**PARTICULAR TECHNICAL SPECIFICATIONS**

**1.0 HORIZONTAL FRANCIS TYPE HYDRAULIC TURBINES, INLET VALVES, GOVERNING EQUIPMENT AND AUXILIARIES**

**1.1 SCOPE**

This section of the specifications covers the design, manufacture, tests at works, supply, delivery at site, erection, testing at site and commissioning of 2 numbers of Horizontal Francis hydraulic turbines and associated auxiliary and ancillary equipment.

The scope of supply shall include all parts, accessories, spares etc., which are essential for construction, operation and maintenance of the complete prime mover even though these are not individually or specifically stated or enumerated. Corresponding components, of all the turbines and associated equipment and spares shall be of the same material, dimensions and finish and shall be inter-changeable. The turbine manufacturer shall co-ordinate with the generator supplier so that the generator to be coupled to the turbine is matched in respect of speed, runaway speed, moment of inertia, overload capacities, coupling and other relevant requirements.

**1.2 TYPE AND RATING**

The turbine is selected by using scientific methods for selection of turbine which is based on specific speed (Ns), i.e.

Ns = NP/H5/4

where N is the speed of turbine (r.p.m). For direct coupling, the speed of the turbine is assumed to be equal to the speed of the generator (say 1500 r.p.m). P is the power output of turbine (kW) and H is the net head (m). The calculated value is within the specific speed range of Francis turbine.

The turbine shall be of the Horizontal shaft Francis suitable for coupling directly to horizontal shaft synchronous generator of nominal rating of 50kW each. The direction of rotation shall be clock-wise when viewed from drive end. The rated net head of the turbine shall be **50 m**.

The turbines shall be capable of giving outputs higher than rated outputs to match the overload capability of the generators. Each turbine shall be designed to give a rated output at rated head at generator terminals with guide vane opening of about 80-85 Percent. The turbine shall have adequate capacity commensurate with the 10 % continuous overload capacity of the generators. The turbine would have output higher than the rated output when operating at heads higher than the rated head. The supplier may offer his nearest standard design. The maximum output both at maximum and minimum heads shall be stated in the offer.

The specific speed of the turbine shall be as per the best modern practice and of proven design and operation.

**1.3 OUTPUTS AND EFFICIENCY GUARANTEES AND PENALTIES**

**1.3.1 OUTPUT AND EFFICIENCY GUARANTEES**

The rated output of the turbine at rated head shall be stated and guaranteed. The efficiency of the turbine at rated head for 100%, 80% and 60% rated output shall also be guaranteed. These figures shall be applicable for purpose of penalties, rejection limits and bid evaluation as defined in following clauses 1.3.2, 1.3.3 and 1.9. In addition, the output of the turbine at full gate opening at net head and rated head shall be stated in the tender.

**1.3.2 PENALTIES**

**Penalty for Shortfall in Weighted Average Efficiency and Output**

For any shortfall in the tested values of rated output and weighted average efficiency (as determined on the basis described in clause 1.3.4) from the guaranteed values penalty shall be applied at rate of 0.5 (Half) percent of ex-works price of turbine including governing system for every 0.1(one tenth) percent or part thereof by which test figure is less than the corresponding guaranteed figure. The penalties for output and efficiency shall be computed separately and the total amount of penalty shall be the sum of these two. No tolerance shall be permissible over the test figures of rated output. In case of efficiency, tolerance will be allowed as per appropriate IEC test code.

The ceiling on the total amount of penalty on account of shortfall in the weighted average efficiency and output shall be 10% of the total unit price of turbines and governing system.

**1.3.3 REJECTION LIMIT**

The purchaser has the right to reject the turbine if the test value of either weighted average efficiency or the rated output is less than the corresponding guaranteed value by 2(two) percent or more after allowing tolerance in computation of efficiency.

**1.3.4 WEIGHTED AVERAGE EFFICIENCY**

The weighted average efficiency of the prototype turbine shall be determined from the field test or model test values of efficiency at rated head in accordance with the following formula for purpose of penalty and rejection limit and bid evaluation. Tμav =k1 x Tμ100 +k2 xTμ80+ k3 x Tμ60 Where Tμav is the Weighted average efficiency of the turbine, Tμ100, Tμ80 and Tμ60 are efficiencies of turbine at 100%, 80% and 60% rated output at rated head respectively. The value of K1=0.4, K2=0.3 and K3=0.3

**1.3.5 RECTIFICATION TO MEET GUARANTEES**

The contractor shall be given 4 months or mutually agreed time to improve/modify the design of turbine or to carry out rectifications, etc., as may be required so that the guarantees are met in case the tests prove unsuccessful in meeting the guarantees. If the second meeting is also unsuccessful, penalty or rejection of the equipment, as the case may be, shall be applied. However, no delay in the original delivery schedule shall be allowed if the model test results do not meet the guarantees and rectifications are made by the contractor thereafter within a period of 4 months or mutually agreed period as stated above.

**1.4 CAVITATION GUARANTEES**

The tenderer shall guarantee the runner against excessive pitting caused by cavitations for 18 months from the date of commissioning or 8000 hours of operation, whichever is more. If the 18 months of guarantee period expires before completion of 8000 hours of operation, the guarantee shall apply to the actual hours of operation proportionately.

Excessive pitting shall be defined as the removal of metal from the runner of a weight of W= 0.15 D2 per 1000 hours of operation, where, D = Discharge diameter of the runner and W = weight in Kg.

