

CHAPTER- 11

GENERATOR TECHNICAL & EXCITATION SYSTEM SPECIFICATION

11.1 Specifications

Typical specifications of a large vertical peaking hydro generators (umbrella/semi umbrella) with static excitation system detailing the requirements of various components of generators and exciter, applicable standards, performance guarantees, erection, testing and commissioning requirements are given below. (Specification for small and other generator may be modified).

11.1.1 Scope

- (i) Vertical shaft synchronous generators kW at PF with closed system of ventilation with surface air cooler.
- (ii) Static excitation system including excitation cubicle and voltage regulating equipment and accessories.
- (iii) Special provision for peaking operation i.e. brake dust collection system (if required).
- (iv) Generator transformer connection (Isolated Phase bus duct/segregated phase bus duct)
- (v) Neutral grounding equipment.
- (vi) Surge protection equipment, potential transformer.
- (vii) Generator bus bar current transformers
- (viii) Carbon dioxide fire extinguishing equipment
- (ix) Lubrication system (if required).
- (x) Oil water and air piping with valves and fitting.
- (xi) Instrumentation, control and safety devices.

11.1.2 Applicable Standards

Latest edition of the following standards shall be applicable.

IEC-34-1: 1983 –	Rotating Electrical Machines Rating and Performance
IEC-34-2A-1972 -	Rotating Electrical Machines Methods for determining losses and efficiency of electrical machinery from tests (excluding machines for traction vehicles)
IEC-34-5-1991 –	Classification of degrees of protection provided by enclosures for rotating electrical machines (IP Code)
IEC-85-1987 -	Classification of materials for the insulation of electrical machines
ANSI C50.12	“Requirements for Salient-Pole Synchronous Generators and Generator/Motors for hydraulic Turbine Applications”,
IEEE No. 115	“Test Procedures for Synchronous Machines”,
IS-4722 –1992	Rotating electrical machines
IS-325 –1996	Three phase induction motor
IS-8789 –1996	Values of performance characteristics for three phase induction motors
IS-4889-2002	Method of determination of efficiency of rotating electrical machines
IEEE std. 421.1-1986,	IEEE standard definitions for excitation systems for synchronous machines

IEEE std. 421.2 TM -1990, IEEE Guide for identification, testing, and evaluation of the dynamic performance of excitation control system

11.2 Type and Rating

The generator to be furnished under these specifications shall be umbrella/semi umbrella type with thrust bearing at bottom and direct driven by the turbine. The turbine generator shall be designed as a complete unit with all the necessary supports, access, lubrication cooling, lighting, ventilation system, fire protection,

dehumidifying, (for bulb generators) draining, wiring, piping and all other auxiliary systems. The generator shall be supplied with a complete static excitation and voltage regulation system. Except as otherwise provided, major components of the generator shall be designed by the Contractor. This shall not preclude a wholly-owned subsidiary from utilizing the design of its parent company. The rating of the generator shall be as follows. The generators shall be suitable for peaking operation requiring daily starting and stopping schedules (if required).

(a) Capacity kVA

A net capacity of kVA at rated conditions is required. The generator nameplate rating shall reflect the necessary additional capacity to supply the excitation equipment.

- (b) Power factor lagging
- (c) Frequency 50 cycles
- (d) Number of phases 3
- (e) Voltage between phases, rated (kV) 11 kV or higher
- (f) Speed (RPM) To match turbine speed
- (g) Stator winding connections Star, (suitable both for Grounded or ungrounded operation)
- (h) Excitation voltage, not to exceed VDC

Rating, tests and characteristics shall be in accordance with the latest IEC IEEE Standards ANSI C50.12 “Requirements for Salient-Pole Synchronous Generators and Generator/Motors for hydraulic Turbine Applications”, IEEE No. 115 “Test Procedures for Synchronous Machines”, each as they apply, unless otherwise definitely specified.

The generator shall be designed in accordance with best International practice, with liberal factors of safety, and for continuous operation at 100 percent rated kVA at rated voltage, power factor and frequency.

The following paragraphs, prescribe the minimum requirements for one generator, but these requirements shall apply also to all generators furnished under these specifications. Similar parts of the generator shall be of the same materials and workmanship and insofar as practicable, shall be interchangeable.

Generator shall be designed for peaking operation requiring starting and stopping schedule every day. Special provision for braking collecting brake dust shall be made so that maintenance is minimized (if required).

Generators shall be designed to run as synchronous condenser (if required).

11.3 Electrical Characteristics

Each generator shall have the following principle characteristics.

- 1. Rated continuous rating at
0.9 lagging power factor and at
normal rated terminal voltage MVA
- 2. Continuous overload capacity 10 %
- 3. Terminal voltage at which the maximum
Continuous rating must be achieved (kV)
- 4. Minimum terminal voltage under 10 % lower than the
Operating continuous with unloaded system normal rated voltage
- 5. Excitation at maximum leading kVA Not less then 12 %
expressed as percentage of that required
at rated output and power factor
- 6. Terminal voltage at which the maximum 5 % higher then the
Continuous rating must be achieved normal rated voltage
- 7. Short circuit ratio on rated kVA 1.0

	Base, not less than	
8.	Telephone harmonic factor (THF) of the line-to-line Terminal voltage as measured according to IEC 34-1 not more than	1.5%
9.	Efficiency at kVA power factor lagging at normal rated voltage and frequency not less than percent %
10.	Normal exciter response (as defined in IEEE std. 4.21.1) for the exciter, not less than (after study)
11.	Ceiling voltage of exciter when connected to the generator field and with rated exciter current delivered (80 degree C)	To suit above ratio
12.	Line charging capacity of the generator, when charging a transmission line, at rated speed and voltage, without being completely self excited or unstable not less than MVA
13.	Maximum ambient air temperature degrees centigrade °C

11.4 Mechanical Characteristics

1.	Flywheel effect (WR^2) of rotating parts of the generator and exciter
2.	Direction of rotation	To match turbine
3.	Maximum runaway speed r.p.m.	To match turbine
4.	Maximum Temperature of inlet cooling water for air cooling system °C
5.	Design mechanically to withstand Continuously. Without exceeding the specified operating stress, a load of MW (1.0 pf) MW
6.	Designed for operation with a turbine having the rated output MW. (at generator terminal) at rated head

11.5 Insulation and Temperature Rise

Insulation shall be provided as follows:

(i)	Stator Winding	Material corresponding to class F
(ii)	Rotor Winding	Material corresponding to class F

The generator shall be capable of delivering rated output at any voltage and frequency in the operating range at rated power factor without exceeding the following values of temperature. Cooling air entering the generator at not more than. Ambient temperature (50°C) with temperature of cooling water being 30°C.

(i)	Stator Winding	105°C
(ii)	Rotor Winding	105°C
(iii)	Stator core	105°C

The maximum temperature when the generator is delivering maximum output corresponding to continuous overload capacity for conditions rated above shall not exceed 125°C for both stator and rotor winding respectively. Temperature rise shall be guaranteed in the tender and shall be measured on site in accordance with IEC 34 or relevant IS. Armature winding by embedded temperature detectors located in armature winding and temperature of field winding by resistance method. Water for cooling purposes will be available at temperatures not exceeding 30°C.

