock.

5.3.15 Cubicle Construction (VT and SP, NG cubicle etc.)

All cubicles shall be fabricated from cold rolled sheet steel for minimum 2mm thick suitably reinforced to ensure structural rigidly. The degree of protection for all indoor cubicle shall be IP:52 except for neutral grounding resistor enclosure which shall be minimum IP:23.

5.3.16 Space heater, Illumination and Grounding

Each cubicle shall be equipped with space heater with thermostat, internal illumination lamp, 240 V AC, 5A receptacle. Ground bus suitable for receiving two (2) numbers of 50x6mm galvanised steel flats shall be provided on each cubicle.

5.3.17 Finish

i) Except for supporting steel structures which shall be galvanised, all equipment including bus duct enclosure shall be finished with an under coats of high quality primer followed by two coats of synthetic enamel paint which shall have a thickness not less than 50 microns.

ii) The interior surface finish of bus duct enclosure shall be as per manufacturer's standard. The shade of exterior surface shall be shade RAL 5012 for bus duct and equipment. The shade of interior surface of cubicles shall be glossy white. The identification tag shall be signal red shade ISC 537 or RAL 3001.

5.4 POWER TRANSFORMERS

Three (3) nos. single phase generator transformers and two (2) nos. unit auxiliary transformers for each unit and two (2) nos. station transformers shall be provided. In addition, one (1) no. single phase generator transformer shall be provided as spare.

5.4.1 Codes and Standards

The generator transformers, station transformers and unit auxiliary transformers shall be complete with all accessories and fittings etc. The equipment, materials and service covered by this section shall conform to the following standards :

IS:2026(Part I to IV)	Power transformers
IS:6600/ BS:CP:1010	Guide for loading of oil immersed transformers
IS:335	New insulating oil for transformers and switchgears
IS:3639	Fittings and accessories for power transformers
IS:2099	High voltage porcelain bushings
IS:2705	Current transformers
IS:3347	Dimensions for porcelain transformer bushings
IS:3202	Code of practice for climate proofing of electrical equipment
IS:2147	Degree of protection
IS:2071	Method of high voltage testing
IS:3637	Gas operated relays
IS:1271	Classification of insulating materials for electrical machinery and apparatus in relation to their stability in service
IS:5	Colours for ready mixed points
IS:10028 Part I, II, III	Code of practice for selection, installation and maintenance of transformers.
IS:5561	Electric power connectors
C.B.I.P. publication	Manual on transformers
IEC:60076, Part 7	Power transformers
IS:354	Method of sampling and test for resins for paints
IEC:137	Insulated bushings for alternating voltages above 1000V.
IEC:185	Current transformers.

5.4.2 General Technical Requirements

The transformers shall be capable of remaining in operation at full load for ten (10) minutes after the failure of oil pump or fans without exceeding the winding hot spot temperature of 140^0C. The transformer fitted with two coolers, each capable of dissipating 50% of losses at continuous maximum rating shall be capable of remaining in operation for twenty minutes in the event of failure of pump or fans associated with one cooler without exceeding hot spot temperature of 115^0C.

5.4.3 Specific Technical Requirements

5.4.3.1 Generator Transformers

1) The MVA capacity of the 3 phase bank shall be chosen equivalent to the

maximum MVA capacity of the generator for an ambient temperature of 50^0C. No reduction in capacity shall be made for the auxiliary load tapped before the generator transformer.

2) One (1) no. single phase generator transformer shall be provided as spare and suitably located in the transformer yard.

3) The HV phase & neutral and LV bushing shall be provided with bushing type current transformers (CT)**.**

4) Salient features of the Generator Transformer

i)	Service	Outdoor
ii)	No. of phases	3 Nos. single phase, 2 winding, 200 MVA for each 500MW unit (or … MVA for … MW unit)[2]
iii)	Voltage	HV : 420/ √3kV LV : as per generator terminal voltage
iv)	Frequency	50Hz
v)	Winding connection	HV : Star (with neutral solidly earthed) LV : Delta
vi)	Vector Group	YN d11
vii)	Type of cooling	OFAF
viii)	Impedance (%)	15 (indicative)
ix)	Maximum permissible temperature rise over an ambient of 50^oC	In top oil : 50^0C In winding: 55^0C
x)	Cooling equipments	2x50% cooling radiator banks (suitable no. of working fans and one no. stand-by fan and 2x100% oil pumps)
xi)	Type of tap changer	Off circuit tap changer (OCTC)
xii)	Tapping range	(+)5% to (–)5% in 4 equal steps on HV side
xiii)	Short circuit capability	To withstand the rated short circuit at its terminals for three seconds
xiv)	Type of insulation	HV : Graded insulated LV : Uniform
xv)	System fault level	400kV system : 40/ 50kA[3] for 1 second
xvi)	HV neutral earthing	Solidly earthed through a CT with copper bar suitably with bolted isolating link.
xvii)	HV terminal details	Out door type oil filled condenser bushing insulators with test taps. Terminal connectors suitable for ACSR conductor.
xviii)	HV neutral terminal details	Outdoor type porcelain bushing with all accessories

[2] To be indicated by purchaser as applicable
[3] Fault level to be decided as per system requirement

xix)	LV terminal details	Outdoor type top cover mounted porcelain-bushing suitable for isolated phase bus duct connections.
xx)	Phase arrangement on HV side	R, Y, B sequence (from left while viewing from switchyard and towards the power house).

5.4.3.2 Station Transformers

1) Two (2) nos. station transformers of minimum 63/31.5/31.5 MVA capacity for 500MW (or ....MVA for …MW)[4] units shall be provided.

2) The HV side and neutral bushings shall be provided with bushing type current transformers (CTs)**.**

3) Impedance values of the Station Transformers shall be 9.5 on 40MVA base (with 50%MDBFP). However, the impedance values shall be chosen to ensure the short circuit current to 40kA on the 11kV side including motor contribution under worst loading condition and largest motor motor driven boiler feed pump (MDBFP) starting requirements.

4) **Salient features of the station transformer**

i)	Service	Outdoor
ii)	No. of phases	Three (3) phase bank
iii)	Voltage	HV : 400kV LV : 11kV
iv)	Frequency	50Hz
v)	Type	3 Phase, 3 winding (with two secondary windings of equal voltage and MVA rating)
vi)	Winding connection	HV : Star (with neutral solidly earthed) LV : Delta (Non-effectively earthed)/ Star (Non-effectively earthed)
vii)	Vector Group	**YNd11 d11 or YN y0 y0**
viii)	Type of cooling	ONAF (100% rating)/ONAN (60% rating)
ix)	Maximum permissible temperature rise over an ambient of 50^{o}C	In top oil : 50^{0}C In winding : 55^{0}C
x)	Cooling equipments	2x50% cooling radiator banks (suitable no. of working fans and one no. stand-by fan and 2x100% oil pumps)
xi)	Type of tap changer	On Load Tap changer (OLTC)

[4] To be indicated by purchaser as applicable

xii)	Tapping range	(+)10% to (–)10% in 16 equal steps on HV side
xiii)	Type of insulation	HV : Graded insulated LV : Uniform
xiv)	Maximum fault level	HV : 40/ 50kA[5] for 1 second LV : 40 kA for 1 second
xv)	Neutral terminal to be brought out	On HV winding
xvi)	Short circuit capability	To withstand rated short–circuit at its terminals for 2 seconds.

5.4.3.3 Unit Auxiliary Transformers (UATs)

1) Two (2) nos. unit auxiliary transformers for each unit shall be provided. The capacity of each transformer shall have at least 20% margin over the calculated load requirement. However, minimum capacity of each UAT shall be minimum 25MVA for 500 MW (……MVA for ….MW) unit.[6]

2) **Salient features of the unit auxiliary transformer**

i)	Service	Outdoor
ii)	No. of phases	Three (3) phase bank
iii)	Voltage	HV : as per generator terminal voltage LV : 11kV
iv)	Frequency	50Hz
v)	Winding connection	HV : Delta LV : Star (Non-effectively earthed)
vi)	Vector Group	Dyn1 or Dd0
vii)	Type of Cooling	ONAF / ONAN
viii)	Cooling equipments	2x50% cooling radiator banks (suitable no. of working fans and one no. stand-by fan)
ix)	Maximum permissible temperature rise over an ambient of 50°C	In top oil : 50^0C In winding : 55^0C
x)	Percentage impedance	10 (indicative)
xi)	Type of tap changer	On load tap changer (OLTC)
xii)	Tapping range	± 10% in 16 equal steps for OLTC
xiii)	Type of insulation	HV : Uniform LV : Uniform
xiv)	Maximum fault level	LV : 40kA for 1 second
xv)	LV neutral earthing	Through Neutral Grounding Resistor

[5] Fault level to be decided as per system requirement
[6] To be indicated by purchaser as applicable

xvi)	Short circuit capability	To with-stand rated short–circuit at its terminals for a time duration considering the actual duty to which the transformer is subjected depending upon the generator's initial loading and other design parameters under AVR/ manual mode of operation. Calculations for the above duty shall be carried out and the values could be 3 to 5 seconds instead of 2 seconds indicated in I.S.

3) Neutral Bushing Current Transformer

i)	Rated Transformation ratio	Standard transformation ratio based on 'UAT rating / 1A '
ii)	No. of identical cores	2
iii)	Accuracy	PS
iv)	Short time current, dynamic rating etc	Same as 415V Switchgear
v)	Purpose	Protection

5.4.4 Design requirements

i) Loading Capability

Continuous operation at rated MVA on any tap with voltage variation of ±10% corresponding to the voltage of the tap and in accordance with IS:6600 shall be possible. All the transformers shall operate at full load for at least ten minutes without exceeding the calculated winding hot spot temperature of 140^0C in the event of complete failure of power supply to cooling equipment.

ii) Flux density

The flux density of transformers shall not exceed 1.9Wb/m^2 at any tap position with ±10% voltage variation from voltage corresponding to the tap. Transformer shall also withstand following over fluxing conditions on combined voltage and frequency fluctuations:

a) 110% for continuous rating.
b) 125% for at least one minute.
c) 140% for at least five seconds.

