9. Generator Description

9.1 Generator

9.1.1 Electrical Rating

The generator is designed for continuous operation. The generator is constructed to withstand, without harm, all normal conditions of operation, as well as transient conditions such as system faults, load rejection and mal–synchronization.

The armature and field windings of the generator are designed with insulation systems that are proven Class "F" materials.

Temperature detectors installed in the generator permit the measurement of the stator winding and gas temperatures. The temperature rise limits, per ANSI or IEC standards (as applicable), will be limited to the following, throughout the allowable operating range:

- Class "B" temperature rise limits

The generator is designed to exceed the turbine capability as stated in the performance section of this proposal.

9.1.2 Packaging

The generator is a three phase, synchronous machine designed for compactness and ease of service and maintenance. The machine is designed to operate continuously over a long and trouble-free life and to provide maximum protection against damage due to abnormal operating conditions.

The following items will ship separate for assembly to the generator at the Customer's site:

- Generator rotor
- End shields
- High voltage bushings
- Generator feet
- Collector enclosure (doghouse)

All generator wiring, including winding and gas Resistance Temperature Detectors (RTDs), bearing metal and drain temperature detectors (as applicable), and vibration detection systems are terminated on the main unit with level separation provided.

Prior to full assembly, the generator stator receives an overpressure test followed by a leakage test.

Field assembly of the lube oil piping is required but should be limited to the following:

- Bearing drain enlargement (BDE)
- Lube oil drain and feed piping connections to the end shields are assembled.

9.1.3 Terminal Arrangement

All lead connections terminate at the excitation end of the generator. Customer line connections and the generator neutral tie make-up is made external to the main generator stator frame.

The generator line and neutral lead circuits are connected to high voltage bushings (HVBs) as they exit the stator frame to form a hydrogen tight seal.

9.1.4 Stator Frame Fabrication

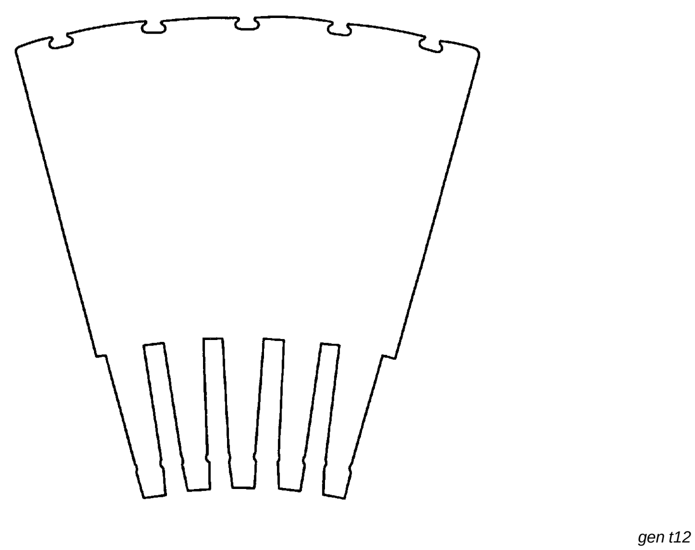
The stator frame is a stiff structure, constructed to be a hydrogen vessel and to be able to withstand in excess of 200PSI. It is a hard frame design with its four-nodal frequency significantly above l20Hz. The ventilation system is completely self contained, including the gas coolers within the structure. The gastight structure is constructed of welded steel plate, reinforced internally by radial web plates and axially by heavy wall pipes, bars and axial braces.

A series of floating support rings and core rings are welded to keybars which in turn support the core, allowing the entire core to be spring mounted. This arrangement isolates the core vibration, resulting from the radial and tangential magnetic forces of the rotor, by damping the amplitude and reducing the transmissibility by 20:1. Excessive movement of the core, as may result from out of phase synchronization, is limited by the use of stop collars at certain circumferential locations around the frame. The clearance is designed to allow the spring action of the bar to be unrestricted during normal operation but to transmit the load of excessive movement through the structure prior to yielding of any of the components. This entire arrangement is in keeping with long standing practices and experience with similar frame designs that have proven to be very effective and reliable.

