PROTECTION OF 600MW TURBOGENERATOR

A project report submitted to

SREENIDHI INSTITUTE OF SCIENCE AND TECHNOLOGY

BACHELOR OF TECHNOLOGY

IN

ELECTRICAL AND ELECTRONICS ENGINEERING

Done by

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KTPP, Chelpur	

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2017-18

SREENIDHI INSTITUTE OF SCIENCE AND TECHNOLOGY

Ghatkesar, Hyderabad- 501301

CERTIFICATE

This is to certify that the project report entitled

"PROTECTION OF 600MW TURBOGENERATOR"

is the bonafide work done by

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Department of Electrical & Electronics Engineering

and is submitted to Sreenidhi Institute of Science and Technology, Hyderabad

in partial fulfillment of the requirements for the award B.Tech degree in

Electrical & Electronics Engineering

This work has been carried out under the guidance of

EXTERNAL EXAMINER

Kakatiya Thermal Power Project

TELANGANA POWER GENERATION CORPORATION LTD

Chelpur (V), Ghanpur (M), Jayashanker Bhupalapally district-506169, Telangana.
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---- Project Associates

ABSTRACT

In a power plant, generator is the most important and costliest equipment. So it is essential to know about the components of a generator and auxiliary systems which help in its operation. The knowledge of the components helps in better understanding of the effect of any fault which occurs and the need for protection of generator against the fault.

Sealing the generator shaft so that the gas inside the generator doesn't come out, providing primary water for cooling purpose, providing gases for cooling and purging purposes, providing excitation for the generator are done by the auxiliary systems thereby helping in generator's operation. Thus it is also important to know about the auxiliary systems.

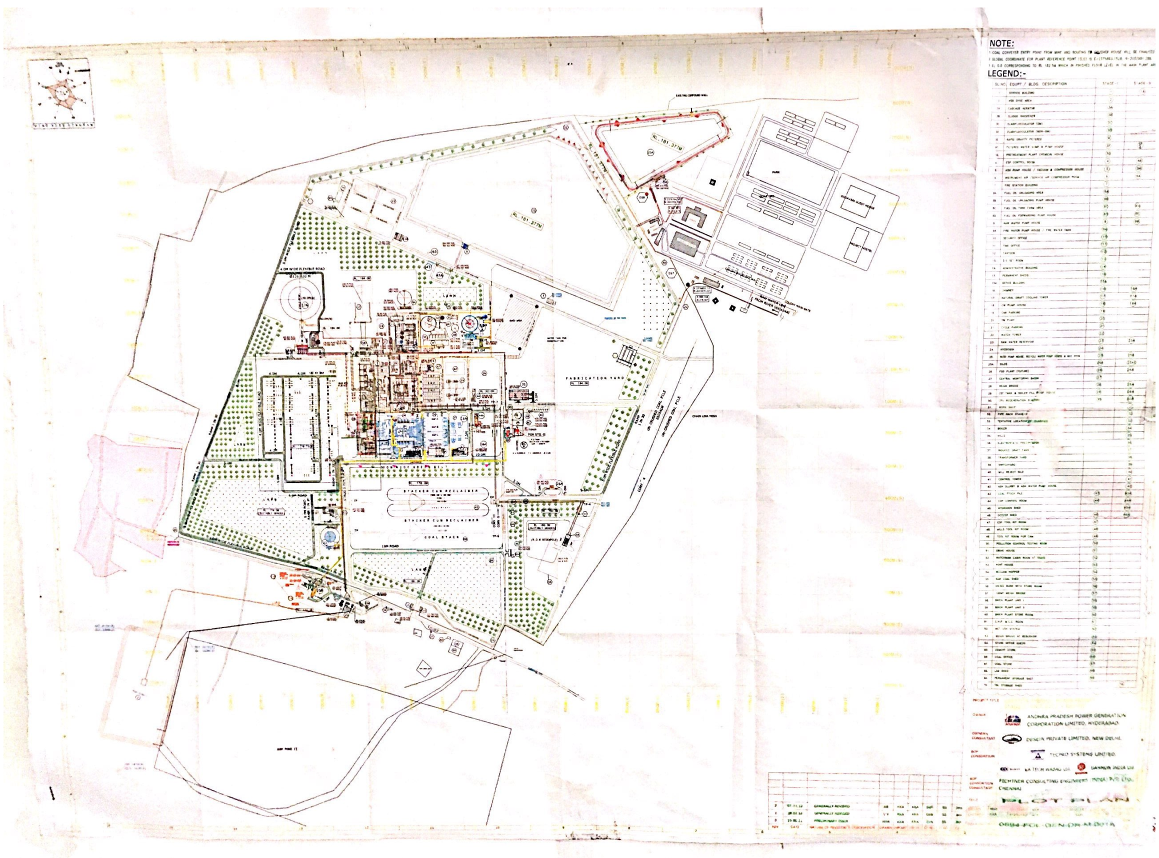
Every generator is connected to a power system. In order to protect it from faults and other disorders protection system contains elements which disconnect it from the system if necessary. Even though manual observation is present, the effective protection of the system is achieved by the automatic detection and prevention of faults for continuous generation safeguarding the apparatus. We make use of relays for this purpose.

A relay is a circuit that senses the abnormal conditions and ensures the safety of the circuit equipment from damages and normal working of the healthy portion of the system. Relays have good characteristics like selectivity, sensitivity, speed, reliability, simplicity etc. which help in efficient protection of generator. Thus in this project report all of these are discussed in a detailed manner.

CONTENTS

AUXILIARY SYSTEMS **21-30**

KTPP LAYOUT



CHAPTER-1

PLANT DESCRIPTION

Kakatiya Thermal Power Project (KTPP) of Telangana Generation Corporation Limited is situated near Chelpur village of Ghanpur mandal in Bhupalapally district,Telangana. Chelpur village is 60 kms away from Warangal and KTTP is 2.2 kms away from Chelpur. KTPP consists of 1 x 500MW stage-I and 1 x 600MW stage-II.

The government of AP has allocated 1 TMC of water from Godavari at Kaleswaram near Metpalli village. Main power house works such as turbo generator, boiler and ESPs were awarded to BHEL. All civil works and balance electrical and mechanical works were awarded to BGR Energy Systems Ltd. Chennai. REC sanctioned loan of Rs. 1544.51 crores for the project.

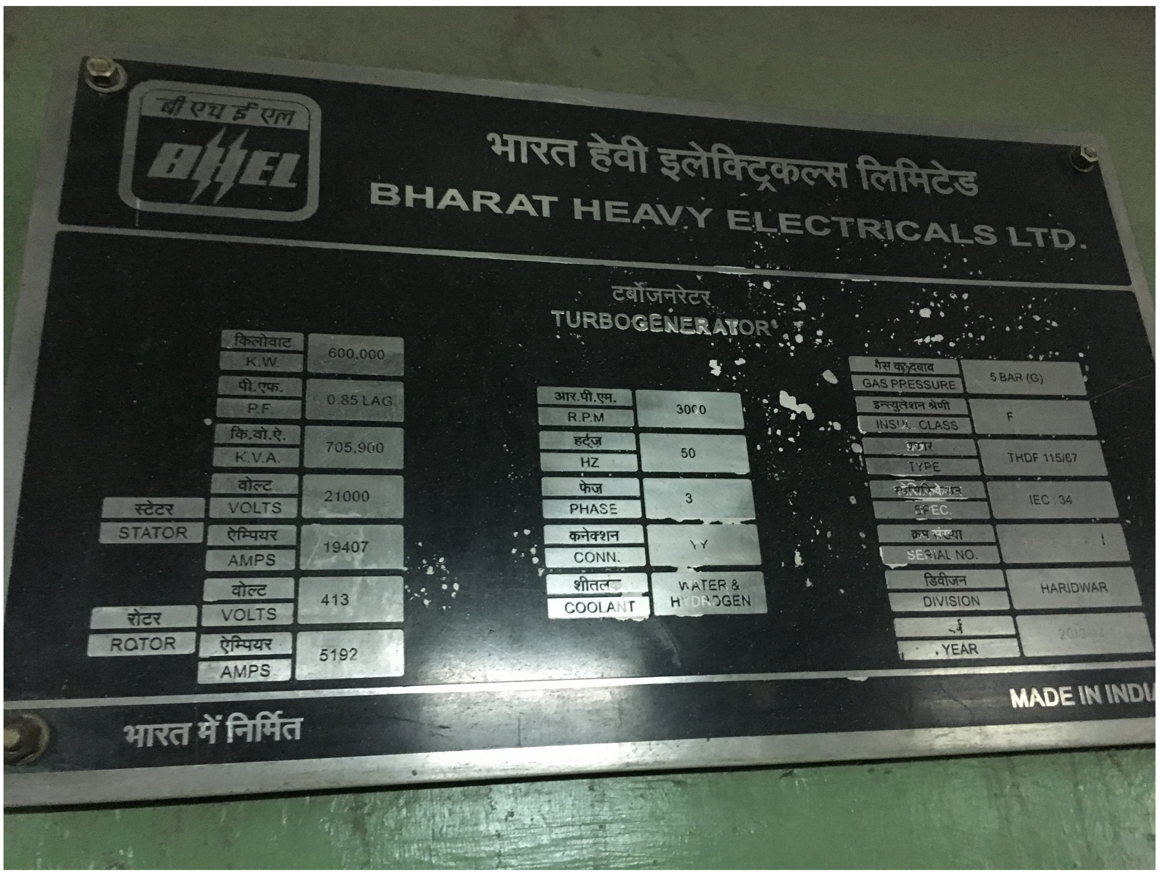
KTTP stage-I unit generates power at a voltage 21KV. Stage-I commissioned and COD declared on 14.09.2010. The fuel (coal) is being supplied by Singareni Collieries Company Limited (SCCL) from the mines of Bhupalpally and Godavarikhani. Water is being supplied from Godavari through underground pipe line from Kaleswaram. KTPP is a green filled project and is a pit head station. It synchronized with grid for the first time on 31.03.2010.

The following are the major reasons for selection of this site:

- Near to the coal source (pit head station)
- Low fuel transportation cost
- Availability of uninhabited land at a reasonable cost
- Raw water source is the river Godavari
- Development of employment opportunities in backward area

RATING PLATE DATA OF 600MW GENERATOR/KTPP STAGE-II

BHARAT HEAVY ELECTRICALS LTD		
KW 600,000		R.P.M 3000
P.F. 0.85 LAG		Hz 50
KVA 705,900		Phase 3
Type: THDF 115/67		Connections : YY
Stator	Volts 21000	Coolant : Hydrogen & Water
	Amps 19407	Gas Pressure : 5 Kg/cm^2 (g)
Rotor	Volts 413	Insulation : Class F
	Amps 5192	Specn.: IS:5422 IEC:34
MADE IN INDIA		Division: Haridwar


बी एच ई एल
BHEL
भारत हेवी इलेक्ट्रिकल्स लिमिटेड
BHARAT HEAVY ELECTRICALS LTD.
टर्बोजनरेटर
TURBOGENERATOR
किलोवाट
K.W.
600,000
पी.एफ.
P.F.
0.85 LAG
कि.वो.ऐ.
K.V.A.
705,900
स्टेटर
STATOR
वोल्ट
VOLTS
21000
ऐम्पियर
AMPS
19407
रोटर
ROTOR
वोल्ट
VOLTS
413
ऐम्पियर
AMPS
5192
आर.पी.एम.
R.P.M
3000
हर्ट्ज़
HZ
50
फेज
PHASE
3
कनेक्शन
CONN.
शीतलक
COOLANT
WATER &
HYDROGEN
GAS PRESSURE
5 BAR (G)
इन्सुलेशन श्रेणी
F
TYPE
THDF 115/67
IEC : 34
SERIAL NO.
डिवीजन
DIVISION
HARIDWAR
YEAR
MADE IN INDIA
भारत में निर्मित

CHAPTER-2

GENERATOR

GENERATOR:

An electrical generator is a machine which converts mechanical energy into electrical energy. The energy conversion is based on the principle of the production of dynamically induced emf. According to faraday's laws of electromagnetic induction, whenever a conductor cuts magnetic flux dynamically induced emf is produced in the conductor.