The over- fluxing characteristics upto 170% shall be furnished.

5.4.5 Noise Level

The noise level of transformer shall not exceed the values specified in NEMA TR-1.

5.4.6 Insulation Level

The insulation level for the transformer windings and bushings shall be as follows:

Highest system voltage	Winding			Bushing		
	Rated power frequency withstand voltage	Rated switching Impulse withstand voltage	Rated lightning impulse withstand voltage	Rated power frequency withstand voltage	Rated switching Impulse withstand voltage	Rated lightling impulse withstand voltage
(kV)	(kVrms)	(kVp)	(kVp)	(kVrms)	(kVp)	(kVp)
3.6	10	-	40	10	-	40
12	28	-	75	28	-	75
24	50	-	125	50	-	170
245	395	-	950	460	-	1050
420[7]	-	1050	1300	630	1050	1425

5.4.7 Other Requirements

i) Generator transformers shall be suitable for back charging. It shall be capable of being charged from HV side and kept charged continuously with no load on the LV side without any adverse impact on the transformer life.

ii) Two auxiliary power supplies, 415V, three phase, 4 wire shall be drawn from two separate switchgears for the cooler control cabinet and OLTC cubicle. Cooler control equipments shall be divided in two halves, each having one power supply incomer with bus section between two halves.

iii) Vibration level at rated voltage and frequency shall not be more than 200 microns peak to peak. Average vibration shall not exceed 60 microns peak to peak. Tank stresses shall not exceed 2.0 Kg/mm2 at any point on the tank.

5.4.8 Transformer transportation

Nitrogen filled with sufficient number of impact recorders with necessary arrangement to maintain nitrogen pressure during transit and storage.

5.4.9 Fittings for main and OLTC tank - Following fittings shall be provided with provision for remote indication :

i) Buchholz relay
ii) Oil surge relay to be provided for OLTC
iii) Pressure relief device
iv) Oil temperature indicator
v) Winding temperature Indicator (WTI)

[7] Next higher value of insulation may be adopted for Generator Transformer bushing

vi) Magnetic oil level gauge for main conservator
vii) Remote WTI
viii) Oil level gauge
ix) Remote tap position indicator
x) One no. oil flow indicator for each pump
xi) OLTC features:
- Local control, both manual and electrical
- Remote electrical control.
- Safety interlocks and protection

5.4.10 Transformer Oil Centrifuging Plant

One no. mobile transformer oil centrifuging plant shall be provided. It shall be of sufficient capacity suitable for generator transformer with the following features :

i) The capacity of the transformer oil centrifuging plant shall not be less than 10KLPH and vacuum in three stage degassing plant shall be better than one torr. First stage will be evacuated by a two stage rotary oil sealed pump. Second stage of degassing column will be evacuated by a mechanical booster pump. Third stage of the degassing column will be evacuated by a roots pump. The plant shall be rated for continuous operation. The plant shall be mobile with four (4) wheel pneumatic tyres and suitable for being towed on motorable roads. The plant shall also be supplied along with transformer evacuation system consisting of roots pump backed by a two stage rotary pump. Provision at suitable place in the path of oil being processed shall also be made for connecting an ionic reaction column to be used for the removal of acidity and product of oxidation and ageing in used transformer oil. The ionic reaction column shall also be supplied with the plant. The plant shall be complete with on-line testing instruments and annunciating panel.

ii)

a)	Dielectric strength	:	Suitable for 70kV or better with spark gap of 2.5 mm for 1 minute
b)	Water content in purified oil	:	Better than 20 ppm in single pass
c)	Suspended particles	:	1 Micron
d)	Gas content	:	0.1% by volume
e)	Dissipation factor of oil at 90^0C after filling into the equipment	:	0.05

iii) The centrifuging plant shall be supplied with the essential testing equipments including but not limited to the following :-

a) Neutralization valve or total acidity test set to measure neutralization value of or total acidity content of transformer oil (organic or inorganic) as per IEC 296 and IS 335.

b) Gas content measuring instrument to measure dissolved gas content in percentage of volume of same sample of transformer oil.

c) Karl Fischer Apparatus to measure precisely dissolved moisture content in transformer oil.

d) Inter facial tensiometer to measure the inter facial tension of insulting oil against water under non-equilibrium conditions in dynes/cm.

e) Relative humidity (RH) and Oil dryness test set to measure accurately water vapor pressure dew point and RH of a sample of insulating oil which in turn shall be used to assess the state of dryness of oil immersed solid insulation.

f) Electronic vacuum gauge to measure with precision high vacuum inside the tank if new transformer supplied with protected nitrogen blanket while the same is being evacuated for filling of oil.

g) Dew point meter to measure the dew point of the gas/ air surrounding the insulation of windings inside the transformer tank in order to determine surface mean moisture content of insulation.

h) Automatic Dissolved Gas Analyzer to extract and measure various gases dissolved in electrical insulating oil of EHV transformers which are in service and also the estimation of hydrocarbon gases present in the layers above the transformer oil.

5.5 11kV & 3.3kV SEGREGATED PHASE BUS DUCTS

The 11kV segregated phase busduct shall be provided for i) between UATs secondary terminals and 11kV unit switchgears ii) between station transformer secondary terminals to 11kV station switchgears. The 3.3kV segregated phase bus duct shall be provided between 11kV/ 3.3kV auxiliary service transformers secondary terminals to 3.3kV unit switchgears.

5.5.1 Codes and standards

The Design, manufacture, erection, testing and performance of segregated phase bus duct shall comply with the latest edition including amendments of the following standards :

IS:226	Structural steel (Standard quality)
IS:737	Specification for wrought aluminum and aluminum alloys, sheet and strip (for engineering purpose).
IS:800	Code of practice for use of structural steel in general building construction.
IS:1367 Part-13	Hot dip galvanised coatings on threaded fasteners.
IS:2099	Bushing for A.C. voltage above 1000 volts.
IS:13947 Part-1	Low voltage switchgear and controlgear
IS:2544	Porcelain post Insulators for system with normal voltage greater than 1000 volts.
IS:2633	Methods of testing uniformity of coating on zinc coated articles
IS:4759	Hoot dip zinc coating on structural steel and allied products.
IS:5082	Specification for wrought Aluminum alloys bars, rods, tubes and sections for electrical purposes.
IS:8084	Interconnecting bus bars for A.C. voltage above 1KV upto and including 36KV.
ANSI C-37:23	Metal enclosed bus.
ANSI C-37:24	Effect of Solar radiation on metal enclosed bus.

5.5.2 General Technical Requirements

i) The bus ducts will serve as interconnections between transformers and switchgears. The technical parameters of 11kV and 3.3kV bus ducts are given below :

		11 kV	**3.3 kV**
a)	Number of phase	3	3
b)	Frequency	50 Hz	50 Hz
c)	Nominal voltage	11kV	3.3 kV
d)	Highest system voltage	12 kV	3.6 kV
e)	One minute power frequency withstand voltage (dry and wet)	28 kV	10 kV

f)	Impulse voltage withstand value with 1.2/50 micro-sec wave shape	75 kV	40 kV
g)	Continuous current rating	as required	as required
h)	Short time current rating for 1 second	40kA	40kA
i)	Dynamic current withstand rating	100 kA(peak)	100kA(peak)
j)	Type of cooling	Natural	Natural
k)	Type of bus enclosure	Phase segregated	Phase segregated
l)	Service	Indoor/ Outdoor	Indoor/ Outdoor
m)	Clearance of live parts in air	As per IS	As per IS
	- Phase to phase	---do---	---do--
	- Phase to earth	---do---	---do--
n)	Busbar material	Aluminum alloy	Aluminum alloy
o)	Enclosure and partition material	Aluminum alloy	Aluminum alloy
p)	Minimum thickness of enclosure	3 mm	3 mm
q)	Minimum thickness of partition	2 mm	2 mm
r)	Insulators and bushings		
	- Rated voltage	12 kV	3.6 kV
	- One minute power frequency withstand voltage		
	Dry	35 kV	20kV
	Wet	35 kV	20kV
	- Impulse voltage withstand value with 1.2/50 micro sec. wave shape.	75 kV	40kV
	- Minimum creepage distance	240 mm	130 mm
	- Material of insulator	Porcelain	Porcelain
s)	Size of earthing conductor (mild steel)	65mmx8mm galvanized	65mmx mm galvanized
t)	Design ambient temperature.	50^0C	50^0C
u)	Maximum temperature when carrying rated current continuously		
	- Bus conductor:		
	Bolted joints (Plain or tinned)	90^0C	90^0C
	Bolted joints (silver plated)	105^0C	105^0C
	- Bus duct enclosure	80^0C	105^0C

ii) The bus ducts will be installed partially indoor and partially outdoor and shall be suitable for hot, humid and tropical atmosphere.

iii) The maximum temperature of the bus conductor and enclosure shall be as defined in the technical parameters when operating at maximum ambient temperature and carrying rated current continuously. For outdoor portions the effect of solar radiation shall also be considered. The bidder shall furnish calculation for temperature rise taking effect of solar radiation into consideration.

iv) The bus ducts shall be capable of withstanding the mechanical forces and thermal effects of three phase short circuit currents, mentioned in the technical parameters, without any damage, deformation or deterioration of material.

