

VOLUME-2
PART- I
Section-5
Generator with
Excitation
system and Auxiliaries

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5. Generator with Excitation System and Auxiliaries

5.1 Intent of Specifications

The intent of these specifications is to define the scope of work under this section which covers the provision of labour, tools, plants, materials and performance of work necessary for the design, manufacture, quality assurance, quality control, shop assembly, shop testing, delivery at site, site storage and preservation, installation, erection, commissioning, performance testing, acceptance testing, training of Purchaser's personnel, handing over to Purchaser and guarantee trouble free operation of horizontal shaft synchronous generators with excitation system and auxiliaries for Keyi Hydro Electric Project, Arunachal Pradesh, as per the specifications hereunder, complete with all auxiliaries, accessories, spare parts and warranting a trouble free safe operation of the installation.

The Generators shall be complete with accessories, instrumentation, controls, auxiliaries such as excitation system, voltage regulating equipment, neutral grounding cubicle, generator line terminal equipment including CTs, PTs, surge protection equipment, lubricating oil system, oil piping, valves, fittings, safety devices, cabling, special tools & testing devices etc., as described and detailed in the specification and in the details of requirements. The scope of supply shall also include all parts, accessories, spare etc., which are essential for construction, operation and maintenance of the complete generator even though these are not individually or specifically stated or enumerated. Corresponding components of all the generators and associated equipment and the spares shall be of the same material, dimensions and finish and shall be interchangeable.

It is not the intention to specify the minute details/smallest items to deliver a functional system or to curb/define the standard manufacturing practice but to outline the performance, constructional, operational and guaranteed requirements. It is the responsibility of the contractor to ensure these requirements.

5.2 Scope of Supply

5.2.1 Material

The scope of work shall be a comprehensive functional system complete in every respect including but not be limited to following:

- Two (2) sets of horizontal shaft synchronous generators directly driven by Francis turbine, and having a rated output of 11.5MW (0.85 pf) & maximum output of 12.65MW at generation voltage of 11kV \pm 10%, 3 phase, 50 Hz, 600 rpm as specified hereunder. Each generator shall be horizontal shaft, with enclosure naturally /Fan air cooled and equipped as follows in accordance with the specifications.

Equipment Details	Quantitative Requirement for each generator
Generator stator complete with frame, foundation arrangement, core, winding with accessories and terminals	One (1) no.

Generator rotor complete with shaft, rim, poles with windings and accessories	One (1) no.
Bearings (DE & NDE with thrust bearing)	One (1) set
Anti-condensation space heaters	One (1) set
Air guides	One (1) set
Static excitation and voltage regulation equipment	One (1) set
Fabricated base plate, foundation bolts for generator and its bearings	One (1) set
Resistance type temperature detectors (duplex RTDs)	One (1) set
Dial thermometer with electrical contacts for alarm and trip for bearings	One (1) set
Oil operated brakes with necessary piping	One (1) set
Shaft mounted Fans	One (1) set
Coupling with guard (if applicable)	One (1) no.
Instruments, controls and safety devices, as required	One (1) set
Fly Wheel with Guard	One (1) set
Bearing oil coolers	One (1) set
Toothed wheel, speed signal generators mounted on the generator shaft	One (1) set
All required oil, air pipes, fittings, valves, pressure gauges	One (1) set
All interconnecting cables, termination, etc. between various parts/elements	One (1) set
Oil for the first filling of bearings with 10% extra quantity in non-returnable drums	One (1) set
All necessary control, monitoring, safety and metering instruments/devices/system	One (1) set
LAVT cubicle	One (1) set
Neutral Grounding cubicle	One (1) set
Co-ordination and supply of associated interfaces, provision of necessary contacts and/or ports for integration of all generators, excitation system along with accessories and monitoring systems with plant SCADA and UCB system including all hardware, software, services and other inputs.	One (1) set
Special lifting devices along with hardware etc. for stator, rotor, assembled generator, shaft, bearing assembly and other components	One (1) set
All devices required for stator and rotor erection and assembly in service bay(if applicable)	One (1) set
GLOP with AC and DC pumps	One (1) set

Mandatory Spares	One (1) set
Tools and Instruments	Special Tools as per bidder

5.2.2 Scope of services

- Site installation and successful commissioning.
- Field / touch-up painting including all painting materials.
- Performance and field acceptance testing as per the relevant clause of this section and submission of report.
- Training of Purchaser's personnel including operation and maintenance staff as defined in Clause 1.1.2 "Section 1 - General Technical Specification".
- All the technical documentation including preparation and submission of O&M manuals.

Any other item(s) not mentioned specifically but necessary for the satisfactory completion of scope of work defined above, as per accepted standard(s) / best international practices.

5.3 Special Design and Layout Conditions

5.3.1 Layout and general arrangement

General arrangement of the Powerhouse and generating units has been outlined in the layout drawings. Various levels of Power House mentioned in layout drawings are to be maintained by the Contractor during detailed design.

The design and construction of turbine & generator shall be adequately coordinated to meet the requirement of specification and layout.

5.3.2 Design considerations

The generators shall be capable of safely withstanding maximum stresses during normal operation, runaway-speed conditions, two phase and three phase short-circuit conditions or single phase earth fault at maximum output for which generators are capable of; 180 deg and 120 deg out-of-phase synchronization; Magnetic unbalance at rated speed with 50% of the poles short circuited and brake application, seismic forces etc.

The generator and/or generating unit shall be designed to withstand the additional stresses resulting from operation of unit with two or more adjacent guide vane passages in blocked condition.

The generator construction and mounting arrangement shall be as per IM 1001 code according to IEC 60034-7. The generator cooling shall be as per IC01 according to IEC 60034-6.

The generator pedestal bearings lubricating oil shall be of the same specification as the turbine bearing and governor oil.

The shaft shall be designed to withstand critical speed without any distortion.

The plant shall be capable of black start operation and shall be suitable for operating in both grid connected and stand alone modes with specified output.

5.3.3 Operating conditions

The turbine and generator shall be capable of operation in purely run of the river mode without any pondage. The generators shall be capable of delivering continuous output from 100% to 40% of rated output without exceeding the temperature rise limits.

When one of the generating units is under planned / unplanned maintenance, the turbine shall experience heads higher than the rated head due to reduced head loss in the water conductor system. To utilize this capability of turbine of developing higher output with the normal discharge at heads higher than rated net heads, the generator shall also be designed to produce correspondingly higher output.

5.3.4 Generator characteristics

The generator shall be designed for direct coupling to a horizontal shaft Francis turbine having capacity as detailed in "Section 2 - Turbine and Accessories".

The Inertia constant of generating units at maximum output shall be adequate to suit the requirement of pressure rise and speed rise at the specified GV closing time. The flywheel effect (GD²) of generating unit shall be worked out accordingly in coordination with turbine manufacturer.