The generator consists of the following components:

1. Stator
2. Rotor
3. Hydrogen coolers
4. Bearings
5. Shaft seals

The following additional auxiliaries are required for generator operation:

1. Seal oil system
2. Gas system
3. Primary water system
4. Excitation system

Figure 2. Turbo generator

CHAPTER-3
COMPONENTS

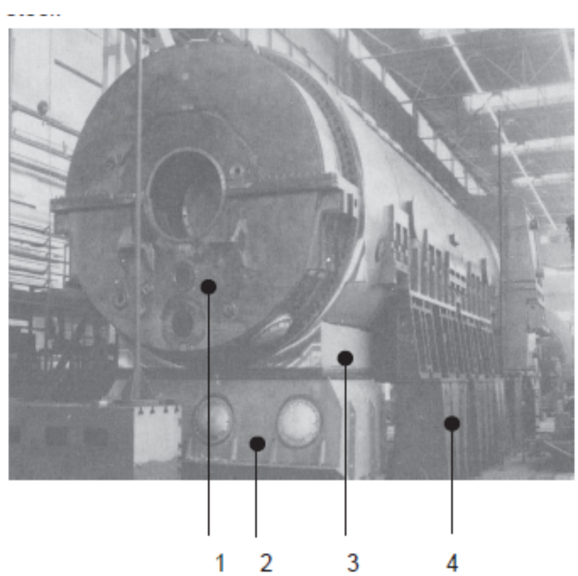
3.1. STATOR:

The stationary part of generator in which electrical energy is produced is called stator.

3.1.1.STATOR FRAME:

The stator frame with flexible core suspension components, core, and stator winding is the heaviest component of the entire generator. A rigid frame is required due to the forces and torques arising during operation. In addition, the use of hydrogen for the generator cooling requires the frame to be gas tight and pressure resistant up to an internal pressure of approximately 10 bar (130 psi g).

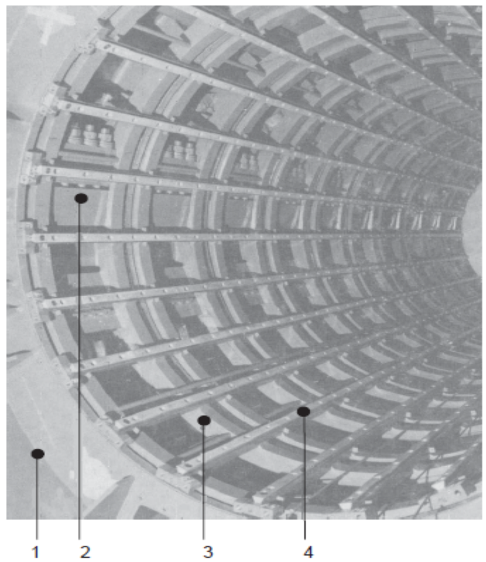
The welded stator frame consists of the cylindrical frame housing, two flanged rings and axial and radial ribs.



1 Stator End shield 2 Bushing compartment
3 Frame housing 4 Stator foot

Figure 3.1.1.1 Stator frame

Two lateral supports for flexible core suspensions in the frame are located directly adjacent to the points where the frame is supported on the foundation. Due to the rigid design of the supports and foot portion, the forces due to weight and short circuits will not result in any over-stressing of the frame.



1 Frame housing
2 Clamp
3 Supporting ring
4 Dovetail bar

Figure 3.1.1.2 Stator frame interior

Manifolds are arranged inside the stator frame at the bottom and top for filling the generator with CO_2 and H_2. The connections of the manifolds are located side by side in the lower part of the frame housing. Access to the end winding compartments is possible through manholes in the end shields.

In the lower part of the frame at the exciter end, an opening is provided for bringing out the winding ends. The generator terminal box is flanged to this opening. The stator is firmly connected to the foundation with anchor bolts through the feet.

3.1.2. STATOR END SHIELDS:

The ends of the stator frame are closed by pressure containing end shields. The end.

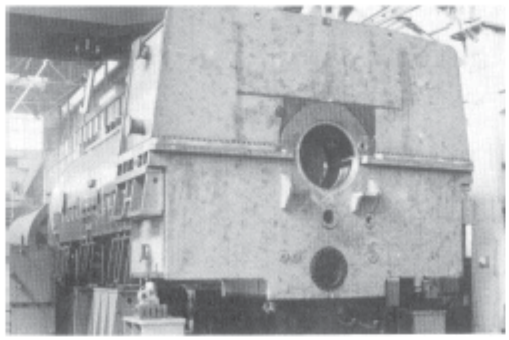


Figure 3.1.2.1. TE stator end shield

The end shields contain the generator bearings. This results in a minimum distance between bearings and permits the overall axial length of the TE end shields to be utilized for accommodation of the hydrogen cooler sections. The hydrogen coolers are arranged vertically inside of the cooler section at the turbine end.

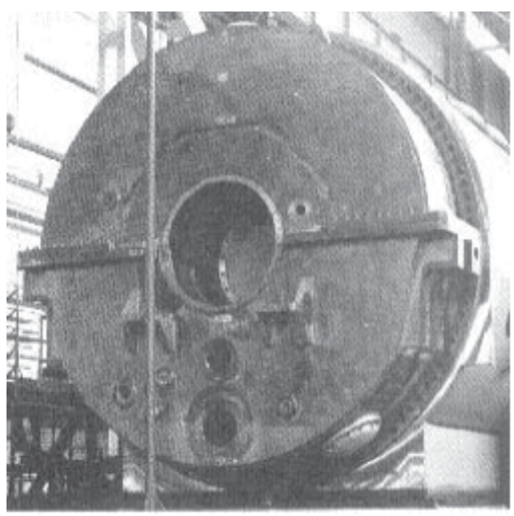


Figure 3.1.2.2. EE stator end shield

3.1.3. GENERATOR TERMINAL BOX:

The phase and neutral leads of the three-phase stator windings are brought out of the generator through six bushings located in the generator terminal box at the exciter end of the generator.

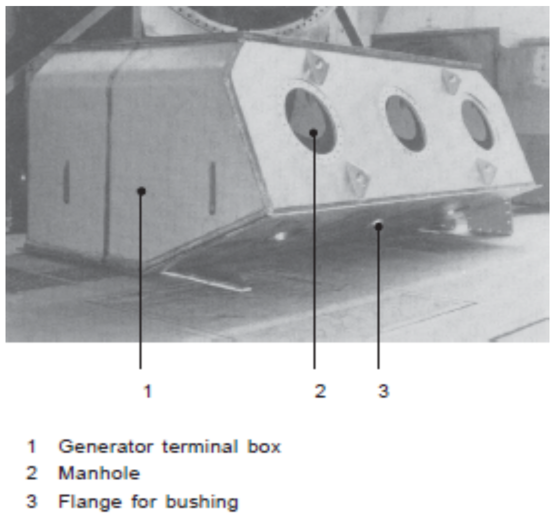


Figure 3.1.3. Terminal box interior

The terminal box is a welded construction of non-magnetic steel plate. This material reduces stray losses due to eddy currents.Welded ribs are provided for the rigidity of the terminal box. Six manholes in the terminal box provide access to the bushings during assembly and overhauling.

3.1.4. STATOR CORE:

In order to minimize the hysteresis and eddy current losses of the rotating magnetic flux which interacts with the core, the entire core is built up of thin laminations. Each lamination layer is made up from a number of individual segments.

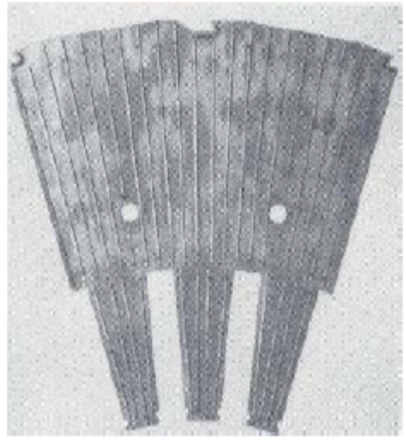
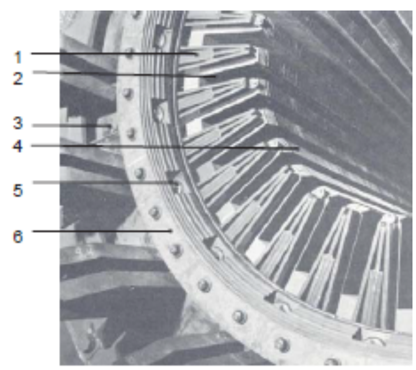


Figure 3.1.4.1 Segment with spacers

The segments are mounted on supporting rings over insulated dovetailed guide bars. Core is stacked with lamination segments in individual layers. The segments are staggered from layer to layer so that a core of high mechanical strength and uniform permeability to magnetic flux is obtained. On the outer circumference the segments are stacked on insulated dovetail bars which hold them in position. One dovetail bar is not insulated to provide for grounding of the laminated core.



1 Clamping finger
2 Stator Slow
3 Pressure Plate
4 Stator core tooth
5 Clamping bolt
6 Shield

Figure 3.1.4.2. Stator core after compression

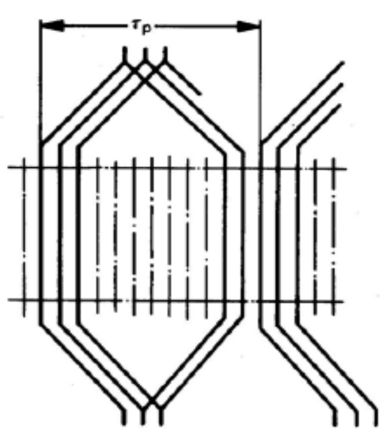
The complete stack of laminations is kept under pressure and located in the frame by means of clamping bolts and pressure plates.

The supporting rings form part of an inner frame cage. This cage is suspended in the outer frame by a large number of separate flat springs distributed over the entire core length. The springs are so arranged and tuned that forced vibrations of the core resulting from the magnetic field will not be transmitted to the frame and foundation.

The clamping bolts running through the core made of non-magnetic steel and are insulated from the core and the pressure plates to prevent from short-circuiting the laminations and allowing the flow of eddy currents. The pressure is transmitted from the pressure plates to the core by clamping fingers which are made of nonmagnetic steel to avoid eddy current losses. To remove the heat, space segments, placed at intervals along the bore length, divide the core into sections to provide radial passages for cooling gas flow.

3.1.5.STATOR WINDING:

The three-phase stator winding is a fractional-pitch two-layer type consisting of individual bars.



τ_p=pole pitch

Figure 3.1.5.1 Lap type winding

3.1.5.1. CONSTRUCTION:

Each stator slot accommodates two bars. The slot bottom bar and top bars are displaced from each other by one winding pitch and connected at their ends to from coil groups. The coil groups are connected together with phase connectors inside the stator frame.

The bar consists of a large number of separately insulated strands which are transposed to reduce the skin effect losses. The strands of small rectangular cross-section are provided with braided glass insulation and arranged side by side over the slot width. The individual layers are insulated from each other by a vertical separator. In the straight slot portion the strands are transposed by 540^0.

The transposition provides for a mutual neutralization of the voltages induced in the individual strands due to the slot cross-field and end winding flux leakage. The current flowing through the conductor is thus uniformly distributed over the entire bar cross-section so that the current-dependent losses will be reduced.

The alternate arrangement of one hollow strand and two solid strands ensure optimum heat removal capacity and minimum losses.

To prevent potential differences and possible corona discharges between the insulation and the slot wall, the slot sections of the bars are provided will an outer corona protection. A final wrapping of glass fabric tapes impregnated with epoxy resin serves as surface protection.In addition, the end turn covering provides good protection against external damage.

3.1.5.2. MICALASTIC HIGH VOLTAGE INSULATION:

High-voltage insulation is provided according to the proven Micalastic system. With this insulating system, several half-overlapped continuous layers of mica tape are applied to the bars. The mica tape is built up from large area mica splittings which are sandwiched between two polyester backed fabric layers with epoxy as an adhesive. The number of layers, i.e., the thickness of the insulation depends on the machine voltage. The bars are dried under vacuum and impregnated with epoxy resin which has very good penetration properties due to its low viscosity.

The impregnated bars are formed to the required shape in moulds and cured in an oven at high temperature. The high-voltage insulation obtained is nearly void free and is characterized by its excellent electrical, mechanical and thermal properties in addition to being fully waterproof and oil-resistant.

To minimize corona discharges between the insulation and the wall of the slot, the insulation inthe slot section is then provided with a coat of conductive varnish.

In addition, all bars are provided with an end corona protection, to control the electric field at the transition from the slot to the end winding and to prevent the formation of creepage spark concentrations.