5.5.3 Equipment Description

i) Bus conductor

The bus conductor shall be of high conductivity aluminium alloy, adequately supported on insulators to withstand dynamic stress due to the specified short circuit current, without permanent deformation and suitable flexible joints shall be provided wherever required.

ii) Enclosure

a) The bus duct enclosure shall be phase segregated type. The three phases of bus conductors shall be enclosed in a weather and vermin proof, dust-tight enclosure made of Aluminum alloy. Phase barriers made of aluminum alloy shall be provided in the bus ducts for phase segregation. The shape of the enclosure shall preferably be rectangular. All horizontal runs of the bus ducts shall have a suitably sloped enclosure top to prevent retention of water.

b) Bus duct enclosure shall have a degree of protection conforming to IS : 8084 requirements for water tightness test and air leakage test. Minimum enclosure thickness shall be 3 mm. The bus duct enclosure shall have expansion bellows to take care of temperature changes and vibrations.

c) At each enclosure joint in the outdoor portion of the bus duct run, a suitable rain hood shall be provided for additional protection against water ingress. The gaskets shall preferably of the jointless type, in case of a joint, the same shall be at bottom.

d) Opening covered with louvers backed up with removable dust filters and silicagel breather shall be provided at indoor and outdoor potion of bus duct to enable the bus duct enclosure to breathe in a manner so that possibility of condensation and ingress of dust is minimized.

e) Filtered drain plugs for drainage of condensate and seepage water if any shall be provided at the lowest points and at such location where accumulation of condensate can be expected. These drain plugs shall be located at a suitable place convenient to operate.

iii) Insulators

a) Bus support insulators shall be interchangeable, high creep, high strength and made of fine glazed solid porcelain manufactured by wet process.

b) The insulators shall be designed and mounted in such a manner so as to facilitate easy inspection, removal and replacement without disturbing the conductor.

iv) Space heaters

The bus ducts shall be provided with adequate number of thermostatically controlled space heaters of adequate capacity to maintain the internal temperature above the dew point to prevent moisture condensation within the bus duct. Space heaters shall be rated for 240V, single phase, 50Hz AC supply.

v) Bus duct support

a) Bidder shall provided necessary support structures and all hardware structures to support the bus ducts all along its route.

b) In the indoor portions, the bus ducts shall be supported from floor / roof beams or steel inserts in upper floors. In the outdoor potions, they shall be supported from the ground, by means of steel structures, unless indicated otherwise in the specification drawings.

c) All hardware shall be galvanised or cadmium plated.

vi) Earthing

A continuous 65x10 mm galvanised mild steel earth bar shall be provided along the entire run of each bus duct. Each section of the bus duct enclosure shall be bonded to this earth bar at least at both ends of the enclosure. The earth bar shall be connected to the main earthing system at its two ends by the contractor.

vii) Connection and termination

a) All matching flanges, flexible connections, adopter boxes, gaskets, fittings, hardware and support required for termination of the bus duct at transformer and switchgear ends, shall be provided by the Bidder.

b) Flexible connections at equipment termination shall be able to take care of misalignment upto 25mm in all directions.

c) The equipment terminal connections shall be easily accessible and shall provide sufficient air gap for safe isolation of equipment during testing.

d) Suitable bi-metallic connectors shall be provided wherever the material of bus conductor and equipment terminals are different.

viii) Paint and finish

a) The paints shall consists of one coat of primer followed by one anti-corrosive coat for steel structures. Finally two coast of finishing paint shall be given. The final colour shade shall be BLUE RAL:5012 .

b) The bus conductor and the inside surface of the enclosure shall be treated with matt black paint for efficient heat dissipation.

5.6 AUXILIARY SERVICE TRANSFORMERS

The auxiliary service transformers shall be provided to obtain the 3.3kV and 415V power supply for main plant area.

i) The 3.3kV power supply to the unit auxiliaries shall be obtained from 11kV/ 3.3kV auxiliary service transformers.

ii) The 415V power supply to the unit auxiliaries shall be obtained from 11kV/ 433V or 3.3kV/433V auxiliary service transformers.

5.6.1 Codes and standards

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

IS:2026 (Part I to IV)	Power Transformers.
IS:6600/BS: CP:1010	Guide for loading of oil immersed transformers
IS:335	New insulating oil for transformers and switchgears
IS:3639	Fittings and accessories for power Transformers
IS:2099	High voltage porcelain bushings
IS:2705	Current transformers
IS:334	Dimensions for porcelain Transformer bushing
IS:3202	Code of practice for Climate proofing of electrical equipment
IS:2147	Degree of protection.
IS:2071	Method of high voltage testing
IS:3637	Gas operated relays.
IS:1271	Classification of insulating materials for Electrical Machinery and apparatus in relation to their stability in service.
IS:5	Colours for ready mixed points.
IS:10028	Code of practice for selection, Installation and maintenance of transformers Part I, II and III
IS:5561	Electric Power connectors
IS: 11171	Dry type transformers
CBIP	Manual on transformers.

5.6.2 Technical Parameters

i) The transformers shall be provided with delta-connected primary and a star–connected secondary with the star point brought out and resistance earthed for 3.3KV system and solidly earthed for 415V system.

ii) The transformers shall have following technical parameters :

a) Type	Two winding
b) Service	Outdoor (Oil Filled) / Indoor (Dry type :epoxy cast resin/ resin encapsulated air cooled type)

c)	Number of phases	Three
d)	Frequency	50 Hz
e)	Type of cooling	ONAN for oil filled
f)	Ratings	As per system requirement.
g)	Impedance	As per system requirement.
h)	Duty	Continuous
i)	Over load	As per IS:6600
j)	System fault level	
	11 kV	40 kA for 1 second
	3.3 kV	40 kA for 1 second
	415V	50 kA for 3 second

		11 kV	**3.3 kV**	**433V**
k)	Windings			
	Insulation		-----Uniform----	
	- Power frequency test level (KV rms)	28	10	3
	- Basic impulse level (kV peak)	75	40	--
	- Highest voltage for each(kV) winding	12	3.6	1.1

l) Earthing

a) 415V : solidly grounded,

b) 11kV, 3.3kV : earthed through resistance to limit the current to 300A or high resistance grounding through artificial earthing transformer and earthing resistance

m) Tap changer — Off circuit tap changer with ±5% in steps of 2.5 % on HV side

		11 kV	3.3 kV	0.433 kV
n)	Bushing			
	- Rated voltage(kV)	12	3.6	1.1
	- Basic Impulse level (kVp)	75	40	--
	- Wet, dry power withstand voltage(kV)	28	10	3
	- Minimum creepage distance (mm)	As per relevant IEC/ IS		
	- Mounting (mm)	Tank / Transformer body		

o) Terminal details

- High Voltage (3.3kV and11 kV)	Busduct/ Cable
- 433V phase and neutral	Busduct/ Cable box However, non-segregated busduct for transformers rated 1000 KVA and above shall be provided.

iii) Temperature rise over an ambient of 50°C

a) Out-door transformers :

In top oil (measured by thermometer):	50°C
In winding (measured by resistance):	55°C

b) In-door transformers :

In winding (by resistance method)	90^0C or lower as permissible for class of insulation offered

iv)	Class of insulation	F or better (for dry type transformers) A or better (for oil filled transformers)
v)	Noise level at rated voltage and frequency	As per NEMA Pub TR-1

5.6.3 Neutral Grounding Resistor

i)	Resistance (ohm)	As per requirements
ii)	Rated current and duration	300A for 10 seconds
iii)	Application	Grounding of 11kV and 3.3 kV system
iv)	Service	Outdoor
v)	Resistor materials	Punched stainless steel grid element
vi)	Maximum allowable temperature rise	350°C

vii)	Mounting	12kV grade insulator (for 11kV)/ 3.6kV grade insulator (for3.3 kV)
viii)	Enclosure degree of protection	IP-33 as per IS-2147
ix)	Terminal bushing rated voltage	12kV grade insulator (for 11kV)/ 3.6kV grade insulator (for3.3 kV)
	Rated current	300 A
	Basic Impulse level	75kVp (for 11kV)/ 20kVp (for 3.3kV)
	Quantity	two each
	Mounting	Roof of enclosure
x)	Terminal details	
	- To transformer neutral	Copper flat of minimum 50 mm x 6 mm
	- To earth	Through Galvanized steel flat of size 50mm x 10mm

5.6.4 Performance

Fault conditions :

a) The transformer and all accessories including CT's etc. shall be capable of withstanding for two (2) seconds without any damage on external short circuit at bushing terminal.

b) The flux density at normal voltage and frequency shall be such that flux density in any part of the core and yoke at rated MVA, rated Voltage and frequency, with 10% voltage variation from the voltage corresponding to the tap, shall not exceed 1.9 wb/m^2.

c) Transformers shall accept without injurious heating, combined voltage and frequency fluctuations which produce an overfluxing condition of 120% for one (1) minute.

d) Noise level when energized at normal voltage and frequency shall not exceed, when measured under standard conditions as per NEMA standard publication TR-1, the values specified are as below:

- For 3 MVA transformers - 63 db
- For less than 2 MVA Transformers - 60 db

5.6.5 Painting

All steel surfaces shall be thoroughly cleaned by sand blasting or chemical agents as required, to produce a smooth surface free of scales, grease and rust. The internal surfaces in contact with insulating oil shall be painted with heat resistant insulating varnish which shall not react with and be soluble in the insulating liquid used. The external surfaces, after cleaning, shall be given a coat of high quality red oxide or yellow chromate primer followed by filler coats. All supporting structures and hardware shall be hot dip galvanized.

The transformer shall be finished with two coats of battle ship grey (IS Shade # 632) synthetic enamel paint unless otherwise specified.

