



Exploration & Production

GENERAL SPECIFICATION

ELECTRICAL

GS ELE 113

AC generators driven by turbines

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1. Scope

The purpose of this specification is to set out the general requirements for the electrical design, manufacture and performance of gas turbine driven synchronous generators, associated excitation/protection systems and accessories included in gas turbine sets, to be installed in COMPANY sites located either onshore or offshore.

It should be read in conjunction with the corresponding mechanical specification issued by COMPANY. Refer also to Project particular specification and/or data sheets.

2. Reference documents

The reference documents listed below form an integral part of this General Specification. Unless otherwise stipulated, the applicable version of these documents, including relevant appendices and supplements, is the latest revision published at the EFFECTIVE DATE of the CONTRACT.

Generators shall conform in design, materials and performance with the appropriate sections of the latest editions (with amendments) of the relevant IEC and CENELEC standards.

The following order of precedence applies specifically to electrical equipment:

- COMPANY Specifications
- Data sheets
- IEC Publications
- European Standards by CENELEC
- Standards and codes (UTE, BS, VDE, etc.) when IEC publications have not yet been issued.

Standards

Reference	Title
EN 50014	Electrical apparatus for potentially explosive atmospheres
IEC 60034	Rotating Electrical Machines
IEC 60044	Instrument transformers
IEC 60072	Dimensions and output ratings for rotating electrical machines
IEC 60079	Electrical apparatus for explosive gas atmospheres
IEC 60085	Thermal evaluation and classification of electrical insulation
IEC 60186	Voltage transformers
IEC 60255	Electrical relays
IEC 60332	Tests on electric cables under fire conditions
IEC 60529	Classification of Degree of Protection Provided by Enclosures
IEC 60801	Electromagnetic compatibility for industrial process measurement and control equipment

Reference	Title
IEC 60947	Low voltage switchgear and control gear
IEC 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code)
ISO 10816	Mechanical vibration

Professional Documents

Reference	Title
Not applicable	

Regulations

Reference	Title
Not applicable	

Codes

Reference	Title
Not applicable	

Other documents

Reference	Title
Not applicable	

Total General Specifications

Reference	Title
GS ELE 079	Electrical apparatus for explosive gas atmospheres

3. Environmental conditions

Outdoor installation: refer to project data sheet.

The associated equipment located indoors (e.g. control panels) shall be installed within air conditioned rooms with an ambient air temperature of 25°C but shall be able to operate as long as temperature does not exceed 40°C.

The minimum degree of protection of enclosures shall comply with the following (according to IEC 60529):

- Indoor equipment IP 23
- Outdoor equipment IP 55



- Exposed deck (FPSO) IP 56
- Indoor or outdoor equipment IK 08

4. General

4.1 Materials, workmanship and suitability

All materials and parts included in the construction of the specified generation system shall be new and unused, of current manufacture, of the highest grade, and free from all defects and imperfections likely to affect its performance.

The equipment shall be the produce of a COMPANY regularly engaged in the manufacture of alternating-current generators and shall be of modern design, of proven performance and in regular production at the MANUFACTURER's place of business.

4.2 Specification deviations

The SUPPLIER shall advise COMPANY of any deviations made in respect of this specification at the time of tendering. Should this Specification conflict with requirements of the listed standards, the SUPPLIER shall request clarification from the COMPANY.

4.3 Rating and performance

4.3.1 General

The Generating units shall be suitable for continuous full load service, duty type S1, at the rated power and specified ambient conditions without any harmful effects.

The rated power of the generators shall exceed the installed capability (under peak load) of the associated driving machine (turbine) under all conditions and at all temperatures in the specified range.

The generators, excitation systems and all accessories shall be designed and constructed in accordance with good engineering practices which should result in an expected lifetime of at least 20 years. The machines shall be suitable for at least three years uninterrupted operation under the conditions specified.