9.1.4.1 Stator Core

The core is laminated from grain oriented silicon steel to provide maximum flux density with minimum losses, thereby providing a compact electrical design. The laminations are coated on both sides to ensure electrical insulation and reduce the possibility of localized heating resulting from circulation currents.

Stator Punching
(Typical)



The overall core is designed to have a natural frequency in excess of 170 hertz, well above the critical two-per-rev electromagnetic stimulus from the rotor. The axial length of the core is made up of many individual segments separated by radial ventilation ducts. The ducts at the core ends are made of stainless steel to reduce heating from end fringing flux. The flanges are made of cast iron to minimize losses. To ensure compactness, the unit receives periodic pressing during stacking and a final press in excess of 700 tons after stacking.

9.1.4.2 Armature Winding

The armature winding is a three phase, two circuit design consisting of "Class F" insulated bars. The stator bar stator ground insulation is protected with a semi-conducting armor in the slot and well proven voltage grading system on the end arms.

The ends of the bars are pre-cut and solidified prior to insulation to allow strap brazing connections on each end after the bars are assembled. An epoxy resin filled insulation cap is used to insulate the end turn connections.

The bars are secured in the slot with side ripple springs (SRS) to provide circumferential force and with a top ripple spring (TRS) for additional mechanical restraint in the radial direction. The end winding support structure consists of glass binding bands, radial rings, and the conformable resin-impregnated felt pads and glass roving to provide the rigid structure required for system electrical transients.

9.1.5 Ventilation

The generator is cooled by an internally recirculating gas stream that dissipates generator heat through gas-to-water heat exchangers. The ventilation system is completely self contained, including the gas coolers within the structure.

Ventilation fans are mounted at each end of the rotor. The fans provide cooling gas for the stator winding and core. Cooling of the stator core is accomplished by forcing gas through the radial ducts formed by the space blocks in the punchings. The axial length of the core is made up of many individual segments separated by the radial ventilation ducts. This arrangement results in substantially uniform cooling of the windings and core.

The rotor winding, which is a directly cooled radial flow design, is self-pumping and does not rely on the fan for airflow. The rotor is cooled externally by the gas flowing along the gap over the rotor surface, and internally by gas that flows through subslots under the field coils within the rotor body and passes directly through cooling ducts in the copper coils and wedges

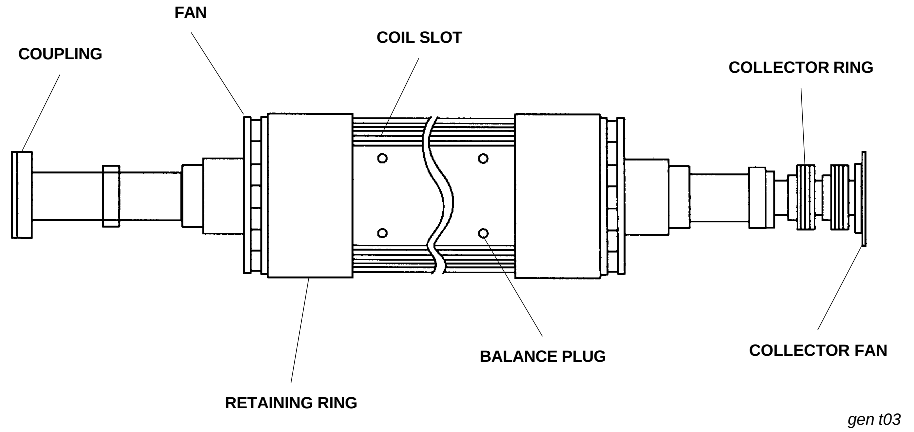
After the gas has passed through the generator, it is then directed to four vertically mounted gas-to-water heat exchangers at the four corners of the frame. After the heat is removed, cold gas is returned and recirculated.

Water inlet, outlet and vent pipe connections for the generator coolers are made externally to the machine. The method of sealing is such that the water boxes and covers can be removed to clean a cooler without opening the generator ventilation circuit.

