BHARAT HEAVY ELECTRICALS LTD.

HARDWAR

TRAINING REPORT

SUBMITTED TO :
GENERAL MANAGER
CFFP (BHEL)

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ACKNOWLEDGEMENT

"***An Engineering Diploma is incomplete without practical knowledge and skills. An engineer is expected to be a designer of dynamic world of innovation for which practical experience matters a lot***"

It gives me a great pleasure to have an opportunity to acknowledge and to express gratitude to those who were associated with my project training in BHEL, HARIDWAR.

Special thanks to GENERAL MANAGER CFFP, BHEL for his

Incessant support. And guidance throughout my project training. I am grateful to MR. KHUSHWANT SINGH (VPI) for his support.

I express my sincere thanks and gratitude to BHEL authorities for allowing me to undergo my project training in this Prestigious Organization. I shall always remain Indebted to them their constant interest and excellent guidance in my Project work.

I acknowledge to the support of other authorities also with a deep sense of gratitude.

SAFETY

S	-	Science for Self & Society
A	-	Art of Action for Accidence Avoidance
F	-	Foolproof with failsafe devices
E	-	Engineering control to system
T	-	Training & Teaching to all
Y	-	Yardstick to save humanity

Factor Impending the Safety:

- Personal Factors – III health, Age, Physical disability
- Physiological Factors – Work environmental factors / problems, Rest pause cycle.
- Psychological Factors – Worries, depression, aggression.
- Sociological Factors –
  (a) Safety literature in regional language, tendency for bargaining for unsafe & unhealthy working conditions.
  (b) Lack of interest in the job/employment.
- Job Climate & its Defects on attitude – Job training, Incomplete/untrained supervisory personal, Poor working conditions, Political interference.

Unsafe Act

- Abuse of safety devises.
- Unsafe working procedure.
- Moving near running part of the machines.
- Horseplay, Use of drug, quarrelling.
- Lack of personal protective equipment.
- Lack of attention.

Unsafe Conditions

- Inadequate machine guarding.

- Defective tools
- Unsafe design/construction of the work place.
- Improper illumination.
- Excess Noise
- Poor housing keeping
- Excess heat in work place

Safety is the responsibility of every one

One has not only to provide Safe & Best product but also create a climate where the safe operation can be possible.

The safety means, not only to prevent the accident but also

- Control of occupational health
- To make machine or equipment or situation totally safe.
- Taking in mind for safe operation activities for man, machine, material & money.

BHEL is the largest engineering and manufacturing enterprise in India in the energy-related / infrastructure sector, today. BHEL was established more than 40 years ago, ushering in the indigenous Heavy Electrical Equipment industry in India – a dream that has been more than realized with a well – recognized track record of performance. The company has been earning profits continuously since 1971-72.and paying dividends

since 1976-77.

BHEL caters to core sectors of the Indian Economy viz., Power Generation & transmission, Industry, Transportation, Telecommunication, Renewable Energy and Defense etc.

The wide network of BHEL's 14 manufacturing division, four power sectors regional centers, over 100 project sites, eight service center and 14 regional offices enables the company to be closer to its customers and provide them with suitable products, systems and services efficiently and at competitive prices. Having attained ISO9000,ISO14000,ISO18000 certification, BHEL is now well on its journey towards Total Quality Management (TQM).

BHEL has

- Installed equipment for over 90,000 MW of power generation – for utilities, captive and Industrial users.
- Supplied over 225000 MVA transformer capacity and other equipment operating in Transmission and Distribution network upto 400 KV (AC & DC).
- Supplied over 25000 Motors with drive control system to power projects, petrochemicals, Refineries, Steel, Aluminum, Fertilizer, Cement plants, etc.
- Supplied Traction electrics and AC / DC locos to power over 12000 Kms Railway network.

- Supplied over one million valves to power plants and other Industries organization

BHEL, Haridwar

a) Vision:-

A world class Engineering Enterprise committed to Enhancing stakeholder value.

b) Mission:-

To be an Indian Multinational Engineering Enterprise providing total Business solutions through quality products, systems and services in the fields of Energy, Industry, Transportation. Infrastructure and other potential areas.

c) VALUES:-

- Meeting commitments made to external & internal customers.
- Foster learing,creativity and speed of response.
- Respect for dignity and potential of individuals.
- Loyality and pride in the company.
- Team playing.
- Zeal to excel.
- Integrity and fairness in all matters.

BHEL, Haridwar Complex

a) Area:-

BHEL, Haridwar complex consist of two manufacturing units, namely Heavy Electrical Equipment Plant (HEEP) and central Foundry, Forge Plant (CFFP). The approximate area of these plant is a follows:

HEEP: 0.845 sq km. (Approx.)

CFFP: 1.0 sq km. (Approx.)

b) Location:-

BHEL, Haridwar complex is situated in the foot hills of Shivalik range in Haridwar district of Uttaranchal state. The main Administrative Building is a distance of about 6 km from Haridwar Railway station.

Product Profile

HEEP

S.No.	Products	Installed capacity (Licensed)
1	Thermal Sets	3000 MW
2	Hydro Sets	625 MW
3	Electric Machines	450 MW
4	Gas Turbines	@60MW to 600 MW
5	Super Rapid gun	3 Nos.

Note: @ Capacity installed for manufacturing of gas turbines like rotor equivalent to 600 MW Gas turbines. Balance components for gas turbines from existing thermal sets facilities.

CFFP

S.No.	Products	Installed capacity (Licensed)
1	Castings	6000 MT
2	Forgings a. Heavy forgings b. Medium forgings	 2410 MT 3000 MT
3	Billets and Blooms	4000 MT
4	CI castings	7180 MT
5	Non ferrous castings	250 MT

Facilities in HEEP

S.No.	Area / Block	Major Facilities	Products
1.	Block-I (Electrical Machines	Machine shop, winding bar preparation, assembling, painting section, packing and preservation,	Turbo generators, exciters, Motors (AC & DC).

		oven speed balancing, test bed, test stand, micalastic impregnation, babbitting etc.	
2.	Block-II (Fabrication Block)	Marking, cutting, straightening, gas cutting, press, welding grinding, assembly, heat treatment, cleaning and shot blasting, machining, fabrication of pipe coolers, painting.	Large size fabricated assembles/ components for power equipments
3.	Block-III (Turbine and Auxiliary block)	Machining, assembly, preservation and packing, test stands/ station, painting, grinding, broaching, facing, wax metting, milling, polishing etc.	Steam turbines, hydro turbines, gas turbines, turbine blades, special tooling.
4.	Block-IV (Feeder block)	Bar winding, mechanical assembly, armature windings, sheet metal working, machining, copper profile drawing, electroplating, impregnation, machining and preparation of insulating components plastic moulding, press moulding.	Windings for turbo generators, hydro generators, insulation for AC and DC motors, insulating components for TG, HG and Motors, control panels, contact relays, master control etc.
5.	Block-V	Fabrication, pneumatic hammer for forging, gas fired furnaces, hydraulic manipulators.	Fabricated parts of steam turbine water box, storage tank, hydro turbines assemblies and components.
6.	Block-VI (Fibrication)	Welding, drilling shot blasting, CNC flame cutting, CNC deep drilling, shot blasting, sheet metal work, assembly.	Fabricated oil tanks, hollow guide blades, rings, stator frames,

			rotor spiders.
7.	Block-VI (Stamping and Dia manufacturing)	Machining, turning, grinding, jig boring, stamping press, de-varnishing, de-greasing, de-rusting, varnishing, spot welding, painting.	All types of dies, including stamping dies and press forms stamping for generators & motors.