4.3.2 Auxiliary supplies

The voltages (provided by COMPANY unless otherwise specified in Project particular specification) for auxiliary equipment shall be:

- 400 V AC - 3 phase from normal supply (earthed through a 150 mA high impedance)
- 230 V AC - 3 phase from normal supply (earthed through a 150 mA high impedance)
- DC voltage - 24 or 48 V DC floating
- AC UPS - 230 V 1 phase floating.

The auxiliary loads shall be included into the power balance.

4.3.3 Momentary excess current

Machines shall be capable, from normal operating temperature, of carrying without damage a stator current of:

- 150% of the rated current for a period of at least 30 seconds
- 110% of the rated current for a period of at least one hour, without dangerous overheating.

4.3.4 Sudden short circuit

Machines shall be designed to withstand without damage a short circuit of any kind (and especially, at least 300% of the rated generator current) at the terminals, whilst operating at rated load and 105% of rated voltage, for a period of three seconds.

4.3.5 Form and symmetry of voltages and currents

The machine shall be able of operating on an unbalanced system as defined in [IEC 60034-1](#) paragraph 6.2. Should the limits of deformation and balance occur simultaneously in service at the rated load, this shall not lead to any deleterious temperature in the generator and the excess resulting temperature rise or temperature related to be limits specified in this standard should be not more than approximately 10K.

4.3.6 Telephone Harmonic factor

Irregularities of waveform (THF) shall be as per [IEC 60034-1](#) prescription paragraph 8-10.

The MANUFACTURER shall specify the maximum acceptable harmonic rejection from consumers for generators to operate in satisfactory conditions.

4.3.7 Excitation system

The machines, including excitation systems, shall be designed for a rated power factor of 0.8 lagging (overexcited) at rated output, expressed in kilo-volt-amperes, and with the generator voltage between 90% and 110% of the rated value. Each excitation system shall be rated for at least 110% of the excitation current required during full load operation at rated voltage and rated power factor.

The Automatic Voltage Regulator (AVR) shall be of voltage droop control type. The steady-state voltage variations shall be limited, when machine operating individually, to $\pm 0.5\%$ of the rated voltage.

The excitation system shall be designed to ensure the stability of the generators in respect of voltage and reactive load sharing, with stable damping of post-disturbance voltage oscillations, under all conditions, such as:

- Heavy external system faults
- Starting of large motors
- Tripping of on-line generator.

The voltage variation after instantaneous application of 100% load shall not exceed -15%, and recovery to 97% of rated voltage shall occur within 1.5 seconds.

In any case, voltage dip on generator terminals shall not exceed 15% of rated voltage.

Should the automatic control fail, the AVR shall revert to manual voltage control without change to the excitation.

The MANUFACTURER shall design impedance and time constants of generator and shall adjust the parameters of the AVR (gain and time constants) in order to obtain minimum voltage recovery time, minimum voltage dip, according to the network configuration stated in the single line diagrams/data sheets and especially in case of:

- Direct-on line starting of the largest installed motor with the whole network loaded
- Failure of one generator involving the transfer of his load on to the other generator (in case of several machines in parallel).

The MANUFACTURER shall provide details of the voltage response of the generators to the sudden application of large loads (i.e. half rated output and rated output), for COMPANY approval.

4.3.8 Speed regulation

The generating unit shall have a high accuracy governor providing close control over the speed. The speed shall be adjustable over the range 95% to 105% of the rated speed during normal operation.

The steady state speed variations, at all loads when operating isolated from the electrical network shall be limited to 0.5% of the rated speed.

The governor shall be equipped with adjustable droop characteristic, from zero to at least 10%.

4.3.9 Parallel operation

Where more than one generator is specified the units shall be suitable for parallel operation with each other or network. The specified generating units shall operate with the other units under load conditions up to their maximum output whereby the power factor shall be maintained approximately at the same value between each generator by means of automatic reactive load sharing.

The generators shall share the reactive load without hunting, in accordance with their rating under all conditions.

The turbines shall share the active load without hunting, in accordance with their rating under all conditions.