In case of cavitations pitting exceeding the guarantee, the turbine supplier shall, at his cost, take corrective measures such as modification of design, finish, replacement, repair, etc., and the turbine after modification, etc. shall be subject to cavitations guarantee as for the original equipment. In determining whether or not excessive pitting has occurred metal removal by erosion, corrosion or by the presence of injurious elements in water, etc., shall be excluded.

**1.5 CRITICAL AND PLANT SIGMA**

Values of critical sigma as determined from cavitations model tests as per IEC 193A shall be given in the forms of curves for different heads of operation. Plant sigma curves as recommended by the manufacturer shall also be plotted on it clearly to show the safety margin available.

**1.6 SPEED RISE AND RUNAWAY SPEED**

The moment of inertia of the unit and the normal wicket gate closing time and runner blade angle shall be so adjusted that the maximum momentary speed rise of the unit shall not exceed 35% and the maximum pressure rise in the penstock shall not exceed 25% of the maximum rated head under any condition of operation. The turbine manufacturer shall coordinate with the generator manufacturer for limiting the speed and pressure rise values. The maximum runaway speed of the unit, both off cam and on- cam, under any combination of head and load conditions shall be stated in the tender. The turbine shall be capable of running safely at maximum runaway speed without any damage to its parts for a period of not less than 15 minutes for every such occurrence, with cooling water supply on.

**1.7 NOISE LEVEL**

Maximum noise level resulting from any of the operating conditions shall not exceed 90 db (A) at any place 1.0 m away from operating equipment in the machine hall.

**1.8 STRESS AND FACTOR OF SAFETY**

All parts of turbine shall be designed and constructed to safely withstand the maximum stresses during the normal running and runaway and short circuit conditions, out of phase synchronizing and brake application. The maximum unit stresses of the rotating parts shall not exceed two-thirds of the yield point of the material. For other parts, the factor of safety based on yield point shall not be less than 3 at normal conditions. For over-load and short circuit conditions, a factor of safety of 1.5 on yielding point shall be permitted.

**1.9 BID EVALUATION**

In the comparison of the tenders; the equalization on account of differences in the efficiencies of various offers will be made on the basis of weighted average efficiency as calculated by the formula given below: Tμav = K1 x Tμ100 + K2 x Tμ80 + K3 x Tμ60 at rated head. Where Tμav = weighted average efficiency and Tμ100, Tμ80, and Tμ60 are efficiencies at100%, 80% and 60% outputs, respectively, at rated head. The highest figures of weighted average efficiency will be the basis for comparison of prices of turbines with lower efficiencies and will be loaded at the rate of 0.5% of their ex-works prices for each 0.1% difference in weighted average efficiency as compared with the highest weighted average efficiency.

The weighted average efficiency of the turbine will be multiplied by the efficiency of the gear box (if provided) for obtaining overall weighted average efficiency which will be used for bid evaluation.

The basis for selection of the offers shall be the overall economy to the purchaser considering power house civil works, monetized values of efficiencies, prices of matching generator, prices of powerhouse crane required, etc. The speed and setting of the turbine and its design shall be such as to result in the installation of the best generating unit at least cost.

**1.10 MODEL TEST**

The rates for model test as per relevant standards may be quoted separately. The purchaser shall have the option to get the model test performed by the contractor at an extra cost after the award of the contract. In that event, the manufacture of any part of prototype turbine shall be started only after the efficiency and other guarantees and requirements of the turbine are established and fulfilled on the basis of model tests. In case the contractor has already performed model tests on homologous models, the purchaser may, at his discretion, permit the contractor to proceed with the manufacturer after approval by the purchaser of the model test report.

The performance of the model tests either afresh or that had been done earlier shall be as per IEC 193 and 193A in all respects. Hydraulic performance tests shall be made at various guide vane openings to determine machine characteristics including regimes of safe operations, zones of cavitation and vibration, etc. The phenomenon of cavitation and vibration, particularly at lesser guide vane openings shall be specially investigated. These tests shall include determination of capacity, cavitation limits, hydraulic thrust, runaway speed, wicket gate torque relationship, etc., and such other details as covered in IEC 193 and 193A. Prototype efficiencies shall be derived from model tests by Moody’s step-up formula as contained in IEC 193 for Francis turbines. Model tests shall simulate all possible normal operating conditions of the prototype for entire range of forebay/reservoir and tailrace levels. The tenderer shall clearly mention the time within which the model tests including manufacture of a new model, if required, will be completed. The delivery schedule given by the tenderer shall be reckoned from the date of approval of model tests or model test report or from the time of permission to proceed with the prototype manufacture. If the model test is already available, this shall be submitted within 1(one) month after the award of the contract if required by the purchaser.

**1.11 GENERAL ARRANGEMENT AND CONSTRUCTION**

The turbine shall be of spiral casing type so constructed as to allow all the removable parts to be dismantled conveniently. The design shall also permit removal of rotating parts without disturbing the guide apparatus. The design shall also permit horizontal/vertical\* movement of runner shaft by an amount sufficient for adjustment of bearings and for clearing the joint at the coupling between the turbine and the generator. All equipments in the turbine pit shall be neatly arranged and shall be readily and easily accessible for operation and maintenance. Necessary walkways, ladders, hand rails, chequered plates, platforms, etc., required in the turbine pit shall be provided by the contractor.

**1.11.1 Runner**

The runner shall be of 13/4 chromium-nickel stainless steel. The composition of the material and the source of runner casting shall be stated in the tender. The runner shall be cast integrally of stainless steel. The runner will be a one-piece construction. The runner will have adequate number of blades which shall be polished and ground smooth and shall be free from roughness, cracks, high spots, etc. The finished machine and ground runner shall be dynamically balanced in the works before dispatch. For runner of diameter more than 1000 mm, renewable wearing rings shall be provided.