5.6.6 Detailed description

i) Tank

The transformer tank and cover shall be fabricated from high grade low carbon plate steel of tested quality. The tank and the cover shall be of welded construction. At least two inspection openings, one at each end of the tank with welded flange(s) and bolted cover(s) shall be provided on the tank cover. The inspection opening(s) shall be of sufficient size to afford easy access to the lower ends of the bushings, earth connection etc.

ii) Under Carriage

a) The transformer tank shall be supported on steel structure with detachable forged steel flanged wheel suitable for moving the transformer completely filled with oil. Rail gauge shall be 1676 mm in both directions. Flanged wheels shall be spaced accordingly. Wheels shall be provided with suitable bearings, which will resist rust and corrosion and shall be equipped with fittings for lubrication. It shall be possible to swivel the wheels in two directions, at right angels to or parallel to the main axis of the transformers.

b) Jacking pads shall be provided on the transformer. It shall be possible to change the direction of the wheels through 90 degree when the transformer is lifted on jacks to permit movement of the transformer both in longitudinal and transverse directions.

c) Suitable hydraulic (synchronous) jacks (4 nos.) for lifting the transformer shall be supplied.

iii) Conservator tank

a) The conservator tank shall have adequate capacity to accommodate oil preservation system and volumetric expansion of the total cold oil volume in the transformer and cooling equipment for a change in temperature from minimum ambient temperature as per IS.

b) The conservator shall be fitted with magnetic oil level gauge with two independent low level electrically insulated alarm contacts.

c) Each conservator vessel/ air bag shall be fitted with a silica gel filter breather.

iv) Pressure relief device and explosion vent

a) For all transformers, the conventional diaphragm type of explosion vent shall be provided.

b) In addition to the explosion vent, pressure relief device shall be provided for transformers rated 2 MVA and above which shall be of sufficient size for rapid release of any pressure that may be generated within the tank and which may result in damage of the equipment.

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

v) Buchholz relay

A double float type Buchholz relay conforming to IS:3637 shall be provided. All gas evolved in the transformer shall collect in this relay. The relay shall be provided with a test cock suitable for a flexible pipe connection for checking its operation. A copper tube shall be connected from the gas collector to a valve located about 1200 mm above ground level to facilitate sampling with the transformer in service. The device shall be provided with two electrically independent potential free contacts, one for alarm on gas accumulation and the other for tripping on sudden rise of pressure.

vi) Temperature indicator

a) Oil temperature indicator :

All transformers shall be provided with a 150 mm dial type thermometer for top oil temperature indication. The thermometer shall have adjustable, electrically independent ungrounded alarm and trip contacts, maximum reading pointer and resetting device and shall be mounted in the Marshalling Box.

b) Winding temperature indicator :

A device for measuring the hot spot temperature of the winding shall be provided. The accuracy class of winding temperature indicator shall be ± 2^0C or better.

vii) Earthing terminals

Two earthing pads suitable for connecting 50 x 10 mm mild steel flat shall be provided at positions close to the two diagonally opposite bottom corners of tank. These grounding terminals shall be suitable for bolted connection.

viii) Core

a) The core shall be constructed from high grade non-aging, cold rolled grain oriented silicon steel laminations.

b) The insulation of core to bolts and core to clamp plates shall be able to withstand a voltage of 2kV RMS for one (1) minute.

c) Eye and lugs shall be provided for lifting the core.

ix) Windings

a) The conductors shall be electrolytic grade copper free from scale and burrs.

b) Tappings shall be so arranged as to preserve the magnetic balance of transformers at all voltage ratios.

x) Insulating oil

a) The new insulating oil, before pouring into the transformer (i.e. 10% topping up oil) shall confirm to the requirements of IS:335. No inhibitors shall be used in the oil.

b) The oil samples taken from the transformer at site shall conform to the requirement of IS:1866 and the value for various parameters shall not lie very close to the limiting values specified in IS:1866 with respect to the reconditioning of oil.

c) 5% extra oil shall be supplied for topping up, in non returnable containers suitable for outdoor storage.

xi) Oil preservations system

a) The transformers rated below 7.5MVA shall be provided with conventional single compartment conservator with dry air filling the space above the oil.

b) The transformers rated 7.5MVA and above shall be provided with diaphragm sealing type (air bag) oil preservation arrangement in the conservator to prevent oxidation and contamination of oil due to contact with atmospheric air.

xii) Valves

a) Valves shall be of gun metal/ cast steel up to 50 mm size and of cast iron bodies with gunmetal fittings for sizes above 50 mm.

b) Each transformer shall be provided with atleast following valves on the tank:

- Drain valves so located as to completely drain the tank.

- Two filter valves on diagonally opposite corners of 50 mm size.

- Oil sampling valves not less than 8 mm at top and bottom of main tanks.

- One 15 mm air release plug.
- Valves between radiators and tanks.

5.6.7 Transformer cooling system

Tank mounted radiators banks shall have bolted flanged connections and pipe extensions to permit withdrawal of transformer tank without disturbing the radiators. Flexible joints shall be provided in the interconnecting pipes (unless otherwise approved) to facilitate erection and dismantling and reduce transfer of vibrations from tank to radiator. The interconnecting pipes shall be provided with drain plug and air release vents.

5.6.8 Terminal arrangement

i) Bushings

a) The bushing shall conform to the requirements of IS:2099 and IS:3347.

b) All transformer bushings shall be of porcelain (for oil filled)/ epoxy (for dry type).

c) The neutral terminal of 433V winding shall be brought out on a bushing along with the 433V phase terminal to from a 4 wire system for the 433V. Neutral CTs shall be located in the lead coming out of the winding and location of these CTs shall not be inside the tank.

d) The neutral terminal of secondary shall be brought out through an outdoor bushing. Further this neutral terminal shall be connected by a copper flat of size 50 mm x 6 mm, which shall be brought down upto 100 mm above ground. The copper flat shall be insulated and supported from the tank body.

ii) Cable boxes

a) Wherever cable connections are specified, suitable cable boxes shall be provided and shall be air insulated.

b) Cable boxes shall have drilled gland plate of adequate size to receive cables and to allow easy termination.

c) Removable drilled gland planes shall be provided in the cable boxes.

d) The additional supports for the cable boxes shall be galvanised iron.

e) The contractor shall provide earthing terminals on the cable box, to suit 50mmx6 mm GI flat.

iii) Bus duct

a) Wherever Bus duct termination is specified a flanged throat or equivalent-connection shall be provided for termination of bus duct enclosure. The winding termination shall be outdoor type bushing. The material of the bus duct termination arrangement of the transformer shall be nonmagnetic. The bus duct may be either phase-segregated or non-segregated.

b) Tolerance permissible for the height of terminals and bus duct flange location specified for bus duct termination over ground level is ±5mm. Contractor has to ensure that radiator, conservator and explosion vent do not obstruct the path of the bus-ducts.

5.6.9 Current Transformers

i) The protection CT's on neutral of transformers and neutral grounding transformers shall be bushing mounted. It shall be possible to remove the turret mounted CT's from the transformer tank without removing the tank cover.

ii) The current transformers shall be comply with IS:2705.

iii) All secondary leads of bushing mounted CT's shall be brought to a terminal box near each bushing and then wired upto transformer marshalling box.

iv) The CT terminals shall have shorting facility.

5.6.10 Marshalling box

i) A sheet steel weather, vermin and dust proof marshalling box shall be furnished. The sheet steel used shall be at least 2.0 mm (CRCA) thick. The box shall be free standing floor mounted/tank mounted type and have a sloping roof. The degree of protection shall be IP-55 in accordance with IS:2147.

ii) The marshalling box shall have a glazed door of suitable size for convenience of temperature indicators reading.

iii) All incoming cables shall enter the marshalling box from the bottom.

5.6.11 Off-circuit tap changer (OCTC)

i) The tap change switch shall be three phase, hand operated for simultaneous switching of similar taps on the three phases by operating on external hand wheel.

ii) Arrangement shall be made for securing and pad-locking the tap changer in any of the working positions, and it shall not be possible for setting or padlocking it in any intermediate position. An indicating device shall be provided to show the tap in use.

5.6.12 Fittings

The following fittings (wherever applicable) shall be provided with all the transformers, unless mentioned specifically otherwise.

a) Conservator with oil filling hole and cap, isolating valve, drain valve, vent valve and oil preservation equipment as specified.
b) Magnetic oil level gauge with low level alarm contacts. It shall be welded to the tank.
c) Prismatic glass oil level gauge.
d) Pressure relief device and Explosion Vent.
e) Air release plug.
f) Inspection opening and covers
g) Bushing with metal parts and gaskets to suit the termination arrangement specified in Technical Parameters.
h) Oil temperature indicator with alarm and trip contacts.
i) Winding temperature indicator (s) with alarm and trip contacts.
j) Covers, lifting eyes, transformer lifting lugs, jacking pads, towing holes, core and winding lifting lugs, supporting structure, foundation bolts etc.
k) Protected type Mercury or alcohol in glass thermometer.
l) Bottom and top filter valves with threaded male adopters, bottom sampling valve and drain valve.
m) Rating and diaphragm plates.
n) Off circuit tap changing equipment.
o) Marshalling Box
p) Cable Boxes
q) Buchholz Relay
r) Dehydrating filter breather
s) Bushing current transformers (wherever applicable)
t) Earthing terminals.
u) Remote WTI. It shall nor be repeater dial of local WTI
v) Radiator
w) Wheels
x) Oil
y) V/v schedule plate
z) Rain hoods for B/z relay, MOG and PRV

5.7 MOTORS

All the 11kV, 3.3kV and 415V motors required for unit auxiliaries shall be provided.