The ceiling voltage and response to system faults shall be such that a rapid field forcing is obtained, with benefit to the stability between generators. Sufficient current shall be available to energize backup protective devices in the event of short circuits.

The excitation system shall withstand the following duty cycle, repeated every five minutes:

- Continuous rated current
- Ceiling voltage for 20 seconds
- Continuous rated current.

The excitation system shall allow 100% voltage to be maintained at 90% speed.

A reactive power limiting device shall be incorporated to ensure that each generator is always working within its capability and within its stability limits.

The output voltage of the generating unit shall be adjustable between 90% and 110% of the rated value during normal operation.

4.3.10 Earth faults

The MANUFACTURER shall provide COMPANY with the external earth fault withstand capability curve: $i_0 = f(t)$.

Unless otherwise specified in the Project particular specification, the minimum requirement current shall be 30A for three seconds, without exceeding the specified temperature rise limits.

4.3.11 Mechanical

4.3.11.1 Critical speeds

Machines with a rigid, subcritical rotor bearing system shall have the first critical speed not lower than 125% of the rated speed. For machines with a flexible, overcritical rotor bearing system, the first critical speed shall not be above 80% of rated speed and the second not lower than 125% of rated speed.

The prime mover MANUFACTURER shall perform a torsional analysis of the complete system. The generator MANUFACTURER shall provide all required data in a timely fashion to allow this work to proceed including dimensional data to prepare the torsional model as well as generator air gap torque and dynamic torque characteristics during system fault conditions.

4.3.11.2 Vibration

Maximum vibration level of the bearing housing on load or offload shall be 2.5 mm/s rms. The vibrations measured on the shaft shall be 50 microns peak to peak plus 10 microns maximum runout if runout demonstrated.

When freely suspended, the bearing vibration shall not exceed 1.8 mm/s rms in any direction. When rigidly mounted, the bearing vibration of machines shall not exceed 2.8 mm/s rms in any direction.

Vibration of the generator frame, including terminal boxes, shall not cause any damage to the machine and shall be limited to 4.5 mm/s.

These maximum allowable vibration levels shall apply for testing the machine alone in the factory and testing the machine mounted "in situ". These levels shall apply to all operating temperatures between ambient and maximum operating temperature, and all operating conditions between no-load and maximum capability, and all levels of bearing oil viscosity between the minimum and maximum specified for the bearings.

5. Construction requirements

5.1 General

Products that are highly toxic to the environment or that are considered potentially carcinogenic (e.g. asbestos) shall not be used. The use of hygroscopic materials shall be avoided. Materials shall be selected to prevent contact corrosion.

Generators shall have jacking bolts or facilities to raise the machine with the aid of a mechanical jacking device to facilitate alignment of the generator with the turbine.



Safety during operation and maintenance shall be carefully considered during design of the generators and auxiliaries.

Frames shall be equipped with two earth connection facilities located at readily accessible locations on opposite sides of the complete skid. In the case of a remotely located terminal box, an earth connection shall be provided within the box.

5.2 Machine cooling

Generators shall be air-to-water (CACW) or air-to-air (CACA) cooled unless otherwise specified in the Project particular specification.

Cooling system assemblies shall be designed such that the natural frequency of vibration is neither excited by the generator running frequency nor its harmonics.

Cooling pumps and fans shall have 100% standby capacity.

5.2.1 CACW machines

Each cooler shall be provided with a water leakage detector. The water box/header construction shall be such that leaking tubes can be readily plugged and that all tubes are accessible for cleaning.

Machines shall be provided with local temperature indicators for water inlets and outlets and also cooling air temperature detectors to measure the temperature of the primary air after the heat exchangers.

Primary coolant shall always be air.

Secondary coolant shall be either sea water or "treated" water depending on local availability.

Where seawater is circulated within the heat exchanger then double tube design shall be used. In the case of treated water, single tube design shall be used. In all cases, tubes shall be made from cupro-nickel.

