Rotor and Stator

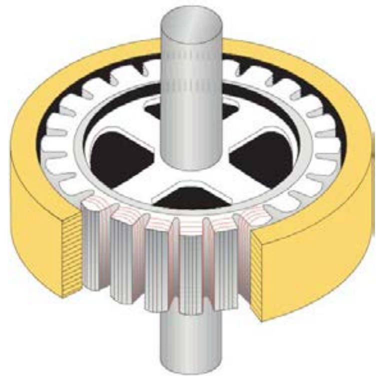
Rocky Reach

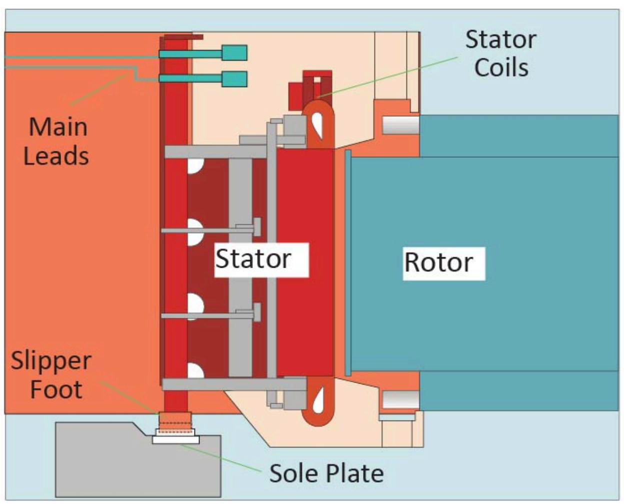
Table of Contents

OVERVIEW

The Rocky Reach powerhouse is equipped with seven 117,000 KVA capacity generators and four 132,000 KVA capacity generators. The two principal working parts of the generator are the stator (or the armature winding), the stationary higher voltage component; and the rotor, the rotating DC component. Primary auxiliary equipment associated with the rotor and stator are described in separate OMIs. These OMIs include the ***Generator Cooling System***, the ***Generator Protection Equipment***, the ***Excitation and Voltage Regulation System***, and the rotor ***Brake System***. Some of the units are also equipped with ***Machine Condition Monitoring Equipment***.

New rotors and stators on units C1-C7 were replaced beginning in the fall of 2002. The new rotors were built by ABB. Design changes included upgrading the unit capacity to 120,000 KVA. The new stators were constructed in place to form a continuous stator core, as opposed to the current sectional design. This strengthened the stator core structure.

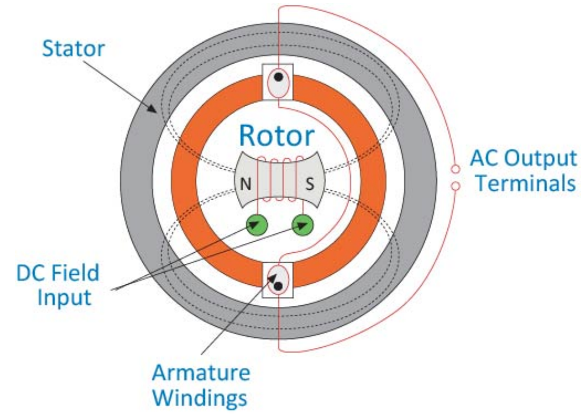


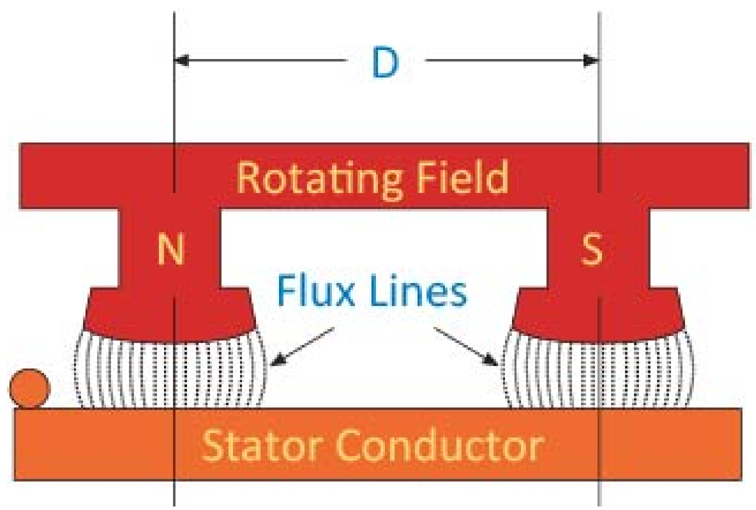


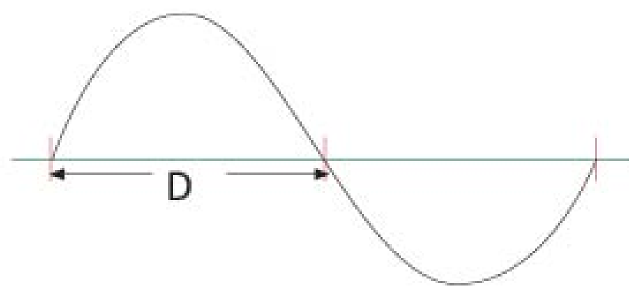
The rotors for units C8-C11 are original equipment, manufactured by Allis-Chalmers in 1961. The stators were replaced by ABB as part of the unit rehabilitation (1999-2002).

Generation Theory

The rotor and stator are made up of numerous coils of conductor. The principals of electric power generation are that a coil of wire carrying an electric current produces a magnetic field. As each rotor field coil sweeps past the stator coils, the lines of magnetic flux from the field coil cut that of the stator coils, resulting in an alternating electromotive force or Alternating Current power.







Generation Theory (continued)

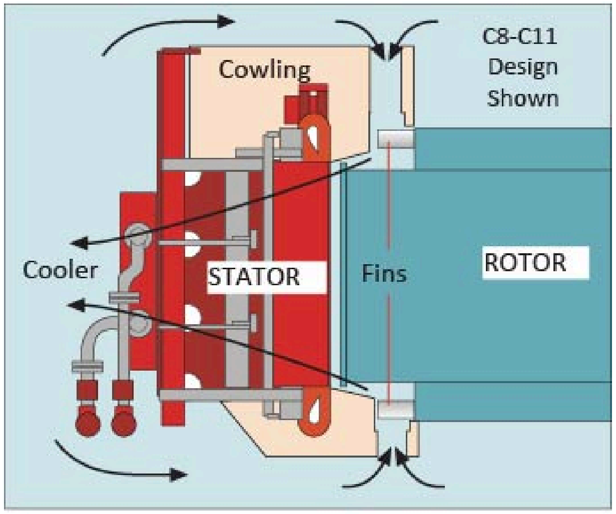
Rocky Reach generators are synchronous machines, which mean that there is a definite ratio between frequency, the number of poles, and the machine speed. In order to produce one cycle of alternating current, a north and a south pole of the field must pass a given point on the stator.