5.7.1 Codes and Standards

All the motors shall conform to the following standards :

IS:325, IEC:60034	Three phase induction motors
IS:996, IEC:60034	Single phase AC motors
IS:3177, IEC600:34	Crane duty motors
IS:4722	DC motors

5.7.2 General Requirements

i) All the motors shall be suitable for an ambient temperature of 50^0C and relative humidity of 95%. The motors shall be suitable for operation in a highly polluted environment

ii) Voltage and Frequency variations : All motors shall be suitable for follwing variations

Frequency variation	(+) 3% and (-)5%
Voltage variation	a. (±) 6% for 11kV/ 3.3 kV b. (±) 10% for 415 V
Combined variation of voltage and frequency.	10% (absolute sum)

iii) The voltage level for motors shall be as follows

1)	Upto 200 KW	415V
2)	Above 200 kW and upto 1500 kW	3.3 kV
3)	Above 1500 kW	11 kV

iv) Fault level

1)	11 kV and 3.3 kV	40kA for 1 second
2)	415V	50kA for 3 second
3)	220V DC	25kA for 1 second

v) System grounding

1)	11 kV and 3.3 kV	Earthed through resistance to limit the current to 300A or high resistance grounding through artificial earthing transformer and earthing resistance
2)	415V	solidly grounded
3)	220V DC	Ungrounded

vi) Paint shade shall be RAL 5012 (Blue).

vii) Degree of protection

a.	Indoor motors	IP 54
b.	Outdoor motors	IP 55
c.	Cable box – indoor area	IP 54
d.	Cable box – outdoor area	IP 55

5.7.3 Type

i) AC Motors:

- Squirrel cage induction motor suitable for direct-on-line starting.
- Crane duty motors shall be slip ring type induction motor

ii) DC Motors: Shunt wound.

5.7.4 Rating

i) Continuously rated (S1). However, crane motors shall be rated for S4 duty i.e. 40% cyclic duration factor.

ii) Maximum continuous motor ratings shall be at least 10% above the maximum load demand of the driven equipment unless otherwise specified, under entire operating range including voltage and frequency variations.

iii) Motors starting shall be as per IEC-60034 (part12)

5.7.5 Temperature Rise

i)	Air cooled motors	70^0C by resistance method for both class 130(B) and 155(F) insulation.
ii)	Water cooled motors	80^0C over inlet cooling water temperature, by resistance method for both class 130(B) and 155(F) insulation.

5.7.6 Operational Requirements

i) Starting Time

a) For motors with starting time upto 20 secs. at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit shall be at least 2.5 secs. more than starting time .

b) For motors with starting time more than 20secs. and upto 45secs. at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit shall be at least 5 secs. more than starting time.

c) For motors with starting time more than 45secs. at minimum permissible voltage during starting, the locked rotor withstand time under hot condition at highest voltage limit shall be more than starting time by at least 10% of the starting time.

d) Speed switches mounted on the motor shaft shall be provided in cases where above requirements are not met.

ii) Torque Requirements

a) Accelerating torque at any speed with the lowest permissible starting voltage shall be at least 10% motor full load torque.

b) Pull out torque at rated voltage shall not be less than 205% of full load torque. It shall be 275% for crane duty motors.

iii) Starting voltage requirement

a) All motors (except mill motors):

80% of rated voltage for motors upto 4000 kW
75% of rated voltage for motors above 4000 kW

b) For mill motors

85% of rated voltage for motors above 1000 kW
90% of rated voltage for motors below 1000 kW

5.7.7 Design and constructional features

i) Suitable single phase space heaters shall be provided on motors rated 30kW and above to maintain windings in dry condition when motor is standstill. Separate terminal box for space heaters and RTDs shall be provided.

ii) All motors shall be either totally enclosed fan cooled (TEFC) or totally enclosed tube ventilated (TETV) or closed air circuit air cooled (CACA) type. However, motors rated 3000 kW or above can be closed air circuit water cooled (CACW).

iii) For hazardous location such as fuel oil facilities area, the enclosure of motors shall have flame proof construction conforming to IS:2148 as detailed below

1)	Fuel oil area	Group – IIB
2)	Hydrogen generation plant area	Group – IIC (or Group-I Div-II as per NEC)

iv) Winding and Insulation

1)	Type	Non-hygroscopic, oil resistant, flame resistant

2)	Starting duty	Two hot starts in succession, with motor initially at normal running temperature
3)	11kV, 3.3 kV AC motors	Class 155(F) : with winding temperature rise limited to class 130(B). They shall withstand 1.2/50microsec. Impulse Voltage wave of 4U+5 kV (U=Line voltage in kV). The coil inter-turn insulation shall be as per IEC-60034 – Part 15 followed by 1 min power frequency high voltage test of appropriate voltage on inter turn insulation.
4)	415V AC and 220V DC motors	Class 130 (B)

v) Motors rated above 1000KW shall have insulated bearings to prevent flow of shaft currents.

vi) Motors with heat exchangers shall have dial type thermometer with adjustable alarm contacts to indicate inlet and outlet primary air temperature.

vii) Noise level and vibration shall be limited within the limits prescribed in IS: 12065 and IS: 12075 respectively.

viii) In 11kV and 3.3kV motors, at least four numbers simplex/ two numbers duplex platinum resistance type temperature detectors shall be provided for each phase of stator winding. Each bearing shall preferably be provided with dial type thermometer with adjustable alarm contact and two numbers duplex platinum resistance type temperature detector Motor body shall have two earthing points on opposite sides.

ix) 11kV and 3.3kV motors can be offered with either elastomould termination or dust tight phase separated double walled (metallic as well as insulated barrier) cable boxes. In case elastomould terminations are offered, then protective cover and trifurcating sleeves shall also be provided. Removable gland plates of thickness 3 mm (hot/cold rolled sheet steel) or 4 mm (non magnetic material for single core cables) shall be provided in case of cable boxes.

x) All motors shall be so designed that maximum inrush currents and locked rotor and pullout torque developed by them at extreme voltage and frequency variations do not endanger the motor and driven equipment.

xi) The motors shall be suitable for bus transfer schemes provided on the 11kV, 3.3 kV, 415V systems without any injurious effect on its life.

xii) Motors rated 2000kW and above shall be provided with neutral current transformers of PS class on each phase in a separate neutral terminal box for differential protection.

5.8 11kV & 3.3kV SWITCHGEARS

The following 11kV and 3.3kV switchgears shall be provided:

a) All 11KV unit switchgears as required for unit auxiliaries
b) All 3.3KV unit switchgears as required for unit auxiliaries
c) 11kV station switchgears for providing 11kV supply feeders to station facilities (e.g. coal handling system, ash handling system, water systems etc.) and tie feeders with unit switchgears

5.8.1 Codes and standards

The equipment, materials and service shall conform to the latest applicable provision of the following standards :

IS : 722	AC electricity meters
IS : 996	Single phase small AC and universal electrical motors.
IS : 1248	Direct Acting indicating analogue electrical measuring instruments and Accessories
IS : 13947	Degree of protection provided by enclosures for low voltage switchgear and control gear
IS : 2544	Porcelain post insulators for systems with nominal voltages greater than 1000V
IS : 2705	Current transformers.
IS : 3156	Voltage Transformers
IS : 3231	Electrical relays for power system protection
IS : 3427	Metal enclosed switchgear and control gear
IS : 5082	Specification for wrought aluminium and aluminium alloy bars, rods, tubes and selections for electrical purposes.
IS : 6005	Code of practice for phosphating of iron and steel.
IS : 8686	Specification for static protective relays.
IS : 9046	AC contactors for voltages above 1000 volts and upto and including 11000V.
IS : 9224	Low voltage fuses
IS : 9385	HV fuses
IS :9431	Specification for indoor post insulators of organic material for system with nominal voltages greater than 1000 volts upto and including 300 kV
IS : 9921	AC dis-connectors (isolators) and earthing switches for voltages above 1000V
IS : 11353	Guide for uniform system of marking and identification of conductors and apparatus terminals.
IS : 13118	Specification for high voltage AC circuit breakers.
IEC-60099 part 4	Metal oxide surge arrestor without gap for AC system
IEC-62271-100	High voltage alternating current circuit breakers.
IEC-60099-1	Non-linear resistor type gapped arrestor for AC systems
IEC-60298	High voltage metal enclosed switchgear and control gear.
CIGRE WG 13.02 Chapter-3	Recommendation for substitute test for switching over voltage test

5.8.2 Technical Parameters

i) The switchgears shall be indoor, metal clad, draw out type. The feeders rated 2000kW and above shall be provided with vacuum/ SF_6 circuit breakers. Outgoing breakers shall be suitable for switching transformers and motors at any load. They shall be capable of being used for frequent direct-on-line starting of squirrel cage induction motors of following ratings

a) 3.3KV Above 200 kW up to 1500 kW

b) 11 kV Above 1500 kW

Surge arrestor shall be provided for each motor feeder

The operating mechanism of the circuit breakers shall be of the stored energy type DC motor operated charging springs.

ii) The circuit breaker, contactor and switchgear assemblies shall have the following technical parameters :

a) System parameters

1)	Nominal System voltage	11 kV	3.3 kV
2)	Highest System voltage	12 kV	3.6 kV
3)	Rated Frequency	50 Hz	50 Hz
4)	Number of phases	Three	Three
5)	System neutral earthing	Earthed through resistance to limit fault current to 300A or High resistance grounding through artificial earthing transformer and earthing resistor	
6)	One minute power frequency withstand voltage		
	- for Type tests	28	10
	- for Routine tests	28	10
7)	1.2/50 microsecond Impulse withstand voltage	75 kV (peak)	40 kV(peak)
8)	Maximum system fault level including initial motor contribution	40 kA for 1 second	40 kA for 1 second
9)	Dynamic withstand rating	100 kA (peak)	
10)	Control supply voltage		
	- Trip and closing coils	----- 220V DC -----	