BHEL:-

Technology / Collaborations:-

The technology base of BHEL in the area of steam turbines and Turbo generators has been created by acquiring technological information from the collaborators.

Initially BHEL had collaboration with M/s LMW USSR for 100 and 210 MW sets. In 1976, BHEL interred into technical collaboration agreement with M/s Siemens – Kwu, Germany to acquire the know-how and know-why for turbine generator sets upto 1000 MW. This collaboration still continues.

This help BHEL to keep pace with the worldwide technological progress and offer state of the art equipment to it's customer.

Under this collaboration agreement BHEL has established strong design manufacturing and servicing base for units upto 500 MW ratings.

Manufacturing Facilities:-

HEEP Haridwar plant is equipped with most modern and sophisticated machines tools, facilities and test equipment to manufacture and test generators upto 1000 MW rating, which include.

1) Most modern micalastic insulation plant for stator bars.
2) Over speed and vacuum balancing tunnel.
3) Kollmann rotor slot milling machine upto maximum barrel length of 7000 mm, barrel diameter of 1800 mm and rotor weight of 225 tones.
4) Two computerized test beds to test large size generators upto 1000 MW.

5) Wotan CNC horizontal boring maching.
6) Center lathe machine upto maximum length of 16 m and diameter of 3.15 m.
7) Insulation life endurance test assessment facility.

Beside these, HEEP has also set up a Generator Research Institute with an objective to develop basis know-how and know-why through experimental studies for reliable, efficient and optimum design of generators and improve their performance in service.

(A) Turbo Generator
Main Components

1. Stator:

(a) Stator Frame
(b) End Shields
(c) Bushing Compartment.

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 forces and torques arising during operation. In addition, the use of hydrogen for the generator cooling requires the frame to be pressure resistant upto an internal pressure of approx 10 bar.

The welding stator frame consist of the cylindrical frame housing two flanged rings and axial and radial ribs. Housing and ribs within the range of the phase connectors of the stator winding are made of non magnetic steel to prevent eddy current losses, while the remaining frame parts are fabricated from structural steel.

The arrangement and dimensioning of the ribs are determined by the cooling gas passages and the required mechanical strength and stiffness. Dimensioning is also dictated by vibrational considerations, resulting partly in greater wall thickness than required from the point of view of mechanical strength. The natural frequency of frame does not correspond to any exciting frequencies.

Two lateral support for flexible core suspension 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.

Manifolds are arranged inside the stator frame at the bottom and top for filling the generator with CO_2 and H_2. The connection of the manifolds are located side by side in the lower part of the frame housing.

Additional opening in the housing, which are sealed gas tight by pressure resistant covers, afford access to the core clamping flanges of the flexible core suspension system and permit the lower portion of the core to

be inspected Access to the end winding compartments is possible through manholes in the end shield.

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 ends of the stator frame are closed by pressure contaning end shields. The End Shield features a high stiffness and accommodate the generator bearings, shaft seals and hydrogen coolers. The end shields are horizontally split to allow for assembly.

The end shields contains the generator bearings. This result in a minimum distance between bearings and permits the overall axial length of the TE end shield to be utilized for accommodation of the hydrogen cooler sections. Cooler wells are provided on the end shield on both sides of the bearing compartment for this purpose – one man hole in both the upper and lower half of end shield provides access to the end winding compartments of the completely assembled machine.

Inside the bearing compartment the bearing saddle is mounted and insulated from the lower half end shields. The bearing saddle supports the spherical bearing sleeve and insulates it from ground to prevent the flow of shaft currents.

The bearing oil is supplied to the bearing saddle via a pipe permanently installed in the end shield and is then passed on to the lubricating gap through ducts in the lower bearing sleeve. The bearing drain oil is collected in the bearing compartment and discharged the lower half of the end shield via a pipe.

The bearing compartment is sealed on the air side with labyrinth rings. On the hydrogen side the bearing compartment is closed by the shaft seal and labyrinth rings. The oil for the shaft seal is admitted via integrally welded pipes. The seal oil drained toward the air side is drained together with the bearing oil. The seal oil drained towards the hydrogen side is first collected in a gas and oil tight chamber below the bearing compartment for deforming and then passed via a siphon to the seal oil tank of the hydrogen side seal oil circuit.

The static and dynamic bearing forces are directly transmitted to the foundation via lateral feet attached to the lower half end shield. The feet can be detached from the end shield, since the end shields must be lowered into the foundation opening for rotor insertion.

Stator Frame:

The stator frame consist of a cylindrical center section and two end shields which are gas tight and pressure resistant.

The stator end shields are joined and sealed to the stator frame with an O-ring and bolted flange connection the stator frame accomdates the electrically active part of the stator, i.e. the stator core and the stator windings. Both the gas ducts and a large number of welded circular ribs provides for the rigidity of the stator frame. Ring shaped support for resilient core suspension are arranged between the circular ribs. The generator cooler is subdivided into cooler sections arranged vertically in the turbine side stator End Shield. Stator End Shield also contain the shaft seal and bearing components. Feet are welded to the stator frame and end shields to support the stator on the foundation. The Stator is firmly connected to foundation with anchor bolts through the feet.

Stator Core:

The stator core is stacked from insulated electrical sheet-steel laminations and mounted in supporting rings over insulated dovetail guide bars. Axial compression of the stator core is obtained by clamping fingers, pressure plates and non-magnetic through type clamping bolts, which are insulated from the core. 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 flat springs are tangentially arranged on the circumference in sets with three springs each i.e. two vertical supporting ring on both sides of the core and one horizontal stabilizing ring below the core. 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 pressure plates and end portion of the stator core are effectively shielded against stray magnetic fields. The flux shields are cooled by a flow of hydrogen gas directly over the assembly.

Stator Winding:

1. Construction:-

Stator bars, phase connectors and bushings are designed for direct water cooling. To minimize the stray losses, the bars are composed of separately insulated strands which are transposed by 540 in the slot portion and bonded together with epoxy resin in heated mold after bending the end turns are likewise bonded together with baked synthetic resin filters.

The bar consist of solid and hollow strands distributed over the entire bar cross-section so that good heat dissipation is ensured at the bar ends, all the solid strand are jointly brazed into a connection sleeve and the hollow strands into a water box from which the cooling water enters and exits via Teflon insulating hoses connected to the annular manifolds. The electrical connection between top and bottom bars is made by a bolted connection at the connection sleeve.

The water manifolds are insulated from stator frame, permitting the insulation resistance of water-filled winding to be measured. During operation water manifolds are grounded.