**1.11.2 Shaft and Coupling**

The turbine shaft shall be forged carbon steel or alloy steel conforming to IS or other equivalent international standards. Wherever the flanges are integral with the shaft, the same should be conform to American standard ANSI-49.1, 1967. For long larger size shafts, tubular construction of proven design will also be considered. The turbine shaft shall be connected to the runner on one side and to the gear box/flywheel generator shaft on the other side. It shall be of ample size to transmit torque at rated speed without excessive vibration or any distortion.

A renewable and removable sleeve of stainless steel shall be provided wherever the shaft passes through a shaft seal or a gland.

The turbine manufacturer shall co-ordinate and co-operate with the generator manufacturer for proper design and construction. The final alignment of the shaft at site shall be the responsibility of the generator manufacturer.

**1.11.3 Bearings**

The turbine bearings can be:

(i) The pad type or sleeve type or Babbitt lined, oil/grease lubricated either self lubrication or forced lubrication type.

(ii) Anti-friction ball, roller bearings, oil or grease lubricated.

These bearings shall be guaranteed for a minimum continuous operation of 100,000 (one hundred thousand) hours and the design and performance shall be well proven and established.

The turbine shall be provided with adequate number of bearings. The bearings shall be designed to withstand operation at maximum runaway conditions with cooling water supply on (if cooling water is provided) for a period of not less than 15 minutes and also for operation at normal speed without cooling water supply for 15 minutes. The bearings shall be provided with a dial type or resistance type thermometer and a pressure gauge with provision for alarm annunciation/shut down on excessive bearing temperatures. The number and type of bearings shall be stated in the tender.

**1.11.4 Shaft Gland**

The shaft gland shall be of the stuffing box/carbon ring type with self-lubricated packing and lantern ring. Any other suitable type of shaft gland will also be considered. The gland shall effectively prevent leakage of water along the shaft under all operating conditions and at standstill and prevent entry of air. In case the location of the gland is below maximum tail water level, an inflatable rubber seal shall be provided for attending the main gland without dewatering the draft tube. A stainless steel sleeve shall be provided on the shaft where it passes through the gland.

Arrangement for providing clean water supply to the gland, if required, shall be made by the contractor.

**1.11.5 Spiral Casing and Speed Ring**

The spiral casing shall be fabricated from welded steel plate/mild steel plates and shall have suitable sections for ease of shipment and to be within transport limitation. The spiral case shall be designed to withstand maximum water pressure including water hammer and shall be complete with anchors, supports, sole plates, turn buckles, hold-down rods, all types of clamps, etc. The speed ring shall be low alloy cast steel or of welded plate steel and shall be in suitable number of sections. The assembled stay ring shall be suitable for welding on to the casing.

**1.11.6 Draft Tube**

Each turbine shall be provided with a draft tube liner/suction bend of welded construction of structural steel. The draft tube cone shall have machined flange for bolting with the runner chamber. Drain box and drain pipes for dewatering the draft tube (if applicable) shall be included in the scope of supply. The design of the draft tube shall be such as to ensure the best overall efficiency for the turbine and stable and pulsation-free operations of the machines.

**1.11.7 Guide Vanes**

The guide vanes shall be made from stainless steel. Sleeves of stainless steel at the bearing and sealing surfaces shall be provided, if required. The guide vane bushes shall be of the self lubricating type with protective seals or shall be suitable for grease lubrication. In case of grease lubrication, arrangement for manual and automatic grease lubrication to all bushes shall be made.

**1.11.8 Operating Mechanism**

The operating mechanism shall have ample strength to withstand the maximum load that can be imposed on it by the most severe operating condition. All working points with relative motion shall be bronze bushed, grease lubricated/ self lubricated. Means shall be provided for adjusting the position of the individual guide vanes to ensure close contact with adjacent guide vane in the closed position. Each guide vane shall be individually connected to the regulating ring through suitable levers and links. Shear/ breaking link or some other suitable arrangements shall be provided on each guide vane to protect guide vane and to provide alarm on foreign body getting wedged between guide vanes. The regulating ring shall be fabricated from welded steel plates. It shall be supported on the outer casing of top/side cover on bronze strips with provision for grease/ self-lubrication.

**1.11.9 Guide Vane Servomotor**

The guide vane shall be operated by two double acting oil operated servomotors of adequate capacity. The servomotors shall be capable of moving guide vanes smoothly during full opening and closing in required time. Standard available hydraulic cylinders of approved make, proven design and of suitable material can also be used as a servomotor.

**1.11.10 Top Cover/ Side Cover**

The top/side cover shall be of cast steel or welded plate construction. Suitable stainless steel labyrinth rings or similar sealing arrangements shall be provided in the covers.

**1.11.11 Turbine Platform, Walkways, Handrails Etc**

Necessary platforms, walkways, handrails, chequered plates, ladders, etc., complete with supporting steel structure, shall be supplied.

**1.12 Inlet Valves**

The main inlet valves of the turbines shall be butterfly valve type suitable for Gross Head and discharge required for over load capacity of the turbine / generator and connecting to the proposed penstock. The valve shall be suitable for all operating conditions of transient and maximum water hammer. The valves shall be operated by oil, pressure and closed by oil pressure/counterweight, so that it is capable of being closed under all emergencies. All associated equipments such as servomotors, oil pressure units, counterweights, etc., shall be included in the offer. The valve shall close automatically under normal and emergency shutdown conditions. The valve will be complete with inlet pipe, outlet pipe, with expansion joint, by-pass arrangement if required for equalization of pressure on either side of the valve etc.