3.1.5.3. BUS SUPPORT SYSTEM:

To protect the stator winding against the effects of magnetic forces due to load and to ensure permanent firm seating of the bars in the slots during operation, the bars are inserted with a top ripple spring located beneath the slot wedge. The gaps between the bars in the stator end windings are completely filled with insulating material which in turn is fully supported by the frame. The stator winding connections are brought out to six bushings located in a compartment of welded non-magnetic steel below the generator at the exciter end. Current transformers for metering and relaying purposes can be mounted on the bushings.

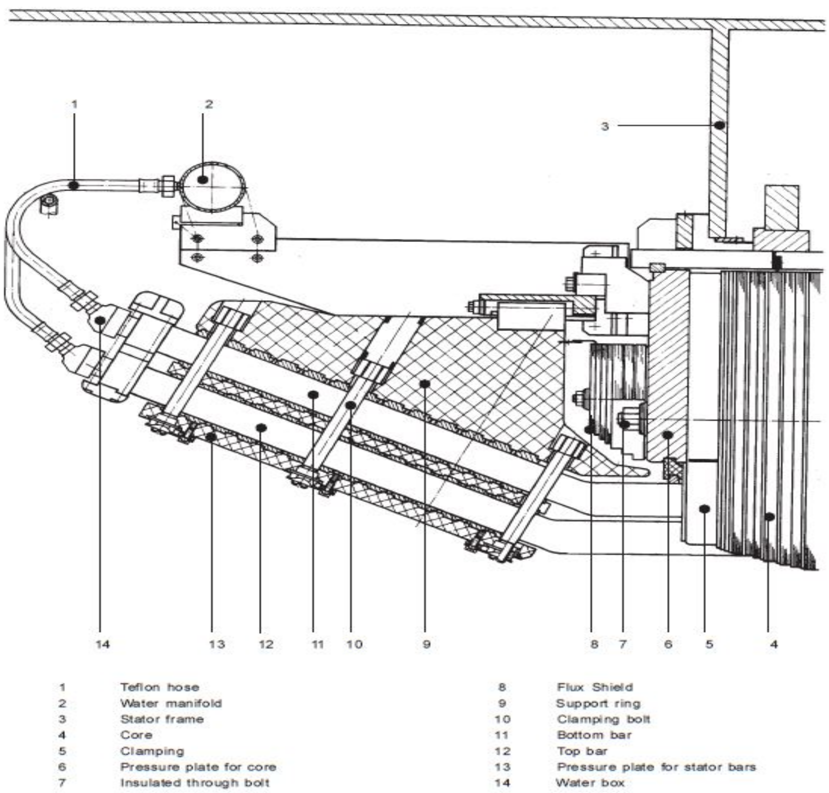
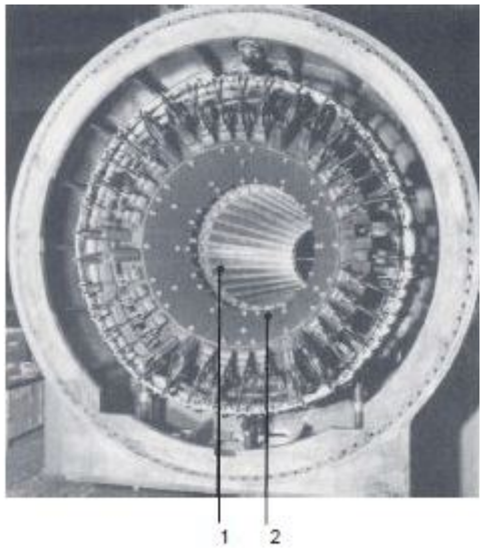


Figure 3.1.5.2 Stator end winding

In addition, the end turn covering provides good protection against external



1 Slot wedge
2 End turn covering

Figure 3.1.5.3 Stator with complete stator winding

3.2. ROTOR:

The rotating part of generator in which rotating magnetic field is generated is called rotor.

3.2.1. ROTOR SHAFT:

The rotor shaft is a single-piece solid forging manufactured from a vacuum casting. Slots for insertion of the field winding are milled into the rotor body. The longitudinal slots poles are obtained. The rotor poles are designed with transverse slots to reduce twice system frequency rotor vibrations caused by deflections in the direction of the pole and neutral axis.

To ensure that only high-quality forging is used, strength test, material analysis and ultrasonic tests are performed during manufacture of the rotor. After completion, the rotor is balanced in various planes at different speeds and then subjected to an over speed test at 120% of rated for two minutes.

Approximately two-thirds of the rotor body circumference is provided with longitudinal slots which hold the field winding. Slot pitch is selected so that two solid poles are displaced by 180^0.

The solid poles are also provided with additional longitudinal slots to hold the copper bars of the damper winding. The rotor wedges act as a damper winding in the area of the winding slots.

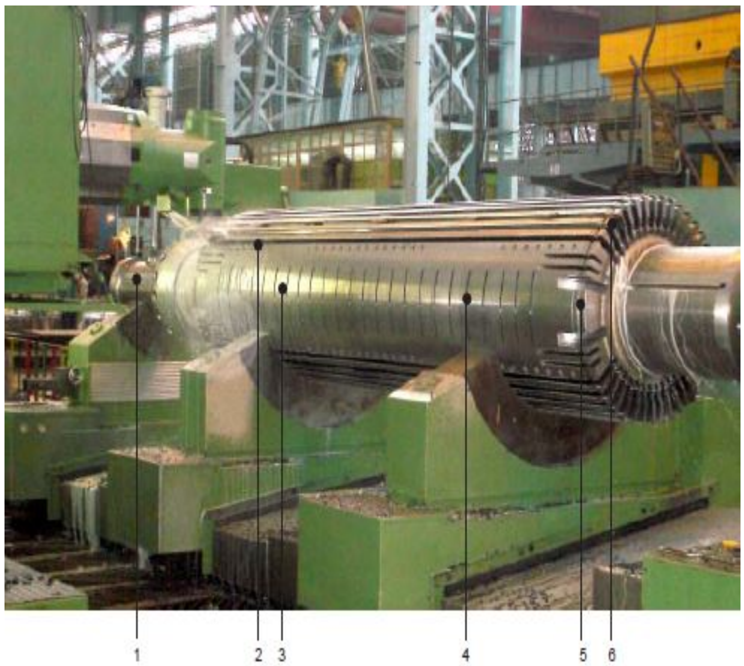


Figure 3.2.1 Rotor shaft

3.2.2. ROTOR WINDING:

3.2.2.1. CONSTRUCTION:

The rotor winding consists of several coils which are inserted into the slots and series connected such that two coil groups form one pole. Each coil consists of several series connected turns, each of which consists of two half turns which are connected by brazing in the end section. The conductors are made of copper with a silver content of approximately 0.1%. As compared to electrolytic copper, silver-alloyed copper features high strength properties at higher temperatures so that coil deformations due to thermal stresses are eliminated.

3.2.2.2. INSULATION:

The insulation between the individual turns is made of layers of glass fibre laminate. The coils are insulated from the rotor body with L-shaped strips of glass fibre laminate with Nomex filler. To obtain the required creepage paths between the coil and the frame, thick top strips of glass fibre laminate are inserted below the slot wedges.

3.2.2.3. ROTOR SLOT WEDGES:

To protect the winding against the effects of the centrifugal force, the winding is secured in the slots with wedges. The slot wedges are made from a copper-nickel-silicon alloy featuring high strength and good electrical conductivity, and are used as damper winding bars.

3.2.2.4. END WINDING BRACES:

The spaces between the individual coils in the end winding are filled with insulating members which prevent coil movement.

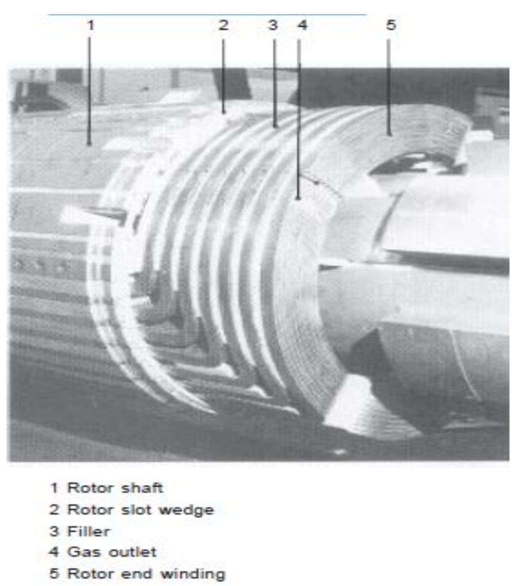


Figure 3.2.2.4 Rotor end winding with filler

3.2.3. ROTOR RETAINING RINGS:

The centrifugal forces of the rotor end windings are contained by single-piece rotor retaining rings. The retaining rings are made of non-magnetic high-strength steel in order to reduce stray losses. Each retaining ring with its shrink-fitted insert ring is shrunk onto the rotor body in an overhung position. The retaining ring is secured in the axial position by a snap ring.

3.2.4. FIELD CONNECTIONS:

The field connections provide the electrical connection between the rotor winding and the exciter and they consists of:

3.2.4.1. FIELD CURRENT LEAD AT END WINDING:

The field current lead at the end winding consists of hollow rectangular conductors which are inserted into shaft slots and insulated. One end of each field current lead is brazed to the rotor winding and the other end is screwed to a radial bolt. Cooling hydrogen is admitted into the hollow conductors via radial bolts.

3.2.4.2. RADIAL BOLTS:

The field current leads located in the shaft bore are connected to the conductors inserted in the shaft slots through radial bolts which are secured in position with slot wedges. The radial bolt is made from forged electrolytic copper to reduce contact resistance.

3.2.4.3. FIELD CURRENT LEAD AT SHAFT BORE:

The leads are run in the axial direction from the radial bolt to the exciter coupling. These consist of two semicircular conductors insulated from each other and from the shaft by a tube. The field current leads are connected to the exciter leads at the coupling with multi contact plug-in contact which allow for unobstructed thermal expansion of the field current leads.

3.3. HYDROGEN COOLERS:

The hydrogen cooler is shell and tube type heat exchanger which cools the hydrogen gas in the generator. The heat removed from the hydrogen is dissipated through the cooling water. The cooling water flows through the tubes while the hydrogen is passed around the finned tubes. The cooler consists of individual sections for vertical mounting which permits the coolers to be mounted without an increase in the overall generator axial length or cross-sectional area of the stator frame. The hydrogen flows through the coolers in a horizontal direction. The cold cooling water flows from the bottom to the top of the cooler on the cold gas side and, after reversal in the return water channel, the heated water flows downwards on the hot gas side.

Each cooler consists of the tube bundle, the upper and lower tube-sheets, the return water channel and the inlet/outlet water channel. The tubes have copper fins to obtain a larger heat transfer surface, the fins being joined to the tubes by tinning. The ends of the tubes are expanded into the upper and lower tube-sheets. The two side walls of structural steel base the cooler and direct the hydrogen flow. They are solidly bolted to the upper tube-sheet. While the attachment to the lower tube sheet permits them to move freely to allow for expansion of the tube bundle.

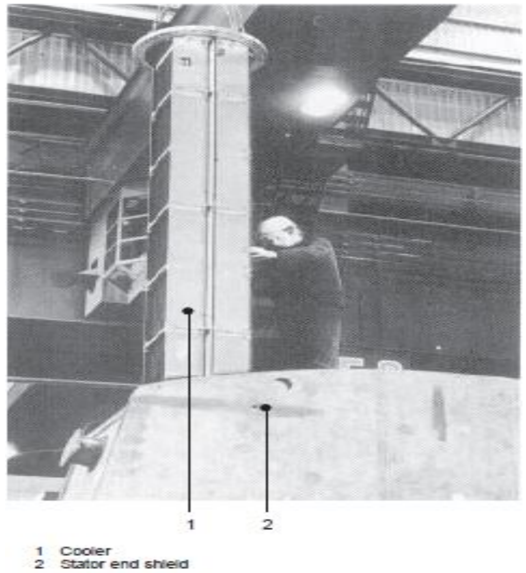


Figure 3.3.1 Arrangement of hydrogen cooler

The cooler sections are solidly bolted to the upper half stator end shield, while the attachment at the lower water channel permits them to move freely to allow for expansion. Attached to the lower tube sheet is the inlet/outlet water channel with its cooling water inlet and outlet pipes.

The cooler sections are parallel-connected on their water sides. Shut off valves are installed in the lines before and after each cooler. The required cooling water volumetric flow depends on the generator output and is adjusted by a control valve on the heated water side. Controlling the cooling water flow on the outlet side ensures an uninterrupted water flow through the coolers, with proper cooler performance not being impaired.