2. Micalastic High – Voltage Insulation:

High-voltage insulation is provided according to the proven Micalastic system. With this insulation system, several half – over lapped continuous layer of mica tape are applied to the bars. The mica tape is built up from large area mica splitting 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. After impregnation under vacuum, the bars are subjected to pressure, with nitrogen being used as pressurizing medium (VPI process). The impregnation bars are formed to the

required shape in molds and cured in an over 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 slot wall, a final coat of semi conducting varnish is applied to the surfaces of all bars within the slot range. 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 creep age spark concentrations.

Bar 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 side ripple spring, a slot bottom equalizing strip, and 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 and cured after installation. For radial support the end windings are clamped to a rigid support ring of insulating material which in then is fully supported by the frame. Hot – curing conforming fillers arranged between the stator bars and the support ring ensures a firm support of each individual bar against the support ring. The bars are clamped to the support ring with pressure plates held by clamping bolts made from a high strength insulating material. The support ring is free to move axially within the stator frame so that movements of the winding due to thermal expansion are not restricted.

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 transformer for metering and relaying purposes can be mounted on the bushings.

Total Impregnation facility in BHEL:-

Facilities:-

1. Impregnation capacity upto turbo generators of 470 MVA.

2. Main Impregnation tank.
   height = 4.5 meters and length = 9 meters.
3. Resin tank
   5 number of tank with a storage capacity = 12000 litres per tank.
4. Total resin storage capacity = 60,000 litres.
5. Explosive proof software controlled oven with rotor facility.

VPI Process:-

1. Assembly of winding bars in green stage and impregnation of assembled wound core.

2. Pre heating and curing oven for about 1hour.
3. Drying under vacuum (< = 0.1 m bar)
4. Impregnation with resin mix and pressure is increased gradually to ensure filling of voids.
5. Curing in oven at 145°C for minimum 8 hours.
6. Epoxy resin fills all gaps / voids by capillary action without blocking vent canals due to its low viscosity.

Process Before:-

Stator bar forming	⇒	**Stator bar Insulation**	⇒	**Stator bar Impregnation**

Number of parallel activities = 2

Stator frame fabrication	⇒	**Stator Core assembly**	⇒	**Stator Winding and assembly**

Process After:

Stator bar		Core Assembly	Stator frame fabrication
		⇓	⇓
forming		Number of parallel activities = 3 stator	Stator frame machine
⇓		⇓	⇓
Stator bar insulation	⇒	Impregnation of wound core	Stator Assembly

4. Reduction in time as above by 5-6 days.
5. Additional revenue of approx Rs 3750 lakhs.
6. Improved heat transfer during operation.
7. Manufacturing cycle time reduction by 4-5 months.
8. Void free high voltage Insulation.
9. Mechanically firm winding between core and winding component better suited against thermal stress.
10. Thermal conductivity of VPI insulation = 2.2 – 2.5 mw / cm - °C against that of air = 0.257 mw / cm – °C.

Hydraulic Testing and Anchoring of stator frame:-

1.Hydraulic Testing of Stator Frame:

The empty stator frame with attached end shields and terminal box is subjected to a hydraulic test at 10 bar to ensure that it will be capable of with standing maximum explosion pressures. The water pressure is increased in steps, with the pressure being reduced to atmospheric pressure after each step to allow for measurement of any permanent deformations.

This test also check for leakage at the weld seams. In addition the welded structure is subjected to an air pressure test to check its gastightness.

2. Sealing the bolted flange joints:

The bolted flange joints which must be gastight (e.g., end shields, terminal box, manhole covers) are sealed with elastically deformed O-ring packings. Each O-ring packing is inserted into a large groove of rectangular cross-section and compressed by the flanges. The elastic deformation of the O-ring packing provides for a sufficient sealing force.

3. Anchoring and Aligning the stator frame and End Shields to the foundation:

The stator frame is anchored to the foundation with anchor bolts in conjunction with aligning elements and sole plates set in grout on the foundation.

The leveling screws are screwed into the support fort of the frame and permit a rapid and exact alignment of the stator. To ensure a uniform transmission of the forces they are arranged symmetrically about the anchor bolts. The spherical portion of the leveling screws ensures complete contact and thus a rigid connection between stator and foundation.

The stator end shields are aligned on the machine sole plates with shims.

Different thermal expansion of the stator and foundation result in differential movements between the frame and machine sole plates. The stator is therefore fixed in position in a manner allowing for expansion while retaining alignment. Fixed keys located at the feet in the middle of the stator frame secure the frame axially in a central position.

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

The segments are punched in one operation from 0.5 mm thick electrical sheet-steel laminations having a high silicon content, carefully deburred and then coated with insulating varnish on both the sides. The stator frame is turned on end while the 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, stacking guides are inserted into the winding slot during stacking provide smooth slot walls.

To obtain the maximum compression and eliminate under scathing during operation, the laminations are hydraulically compressed and heated during the stacking procedure when certain heights of stacks are reached the complete stack is kept under pressure and located in a frame by means of clamping bolts and pressure plates.

The clamping bolts running through the core are made of non magnetic steel and are insulated from the core and the pressure plates to prevent the clamping bolts 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. The clamping finger extends upto the end of the teeth, thus ensuring a firm compression in the area of the teeth. The stepped arrangement of the laminations at the core ends provides for an efficient support of the tooth portion and, in addition contributes to a reduction of eddy current losses and local heating in this area. The clamping fingers are made of non-magnetic steel to avoid eddy current losses.

For protection against the effect of stray flux in the coil ends, the pressure plate and core end portion are shielded by gas-cooled rings of insulation bonded electrical sheet-steal.

To remove the heat, spacer segments, placed at intervals along the bore length, divide the core into sections to provide radial passages for cooling gas flow. In the core end portions the cooling ducts are winder and spaced more closely to account for the higher losses and to ensure more intensive cooling of the narrow core sections.

Spring Support of Stator Core:-

The revolving magnetic field exerts a pull on the core, resulting in a revolving and nearly elliptical deformation of the core which sets up a stator vibration at twice the system frequency. To reduce the transmission of these dynamic vibrations to the foundation, the generator core is spring mounted in the stator frame. The core is supported in several sets of rings. Each ring set consists of two supporting rings and two core clamping rings. The structural members to which the insulated dovetail bars are bolted are uniformly

positioned around the supporting ring interior to support the core and to take up the torque acting on the core.

For firm coupling of the ring sets to the core, the supporting ring is solidly pressed against the core by the clamping ring. The clamping ring consist of two parts which are held together by two clamps.

Tightening the clamps reduces the gap between the ring segments so that the supporting ring is pressed firmly against the core.

Each ring set is linked to the frame by three flat springs. The core is supported in the frame via two vertical springs in the vicinity of the generator feet.

The lower springs prevents a lateral deflection of the core. The flat springs are resilient to radial movements of the core suspension points and will largely resist transmission of double frequency vibration to the frame. In the tangential direction they are, however sufficiently rigid to take up the short circuit torque of the unit. The entire vibration system is turned so as to avoid resonance with vibrations at system frequency or twice the system frequency.