**1.13 Governing Equipment**

Each turbine shall be equipped with suitable electronic governor conforming to IEC No. 308/Hydro – Mechanical Governor complete with all accessories. The governor shall be of proven design capable of maintaining control of speed under all conditions of heads and loads. Such governing system shall be complete with actuator unit comprising speed responsive element, restoring mechanism having adjustable temporary and permanent droop setting, load limiting device, speed level control, etc.

The speed responsive element of the governor can be operated by a toothed wheel mounted on the generating unit shaft with speed pick-ups or its equivalent is normally used as an input to speed sensing device. Standard protections like over speed device, brake control, emergency shut down and alarms, etc., shall be provided in the governing systems. The turbines shall also be equipped with suitable load controlling system for parallel operating with grid.

**1.14 Pressure Oil System**

Oil pressure Units system shall comprise a sump tank and a pressure tank separate for each generating unit. Two numbers of electrically operated governor oil pumps will be provided, one for normal running and the other acting as standby for each unit.

Provision for emergency shutdown of the unit without any oil pump running shall be made. Gauges, pressure switches etc., will be provided as may be necessary.

**1.15 Compressed Air Equipment**

A centralized high pressure compressed air system common for all the units, if applicable, shall be provided for charging the governor oil pressure vessels. The system shall comprise two numbers of high pressure compressors of suitable capacity, one of them being a standby, a common air receiver and necessary pipes, fittings, valves, pressure switches, etc. The capacity of the system shall be sufficient to cater to all the generating units. The compressed air system shall be of the automatic start-stop design operating under pressure switches control sensing the pressure in the receiver.

The high pressure system shall also be used to supply low pressure air requirements for generator brakes, inflatable seals and the centralized grease system, if required. Suitable outlet connections shall be provided for the above purpose and pressure reducers wherever necessary shall be supplied by the turbine contractor to meet the turbine requirements. For generator brakes, pressure reducer, and air-lines will be arranged by the turbine contractor. The compressors and receivers shall have necessary fittings, mountings, safety devices, etc.

The tenderer may also quote as an alternative for providing necessary equipment and devices including nitrogen filled cylinders requires for pressuring the oil pressure vessels with nitrogen gas.

**1.16 Dewatering and Drainage Sytem**

Complete equipment for the draft tube dewatering system common for all the units and the station drainage system shall be supplied by the contractor. The equipment for each of the dewatering and the drainage system shall include two motor driven dewatering pumps, necessary piping fittings/gate valve/non-return valves/float switches, controls, accessories etc.

**1.17 Cooling Water System**

The cooling water for generator air coolers (if applicable) generator and turbine bearing coolers, turbine shaft seal if applicable and for other equipment in the powerhouse needing cooling water shall be provided by tapping the penstock. If a higher pressure is needed at low head conditions, booster pumps to obtain the required pressure shall be provided for each tapping. In case the pressure at the tapping is high, suitable pressure reducer shall be provided. The system shall be complete with required number of duplex strainers, fine mesh filters, flow meters, flow indicators, flow relays, pressure gauges, etc.

**1.18 Turbine Instrumentation, Control and Safety Devices**

Each turbine shall be provided with a complete set of instruments, gauges, controls and safety devices on unit control board for monitoring the conditions of the unit during normal running and emergencies. These shall permit the unit to be started and brought up to speed at the governor location and control during normal running. The instruments and gauges for the turbines include, inter alia, pressure gauges, level indicators, temperature and flow indicators, position indicator, indicating lamps for status indication etc. These shall be placed near the locations of apparatus or in the UCB or both. The safety devices shall comprise equipment and devices for sensing abnormal operating conditions, for giving visual and audible annunciation and shut down the unit, if required. The items, quantities and location are to suit the requirements for safe and satisfactory operation of the generating units and the auxiliary systems.

All the instruments, indicator, gauges, controls, safety devices, etc., shall be complete with necessary detecting element, auxiliary relays, etc.

**1.19 Special Tools, Slings, Consumables etc.**

All special tools, slings, lifting devices, jacks, turn buckles, foundation plates/ bolts, etc., required for erection of the equipments shall be listed and supplied. First filling of oil and grease (if applicable) with 10% extra quantity is included in the overall scope shall be and supplied along with equipment. Welding electrodes as required for site welding and paint for finishing coat shall be supplied by the contractor.

**1.20 Spares**

The spare parts for the turbine and associated equipment considered necessary for 5 years of operation of the generating units shall be supplied by the contractor along with the turbines.

**1.21 Shop Assembly and Tests**

The following assemblies and tests shall be carried out on the turbines and associated equipment at the manufacturer’s works before dispatch in the presence of the purchaser’s representatives if desired by the purchaser and test certificates shall be submitted whether or not the tests were witnessed by the purchaser.

(i) One turbine, manufactured first, shall be assembled in the shop to the extent possible.

(ii) Static and dynamic balancing of runners.

(iii) Hydrostatic testing at 1.5 times the maximum working pressure including water hammer for not less than 15 minutes for the main inlet valve, spiral case, servomotors, etc.

(iv) Non-destructive testing of welds.

(v) Performance tests for individual auxiliary equipment.

(vi) Complete assembly and operational tests of governors.

(vii) Assembly of spiral case and draft tube liner.

(viii) All motors/pumps/compressors, etc., shall be tested as per relevant Indian or other standards.

**1.22 Field Acceptance Tests**

The turbines shall be tested at site for establishing fulfillment of guarantees in respect of turbine output and efficiencies including weighted average efficiency. The tests shall be carried out as per IEC 41 for Field Acceptance Tests of hydraulic turbines.