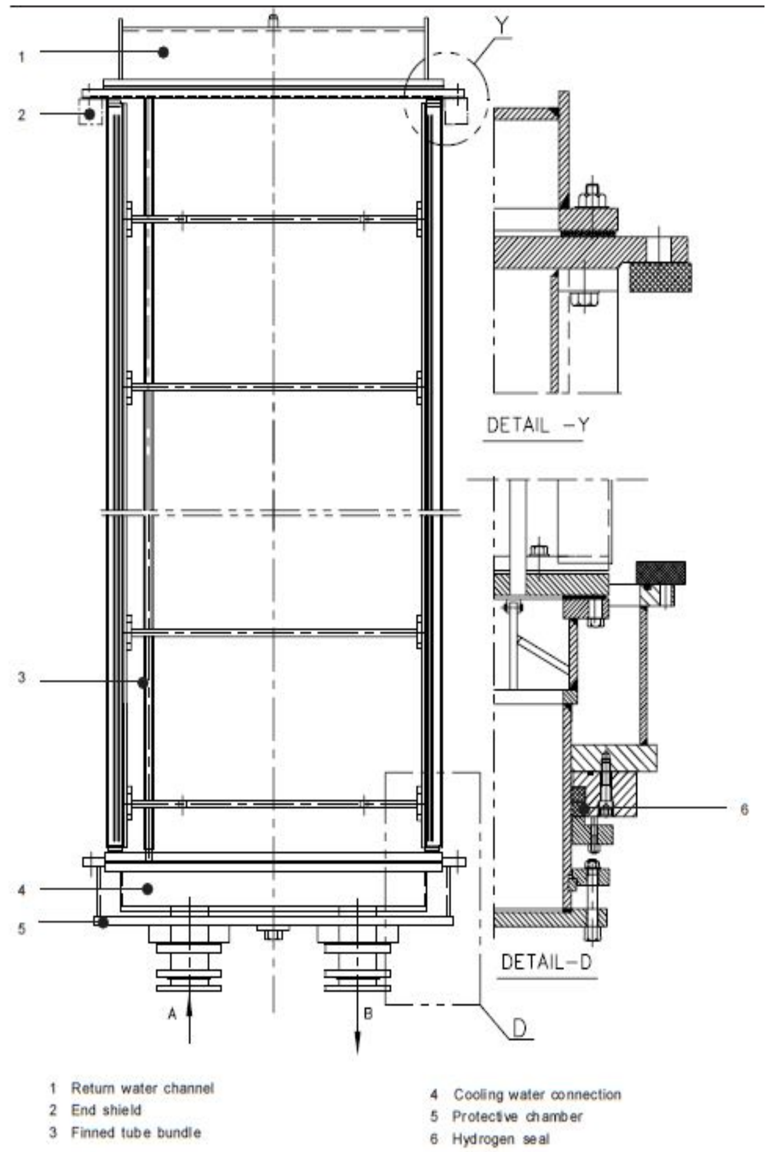


Figure 3.3.2 Hydrogen cooler interior

3.4. BEARINGS:

The rotor shaft is supported in sleeve bearings having forced-oil lubrication. The bearings are located in the stator end shields. The oil required for bearing lubrication and cooling is obtained from the turbine oil supply system and supplied to the lubricating gap via pipes permanently installed inside the lower half of the stator end shield and via grooves in the bearing saddle and lower bearing sleeve.

The lower bearing sleeve rests on the bearing saddle which is insulated from the stator end shield.

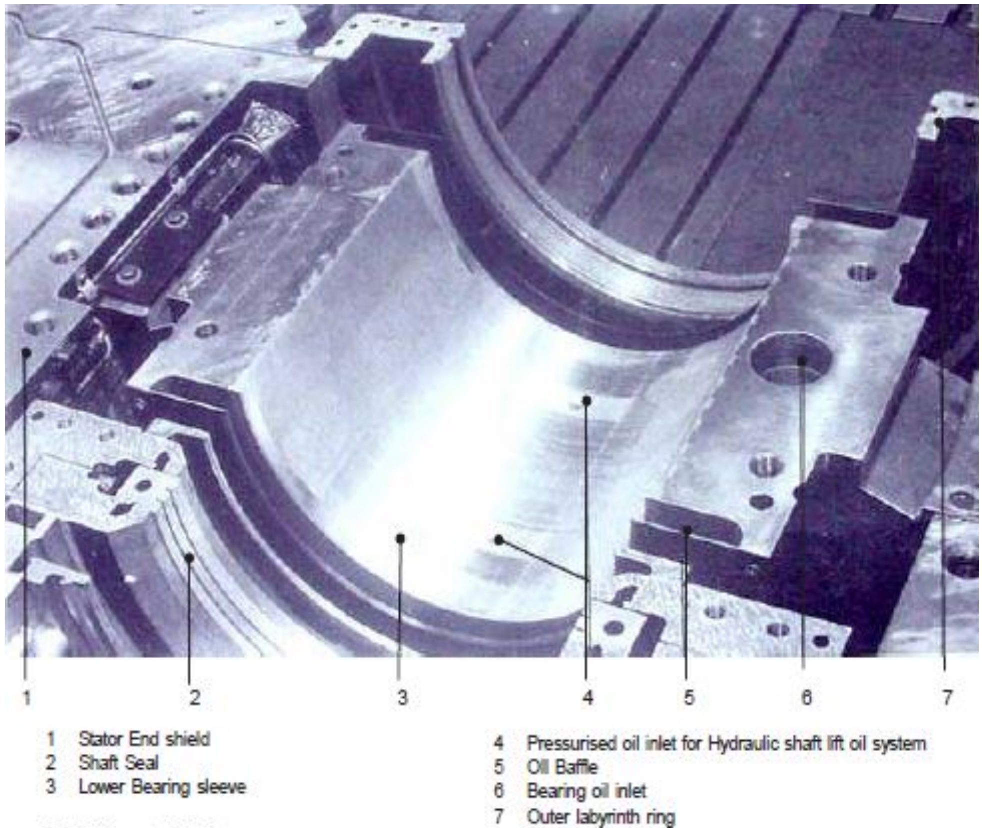


Figure 3.4.1 Generator bearing

A radial locator serves to locate the bearing in the vertical direction and is bolted to the upper half of the stator end shield. A tangential locator is located at the bearing sleeve joint to prevent the bearing from turning in the saddle.

The lower bearing sleeve has a groove to admit the bearing oil to the bearing surface. The upper sleeve has a wide overflow groove through which the oil is distributed over the shaft journal and fed to the lubricating gap. The oil is drained laterally from the lubricating gap, caught by baffles and returned to the turbine oil tank. All generator bearings are provided with a hydraulic shaft lift oil system to reduce bearing friction during startup. High pressure oil is forced between the bearing surface and the shaft journal, lifting the rotor shaft to allow the formation of a lubricating oil film. The bearing temperature is monitored with one double element thermocouple screwed in position on both sides of the lower bearing sleeve.

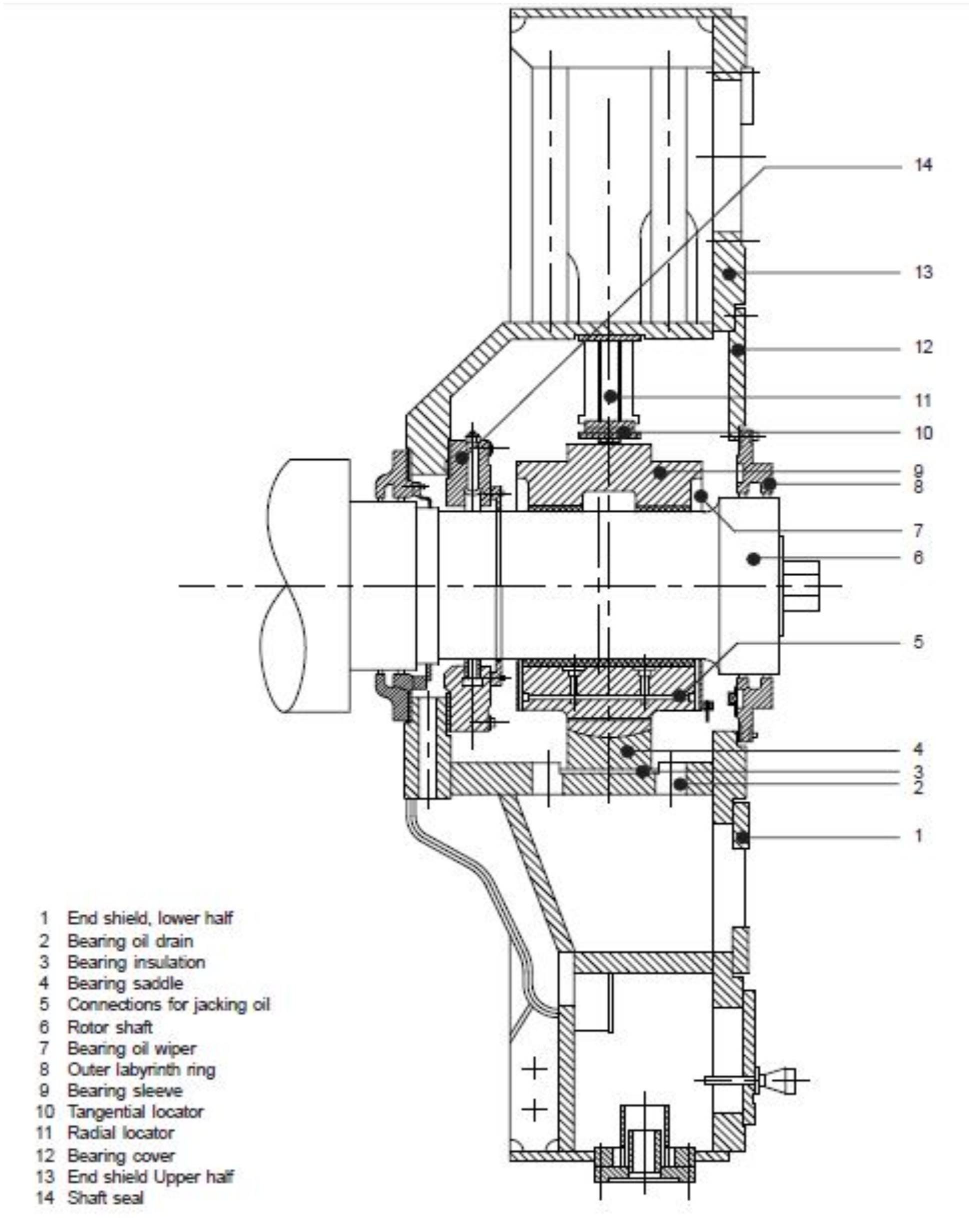


Figure 3.4.2 Generator bearing insulation

3.5. SHAFT SEALS:

The points where the rotor shaft passes through the stator casing are provided with a radial seal ring. The seal ring is guided in the seal ring carrier which is bolted to the seal ring carrier flange and insulated to prevent the flow of shaft currents. The seal ring is lined with Babbitt on the shaft journal side. The gap between the seal ring and the shaft is sealed with seal oil on hydrogen side and air side.

The seal oil drained from the hydrogen side is passed to the intermediate oil tank via the generator prechambers. The intermediate oil chambers acts as a gas barrier. A float-operated valve in the drain line keeps the oil level in the intermediate oil tank at a predetermined level, thus preventing gas from entering the oil drain system. During normal operation the float-operated valve remains continuously activated to return the hydrogen side seal oil to the seal oil circuit. The seal oil leaving the intermediate oil tank is admitted into the seal oil tank by the action of the vacuum maintained in the seal oil tank.

The seal oil drained from the air side of the shaft seals flows directly into the bearing oil return line for being returned to the seal oil storage tank.