9.1.6 Rotor

The rotor is machined from a single-piece, high-strength alloy steel forging. The retaining ring is nonmagnetic 18 Cr 18 Mn stainless steel for low losses and high stress-corrosion resistance. The rings are shrunk onto the rotor body, thus eliminating any risk of top turn breakage. A snap ring is used to secure the retaining ring to the rotor body, which minimizes the stresses in the tip of the retaining ring. An illustration of the rotor is provided below.

Generator Field
(Typical)



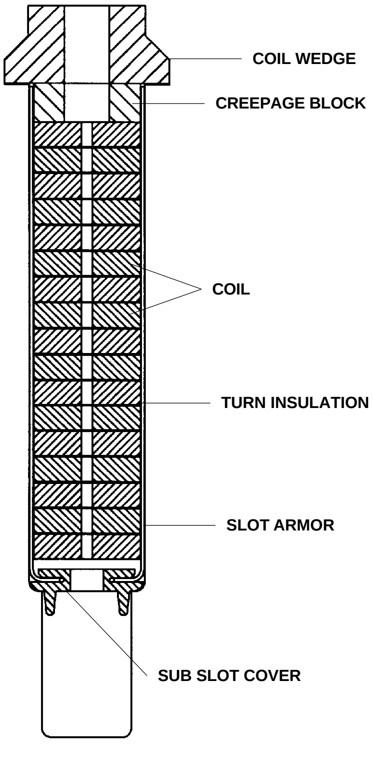
Axial slots are machined radially in the main body of the shaft to locate and retain the coils. The axial vent slots machined under the main coil slots are narrower than the main slots and provide the direct radial cooling of the field copper.

Depending on the design, wedges may be stainless steel, or a combination of aluminum, stainless steel, and magnetic steel.

9.1.6.1 Field Assembly

The field consists of several coils per pole with turns made from high conductivity copper. Each turn has slots punched in the slot portion of the winding to provide direct cooling of the field.

Field Winding Support
(Typical)



The slot armor used in the slots is a Class ""F"" rigid epoxy glass design. An insulated cover is positioned at the bottom of each slot armor and on top of the subslot. The cover will provide the required creepage between the lower turns and the shaft. Epoxy glass insulation strips are used between each coil turn. A pre-molded glass retaining ring insulation is utilized over the end windings and a partial amortisseur is assembled under the rings to form a low resistance circuit for eddy currents to flow.

The entire rotor assembly is balanced up to 20% over operating speed.

The rotor slot armor, and all the insulation materials in contact with the winding, are full class F materials and are proven reliable materials through use on other generator designs.

9.1.7 End Shield Bearings

The unit is equipped with end shields on each end, designed to support the rotor/bearings, to prevent gas from escaping, and to be able to withstand a hydrogen explosion in the unlikely event of such a mishap. In order to provide the required strength and stiffness, the end shields are constructed from steel plate and are reinforced. The split at the horizontal joint allows for ease of assembly and removal.

The horizontal joints, as well as the vertical face which bolts to the end structure, are machined to provide a gas tight joint. Sealing grooves are machined into all these joints. These steps are taken to prevent gas leakage between all the structural components at operating pressure.

Horizontally split inner and outer oil deflectors are bolted into the end shield and provide sealing of the oil along the shaft. The deflectors are either fabricated or cast aluminum. All faces of the deflectors have “O” ring grooves to provide additional protection from oil leaks.

The hydrogen seal casing and seals, which prevent hydrogen gas from escaping along the shaft, utilize steel babbitted rings. Pressurized oil for the seals is supplied from the main oil system header to the seal oil control unit where it is filtered and regulated.

The seal oil control unit is a factory assembled skid mounted system and includes the following components:

- Differential pressure transmitter
- Differential pressure gage (seal oil pressure versus casing gas pressure) and two differential pressure switches: one for alarm and one for actuating the DC emergency seal oil pump
- Shut-off and isolation valves for operation and maintenance

Oil from the hydrogen side of the seals is scavenged in the seal drain enlargement and finds its way back to the lube oil drain system through the float trap. All drain oil from the generator, seals and bearings, is isolated from the main lube tank by the loop seal and the piping system is vented to the atmosphere, assuring additional safety.