The arrangements for these tests will be made, including the testing devices, by the contractor.

**1.23 Commissioning Tests**

The contractor shall carry out the commissioning tests in accordance with IEC 545. The turbine, after continuous operation during the trial operation of one month, shall be free from problems of leakages, overheating, failure, damage etc. The machine will be handed over to purchaser thereafter. Subject to fulfillment of all other conditions laid down in the contract elsewhere.

**1.24 Erection**

The contractor shall depute experts in erection, testing and commissioning of turbines, governors and associated equipments for erection, testing and commissioning of these.

**1.25 Tender Drawings**

The following drawings shall be furnished by the tenderer for vetting and approval:

(a) Drawings of the main cross section of the turbine showing the various components, parts/assemblies of the turbine to the extent possible.

(b) Layout drawings of the power house showing the overall dimensions and layout of turbines, etc., clearly indicating unit spacing dimensions of spiral casing, draft tube and all important elevations.

(c) Schematic drawings of piping system, control system and instrumentation.

(d) Physical and schematic drawings and descriptive literature on the governor and governor mechanism.

(e) Charts/curve showing performances and cavitations characteristic of the turbine

(f) Curve showing areas and velocities at different sections of draft tube.

(g) A list of tests to be performed at site on sub-assemblies and equipments.

(h) A complete list of equipments auxiliaries, etc. covered in the quotations.

(i) Model Test Report

(j) Quality Assurance Plan

**2. ALTERNATING CURRENT GENERATORS, EXCITERS, VOLTAGE REGULATORS AND ACCESSORIES**

**2.1 SCOPE**

This section of the specifications covers the design, manufacture, test at works, supply, delivery at site, erection, testing at site and commissioning of 2 nos. Horizontal AC generators complete with excitation system, voltage regulating equipment, neutral grounding and generator terminal equipments including CTs. PTs, (as per protection schemes) surge protection equipment, etc., and auxiliaries such as CO2 generator firefighting equipment (if required), lubrication system (if required), oil, water and air piping with valves and fittings, instrumentation, controls and safety devices (as required), spares for 5 years operation of the plant, special tools and testing devices. The scope of supply shall include all parts, accessories, and spares 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 equipments and the spares shall be of the same material, dimensions and finish and shall be interchangeable.

The generator manufacturer shall co-ordinate with the turbine supplier so that the generators to be coupled to the turbine is matched in respect of speed direction of rotation, runaway speed, moment of inertia, overload capacities, coupling and other relevant requirements

**2.2 TYPE AND RATING**

The generator shall be designed and manufactured on the basis of following requirement

i) Number required two sets

ii) Type Horizontal shaft, water wheel driven, alternating current synchronous generator

iii) Rated output 50kW

iv) Rated kVA 62.5

v) Power factor 0.8 lagging

vi) Frequency 50 Hz

vii) No. of phase 3

viii) Rated terminal voltage between the phases 0.415 kV

ix) Range of voltage with which rated output + 10 percent

must be available

x) Range of frequency variation + 3 percent (48.5 Hz – 51.5.Hz)

xi) Rated speed to be given by manufacturer.

xii) Direction of rotation In accordance with the turbine

xiii) Runaway speed To co-ordinate with turbine manufacture

xiv) Short circuit ratio Not less than 0.8

xv) Moment of inertia at the whole generating Not less than 1

unit GD2

xvi) Stator-winding connection Star (Y)

xvii) Ratio of quadrature axis sub transient Less than 1.25

reactance to direct axis sub transient

reactance xnq/xnd

xviii) Generator earthing through a distribution Star point earthed

transformer

xix) Cooling water temperature 30 degree Celsius

The generator shall be capable of delivering maximum continuous output of 110% of the rated output at rated power factor. The tenderer may offer his nearest standard. The generator will be connected to the turbine directly or through speed increaser which will be supplied by the turbine supplier. All generator terminals shall be brought out of the stator frame for insertion of current transformer for protection, metering and surge protection apparatus. The generator neutral shall be grounded suitably and the generators shall be designed to safely withstand any mechanical/magnetic stresses resulting from either a three phase or a single phase fault.

Each generator shall comply in all respects with the requirement of the latest issue of Indian Standard IS:4722 except where specified otherwise.

**2.3 SPEED RISE AND RUNAWAY SPEED**

The moment of inertia of the generator together with the moment of inertia of the turbine and flywheel (if any) shall be such that the maximum momentary speed rise on full load rejection shall not exceed 35 % of the rated speed. The generator manufacturer shall co-ordinate with the turbine manufacturer to limit the speed rise to this value.

Each generator shall be designed and constructed so as to be capable of running for a period of 15 minutes at the maximum runaway speed. The runaway speed test shall be considered successfully if after undergoing the test ‘no injury’ is apparent. The runaway speed test may be carried out at site for which the purchaser would provide suitable foundations that will withstand the test.

**2.4 NOISE LEVEL**

The noise level shall not exceed 90 db (A) when measured at a distance of 1m from any component of the generator.

**2.5 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 continuously at any voltage and frequency in the operating range at rated power factor without exceeding the following values of temperature rise over ambient temperature (300C)

(a) Stator winding: 600 C

(b) Rotor winding: 600C

Stator Core: 550C

The maximum temperature rise when the generator is delivering maximum output corresponding to continuous overload capacity for conditions stated above shall not exceed 600C for both stator and rotor windings.