Frequency is expressed in cycles per second or units of Hertz (Hz), while machine speed is noted in revolutions per minute. The relationship between the number of field poles, cycles per minute and RPM of a rotating field generator is shown in the following equation:

Number of field poles = (Cycles per minute times 2)/RPM

Units C1-C7 have a frequency of 60 cycles per second and a synchronous speed of 90 RPM, so they have 80 poles (60 x 60 x 2 / 90 **= 80 poles**). Units C8-C11 have a frequency of 60 cycles per second and a synchronous speed of 85.7 RPM, so they have 84 poles **(60 x 60 x 2 / 85.7 = 84 poles).**

Rotor and Stator Cooling

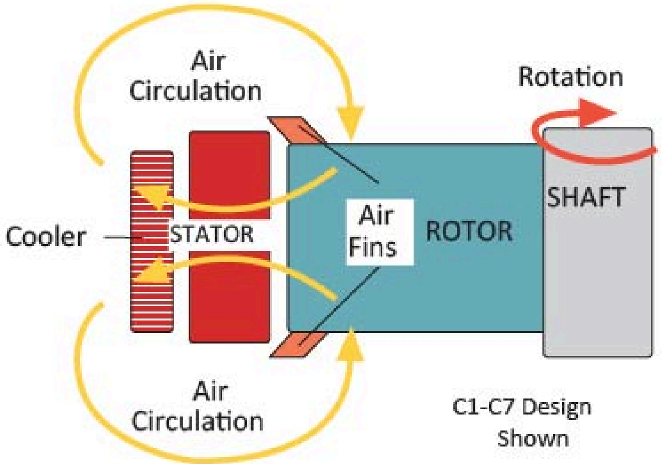


The generator cooling system is designed to maintain generator stator temperatures with as small a differential as possible under varying load conditions between 50 MW and maximum output. River water delivered from the raw water header is circulated through a series of cooling coils installed around the stator.

Fins on the top and bottom of the rotor circulate the air around the stator and cooling coils.

The degree of cooling supplied by the system depends on the temperature of the river water and the flow rate of the water through the cooling coils. Water flow rate is regulated by the position of automatically-controlled discharge valves. The unit PLC continuously monitors the stator outlet air temperature to determine the proper positions for the discharge valves to maintain the target temperature.

For more information, see the OMI titled "Generator Cooling System".

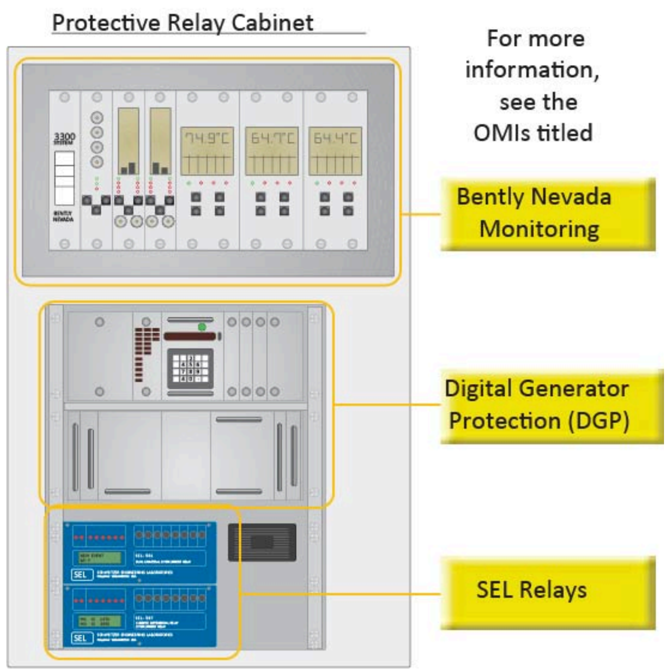


Generator Protection

Each generator is connected through a separate 15KV main generator circuit breaker to a separate step-up transformer. The main generator terminals are arranged for connection to an isolated phase bus duct. The generator neutral leads are provided with three single secondary and three double secondary current transformers used for split phase and generator differential protection. A split phase differential protection relay can trip the generator. A single phase transformer and a grid type resistor connect the neutral of the generator to ground.

Protective Relay Cabinet Protection against excessive generator ground current is provided by a digital generator protection system relay connected across the resistor and arranged to trip the generator.

The Bently Nevada monitoring system provides generator trip capability if excess vibration or temperature is detected.



Rotor Brakes

Combined air operated brakes and oil operated lifting jacks are used to brake the rotor and raise it from the thrust bearing. The jacks are operated by compressed air for braking and by oil from a portable motor-driven oil pump for jacking.

For more information, see the OMI titled, “Brake System”.

Monitoring Equipment

The stator temperature is monitored by various RTDs embedded in the windings during construction. The rotor and stator air gap and winding temperatures are also monitored by on-line Machine Condition Monitoring equipment supplied by Bently Nevada Corp. Four vibration transducers measure shaft vibration near the generator and turbine guide bearings. The Digital Generator Protection (DGP) system samples current and voltage inputs to provide protection, control, and monitoring of the generators. Examples include stator ground (64 relay), stator differential (86G relay) and current unbalance (46T relay). All these monitoring devices are explained in individual OMIs: “Bently Nevada Monitoring”, “SEL Relays”, and “Digital Generator Protection (DGP)”.