The lower halves of the bearings are equipped with dual element temperature detectors. Provisions for velocity type vibration sensors are provided on the end shields. Provisions for proximity probes are also on the end shields.

All exiting wiring from the temperature indication devices and the insulating test leads are brought out of the unit through gas tight seals to prevent any chance of a hydrogen leak.

The bearing at the exciter end of the generator is electrically insulated from the generator frame to prevent the flow of shaft currents.

9.1.8 Lubrication System

Lubrication for the generator bearings is supplied from the turbine lubrication system. Generator bearing oil feed and drain interconnecting lines are provided, and have a flanged connection at the turbine end of the generator package for connection to the turbine package.

9.1.9 Hydrogen Control Panel

To maintain hydrogen purity in the generator casing at approximately 98 percent, a small quantity of hydrogen is continuously scavenged from the seal drain enlargements and discharged to atmosphere. The function of the hydrogen control panel is to control the rate of scavenging and to analyze the purity of the hydrogen gas. The panel is divided into two compartments, the gas compartment and the electrical compartment, which are separated by a gas-tight partition.

9.1.9.1 Control Panel Functions

The GE hydrogen control panel is designed for use on hydrogen cooled generators with scavenging systems. The panel functions are described below:

- The hydrogen control panel allows manual control of the continuous scavenging rate, both turbine end and collector end, via metering valves.

- Hydrogen from the generator turbine end and generator collector end is continuously monitored for purity. At predetermined time intervals, the purity of the generator core gas is also checked. Two independent, switchable, triple range hydrogen purity analyzers are used, thus providing total redundancy, for two out of two voting. Each display and control panel will include three digital displays providing real time readout of gas purity, gas temperature and the status of the analyzers operating parameters. All information is provided to the turbine control panel.

- In the event that one of the analyzers detect a drop in purity, a confirmation by the other gas analyzer is performed. Time for the measurement, which requires reconfiguration of the valves, as well as the handling of possible disagreements in measurement results, is also negotiated between the analyzers.
- In the event that either analyzer indicates a low purity alarm, the rate of scavenging is increased automatically and an alarm is annunciated.
- All components used in the hydrogen control panel are specifically designed and / or third party approved for use in an Class I, Division I, Group B environment.

9.1.9.2 Control Panel Devices

9.1.9.2.1 Differential Pressure Gas Transmitter

The differential pressure gas transmitter measures the generator fan differential gas pressure. It provides a 4-20 mA DC signal proportional to differential gas pressure and includes a 316L stainless steel diaphragm all housed in a Factory Mutual approved explosion proof enclosure.

9.1.9.2.2 Differential Gas Pressure Gage

The differential gas pressure gage provides local indication of the generator fan differential gas pressure. The gage is flush mounted, waterproof, dual range and stainless steel movements.

9.1.9.2.3 Gas Pressure Transmitter

The gas pressure transmitter measures the generator core gas pressure or machine gas pressure as it is sometimes called. It provides a 4-20 mA DC signal proportional to gas pressure and includes a 316L stainless steel diaphragm all housed in a Factory Mutual approved explosion proof enclosure.

9.1.9.2.4 Gas Pressure Gage

The gas pressure gage provides local indication of the generator core gas pressure. The gage is flush mounted, water proof, dual range and stainless steel movements.

9.1.9.2.5 Total Gas Flowmeter

The total gas flowmeter provides local indication of the total flow of scavenged gas. The flowmeter is a flush mounted, in line, direct read flowmeter with stainless steel body.

9.1.9.2.6 Gas Analyzer Flowmeters (2)

Gas analyzer flowmeters provide local indication and control of the gas flow through each of the gas analyzers. Each flowmeter is a flush mounted, in line, direct read flowmeter with stainless steel body.