Locating the Bars:-

The stator windings are placed in rectangular slots which are uniformly distributed around the circumference of the stator core.

The bars are protected by a cemented graphitized paper wrapped over the slot portion of the bar. The bars fit tightly in the slots. Manufacturing tolerance are compensated with semi-conducting filler strips along the bar sides which ensure good contact between the outer corona protection and the slot wall.

Radial slot positioning of the bar is done with slot wedges. Below the longitudinally divided slot wedges a top ripple spring of high-strength fiber glass fabric is arranged between the filler and slide strip which presses the bar against the slot bottom with a specific preloading. An equalizing strip is inserted at the slot bottom to compensate any unevenness in the bar shape and slot bottom surface during bar insertion. The strip is cured after insertions of the bars. These measures prevent vibrations. The specific preloading is checked at each slot wedge.

With the windings placed in the slots, the bar ends form a cone-shaped end winding. A small cone taper is used to keep the stray losses at a minimum.

Any gaps in the end winding due to design or manufacturing are filled with curable plastic fillers, ensuring solid support of the cone-shaped top and bottom layers.

The two bar layers are braced with clamping bolts of high-strength fiber glass fabric against a rigid, tapered supporting ring of insulating material. Tight seating is ensured by plastic filler on both sides of the bars which are cured on completion of winding assembly.

Each end winding thus forms a compact, self supporting arch of high rigidity which prevents bar vibration during operation and can with stand short circuit forces.

In addition, the end turn covering provides good protection against external damage. The supporting rings rest on supporting brackets which are capable of moving in the axial direction. This allow for a differential movement between the end windings and the core as a result of different thermal expansions.

Electrical connection of bars:-

The electrical connection of top and bottom bars is by a bolted contact surface.

At their ends the strands are brazed into a connecting sleeve, the strand rows being separated from each other by spacers. The contact surfaces of the connecting sleeves for the top and bottom bars are pressed against each other by nonmagnetic clamping bolts. Special care is taken to obtain flat and parallel contact surfaces. In order to prevent any reduction in contact pressure or any plastic deformations due to excessive contact pressure, Belleville washers are arranged on the clamping bolts which ensure a uniform and constant contact pressure.

Water Supply:-

The water connection at the stator bar is separate from the electrical connection. As a result no electrical forces can act on the water connection.

Which the solid strands of the stator bars terminates at the connecting sleeve, the hollow strands are beared into water boxes, with solid spacers inserted to compensate for the solid strand. Each water box is consist of two part i.e., the sleeve shaped lower part enclosing the hollow strands and the cover type upper part the strand rows are separated from each other by spacers. Each water box is provided with a pipe connection of non magnetic stainless steel for connection of the hose. The exciter end water boxes serve for water admission and distribute the cooling water uniformly to the hollow strand of the bars. The hot water is collected on leaving the hollow strand in the turbine end water boxes. The cooling water is then discharged from the generator via the hoses and the ring header.

During manufacturing of the stator bars, various checks are performed to ensure water tightness and unobstructed water passages. The flow check ensures that no reduction in the cross-sectional area of the strand ducts has occurred, and that all strands are passed by identical water flows. After brazing of the upper part of water box, all brazed joints are subjected to a helium leakage test oreceded by a thermal shock test.

The tangential air clearance between the water boxes and bar connections within a coil group and the axial clearance relative to the inner shields, which is at ground potential, is so dimensioned that additional insulation is not required. For the spaces between the individual phases insulating caps, which enclose both the connecting sleeves and the water boxes, are connected to the stator bars.

Phase Connectors:-

The phase connectors interconnect the coil groups and link the beginning and ends of the winding to the bushings. They consist of thick-walled copper tubes. The stator bar ends coupled to the phase connectors are provided with connecting fittings which are joined to the cylindrical contact faces of the ring headers. The connection is by a bolted contact surface with

Bellville washers on the bolts to maintain a uniform and constant contact pressure.

The phase connectors are provided with micalastic insulation. In addition, a grounded other corona protection consisting of a semi conducting coating is applied over the entire length. At the beginnings and ends of the phase connectors several layers to semi-conductive end corona protection is applied in varying lengths.

The phase connectors are mounted on the end winding supporting ring over support brackets. Neighboring phase connectors are separated with spacers and tied securely in position. This ensure a high short-circuit strength and differential movements between phase connectors and end windings are thus precluded.

Components for water cooling of stator windings:-

1. General:

Two separate water cooling circuits are used for the stator winding and the phase connectors and bushings.

All water connections between ungrounded parts and the distribution manifolds and water manifolds of the cooling circuits are insulated Teflon hoses. The water connections are equipped with O-rings of viton and Belleville washers to prevent loosening of the connection. The fittings are made from non-magnetic stainless steel.

2. Winding cooling circuit:-

The end windings are enclosed by an annular water manifold to which all stator bars are connected through hoses. The water manifolds is mounted on the holding plates of the end winding support ring and connected to the primary water supply pipe. This permits the insulation resistance of the water filled stator winding to be measured. The water manifold is grounded during operation. For measurement of the insulation resistance, eg. during inspection, grounding is removed by opening the circuit outside the stator frame.

The hoses, one side of which is connected to ground, consist of a metallic section to which the measuring potential is applied for measurement of the insulation resistance of the water-filled stator winding.

The cooling water is admitted to three terminal bushings via a distribution water manifold flows through the attached phase connectors and is then passed to the distribution water manifold for water outlet via the terminal bushings on the opposite side.

The parallel-connected cooling circuits are checked for uniform water flows by a flow measurement system covering all three phases.

Terminal Bushings:-

1. Arrangement of terminal bushing:-

The beginning and ends of the three phases windings are brought out from the stator frame through terminal bushings, which provides for high-voltage insulation and seal against hydrogen leakage.

The bushings are bolted to the bottom plate of the generator terminal box by the mounting flanges.

The generator terminal box located beneath the stator frame at the exciter end is made from non-magnetic steel to avoid eddy-current losses and resulting temperature rises.

Bushing-type generator current transformers for metering and relaying are mounted on the bushing outside the generator terminal box. The customers bus is connected to the air side connection flange of the bushings via terminal connectors.

2. Construction of Bushings:-

The cylindrical bushing conductor consist of high conductivity copper with a central bores for direct primary water cooling.

The insulator is wound directly over the conductor. It consist of impregnated capacitor paper with conducting fillers for equalization of the electrical direct-axis and quadrature-axis fields.

The shirunk-on mounting sleeve consist of a gas tight casting of nonmagnetic steel with a mounting flange and a sleeve type extension extending over the entire height of the current transformers.

The cylindrical connection ends of the terminal bushing conductors are silver plated and designed to accommodate bolted two part cast terminal connectors.

Connection to the beginning and each phase inside the terminal box and to the external bus in by means of flexible connectors. To maintain a uniform and constant contact pressure, Belleville washers are used for all bolted connections.

Covers with brazed sockets for connection to the water supply are flanged to the ends of terminal bushing conductors.