15 Seal oil groove (Air side)
16 Babbit
17 Seal ring
18 Oil wiper ring (Air side)

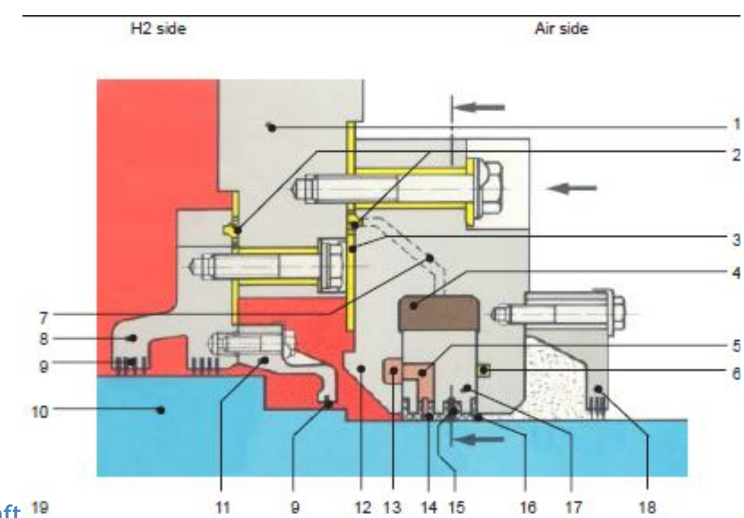


Figure 3.5. Shaft seal

1 End shield
2 Packing
3 Insulation
4 Seal ring chamber
5 Seal oil inlet bore
6 Pressure oil groove
7 Seal oil groove
8 Inner labyrinth ring
9 Seal strip
10 Rotor shaft
11 Oil wiper ring (H_2 side)
12 Seal ring carrier
13 Seal oil groove (H_2 side)
14 Seal oil groove (H_2 side)

CHAPTER-4

AUXILIARY SYSTEMS

4.1. SEAL OIL SYSTEM:

4.1.1. CONSTRUCTION:

Shaft seals supplied with pressurized seal oil areprovided to prevent hydrogen losses at the shaft and the ingress of air into the hydrogen-cooled generator. As long as the seal oil pressure in the annular gap exceeds the gas pressure in the generator, no hydrogen will escape from the generator housing. The shaft seal is supplied with seal oil by a separate system consisting of a hydrogen side seal oil circuit and an air side seal oil circuit.The shaft seals are supplied with seal oil from the seal oil system which consists of the following principal components.

- Seal oil storage tank (in bearing oil drain line)
- Seal oil tank incl. vacuum pump
- Intermediate oil tank
- Seal oil pumps (2*100%)
- Standby seal oil pump (1*100%)
- Differential pressure control valves (2*100%)
- Pressure controller downstream of each pump.
- Seal oil coolers (2*100%)
- Seal oil filters (2*100%)

SEAL OIL DRAIN:

4.1.2. HYDROGEN SIDE SEAL OIL DRAIN:

The seal oil drained from the hydrogen side is passed to the intermediate oil-tank via the generator prechambers. The intermediate oil tank acts as a gas barrier. A float-operated valve in the drain line keeps the oil level in the intermediate oil tank at a predetermined level, thus preventing gas from entering the oil drain system. During normal operation , the float-operated valve remains continuously activated to return the hydrogen seal oil to seal oil circuit. The seal oil leaving the intermediate oil tank is admitted into the oil seal tank the action of vacuum maintained in the seal oil tank.

4.1.3. AIR SIDE SEAL OIL DRAIN:

The seal oil drained from the air side of the shaft seals flows directly into the bearing oil return line for being returned to the seal oil storage tank.

4.1.4.SEAL OIL CIRCUIT:

The seal oil is drawn seal oil tank by the seal oil pump in service and passed to the shaft seals via coolers , filters and differential pressure regulating valve.

4.1.5. SEAL RING RELIEF:

To ensure free movement of the seal ring, the shaft seals are provided with pressure oil for ring relief. The oil supply for ring relief is obtained from the air side oil circuit. The required pressure setting for each shaft seal is accomplished separately.

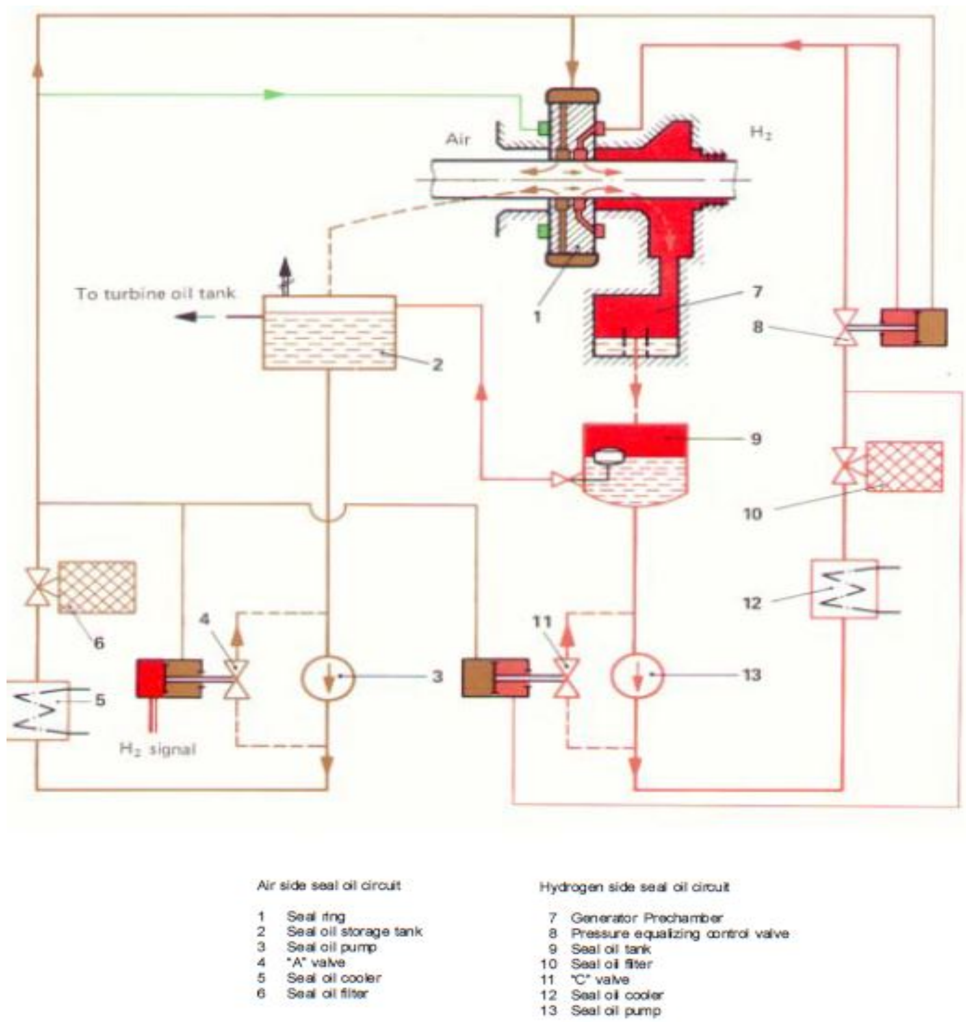


Figure 4.1 Simplified seal oil system

4.2. GAS SYSTEM:

The gas system contains all equipment necessary for filling the generator with CO_2, hydrogen or air and removal of these media, and for operation of the generator filled with hydrogen. In addition, the gas system includes a nitrogen (N_2) supply. The gas system consists of: Pressure reducers, pressure gauges, miscellaneous shutoff valves, purity metering equipment, gas dryer, CO_2 flash evaporator, flow meters,H2 supply , CO2 supply, N2 supply, gas analyzer, gas dryer.

4.2.1. H_2 SUPPLY:

The heat losses arising in the generator are dissipated through hydrogen. The heat dissipating capacity of hydrogen is eight times higher than that of air. For more effective cooling, the hydrogen in the generator is pressurized.

4.2.2. CO_2 SUPPLY:

As a precaution against explosive hydrogen air mixtures, the generator must be filled with an inert gas (CO_2) prior to H_2 filling and H_2removal. The generator must be filled with CO_2until it is positively ensured that no explosive mixture will form during the subsequent filling or emptying procedures.

4.2.3. COMPRESSED AIR SUPPLY:

To remove CO_2 from the generator, compressed air is to be admitted into the generator. The compressed air must be clean and dry. For this reason, a compressed air filter is installed in the filter line.

4.2.4. N_2 SUPPLY:

Nitrogen is required for removing the hydrogen or air during primary water filling and emptying procedures. A nitrogen environment is maintained above the primary water in the primary water tank for the following reasons.

- To prevent the formation of a vacuum due to different thermal expansions of the primary water& tank.
- To ensure that the primary water in the pump suction line is at a pressure above atmospheric pressure so as to avoid pump cavitation.
- To ensure that the primary water circuit is at a pressure above atmospheric pressure so as to avoid the ingress of air on occurrence of a leak.

4.3. PRIMARY WATER SYSTEM:

The losses occurring in the stator windings,terminal bushings and phase connectors are dissipated through direct water cooling. Since thecooling water is the primary coolant to dissipate the losses, it is designated as primary water.

The primary water system basically consists of the following components:

- Primary water supply unit
- Primary water coolers
- Primary water valve rack
- Primary water tank

The primary water supply unit combines the following components for primary water supply to the generator:

- Primary water pumps
- Primary water filters
- Conductivity transmitter
- Water treatment system
- Flow, pressure and temperature transmitters.

4.3.1. PRIMARY WATER QUALITY:

The primary water system may be filled with oxygen-free,mechanically clean

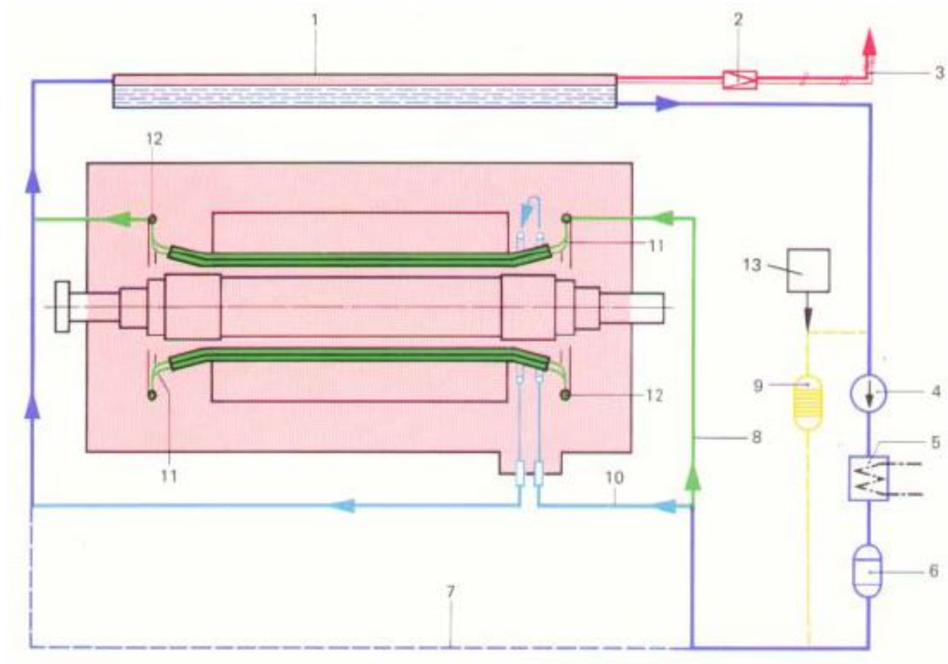
- distilled water
- fully de-mineralized water from boiler feed water treatment plant
- condensate

Since the primary water comes into direct contact with the high-voltage stator winding, it must have an electrical conductivity below a value of 2µmho/

cm. The water in the primary water circuit is therefore treated in a water treatment system. Fully de-mineralized water from the boiler feed water treatment plant and condensate may only be used if no chemicals, such as ammonia, hydrazine, phosphate, etc. were added to the water or condensate.

4.3.2. PRIMARY WATER CIRCUIT:

Fig.4.3.2 shows a simplified schematic of the primary water system. Note that the diagram shows that the external portion of the system may be operated through a bypass line, with no primary water flowing through the water-cooled generator components.



1 Primary water tank
2 Pressure regulator
3 Waste gas to atmosphere
4 Pump
5 Cooler
6 Filter
7 Bypass line
8 Cooling water for stator winding
9 Ion exchanger
10 Cooling water for main bushings and phase connectors
11 Teflon hose
12 Cooling water manifold
13 Alkaliser unit

Figure 4.3.2 Simplified schematic of the primary water system

The primary water is circulated by one of the two pumps on the primary water supply unit. Both primary water pumps are of full-capacity type. The electric control circuit of the pumps is arranged so that either pump may be selected for normal service.

The primary water is drawn from the primary water tank and passes to a primary water manifold (inlet) via coolers and filters and from there to the stator bars via teflon hoses. The primary water leaving the stator winding is passed through similar teflon hoses to another primary water manifold (outlet) and is then returned to the primary water tank. A separate flow path cools the bushings and phase connectors before the stator winding inlet.