5.4 Rating and Functional Characteristics

5.4.1 Rating

S. No.	Particulars	Details
1.	Type	Synchronous generators with brushless excitation system
2.	No. Of generators	Two (2)
3.	Output	
a.	Rated output	11.5 MW (at 0.85 pf)
b.	Maximum continuous output	12.65 MW (at 0.85 pf)
4.	Rated voltage	11 kV
5.	Rated power factor	Cos ϕ = 0.85 (lag)
6.	Rated frequency	50 Hz
7.	Rated speed	600 rpm or as per requirement of turbine from performance considerations
8.	Runaway speed	1.8 times the rated speed

9.	Moment of inertia	To suit the requirement of pressure rise and speed rise at the specified GV closing time. Inertia of system shall be 58 Tm ² .
10.	Insulation class	Class 'F' with temperature rise limited to class 'B' insulation at rated & maximum output (as measured by RTD)
11.	Form of enclosure protection	Corresponding to SPDP/IP 23
12.	Incoming cool air max. Temperature	As per ambient air temperature condition
13.	Rise in temperature over cooling air at rated output / max. output by RTD	Stator - 80°C (measured by RTDs) at rated output & at maximum output Rotor - 90°C (measured by resistance method) at
14	Temperature monitoring of stator winding and bearings	By RTDs of PT100 type connected to temperature scanner
15.	Type of duty	Continuous
16.	Type of control	Manual / auto
17.	Insulation class	Class "F"
18.	Range of voltage adjustment	± 10%
19	Range of voltage variation	±10%
19.	Range of frequency variation	+ 5%, -5%
20.	Combined variation of voltage & frequency	± 10%
21.	Stator winding connection	All six terminals to be brought out and neutral to be formed outside

22.	Short circuit ratio	1.0 (minimum)
23.	First critical speed	20% higher than maximum runaway speed
24.	Cooling	Fan air cooled
25.	Excitation	Brushless Excitation system
26.	Stator neutral earthing	Distribution transformer and resistance on secondary through an isolating switch
27.	Shaft orientation	Horizontal
28.	Direction of rotation	To suit the layout
29.	Sound emission	< 90 db (a)

5.4.2 Capacity and temperature rise

The generator shall be capable of delivering a guaranteed rated continuous output at rated power factor, rated voltage and rated frequency at the terminals without exceeding temperature rise in the stator and rotor windings as specified above. The generator shall be capable of delivering rated & maximum outputs at the rated power factor over the ranges of 90% to 110% of rated voltage and 95% to 103% of rated frequency without exceeding the maximum permissible temperatures stated above.

The maximum output at rated conditions without exceeding the maximum permissible temperatures shall be indicated by the Contractor.

5.4.3 Temperature Rise Limits

The maximum temperature rise of stator and rotor windings shall not exceed following limits while delivering rated / maximum output

- (a) Stator winding - Maximum Temperature rise 80°C at rated & maximum output
- (b) Rotor winding - Maximum temperature rise 90°C at rated & maximum output

Even though insulation of Class F is specified and must be used, the generator temperature rise shall not exceed the limits specified for Class B insulation temperature rise limit when the generator is operating continuously at rated & maximum output and at any working voltages & any frequency range specified.

5.4.4 Short circuit withstand capability

The generator shall be capable of withstanding a three phase short circuit test at the generator terminals when operating at maximum continuous power output at rated power factor with 10% over voltage for a period not less than 3 sec.

5.4.5 Occasional excess current

The generator shall be capable of withstanding occasional excess current equal to 1.5 times the rated current for not less than 30 seconds each time.

5.4.6 Wave form and poly-phase symmetry

The waveform of the EMF between terminals of the generator on open circuit shall be practically sinusoidal. The waveform shall be accepted as practically sinusoidal if none of its instantaneous values varies from instantaneous value of the same phase of the fundamental wave (50 Hz) by more than 5 per cent of the peak value of the fundamental.

The poly-phase voltage system of each generator shall be practically symmetrical. Poly-phase voltage system is considered as practically symmetrical if neither the negative sequence nor the zero sequence components exceed 5 per cent of the positive sequence component.

Special steps shall be taken to eliminate harmonic voltage wave, which may cause inductive interference with communication circuits or resonance in the transmission system. Telephonic harmonic factor shall not exceed 1.5 per cent.

The calculated no-load harmonics in the voltage waveform shall be furnished for approval.

5.4.7 Runaway speed withstand capability

The generating unit shall be designed to withstand the forces and stresses without any damage in the following operating conditions:

1. 15 minutes at normal speed without Cooling water.
2. 5 minutes at runaway speed with Cooling water supply.
3. 2 minutes at runaway speed without Cooling water supply.

The runaway speed shall be 1.8 times of rated speed.

5.4.8 Maximum momentary over speed

The flywheel effect of the generating unit and governor closing and opening times shall be so adjusted that the speed rise shall not exceed 50% (fifty per cent) of rated speed under any condition of operation considering the worst condition of load acceptance/ rejection and shall be indicated by the contractor.

5.5 Performance Criteria and Guarantee**5.5.1 Performance Criteria**

The generator along with all auxiliaries and accessories shall be capable of performing intended duties under specified conditions. It is the responsibility of the Contractor to supply the equipment as per guaranteed technical particulars to be furnished along with bid and shall also guarantee the reliability and performance.

The Contractor shall supply generator having the specified ratings and highest feasible efficiencies in the permissible range of operation. The output and the weighted average efficiency shall be guaranteed by the Contractor.

The peak efficiency of the generator at the rated output is expected to be 96.5% or higher.

5.5.2 Guaranteed output

The generator output shall be guaranteed by the Contractor in respect of the following:

Rated output of 11.5MW at rated power factor of 0.85 and at any voltage and frequency in the specified operating range without exceeding the maximum permissible temperature limits.

Max. continuous output of 12.65 MW at power factor of 0.85 without exceeding the maximum permissible temperature.

The liquidated damages per generator shall be levied for shortfall in rated output at rated power factor of 0.85 and at any voltage and frequency in the specified operating range without exceeding the permissible temperature limits. No tolerance shall be permissible over the calculated value of rated output.

5.5.3 Guaranteed efficiency

The guaranteed weighted average efficiency, at rated voltage and frequency as determined from the following formula, shall not be less than 97.0 per cent.

$$ngAv = 0.7 \times ng100 + 0.15 \times ng80 + 0.1 \times ng60 + 0.05 \times ng50$$

where,

ngAv = Weighted average efficiency

ngi00 = Generator Efficiency at 100 percent rated (5.836) MVA and 0.85 p.f

ng80 = Generator Efficiency at 80 percent rated MVA and 0.85 p.f

ng60 = Generator Efficiency at 60 percent rated MVA and 0.85 p.f

ng50 = Generator Efficiency at 50 percent rated MVA and 0.85 p.f

Liquidated damages shall be imposed as per Clause 5.5.5, "Liquidated damages for shortfall in output and efficiency" in case of shortfall in weighted average efficiency vis-à-vis the corresponding guaranteed value.

The liquidated damages on account of shortfall in efficiency from the guaranteed figures shall be computed separately for each unit and the total amount of liquidated damages shall be the sum of all the units. However, tolerance in computation in efficiency shall be in accordance with the IEC 60034-1 for field acceptance test for generators.

Following losses shall be taken into account for calculation of generator efficiency:

- bearings: friction losses,
- ventilation losses (windage losses),
- power for excitation system requirement,
- I²R losses for stator winding,
- I²R losses for rotor winding,
- stator magnetic core iron losses,
- any other additional losses.

Tolerances for losses used by the Contractor shall be those specified in IEC 60034-1, section 11.

5.5.4 Output and efficiency tests

Field test for output and efficiency as per IEC 60034-2 shall be conducted as elaborated in clause 5.20.4, "Field Acceptance Test" on any one of the generators selected by the Purchaser.

Field test (as per IEC 60034-2) shall form the final basis to establish fulfilment of guarantee of the generator and for purposes of liquidated damages and rejection of plant & encashment of bank guarantee. Individual losses shall be established using suitable method as per IEC 60034-2 and the efficiencies shall be determined according to the international code, IEC 60034-2.

5.5.5 Liquidated damages for shortfall in output and efficiency

Liquidated damages for any shortfall in the tested values of rated output and the weighted average efficiency of turbine and generator vis-à-vis the corresponding guaranteed values respectively, shall be computed as per Volume 1, Section 9- Appendix 9 (point 3).

5.5.6 Rejection limit

The Purchaser reserves the right to reject the generator if the tested values of either weighted average efficiency or the rated output falls short by two (2) per cent or more of the corresponding guaranteed values during field acceptance tests.