11.6 Speed Rise and Runaway Speed

The moment of Inertia of the generator together with the moment of inertia of the turbine shall be such that the maximum momentary speed rise under Governor Control on full load rejection shall be as per requirement given in turbine section. Extra flywheel effect if required shall be incorporated in the rotor. Separate flywheel shall not be allowed.

The maximum runaway speed shall be stated and guaranteed by the supplier. All rotating parts and bearings shall be capable of withstanding the forces and stresses occurring during runaway speed for at least 30 minutes without any damage to any part. The guide bearing and guide cum thrust bearing shall be capable to withstand runaway speed for 15 minutes without supply of cooling water and continuously with cooling water without abnormal increase of vibrations and temperature (For mega generator may consider relaxation).

11.7 Noise Level

The noise level shall not exceed 85 dB when measured at a distance of 1 m from any component of the generator.

11.8 Efficiency and Output Guarantees

Within the limits of temperature rise specified in clause 11.5 above, the rated continuous out put of the generator shall be guaranteed under penalty with a rejection limit of minus 2 percent for the rated generator terminal conditions.

The weighted average efficiency of the generator shall be guaranteed under penalty with a rejection limit of minus 2 percent. The efficiencies shall be determined by the summation of losses method as specified in latest Indian standard IS: 4889. For any short fall in the test value of output and weighted average efficiency (as determined below) from the guaranteed figures, efficiency (as determined below) from the guaranteed figures the penalty shall be at the rate of five (5) percent of the ex-works value of generator per generator for every one (1) per cent by which the test figure is less than the guaranteed figure. The weighted average efficiency (see note)= $0.4 \times \text{efficiency at full load} + 0.4 \times \text{efficiency at 80 percent full load} + 0.2 \times \text{efficiency at 60 percent full load}$. The total penalty on account of output and efficiency shall be computed separately and the total amount of penalty on account of shortfall in the weighted average efficiency and output will be mutually decided by the purchaser with the contractor.

No tolerance shall be permitted over test figures of output. Tolerance in determination of efficiency shall be as per relevant Indian Standard.

Note: weighted average efficiency to be worked as per site.

11.9 Bid Evaluation

In the evaluation of bids, equalization on account of differences in efficiencies of generator of the various bids will be made at the rate of Rs. 10,00,000.00 (Rs. Ten Lac) per generator (to be worked out as per size and cost of energy) for each one tenth of one percent (0.1%) by which the rated average efficiency given in (or computed for) any offer is lower than the highest weighted average efficiency among the various offers. For differences lower or higher than one tenth of one percent (0.1%), the equalization will be computed on pro-rata basis.

11.10 Structural Details

Each generator furnished under these specifications shall be designed for clockwise rotation (site) when looking down on the unit. All the parts of the generator shall be designed and constructed to withstand

safely, the maximum stresses under short circuit and runaway conditions. Maximum stresses at runaway speed shall be stated by the bidder.

Each stator frame of the generator will be supported on sole plates laid in the concrete foundation constructed as part of the power house structure. The generator shall be provided with bolts and dowels for fastening the stator frame to the sole plates and for preserving the alignment between the generator frame and the sole plates. A liberal number of dowels shall be provided in order to prevent any possible movement of the stator frame in the sole plates when the generator is subjected to stresses resulting from the most severe short circuit conditions. The number of sole plates shall also be sufficient so as to give low stresses in the concrete foundation. Sole plates and foundation bolts for the stator frame and the lower bearing bracket shall be furnished by the Contractor and the foundation bolts will be installed by the purchaser under the direction of the company. The stator and the pit beneath cash generator shall be designed to permit the removal of the largest turbine part, required to be passed through it when disassembling for repairs.

The brackets supporting the bottom thrust bearing in the generator shall be of massive welded construction and have sufficient strength and rigidity to support the weight of entire rotating element of the generator together with the turbine runner and shaft and the unbalanced hydraulic thrust of the turbine runner. The bearing bracket shall be strong enough to withstand horizontal and vertical component of earth quake forces (para-9.4.10). The thrust bearing housing shall be made in suitable sections, so that thrust bearing shoes and thrust-bearing runner can be inspected or removed conveniently. The upper guide bearing if provided will be designed so that it will not be necessary to remove the slip rings, when dismantling the bearing. The lower guide bearing bracket shall be designed and constructed so that after the bearing is removed the shaft flange will pass through the bracket bore, when the rotor is lifted out and the bearing bracket can be removed through the stator of the generator.

The design of the generator brackets, floor plates and structures in which resonance might become objectionable shall be so proportioned that any possibility of synchronism with the natural frequency or any of its multiples of the turbine will be avoided. The natural frequency of the turbine shall be intimated for approval.

The generator shall be designed and constructed so that it can be assembled and disassembled with the power house crane, the maximum lift of which shall be stated in the bid. Provision shall be made for attaching lifting devices; slings, eye bolts etc. for readily handling parts.

Suitable guard, cover and around all live and moving parts shall be provided. Guards for the shaft-coupling flange will be furnished by the turbine manufactures, who will make the shaft alignment test.

Suitable platforms, with stairs and hand railings shall be provided for inspection and maintenance of exciters, thrust bearing and guide bearings. The stairs shall be of the type having closed risers and the treads and walkway surfaces, shall have non-slip finish.

11.10.1 Stator

The stator core shall be built up with high-grade, non-aging thin-laminated silicon steel each Lamination coated on both sides with an insulating, varnish or other suitable material to minimize eddy current losses. The laminations shall be stacked in the stator frame at the factory, with the frame completely assembled and all sections bolted-together.

The laminations shall be adequately supported by the stator frame and securely held in place by clamping flanges at each end. To insure uniform tightness of laminations, core lengths of 760 mm (30 inches) or longer, shall have full and final clamping pressure applied to successive layers of laminations while being stacked, layers to be between 380 mm and 450 mm (15 and 18 inches) in depth. There shall be no perceptible buzzing of laminations during operation. The air ducts in the stator core shall be arranged to make the flow of air smooth and quiet and to minimize air friction losses. The coil slot wedges shall be of fabric base phenolic material, of a glass reinforced polyester material, or other suitable Class "F" material.

All coils, except the coils at the stator trampoline joints (when stator is sectionalized), shall be installed wedged, tied, and connections made before stator sections are shipped from the factory.

The stator winding shall be star connected. Both ends of each phase shall be brought out within the generator housing at an approved location. All necessary conductors, connectors, terminals and materials for forming the generator neutral lead buses shall be furnished by the Contractor. These connections shall be insulated for rated kV. Suitable barriers, within the generator housing, shall be provided around the main and neutral leads for protection of personnel while the generator is in operation. Removable sections shall be provided in the barriers for access to the leads compartment. All bolted bus connections shall be silver surfaced and have drilled holes.