	- Spring charging motor	------220V DC ----- (240V AC can be accepted for off-site areas)
	- Space heaters	----- 240V AC ----
11)	Ambient temperature	50^0C

b) Busbars

1)	Continuous current rating at 50^0C ambient	as per system requirements
2)	Temperature rise	- 40^0C for plain joints - 55^0C for silver plated joints

c) Constructional requirements

1)	Colour finish - exterior and interior	as mentioned elsewhere
2)	Cable entry	
	- Power cables	Bottom
	- Control cables	Bottom
3)	Bus duct entry	----Top---
4)	Earthing conductor	Galvanised steel strip

d) Circuit breakers

1)	Short circuit breaking current	
	- AC component	40 kA
	- DC component	As per IS 13118 or IEC 62271
2)	Short circuit making current	100 kA (peak)
3)	Operating Duty	B – 3min – MB – 3min – MB
4)	Total break time	Not more than 4 cycles
5)	Total make time	Not more than 5 cycles
6)	Operating Mechanism	Motor wound spring charged stored energy type as per IEC 62271

e) Relays

	One minute power frequency	2.0 kV (rms)	2.0 kV (rms)

f) Meters

1)	Accuracy class for	
	a) Energy accounting and audit meters	
	- on each incoming feeder of 11/ 3.3kV buses	Not inferior to 1.0S
	- on all 11kV and 3.3kV motor feeders	-------do-------
	b) other meters	1.0

Note : In case, numerical relays having built-in features of energy measurement of requisite accuracy are provided in switchgear, separate energy meter is not necessary.

2)	One minute power frequency	2.0 kV (rms)

g) Current Transformer

1)	Class of Insulation	Class E or better
2)	Rated output of each	Adequate for the relays and devices connected, but not less than fifteen (15) VA.
3)	Accuracy class	
	a) Measurement core for energy accounting and audit meters	
	- on each incoming feeder of 11/ 3.3kV buses	Not inferior to 1.0S
	- on all 11kV and 3.3kV motor feeders	------do------
	b) Other meters	1.0
4)	Protection core	
	- differential and core balance CTs	PS
	- other protection CTs	5P20
5)	Minimum primary earth fault current to be detected by core balance CT	3 A

h) Voltage Transformers

1)	Rated voltage factor	1.2 continuous for all VTs, and 1.9 for 30 sec. for star connected VTs
2)	Measurement	
	- for energy accounting and audit	Not inferior to 1.0S
	- for others	1.0
3)	Protection	3P

i) Fuses

1)	Voltage class	11kV	3.3kV
2)	Rupturing Capacity	Adequate for 100 kA (peak)	
3)	Rated current	As per application	

j) Surge arresters

		11 kV	3.3kV
1)	Nominal discharge current (8x20 micro second)	500 Amp	

2)	Maximum system voltage	12 kV	3.6kV
3)	Maximum standard impulse spark over voltage (peak)	25 kV (without any positive tolerance)	
4)	Residual voltage at nominal discharge current	25 kV	8kV
5)	Temporary over voltage capability (rms)		
	- For 10,000 seconds	12 kV	3.6kV
	- For 5 seconds	14.3 kV	4.3kV
6)	Installation	Inside the switchgear panel	

k) Contactors

1)	Nominal system voltage	----	3.3kV
2)	Highest system voltage	----	3.6kV
3)	Rated frequency	----	50kZ
4)	Control supply voltage	-----	220 V DC
5)	Utilization category	-----	AC-3

l) Transducers

1) **Current transducers**

a)	Input	0-1 A (CT secondary)
b)	Rated frequency	50 Hz
c)	Output	4-20 mA (2 Nos. decoupled)
d)	Accuracy	0.5%

2) **Voltage transducers**

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

3) **VAR transducers**

a)	Input	3 phase, 3-wire 1 A (CT secondary) 110 V (VT secondary)
b)	Rated frequency	50 Hz
c)	Output	4-20 mA (2 nos. de-coupled)
d)	Accuracy	0.5%

4) **Watt transducers**

a)	Input	3 phase, 3-wire 1A (CT secondary) 110V (VT secondary)
b)	Rated frequency	50 Hz
c)	Output	4-20 mA (2 nos. decoupled)
d)	Accuracy	0.5%

5) **Frequency transducers**

a)	Input	110V (VT secondary)
b)	Rated frequency	50 Hz
c)	Range	45 to 55 Hz
d)	Output	4-20 mA (2 nos. decoupled)
e)	Accuracy	0.5%

5.8.3 Bus Transfer Scheme

i) The 11kV buses of unit switchgears shall be connected to their respective unit auxiliary transformer through segregated bus-ducts. These buses of unit switchgears shall also be connected to 11kV buses of station switchgears through tie feeders and breakers located at the unit and station end. Automatic fast bus transfer scheme shall be provided between 11kV unit and station switchgears such that in case of loss of supplies to unit switchgears from UAT, the same shall be restored from respective station switchgears. The automatic bus transfer system shall consist of fast, slow etc. transfer in auto mode. The bus transfer scheme shall also have manual mode to initiate transfer command manually.

ii) Manual live change-over and Automatic Reserve Closure (ARC)/ slow change-over shall be provided for 11kV station to station switchgear and for main and reserve incomers to 3.3kV unit switchgears.

5.8.4 Metering

The energy meters shall be provided as per the Central Electricity Authority (Installation and Operation of Meters) Regulations,2006 and its amendments. However, the following energy accounting and audit meters shall be provided in general :

- On each incoming feeder of 11kV and 3.3kV buses.
- On all 11kV and 3.3kV motor feeders

Energy accounting and audit meters shall be of accuracy class of 0.2S. 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.

5.8.5 General Technical Requirements

a) Switchgear panel

i) The switchgear shall have a single front, single tier, fully compartmentalized, metal clad construction complying with clause No. 3.102.1 of IEC-60298, comprising of a row of free standing floor mounted panels. Each circuit shall have a separate vertical panel with distinct compartments for circuit breaker/contactor truck, cable termination, main busbars and auxiliary control devices. The adjacent

panels shall be completely separated by steel sheets except in busbar compartments where insulated barriers shall be provided to segregate adjacent panels.

ii) The circuit breakers/ contactors and bus VTs shall be mounted on withdrawable trucks which shall roll out horizontally from service position to isolated position.

iii) The trucks shall have distinct Service, Test and Isolated positions. It shall be possible to close the breaker/contactor compartment door in Isolated position also, so that the switchgear retains its specified degree of protection. While switchboard designs with doors for breaker/contactor compartments would be preferred, standard designs of reputed switchgear manufacturer's where the truck front serves as the compartment cover may also be considered, provided the breaker/ contactor compartment is completely sealed from all other compartments and retains the IP-4X degree of protection in the Isolated position.

iv) The switchgear assembly shall be dust, moisture, rodent and vermin proof with the truck in any position Service, Test and Isolated or removed, and all doors and covers closed. All doors, removable covers and glass windows shall have gaskets all round with synthetic rubber or neoprene gaskets.

v) The VT/ relay compartments shall have degree of protection not less then IP:52 in accordance with IS:13947. However, remaining compartments can have a degree of protection of IP: 4X. No louvers/opening shall be provided on the top of the panel. All other louvers if provided, shall have very fine brass or GI mesh screen. Tight fitting gourmet/gaskets are to be provided at all openings in relay compartment.

vi) Enclosure shall be constructed with rolled steel sections and cold rolled steel sheets of at least 2.0 mm thickness, Gland plates shall be 2.5 mm thick made out of hot rolled or cold rolled steel sheets and for non magnetic material it shall be 3.0 mm.

vii) The switchgear shall be cooled by natural air flow and forced cooling shall not be accepted.

viii) Total height of the switchgear panels shall not exceed 2600 mm. The height of switches, push buttons and other hand operated devices shall not exceed 1800 mm and shall not be less than 700 mm.

ix) Safety shutters complying with IEC-60298 shall be provided to cover up the fixed high voltage contacts on busbar and cable sides when the truck is moved to TEST and ISOLATED position. The shutters shall move automatically, through a linkage with the movement of the truck.

x) The switchgears shall have the facility of extension on both sides.

b) Circuit breaker

i) The circuit breakers shall be of Vacuum/ Sulphur hexa flouride (SF_6) type. They shall comprise of three separate, identical single pole interrupting units, operated through a common shaft by a sturdy operating mechanism. Surge arrestor shall be provided for each motor/ transformer feeder.

ii) Circuit breaker shall be restrike free, stored energy operated and trip free type. Motor wound closing spring charging shall only be acceptable. An anti-pumping relay shall be provided for each breaker, even if it has built-in mechanical anti-pumping features.

iii) Plug and socket isolating Contacts for main power circuit shall be silver plated, of self aligning type, of robust design and capable of withstanding the specified short circuit currents. They shall preferably be shrouded with an insulating material. Plug and socket contacts for auxiliary circuits shall also be silver plated, sturdy and of self aligning type having a high degree of reliability. Thickness of silver plating shall not be less than 10 microns.

iv) In case of SF_6 gas type circuit breaker, necessary pressure/ density monitoring switch along with the contact for remote indication shall be provided.

v) Supervision relays provided for trip coil monitoring.

vi) Castle key interlocks shall be provided to prevent opening of cable compartment door when breaker is closed and bus bar compartment when any of the incomers to bus are closed.

vii) Testing of circuit breaker shall be possible in isolated position by keeping the control plug connected.

viii) In a switchgear if there are more than one possible feed (including bus coupler) then lockout relay (86) contact of incoming breakers shall be connected in series in closing circuit of each of incoming breakers.