5.5.7 Tender Evaluation on Account of Efficiency Differences

The differences in the efficiencies of generators in the various bids shall be taken into account in evaluation of bids. Loading for equalization for this purpose shall be done on the same basis as adopted for penalty as specified in 5.5.5 above for shortfall in weighted average efficiency.

5.5.8 Stability and performance

The generators shall operate satisfactorily in parallel with each other and with other machines connected to the grid. The generators shall be able to operate on sudden application / or loss of maximum load and during momentary short circuits and sustained ground faults without causing any abnormal vibration or resonant conditions.

The generators shall be capable of operating continuously on an unbalanced system such that with none of the phase currents exceeding the rated current, the ratio of negative sequence component of current (I_2) to the rated current (I_n) up to 20%, and under fault conditions shall be capable of operation with the product of (I_2/I_n) 2 and time in seconds (t) not exceeding 40.

5.6 Design and Construction

5.6.1 Standards

All equipment shall be designed, built, tested and installed to the latest revisions of the following applicable IEC standards. In the event of other standards being applicable they will be compared for specific requirement and specifically approved during detailed engineering for the purpose:

Standards	Description
IEC 60034 (Pt 1 to Pt 16)	Rotating electrical machine
IS 4722	Rotating electrical machine- specification

5.6.2 Design stress limits

Design stress limits shall be as per clause "Maximum allowable stresses" of "Section 1 - General Technical Specification" as per ASME code.

The unit stresses under normal operating conditions shall not exceed one-third ($1/3$) of the elastic limit (yield point) of the material or one-fifth ($1/5$) of the UTS (Ultimate Tensile Strength) of the material whichever is lesser, except where specified otherwise. The minimum factor of safety under the worst conditions shall not be less than 1.5 on yield point (Y.P.) or 3 (three) on ultimate tensile strength (UTS).

5.6.3 Material selection and standards

The material specifications and their standards for major components of generator shall be as shown below. The material grade and classification wherever specified are obligatory and proposed equivalent national/international standard for the same shall only be considered if their chemical composition, mechanical properties, manufacturing methods are same/superior and are suitable for proposed use. The Contractor shall establish the equivalence/superiority for acceptance by the Purchaser.

Sl. No.	Item	Material and Manufacturing Method	Material Standard
1	Structural steel for supports, brackets and components	Structural steel sections/plate	ASTM A 283 GR C
2	Stator frame	Fabricated from steel sections/plate	ASTM A 283 GR C
3	Stator core	Cold rolled silicon steel with non-oriented grains	
4	Stator coil	Rectangular copper conductor	
5	Rotor spider	Fabricated from steel sections/plate	ASTM A 283 GR C
6	Rotor rim	High tensile magnetic steel sheet	
7	Rotor pole lamination	High permeability magnetic steel sheet	
8	Rotor pole coil	Rectangular copper conductor	
9	Brake ring	Fabricated from steel plate	ASTM A 283 GR C
10	Bearing Pad lining	White metal	ASTM B 23 No.3
11	Generator shaft	Steel, Forging	ASTM A 668 Class D / ASTM A 678 Grade A
12	Coupling bolts	Alloy steel NiCrMo, Forged	ASTM A 434 Class BD
13	Bearing housing	Carbon Steel, Fabricated from steel plate	ASTM A 283 GR C
14	Pressure Pipes	Carbon Steel, Seamless	ASTM A106 GR B / ASTM A53 GR B
15	Fasteners on parts requiring frequent dismantling.	Stainless Steel	

5.7 Constructional features

5.7.1 Stator Frame and Core

The stator shall be constructed and assembled at works. The stator frame shall be built-up of welded plate steel in one complete assembly and shall be designed to support the stator core and winding. Each part of the stator shall be provided with suitable lifting lugs and earthing terminals. The stator shall be sturdy to prevent distortion during transport and under any abnormal operating conditions. Bolted and dowelled joints shall be provided between the sections of the frame, being heavily flanged internally and coupled by a number of short bolts.

The core shall be built up with low loss high permeability silicon steel laminations and shall be mounted rigidly in the inner frame. Each lamination shall be coated on both sides after punching and removal of burrs with insulating varnish to minimize eddy current losses. Ventilation ducts shall be provided at intervals along the stator core, being formed by means of non-magnetic steel spacing bars securely welded to adjacent punching. The core shall be clamped between pressure plates. A number of through bolts shall be provided for adequate and permanent compression of the active core. Compression fingers of non-magnetic material shall be welded to end plates for distribution of the pressure over the whole surface of core uniformly.

Sufficient number of resistance type temperature detectors of duplex type shall be installed at suitable places for monitoring temperature of stator core, stator teeth and stator winding on temperature recorder as well as for supervisory control and data acquisition system.

5.7.2 Stator Winding

The stator winding shall be insulated with class 'F' insulation as defined in IEC or equivalent International Standards. The winding of the stator shall be done fully at the manufacturer's works only. The stator windings shall be of the double layer bar or coil type. All the bars shall be formed, insulated and tested before being placed in the slots. Each coil shall be built up from a number of strands of polyesteramide varnish (or other suitable insulating compound) bonded copper of electrolytic quality to minimize eddy current losses.

The finished wound stator core shall be subjected to high voltage test followed by impregnation under vacuum with epoxy resin of whole core.

Adequate number of duplex resistance temperature detectors shall be installed between the upper and lower layer of the same phase and distributed in the winding over all three phases

The wound stator shall be dispatched to site in one piece complete set.

5.7.3 Rotor

The rotor shall be constructed and assembled at works.

The rotor shall be salient pole type.

The rotor structure shall be built in accordance with the best modern practice. The factor of safety at maximum runaway speed based on yield point of material shall not be less than 1.5. The rim of the rotor

shall be constructed out of 2 mm thick or less, laminated sheet steels having radial ventilating ducts located along the lengths & bolted together to make a compact structure. The hub of the rotor shall be securely attached to the main shaft taking care of requirements both at normal operating speed and at maximum runaway speed conditions. The rotor spider shall be of fabricated construction with arms radiating from the central hub. The pole shall be built up of thin laminations secured by bolts passing through supporting end plates. The pole shall be attached to the rim by means of die punched tee heads and corresponding tee slots in rotor rim. After the poles are assembled, the slots in the rim of rotor shall be fitted accurately to the tee heads so as to secure adequate bearing of each lamination. The pole shall be firmly held in position by means of tapered keys and the keys shall be locked in position on top of the rotor by plates so as to prevent the keys from coming out in the event of their becoming loose. The pole shall be locked in position so that they cannot drop-out, should one or more of the keys become loose. The inter-polar connections shall be adequately supported.

As far as possible, necessary flywheel effect shall be incorporated into the rotating parts of the generator without adding additional weights and the same shall be determined in consultation with the turbine manufacturer. In case requisite moment of inertia is not available from the rotor, a separate flywheel shall be provided, to get additional flywheel effect required.

5.7.4 Field Winding

The field winding shall be insulated with class F insulation as defined in IEC or approved equivalent International Standards & shall consist of fabricated copper strips. The nominal field voltage shall be indicated. The field winding shall be adequately braced to withstand all mechanical stresses imposed during the maximum runaway speed. The completely insulated field coil shall be pre-compressed in the factory before assembly on the field pole so that there is no shrinkage and loosening of the same when in service. The pole body insulation shall be of epoxy.

The field poles shall be provided with adequate continuous type Amortisseur winding of the low resistance type to improve stability under single phase fault conditions. The ratio of quadrature axis sub-transient reactance to the direct axis sub-transient reactance shall be stated in the schedule of guaranteed technical particulars. The field leads shall have at least 30 % extra cross-section of copper over and above that normally required for maximum field excitation, allowing normal factor of safety. The field leads shall be neatly and rigidly fixed on the rotor with minimum bends duly taking care of centrifugal forces.