The stator windings shall be insulated with full Class "F" insulation as defined in 11.5 in accordance with IS/IEC. Turn and ground insulation shall be mica tape with equal thickness applied to end turn and slot sections, except for the portions to be used for making the connections. The connections shall be insulated for not less than the same voltage level as the coil or circuit rings. Strand insulation shall be a tape. The coils shall be so impregnated with high-grade insulating varnish, epoxy or similar material that the insulation becomes a dense, homogenous mass, essentially free from air pockets. The coils shall be treated so as to prevent permanent injury from temporary exposure to dampness. The stator coils, shall be provided with a semi-conducting material to provide Corona shielding and shall have secure electrical contact with the core throughout the entire core length. The Corona shielding shall extend a suitable distance beyond the core, The outer protective taping shall be heat-resisting and shall not deteriorate under designed operating temperatures. The coils shall be form wound and interchangeable. Slot liners, if used, shall not be employed for the purpose of providing mechanical protection or additional dielectric strength to the stator winding and will be fabricated of an approved semi-conducting material. Side filler strips and spacers, if used, shall be installed on one side of the slot only and shall be fabricated from an approved semi-conducting material.

A type of winding is desired which will minimize losses and heating due to circulating currents. The strands shall be of annealed copper, free from splinters, flaws, rough spots, or sharp corners. All connections shall be made in a workmanlike manner. The end portions of the coils and the connections shall be rigidly supported and braced to prevent vibration and distortion under stresses caused by the most severe short circuit conditions to which the generator may be subjected, as specified. All joints or connections, including those made in the field, shall be brazed with a suitable copper or silver brazing alloy.

The alternator shall be capable of withstanding sudden 3-phase short circuits at its terminals in accordance with IEC, Line to ground fault currents shall be limited to a value not exceeding that obtained with a three-phase-fault at the terminals of the generator.

Temperature Detectors: Standard Pt-100 type temperature detectors of 10 ohms at 25 degrees C, and having a temperature co-efficient of resistance of 0.00385 at 25 degrees C., shall be furnished and installed as follows:-

Quantity	Location
One	Each thrust bearing shoe.
Two	Thrust bearing and each guide bearing oil reservoir
Two	Each guide bearing located diametrically opposite.
Nine (minimum)	Generator stator winding, located in accordance with I.S./I.E.C. or other recognized standards of other countries

Each detector shall be connected by three leads to terminal blocks located in the terminal cabinet. one wire from each detector shall be connected to a common point or bar on the terminal blocks. The common points shall be insulated from ground but provisions shall be made for a grounding connection on or near each block. All wiring between the terminal blocks and the individual temperature detectors shall be furnished.

A temperature scanner shall be supplied for mounting on the unit control Panels. The wiring from the terminal blocks on the generator casing to the recording panel shall be provided.

The stator winding shall be star connected. Both ends of the conductor of each phase, as nearly equal as feasible, be brought out within the generator housing at approved locations and provided with suitable terminals.

11.10.2 Rotor

The rotor shall be built in accordance with the best modern practice. The rim of the rotor shall be laminated and constructed of steel plates bolted together to make a solid structure. The diameter of the temporary rim bolts, used for constructing rim shall preferably be of the same size as of permanent rim bolts. The hub of the rotor shall be attached to the main shaft so that at normal operating speed and at maximum over speed, secured attachment will be maintained.

The pole pieces shall be built up of thin steel laminations secured by rivets or bolts and shall be fastened to the rotor rim by means of accurately machined or die punched dove tails, matching similar slots in the rotor rim and secured firmly in place by means of tapered keys.

The keys shall be locked in place on both sides of the rim so as to prevent the keys from coming out in the event they should become loose. If necessary, brackets shall be placed between adjacent pole pieces to brace the windings and prevent them from becoming distorted when subjected to the centrifugal forces due to runaway speed. The bidder shall submit details showing how connections are to be made between field coils and how the connections are to be supported.

A suitable brake plate shall be provided on the rotor with which the brake shoes will make contact. The wearing surface of the brake plate shall be in segments which shall be readily removable and renewable. Adequate provision shall be made for dissipation of heat resulting from the application of the brakes and to take care of the expansion of the brake plate segments. Special attention shall be given to the mechanical design of the fans and to the method of attaching and supporting the on the rotor.

The entire rotor shall be designed to withstand safely the maximum runaway speed. The specified WR^2 shall be incorporated into the rotating parts of the generator and exciter and a separate flywheel will not be permitted.

The field winding shall be insulated with class F insulation as defined in para 11.5 and in accordance with the relevant standards of IEC/IS and shall consist of copper strips wound edgewise. There shall be no shorted turns in the field windings. The normal field voltage shall be as specified in paragraph 11.2. The turn Insulation shall be thoroughly cemented to the adjacent turns. Insulating collars of bakelized asbestos fibre, duck, micrata of equivalent material shall be provided at the top and bottom of each field coil and collars shall be adequately supported at all points and shall be made in one piece. The bottom collar shall be supported in such a manner so as to compensate for shrinkage in the insulation and to maintain adequate pressure on the field coil. The winding and insulation shall be capable of withstanding all mechanical stresses to be imposed by the maximum runaway speed of the turbine, special care being used to prevent the end turns from deforming or slipping due to centrifugal stresses in the interconnections. The winding shall be designed to stand the dielectric test in accordance with the IEC/IS standards.

A damper winding shall be provided. The winding shall be of low resistance and rugged construction. It shall be designed for a calculated ratio of quadrature axis sub-transient reactance to direct axis sub-transient reactance, not exceeding 1.35 (or specify).

The collector rings shall be made of suitable material and shall be above the rotor. They shall be sufficiently spaced or barriered, and with brushes so arranged as to minimize the possibility of an operator, causing a short circuit between collector ring, while changing or adjusting the brushes. The design of the brushes shall be such that the current density will be sufficiently low to prevent damage under operating conditions. The field leads shall be arranged and shall have sufficient length so that the connections to the slip rings can be made without removing or dismantling either the field leads or the collector rings. The

field leads shall have 25% extra cross section of copper over and above the amount normally required for the maximum field excitation. The brushes on the collector rings shall be staggered and shall have an unequal spacing on the periphery of the collector rings. An extra pair of collector ring brushes, brush holders and terminals shall be provided for use with the field temperature recorder which will be furnished by the supplier. The manufacture shall furnish and install conduits and leads from the insulated brush holders to the terminal boards inside the generator housing.

The WR^2 of the generator rotor and shaft shall be not less than specified in 11.4. This value of WR^2 shall be incorporated into the rotating parts of the generator. A separate flywheel will not be permitted.

11.10.3 Shafts & Shaft Alignment

The generator shafts shall be made of forged open hearth carbon or alloy steel properly heat treated. The shafts shall be of ample size to operate safely at any speed up to and including the full runaway speed of the turbine, without detrimental vibration or distortion and to carry the generator loads without exceeding the unit stresses permissible.

The generator shafts shall be of the proper length to connect with the turbine shaft and shall have an integrally forged flanged female half coupling on the lower end for connection to a male, half coupling in the upper end of the turbine shaft.

The generator shaft shall be machined accurately all over and polished at the guide bearings surfaces and at accessible points below or above each guide bearing for alignment checks. Each shaft shall have a hole preferably not less than 150 mm in diameter, bored axially throughout its entire length and the hole shall be finished sufficiently smooth to permit visual inspection of the metal in the interior of the shaft.