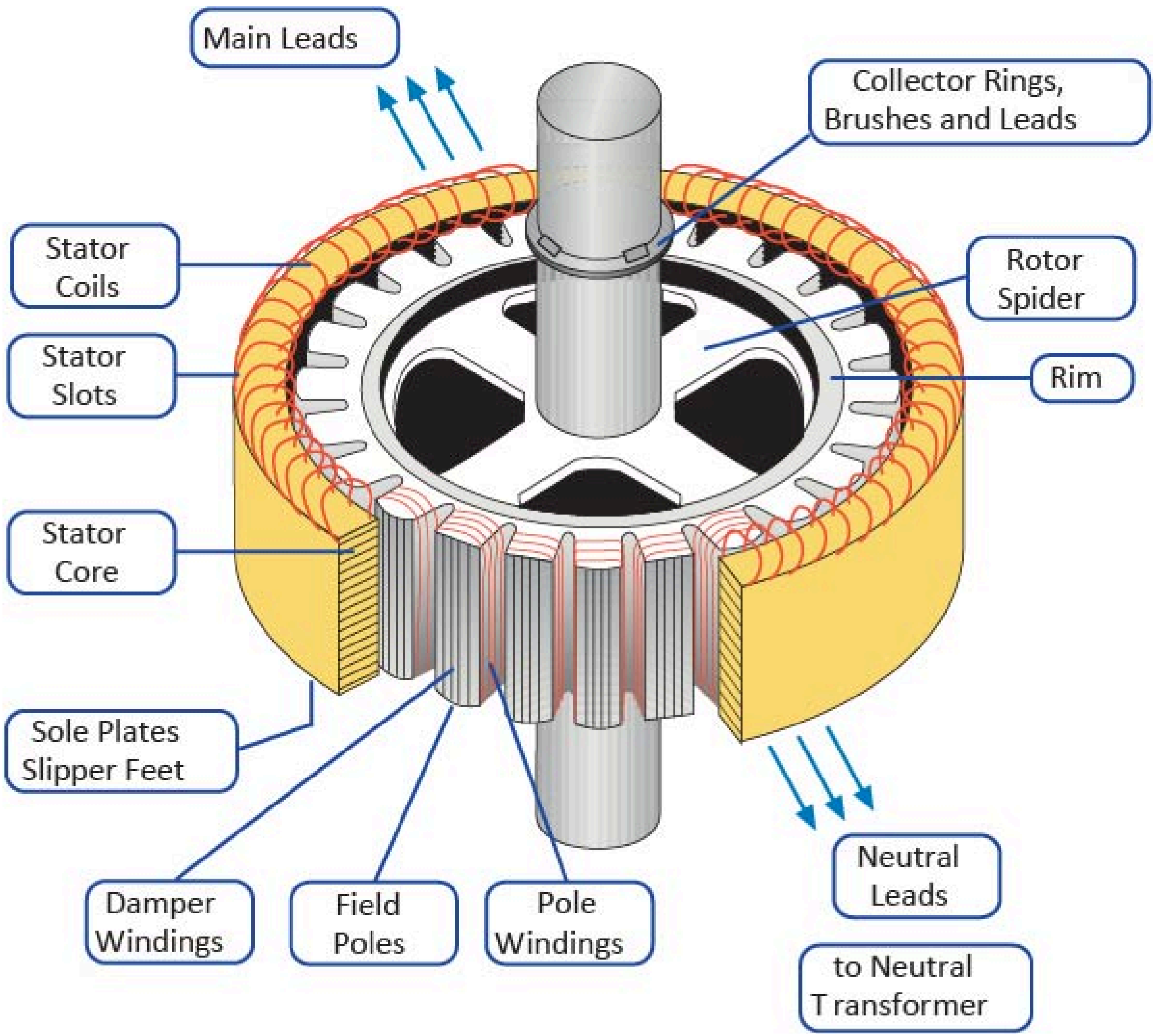
Nameplate Information

C1-C7 SYNCHRONOUS GENERATOR
Manufacturer: Alstom Canada Inc. Power
UPRATED CAPABILITY: 120,000 KVA 15 kV AMPS PER PHASE 4619A P.F. 0.95
3 PHASE Y CONNECTED 60 Hz 90 RPM
INSULATION: STATOR CLASS F ROTOR CLASS F
EXCITATION: 1130 A 186 V
MAX. TEMP. RISE: STATOR 75 °C ROTOR 80 °C
CLASS OF INSULATION: F
APPROXIMATE WEIGHT: 50,000 POUNDS

C8 - C11 SYNCHRONOUS GENERATOR
Manufacturer: Allis Chalmers
UPRATED CAPABILITY: 132,000 KVA
60 Hz P.F.: 0.95 LAGGING VOLTS: 15,000
PHASE: 3 AMPS PER PHASE: 5,075
ROTOR POLES: 84 SPEED: 85.7 RPM
CLASS OF INSULATION: B
APPROXIMATE WEIGHT: 50,000 POUNDS

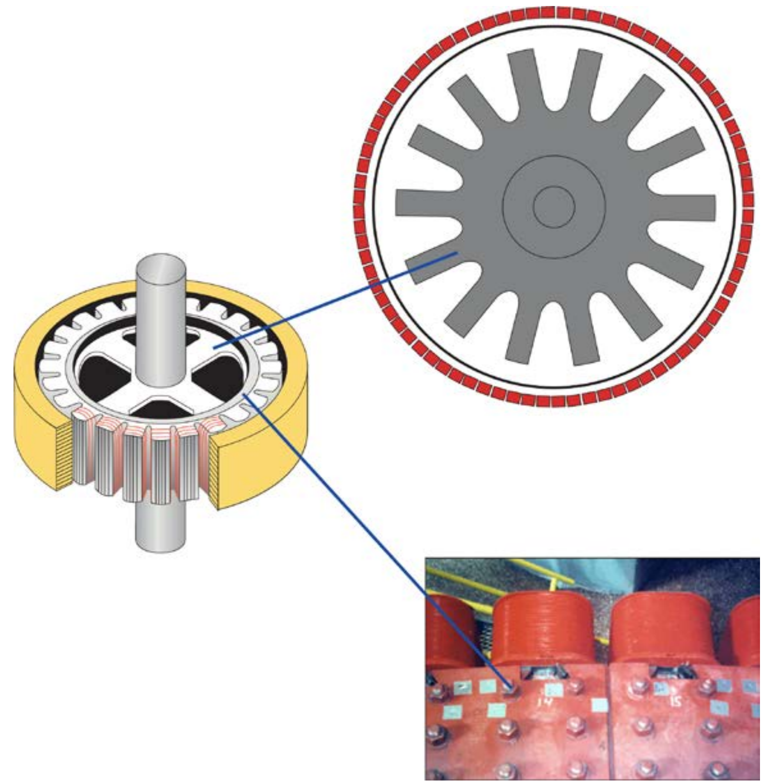
COMPONENTS

System Components



Rotor Spider Assembly

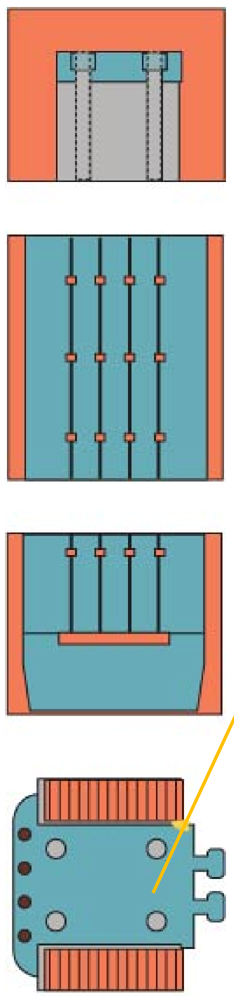
The spider is the fabricated spoke assembly connected to the generator shaft.