9.1.9.2.7 Gas Purifiers (3)

Gas purifiers remove oil, water and foreign particles from each of the gas sampling lines (turbine end, collector end and core gas).

9.1.9.2.8 Moisture Indicators (3)

Moisture indicators provide local indication relating to the operating condition of the gas purifiers in each of the gas sampling lines (turbine end, collector end and core gas).

9.1.9.2.9 Control Cabinet

The standard cabinet is NEMA 1 rated and fabricated from #10 standard gauge, sheet steel. Gas piping and electrical field connections can be located at either the top, bottom or rear of the cabinet per customer request.

9.1.9.2.10 Solenoid Valves

All solenoid valves have stainless steel bodies with class H temperature rated coils. The solenoids are also third party approved for use in a Class 1, Division 1, Group B environment.

9.1.9.2.11 Gas Analyzers

The gas purity analyzer utilizes the principle of fixed geometry diffused flow thermal conductivity to measure the purity of a known component of a binary gas mixture. Digital acquisition at the sensor level by precision components, rather than the previous Wheatstone bridge arrangement, increases measurement accuracy. A novel aspect of the analyzer is its ability to operate in a redundant configuration; the two, identical, microcontroller based subsystems which comprise the analyzer are interconnected by a communications channel to enable the analyzer to confirm an alarm condition, (i.e., two out of two voting). This communications channel also allows the analyzer to negotiate and report possible malfunctions in the measurement system.

9.1.9.3 Fault Detection and Reporting

Each subsystem within the analyzer is self-supervising and continuously checks itself for acceptable processor functioning, internal voltages, analog to digital conversion accuracy, integrity of cabling and relay operation. Any faults are immediately annunciated at the cabinet and a contact signal indicating analyzer trouble is opened. A faults log, which maintains a date/time stamp of detected failures can be viewed at any time. The analyzer can also execute detailed self-diagnostics.

9.1.10 Hydrogen Control Manifold

Hydrogen is admitted to the generator casing through the use of the hydrogen gas manifold. The following instrumentation is provided and is located in the collector compartment:

- Generator gas pressure gage
- High and low generator gas pressure switches

The H2 bottle manifold consists of two stages. A high pressure regulator reduces the bottle pressure for delivery into the control header, where a low pressure regulator maintains generator gas pressure. A bottle pressure gage and low bottle pressure switch are provided.

9.1.11 Carbon Dioxide Control Manifold

A carbon dioxide system is used for purging the generator casing of air before admitting hydrogen, and also to purge hydrogen before admitting air. The following instrumentation is provided:

- Purging control valve assembly
- Relief valve

The carbon dioxide bottle manifold consists of the following:

- Pressure gage with shut-off valve
- Bottle connectors

9.1.12 Detraining System

The air-side seal oil and the generator bearing oil drain to a bearing drain enlargement mounted under the generator casing. This bearing drain enlargement is a detraining chamber and provides a large surface area for detraining the oil before it is returned to the main oil tank.

Two seal drain enlargements are provided for removing entrained hydrogen from the oil which drains from the hydrogen-side seal rings. They are drained through a common line to a float trap which then drains to the bearing drain enlargement for further detraining. A high liquid level alarm switch is provided to detect abnormal oil level in the seal drain enlargement.

9.1.13 Collector Assembly

The spirally grooved collector rings are heat-treated steel forgings, shrunk on to the generator shaft over non-metallic rings which insulate the collector rings from the shaft. The collector assembly features permanently mounted brush holders and brushholder rigging with constant tension springs to press the brushes against the collector rings. Included are easily removable graphite brushes with integral pigtails and a terminal for connection to the brush holder. An insulated handle is supplied that permits brush removal while the generator is in operation. Collector inlet air is effectively drawn into the base of the collector housing through a filter. This air cools collector rings and brush rigging inside the enclosure using a shaft mounted fan adjacent to the collector rings. The heated air then exits the enclosure being discharged to ambient via outlet air ducting.

The enclosure has a door on each side of the collector enclosure for brush maintenance. Each door has a viewing window for visual inspection of the brushes from outside the enclosure.