Rotor Shaft:-

The high mechanical stresses resulting from the centrifugal forces and short-circuit torques call for a high quality heat-treated steel. Therefore, the rotor shaft is forged from a vacuum cast steel ingot. Comprehensive tests ensure adherence to the specified mechanical and magnetic properties as well as a homogeneous forging.

The rotor shaft consists of an electrically active portion, the so called rotor body, and the two shaft journals. Integrally forged flange couplings to connect the rotor to the turbine and exciter are located out board of the bearings. Approximately two-thirds of the rotor body circumference is provided with longitudinal slots which hold the field winding slot pitch is selected so that the two solid poles are displaced by 180.

Due to the non-uniform slot distribution on the circumference, different moments of inertia are obtained in the main axis of the rotor. This in turn causes oscillating shaft deflections at twice the system frequency. To reduce these vibrations the deflections in the direction of the pole axis and neutral axis are compensated by transverse slotting of the pole.

The solid pole 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 winding slot.

Cooling of Rotor Winding:-

Each turn is subdivided into eight parallel cooling zones. One cooling zone includes the slots from the center to the end of the rotor body, while another covers half the end winding.

The cooling gas for the slot portion is admitted into the hollow conductors through milled openings directly before the end of the rotor body and flows through the hollow conductor to the center of the rotor body. The hot gas is then discharged into the air gap between the rotor body and stator core through radial openings in the conductors and rotor slot wedges. The cooling gas passages are arranged at different levels in the conductor assembly so that each hollow conductor has its own cooling gas outlet.

The cooling gas for end windings is admitted into the hollow conductor at the end of rotor body. It flows through the conductors approximate upto the pole center for being directed into a collecting compartment and is then discharged into the air gap via slots.

At the end winding, one hollow conductor passage of each bar is completely closed by a brazed copper filler section.

The enlargement of the conductor cross-section results in both a reduction of losses and increased conductor rigidity.

Rotor Winding:-

Construction:-

The field winding consist of several coils inserted into the longitudinal slots of the rotor body. The coils are wound around the poles so that one north pole and one south magnetic pole are obtained.

The hollow conductors have a trapezoidal cross-section and are provided with two cooling ducts of approximately semi-circular cross-section. All conductors have identical copper and cooling ducts cross-section.

The individual conductors are bent to obtain half turns. After insertion into the rotor slots, there turns are combined to form full turns, the series connected turns of one slot constituting one coil. The individual coil of the rotor winding are electrically series connected.

Conductor Material:-

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.

Insulation:-

The insulation between the individual turns is made of layers of glass fiber laminate. The coils are insulated from the rotor body with L-shaped strips of glass fiber laminate with Nomex filler.

To obtain the required creepage paths between the coil and the frame thick top strips of glass fiber laminate are inserted below the slot wedges.

Loactions of parts in the Rotor Winding:

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. The slot wedges extend below the shrink seats of the retaining rings. The rings act as short-circuit rings to induced currents in the damper windings.

End Winding Bracing:-

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

Rotor Retaining Ring:-

The rotor retaining rings contain the centrifugal forces due to the end winding. One end of each ring is shrunk on the rotor body, while the other end of the ring overhangs the end windings without contacting the shaft. This ensures an unobstructed shaft deflection at the end windings.

The shrunk on end ring at the free end of the retaining ring serves to reinforce the retaining ring and secures the end winding in the axial direction at the same time.

A snap ring is provided for additional protection against axial displacement of the retaining ring.

To reduce the stray losses and retain strength, the rings are made of non-magnetic cold worked material.

Comprehensive tests, such as ultrasonic examination and liquid penetrate examination, ensure adherence to the specified mechanical properties.

The retaining ring shrink-fit areas act a short-circuit rings to induced currents in the damper system. To ensure low contact resistance the shrink seats of the retaining rings are coated with nickel, aluminum and sliver by a three step flame spraying process.

Field connections:-

The field connections provides the electrical connection between the rotor winding and the exciter and consist of

1. Field current lead at end winding.
2. Radial bolts.
3. Field current lead in shaft bore.

Field current lead at End Winding:-

The field current lead at the end winding consist of hollow rectangular conductors. The hollow conductors are inserted into shaft slots and insulated. The are secured against the effect of centrifugal force by steel wedges. The 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. The hot gas is discharged into the air gap discharged into the air gap together with the gas used to cool the end winding.

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. Contact pressure is maintained with a tension bolt and an expanding cone in each radial bolt. Contact pressure increases due to centrifugal forces during operation. All contact surface are silver-plated to attain a low contact resistance. The radial bolt is made from forged electrolytic copper.

The seal between air and hydrogen spaces is located close to the radial bolt. This seal consists of an insulating ring which is pressed between the shaft and the radial bolt with a threaded ring.

3. Field current lead in shaft bore:-

The leads are run in the axial direction from the radial bolt to the exciter coupling. They 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 Kontakt plug in contacts, which allow for unobstructed thermal expansion of the field current leads.

Rotor Fan:-

The generator cooling gas is circulated by one axial-flow fan located on the turbine-end shaft journal. To augment the cooling of the rotor winding, the pressure established by the fan works in conjunction with the gas expelled from the discharge parts along the rotor.

The moving blades of the fan are inserted into T-shaped grooves in the fan hubs. The fan hubs are shrink-fitted to the shaft journal spider.

Generator 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 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 sleeves.

The lower bearing sleeve rests on the bearing saddle via three brackets with spherical support sets for self-alignment of the bearing. The bearing saddle is insulated from the stator end shield and the bearing bracket are insulated from the bearing sleeve to prevent the flow of shaft currents and to provide for double insulation of the generator bearing from ground. A radial locator serves to locate the bearing in the vertical direction and is bolted to the upper half of the stator end shield. The locator is adjusted to maintain the required clearance between the bearing sleeve and the insulation of the radial locator.

A tangential locator is provided at the bearing sleeve joint to prevent the bearing from turning in the saddle. The tangential locator is supported on the bearing saddle over a piece of insulating material.

The inner surface of the cast bearing sleeve body is provided with spiral dovetail grooves, which firmly hold the Babbitt liner to the bearing sleeve body. 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 start up. High pressure oil is forced between the bearing surface and the shaft journal, lifting the rotor shaft to allow the formation of the lubricating oil film.

The bearing temperature is monitored with one double element thermocouple located approximately in the plane of maximum oil film pressure.

Shaft Seal:-

The rotor shaft ends are brought out of the gastight enclosure through double – flow shaft seals.

With this type of shaft seal, the escape of hydrogen between the rotating shaft and the housing is prevented by maintaining a continuous film of oil between the shaft and a non-rooting floating seal ring. To accomplish this, seal oil from two separate circuits i.e., the air side and hydrogen side seal oil circuits, is fed to the seal ring at a pressure slightly higher than the hydrogen pressure. In addition, higher pressure air side oil is supplied to the shaft seal for thrust load compensation of the seal ring.

The double flow shaft seal is characterized by its short axial length, its independence from the respective axial and radial position of the shaft, and low hydrogen losses due to absorption by the seal oil.