4.3.3. PRIMARY WATER TANK:

The primary water tank is mounted on the stator frame on anti-vibration pads and is covered by the generator lagging. The purpose of primary water tank is to remove the hydrogen in the primary water after it leaves the stator winding. The hydrogen occurs in the primary water due to diffusion through the teflon hoses which connect the stator winding to inlet and outlet manifolds.

The hydrogen gas in the primary water tank is vented to atmosphere via the primary water valve rack and a pressure regulator. The pressure regulator can be adjusted to set the gas pressure in the primary water tank. The water level in the primary water tank can be read at a water level gauge. Additionally, a capacitance type measuring system is provided for activating an alarm at minimum and maximum water level.

4.4. EXCITATION SYSTEM:

The exciter consists of

- Rectifier wheels
- Three-phase pilot exciter
- Cooler
- Metering and supervisory equipment

Fig.4.4.1 shows the basic arrangement of the exciter. The three-phase pilot exciter has a revolving field with permanent magnet poles. The three-phase AC generated by the permanent-magnet pilot exciter is rectified and controlled by the AVR to provide a variable DC current for exciting the main exciter. The three-phase AC is induced in the rotor of the main exciter. This three-phase AC induced in the rotor of the main exciter is rectified by the rotating rectifier bridge and fed to the field winding of the generator rotor through the DC leads in the rotor shaft.

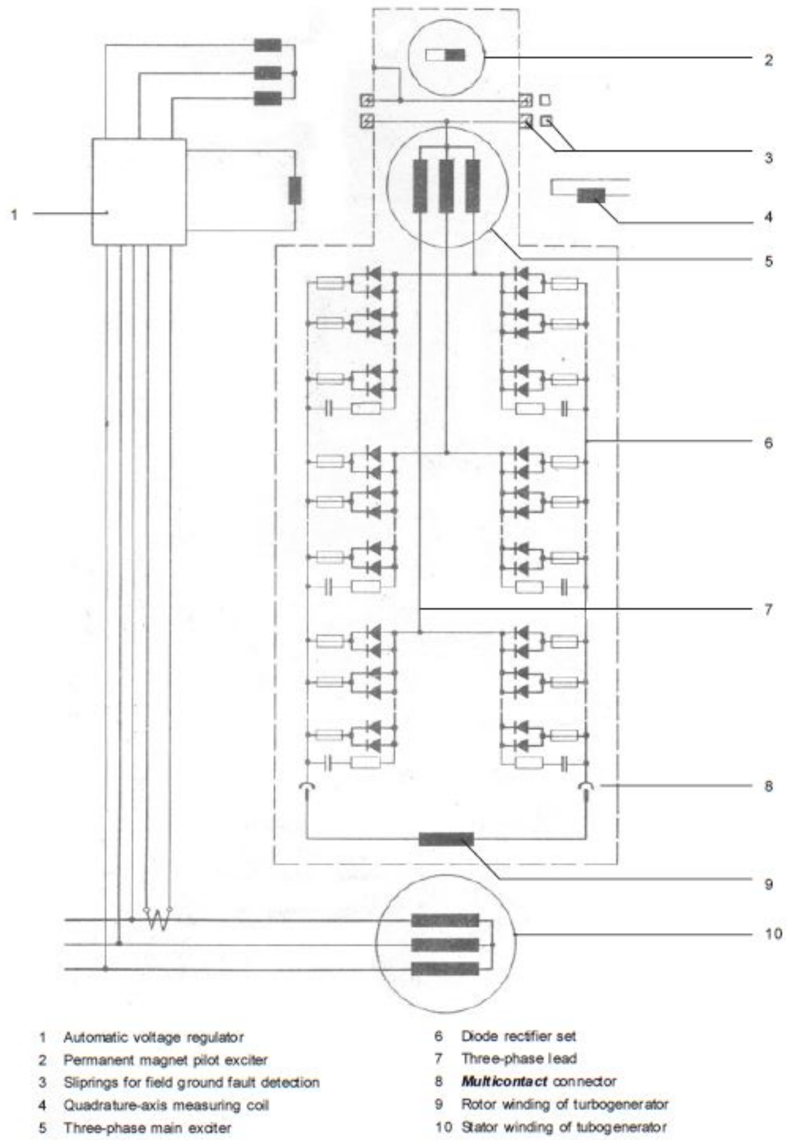
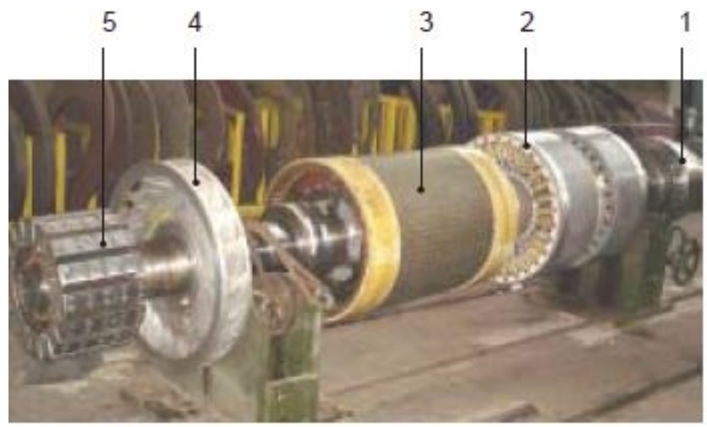


Figure 4.4.1 Basic arrangement of brushless excitation system with rotating diodes

The exciter rotor shown in fig. 4.4.2 corresponds to the basic arrangement described above. A common shaft carries the rectifier wheels, the rotor of the main exciter and the permanent-magnet rotor of the pilot exciter. The shaft is rigidly coupled to the generator rotor. The exciter shaft is supported on a bearing between the main and pilot exciter. The generator and exciter rotors are thus supported on total of three bearings.



1 Coupling
2 Rectifier wheel
3 Rotor of main exciter
4 Fan
5 Permanent magnet rotor

Figure 4.4.2 Exciter rotor

Mechanical coupling of the two shaft assemblies results in simultaneous coupling of the dc leads in the central shaft bore through the Multi-contact electrical contact system consisting of plug-in bolts and sockets. This contact system is also designed to compensate for length variations of the leads due to thermal expansion.

CHAPTER-5

NEED FOR PROTECTION

NEED FOR GENERATOR PROTECTION:

A fault in power system is defined as a defect in its electrical circuit due to which the flow of current is diverted from the intended path. Failure of insulation causes faults. Fault impedance is generally low and fault current is generally high. During the faults, the voltages of the phases become unbalanced and the supply to the neighbouring circuit is affected. Fault currents being excessive they can damage not only the faulty equipment, but also the installation through which the fault current is fed.

Generators are high-quality machines for securing the best possible continuity of power supply. A generator is the most important and costly equipment in power system. In generating station, as a continuous operation of generators is much more necessary, the faulty part has to be cleared very quickly for uninterruptable power supply. Unlike other apparatus, opening a breaker to isolate the faulty generator is not sufficient to prevent further damage. Therefore, in addition to a suitable technical design and responsible mode of operation, provision must therefore be made for automatic protection facilities. As it is accompanied by prime mover, excitation system, voltage regulator, cooling system etc.its protection becomes very complex and elaborate.

The basic electrical quantities those are likely to change during abnormal fault conditions are current, voltage, phase angle and frequency. Protective elements utilize one or more of these quantities to detect abnormal conditions for taking further essential steps to isolate the faulty equipment to keep the healthy part in normal working condition.

By providing protection

- Damage is minimized
- Over speeding of the generator due to sudden load throw off is avoided

- Impact of tripping of large set on the grid is minimized
- Auxiliaries if possible are kept energized and time to restart the unit is minimized

CHAPTER-6

GENERATOR PROTECTION

6.1 INTRODUCTION:

Generator protection is conventionally made up of individual relays such as differential, stator earth fault, over current, over voltage, negative phase sequence, loss of field etc. These relays with ancillary functions like tripping and signaling arrangements, logic circuits and supervision and testing facilities are considered in modern generator protection.

The protection equipment must be designed so that any serious fault will result in an immediate disconnection and de-excitation of the generator. Faults which do not cause any direct damage must be brought to the attention of the operating staff, enabling them to operate the unit outside the critical range or to take precautionary measures for shutdown. Generators may be endangered by short-circuits, ground faults, over-voltages, under-excitation and excessive thermal stresses.

6.2 CLASSIFICATION OF TRIPPING:

6.2.1. CLASS-A:

This is adapted for those electrical faults of generator, generator transformer and unit auxiliary transformer for which tripping cannot be delayed.

This leads to simultaneous tripping of

- Generator transformer HV side circuit breaker
- Field circuit breaker
- LV side incomer breakers of UAT
- Auto changeover from unit to station for unit auxiliaries and tripping of turbine

6.2.2. CLASS-B:

This is adapted for all turbine (mechanical) faults and for some electrical faults of generator, generator transformer and unit auxiliary transformer for which it is safe to trip the turbine. Subsequently the generator is tripped through low forward power interlock. This ensures that unit does not over speed due to trapped steam in the turbine during the shutdown and also the loss of power to the grid from the generator is not sudden.

6.2.3. CLASS-C:

This is adopted for all faults beyond the generator system which can be cleared by tripping of generator transformer HV side CB alone. In this case the generator set runs with HP-LP bypass system in operation and the generator continues to feed the unit auxiliary load through unit auxiliary transformers.

6.3 PROTECTION USING RELAYS:

6.3.1. DIFFERENTIALPROTECTION:

Breakdown of insulation between different stator phase windings results in an internal short-circuit. The extent of damage depends upon the fault current level and the duration of the fault. Protection should be applied to limit the degree of damage in order to limit the repair costs. It is common to apply generator differential protection. The fault is detected by a differential relay which initiates immediate isolation and de-excitation of the generator. In order to obtain a high sensitivity, the protected area should include the generator only.

Two sets of identical CTs are required with each set mounted on either side of stator phase winding. The secondaries of these CTs are connected in star and their ends are connected through pilot wires. At normal operating conditions, the currents at the two ends of the protected section are same. So the relay will not operate.

When a fault occurs, the balance is disturbed and a differential current flows through the operating coil of the relay causing its operation and the trip circuit of the circuit breaker is closed.

Operating value: 0.2-0.4 I_n

Relay time: < 60 ms

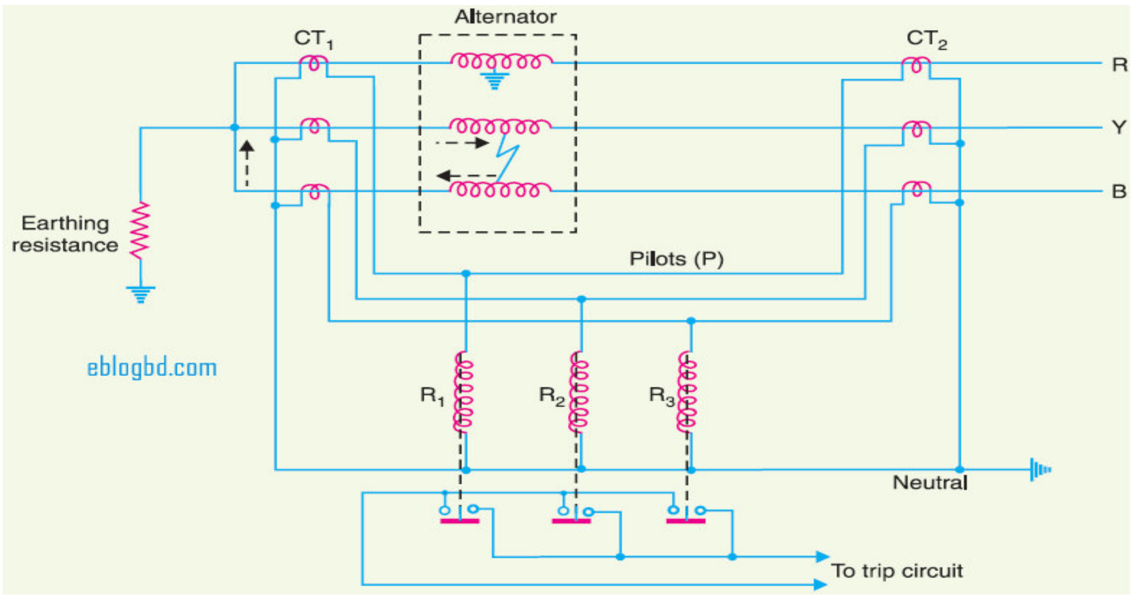


Figure 6.3.1 Differential protection relay

6.3.2. STATOR EARTH FAULT PROTECTION:

Breakdown of insulation between the stator winding and frame results in a stator ground fault. If possible, the stator ground fault protection should cover the complete winding, including the neutral point of the generator. The protection is to initiate immediate isolation and de-excitation of the generator.