ix) Automatic change-over shall be provided for bus sections with suitable synchronizing check facility. The change-over shall be blocked in case of fault on the bus section. Dead Bus change-over after voltage collapse shall also be provided as back-up.

x) Core balance CTs shall be provided for outgoing motor and transformer feeders having CT ratios greater than 50/1A.

c) Protections

i) Incomer, bus-coupler and outgoing feeders except motor and transformer feeders :

a) Time graded over-current protection

b) Under voltage protection for bus to trip motors under sustained under voltage conditions

c) Earth fault relays shall be provided for selective tripping of feeders

ii) Outgoing 11kV/3.3kV, 11kV/433V auxiliary service transformers feeders :

a) Inverse/ Definite time over-current protection (with instantaneous element)

b) Buchholz protection (for oil filled transformers)

c) Zero sequence/ earth fault current protection for transformer feeder protection

d) Winding temperature high (alarm and trip)

e) Oil temperature high (alarm and trip) (for oil filled transformers)

f) Zero sequence protection on LV side (neutral CT to be provided in case of solid grounding)

iii) Outgoing 11kV, 3.3kV motor feeders :

a) Instantaneous short- circuit protection

b) Over-load protection with unbalance current feature

c) Differential protection (for motors above 2000KW)

d) Locked rotor protection, if not covered by the overload protection

e) Zero sequence current protection

f) Winding/ bearing temperature protection by means of RTDs connecting the same to DDCMIS.

d) General requirements of Numerical Relays

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 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 220 V DC control voltage.

v) Failure of a control or auxiliary supply and de-energisation of a relay shall not initiate any circuit breaker /contactor operation. All relays shall withstand a minimum test voltage of 2 KV AC Rms for one minute.

vi) 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.

vii) Relays shall be suitable for electrical measurement including voltage, current, power (active/reactive) and energy parameters.

viii) Mapping details of all the details shall be submitted in IEC format.

ix) Relays shall have separate output for individual functionality and the master trip shall be software configurable in case of multi output relays. Relays shall have event recording feature, recording of abnormalities and operating parameters with time stamping.

x) Preferably comprehensive single numerical relay shall have provision of both current and voltage inputs. The current operated relay shall have provision for 4 sets of CT inputs, 3 nos. for phase fault and 1 CT input for earth fault. Relay shall be suitable for both residually connected CT input as well as CBCT input. The voltage-operated relay shall have provision for 3 PT inputs. Relays shall be suitable for CT secondary current of 1A/5A selectable at site. Relays used in incomers and bus couplers shall have provision of two sets of voltage signal inputs for the purpose of synchronization.

xi) All CT and PT terminals shall be provided as fixed type terminals on the relay to avoid any hazard due to loose connection leading to CT opening or any other loose connection. In no circumstances Plug In type connectors shall be used for CT/ PT connections. Vendor to ensure the same for all protective relay models offered.

xii) All numerical relay shall have key pad / keys to allow relay settings from relay front. All hand reset relays shall have reset button on the relay front. Relay to be self or hand reset shall be software selectable. Manual resetting shall be possible from remote.

xiii) Relays shall have suitable output contact for breaker failure protection.

xiv) Relays shall have self diagnostic feature with self check for power failure, programmable routines, memory and main CPU failures.

xv) Relays shall have at least two sets or groups of two different sets of adaptable settings. Relays shall have multiple IEC/ ANSI programmable characteristics.

xvi) Design of the relay must be immune to any kind of electromagnetic interference. Vendor to submit all related type test reports for the offered model along with the offer.

xvii) For breaker control from DDCMIS/PLC, hardwired potential free contacts shall be provided from DDCMIS/PLC, to the numerical relays. No separate coupling relays shall be provided.

xviii) Trip circuit supervision shall be provided for all feeders to monitor the circuit breaker/ contactor trip circuit both in pre trip and post trip conditions.

xix) Schematics requiring auxiliary relays /timers for protection function shall be a part of numerical relay. The number of auxiliary relay and timer function for protection function shall be as required. Auxiliary relays for interlocking purpose shall be of self reset type.

xx) Bus no volt condition shall be configured to a output contact of the relay of all incomers

xxi) Timer functions shall be programmable for on/off delays.

xxii) The numerical relay shall be able to provide supervisory functions such as trip circuit monitoring, circuit breaker state monitoring, PT and CT supervisions and recording facilities with Post fault analysis.

xxiii) The numerical processor shall be capable of measuring and storing values of a wide range of quantities, all events, faults and disturbance recordings with a time stamping using the internal real time clock. Battery back up for real time clock in the event of power supply failure shall be provided.

xxiv) 150 time tagged events/ records should be able to store with time stamping Last 5 faults storage including the indication, protection operated , fault location relay and operating time, currents, voltage and time.

xxv) Diagnostics Automatic testing, power on diagnostics with continuous monitoring to ensure high degree of reliability shall be shall be provided. The results of the self reset functions shall be stored in battery back memory. Test features such as examination of input quantities, status of digital inputs and relay outputs shall be shall be available on the user interface

xxvi) The alarm/status of each individual protection function and trip operation shall be communicated to DDCMIS/PLC The numerical relay system shall have built-in features/hardware interface to provide such inputs to DDCMIS/PLC for analog/digital values The provision of receiving the DC incoming supplies and its monitoring shall preferably be made in one bus PT. Panel.

xxvii) Sequence of events shall have 1 ms resolution at device level.

xxviii) Measurement accuracy shall be 1 % for RMS Current and voltage.

xxix) It shall be possible to carryout open / close operation of breakers from a laptop by interfacing from the relay front port (RS232) during initial commissioning.

xxx) Ethernet switches shall be ‘substation hardened’ and shall comply to IEC61850-3 for communications and environment requirements. The Ethernet switches shall be of managed type with two(2) no. of Fibre optic cable ports and Fourteen/Six of Copper ports to achieve the LAN configuration. These switches shall be mounted inside the switchgear Panel.

xxxi) Relay shall be suitable to accept both AC & DC supplies with 110V AC or 220V DC with tolerance of 80% to 120 % of rated voltage

xxxii) Relay shall be immune to capacitance effect due to long length of connected control cables. Any external hardware, if required for avoiding mal operation of the relay due to cable capacitance shall be included as a standard feature. All IOs shall have optical isolation. Analog inputs shall be protected against switching surges, harmonics etc.

xxxiii) No separate earth bus shall be required for the relays. It shall be possible to connect the relay earth to the common earth bus in the switchgear panel which shall be connected to the plant earth mat.

xxxiv) Numerical relays shall have two level pass word protections, one for read only and other for authorization for modifying the setting etc.

e) Contactor

i) Mechanically latched type contactors shall be backed by HRC fuses for outgoing motor feeders. The high voltage contactors shall be of AC-3 utilization category and shall be SF_6 or vacuum type. The fuse and contactor assembly shall be mounted on a withdrawable truck. Circuits shall be provided with suitable single phasing protection.

ii) Surge supressors shall be provided on all contactor controlled motor feeders.

iii) The contactors shall close satisfactorily with a control voltage between 85 to 110 per cent and trip satisfactorily with a control voltage between 70 to 100 percent of the rated control supply voltage. Mechanical indication of contactor open / closed shall be provided. An anti-pumping relay shall be provided even if it has mechanical anti-pumping feature. Trip circuit supervision relay shall be provided to monitor the healthiness of trip coil.

f) Surge arrestor

The surge arrestors shall be provided for all motor/ transformer feeders and shall be metal oxide, gapped or gap less type generally in accordance with IEC 60099-1 and suitable for indoor duty. These shall be mounted within the switchgear cubicle between line and earth, preferably in the cable compartment. Surge arrestor selected shall be suitable for non-effectively earthed system and rating shall be in such a way that the value of steep fronted switching over voltage generated at the switchgear terminals shall be limited to the requirements of switchgear.

g) Control and Interlocks

i) The circuit breaker/ contactor will normally be controlled from remote control panels through closing and shunt trip coils. The control switch located on the switchgear would normally be used only for testing of circuit breaker/ contactor in isolated position, and for tripping it in an emergency.

ii) The circuit-breaker shall have three distinct positions as follows:

'Service'	Both power and control contacts connected.
'Test'	Power contacts isolated, control contacts connected.
'Isolated'	Both power and control contacts isolated.

iii) 'Red', 'Green' and 'white' indication lamps shall be provided on the panel to indicate breaker 'Close', 'Open' and 'Auto-Trip' position. In addition to above, mechanical indicator shall be provided which shall be clearly visible to the operator standing in front of the panel.

iv) Suitable indication to show the circuit-breaker 'Service' and 'Test' positions shall be provided.

v) Facilities shall be provided for mechanical tripping of the breaker/ contactor and for manual charging of the stored energy mechanism for a complete duty cycle, in an emergency. These facilities shall be accessible only after opening the compartment door.

vi) Six (6) normally open (NO) and six (6) normally closed (NC) auxiliary contacts shall be provided in Incomer, Bus coupler and tie feeders for future use. For all other breakers/ contactor modules four (4) NO and four (4) NC contacts shall be provided. The above contacts shall be wired out to the terminal blocks. Contact multiplication, if necessary to meet the above contact requirement, shall be done through electrical reset latch relay.

h) Busbars and Insulators

i) All busbar and jumper connections shall be of high conductivity aluminium alloy. They shall be adequately supported on insulators to withstand electrical and mechanical stresses due to specified short circuit currents.