The two halves of the babbitted seal ring float on the shaft journal with a small clearance and are guided in the axial direction by a seal ring carrier resistant to distortion and bending. The seal ring is relatively free to move in the radial direction, but is restrained from rotating by use of a pin. The seal ring carrier, bolted to the end shield is insulated to prevent the flow of shaft current. The oil is supplied to the shaft seal at three different pressures over pipes and the mounting flanges of the seal ring carrier at the end shield. The air side and the hydrogen side seal oil is admitted into the air side and hydrogen side annular grooves, respectively, of the seal ring via passages in the seal ring carrier and seal ring. A continuous film of oil is maintained between the shaft and the seal ring clearance between the shaft and seal ring is such that friction losses are minimized and a oil film of sufficient thickness is maintained without an unnecessarily large oil flow. Temperature rise of the seal oil is therefore small which contributes to reliable sealing. The Babbitt lining of the seal ring ensures high reliability even in the event of boundary friction.

The air side seal oil pump delivers the oil at a pressure maintained at 71.4 bar above the generator hydrogen gas pressure at the shaft seal by means of differential pressure value ("A" value).

On the hydrogen side, the hydrogen saturated seal oil is circulated in a closed circuit. A pressure equalizing value maintains the oil pressure on the hydrogen side slightly below that on the air side, thus keeping the interchange of oil between the air and hydrogen sides to a very small value.

Air side seal oil for ring relief is fed to the annular groove in the air side seal ring carrier and forced between the seal ring and seal ring carrier. In this way the oil and gas pressure acting on seal ring are balanced, and the friction between the seal ring and seal ring carrier is reduced. The seal ring is thus free to adjust its radial position, which is important during the starting and shut-down period. The seal ring will adjust its position according to the shaft position as dictated by the oil film thickness and the vibratory condition.

The seal ring need not follow the axial displacement of the generator shaft, which is primarily caused by turbine expansion. The design permits the shaft to slide through the seal ring without impairing the sealing effect.

Hydrogen Cooler:-

The hydrogen cooler is a 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 mountings. This arrangement 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 the horizontal direction. The cold cooling water flows from the bottom to the top end of the cooler on the cold gas side and, after reversal in the return water channel, the heated water flows downward on the hot gas side. This cooling water flow passage is obtained through a partition in the inlet / outlet water channel.

Each cooler is 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 large heat transfer surface, the fins being joined to the tubes by tinning. The ends of the tube are expanded into the upper and lower and lower tube sheets.

The two side walls of structural steel brace the cooler and direct the hydrogen flow. They are solidly bolted to the upper tube sheet, which the

attachment to the lower tube sheet permits them to move freely to allow for expansion of the tube bundle.

Flexible seal strips bolted to the side walls seal the gap between the cooler and the cooler well in the cooler assembly, thus preventing uncooled hydrogen from flowing part the cooler.

The upper tube sheet is larger than the cooler well opening and is used to fix the cooler. Gas tight sealing of this tube sheet is done by packing.

The return water channel is bolted to the upper tube sheet over a flat gasket. This arrangement permits the return water channel to be detached for cleaning, even when the generator is in operation and filled with hydrogen.

The lower tube sheet is freely movable and capable of following the differential movement between stator frame and cooler due to the different thermal expansions resulting from the different materials and temperatures.

Attached to the lower tube sheet is the inlet / outlet water channel with its cooling water inlet / outlet pipes.

A seal cap is bolted over the inlet / outlet water channel. The seal cap has openings for bringing out the cooling water pipes. Gas tight sealing is done by a gland type seal which is simultaneously pressed against the outer circumference of the tube-sheet and against the sealing face of the seal cap by a compression ring.

The cooler are parallel connected on their water sides shutoff 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 value 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.

Oil Supply for bearing and shaft seals:

1. Bearing Oil System:-

The generator and exciter bearings are connected to the turbine lube oil supply.

2. Seal Oil System:-

Construction- The shaft seals are supplied with seal oil from two seal oil circuit which consist of flowing principal components.

a) Hydrogen Side Seal oil circuit:

Seal oil tank
Seal oil pump
Oil cooler 1
Oil cooler 2
Seal oil filter
Differential pressure valve C
Pressure equalizing valve TE
Pressure equalizing valve EE

b) Air side seal oil circuit:

Seal oil storage tank
Seal oil pump 1
Seal oil pump 2
Standby seal oil pump
Oil cooler 1
Oil cooler 2
Seal oil filter
Differential pressure valve A1
Differential pressure valve A2.

a) Hydrogen side seal oil circuit:-

The seal oil drained towards the hydrogen side is collected in the seal oil tank. The associated seal oil pump returns the oil to the shaft seal via a cooler and filter. The hydrogen side seal oil pressure required down streams of the pump is controlled by differential pressure valve C according to the preset reference value. i.e., the preset difference between air side and hydrogen side seal oil pressures.

The hydrogen side seal oil pressure required at the seats is controlled separately for each shaft seal by the EE or TE pressure equalizing valve, according to the preset pressure difference between the hydrogen side and air side seal oil.

Oil drained from the hydrogen side is returned to the seal oil tank via the generator prechambers. Two float-operated valves keep the oil level at a predetermined level, thus preventing gas from entering the suction pipe of the seal oil pump. The low level float-operated valve compensates for an insufficient oil level in the tank by admitting oil from the air side seal oil circuit. The high level float-operated valve drains excess oil into the sea oil storage tank. The hydrogen entrained in the seal oil comes out of the oil and is extracted by the bearing vapour exhauster for being vented to the atmosphere above the power house roof. During normal operation the high level float-operated drain valve is usually open to return the excess air side seal oil, which flowed to the hydrogen side via the annular gaps of the shaft seals, to the air side seal oil circuit.

b) Air side Seal Oil Circuit:-

The air side seal oil is drawn from the seal oil storage tank and delivered to the seal oil pump 1. In the event of failure of seal oil pump 1 of the air side seal oil circuit, sea oil pump 2 automatically takes over the seal oil supply.

Upon failure of seal oil pump 2, the standby seal oil pump is automatically started and takes over the seal oil supply to the shaft seals. In the event of a failure of the seal oil pump oil pump of the hydrogen side seal oil circuit, the seal oil is taken from the air side seal oil circuit.

The air side seal oil pressure required at the seals is controlled by differential pressure value A1 according to the preset value, i.e. the required pressure difference between seal oil pressure and hydrogen pressure. In the event of failure, i.e. when the seal oil for the seals is obtained from the standby seal oil pump, differential pressure value A2 takes over this automatic control function.

The seal oil drained from the air side of the shaft seals is directly returned to the seal oil storage tank.

Seal oil cooler and seal oil filter:-

1. Seal oil coolers:-

The air side and hydrogen side seal oil coolers are each full-capacity coolers. One is always in operation which the second one serves as a standby. The seal oil flow can be changed over from one cooler to the other by means of two interlocked three-way rotary transfer values.