Relay time: <1 s

The load resistance of a found transformer and any required boost to raise the neutral point potential should be selected so that ground current due to a fault will amount to less than 15 A. Although a single phase earth fault is not critical, it requires clearance within a short time due to

- It may develop into a phase to phase fault.
- If a second earth fault occurs the current is not longer limited by the earthing resistor.
- Fire may result from earth fault arc.

6.3.2.1. 95% STATOR EARTH FAULT PROTECTION:

It is provided by an over voltage relay monitoring the voltage developed across the secondary of the neutral grounding transformer in case of ground faults. It covers generator, LV winding of generator transformer and HV winding of UAT. A pickup voltage setting of 5% is adopted with a time delay setting of above 1sec. For all machines of ratings 10MVA and above this shall be provided.

6.3.2.2. 100% EARTH FAULT PROTECTION:

This includes a 95% unit which covers the stator winding from 5% of the neutral and third harmonic under voltage relay. It protects 100% of stator winding. During the machine running condition, there will be certain third harmonic voltage at neutral side of the generator. This third harmonic voltage will come down when a stator earth fault occurs causing this relay to operate. This shall have voltage check or current check unit to prevent faulty operation of the relay at generator standstill or during the machine running down period.

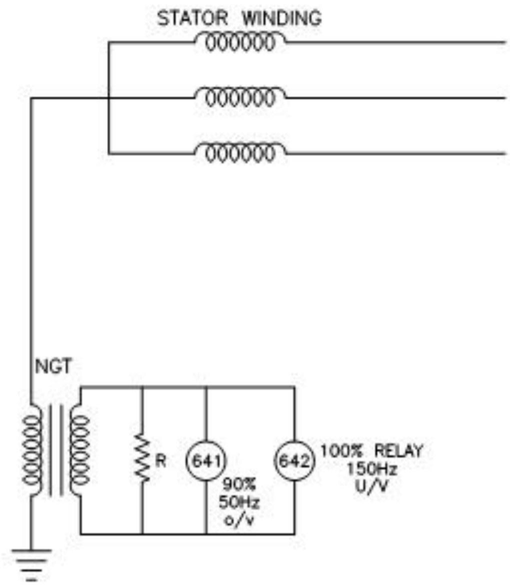


Figure 6.3.2 Stator earth fault relay

6.3.3. STATOR INTER – TURN PROTECTION:

Inter-turn fault on the same phase of the stator winding does not disturb the balance between the currents in the neutral and the high voltage CTs and therefore such a fault cannot be detected by longitudinal differential protection. Transverse differential protection can detect the unbalance between normally identical windings caused by an inter-turn fault when the generator has two windings per phase. Bias is used because the sharing will never be exact.

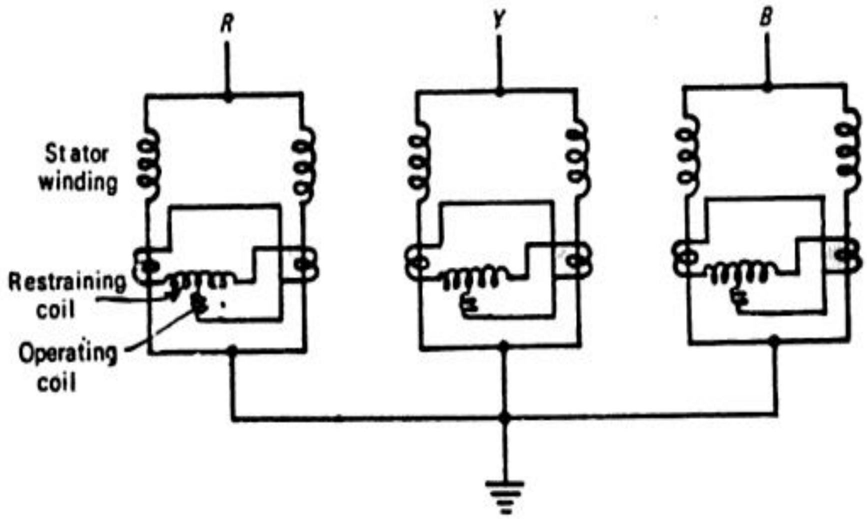


Figure 6.3.3.1 Biased transverse differential protection for inter-turn fault protection for parallel wound stator

Generators having single winding per phase or those generators whose parallel windings are not accessible can be protected by using zero sequence component of voltage caused by the reduction of emf in the faulted phase. The zero sequence voltage appears across the tertiary winding of the three element directional relay. The winding in quadrature to this operating winding of the relay is energized by the secondary of the voltage transformer.

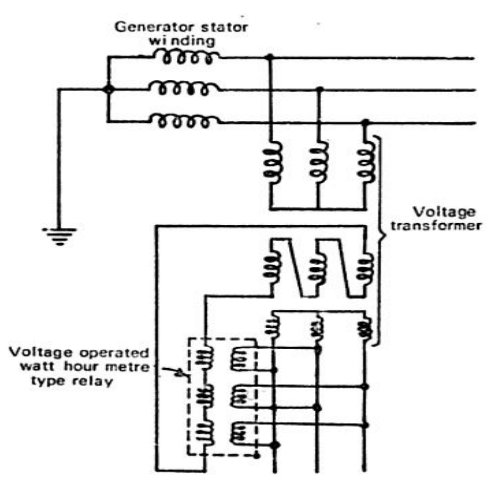


Figure 6.3.3.2 inter-turn fault detection

6.3.4. ROTOR EARTH FAULT PROTECTION:

The field circuit of a generator comprising the winding and the armature of the exciter with any associated field breaker is an isolated D.C. circuit which in itself need not be earthed. Field circuits are normally operated un-earthed. So a single earth fault will not affect its operation. But when a second fault arises then field winding is short-circuited and produces unsymmetrical field system which leads to unbalanced forces on rotor and results in excess pressure and bearing, shaft distortion.

Two methods are available to protect from this type of faults.

1.Potentiometer method: A high resistance is connected across the rotor circuit and its midpoint is grounded through a sensitive earth fault relay. Except the center point, the earth fault relay detects the earth faults for most of the rotor circuit. Thus most of the rotor winding part is protected against the earth faults.

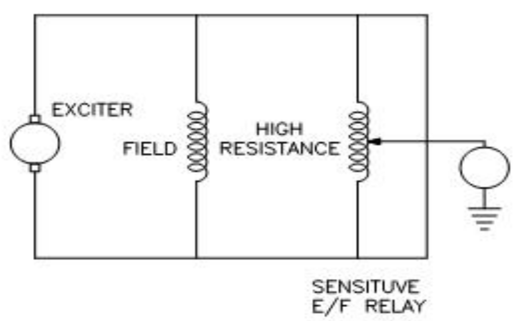


Figure 6.3.4.1 Rotor earth fault protection using potentiometer method

2.The modern method of providing earth fault protection includes D.C. injection or A.C. injection. A small D.C. power supply is connected to the field circuit. A fault detecting sensitive relay and the resistance are also connected in series with the circuit. This high resistance limits the current through the circuit. A fault at any point on the field circuit will pass a current of sufficient magnitude through the relay to cause its operation. The D.C. supply is preferred and simple to use and it has no problem of the leakage currents. In case of A.C. injection, the high resistance is replaced by a capacitor.

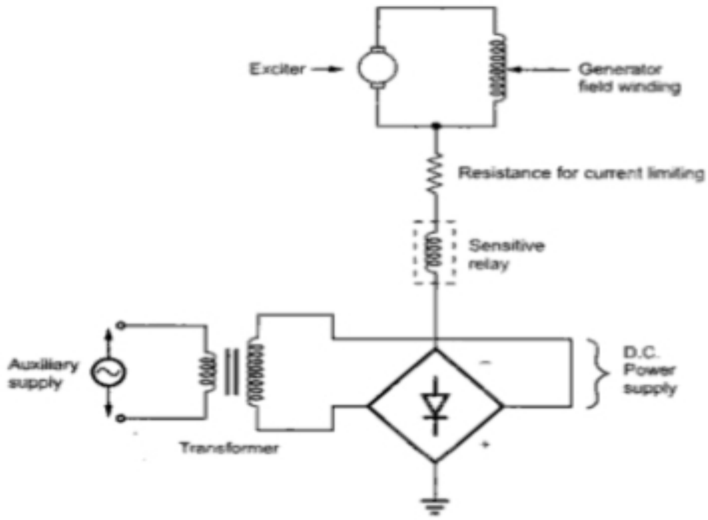


Figure 6.3.4.2 Rotor earth fault protection using D.C. injection method

The earth fault relays are instantaneous in operation and are connected to an alarm circuit for indication and to take the proper action. This is because; a single ground fault does not require an immediate action of isolating the generator.

Relay time: approximately 1 sec.

6.3.5. POLE SLIP PROTECTION:

The pole slip relay is designed to protect synchronous generators against the possibility of the machine running in unstable region of the power angle curve which would result in power oscillations and pole slip. Pole slipping of generators leads to an increase in rotor angular position beyond the generator transient stability limits.

Some of the causes for pole slipping are as follows:

- Large network disturbance

- Faults on the network close to the generator
- Loss of generator field
- Loss of evacuation
- Operating the generator in an excessive under excited mode

Setting recommendations:

a) If the source of oscillation lies between generator and transformer unit, the machine has to be isolated from the network after the first slip forward reach of the relay characteristics shall cover generator/ generator transformer. Tripping in this zone shall be in the first pole slip. The reach of this zone is 0.7*d.

b) If the source of oscillation lies outside the unit in the network, the generator should not be switched off until several pole slips have re-curred.

6.3.6. UNDER FREQUENCY PROTECTION:

Major disturbances in an interconnected system may result from the operation of the generator at under-frequency. At rated voltage, the generator can be continuously operated at rated KVA up to 95% of rated frequency.

Under frequency operation of a generator will occur when the power system load exceeds the prime mover capability of the generator. If the load increases the generation, then frequency will drop and load need to shed down to create the balance between the generator and the connected load. The rate at which frequency drops depends on the time, amount of overload and also on the variation between the load and generation as the frequency changes. Frequency decay occurs within the seconds so we cannot correct it manually. Therefore automatic load shedding facility needs to be applied.

The present practice is to use the under frequency relays at various load points so as to drop the load in steps until the declined frequency return to normal. Non essential load is removed first when decline in frequency occurs.

During the overload conditions, load shedding must occur before the operation of the under frequency relays. In other words load must be shed before the generators are tripped.

Since the frequency deviation due to a system disturbance is normally accompanied by a voltage deviation, the protection should be designed on the basis of the permissible load characteristic of the generator on frequency and voltage deviations.

The under frequency protection

- Prevents the steam turbine and generator from exceeding the permissible operating time at reduced frequencies.
- Ensures that the generating unit is separated from the network at a preset value of frequency.
- Prevents over fluxing (V/f) of the generator (large over fluxing for short times).

The stator under frequency relay measures the frequency of the stator terminal voltage.

Setting recommendations:

For alarm: 48.0 Hz, 2.0 sec time delay

For trip: 47.5 Hz, 1.0 sec (or) as recommended by manufacturers

6.3.7. OVER FREQUENCY PROTECTION:

Over frequency running of a generating set arises only when the mechanical power input to the alternator is an excess of electrical load and mechanical losses. The most common occurrence of over frequency is after substantial loss of electrical loading. Over frequency protection can be considered as back up protection for governor field.

6.3.8. LOSS OF EXCITATION PROTECTION:

Failure of the field system results in generator losing synchronism and running above synchronous speed. It will then operate as an induction generator. Complete loss of excitation may arise as a result of accidental tripping of the excitation system, an open circuit or short circuit occurring in the excitation system.

The main flux is produced by wattles stator currents (reactive current) drawn from the system. Operation as an induction generator necessitates the flow of slip frequency current in the rotor, slot wedges and surface of rotor body. Excitation under these conditions requires a large reactive component even exceeding the normal rating of the generator.