Rim

The rim is attached to the spider arms and is notched to receive the field poles.

Field Poles



Top View

Field pole construction differs depending on the type and size of the generator. The greatest distinction being between cylindrical type and salient pole (Rocky Reach) rotors is cylindrical style rotors are for high speed generators while salient pole rotors work well with slower speed units.

The field poles on the rotors at Rocky Reach are constructed of laminated steel. The laminations are similar to the laminations of the stator core, consisting of 1/16 inch steel sheets punched to shape and stacked. “Through bolts” pass through holes in the iron stack to contain the stack.

This rotor, seen on the generator floor during rehab, is missing one rotor field pole.

Field Poles (continued)

The assembled pole is mounted to the spider assembly and held in place with a dovetail and wedge configuration in a notched slot on the spider rim.

Rotor stack during assembly

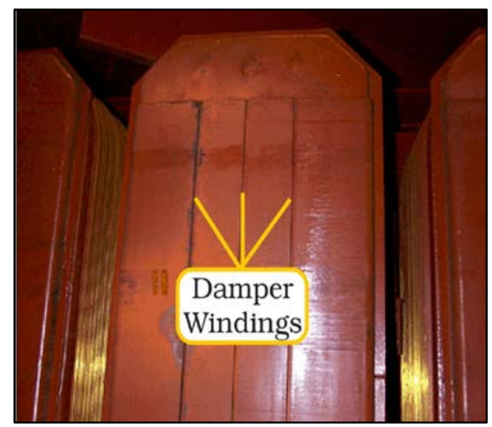
Field Pole Windings

The rotor contains the field windings that are wound on the field poles in a continuous path. The two ends of the winding are connected so that the field windings are in series with each other. These field windings are connected to collector rings mounted on the generator shaft. The collector rings receive DC voltage and current from the unit exciter.

The field winding provides the magnetizing force needed to establish the required magnetic flux to cut the armature winding and initiate the generation of electricity.

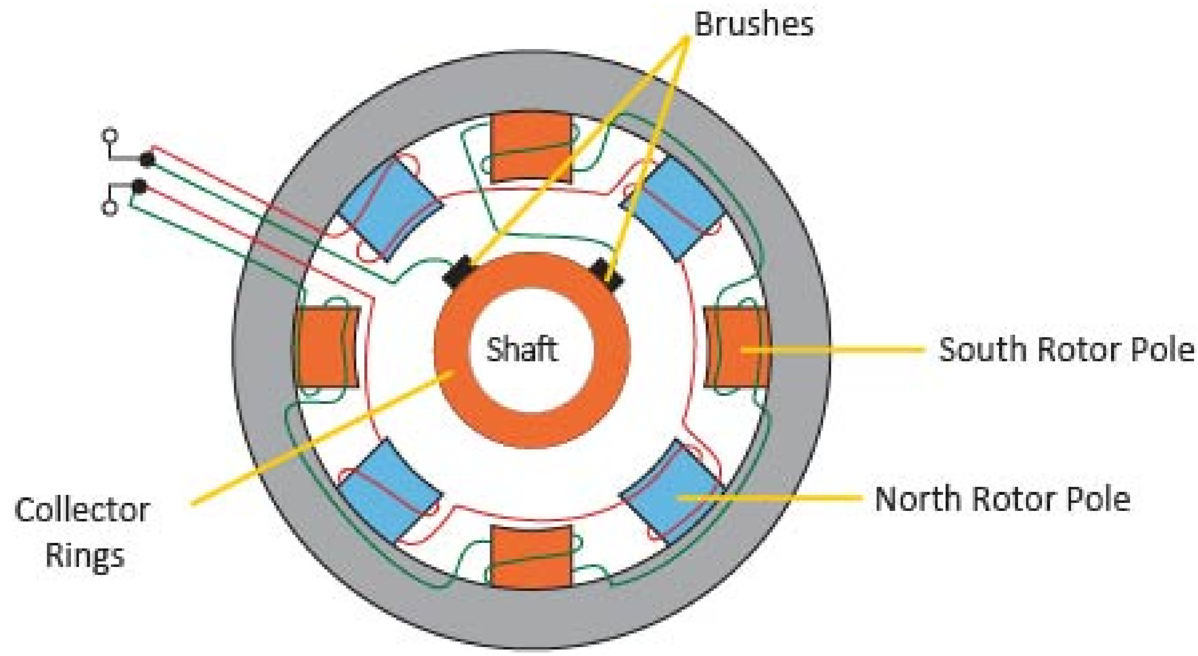
Damper Windings

Damper windings consist of copper or brass bars imbedded in the pole face and connected together so as to form a squirrel cage winding. The purpose of the damper windings is to smooth out the oscillations or hunting effects set up in the electrical circuit of the field due to pulsations of torque from the turbine runner.



Collector Rings, Brushes and Leads

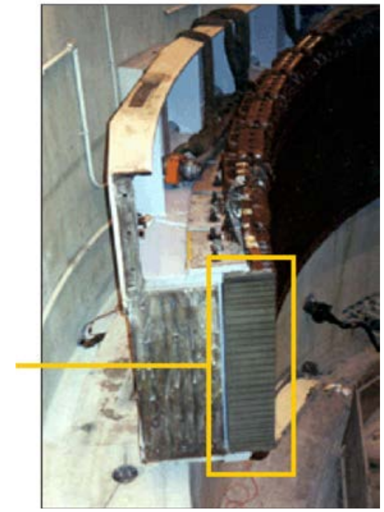
Leads connect the exciter to a set of brushes. The brushes ride on a set of two collector rings. The collector rings receive direct current voltage and current from the unit exciter to energize the rotor poles.