2. Seal oil filters:-

The seal oil filters are arranged directly after the seal oil coolers. The filters have a fine mesh screen which serves to prevent damage to the shaft seals by foreign particles entrained in the oil. By connecting two separate filters in series, one of the two filter can always be maintained in operation, supplying filtered oil to the shaft seals. The changeover value assembly at the filters allows one filter to be taken out of service for cleaning without interruption of the oil flow.

Seal oil pumps:-

General – oil lubricated radial seals at the rotor shaft ends prevents the hydrogen gas from escaping from the generator to the atmosphere.

Seal oil pump are used to supply the seal oil to the shaft seals in a closed circuit.

Construction and mode of operation:-

The seal oil pumps are three screw pumps. One double thread driving rotor and two driven idler screws are closely meshed and run with a close clearance in the casing insert. The pump casing accommodates the casing insert and is closed off by covers at the driven end and non-drive end.

The screw pump is suitable for rigorous service and due to the absence of control parts sensitive to dirt, allows for relatively large variations of seal oil viscosity.

High speeds are readily attainable because all moving parts perform rotary movements only.

By intermeshing the helical passages in the rotors are divided into compartments completely sealed which, while rotating progress completely uniformly and without undue stressing from the suction to the discharge end thus acting like a piston. Dummy pistons compensate for the axial thrust on the thread flank faces at the discharge end. Axial thrust on the deep-groove ball bearing is thus eliminated.

The idler screws are hydraulically driven due to suitable screw dimensioning the thread flanks transmit only the torques resulting from fluid friction, which ensures very quiet running.

The screw pumps are driven by electric motor through a coupling. The motor speed and rating are matched to the expected delivery flow and heads.

Gas System:-

General:

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 consist of –

H_2 supply
CO_2 supply
N_2 supply
Pressure reducers
Pressure gauges
Miscellaneous shut off values
Purity metering Equipment
Gas Dryer
CO_2 flash evaporator
Flow meters

1. Hydrogen Supply:-

i) Generator casing:- 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.

ii) Primary water tank:- A nitrogen environment is maintained above the primary water in the primary water thank.

a) to prevent the formation of a vacuum due to different thermal expansion of the primary water.

b) to ensure that the primary water in the pump suction line is at a pressure above atmospheric pressure so as to avoid pump cavitations.

c) 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.

The hydrogen for the generator is supplied from a hydrogen bottle neck. The hydrogen should have a minimum purity of 99.7%.

H2 bottle Rack:-

The H_2 bottles are connected to the manifold on the bottle rack. Values on the bottle and values on the manifold allow replacement of individual bottles during operation. The hydrogen is stored in the steel bottles at a very high pressure. The hydrogen gas available in the manifold at bottle pressure is passed to two parallel – connected pressure reducers for expansion to the required intermediate pressure and is then passed to pressure reducer on the gas value rack for expansion to the pressure required for generator operation. Relief values on the low-pressure sides of all pressure reducers are connected to an outlet pipe system through which any excess hydrogen is passed to the atmosphere. All pressure reducers are of identical design. Single-stage construction of the pressure reducers ensures a constant pressure, even under low or no flow conditions, and allows large volume flow quantities of hydrogen to be reduced in pressure during the hydrogen filling procedure.

2. CO_2 Supply:-

As a precaution against explosive mixtures, air must never be directly replaced with hydrogen during generator filling nor the hydrogen replaced directly with air during the emptying procedure. In both cases, the generation must be scavenged or purged with an insert gas, carbon dioxide (CO_2) being used for this purpose.

a) CO_2 bottle rack:-

The CO_2 is supplied in steel bottles in the liquid state. The bottle should be provided with risers to ensure completely emptying. The arrangement of the CO_2 bottle rack corresponds to that of H_2 bottle rack. The liquid CO_2 which is stored under pressure, is fed to the gas valve rack via a shutoff valve.

b) CO_2 flash Evaporator:-

At the gas valve rack the liquid CO_2 is evaporated and expanded in a CO_2 flash evaporator. The heat for vaporization is supplied to the flash evaporator electrically. A temperature control is provided so that freezing of the flash evaporator is prevented, and the CO_2 is admitted into the generator at the proper temperature. One safety valve each on the high-pressure and low-pressure sides protects the pipe system against inadmissibly high pressure.

Compressed Air Supply:-

To remove the CO_2 from the generator, a compressed air supply with compressed air filter is connected to the general air system of the power plant.

Under all operating conditions, except for CO_2 purging, the compressed air hoses between the filter and the generator pipe system should be disconnected. This visible break is to ensure that no air can be admitted into a hydrogen-filled generator.

3. Nitrogen (N_2) Supply:-

On a water-cooled turbine generator an additional nitrogen supply is required for

a) Removing the air above the water level in the primary water tank during initial operation of the primary water system.

b) Removing the oxygen dissolved in the primary water during filling of the primary water system.

c) Removing the hydrogen gas above the water level in the primary water tank during shutdown of the primary water system.

d) Removing the hydrogen gas dissolved in the primary water during shutdown of the primary water system.

The N_2 purge during initial operation ensures a compete removal of the oxygen from the primary water circuit, thus eliminating the risk of corrosion attack.

The N_2 purge during shutdown prevents the formation of an explosive hydrogen-air mixture. During operation hydrogen may enter into the primary water tank by diffusion at the insulating hoses.

The nitrogen available from a bottle is passed to a pressure reducer for expansion and admitted into the primary water tank via the N_2 supply line.

4. Gas Dryer:-

A small amount of the hydrogen circulating in the generator for cooling is passed through a gas dryer. The gas inlet and gas outlet pipes of the gas dryer are connected at points of the generator with different static heads (differential fan pressure). So that the gas is forced through the dryer by the differential pressure only.

The gas dryer is a pressure-resistant chamber filled with moisture absorbent material. The absorbent material can be reactivated at any time when the generator is running by means of a heater, a fan and two changeover valves.

Primary Water Supply:-

The primary water required for cooling the stator winding is circulated in a closed system.

In order to prevent corrosion, only copper stainless steels or similar corrosion-resistant materials are used throughout the entire cooling circuit.

The primary water system consist of the following principal components:

1) Primary water tank.
2) Primary water pumps
3) Cooler

4) Filters
5) Primary water treatment system
6) Alkalization unit.

The primary water admitted to the pump from the primary water tank is first passed to the cooling water manifold in the generator interior and then to the main bushings via the cooler and fine filter. After having absorbed the heat losses in the stator winding, phase connectors and main bushings the water is returned to the primary water tank returned to the primary water tank from the other end of the generator or along the main bushings on the other side. The gas pressure above the water level in the primary water tank is maintained constant by a pressure controller.

1) Primary water tank:-

The primary water tank is mounted on the stator frame on antivibration pad and is covered by the generator lagging. The purpose of the 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 the inlet and outlet manifolds.

Since the primary water tank is the lowest pressure point in the system, has a relatively high water temperature, a large water surface and sufficient retention time, intensive degassing of the primary water is ensured. 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 rated at a water level gauge. Additionally, a capacitance type measuring system is provided for activating an alarm at minimum and maximum water level.