Generally, the generator is not designed as an induction machine. The damper windings are not adequate to carry the rotor slip current, so abnormal heating of the rotor and overloading of stator winding will both take place.The active power component will be slightly less than the pre-fault load because of the speed regulation characteristics of the governor

The quantity which changes most when a generator losses synchronism is the impedance measured at the stator terminal on loss of field, the terminal voltage will begin to decrease and the current to increase resulting decrease in impedance and also change in power factor.

The loss of excitation can be unambiguously detected by a mho relay located at the generator terminals.

6.3.9. OVER CURRENT PROTECTION:

As the fault impedance is less than load impedance, the fault current is more than load current. If a short circuit occurs, the circuit impedance is reduced to a low value and therefore a fault is accompanied by large current. Over current relays sense fault currents and also over-load currents. An over current protection is that protection in which the relay picks up when the magnitude of current exceeds the pickup level. The over current relays are connected to the system, normally by means of CTs. A definite-time delay over current relay may be used for this purpose; however, its relay time should be longer than that of the system protection.

Operating value: 1.3 I_n

Relay time: 6-8 sec maximum

To avoid long relay times, it is recommended to equip large generators with an inverse-time-delay (impedance relay). This relay is energized by over current and operates with long or short-time setting, dependent on the location of short-circuit. If connected to the generator neutral point, the over current protection serves as backup protection for the differential protection.

6.3.10. LOAD UNBALANCE PROTECTION:

Generators operating in an interconnected system are normally subjected to small load unbalances only. However, all one and two line-to-ground faults occurring in the system, phase breakages or circuit breaker failures are in fact load unbalances which may result in unduly high thermal stressing of the rotor.

It is recommended to provide a two-stage load unbalance protection. When the continuously permissible load unbalance is reached, an alarm is given, whereas a time-dependent isolation from the system occurs when this value is exceeded.

In case of large units, it is recommended to provide a protection with unbalanced load/time characteristic. Operating value and relay time should be matched to the load unbalanced/time characteristic applicable to the particular generator.

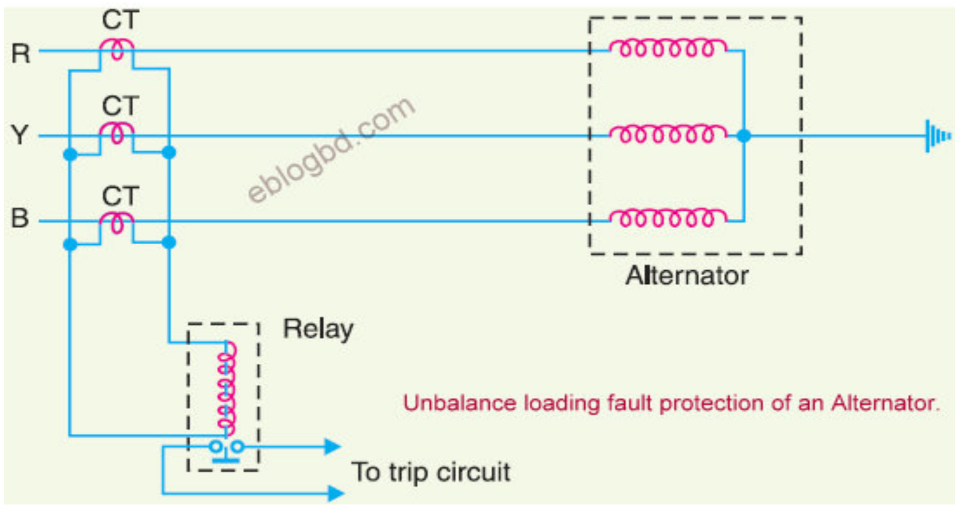


Figure 6.3.10 load unbalance protection

6.3.11. OVER VOLTAGE PROTECTION:

Rejection of partial or complete system loads causes a voltage rise, followed by an increase in the prime mover speed. This may result in the generator and the apparatus connected to it being endangered by unduly high voltages. The generator output is given to the relay as input by using a PT. If the generator output voltage exceeds the setting value the relay will operate. Over voltages can be caused by AVR malfunctions, sudden loss of load on generator or switching on of a long unloaded transmission lines. Due to the sudden voltage variations resulting from switching operations, it is advisable, at least in the case of large units, to provide a two-stage rise-in voltage protection, i.e.:

- With high ($1.45 \times U_n$) operating value and instantaneous tripping.
- With low ($1.2 \times U_n$) operating value and delayed tripping.

6.3.12. REVERSE POWER PROTECTION:

This is basically the protection provided for the prime mover i.e. turbine. If the driving torque becomes less such as closure of main steam valves in case of steam turbo generator, the generator starts to work as a synchronous compensator, taking the necessary active power from the network. The reduction of steam flow reduces the cooling effect on the turbine blades and overheating may occur. The work done by the entrapped steam in the turbine is then zero. As generator is not designed to run as a motor it should be immediately tripped when steam flow to the turbine is stopped and to avoid damage to the turbine blades.

The generator currents remain balanced when the machine is working as a motor. For large turbo-generator, where the reverse power may be substantially less than 1%, reverse power protection is obtained by a minimum power relay, which normally is set to trip the machine when the active power output is less than 1% of rated value.

A reverse power protection relay is a directional relay which measures the product $IX\cos\alpha$ where α is the angle between the polarizing voltage and current.

Operating value: about 50-80% of reverse power

Relay time: longtime setting: approximately 20 sec

Short time setting: approximately 4 sec

6.3.13. NEGATIVE SEQUENCE PROTECTION:

A three phase balanced load produces a reaction field which is approximately constant and rotates synchronously with the rotor field system. Any unbalanced condition of load can be resolved into positive, negative and zero sequence components.

The positive sequence component is similar to the normal balanced load. The zero sequence component produces no main armature reaction. The negative sequence component is similar to the positive system except that the resulting reaction field rotates counter to the D.C. field system and hence produces a flux which cuts the rotor at twice the rotational velocity, there by inducing double frequency currents in the field system and in the rotor body. The resulting eddy-currents are very large and cause severe heating of the rotor and damage the rotor. This can be protected by negative sequence current filter with over current relay.

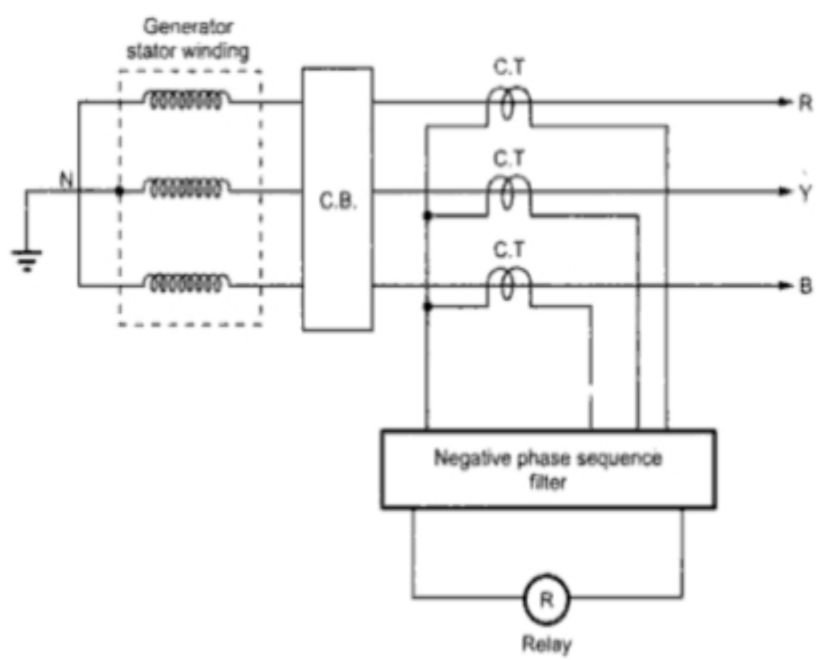


Figure 6.3.13 Negative sequence protection using negative sequence current filter with o/c relay

6.4. TRIPPING SCHEME FOR GENERATOR ELECTRICAL PROTECTION

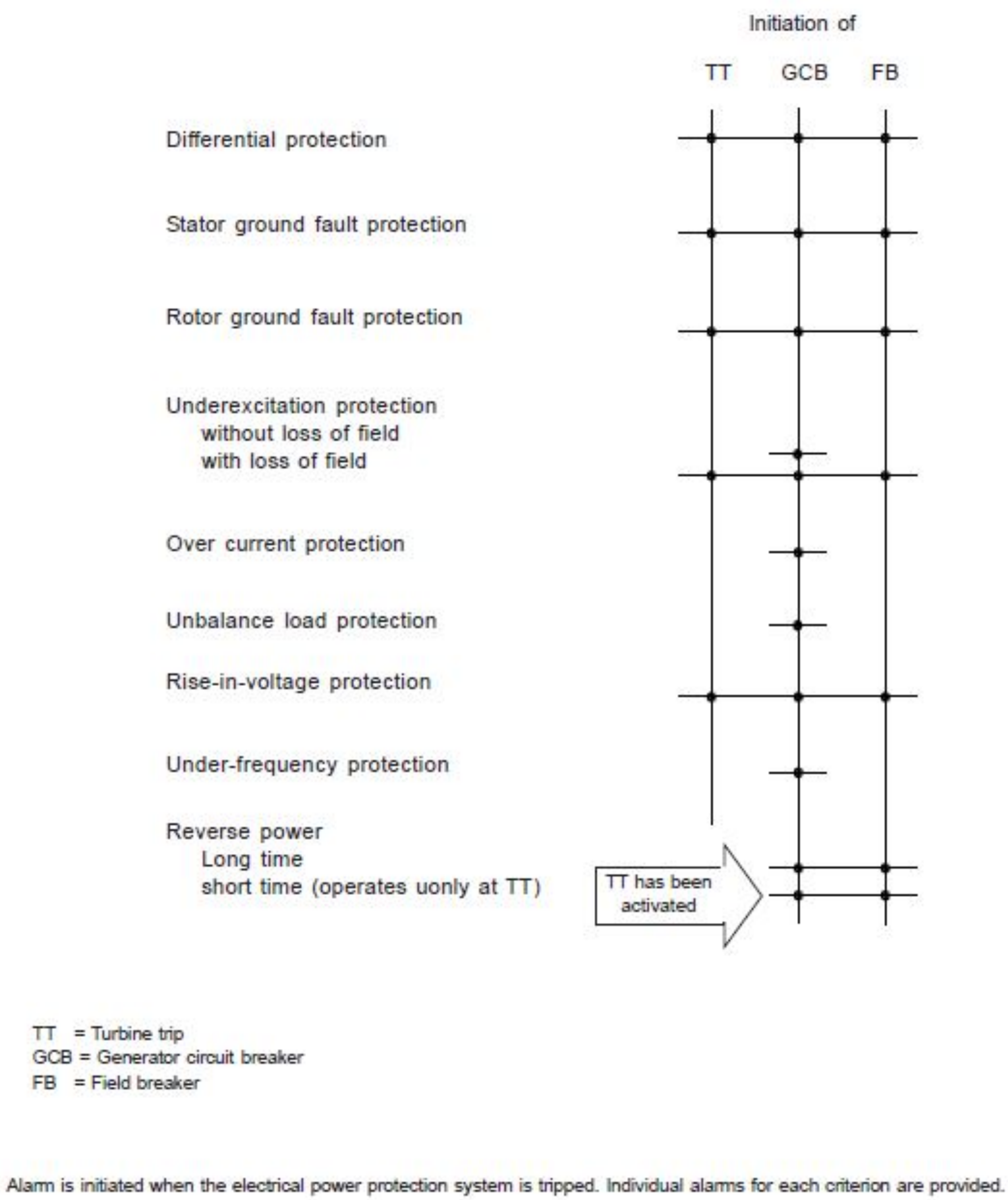


Figure 6.4 Tripping scheme

CONCLUSION

In the power system, the most important equipment is the generator. So it is important to protect it from faults in order maintain its continuous operation without any interruption. This requires the knowledge of design of generator and how it gets affected when a fault occurs.

As the knowledge of the components and auxiliary systems of generator helps in the better understanding of the effect of faults and the need for protection, it has been well studied and observed in this project.

Faults may occur in a power system due to several reasons and these faults can damage the equipment leading to the interruption of the power supply. Hence protective schemes must be employed to avoid these damages. We studied all the protective schemes which use relays with working principle and operation employed in power plant. We studied practically the settings and the relay getting tripped for the respective faults.

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