For more information, see the OMI titled, “Excitation and Voltage Regulation”.

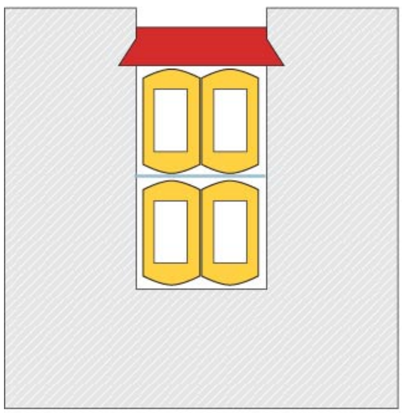
Stator Core

Stator cores are constructed of laminations punched from thin steel sheets. The core is made of steel to provide a low-resistance path for the magnetic flux. Thin laminations minimize eddy currents. Eddy currents tend to circulate in the steel, which creates heat. These currents translate into excess core losses and component temperatures. By insulating the thin laminations with lacquer (varnish, enamel or epoxy) between the laminations, the resistance of the stator assembly is greatly increased. The increased resistance significantly reduces the magnitude of the eddy currents. These laminations are punched in segments of a circle. To ventilate air though the stator core, the laminations are stacked in short axial blocks 1.5 to 2.0 inches high. These blocks of laminations are separated with spacing strips to form ventilating ducts.



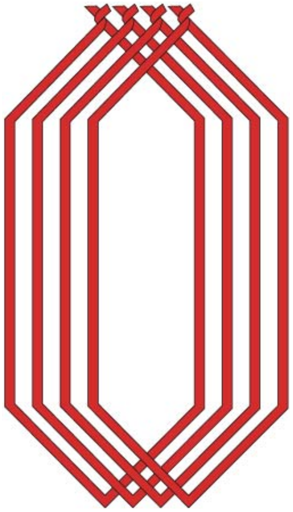
Stator Slots

The stator slots are generally open and the coils are held in the slots by wedges. These wedges are driven in axially after the coils are in place. The wedges are made of a fabric base phenolic that does not shrink with age at temperatures encountered during operation. The purpose of the open slots is to permit the coils to be completely formed before they are placed in the core.



Cross section - stator slot

Stator Coils



The stator coils are shaped by laying the conductor stands in a metal or wooden form built to the shape of the finished coil. The coils must be carefully handled during the insulation process so they will retain their shape and fit properly in the unit.

The number of coils, the number of turns in each coil, and the actual way these coils are connected is determined by design, so the generator will have a specified capacity. The stator winding consists of a set of phase groups evenly distributed around the circumference.

The number of groups is given by the equation:

(number of groups) = (poles) x (phases)

The generator voltage that the insulation must withstand dictates the amount of insulation. The class of insulation used dictates the materials. The insulation used to insulate the turns from each other is called the conductor or turn insulation. The insulation that insulates the entire coil is called the ground wall insulation.

C8-C11 stators have class B insulation. The new C1-C7 stators have class F insulation. The change from class B to class F insulation increases unit capacity by 3 KVA.

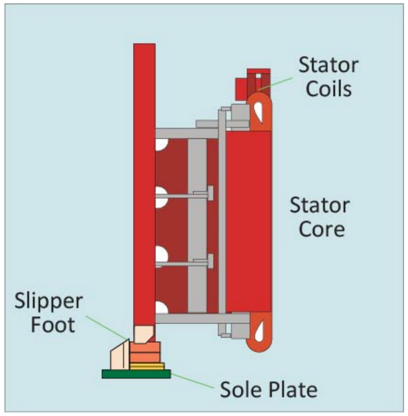
Stator Coils (continued)

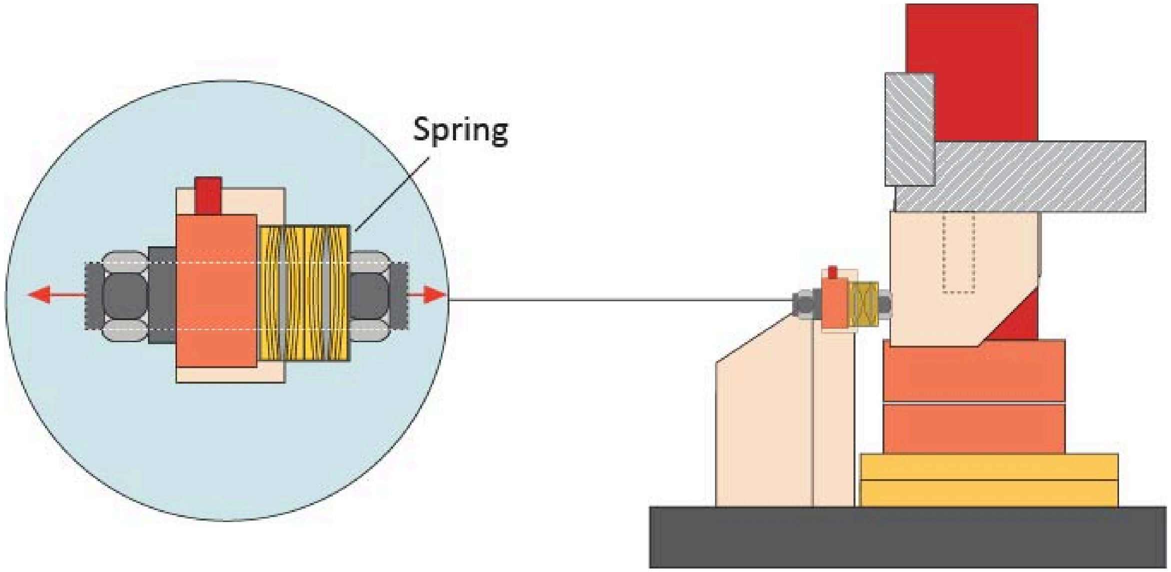
The coils are provided with a protective covering and arranged or treated to reduce corona. Corona results from a breakdown of electrical insulating properties of air caused by high voltages occurring across short air spaces. After considerable time, this corona can result in deterioration of the unit's insulation and eventual damage to the windings. Generally class B winding such as those here at Rocky Reach require mica tape be used to protect the outer coil layer against abrasion of the insulation while the coils are inserted into the slots. The slot portion of the stator's outer coil is provided with a protective covering and arranged or treated to reduce corona. The purpose of this semiconducting compound is to ensure low electrical resistance between the outside of the coil insulation and the slot, so that discharge of corona is minimized.