**2.6 EFFICIENCY AND OUTPUT GUARANTEES**

Within the limits of temperature rise specified above, the rated continuous output of the generator shall be guaranteed under penalty with a rejection limit of minus 2% 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%. The efficiencies shall be determined by the summation of losses method as specified in latest Indian Standard IS:4889. For any shortfall in the test value of output and weighted average efficiency (as determined below) from the guaranteed figures, the penalty shall be at the rate of 5% of the ex-works value of generator per generator for every 1% by which the test figure is less than the guaranteed figure. The weighted average efficiency = 0.40 x efficiency at full load + 0.30 x efficiency at 80% full load + 0.30 x efficiency at 60% full load. The penalty on account of output and efficiency shall be computed separately and the total amount of penalty shall be the sum of the two. The ceiling on the total amount of penalty on account of shortfall in the weighted average efficiency and output will be 10% of the total unit price of the generators.

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

**2.7 BID EVALUATION**

For the purpose of comparison of tenders, the equalization on account of differences in the weighted average efficiencies between various offers will be made on the same basis as indicated for penalties, i.e., the prices of generators with lower efficiencies will be loaded at the rate of 0.5% of x-work price each 0.10% (one tenth) difference in weighted average efficiency as compared with the highest weighted average efficiency.

**2.8 STRUCTURAL DETAILS**

**2.8.1 STATOR**

**2.8.1.1 Stator frame**

Frame shall be fabricated from M.S. plates and to be rigid enough to take the stresses transferred during core assembly. Ventilating ducts of suitable dimensions with wire mesh shall be provided on outer periphery of the frame. The frame shall have its own foundation plate, which shall be fixed with the existing foundation bolts if possible. The bidder shall coordinate with turbine supplier for details of centerline of stator frame to be kept. If necessary, suitable fabricated structure should be provided to fix the generator sole plates with the existing foundations.

**2.8.1.2 Stator core**

Stator core material shall be of high quality Electro technical sheet sheets of grade 50C 270 as per IS 648. Core punching may be in one piece or in segments. Punching shall be degreased cleaned & dried before varnishing. Core plate varnish with class `F’ properties shall be applied and over dried. Both side thickness of the varnish shall be restricted to 6 - 7 microns. Insulation resistance shall be measured and recorded. The segments shall be assembled in stator frame with the help of wedges. In case punching are in segments these shall be staggered in alternate layers. The punching shall be pressed between pressing plates welded with fingers as per bidders shop specifications. However, no looseness in core assembly shall be permitted. Bidders shall ensure monolithic stator core frame inside to outside. Assembled core shall be tested for core losses & hot spots if any. Proper record shall be kept for the test procedures & observations. After completion of core loss test, stator slot portion shall be painted with conducting varnish.

**2.8.1.3 Stator Windings**

Windings shall be multi turn with tip to tip class `F’ insulation system, manufactured by VPI system. The copper for elementary conductors shall be ETP as per IS 191. The section shall be rectangular in shape. The self insulation of elementary conductor shall be glass braiding with class `F’ varnish. Other insulation details like liners, packers & slot wedges shall also be of class `F’ material. Over hang portion of the winding on both sides shall be supported on suitable binding rings and lashed properly with packers of suitable thickness to provide adequate rigidity to the overhanging portion against dynamic forces. Three main & 3 neutral terminals shall be brought out.

**2.8.2 ROTOR**

**2.8.2.1 Shaft & Spider**

Generator shaft shall be of forged steel in one piece including extension for mounting the turbine runner. The shaft shall be heat-treated & accurately machined. Spider shall be of fabricated type with central bush to be shrink fitted on the shaft. Suitable arrangements shall be provided to fix the poles on the rotor body. Generator supplier shall coordinate with turbine manufacturer for mounting the turbine runner on the extended portion of the generator shaft and flywheel required for turbine governing. If any additional flywheel is required excluding generator rotor effect, it shall also be mounted on the generator shaft. The high frequency generator shall also be mounted on the generator shaft.

**2.8.2.2 Poles**

The field poles shall be laminated from stamped sheets of suitable thickness, and fixed between iron plates and fitted to the rotor rim/spider/rotor body. The form of pole shoe shall be such that sine wave of voltage at no load performance of the generator is achieved. Field windings shall be made of copper bends on edges. The subsequent turns shall be insulated with pretreated Nomex paper of suitable thickness of class `F’ properties.

The body of the poles shall be isolated with glass insulation. Temperature limits for field windings shall be 60oC which shall ensure the reliability of operation and long life of insulation system. Pole coil connections shall be soldered with suitable grade of material.

**2.8.2.3 Current carrying leads**

Suitable arrangement from diode wheel shall be provided for transferring power from diode wheel to the field poles. The field current shall be fed directly from diode wheel to the rotor winding through cable. The cable /current carrying leads shall be insulated with class `F’ insulating material. The leads shall be secured perfectly for any slippage due to centrifugal forces.

**2.8.2.4 Bearings**

There shall be two bearings one on either side of the generator, the bearing shall be of pedestal type with bearing sleeves in two half. The bearings shall be cooled by circulating oil coolers mounted in the oil bath. Suitable temperature measuring devices viz. RPT&TSD with two contacts shall be provided for measurement of bearing metal temperature. Suitable flow relays in water flows system with alarm & tripping for low water supply shall also be provided. Bidder shall furnish the complete details of bearing being provided along with the offer. The bearing metal temperature rise shall not exceed 20-250C. The bearing shall be capable to withstand forces due to earthquake of magnitude 0.3g in both the directions.