All coupling dimensions shall be in accordance with A.S.A. standard B.49 1 for shaft coupling integrally forged flange type for hydro-electric units or the latest revision thereof or any other approved standard. The coupling, bolts, nuts and suitable guards for both halves of the coupling will be furnished by the turbine manufacturer. To ensure accurate coupling and alignment of the generator and the turbine shafts, the Contractor shall ensure that the coupling flanges and holes for fitted bolts in both shafts shall be made precise within specified tolerances on CNC machines and/or using common jig. If turbine and generator shafts are manufactured at different manufacturing plants, the Contractor will be fully responsible for correct matching and alignment of turbine generator shafts at site during erection.

11.10.4 Bearings

The generator shall be provided with Kingsbury adjustable shoe type or General Electric spring type or English Electric equalizing ring type or any other latest standard improved type of thrust bearing suitable for peaking (daily start/stop) operation.

The thrust bearing shall have ample capacity to support the combined weight of the rotating parts of the generator, exciter and the turbine including the maximum unbalanced hydraulic thrust of the turbine runner. The thrust bearing shall be provided with an externally pressurized system, automatic manual operation type, for providing high pressure oil to the bearing surfaces, during the starting and stopping of the machine. The bearing shall be of type that unit can be started without jacking and operating continuously without injury at any speed from zero speed to 110% rate speed and for one half hour at any speed from 110% to the maximum runaway speed. Starting at normal operating temperature, the bearing shall be capable of operating at normal speed and load without cooling water for at least 15 minutes. The thrust bearing shall be arranged to permit adjustment, dismantling and assembly without disturbing the rotor or stator other than jacking the load from the bearing.

The pressurized system for providing the high pressure oil to the bearing surfaces shall include a suitable oil pump preferably of the small vane positive displacement type, directly driven by a three-phase 415 volts motor, all necessary motor control and protective equipment, high pressure piping, flexible box, strainers, regulators, check valves connected between the bearing pads and the thrust bearing oil reservoir and the control equipment shall be such as to ensure that unit can be started only, when the desired pressure is built

up and that this oil pressures will be automatically built up, when the unit reaches 50% of rated speed on shut down. A suitable arrangement should be made and mentioned, to prevent corrosive rust or babbitt particles from being drawn to the pump and prevention of accumulation of dirt; so that under no circumstances, the oil passages can be choked up. The oil pump and control equipment shall be mounted in an accessible location, approved by the engineer. A pressure gauge to indicate establishment of oil film pressure shall also be provided for mounting on the instrument panel of unit control board. The pressure gauge shall be equipped with adjustable high and low pressure contacts suitable for use on 220 volts D.C. circuits. The pressure gauge shall match the instruments, supplied by the governor manufacturer. Suitable damping devices shall be provided in the high pressure piping system, if necessary to prevent undue pulsations of the pressure gauge. The high pressure oil grooves on the bearing pads shall be so designed that they will not interfere with normal lubrication of the bearings, while the high pressure system is shut down.

Each generator shall be provided with one or two guide bearings. In case of two bearings the upper guide bearing shall be designed and constructed so that it can be dismantled without disturbing the thrust bearing and the lower guide bearing shall be designed and constructed so that it can be removed without disturbing the rotor or stator.

The guide bearings shall be of babbitt lined oil lubricated type and adequate provision shall be made for preventing oil or oil vapour from entering the generator cooling system. The guide bearing shall be capable of withstanding all stresses, incident to the normal operation of the unit and to the maximum runaway speed of the turbine.

Adequate insulation, to be specified in the bid, shall be provided on the thrust bearing and on all guide bearing and on all guide bearing to prevent harmful circulating electric currents, either inherently generated in the unit or from an external source from passing from the shaft through the bearings to the frame. If during testing and commissioning the circulating currents are detected, the supplier shall take the necessary steps at his own expense to eliminate such currents. Suitable test blocks shall be provided to test the insulation at each bearing.

An oil cooler with suitable cooling coils of corrosion resisting metal shall be provided in thrust bearing oil reservoir and in each guide bearing oil reservoir, if necessary for cooling the lubricating oil and shall have sufficient capacity to maintain the oil at the proper temperature with 30⁰C temperature of cooling water. The cooling coils shall be designed for a maximum allowable working pressure of 245 kg per square meter, and each coil shall be subjected at the factory to a hydrostatic test pressure of 365 kg/m². The allowable pressure loss through the cooling coils shall not exceed 73 kg/m². Companion flanges shall be furnished on the intake and outlet pipes. A water flow indicator, with adjustable ungrounded alarm contacts, suitable for 220 volts D.C. complete with orifice plate in the return flow from each bearing shall be provided.

Standard resistance type temperature detectors and dial type-indicating instruments; temperature recorders, bearing temperature and oil level gauges and relays shall also be provided as specified in paragraph 11.12.

11.10.5 Lubrication

The generator shall be provided with a complete self-contained lubricating system, with no circulation of oil from an external source and shall include the latest improvements to eliminate the throwing of oil and escape of oil vapor from the bearings and the lubricating system. Adequate baffles shall be provided, if necessary, to prevent excessive churning or aeration of oil. The lubrication of the thrust bearing and upper guide bearing shall be entirely independent of the lubricating of the lower guide bearings. Adequate and reliable means shall be provided for circulating the lubricating oil through each bearing. Provision shall be made for filling and draining each bearing reservoir. The overflow for the bearing lubricating oil shall be designed, so as to prevent loss of oil due to centrifugal action and to foaming, which occurs during initial operation.

Each lubricating system shall include suitable oil reservoirs, all oil piping with fittings sight flow meters, valves and all other necessary accessories, including one oil level gauge for each oil reservoir, with scale of sufficient length to indicate the oil level at all room and operating temperatures, to the satisfaction of

purchaser. The gauges shall be so located that they can be easily read. The type of indicator shall be subject to the approval of the purchaser. Each oil level gauge shall have high and low level ungrounded alarm contacts suitable for 220 Volt direct current systems.

The bearings shall preferably be of self-lubricated type and if force lubricated bearings are proposed, the generator shall be supplied with two motor driven oil pumps; one driven by 415 Volts 3 phase 50 cycles A.C. motor and the other by 220 Volts D.C. motor. The direct current motor driven oil pump will run in the event of failure of A.C. supply and it shall be so arranged that in the event of oil pressure falling to a pre-set limit the D.C. motor shall be automatically started and shall re-establish and maintain full normal circulation of oil.

An adjustable pressure switch with sealed mercury contacts or other approved device shall be furnished with each guide bearing for operating an alarm to make contact, when the oil pressure in the bearing oil groove falls 16 percent below normal. The pressure switches shall be located inside the generator housing. All lubricating oil will be furnished by the purchaser. The supplier shall furnish complete specifications for suitable lubricating oil and the quantity required.

11.10.6 Generator Cooling

Each generator shall be provided with surface air coolers spaced symmetrically around the periphery of the stator frame for a closed re-circulating cooling system. The water headers, complete with connections and valves, shall be furnished with the coolers, each connection between the cooler and the headers shall be of flanged type and the header so that any cooler, on the generator, can be readily disconnected and removed for maintenance or repair, without interfering with the operation of the remaining coolers. The entire system shall be designed to prevent accumulation of sediment. A water flow indication with alarm contacts, suitable for 220 Volt D.C. system shall be provided in the surface air cooler water supply line.