Unless otherwise specified in the Project particular specification, dual coolers shall be fitted, each capable of meeting at least 50% of cooling requirements of full rated output of generator. The SUPPLIER shall advise derated output of unit operating on one cooler only.

Where a "remote" heat exchanger is required for cooling the treated water in a closed circuit, this shall generally be provided by COMPANY.

5.2.2 CACA machines

Cooling air for CACA machines shall be obtained from a dedicated air intake system via filtration. The generator MANUFACTURER shall liaise with the turbine MANUFACTURER to ensure all requirements are satisfied and all ducts, fans, etc. provided. Forced draft systems shall have 100% standby capacity.

5.3 Stator frame

5.3.1 Frame

The stator frame shall be of heavy duty fabricated steel construction. The generator frame and bearing supports shall have sufficient strength and rigidity to avoid distortion or increased vibration as a result of external mechanical forces such as tightening of fixing bolts.

5.3.2 Magnetic circuit

The magnetic circuit shall consist of low-loss laminations securely held in position.

5.3.3 Windings

5.3.3.1 Insulation

Unless otherwise specified, the insulation of the generator stator, rotor and exciter shall be class F, however, temperature rise of all parts shall be limited to that allowable for class B insulation according to the standards.

5.3.3.2 Exciter

All windings of the main exciter and pilot exciter shall be of high quality enameled wire with suitable earth and inter-phase insulation. Impregnation procedure shall be as for the stator windings.

When a permanent magnet exciter is used, it shall have its magnets energised so as to avoid any subsequent intervention after an adverse electromagnetic field environment, consecutive to transient phenomena such as heavy or short-circuits.

5.3.3.3 Stator

The stator windings shall consist of identical coils made of copper bar conductors covered with mica materials or equivalent.

All windings shall be fully vacuum pressure impregnated and shall be adequately supported, braced and blocked to withstand without damage the dynamic stresses occurring during short-circuit.

Stator windings shall be externally star connected.

The windings shall be fitted with 2 PT100 resistance temperature detectors in the hottest part of each phase winding. RTDs shall be either three or four wire types.

5.3.3.4 Rotor

The field windings shall be made of copper. The field coils shall withstand all normal transient conditions (electromechanical and electrodynamical stress) occurring during a balanced or unbalanced short circuit.

5.3.4 Anti-condensation heaters

Adequate provisions shall be made to avoid deterioration of the machine due to condensation.

Heaters shall be of a fully insulated design and suitable for 230 VAC supply.

5.4 Terminals and terminal boxes

The machines shall be provided with separate mechanical device between power and control/command circuits.

Power terminal box shall be sized according connection constraints (cable's type Cu or Al, section, bending radius, lug's size, etc.).

The star point terminal box shall accommodate the required current transformers for control, measurement and protection.

Clamping devices to withstand short circuit currents shall be provided within the main terminal box for cable connections, to separate and support the conductors.

The main HV connecting boxes shall be located as specified in the data sheets.

Cable gland plates or cable transits shall be provided, and shall be non-magnetic for single core cable connections.

Cable glands shall be bronze marine for offshore and brass for onshore.

5.5 Rotor

5.5.1 Shafts

Rotor shafts shall be one piece, heat-treated forged steel construction.

Welding on finished shafts and rotors is prohibited. Shafts and/or spiders subject to welding shall be stress relieved after welding.

Fans shall be separately and individually balanced prior to mounting on the rotor shaft. They shall be of non-corroding material or shall be effectively treated with a corrosion resistant coating (after balancing of the rotor assembly).

The rotor shall withstand without any mechanical damage or permanent distortion:

- The maximum torque variations under operating conditions: short-circuit, emergency shutdown, etc.
- The maximum overspeed, which may be reached after a full load rejection or a manual governing action.

Rotor balancing shall be conducted at rated speed, and shall be followed by an overspeed test at 1.2 times rated speed for at least two minutes.

Impedance of the rotor shall be measured before and after the test to detect loose connections. Balancing shall be conducted with a half depth key.