**2.8.3 Ventilation System**

Cooling system for the generator shall be open ventilating type. Two fans of suitable design shall be provided at both ends of the generator rotor. These fans shall suck the cold air from sides and hot air after cooling stator winding & core shall be exhausted from the ducts provided on the stator frame.

**2.8.4 Heating of Generator in Stand Still Conditions**

At each end of the generator heating elements of suitable capacity shall be installed to avoid condensation when the unit is under shutdown. The temperature to be maintained shall be 50C above the surrounding temperature. Necessary thermostat is to be provided for auto on/off of the heating elements.

**2.8.5 Bearing Oil Coolers**

Coolers shall be manufactured with Cupro-nickel tubes grade Cu Ni 30 as per IS 1545. Adequate surface shall be provided to evacuate the bearing losses. These shall be plugged to the oil bath. Necessary cooling water flow arrangement shall be provided for oil cooling. Oil temperature at full load shall be less than 250C.

**2.9 FIRE PROTECTION FOR GENERATOR (OPTIONAL)**

An automatic carbon dioxide fire protection system complete with CO2 cylinders, ring headers, discharge nozzles, temperature detectors etc., shall be provided as a common system for all the generators. The temperature detectors shall be of the rate of the rise of temperature type. Automatic control shall be arranged to discharge CO2 into the generator in the event of operation of temperature detector or of the differential relay of the generator (if provided). The system shall be complete with manual operation arrangement to release CO2 and with all necessary pipes, fittings, directional valves, etc.

**2.10 OIL AND GREASE**

The tenderer shall indicate this requirement and give his recommendations with detailed specifications regarding type of oil/grease to be used for lubrication of generator bearings. The oil if used for generator bearing lubrication, etc., shall be identical with that used for the pressure oil system of governor. The generator and turbine manufacturers shall cooperate to ensure that their recommendations regarding oil are identical. The first filling of oil with 20% extra shall be supplied along with the generator.

**2.11 FLYWHEEL**

A separate flywheel of ample dimensions shall be supplied in case the required moment of inertia for limiting the speed rise/runaway speeds in case not available from the generator rotor (through the speed increaser, if envisaged). Necessary provision for receiving the piston of the brake cylinder on application of brakes shall be made in the flywheel.

**2.12 EXCITATION SYSTEM**

**5.12.1 General**

The excitation system of static type consisting of high performance fully controlled solid state converter bridge, dry type excitation transformer of suitable capacity, static voltage regulator, field breaker, field flashing unit, field discharge resistor, etc., conforming to acceptable relevant international standards may be supplied. The excitation shall be completely described in the tender.

Brushless excitation system or self-excited self-regulated excitation may also be offered.

**2.12.3 Automatic Voltage Regulator (If Not Already Included In the Excitation System)**

An automatic voltage regulator, complete with an enclosed master element, voltage adjusting rheostat, contactors, etc., shall be provided with each generator for the automatic control of the generator exciter. The voltage regulator shall be anti-hunting. The voltage regulator shall be capable of maintaining the generator terminal voltage at and pre-set value and at the same time sharing the reactive kVA of the load between the two similar units.

The voltage regulator shall be sensitive to the charge of plus or minus 0.5 (one half)% 0f normal voltage (average of three 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 110 (One hundred and ten)% of rated load, the automatic voltage regulator shall restore the terminal voltage to a value not more than 5(five)% above or below the voltage being held before the load rejection and shall maintain the voltage within these limits throughout the period of generator over speed. The voltage regulator shall be provided with cross-current compensating devices for parallel operation of generators.

A voltage adjusting rheostat suitable for manual and also for motor operation by remote control shall be furnished with each voltage regulator equipment. The range of the voltage control shall extend from 90 (ninety) % to 110 (One hundred and Ten) % of rated voltage of generator.

**2.13 LINE TERMINAL AND NEUTRAL GROUNDING CUBICLES**

The generator suppliers shall supply 1 no. terminal cubicle for each machine housing surge capacitor, potential transformers, current transformers, lightning arresters, cable boxes, etc., as given in the enclosed drawing. The cubicle shall be complete with necessary tappings for excitation system, etc. The rating of the CTs for AVR shall be decided by the supplier taking into account the requirements of AVR.

The generator supplier shall neutral grounding cubicle one for each machine housing single phase distribution transformer, secondary loading resistor, current transformer, cable boxes, etc., as shown enclosed drawing.

The cubicles shall be sheet suitably compartmentalized with doors and shall be furnished complete with base mounting arrangement, foundation bolts, etc. The internal illumination for cubicles shall be provided with guarded lamps with on/off switches. Copper/Aluminum conductors of appropriate size shall be used for bus bars and connections in the cubicles. The bus bar and main connecting conductors shall be suitably insulated to make them compatible with generator temperature rise and insulation. The support insulators for the bus connection will be provided as necessary. GI earth bus of adequate cross section will be provided in the cubicle.

**2.14 POTENTIAL TRANSFORMERS**

The potential transformers will be single phase, epoxy cast, dry type units. Potential transformer will be protected on primary and secondary side by current limiting fuses. The PT shall conform to IS:3156. The potential transformers shall berate as given in the drawing.

**2.15 CURRENT TRANSFORMERS**

The current transformer will be epoxy cast, dry type unit conforming IS:2705. The current transformer shall be designed to withstand the thermal and magnetic stresses resulting from the maximum short circuit current.

The technical requirement and location of the CTs are given in the drawing. The generator suppliers shall supply suitable transformer for the protection scheme and these shall be installed in the neutral grounding and line terminal cubicles.

The current transformers should be suitable for metering and protection.