5.7.5 Terminal Box

The terminal box shall be located on either side of the generator-one for phase connection and other for neutral connection. A separate terminal box for RTDs and space heater terminals shall be provided. The terminal box shall be capable of withstanding 31.5 kA fault level for one second. The terminal box shall be suitable for taking 11 kV XPLE single core aluminium cables.

5.7.6 Phase Marking

Appropriate phase marking as per IEC shall be provided inside the terminal box. The markings shall be indelible.

5.7.7 Shaft

The generator shaft shall be made of the best quality carbon steel properly heat-treated, ASTM A668. The shaft shall be of adequate size to operate at all speed including maximum runaway speed and shall be able to withstand short circuit stresses without excessive vibrations or distortion. The generator shaft shall be accurately machined all over and polished where it passes through the bearings and accessible points for alignment checks. Generator shaft shall have suitable provision for coupling to the turbine shaft. The monitoring platform and the anchoring devices for the generator must be adaptable ones and all parts shall be included in scope of supply of the bidder. The lowest critical rotation speed shall exceed the highest dynamic runaway speed by at least 20%.

5.7.8 Bearings

The generator bearings shall be

- Pad type or sleeve type, oil self/forced lubricated type. The oil lubrication system for the bearings shall be fail safe and shall work even in the event of power failure.
- For ease of maintenance, the bearings shall be dismantle-able in two halves
- These bearings shall be guaranteed for minimum continuous operation for 100,000 (one hundred thousand) hours and shall be of proven design and performance.
- The bearing shall be suitable to take axial thrusts in both the directions.
- The bearings shall be adequately insulated to prevent any harmful circulating currents.
- The bearing shall be designed to withstand operation at runaway speed for a period of 15 minutes. Thermometers, pressure gauges, flow relays, etc. as required shall be provided.

Bearing shall be adequately insulated to prevent any harmful circulating currents. The thrust bearings shall be suitable to take axial thrusts in both the directions. Thermometers, grease-lubricating points, speed relays etc. as required shall be provided.

Each of the bearings shall be provided with direct reading thermometer of dial type gauge with direct reading pointer and also, provided with signalling switches for temperature indication with two (2) sets of contacts for annunciation and trip of the machine. The bearings shall also be provided with resistance elements of RTD type. Wires shall be run from thermometer and resistor element to the instruments and the junction box mounted on the outside of the stator frame. RTDs shall be interfaced with SCADA system. The connection blocks shall be of detachable type.

5.7.9 Flywheel

A separate flywheel of ample dimensions shall be supplied in case the required moment of inertia for limiting the speed rise / runaway speed is not available from generator inertia. Necessary provision for receiving the piston of the brake cylinder on application of brakes shall be made on the flywheel.

The flywheel may be coupled to generator directly or may be mounted on the turbine shaft just before coupling. Generator manufacturer shall co-ordinate with turbine manufacturer to decide the best location of flywheel.

5.7.10 Brakes

Each generator shall be provided with pressure oil operated spring brakes, which will be operated automatically or manually. The generator brake system shall consist of suitable number of brake shoes, which will operate against a polished segmental steel brake track bolted to rotor or to any other component such as flywheel, if any. Pressure oil at required pressure will be made available from the oil pressure system to be supplied under turbine. A Manometer, which shows the braking pressure during automatic braking, shall be connected to the pressure pipe. The oil pressure keeps the spring of brake in tensed position while the brake will operate under spring pressure.

5.7.11 Cooling & Ventilation

The generator shall be provided with duct ventilated screen protected drip proof enclosure. Each generator shall be preferably of naturally cooled self-ventilated type. Two axial flow centrifugal fans shall be placed on either side of shaft to provide air cooling by fanning action. Necessary arrangement for exhaust of hot air from generator stator to out -side the Powerhouse shall be made through exhaust fans & duct for limiting the temperature rise at machine floor.

Necessary exhaust ducting along with fresh air inlet ducting shall be provided. Since the generators shall be installed well below the service bay floor, hence proper air circulation shall be required.

5.7.12 Vibration

All rotating parts shall be designed to operate without undue vibration. Special precaution is to be taken to run the machines smoothly. The vibration level of the machines shall be within the limits specified in the relevant IS specifications (IS: 14773 / ISO 7919/IEC 60034-14) or equivalent.

Full balancing shall be done at works. Fine balancing shall be carried out at site to bring down vibration level to acceptable limits if required.

5.7.13 Heaters

The generator shall be provided with anti-condensation heaters. Space heaters of adequate rating shall be provided for maintaining stator surrounding air temperature above the ambient during prolonged shutdown period. A fan to be provided for initial start up after a prolonged shutdown is included in the scope of supplies.

5.7.14 Oil & Grease

The tenderer shall indicate the lubrication requirements and give his recommendations with detailed specifications regarding type of grease to be used and frequency of refilling required for lubrication of generator bearings.

The oil used for generator bearing lubrication etc., shall be as far as possible, identical with that used for the turbine pressure oil system and other auxiliaries. The first filling of oil with 10 % (ten percent) extra quantity shall be supplied along with the generator. The generator manufacturer shall co-ordinate with the turbine manufacturers to ensure that their recommendations regarding oil are identical.

5.7.15 Speed Relay, Toothed Wheel & Permanent Magnet Generator

A speed relay to monitor the speed of the generator to measure the 10%, 15%, 30%, 100%, 110% and 150% of rated speed with adequate number of auxiliary (NO & NC) contacts at each speed shall be provided. This speed relay shall be given supply from generator side potential transformer.

A toothed wheel arrangement shall be mounted on the shaft of generator and a photo interceptive pickup shall be mounted on a bracket and connected to speed relay mounted on unit control board through a special screened cable.

5.7.16 Generator Fire Protection System

For Generators of Global VPI type, adequate portable fire extinguishers to be provided with fire sensors.

5.8 Excitation and Automatic Voltage Regulator (AVR)

Each generator shall be provided with brushless excitation system consisting of a 3 phase AC exciter and rotating diode rectifier bridge mounted on the generator shaft extension.

The exciter frame enclosed in a steel made metallic cover with metallic sheets forming the poles is supported on connection side. The DC voltage to the exciter frame shall be fed from excitation panels placed in the machine hall/control room.

The rotor of the exciter shall be mounted on the rotor main shaft of the generator. Its core shall be formed by low losses segments mounted on the ring. At the outgoing ends of the rotor are placed the diodes that transform the Alternating current into Direct current, which is fed to the rotor field.

The system shall be complete along with surge suppressor, automatic voltage regulator of solid state type with thyristor bridge and field suppression equipment etc.

The excitation system shall be suitable for maintaining the voltage for a grid voltage variation of $\pm 10\%$ & for a frequency variation of $\pm 5\%$.

The AVR shall be sensitive to the change of $+/- 0.5\%$ of normal voltage (average of 3 phases) of the Generator when operating under steady load conditions for any load or excitation within operating range and shall initiate corrective action without hunting.

After the initial maximum voltage following any load rejection up to maximum load, the AVR shall restore the terminal voltage to a value not more than 5% above or below the voltage being held before load rejection and shall maintain the voltage within these limits throughout the period of generator over speed.

5.9 Automatic Voltage Regulator

The automatic voltage regulator shall have the following features:

Automatic Voltage Regulator (AVR) shall be digital electronic type. The AVR shall have two operating Channels - Auto Channel & Manual channel. Changeover from Auto to manual channel shall be bump-less.