The stator must be clamped tightly so that the laminations will not shift or vibrate from the forces produced by the changing magnetic flux, which is caused by the ampere surges through the armature coils that the laminations are holding. Finger plates are used in order to provide the strength and rigidity required to withstand short circuit forces and other operational events.

Sole Plates and Slipper Feet

The purpose of the sole plates and slipper feet is to allow expansion and contraction of the stator frame without damage to the equipment. Sole plates are embedded in concrete around the circumference of the stator. The slipper feet are mounted to the bottom of the stator frame. The slipper feet contain springs and dowels to both dampen and direct the expansion forces experienced by the stator. The sole plate provides a platform for the slipper feet to act against.

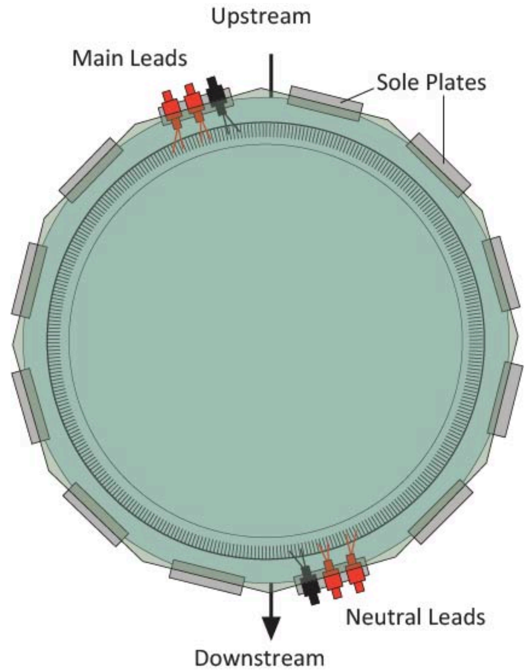




The location of the sole plates around the circumference of the stator is shown on the ***next screen***.

Main Leads

The three independent stator coil windings exit the stator frame and connect to the three generator leads. Current passes through the leads to the generator main circuit breaker. The leads travel beneath the generator floor to the bottom of the generator circuit breaker.



Neutral Leads

The three independent stator coil neutral leads exit the stator frame and connect to one single phase transformer. This transformer and a grid-type resistor connect the neutral of the generator to ground. They are located on the turbine floor just outside the barrel.

Neutral Transformer and Resistor

OPERATIONS

Generator Capability Curves

Capability curves describe how unit output is impacted by changes in power factor, megawatts and megavars.

Power factor is the angular difference between apparent power and true power. The greater the difference, the more unit capability is reduced.

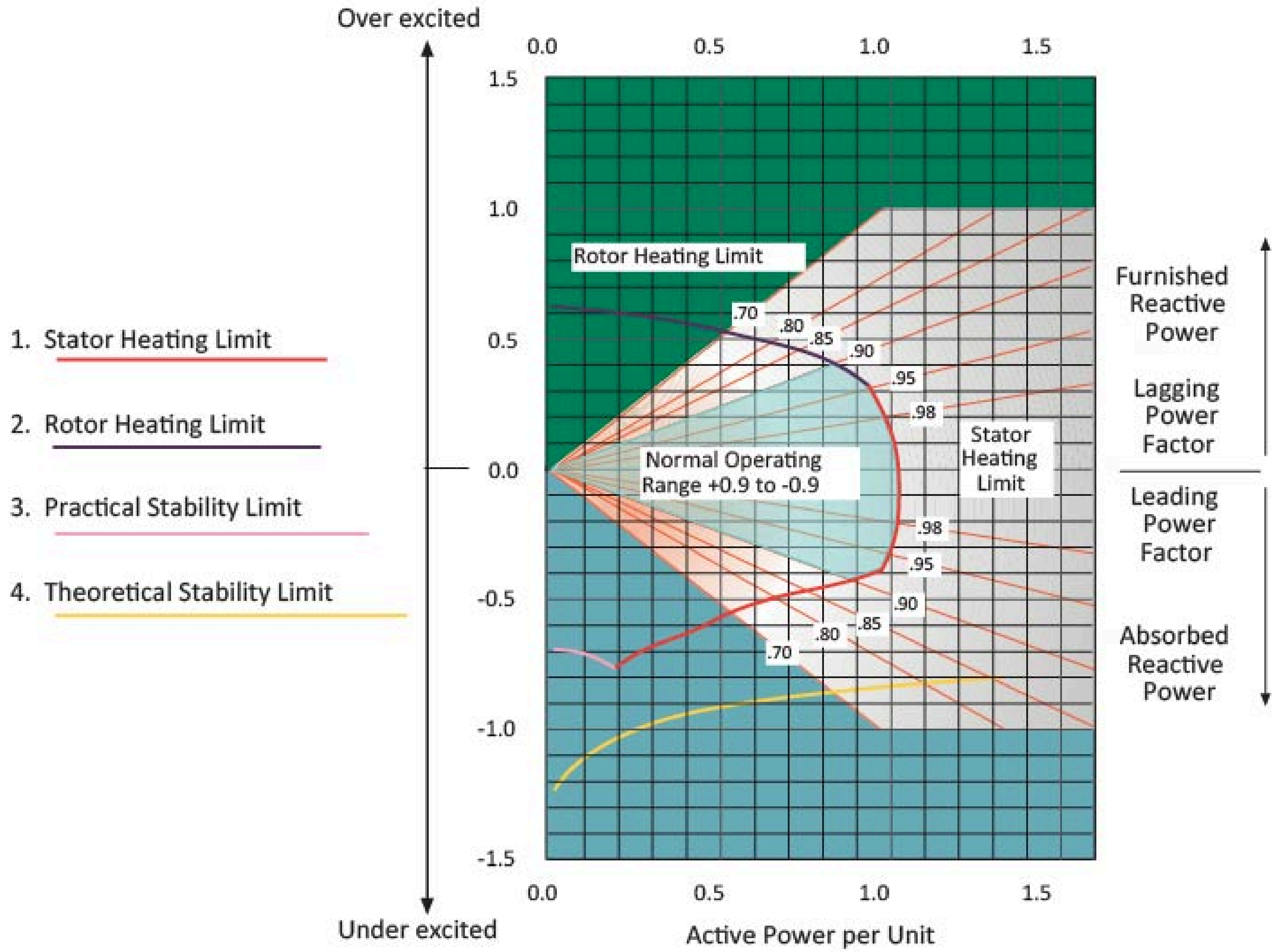
When the power factor is leading, metering indicates negative vars. A lagging power factor indicates positive vars. Generators are operated with a leading power factor to support voltage (higher consumption), and operate with a lagging factor when transmission lines are lightly loaded. Unit capability declines faster with a lagging power factor, as seen on the generator capability curves.