The following protections are recommended:

(i) Three-pole differential relay (87 G)-3 CTs on the neutral of the generator and 3 CTs on the phase.

(ii) Over-current and earth fault relay (50/51 and 64)

(iii) Rotor earth fault protection single stage ( 64 R)

(iv) Stator earth fault protection (64 G)

(v) Over voltage protection (59)

(vi) Field failure protection (40)

(vii Negative phase sequance (46)

(viii) Reverse Power Protection (32)

(ix) Over speed frequency protections (81)

(x) Voltage restrained over current relay (SIV)

In case the generators are provided with static excitation system with excitation transformers, high set instantaneous over-current relay (50) IDMT and over-current relay (51) would be provided in the tapping for excitation transformer for protection of excitation transformers.

**2.16 LIGHTNING ARRESTORS**

The lightning arrestors shall be heavy duty indoor station class non-linear resistor type suitable for repeated operation to limit voltage surges on alternating current power circuits and to interrupt power flow current. The arrestors shall conform to IS:3070 (latest edition)Part-I. The nominal discharge current of lightning arrestor shall not be less than 10KA.

**2.17 SURGE CAPACITORS**

The surge capacitors shall conform to the latest edition of IS:2834 and shall be rated 0.25 microfarad. The capacitors shall be connected in parallel with lightning arrestors and shall be provided with a built-in discharge resistor. The capacitor shall be suitable for indoor mounting.

**5.18 UNIT CONTROL BOARD AND GENERATOR INSTRUMENTATION AND CONTROL**

The generator supplier shall supply all equipment and devices for control, instrumentation and safety relating to the generator. These together with the equipment supplied by the turbine supplier shall constitute a complete and coordinated set of instruments, gauges, and control and safety devices for control of the units during normal running and in emergencies indicating instruments, gauges, control 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. 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, alarm bell, terminal bolts etc., and adequate number of alarm annunciation fascia windows for both turbine and generator shall be provided. The generator manufacturer shall fully co-ordinate with the turbine manufacturer in this regard.

**2. 19 SPARES**

The unit rates shall be quoted for the spares. The tenderer shall also indicate in the tender any additional spares that he would recommend for 5 years’ operation and furnish item wise unit prices for the same.

**2.20 TESTS**

The first generator shall be completely assembled at works and types tests as specified below shall be conducted on the assembled unit and auxiliaries as per the latest edition of IS:4722.

**2.20.1 Type Test on First Generator**

(a) Temperature rise test.

(b) Dielectric test.

(c) Efficiency test.

(d) Excess current test.

(e) Runaway speed test.

(f) Moment of inertia of rotating parts (by mutual agreement between the purchaser and the contractor)

(g) Wave form

(h) Determination of characteristic:

(i) Reactance – Synchronous, transient, sub transient, negative phase sequence and zero phase sequence.

(ii) Rated current, zero power factor lagging saturation curve.

(iii) No load and short circuit saturation curve.

**2.20.2 Routine Tests on all the Generators**

(a) High voltage test on stator coils and stator sections and on assembled stator.

(b) High voltage test on field coils and poles.

(c) Insulation resistance tests.

(d) Impedance and voltage test on field coils.

(e) Accuracy test for RTDs and dial type thermometers.

(f) Hydraulic tests on oil, and air coolers.

**2.20.3 Tests on Exciters and Regulating Equipment (For Rotating Exciters)**

(a) High voltage test.

(b) Temperature rise test.

(c) Measurement of resistances.

(d) Measurement of insulation resistance.

(e) Regulation test.

(f) Commutation test.

(g) Excitation response ratio.

(h) Routine tests on static excitation equipment.

**2.20.4 Additional test, if any, as recommended by the supplier.**

**2.20.5 Tests at Site**

Site test for each generator shall include the following:

(a) Mechanical run.

(b) Measurement of stator and rotor winding insulation resistance.

(c) High voltage dielectric test.

(d) Measurement of shaft voltage (if applicable)

(e) Measurement of stator and rotor winding resistance.

(f) Phase sequence test.

(g) Load acceptance and rejection test at selected loads from no load to full load.

(h) Overall response of machine and excitation system to system voltage changes.

(i) Adjustment of AVR.

(j) Synchronizing test.

(k) Checking and commissioning of various other auxiliary equipment.

**2.20.6 Test on other equipment like CTs, PTs, Las shall comply with the routine tests, etc., as per relevant standards.**

Test report for all type tests on the generator, CTs, PTs, etc., carried out on similar equipment already supplied shall be furnished for approval.

**2.21 TESTING EQUIPMENT**

A list of field testing equipment along with item-wise rental prices rental prices shall be indicated in the tender.

**2.22 SPECIAL TOOLS**

The contractor shall supply a complete set of special tools and other equipment that may be necessary or desirable for operation and maintenance of the generator and auxiliary equipment of his supply. The tenderer shall submit a list of the above and include the price in tender.

Any special reamers or broaches and brazing equipment for all work which must be done in the field, shall be provided by the contractor.

**2.23 DRAWINGS**

In addition to the drawings called for, the following drawings and data shall be submitted with the tender. The drawings containing all the information required for designing the civil works shall be supplied within 60 calendar days of the placement of letter of intent:

(i) The general arrangement and overall dimensions of the generators, exciters (where applicable) and bearings, and showing positions of main and neutral terminals.

(ii) Description of lubrication system along with drawings.

(iii) Physical and schematic drawings of excitation system and AVR along with descriptive literature.

(iv) Graphs showing predicted characteristic of the generator.

(v) Generator layout drawings showing overall dimensions and layout of all ducts, cables, piping, relative positions of auxiliaries, etc.