The following will be general specifications:

- Auto mode can have three/two phases sensing. Voltage regulation at zero droop setting shall be better than 1%.
- Manual mode will constantly follow auto mode and in case of failure of auto mode or if desired by operator, through a push button command, changeover to Manual mode shall take place bumplessly.
- Manual mode to Auto mode change over shall be possible through a null-balance mechanism. Null balance may be done between control signals or between final convertor outputs depending upon design.
- All components for Auto and Manual including Power Convertors and Power Transformers shall be separate; the requirement is non redundant AVR per unit with one Auto and one manual channel to be provided in excitation system.
- Auto mode shall have Power factor controller for parallel operation with grid.
- There will be Reactive current export and import limits, which will give Raise/Lower commands to both Auto and Manual.
- Auto mode voltage set point adjustability will be -15% to +10% of rated voltage.
- Manual mode shall be capable of supplying zero to 120% of rated excitation and will hold excitation constant till it receives raise or lower command from operator or from internal limiter.
- AVR shall have rotating rectifier failure indication and two Change over contacts for trip and remote annunciation.
- AVR voltage sensitivity shall be better than 0.5%.
- Meters giving Excitation parameters are to be provided on AVR panel with provision for remote metering. AVR panel will also have a voltmeter showing Generator voltage.
- AVR panel will have provision for self start on receiving signal from speed switch.
- AVR shall have frequency ROLL-OFF function, to ensure no over excitation under low speed operations.

5.10 Lube Oil System

Lube Oil system shall be supplied for lubricating the generator DE & NDE guide & thrust bearings & for jacking the rotor. The system shall consist of oil tank , main & stand -by AC pump-motors sets & DC pump motor sets along with all pipe, pipe fittings & necessary instrumentation. The oil of lube oil system shall be cooled by the water drawn from cooling water system.

5.11 Cooling Water System

Open loop cooling water system is envisaged for cooling the lubricating oil from Lube Oil System of generator & turbine sealing. The water for cooling water system shall be taken from tail race through pump motor sets & shall be discharged directly in tailrace from LOS coolers. Each unit shall have one set of pump-motor sets with one as stand -by.

The cooling water pressure shall be so arranged that it shall be possible to discharge the outlets from coolers directly to tail race even under conditions of maximum tail race occurring under the floods. Cooling water inlet temperature to be considered as 30°C.

The cooling water requirements of each unit shall be met by pumping water from tail race by a pump for each unit. One pump shall be kept as common standby for all units to enhance the reliability of cooling water supply. The capacity of each pump shall be such that working alone, one pump can supply the water requirements of one unit.

The cooling water system shall be so designed that in case of failure of main pump, standby shall automatically start. In case of failure of all the pumps, immediate shut down of the units will take place.

The pumps shall be horizontal centrifugal type. All the pumps shall be connected to a common cooling water header. The material for pump impeller and casing shall be stainless steel and cast iron respectively. The pumps shall be complete with continuous duty electric motors with class F insulation, control panels, anchor bolts and other mounting material. The motors shall be suitably sized to drive the pump continuously over the specified characteristics without getting overloaded. The pumps shall be suitable for 415 V \pm 10%, 50 Hz \pm 5% with contacts for remote operation, indication and integration with SCADA system.

The cooling water supply to bearings and other components shall be filtered through an Auto backwash duplex filter for each unit to clean the water. Auto backwash duplex filter with coarse (500 microns) and fine (200 microns) arrangement shall be provided for the cooling water system providing redundancy to the system in case of clogging. One Auto backwash duplex filter shall be provided as standby with changeover facility. The capacity of each strainer shall be adequate to meet the cooling water requirements of individual unit. The material for filter elements shall be stainless steel. Automatic drain valve shall be provided for mud drain which shall operate on the basis of both set time and differential pressure. The pressure drop across strainers shall not be more than 0.3 bar at design flow. Adequate instruments and devices shall be provided to sense the pressure drop across the auto clean strainer.

In addition, one no. suction strainer shall be provided at the inlet of each pump to safe guard the pump impeller.

For shaft seal cooling, the water shall be further strained up to degree of 50 microns or lower micron degree if required. One fine strainer shall be kept as standby. The capacity of each fine strainer shall be adequate to meet the requirements of one unit. The material for the filtration elements shall be stainless steel. The pressure drop across fine strainers shall not be more than 0.3 bar at design flow. Adequate instruments and devices shall be provided to sense the pressure drop across the manual clean strainer

Mechanical flow meters with 2 nos. of potential free contacts for interlocks and alarms shall be provided for each pump. The coarse (main filter) and fine strainers (shaft seal stainer) shall be provided with differential pressure gauge with contacts to give an alarm and indication in case of choking of the strainers. Shut-off valves and check valves shall be provided to allow dis-connection and switching of each pump without emptying pipes.

The cooling water system shall include all necessary equipment and devices for satisfactory operation of the entire system whether specifically mentioned or not.

The cooling water system shall be integrated with SCADA system.

The pipes shall be carbon steel ERW with medium grade.

Necessary motorised valve in each unit shall be provided for auto operation of cooling water system.

5.12 Terminal Cubicles

5.12.1 Lightning Arrester and Voltage Transformer Cubicle

The lightning arrester & voltage transformer (LAVT) cubicles for 11kV shall comprise of lightning arresters and capacitors (for surge protection) and voltage transformers. VTs shall be provided for Protection, metering, synchronizing. LAs shall be provided to protect the generator, and other equipment against lightning surge travelling from transmission line. The cubicles shall be metal clad, dust & vermin proof and shall be suitably compartmentalized for accommodating the above equipment. The cubicle shall be fabricated from cold rolled sheet steel of min 2 mm thickness and degree of protection for all indoor cubicles shall be IP-42.

The lightning arrestors and capacitors for each generator shall have the characteristics specifically suited to the protection of alternating current rotating machines. The lightning arrestors shall conform to IEC 60099-4. The lightning arrestors shall be metal oxide gapless type, rated for 9 kV and suitable for indoor installation. These shall be shunted by protective capacitors of 0.25 micro farads and rated for the same voltage. The capacitors shall be provided with built in discharge resistors. The rating and characteristics of the lightning arrestors and capacitors shall be suitable for duty as given below:

Installation	Indoor
Rated voltage	9 kV
Discharge current	10 kA peak
Nominal system voltage	11 kV
Power frequency withstand voltage of housing	35 kV (rms)
Lightning impulse withstand voltage of housing	75 kV peak

The voltage transformers shall conform to IS 3156/IEC 60185. The transformer shall be complete unit in itself and shall be rated as follows:

Purpose	PT-1 AVR	PT-2 Metering, Protection & Synchronizing
Rated primary voltage	$\frac{11 \text{ kv}}{\sqrt{3}}$	$\frac{11 \text{ kv}}{\sqrt{3}}$
Rated transformation	$\frac{11 \text{ kv}}{33 \text{ 'vr}} / \frac{110 \text{ V}}{\sqrt{3}}$	$\frac{11 \text{ kv}}{\sqrt{3}} / \frac{110 \text{ V}}{\sqrt{3}} / \frac{110 \text{ V}}{\sqrt{3}} / \frac{110 \text{ V}}{\sqrt{3}}$

Winding connection	Star / Star	Star / Star
Frequency	50 Hz	50 Hz
Accuracy class	0.5S (or as per CEA metering guidelines)	0.5S (or as per CEA metering guidelines)
Burden per phase	To be calculated by Bidder	To be calculated by Bidder
Rated Voltage Factor	1.1 continuous and 1.9 for 30 sec.	1.1 continuous and 1.9 for 30 sec.

The voltage transformers shall be mounted on a draw out truck that is linked to the hinged compartment door. With the compartment door closed, the primary and secondary disconnect contacts are engaged within respective stationary contacts to complete the circuit.