Each air cooler shall be of the straight tube with fins of either the spatial type or plate fin type. Spiral fin construction shall either consist of copper fins continuously tension wound on the copper water tube in such a manner to ensure continuous contact with the tube or consist of a double tube employing an outer aluminum tube from which the integral fins are extruded and which is continuously mechanically bonded to the inner copper water tube so as to totally enclose it, except at the tube ends. Plate fin construction shall consist of copper plate fins into which are expanded the copper water tube in such a manner so as to ensure continuous contact between the tubes and plate fins. The tubes shall either be expanded into corrosion-resisting tube sheets and provided with water boxes or the tubes shall pass through tube supports and be provided with copper manifold headers. Brass or copper ferrules shall be provided where tubes pass through the tube supports. The tubes shall be expanded into the ferrules so that all wear due to vibration, expansion, and contraction of the tubes will occur between the ferrules and tube supports.

Water boxes shall be constructed with removable cover plates to permit access to all tubes and shall be so arranged to permit removal of any cover for inspection and cleaning of the tubes without disturbing the cooler water supply or drain connections. Tube sheets shall be made of Muntz metal or other approval materials. The copper tubes shall be made of 90-10 copper-nickel conforming to the requirements of ASTM B 111 or equivalent. All steel components of the cooler shall be hot-dipped galvanized conforming to the requirements of ASTM A-123 or equivalent. Lifting lugs shall be provided on each cooler.

For the purpose of design the maximum temperature of water available for cooling shall be 30°C and minimum pressure at the cooler header for overcoming pressure drop through cooler shall have sufficient cooling capacity to maintain the temperature of air leaving the cooler at 40°C or less with the generator delivering continuously the maximum rated output.

The circulation of the air shall be by means of the fan action of the generator rotor. The air shall be circulated out of openings in the stator frame, through the coolers and back into the top and/or bottom of the rotor. The contractor shall furnish all necessary metal ducts, steel plates, connections, valves and piping for the cooling system.

Each surface cooler shall be provided with one dial type indicating thermometer with adjustable ungrounded alarm contacts and with the thermometer bulb located so as to determine the temperature of the air leaving the surface cooler as specified in sub paragraph 11.2.

11.10.7 Generator Housing

A steel housing shall be furnished with each generator of sufficient size to enclose and to provide access for the stator, coolers, piping and electrical connection. Provision shall be made for removing coolers by powerhouse crane. The housing shall be of pleasing appearance, neatly constructed and made sufficiently rigid to prevent objectionable vibrations. All horizontal surface including cover plates shall be suitable for use as walkways. It shall be practically of airtight construction to permit the application of CO₂ fire protection. Necessary pressure release doors shall be provided and shall be of adequate design to release CO₂ gas pressure without distortion of the housing. The air venting system shall be arranged so that lower bearings will be outside of the cooling air passages.

A sufficient number of access doors shall be provided to give easy access for each compartment in the generator housing. Flush locks, master keyed, and suitable handles shall be provided on all access doors with the provision for opening from inside without the use of keys. Suitable lighting fixtures with guards, convenience outlets, conduits and wiring shall be provided for lighting the space between the generator frame and generator housing and the lighting circuit shall be switched at an approved location near each access door. The leads from the lighting circuit shall be brought to suitable terminal boxes, which shall be furnished by the supplier. All internal wiring and conduits for control, relaying, indication, lighting, excitation etc. shall be brought cut to junction boxes in the generator housing. The junction boxes shall be provided with terminal blocks and with conduit connections for convenient attachment to outside conduits through connection plates to be furnished by the Contractor.

11.10.8 Space Heaters

The Contractor shall furnish adequate number of electric heaters, preferably near top and bottom of coil noses and all along the periphery; within the generator housing to prevent condensation of moisture or sweating within the housing under conditions of maximum humidity and temperature as low as zero degree centigrade when the generator is idle. In any event the total number of heater for each generator in 2 or 3 k. w. units shall be subject to approval by purchaser. The voltage rating of the heaters shall be 415 volts and they will be connected across phases of 415 V 3 Phase 50 cycles system. The Contractor shall furnish all wiring in rigid galvanized conduit between the individual heaters and metal enclosed heater circuit terminal box, which shall be furnished and mounted within the generator housing. The wiring shall be stranded and shall be insulated with varnish cambric with an outer belt of as asbestos and with a suitable protective braid.

11.10.9 Piping

All piping systems within the generator and housing for the coolers, bearings, brakes and CO₂ fire protection system including ring headers for surface air coolers, valves and fittings shall be designed and furnished by the supplier and connection to them brought out to approved positions adjacent to the generator housing or turbine pit. All piping shall be clean inside, and where ending in open connections for other work, ends shall be capped for protection, Valves and other operating devices shall be easily accessible, and gauges and other indicating devices shall be located where they can be conveniently read from the floor or walkways.

Pressure piping for brakes and piping for the air cooler connections and supply and discharge headers may be of steel of appropriate strength. Steel piping used for water lines shall be galvanized. All other piping shall be of seamless drawn copper or red brass as required. Valves shall have bronze seats and stems and shall be suitable for service intended. Cooling water pipes shall be insulated so as to avoid condensation in generator housing. All points where piping system must be disconnected for dismantling operations, bolted flanged connections or unions shall be provided. Arrangement of piping and location of valves and joints shall be such that there will be minimum disturbance of piping and interference with other service when the generator is dismantled or parts removed for inspection or repairs.

11.10.10 Brakes and lifting jacks

The generator brakes shall be specially designed for the peaking units requiring daily start/stop operation. Special arrangements are required to be made for collection of brake dust so that frequent maintenance is reduced. The arrangements made shall be subject to specific approval by purchaser.

The air operated brakes shall be of sufficient capacity to bring the rotating parts of the generator and turbine to a stop from half normal operating speed, within 5 minutes after the brakes are applied, without injurious heating of the braking surface on the rotor, without field excitation on the generator, and with leakage through the turbine gates not exceeding an amount, which will produce 1% of the full rated torque. The air brakes shall be designed for operation with an air pressure at about 7 kg/cm² and provided by the Contractor. The brakes shall also be designed to serve as hydraulics jacks to lift the generator rotor and turbine runner for removal or adjustment of the thrust bearing. The distance of this lift should not be less than 25 mm. This lift shall be sufficient to permit easy inspection or removal of the thrust bearing and all parts of the generator shall be so constructed as to permit this lift without dismantling or disconnecting any parts. An approved provision shall be made for blocking the rotor in the fully raised position. The blocking device shall be such that it will be unnecessary to maintain hydraulic pressure on the jacks, while the rotor is in the raised position. A loop header for oil and air supply shall be provided and arranged to drain the oil and to prevent oil entry into the air system. High pressure lock shield valves shall be provided in the oil and air supply lines to the loop header. The brake jacks shall be so designed as to come to the normal position, when pressure air hydraulic is released. A suitable jacking oil shall be recommended which does not form emulsion with air so as to avoid corrosion in the piping.

Necessary control equipment for automatic and manual admission and to release of air from the operating cylinders of the brakes and also control equipment for automatic operation of intermittent and continuous braking will be furnished by the manufacturer.