The SCADA unit control software uses the capability curves to limit megavar output based on power factor, with consideration for voltage schedules. Capability curves for the existing C8-C11 generators and the new C1-C7 generators are shown on the next two screens. Following the curve screens are examples of how to read capability curves.

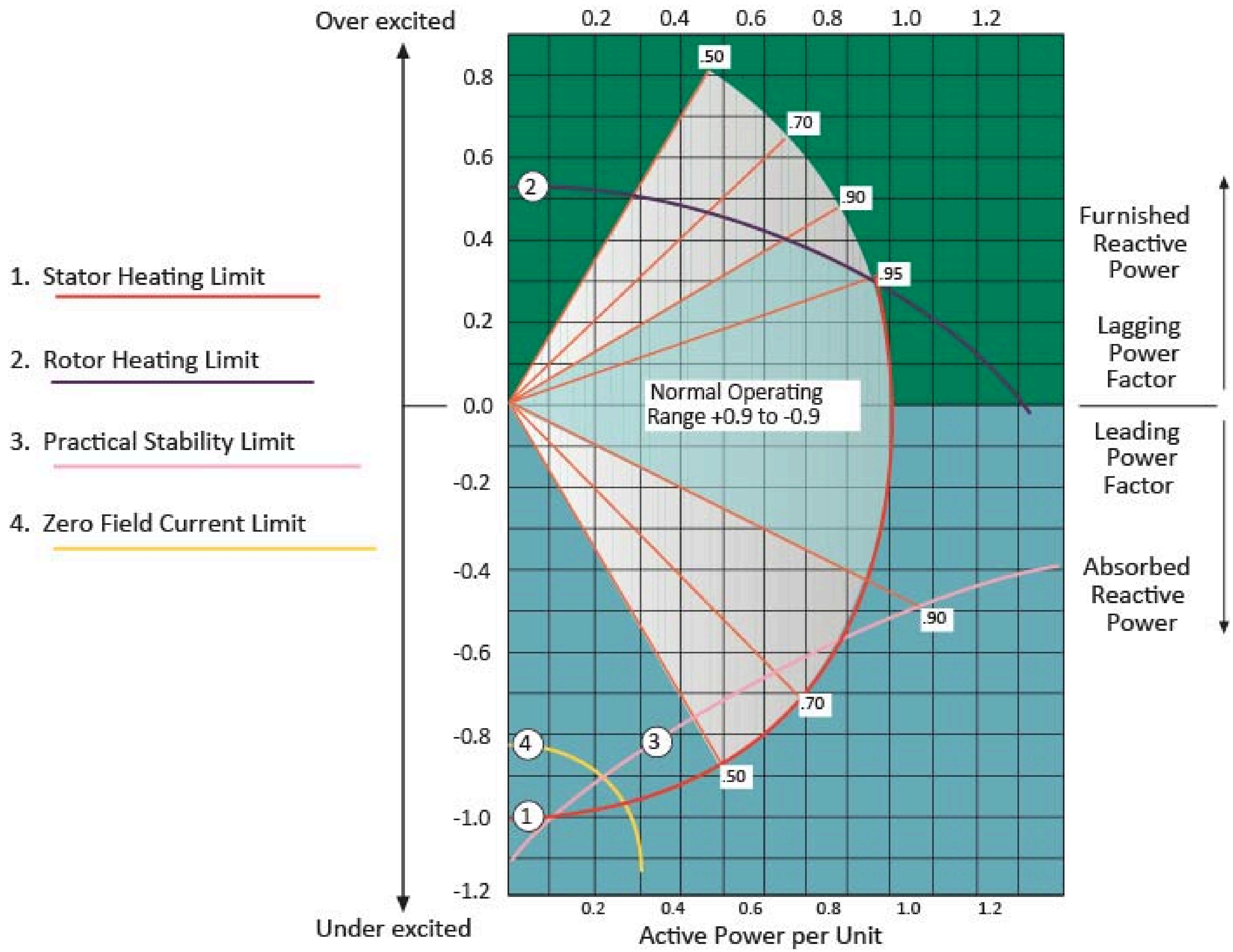
C8-C11 Capability Curve

C1-C7 Capability Curve

C1-C7 Generator Capability Diagram

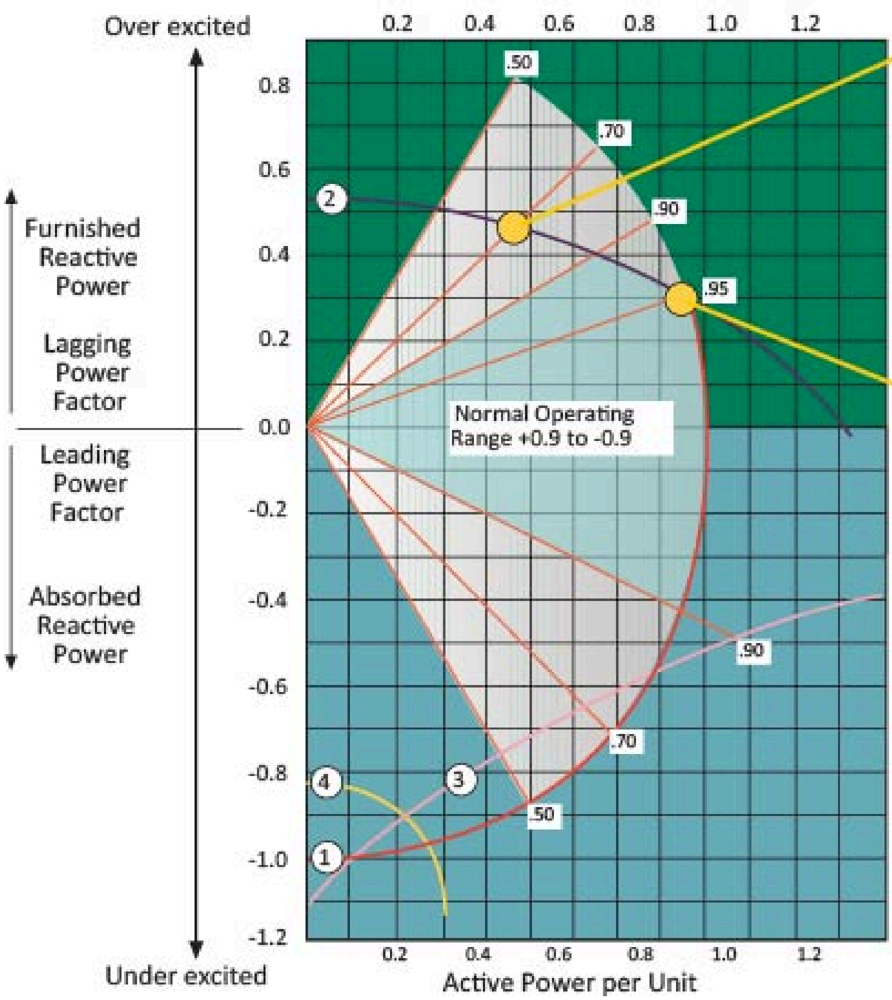


C8-C11 Generator Capability Diagram



Reading Generator Capability Curves

Examples of how to read the capability curves.



Maximum capacity = 132,000 MVA
Power factor = 0.48
0.48 x 132.0 = 63.36 MVARS
132.0 - 63.36 = 68.64 MW

Maximum capacity = 132,000 MVA
Power factor = 0.32
0.32 x 132.0 = 42.24 MVARS
132.0 - 42.24 = 89.76 MW

1. Stator Heating Limit
2. Rotor Heating Limit
3. Practical Stability Limit
4. Zero Field Current Limit

ALARMS

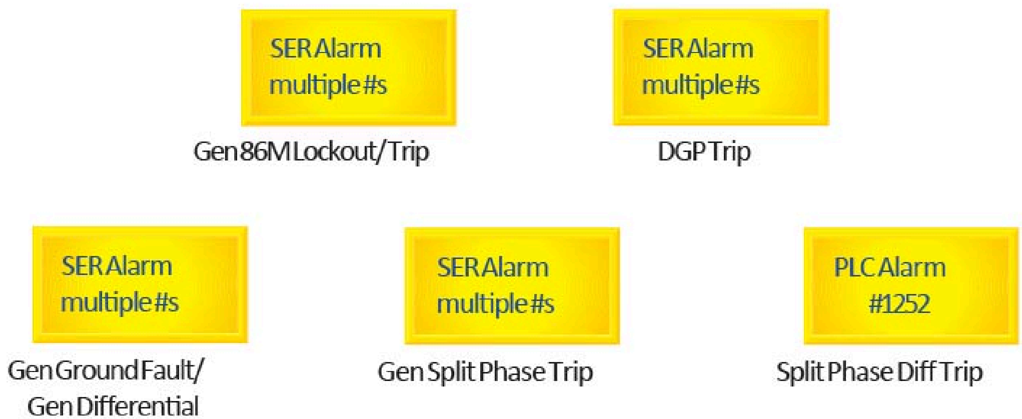
Alarm Signaling

There are 20 alarms directly associated with rotor and stator. The alarms monitor stator winding temperature, winding phase relationship and current and voltage levels. Four of these alarms are SER alarms and the other 16 are initiated through the PLC.

Alarms initiated by problems within the digital governor are sent to the unit PLC. The unit PLC alerts workers in the local unit area with a red light and an alarm message on the PanelView monitor. A duplicate PanelView monitor displays the same alarm message in the control room. The unit PLC also sends the alarm to the plant SCADA control system.

Individual Alarms

The alarms program describes the 20 alarms associated with the rotor and the stator. Click on the alarm to link directly to the associated alarm program response screen.



Individual Alarms (continued)

PLC Alarm #1285 Stator Winding A Hi	PLC Alarm #1384 Stator Winding B Hi	PLC Alarm #1386 Stator Winding C Hi