Upon opening the door the transformers are automatically withdrawn for inspection and maintenance, the primary and secondary disconnect contacts are disengaged and the transformer primary is grounded. The transformers shall be protected with current rating resistors and the design is coordinated to withstand the basic insulation level specified in the relevant standard. Miniature circuit breakers provided on the secondary side shall be adequately rated for protection against overload and short circuit. Two normally open and two normally closed contacts shall be provided. These contacts shall be used in tripping / annunciation circuits, etc.

The cubicle shall be floor mounted and shall be vermin proof and tropicalised. The cubicle shall be furnished complete with base mounting arrangement, foundation bolts, etc. Internal illumination and heating arrangement with space heater for the cubicle shall also be provided.

A compartment for housing the miniature circuit breaker, terminal blocks for voltage transformer secondary side, links, space heaters, etc. shall be provided. Terminal blocks for VT secondary shall have provision for star point formation and for earthing the secondary neutral through link. Each control wire originating from the cubicle and intended for external connection shall be brought to the terminal blocks. Adequate space shall be provided for the cables, which have to be terminated at the terminal blocks. The wiring inside the cubicle shall be flame proof, 1100 V grade and shall conform to IS 1554 Part I.

Each cubicle shall be equipped with space heaters, thermostats, illumination lamps & 240 V AC, 5A receptacle.

5.12.2 Neutral Grounding Cubicle

The generator neutral end terminals shall be brought to Neutral Grounding cubicle (NGC) by XLPE cables and neutral shall be formed inside NGC or at generator terminals.

The generator neutral shall be earthed via a dry type single-phase power transformer. The secondary winding of this transformer shall be loaded with a resistor. The following design parameters shall be considered:

The transformer capacity shall be based on rated voltage and maximum possible current with the secondary loaded as specified.

The transformer primary voltage rating shall be at least 1.5 times generator line-to-line voltage and shall not saturate on phase-to-earth faults with the machine overexcited to the ceiling voltage.

The secondary resistor shall be selected so that for a single phase-to-earth fault at a Generator terminal the power dissipated in the resistor is equal to or greater than the zero sequence reactive volt ampere loss in the zero sequence parasitic capacitance of the generator and cables.

The kVA rating of the earthing transformer for one-minute duty shall be selected for maximum generator voltage at the maximum fault current. The calculations for selecting the kVA rating of the Neutral Grounding Transformer (both for continuous and short time rating) along with calculations for resistor rating shall be furnished by the Contractor to the purchaser for approval. The continuous rating shall match with the maximum possible star point current at normal operation. This preloading shall, as well, be considered for calculation of the short time ratings.

The resistor loading the secondary circuit of the earthing transformer shall be of the dry type.

Sheet steel cubicle for accommodating the neutral isolating link, distribution grounding transformer and secondary loading resistor shall be supplied. The thickness of the sheet steel shall not less than 2 mm. The degree of protection for cubicle shall be IP-42.

The cubicle shall be floor mounted and shall be furnished with the foundation bolts. Door with pad locks shall be provided in the front and sides to facilitate access to equipment mounted inside the cubicle. Provision shall be made for earthing one terminal of 6.6 kV transformer winding and also for grounding of cubicle.

The cubicle shall be complete with interior illumination lamp, isolating switch, space heaters, terminal pads, insulating barrier between transformer and resistor compartment, earthing stud, common marshalling boxes and other accessories for proper functioning.

Terminal board shall be provided for connection to control wires and wiring inside the cubicle shall be flame proof, 1100 V grade and shall conform to IS 1554, Part I.

The single pole isolator of suitable rating shall also be incorporated in the cubicle with its operation status indication contacts for Unit Control & Protection Panel and SCADA system.

5.12.3 Current Transformers

All the current transformers on line and neutral sides of generator are included in the scope of supply of 11 kV switchgear supplier. The current transformers on line side shall be accommodated in 11 kV switchgear panels and current transformers on neutral side shall be accommodated in NGC cubicle or generator neutral terminal box. Neutral grounding cubicle supplier shall keep provision to mount these CTs on its cubicle and shall co-ordinate with 6.6 kV switchgear supplier in this regard.

The current transformers shall conform in all respects to the requirements of IEC 60044/ IS 2705, Part I, II, III & IV. The current transformers shall be designed to withstand the thermal and mechanical stresses resulting from the maximum short circuit current. The current transformers shall be suitable for the purposes intended.

The secondary terminals shall be brought out in a separate compartment for easy access and provision shall be kept for shorting the current transformers secondary terminals.

The rating and characteristics of current transformers are as per SLD and are detailed in 11 kV switchgear section.

5.13 Control and monitoring

The generator and associated accessories/equipment shall be controlled and monitored at three levels:

- By respective Unit Control and Protection Panel
- By Computerized control and monitoring (SCADA) system through Main Control Boards

The generator supplier shall co-ordinate with Computerized Control & Monitoring System and Protection System suppliers in this regard.

The normal control by the SCADA system shall be through Unit Control & Protection Panel. It shall be the responsibility of the Contractor to make all necessary provisions required to achieve seamless and compatible interfacing of the system with SCADA system.

Local control shall be performed in an independent and standalone manner, and all information (faults, alarms, measurements, status) necessary for such control shall be displayed locally.

If the system consists of redundant subsystems, the priority of operation of such subsystems shall be selectable from SCADA system

5.13 Instrumentation, control and safety devices

Necessary sensors/sensing elements, signalizers for sequential control and interlocks, measurement elements (indication, recording of quantities), monitoring of abnormal conditions of operation (for safety, alarm annunciation and shutdown) and related instrumentation which are embedded in and/or mounted on the generator or its adjacent (local) gauge panel, shall be included in the scope of supply of the generator as an integral part.

These items shall generally pertain to the following:

Temperatures	Stator, rotor, bearings, cooling water, cooling air
Liquid Level	Oil in bearing oil baths
Pressure	Brake air, High pressure for pressure oil system, cooling water
Flow	Cooling water for bearing oil coolers
Over speed	Generator

The generator manufacturer shall cover these items in the generator supply. They shall also include any additional item not indicated but which are necessary for smooth operation and safety of the equipment. A list of these additional items shall be decided during detailed engineering.

5.14 Unit Control and Protection Panel

5.14.1 General Requirements

Unit Control, annunciation and gauge boards hereinafter collectively referred to as UCPP, (one set for each unit) shall serve for turbine, governor, generator and accessories as a local control centre for local automatic control of the unit. The local automatic control shall have fully automatic mode or step by step control mode. The step-by-step mode is normally used for testing purposes.

Unit control Protection Panel shall serve the following functions:

- Starting, stopping and emergency stopping of the units. System shall be complete with control switches and selector switches for start/ stop of units in automatic sequential and step by step modes.

The complete details of unit control board are covered in the section “Supervisory Control and Data Acquisition System”

5.15 Painting, Corrosion Protection and Coating

For all structural steel and cast iron parts including piping for areas in contact with air, oil and water the following applies:

Surface Preparation: - On all cast iron and structural steel parts the rust must be removed by mechanical means (sandblasting) to obtain bare surface.

Primer Coat-

Primer Coat for all areas: - 2 layers of primer coat, dry thickness of each layer 40 microns.

Intermediate & Final Coats-

Type A :- Areas in contact with water- After assembling the mechanical parts in the workshop of all items to be delivered, three coats of water resistant paint must be applied with each layer having a minimum thickness of 100 microns.

Type B: - Areas in contact with oil- All those areas will receive three coats with oil resistant paint, for example Keratol, which must be applied as finishing coat.

Type C: - Areas in contact with air- All those areas still accessible after assembling on site, will receive two prime coats with different colours. The prime coat consists of a preliminary final coat in blue for the generator casing and red for all the moveable parts. The applicable RAL colours will be provided after placing of contract.

Areas in contact with concrete- Cast in items will not receive any coating, but must be free of rust and spunk.