A permanently mounted hand operated, high pressure oil pump for use with hydraulic lifting jacks shall be furnished with each generator. The pump shall have sufficient capacity to lift the generator rotor and turbine runner and shaft for a sufficient height, as specified for the hydraulic jack. The pump shall be mounted permanently on the lower bearing brackets or in other suitable accessible locations and connected by suitable pipes and valves to the lifting jacks. All piping used in connection with the air brakes and hydraulic jacks shall be capable of withstanding the maximum oil pressure required for the jacks. The manufacturer shall also furnish one portable motor operated high pressure oil pump capable of delivering, sufficient quantity of oil at adequate pressure to the lifting jacks. The motor shall be suitable for 415 volts, 3 phase, 50 cycles supply and shall be furnished complete with starting contactor and 'start' 'stop' push button control. The portable motor operated oil pump shall be kept, as a standby for power plant and will be used as and when emergency arises in the event of failure of any hand operated oil pump. Necessary provision shall be made for connecting the motor operated oil pump to hand operated oil pump system as and when required.

The brake shoes shall be provided with suitable asbestos metallic friction wearing surfaces, which shall be readily removable and renewable. The brake shoes and wearing surfaces shall be keyed or otherwise securely fastened to the back position. The manufacturer shall furnish all necessary piping, solenoid operated valves, check valves, control switches and relays, limiting switches, interlocks, indicating lamps etc. except the low speed switch for braking and solenoid operated air valve.

11.11 Excitation System

A typical technical specification for static excitation system for a medium/large sized generator connected to a strong power grid is given below. The specifications for small generators and for large generators will be modified accordingly.

11.11.1 General

The excitation system shall be a static potential source type and a “High Initial Response” system as described by IEEE Std. 421 (Standard Criteria and Definitions for Excitation Systems) with a response of not less than 2.0. The equipment shall be capable of continuously carrying the required excitation current at 47°C ambient when the generator is delivering 100% rated kVA at rated power factor, rated frequency and 105% rated voltage. It shall also be capable of carrying ceiling current for 30 seconds after reaching rated temperature when the generator is delivering 100% rated kVA at rated power factor and 100% rated voltage. The excitation system shall be suitable for power generator/synchronous condenser operation of the unit.

The system shall consist of the following major sections arranged in a continuous line-up of NEMA-1 metal cubicles or equivalent, 14 gauge minimum, with hinged front doors (See Note 1) for access to the equipment. Doors shall be equipped with a three point latch and locking handle. Enclosures shall be suitable for lifting, rolling, skidding, and jacking and provided with roof access covers for interconnecting wiring.

- (a) Excitation Transformer
- (b) Power Converter
- (c) Regulating and Sequencing Control

Note 1: Transformer may have bolted access panels

The excitation equipment shall be completely factory assembled, wired, and tested. Interconnections between close connected cubicles in a continuous line-up shall be furnished for field installation

11.11.2 Power Transformer

The power transformer shall be a three-phase, two-winding, self-cooled dry type with a 220°C insulation system and a 115°C maximum rise. It shall receive power directly from the generator terminals. The transformer shall be equipped with two stage over temperature detector. The transformer shall be in accordance applicable standards for the kVA and voltage class.

Over current relay (Instantaneous and delayed), over temperature detection, and grounding pad shall be included.

11.11.3 Power Conversion Section

The power conversion section shall consist of:

- a) One (1) full wave power conversion bridge with thyristor modules capable of producing both positive and negative DC output voltages. The negative DC voltages shall be capable of reducing the field current to zero rapidly to maintain a fast response system of field forcing in both directions. The module shall be complete with a cooling fan, a thyristor over temperature detector, and gate firing and RC snubber circuit boards.

Provide redundant power conversion module to increase the reliability of the system. The standby power conversion module shall automatically switch-on to prevent an interruption of field current should a thyristor failure occur in the lead power conversion module. A “Lead-Standby” selector switch scheme shall be provided to permit the operator to pre-select which power conversion module is to be operative.

- b) One (1) AC breaker, moulded case type, non-drawout, manually operated, with shunt trip and auxiliary switch, for thyristor failure and DC short circuit protection. Breaker shall not trip on normal shutdown sequence.
- c) One (1) AC overload relay (thermal type) for overload protection.
- d) One (1) set of field flashing equipment consisting of the following:

- One (1) set of resistors to limit the field flashing current to the value required to raise the generator terminal voltage to 25% of rated voltage at no load.
- One (1) DC contractor, 2 poles, to automatically connect and disconnect the field flashing source.
- One (1) blocking diode to prevent reverse current into the field flashing source.
- e) One (1) field over voltage relay front door mounted (EE)
- f) One (1) DC shunt, 100 MV, suitably rated.
- g) One (1) set of non-linear field discharge and surge suppression devices.
- h) One (1) control power transformer, 3-phase (or 3 single phase transformers).
- i) One (1) set of DC bus connect terminals
- j) One (1) set of field flashing source connection terminals.

The power converter shall conform to the equipments of “Standard Practices and Requirements for Semiconductor Power Rectifiers”.

11.11.4 Regulator and Sequencing Control

Regulator

For ease of maintenance and to minimize “Time to Repair”, the regulator and sequencing control shall be digital (PLC) and an assembly of card file mounted plug-in type printed circuit cards. Test points shall be provided on the front of each card so that circuit checks can be readily made while the equipment is operational. In addition, the card field assembly shall be front door mounted so that it shall not be necessary to open a cubicle door to make the regular circuit checks.

The following functions shall be provided.

(a) Power Factor and Voltage Regulators

In the “Power Factor” mode, the reactive component of generator current shall be compared to an adjustable DC reference and the amplified error signed shall be used to drive a motor operated potentiometer which raises or lowers the voltage regulator set point, thereby changing field excitation to obtain required reactive current loading. The “Power Factor” regulator shall maintain the reactive current ampere loading on the generator within $\pm 5\%$ without hunting under steady load conditions when the system voltage deviation does not exceed $\pm 10\%$ from nominal.

The operation of the regulator, when in the “Power Factor” mode, shall automatically switch into the “Voltage” mode whenever the unit breaker is open. Thus during the synchronizing period of time, the synchronizer can be used to drive the motor operated potentiometer to adjust the terminal voltage to the required condition for synchronizing.

In the voltage mode, the average generator three phase terminal voltage adjustable DC reference and the amplified error signal applied to the excitation system to maintain the terminal voltage with $\pm 0.5\%$ without hunting under steady load from no-load to full load condition. The range of control shall be from 10% below normal to 10% above normal generator voltage.

The “Power Factor” and “Voltage” regulator shall include reactive droop compensation.

(b) Field Current Regulator

The “Field Current” regulating mode shall provide a back-up system for the “Power Factor and “Voltage” regulators. In this mode, the generator terminal voltage (KVAR loading) shall be under the operator’s manual control. Variations in system voltage which effect MVAR loading must be compensated by readjustment of the “Field Current” regulator “Set Point” adjust. The range of control shall be from approximately 10% less than no-load field current to approximately 5% above maximum required field current.

Maximum Excitation Limiter (Operational and “Power Factor” and “Voltage” Regulating Modes Only).