Rotor shall be equipped with provisions, which allow addition of balancing weights by use of bolts in specially threaded holes directly in the rotor body. Balancing weights shall be of lead or similar ductile material

5.6 Excitation system

The excitation system shall be brushless, consisting of a three-phase inverted synchronous generator, rotating rectifier assembly, permanent magnet pilot exciter or shunt excitation system and voltage regulator for each machine.

The current rating of the semi-conductors utilised in the rotating rectifier shall not be less than 200% of the maximum current flowing through the elements at maximum continuous excitation current.

If parallel connection of semi-conductors is used, the above current rating shall be not less than 220% for the parallel group.

The repetitive reverse blocking voltage rating of the semi-conductors shall be not less than 200% of the maximum peak voltage generated by the main exciter.

Exciter field voltage and current transmitters (4-20 mA output) shall be provided for remote indication.

A device shall be provided to detect the failure of any diode in the rectifier bridge assembly.

The Automatic Voltage Regulator (AVR) controlling the DC voltage applied to the main exciter field winding shall be of the continuous, quick acting electronic type.

The parameters shall be readily adjustable. The reference voltage value shall be adjustable locally or remotely, automatically or manually. Manual control shall be achieved by the use of a separate, independent module controlling the field current, with local control switches or pushbuttons for increasing or decreasing the excitation.

The AVR control circuits shall be modularised and mounted in racks within the excitation control cubicle. Fault indicators (e.g. LEDs or a digital display) shall be provided to allow rapid fault finding.

The voltage transformer for the AVR power supply (when applicable) and generator voltage sensing will be located within the generator switchboard or dedicated cubicle.

5.7 Maintenance access

The generator and exciter enclosures shall be fitted with suitable inspection plates and access covers which shall be designed for quick and simple removal. Access to the rotating excitation rectifier equipment shall be adequately sized to permit easy maintenance.

Ease of rotor withdrawal to facilitate rapid inspection and repair in service shall be considered as a highly desirable feature.

The MANUFACTURER shall indicate in his bid the rotor removal procedure and associated tools

5.8 Generator earthing

The generator frame shall be provided with two earthing points of at least 15 mm diameter located on opposite sides of the machine.

5.9 Bearings

Bearings shall be force oil lubricated sleeve types, of standard design from a specialised MANUFACTURER. For large machines, tilting pad bearings may be used.

The non-drive-end bearing shall be fully insulated from the generator frame to prevent the flow of shaft currents. The insulating material shall be of the sandwich type (bearing/insulation material/conducting material/insulation material/bearing shield).

It shall allow correct bearing insulation resistance measurement during operation without bridging the insulation.

Piping and instrument connections shall not bridge the insulation.

This bearing shall be adequately labeled to indicate the presence of insulation.

Shaft earthing shall be via the drive-end bearing.

Sleeve bearings shall be of the self aligning type.

The bearing design shall be such that the replacement of liners will be possible without the removal of the rotor, the lower half of the end bell or plate, the coupling or the exciter.

Each bearing shall include as a minimum:

- Dual or two resistance temperature detectors (located in the area of minimum oil thickness), giving bearing white metal temperature. RTD shall be PT100, three or four wire types
- Local oil flowmeter or oil level gauge
- X-Y vibration probes (if specified in Project particular specification)
- Accelerometer.

5.10 Lubrication

Lubrication system shall be common for the generator and its driver, in accordance with mechanical specification.

5.11 Control and protection panels

For each turbine-generator set a control panel shall typically house the following:

- AC generator control devices, automatic and manual synchronisation equipment, alarm, VDU display and other devices as required.

Control devices shall include but not be limited to:

- Manual synchroscope
- Automatic synchroniser
- Incoming and running voltage meters
- Incoming and running frequency meters
- AVR raise/lower switches
- Manual/Off/Auto synchronising selector switch
- Circuit breaker status indication lamps
- Circuit breaker control switch
- MW, MVAR and power factor meters
- Control selector switches.
- AC generator protections
- Excitation/voltage regulation.