Cast-in items exposed to air and water must be provided with a prime coat to a depth of approximately 150 mm into the concrete.

Parts located in inaccessible areas, which must not be dismantled after workshop assembling must be protected as follows: -

The electrical equipment such as electric motors, limit switches, control panels etc. must receive corrosion protection according to specifications in the worst atmosphere.

Any coated surface damaged after or during assembling must be reinstated.

Internal and external surfaces of the casing and all metal parts shall be painted with epoxy paint that will resist corrosion due to ambient conditions. The colour of external paint will be confirmed during detailed design and must be of non-hazardous and non- toxic nature.

5.16 Quality Control and Assurance

To ensure quality during each stage of work, the Contractor shall establish a system defining quality assurance plan/procedures during various stages of work.

The Contractor shall maintain quality control during manufacturing of equipment as per the approved quality assurance plan. Inspections and tests shall be carried out by the Contractor as per approved quality assurance plan with due regard to stipulations in of "General Technical Specification" at various stages of manufacturing for assuring the full compliance of supply with the requirements of specification.

The Contractor shall follow the approved site quality assurance plan and installation procedures. The Contractor shall maintain the quality records during site installation and commissioning which shall be produced to the Engineer for approval at defined stages.

Inspection and tests shall be carried out at site by the Engineer during installation and commissioning as described in relevant clauses.

5.17 Drawings, Documents and Design Calculations

5.17.1 Design memorandum

The Contractor shall prepare and submit to the Purchaser a "Design Memorandum" of the proposed equipment/system fulfilling the contract specification/requirement for approval prior to submission of drawings and documents. The memorandum shall include the design philosophy, methodology, system description, input parameters for design, standard and codes, design and selection criteria, equipment data, material specification, major technical features, basic arrangement/ layout etc.

5.17.2 Drawings and documents

The Contractor shall submit all the drawings and documents in accordance with requirements stipulated in "General Technical Specification (GTS)". These drawings and documents shall include at least the following: -

5.17.2.1 To be enclosed along with the tender

- Generator capability curves
- Graphs showing the predicted Generator characteristic curves (OCC and SCC).
- General view of hydro-generator giving the general arrangement and overall dimensions of generator showing position of main & neutral leads and important elevations etc.

The supplier shall also furnish all the data, information and other particulars called for in this specification & at other places.

5.17.2.2 To be submitted after award of contract

The generator manufacturer after the award of the contract shall furnish all drawings, data, manuals and other necessary literature pertaining to the equipment offered by him and as specified under various clauses. A comprehensive list of all such drawings/documents planned to be submitted for reference/approval shall be provided before hand for approval of the purchaser. The contractor shall supply the time schedule for execution of the contract. The contractor in addition shall supply the following information.

- Detailed quality assurance plan giving complete specifications of the materials and specifications relating to inspection and testing of materials and finished components.
- Comprehensive operation, maintenance and installation instructions in the form of O&M manuals for generator, excitation system, Control Boards and auxiliaries.
- Schematic drawings of electrical control for the unit and associated auxiliaries.
- Block schematics showing interconnecting cabling required between panels and equipment like computerized control system, transformers, Switchgear etc. These drawings shall also show the recommended size and type of multi core cables as well as cable numbers.
- Shop tests and inspection procedure for generator and other equipment.
- Field test procedure for generator and auxiliary equipment.
- Storage instruction for generator and other components.
- Foundation details and loads including short circuit forces as well as openings / cable trenches in floors to enable purchaser to design foundation and plan layout of equipment.
- Control & wiring diagram for all electrical connection for generators and associated auxiliaries.
- Wiring schedules showing multi-core cable, sizes, no. of cores with their wire nos. destination, functions etc.
- Mechanical tolerances permissible in the assembly and erection of generator components.
- Design calculations giving basis for selection of various generator parameters (such as generation voltage, pf, SCR, Inertia constant, flywheel effect, etc) and for various generator components. Detailed calculation shall be furnished at design stage and detailed information shall be furnished prior to starting of manufacture.
- Design calculations for selection of pump capacities, strainer capacity, cooling water quantities, degree of filtration and auto cleaning facilities for uninterrupted operation of the plant.

- Other drawings or information specifically required by purchaser in order to check the suitability of design

5.17.2.3 Design calculation

The Contractor shall submit the design calculations as per “General Technical Specification (GTS)” covering at least the following, for approval.

- Structural analysis of different generator parts,
- Foundation loads,
- Runaway speed,
- Critical speeds,
- Strength of all rotating parts to withstand runaway speed and vibration,
- Number of coolers for bearings, the normal working pressure and pressure drop through the coolers, quantity of oil used in the bearings
- GD2 calculations,
- Coupling bolts size,
- Stress calculations for shaft and rotor,
- Calculation to substantiate capability of the generator to withstand the additional stresses resulting from operation of unit with two adjacent guide vane passages in blocked condition,
- Size of the bearings, effective surface area / specific load on bearings with respect to total load (static /dynamic) etc. under worst conditions / runaway condition,
- No load and full load calculations for stator
- Maximum stresses / loads during normal operation, runaway-speed conditions, two phase and three phase short-circuit conditions or single-phase earth fault at maximum output for which generators are capable of, 1800 and 1200 out-of-phase synchronization, magnetic unbalance at runaway speed with 50% of the poles short-circuited and brake application etc.
- Bearing coolers, temperature rise calculations,
- Ventilation of generator,
- Size and no. of brake assemblies.

The Contractor shall also provide other calculations as required by the Engineer for his approval of the Contractor's design.

5.18 Shop Tests

The principal requirements of generator testing procedure and conditions shall be governed by the IEC Recommendations 60034-1, 60034- 2, 60034-2A, 60034-4, IS 4722

All test equipment for conducting tests shall be provided by the Contractor.

5.18.1 Workshop acceptance tests

The generator shall be fully assembled at works and shall be subjected to at least following tests before dispatch.

The shop assembly and tests shall be witnessed by the Engineer as per the requirements of approved Quality Assurance Plan. The scope shall include all type and routine workshop tests and random tests. The tests are listed below -

5.18.1.1 Type Tests

- Measurement of winding resistance
- Phase sequence tests
- Regulation test
- Measurement of leakage reactance and Potier's reactance
- Measurement of open circuit characteristics
- Measurement of short circuit characteristics
- Efficiency test
- Temperature rise tests
- Occasional excess current test
- Over speed test
- Insulation resistance test (both before and after dielectric test)
- Dielectric test
- GD2 Calculation
- Determination of deviation of voltage waveform from sinusoidal
- Measurement of bearing current
- Pressure tests on coolers if applicable

5.18.1.2 Routine Tests

- Measurement of winding resistance
- Measurement of insulation resistance
- Phase sequence tests
- Regulation test
- Run out test
- Measurement of open circuit characteristics
- Measurement of short circuit characteristics
- Dielectric test

- Measurement of bearing current
- Pressure tests on coolers if applicable

5.19 Installation and Commissioning

5.19.1 Installation

The Contractor shall follow the requirements of installation elaborated in “General Technical Specification (GTS)” and “General Information and Requirements”.

The Contractor has to do all the work related to assembly, erection, testing and commissioning complete in all respects. All necessary tools, plants, labour, materials including consumables for performing installation, testing and pre-commissioning shall be provided by the Contractor.

The Contractor shall submit the necessary data/information, layout and foundation/support drawings well in advance.

The Contractor shall provide and install the concrete inserts/embedment; support steels and/or components for foundation/supports purposes as per approved erection drawings and coordinate the activities with civil contractors to keep his activities in synchronism with civil work.

5.19.2 Installation procedure

The Contractor shall submit six copies of all detailed programs and the procedures to be adopted for erection / installation, testing and commissioning, at least three (3) months before start of erection activities/ installation, for approval of the Purchaser.