- (c) Selection of “Power Factor”, “Voltage”, and “Field Current” regulating modes shall be via remote/local control. The control shall permit transfer when the unit is on line.
- (d) Local/Remote control of “Set Point” adjust for the “Power Factor” and “Field Current” regulators.
- (e) Provide minimum excitation limiter to automatically limit the decrease of generator excitation. The limiter shall hold the generator field current at a preset value determined from the reactive capability curve of the generator.
- (f) Provide maximum excitation limiter to limit the field current after an adjustable time delay to prevent sustained field over current. The time delay shall be inversely proportional to rate of change in field current. An instantaneous overcurrent limiter shall be included to prevent excitation from exceeding ceiling current.

11.11.5 Control

Controls shall be microprocessor (PLC) based. The start-stop control shall be arranged for automatic start when the machine speed reaches a pre-set value, and for automatic shutdown whenever an “OFF”, “Unit Breaker Trip” or “Lockout” signal is received. The control shall be designed for a soft shut-down on a normal stop command, with the field current being reduced to zero by the phase control action of the SCR’s before any circuit disconnect device operates.

The following controls and indicating meters shall be mounted on the control (provisions shall be made for remote control):

- a) One (1) “Power Factor”/ “Voltage”/ “Field Current” regulating mode selector switch.
- b) One (1) “Power Factor”, “Set Point Adjust”, switch with limit indicating lights
- c) One (1) “Voltage Set point Adjust” switch limit indicating lights.
- d) One (1) “Field Current Set Point Adjust” potentiometer.
- e) Remote/Local transfer switch.
- f) One (1) Field Ammeter with isolating transducer for remote control.
- g) One (1) Field Voltmeter (provisions for remote indication not required).
- h) One (1) Stator Voltmeter.
- i) One (1) Regulator card file.
- j) One (1) Annunciator, 12 point, substation monitor type.

The following devices shall be mounted inside the control section.

- | | |
|------|---|
| Item | <ul style="list-style-type: none"> a) One (1) set of auxiliary control relays. b) One (1) motor operated potentiometer with limit switches (when remote control is less than 45 meters). c) One (1) set of required power supplies and auxiliary power transformer. d) One (1) set of generator terminal voltage auxiliary PTs (110 VAC open delta signal required). e) One (1) control power breaker, moulded case type, 3-phase, single throw manually operated for - station control power. f) One (1) set of terminal blocks for control connections. |
|------|---|

Terminal blocks shall be rated 1000 volt, 30 amp minimum, except terminal blocks for signal wires which may be rated 600 volt, 20 amperes. Each point shall be marked with the wire number. Ten percent extra terminal blocks shall be provided.

11.11.6 Wiring

The excitation equipment shall be completely factory assembled and wired. Wiring shall be neatly arranged and properly supported. General, control wires shall be 2.5 mm² and signal wires shall be 1.5 mm² switchboard control wire. PT wires shall be 2.5 mm² and CT wires shall also be 2.5 mm² switchboard wire. Power cables field flashing and field suppression circuit wires shall be extra flexible or equivalent and

sized according to the application requirement. Shielded or twisted pair 1.5 mm² wires shall be used in low signal level Wire markers shall be used at each termination of a wire except for card field wiring.

11.11.7 Drawings

The following general type drawings shall be furnished:

Outlines

Start-Stop Logic

3-Line Diagram

Schematics

Wiring Charts

Sequencing and, protective control schematics shall be ladder type with coils and contacts cross-referenced. Regulator schematics shall detail each circuit card for clarity and ease of shooting. Wiring charts shall be table type and shall include drawings showing devices locations.

11.11.8 Additional Items

Following additional items shall also be furnished.

- a) All control switches, transfer switches and indicating instruments that are mounted remote from the excitation cubicles.
- b) Power from properly protected ungrounded 220 volt DC sources, for, use in controlling the elements of the excitation and regulating systems.
- c) Two potential transformers, open delta connected, 110 VAC secondary for use with the synchronous machine voltage regulator, each rated for the normal machine voltage.
- d) Over speed and synchronous speed contacts, master start/ stop relay contacts', and machine protective relaying devices as required for station control and protection.

11.12 Control, Temperature, Instruments, Gauges and Unit Control Board

The generator supplier shall supply all equipment and devices for Control and status data of generator for Control; Protection trip; Annunciation/ Event recording; Temperature Monitoring; Indication (analogue, digital). These together with the equipment supplied by the turbine supplier shall constitute a complete and coordinated set of instruments, gauges, control and safety devices for control of the units during normal running and in emergency.

Indicating instruments, gauges, controls and safety devices will be mounted on the unit control board to be supplied by the generator supplier. The turbine supplier shall supply necessary loose items for mounting on the unit control board. The generator manufacturer shall fully coordinate with the manufacturer of turbine to ensure a neat and functional arrangement of the cubicles. A tentative list of indicating instruments, controls and safety devices to be supplied by the generators supplier is given below. The generator manufacturer may increase/decrease items according to requirements to suit the type and design and also for proper and satisfactory operation of the units. The alarm and annunciation panel with all necessary annunciation relays, aux relays alarms bell terminal bolts, etc. and adequate number of alarm annunciation facia windows for both turbine and generator shall be provided. The generator manufacturer shall fully coordinate with the turbine manufacturer in this regard.

11.12.1 Generator Stator Winding and Bearing Temperature Monitoring

Standard Pt-100 type temperature detectors shall be furnished and installed as follows:-

Quantity	Location
One	Each thrust bearing shoe.
Two	Thrust bearing and each guide bearing oil reservoir
Two	Each guide bearing located diametrically opposite.

Nine (minimum) Generator stator winding, located in accordance with I.S./I.E.C. for monitoring stator winding temperature

Each detector shall be connected by three leads to terminal blocks located in the terminal cabinet. One wire from each detector shall be connected to a common point or bar on the terminal blocks. The common points shall be insulated from ground but provisions shall be made for a grounding connection on or near each block. All wiring between the terminal blocks and the individual temperature detectors shall be furnished.

A temperature scanner shall be supplied for mounting on the unit control Panels. The wiring from the terminal blocks on the generator casing to the recording panel shall be provided.

11.12.2 Generator Rotor Winding Temperature

Monitoring system for complete monitoring of field winding temperature will be supplied.

11.12.3 Vibration Detection

Bearing shaft detection equipment shall be supplied to determine rough load zone operation in conjunction with turbine guide bearing.

11.12.4 Generator Air Gap Monitoring

Equipment for air gap monitoring shall be supplied. The equipment will be subject to the approval of the Purchaser.

11.12.5 Instruments and Guages

- i) For indication and recording on the instrument panel near the Actuator and monitoring. Following instruments, gauges and equipment shall be provided by the supplier.
 - 1. Thrust bearing oil temperature (indication) – to be equipped with tell tale pointer to record maximum temperature.
 - 2. Thrust bearing metal temperature (indication) – to be equipped with tell tale pointer to record maximum temperature.
 - 3. Guide-bearing oil temperature (indication).
 - 4. Guide-bearing metal temperature (indication).
 - 5. Cooling air temperature, each cooler (indication).
 - 6. Thrust bearing cooling water supply pressure.
 - 7. Upper guide bearing cooling water supply pressure (omit if self cooled).
 - 8. Lower guide bearing cooling water supply pressure (omit if self cooled).
 - 9. Air cooling water supply pressure.