A separate cubicle shall normally be provided for the load sharing system of the power plant.

All the above equipment shall normally be installed within a generator control room although the equipment outlined may be grouped together in a separate panel and installed in a switchgear room. These requirements shall be specified in the Project particular specification.

Indicating instruments and alarm annunciations shall be easily readable and shall be located within the normal field of vision of an operator facing the control panel.

Controls shall be logically positioned and give ease of access when observing indications and alarms during operation.

Check synchronising relays shall be provided.

Information exchanged between the generator control panels and the Electrical Distribution System (ECS), if any shall preferably be via a serial link with a recognised/standardised protocol.

All remaining input and output signals of the control and protection panels shall be available at suitable terminals for connection by others.

For data logging purpose, all events shall be chronologically ordered and dated with time base received from an external clock.

The panels shall be vertical and free-standing with front access only via hinged, lockable doors. The panels will be floor mounted and cable access will be from below. They shall be naturally ventilated.

Internal wiring shall be by stranded conductors, with 1000 V flame retardant PVC insulation. Conductors shall have a minimum cross sectional area of 1.5 sq mm (2.5 sq mm for power wiring). Wiring shall be securely and neatly held in position, either loomed or run in trunking.

Each wire shall be identified by numbered ferrules. Wiring for external connections shall be brought to terminals, which shall be arranged for easy access for cable connections, testing, inspection and fault finding.

No more than two wires on internal and one on external shall be terminated to each terminal. Terminals shall be clamp type mounted on DIN rails. 20% spare terminals shall be provided.

Each panel shall be fitted with an earthing terminal for connection to the external earthing system. Equipotential bonding of all parts shall be ensured, including doors. The effects of electromagnetic interference shall be carefully considered by the MANUFACTURER, to prevent disturbance to the machine.

The degree of protection shall be IP 23 and IP 20 when the door is open.

5.12 Generator protection

The recommended protective devices are the following:

- Winding overtemperature (26), alarm and trip
- Bearing overtemperature (26), alarm and trip
- Bearing vibration (39), alarm and trip
- Coolant overtemperature or failure (26), alarm
- Stator differential overcurrent (87 G), trip
- 3 phases stator overcurrent (51 V), trip
- Phase overcurrent (50), trip
- Phase unbalance (46), trip
- Neutral voltage displacement (51N/64S), trip.
- Rotating rectifier diode failure (94 d), trip
- Stator overvoltage and undervoltage (27, 59), trip
- Stator overfrequency and underfrequency (81), trip
- Field failure or loss of synchronism (40), trip

- Stator reverse power (32), trip
- Overload (49), trip
- Rotor earth fault (64R), trip. In case of use in hazardous area, infra-red device shall be proposed.

In addition, other protection devices as recommended by the MANUFACTURER shall be incorporated or deleted after COMPANY approval.

The secondary current transformers for the stator differential protection shall be located either within the generator switchboard or the generator terminal box

The protection relays shall be microprocessor type, withdrawable, with full testing facilities to allow secondary injection of the relays and blocking of the trip signal. The relays shall have serial data interfaces to allow interrogation from a remote location.

If these protection relays are capable of transmitting electrical measurements, transducers need not to be provided.

All these relays shall be housed in the control and protection panels as described in 5.11 or alternatively located in the HV switchboard (see project specification).

5.13 Auxiliary sources (ac and dc)

The MANUFACTURER shall provide COMPANY with a complete load list of all auxiliary equipment. Consumption profile shall be attached to the DC power balance.

5.14 Labels

All items of equipment including generators, exciters, rating plate connecting boxes, panels, circuit breakers, switches, devices, relays, controls, indicators, etc. shall be fully and clearly identified in accordance with the drawings using engraved traffolyte labels with black letters on white background. Labels shall be attached to non-removable parts using corrosion proof screws.

The MANUFACTURER shall supply a second plate to be mounted on the main equipment.

5.15 Noise levels

Refer to mechanical specification.