The installation procedure shall also have a section “site quality assurance plan” containing erection data sheets for various components. These sheets should specify site measurements/ inspections required to be made for ensuring proper installation

5.19.3 Field inspection

The Contractor shall permit the Engineer to perform inspections of the assembly which will include a complete verification of the assembly of all parts as to their levels, clearances, pertinent fits, alignments and quality of workmanship. The field supervisor of the Contractor shall provide The Engineer with three (3) copies of all the clearances, tolerances and data of all pertinent fits, alignments and levels, so that the latter may repeat the Contractor’s measurement, if desired.

Unless otherwise specified, any rejection based on the inspection will be reported to Contractor within fifteen (15) days and injurious defects subsequent to assembly and acceptance will be rejected.

5.20 Field Tests

All field tests including tests during installation, pre-commissioning, commissioning, shall be conducted by the Contractor, in the presence of representative of the Purchaser.

Procedure to be adopted for conducting the operational, pre-commissioning, commissioning, shall be submitted well in advance, at least six (6) months before start of relevant testing, for approval of the Purchaser. All equipment required for testing shall be arranged by the contractor.

The equipment / system shall be considered commissioned and ready for trial run only after successful operation for a “test service period” specified in sub clause “Performance Testing”. In the event of any failure, this period shall be repeated for any number of times till the successful operation as described above is achieved.

5.20.1 Tests during installation and pre commissioning

During erection and before start up, the following measurements and tests shall be performed as a minimum and all other tests, which are deemed necessary by the Purchaser:

- Visual inspection and dimensional check,
- Check of stator bore for exact roundness at both ends of the iron core,
- Checking of the uniformity of the air gap,
- Rotor roundness measurement,
- Checking of the alignment of the ready assembled turbine and generator shaft,
- Checking of all bearing clearances,
- Checking of the bearing oil cooling installation for complete and correct assembly,
- Checking of the entire generator cooling system for complete and correct assembly,
- Tightness tests of all equipment containing/carrying water, oil and compressed air,
- Checking of braking operation
- Measurement of the DC resistance of the field winding,
- Measurement of the stator winding DC resistance, impedance and capacitance per phase,
- Insulation test and H.V. test of the field winding,
- Insulation test (1 min. and 10 min. value), H V test of the stator winding and determination of polarization factor,
- Performance of operational tests on all generator auxiliary equipment, including calibration of related electrical indicating, control and metering instruments, and checks for correctness of wiring and piping,
- Checking of alarm and protection devices,
- Magnetisation test of the ready assembled iron core to verify the absence of hot spots (local overheating) and measurement of core losses,
- High voltage withstand test on individual windings in accordance with IEC 60034-1,
- High voltage withstand test of the ready assembled stator winding in accordance with the IEC publication 60034-1,
- Terminal tests according to IEC 60137.

Any other tests deemed necessary, before commissioning of the unit.

5.20.2 Commissioning tests

At least the following tests shall be performed on each generator:

- Tests of shaft movement, bearing run and shaft eccentricity,
- Checking of start-up and shut down sequence including mechanical braking,
- Dry out run,
- Short circuit and no load curves,
- Insulation resistance test and H.V. withstand test of the stator winding,
- Functional test of generator protection relays,
- Determination of reactance and time constants as derived from specified measurements/tests,
- Measurement of shaft voltages and bearing currents,
- Over speed test, noise and vibration measurement including balancing of the unit,
- Synchronization with the grid system,
- Load rejection tests at different load steps
- Rated output test of the unit including temperature run,
- Operational tests on bearings to be able to operate for 15 minutes at rated conditions without any water cooling auxiliaries,

5.20.3 Performance testing

If nothing unusual has been observed in load run and load rejection tests, the test service period of 72 hours shall follow. During this test service period, the unit must operate continuously at rated

condition without any interruption except of those beyond the control of the Contractor. However, such interrupted period shall not be counted for in the test service period.

The Contractor shall be responsible for the equipment during test service and also for the way it is operated. However, Purchaser's personnel will operate the equipment under the Contractor's guidance during test service period.

5.20.3.1 Test report

Shortly after completion of the field acceptance tests the Contractor shall prepare and forward draft copies of the field acceptance test report to the Engineer for review. After review and acceptance, the Contractor shall furnish ten (10) copies of the final report. The report shall include all information, analysis and presentation of results for tests and shall also include:

- A table of efficiencies at various operating conditions and power outputs used for calculation of the weighted average efficiency,
- A comparison of the test results with the guaranteed values.

5.21 Spare Parts

The spare parts shall include the followings.

S. No.	Description	Quantity
A	Synchronous Generator	
1	Thrust pads	1 set
2	Guide bearing segments comprising one (1) set each for every type of bearing	1 Lot
3	Thrust bearing pads complete with supports	1 set
4	Brake lining pads	2 sets
5	High pressure oil jacking pump with motor, complete in every respect	1 set
6	Seals and gaskets comprising two (2) sets of every type, material, or size.	1 lot
7	High-pressure fittings comprising two (2) sets of every size and type.	1 lot
8	Oil filters and strainers comprising two (2) sets of every size or type.	1 lot
9	Sliprings comprising two (2) pieces including mounting and insulated material.	1 set
10	One (1) instrument each of any kind and size as applicable	1 set
11	Level switches/pressure switches, pressure gauges- one of each type	1 lot

12	DTT's, RTD's of each type - 10% of complete requirement	1 lot
B	Excitation system	
1	Electronic cards pertaining to the AVR, comprising one (1) piece of every kind, type or size.	1 Lot
2	Electronic modules not included in the AVR but necessary for the control of the thyristor circuits	1 set
3	Thyristors (controlled power diodes) comprising one third (1/3) of the total quantity required for one AVR	1 set
4	One hundred percent (100%) of thyristor fuses, comprising the total quantity for one (1) AVR.	1 Lot
5	Field breaker power contacts, each set comprising the total number of replacement part for one unit.	2 sets
6	Field breaker operating coils, each set comprising one (1) piece of every kind and type	2 sets
7	Power pack (consisting of DC/AC and DC/DC convertor) of each type	2 sets

5.22 Special Tools

The Contractor shall propose the list of recommended special tools (other than those included under "Tools and Appliances" above) including their make and detailed specification as recommended by manufacturer(s) and to be accepted by the Purchaser.

5.23 Quality Assurance and Testing

The bidder shall submit the quality assurance plan along with bid for approval of the purchaser. The Contractor shall follow the quality assurance and testing requirements as per quality assurance plan approved by the purchaser.

5.24 Guaranteed and Technical Particulars

Guaranteed and Technical Particulars as called for in Vol. VI shall be furnished along with the bid. Bids lacking in this may be considered unresponsive. Particulars subject to guarantees shall be clearly marked

5.25 Completeness of Equipment

All fittings and accessories of the generator, monitoring equipment, excitation equipment, cooling water system, control devices & instrumentation and associated auxiliary & ancillary equipment which may not have been specifically mentioned in these specifications, but are usually necessary for completion of the above equipment, shall be deemed to be covered by the specification; and shall be indicated and furnished by the supplier without any charges to the purchaser.

5.26 Deviation from Specifications

While the purchaser does not bind himself to accept any deviation, due consideration will be given to any special devices or equipment put forward by the supplier with a view to increase the efficiency of the equipment and minimize the maintenance cost of the equipment as a whole.

Should the supplier wish to depart from these specifications, he shall submit a complete and itemized list of such deviations, together with full particulars of the reasons for the deviations in a separate schedule with special reference to clause and paragraph nos. of this specification. Unless this is done and also the purchaser's concurrence in respect of such deviations is obtained in writing, the equipment offered shall be deemed to comply in every respect with these specifications.