Busbar cross-section shall be uniform throughout the length of switchgear. Busbars and other high voltage connection shall be sufficiently corona free at maximum working voltage. All busbars shall be colour coded.

ii) The temperature rise of the horizontal and vertical busbars when carrying the rated current shall be in no case exceed 55^0C for silver plated joints

and 40^0C for all other type of joints. The temperature rise at the switchgear terminals intended for external cable termination shall not exceed 40^0C. Further the switchgear parts handled by the operator shall not exceed a rise of 5^0C.

i) Earthing and Earthing Devices

i) A galvanised steel or copper earthing bus shall be provided at the bottom and shall extend through out the length of each switchgear. It shall be bolted/ welded to the framework of each panel and each breaker/ contactor earthing contact bar.

ii) The earth bus shall have sufficient cross section to carry the momentary short circuit and short time fault currents to earth as indicated under switchgear parameters without exceeding the allowable temperature rise.

iii) All joint splices to the earth bus shall be made through atleast two bolts and taps by proper lug and bolt connection.

iv) The truck and breaker/ contactor frame shall get earthed while the truck is being inserted in the panel and positive earthing of the truck and breaker/ contactor frame shall be maintained in all positions i.e. Service, Test and Isolated as well as throughout the intermediate travel. The truck shall also get and remain earthed when the control plug is connected irrespective of its position.

v) All metallic cases of relays, instruments and other panel mounted equipment shall be connected to earth by independent stranded copper wires of suitable size.

vi) VT and CT secondary neutral point earthing shall be at one place only on the terminal block. Such earthing shall be made through links so that earthing of one secondary circuit may be removed without disturbing the earthing of other circuits.

vii) Separate earthing trucks shall be provided for maintenance work. These trucks shall be suitable for earthing the switchgear busbars as well as outgoing/ incoming cables or bus ducts. The trucks shall have a voltage transformer and an interlock to prevent earthing of any live connection. The earthing trucks shall in addition have a visual and audible annunciation to warn the operator against earthing of live connections.

As an alternative to separate earthing trucks, built-in earthing facilities for the busbars and outgoing/ incoming connections, in case such facilities are available in their standard proven switchgear design shall also be acceptable. The inbuilt earthing switches shall have provision for short circuiting and earthing a circuit intended to be earthed. These switches shall be quick make type, independent of the action of the operator and shall be operable from the front of the switchgear panel.

These switches shall have facility for padlocking in the earthed condition.

viii) Interlocks shall be provided to prevent :

- Closing of the earthing switch if the associated circuit breaker truck is in Service position.

- Insertion of the breaker truck to Service position if earthing switch is in closed position.

- Closing of the earth switch on a live connection. Three (3) nos. voltage capacitive dividers shall be provided on each phase of the section intended for earthing and three (3) nos. "RED" neon lamps/ LEDs connected to these on the panel front for visual indication.

- Energising an earthed Section : Complete details of arrangement offered shall be included in the bid, describing the safety features and interlocks.

ix) The earthing device (truck/ switch) shall have the short circuit withstand capability equal to that of associated switchgear panel. 4 NO + 4 NC of auxiliary contacts of the earthing device shall be provided for interlocking purpose.

x) All hinged doors shall be earthed through flexible earthing braid.

j) Painting

All sheet steel work shall be pretreated, in tanks, in accordance with IS:6005. Degreasing shall be done by alkaline cleaning. Rust and scales shall be removed by pickling with acid. After pickling, the parts shall be washed in running water. Then these shall be rinsed in slightly alkaline hot water and dried. The phosphate coating shall be "Class-C " as specified in IS : 6005. The phosphated surfaces shall be rinsed and passivated prior to application of stoved lead oxide primer coating. After primer application, Electrostatic Powder Painting shall be used. Finishing paint shade for complete panels excluding end covers shall be RAL9002 and RAL5012 for extreme end covers of all switchgears.

k) Instrument transformers (CT's and VT's)

i) All current and voltage transformers shall be completely encapsulated cast resin insulated type, suitable for continuous operation at the ambient temperature prevailing inside the switchgear enclosure. The class of insulation shall be E or better.

ii) Current transformers may be multi or single core and shall be located in the cable termination compartment. All voltage transformers shall be

single phase type. The bus VTs shall be housed in a separate panel on a truck so as to be fully withdrawable. Separate set of current transformer shall be provided for differential protection of the feeder.

iii) Core balance CTs (CBCT) shall be provided on outgoing motor and transformer feeders having CT ratio 50/1A or more. These CBCTs shall be mounted inside the switchgear panel.

iv) All voltage transformers shall have suitable HRC current limiting fuses on both primary and secondary sides. Primary fuses shall be mounted on the withdrawable portion. Replacement of the primary fuses shall be possible with VT truck in Isolted test position.

l) Instruments and Meters

i) Indicating instruments and integrating meters shall be flush mounted on panel front. The instruments shall be of atleast 96 mm square size with 90^0 scales. The covers and cases of instruments and meters shall provide a dust and vermin proof construction.

ii) Ammeters on motor feeders shall have a compressed scale at the upper current region to cover the motor starting current without graduation from one to six times the rated CT secondary current. These shall be suitable to withstand the above current of motors which can last upto 30 seconds (under stalled condition) without any damage or loss of accuracy.

iii) Watt-hour meters shall preferably be 3-phase two (2) element type suitable for measurement of unbalanced loads in three phase three wire system.

iv) Watt-hour meters shall preferably be provided in drawout cases with built-in testing facilities. Alternatively, they may have test blocks to facilitate testing of meters without disturbing CT and VT secondary connections. Watthour meters shall have reverse running stops. They shall have six digit register indicating primary circuit energy in MWH with atleast count on 0.1 MWH.

v) Suitable self powered transducers as per IS : 12784 Part - I for feeding signals to panel mounted electrical meters (ammeters, voltmeters, VAR meters and wattmeters 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.

vi) 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.

m) Control and Selector switches

i) Control and selector switches shall be of heavy duty, rotary type with escutcheon plates clearly marked to show the positions. The switches shall be of sturdy construction suitable for mounting on panel front. Switches with shrouding of live parts and sealing of contacts against dust ingress shall be preferred.

ii) On-Off control switches shall have three positions and shall be spring return to 'Neutral' from close and trip positions. They shall have two contacts closing in close position and two contacts closing in trip positions, and shall have Pistol Grip handles. Lost motion feature shall be provided wherever required.

iii) Selector switch shall have two stay put positions as per the module requirements indicated elsewhere. They shall have two contacts for each of the positions and shall have black Spade handle.

iv) Ammeter and Voltmeter selector switches shall have four stay-put positions with adequate number of contacts for three phase system. These shall have oval handles. Ammeter selector switches shall have make before break type contacts to prevent open circuiting of CT secondary.

n) Indicating lamps

i) Indicating lamps shall be of the panel mounting, LED type and low watt consumption preferably built in the lamp assembly. The lamps shall have escutcheon plates marked with its function, wherever necessary.

ii) Lamps shall have translucent lamp-covers of the following colours, as warranted by the application :

Red	Closed
Green	Open
White	Auto-trip
Blue	For all healthy conditions (e.g. control supply, spring charged, and lock out relay coil healthy)
Amber	For all alarm conditions (e.g. pressure low, over load) also for Service and Test positions indications.

o) Control supply and Space heater supply

i) Each switchboard shall be provided with two (2) No. of 220V DC feeders for the control supply.

ii) Under voltage relay to monitor each of the control supply shall be provided.

iii) All DC circuits shall be fused on both poles. Single phase AC circuits shall have fuses on line and link on neutral.

p) Space heater

i) Each switchgear panel shall be equipped with thermostatically controlled space heater(s), suitably located in breaker/contactor and cable compartments to prevent condensation within the enclosure. The space heater shall be connected to 240 V single phase AC auxiliary supply available in the switchgear, through switches and fuses provided separately for each panel.

ii) For motor space heater supply, one breaker/ contactor normally closed (NC) auxiliary contact of each motor feeder shall be wired out in series of switch fuse upto terminals block in the respective panels of switch boards. The motor space heater supply shall be taken from Panel space heater supply given to switch board.

iii) A 240V single phase 50 Hz AC plug point shall be provided in the interior of each cubicle with ON-OFF switch for connection of hand lamp.

q) Terminal blocks

i) Terminal blocks shall be 650 Volts grade, 10 Amps rated, one piece moulded complete with insulating barriers. clip on type terminals, washers, nuts and identification strips.

ii) Terminal blocks for CT and VT secondary leads shall be provided with links to facilitate testing, isolation star/ delta formation and earthing. Terminal blocks for CT secondary shall have the short circuiting facility.

iii) Atleast 10% spare terminals for external connections shall be provided on each panel and these spare terminals shall be uniformly distributed on all terminal blocks. Space for adding another 10% spare terminals shall also be available in each panel.

r) Power cable termination

i) Cable termination compartment shall receive stranded Aluminium conductor, XLPE insulated, shielded, armoured/ unarmoured, PVC jacketed, single core/ three core unearthed/ earthed grade power cable(s).

ii) A minimum clearance of about 600 mm shall be kept between the cable lug bottom ends and gland plates for stress cone formation for XLPE cables. Interphase clearance in the cable termination compartment shall be adequate to meet electrical and mechanical requirement besides facilitating easy connections and disconnections of cables.

iii) Cable termination compartment shall be complete with power terminals, power lugs and associated hardware and removable undrilled gland plates. For all single core cables gland plates shall be of nonmagnetic material.

s) Name plates and Labels

i) Each switchgear shall have a name plate for its identification. All enclosure mounted equipment shall be provided with individual engraved name plates for clear equipment identification. All panels shall be identified on front as well as backside by large engraved name plates giving the distinct feeder description along with panel numbers. Back side name plates shall be fixed in panel frame and not on the rear removable cover.

ii) Name plate shall be of non-rusting metal or 3-ply lamicoid with white engraved letterings, on black background. Inscriptions and lettering shall be subjected to Purchaser's approval.

5.8.6 Spare feeders

10% spare feeders with at least one of each type of highest rating shall be provided in each switchgear.