5.16 Special tools

A complete set of any special tools required for operation, maintenance and testing shall be provided.

The SUPPLIER shall provide a list of special tools, individually priced, with his quotation.

5.17 Black start requirements

Unless otherwise specified there will be "black start" power available for the main power generator from an emergency generator.

The SUPPLIER shall indicate in his tender the generator output available without cooling system in operation.

6. Inspection and testing

6.1 Qualification tests

The SUPPLIER shall supply type test certificates carried out on similar equipment in accordance with IEC publications along with proposal:

- Full load heat run (temperature rise test)
- Hot spot temperature test
- Short circuit test for reactances and time constant determination at reduced voltage
- Vibration test at full load
- Noise level test.

6.2 Factory Acceptance Tests

Acceptance tests shall be carried out in the presence of COMPANY at the MANUFACTURER's works on each machine and will comprise routine tests, in accordance with the relevant standards and other additional tests if specified in the data sheet.

6.3 Routine tests

- Physical inspection for compliance with specification and standards
- Dimensional checks
- Insulation resistance test on all windings, heaters, RTDs, etc.
- Power frequency voltage withstand test
- Cold winding resistance measurement of stator, rotor and exciter
- No-load saturation test
- Phase sequence
- Dielectric tests
- Vibration test at no load, full speed
- Bearing temperature rise at no load, full speed
- Sleeve bearing inspection plus insulation measurement
- Noise level test
- Tests on all auxiliary devices, sensors, etc.

6.4 Full set tests

In addition to routine tests:

- Calculation of efficiency at 50%, 75% and 100% load, at rated power factor
- Rotor balancing test (during manufacture)
- Winding insulation resistance before and after heat run
- Temperature rise test at full load 4 hr

- Vibration test at full load
- Bearing temperature rise
- Overspeed test (120% - 2 min, during manufacture)
- Full load wave analysis
- Voltage and current phases balance
- Over load test 110% 1 hr.

For associated equipment i.e. control panels, excitation panel, etc.:

- Functional tests
- Potential transformer ratio check
- Protection relay secondary injection (The SUPPLIER shall provide the MANUFACTURER's certificate test for current transformers).

6.5 String test

During string test the following tests shall be carried out unless otherwise agreed with COMPANY:

- Insulation resistance test of generator and exciter
- Generator control tests (trips, alarms, changeover from duty to standby equipment, etc.).
- Response of AVR and frequency to sudden loading and load shedding of 25, 50, 75 and 100% of rated load.

6.6 Tests after erection on site (Commissioning)

Tests shall be carried out with the associated turbine driver and auxiliary equipment.

6.7 Test reports

A pro-forma of test reports shall be presented to the COMPANY for approval before placing the order.

The test reports shall detail as a minimum:

- The expected theoretical values
- The tolerances
- The results of the measurements, including if applicable, any intermediate value which has caused a temporary rejection.

The test reports shall be included in the Contractual technical documents, and shall be considered as an integral part of them.

7. Documentation to be provided

As a minimum, the following drawings and documentation shall be supplied in timely fashion according to the specified schedule:

- General arrangement of generator and exciter
- Generator rotor detail drawings
- Arrangement details of auxiliary equipment
- Layout of control, protection and excitation panels
- Schematic diagrams of control/protection/excitation panels
- Cable schedules, wiring and termination diagrams
- Interface drawings (with turbine, etc.)
- AC and DC schematic diagrams (auxiliary power supplies)
- Detail drawings of all terminal boxes
- Rating plate and nameplate drawings
- Turbo generator and excitation system model for stability studies
- Short circuit current versus time and voltage/speed versus time after 50% block load acceptance curves
- Data sheet showing full machine characteristics: short circuit ratio, reactances (X_d , X'_d , X''_d , X_2 , X_0 , ...), time constants (T'_{do} , T'_d , T''_d , ...), etc.
- Generator capability charts and P-Q diagram
- Preliminary protection setting recommendation
- Operation and maintenance manuals
- Spare part list for commissioning and two year operation.