The above instrument shall be mounted on the instrument panel. The dial thermometers shall be preferably vapour tension type, with stainless-steel tubes and suitable for flush mounting. The thermometer bulbs shall be located, so as to indicate temperature of the hottest parts.

11.12.6 Temperature and Level Monitoring – For indication at the apparatus

Cooling water supply temperature located in main water supply header for bearing and coolers.
Thrust bearing cooling water return temperature
Guide bearing cooling water return temperature
Thrust bearing oil level
Guide bearings oil level

11.12.7 Alarm and Protection Trips - For remote operation of alarms for excessive

temperature, or loss of pressure, on unit control board and main control room:

- A. Thrust bearing oil and metal (temperature).
- Guide bearing oil and metal (temperature).

Cooling air, each cooler (temperature).
Main cooling water supply (pressure failure).

All electrical contacts for auxiliary alarm devices shall be of the sealed mercury type. The devices to be used for actuating alarm shall be suitable for 110 Volts, Direct Current.

- B. Bearing Temperature Relays for remote operation:

- 1. Thrust bearing
- 2. Guide bearing

The relays located in the babbit of the bearings, will each have 2 sets of electrically independent contacts, each relay shall close its contacts, when the bearing temperature reaches approximately 105⁰C. The contacts shall have a current carrying capacity of not less than 5 amps, shall be ungrounded and shall be suitable for 110 volts. D.C the relays shall be mounted in approved locations and leads brought to a terminal board, located on the stator frame. The tubing shall be insulated; where necessary to prevent bearing currents.

- C. Oil Level gauges:-

- 1. Oil level gauge thrust bearing.
- 2. Oil level gauge Guide bearing.

The scale of the gauge will be of sufficient length to indicate the oil level at all room and operating temperatures. The gauges shall be located near the reservoirs, in an approved accessible location where they can be easily read. The type of indicator shall be subject to the approval of the Engineer, Each oil level gauge shall have high and low oil level ungrounded alarm contacts suitable for 110 Volts, D.C. (High pressure oil pump).

11.13 Generator Transformer Connection

11.13.1 Type

Following types of bus bar connections are used for hydro electric generators connecting generator output terminals to low voltage side of the unit step up transformer and auxiliary bus duct connecting the generator to unit auxiliary transformer, excitation cubicles, potential transformer and surge protection cubicles.

- a) Large and mega generators isolated phase bus in which each bus bar is housed in a separate grounded metal enclosure providing protection against phase to phase faults and induced circulating currents. This type of bus duct was used in Bhakra and Beas project generator. The layout is arranged to use the most economical combination of bus rating and length of single phase bus runs. The runs to the single phase transformer (if used) are sized to carry the current corresponding to maximum kVA rating of transformer.

Specification for isolated phase bus as specified for Bhakra power plants is given in 11.13.2.

- b) Medium sized hydro generator: Segregated phase bus is used in which three bus bars are housed in a single grounded enclosure, but are separate by phase barriers. The phase barriers provide protection against phase to phase short circuits.
- c) Small Hydro Generators: Armoured unearthed system power cables are used with XLPE/EPR Armoured insulation as per IS: 7098 (Part II). Preferably with copper conductor as per technical specification given in Para 4.55 of Part II.

11.13.2 Typical specification of isolated phase bus generator transformer connection based on specification of Bhakra Generator.

Applicable Standards: Latest edition of following standards shall be applicable.

IEC: 298 - High voltage metal enclosed switchgear and control gear

ANS/IEEE: C.37.23 -1987- Guide for Metal Enclosed bus and calculating losses in isolated phase bus

Description

The generator bus shall be of the latest design. Incorporating the most advanced features in isolated phase bus and shall include the following:

- i. 12 kV class, 3 phase generator bus structures of isolated phase bus type of adequate rating.
- ii. Sets of 12 kV, bolted type isolating links
- iii. 12 kV, 200 amps. Triple pole disconnecting switches for station service transformers.
- iv. Price increase or decrease per 0.3 m for generator and station service transformer buses.

Bus structures shall be required to run from generator terminals, to the main step up 12/245 kV, 3 phase power transformers bushing terminals. Suitable taps for 12/3.6 kV, 3 phase station service transformers 12 kV bushing terminals shall also be furnished. The bus bars shall be complete with bolted splice plates, insulators support assembly, expansion joints and fittings etc.

Type and Rating: Each bus structure shall be of the 3 phase, 50 cycles, self supporting, rigid, completely metal enclosed, fully air insulated, isolated phase type of 12 kV class and shall confirm to the standard of IEC/IEEE any other approval equal standard, as regards rating, characteristics, tests etc., unless otherwise specified therein. The bus conductor shall be copper and shall confirm to relevant Indian standards.

Temperature Rise: The max. temperature rise of each bus structure when carrying continuously maximum generator current at rated voltage and frequency shall not exceed 30⁰ above an ambient temperature of 45⁰C for indoor bus structures and 20⁰ C above an ambient air temperature of 55⁰c for outdoor bus structures. The temperature rise of embedded reinforcing steel in proximity to the bus structures and gratings and structural, steel, due to operation of the bus structures, shall not exceed 10⁰C above the ambient air temperatures.

Bus Bar Conductors: The copper for bus bars shall be hard drawn and deoxidized. It shall have conductivity of not less than 98%. The conductor shape may be either box type and perforated for adequate ventilation or double channel section.

Disconnecting Switches: Manually operated disconnecting switches with necessary locking devices, mounted with the bus housing, shall be provided for at convenient location. The switches shall be 3 pole, single throw, gang operated type, rated at 200 amperes, continuously current carrying capacity, capable of interrupting and closing the magnetizing current of the station service transformers.

Bus Structure: The Supplier shall furnish all supporting beams required for securing the bus structure to floors, ceilings and walls. Each bus structure shall withstand momentary short circuit current. The bus structure shall be self supporting and shall be sufficiently tight and gasketed to prevent entrance of dust or water. Each section of each bus structure shall be provided with flexible connectors, for connection to the transformers. The ground bus, for bus structures, running along with the length of the section, shall be provided by the supplier.

Each conductor shall be mounted within a suitable non-magnetic metal enclosed housing having a minimum thickness of 3 mm. The housing shall be so arranged that a rupture of any one housing, will not open an air path from one conductor to another. Except the bus housings, all exposed metal for the outdoor portion of the bus structure, shall be either non-ferrous, corrosion resistant, or shall be galvanized. Adequate provision shall be made for expansion and contraction, caused by temperatures varying from 0⁰C

to the maximum operating temperature of the bus structures and also for minimizing vibration under all conditions of operation. Outdoor bus structures may be provided with forced cooling for dissipation of heat, when operating under max. ambient air temperature of 55⁰C.

Mounting beams shall be of structural steel and shall be integral part of the whole assembly. Insulation spacers shall be provided, between the housing and the beams, to break up circulating currents to avoid over-heating. Bus spacer clamps, shall be made of nonmagnetic material having relatively low electrical resistance.

Current transformers: The current transformers in generator and station service transformer buses, shall be mounted and so arranged as to permit their easy removal, without disturbing the section carrying these CTs.