PLC Alarm #1266 Generator A Phase Current Hi	PLC Alarm #1267 Generator A Phase Current Hi Hi	PLC Alarm #1269 Generator B Phase Current Hi
PLC Alarm #1270 Generator Phase B Current Hi Hi	PLC Alarm #1276 Generator Phase C Current Hi	PLC Alarm #1277 Generator Phase C Current Hi Hi
PLC Alarm #1272 Generator Phase A-B Voltage Hi	PLC Alarm #1273 Generator Phase A-B Voltage Low	PLC Alarm #1274 Generator Phase B-C Voltage Hi
PLC Alarm #1275 Generator Phase B-C Voltage Low	PLC Alarm #1284 Generator Phase C-A Voltage Hi	PLC Alarm #1283 Generator Phase C-A Voltage Low

MAINTENANCE

Maintenance Information

There are no routine maintenance tasks associated with rotor or stator. Maintenance of the primary auxiliary equipment associated with the rotor and stator are described in separate OMIs. These OMIs include the ***Generator Cooling System***, the ***Generator Protection Equipment***, and the rotor ***Brake System***.

REFERENCE

Computer Programs

Alarms Program

This intranet program lists alarm source and response data for all PLC and SER alarms. Access it by clicking on the Alarm button on the right margin of any OMI screen.

Manuals

None

Drawings

See next screen

Drawings	Identification No.	Subject
	2-50000-001	Generator Assembly
Alstom Drawings for New C1-C7 Units	2-50001-001	Unit Nameplate
	2-51100-001	Rotor Spider Site Assembly
	2-51101-001	Rotor Spider Site Assembly
	2-51202-001	Set of Rotor Rim Plates
	2-51300-001	Field Pole Arrangement
	2-51301-001	Pole Core Arrangement
	2-51310-001	Field Winding Arrangement
	2-51921-001	Rotor Support
	2-52402-001	Set of Stator Core Lamination
	2-52408-001	Set of Stator Vent Lamination
	2-52501-001	Stator Slot Cross Section and Wedging Material
	2-52503-001	Stator Bars insulated Connections Arrangement
	2-52503-002	Set of Stator Bars Bare Connections
	2-52508-001	Stator Winding Diagram
ABB Drawings for C8-C11 Units	XO 303 000-CNE	Generator Foundation
	XO 310 020-CNE	Stator Complete
	4421 981-EE	Rotor Stator Cross-section