2) Primary water pumps:-

The primary water is circulated in a closed circuit. To ensure uninterrupted generator operation, two full capacity pumps are provided. Each pumps is driven by separate motor. In the event of failure of one pump the standby pump is immediately ready for services and cuts in automatically.

3) Primary water cooler:-

The primary water cooler is of straight tube type. One tube sheet is stationary, while the other tube sheet is a floating type. The floating tube sheet is sealed by two glands. The intermediate ring between the two glands has leakage water drain holes.

Advantages of this type of tube sheet design:-

1. Tube bundle is free to move in response to temperature changes.
2. The water channel at the glands can be removed without draining the primary water.
3. If a gland leaks, no cooling water can center the primary water circuit.
4. Any gland leakage will be indicated at the leakage water drain holes of the intermediate ring.

5) Primary water treatment system:-

Because the primary water makes direct contact with the high-voltage winding, the conductivity of primary water must be very low. During operation, the electrical conductivity is maintained below a value of 2μs/cm. In order to maintain such a low conductivity, it is necessary to provide for continuous treatment of the primary water. For this purpose a small quantity of the primary water flow is continuously passed through an ion exchanger arranged in a by pass to the main cooling circuit. The ion-exchanger resin material requires replacement at infrequent intervals. The resin can be replaced during operation of the turbine generator, since even with the water treatment system out of service; the conductivity will rise only very slowly.

The primary water system can be filled during commissioning and topped up from the condensate system.

6) Alkalization Unit:-

The low oxygen primary water is alkalized to prevent flow blockages due to copper corrosion in the water cooled winding. The PH of the primary water is kept constant at 8.5 to 9 by continuous dosing of diluted sodium hydroxide solution.

EXCITER:

1. The Exciter consist of:

Rectifier wheels

Three phase main Exciter

Three phase pilot Exciter

Cooler

Metering and supervisory equipment.

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 TVR to provide a variable dc current for exciting the main exciter. The 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.

A common shaft carrier 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 exciters. The generator and exciter rotors are thus supported on total of three bearings.

Mechanical coupling of the two shaft assemblies results in simultaneous coupling of the dc leads in the central shaft bore through the multikntakt 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.

Rectifier Wheels:-

The main components of the rectifier wheels are the silicon diodes which are arranged in the rectifier wheels in a three phase bridge circuit. The contact pressure for the silicon wafer is produced by a plate spring assembly. The arrangement of the diode is such that this contact pressure is increased by the centrifugal force during rotation.

Additional components are contained in the rectifier wheels. Two diodes each are mounted in each aluminum alloy heat sink and thus connected in parallel. Associated with each heat sink is a fuse which serves to switch off the two diodes if one diode falls (Loss of reverse blocking capacity).

For suppression of the momentary voltage peaks arising from commutation, each wheel is provided with six RC networks consisting of one capacitor and one damping resistor each, which are combined in a single resin-encapsulated unit.

The insulated and shrunken rectifier wheels serves as dc buses for the negative and positive side of the rectifier bridge. This arrangement ensures good accessibility to all components and a minimum of circuit connections. The two wheels are identical in their mechanical design and differ only in the forward direction of the diodes.

The direct current from the rectifier wheels is fed to the dc leads arranged in the center bore of the shaft via radial bolt.

The three-phase alternating current is obtained via copper conductors arranged on the shaft circumference between the rectifier wheels and the three-phase main exciter. The conductors are attached by means of banding clips and equipped with screw-on lugs for the internal diode connection. One three phase conductor each is provided for the four diodes of a heat sink set.

3. Three-phase Main Exciter:-

The three-phase main exciter is a six-pole revolving-armature unit. Arranged in the stator frame are the poles with the field and damper winding. The field winding is arranged on the laminated magnetic poles. At the pole shoe bars are provided, their ends being connected so as to form a damper

winding. Between two poles a quadrature-axis coil is fitted for inductive measurement of the exciter current.

The rotor consist of stacked laminations, which are compressed by through bolts over compression rings. The three phase winding is inserted in the slots of the laminated rotor. The winding conductors are transposed within the core length and the end turns of the rotor winding are secured with steel bonds. The connections are made on the side facing the rectifier wheels. The winding ends are run to a bus ring system to which the three phase leads to the rectifier wheels are also connected. After full impregnation with synthetic resin and curing, the complete rotor is shrunk on to the shaft.

A general bearing is arranged between main exciter and pilot exciter and has forced-oil lubrication from the turbine oil supply.

4. Three-Phase Pilot Exciter:-

The three-phase pilot exciter is a 16 pole revolving-field unit. The frame accommodates the laminated core with the three-phase winding. The rotor consist of a hub with mounted poles. Each pole consist of 10 separate permanent magnets which are housed in a non-magnetic metallic enclosure. The magnets are braced between the hub and the external pole shoe with bolts. The rotor hub is shrunk onto the free shaft end.

5) Cooling of Exciter:-

The exciter is air cooled. The cooling air is circulated in a closed circuit and recooled in two cooler sections arranged alongside the exciter.

The complete exciter is housed in an enclosure through which the cooling air circulates.

The rectifier wheels, housed in their own enclosure, draw the cool air in at both ends and expel the warmed air to the compartment beneath the base plate.

The main exciter enclosure receives cool air from the fan after it passes over the pilot exciter. The air enters the main exciter from both ends and is passed into ducts below the rotor body and discharged through radial

slots in the rotor core to the lower compartment. The warm air is then returned to the main enclosure via the cooler sections.

Emergency cooling of Exciter:-

Emergency cooling is provided to permit continued operation in the event of cooler failure. In such an emergency, flaps in the hot and cold air compartments are automatically operated by actuators admitting cold air from outside the exciter enclosure and discharging the hot air through openings in the base frame.

7. Replacement of air inside Exciter Enclosure:-

When the generator is filled with hydrogen an adequate replacement of the air inside the exciter enclosure must be ensured. The air volume inside the exciter enclosure requires on air change rate of 125 m^3/h.

While the generator is running the air leaving the exciter enclosure via the bearing vapour exhaust system and the leakage air outlet in the foundation provides for a pull-through system. The volume of air extracted from the cooling air circuit is replaced via the filters located at the top of the enclosure.

When the generator is at rest, the air dryer of the exciter unit discharges dry air inside the exciter enclosure via the leakage air filter and leakage air outlet at the shaft as well as through the bearing vapour exhaust system of this system is in service.

Merits of Brushless Exciter:

1. Eliminate slip rings, brush gear, filed braker and excitation bus/cables.
2. Eliminates all the problem associated with transfer of current via sliding contacts.
3. Simple reliable and ideally suited for large sets.

4. Minimum operation and maintenance costs.
5. Self generating excitation unaffected by system faults or disturbances of shaft mounted pilot exciter.
6. Increasingly popular system the world over.

1. General:-

The two pole generator uses direct water cooling for the stator winding phase connectors and bushings and direct hydrogen cooling for the rotor winding. The losses in the remaining generator components, such as iron losses, wind age losses and stray losses, are also dissipated through hydrogen.

The generator frame is pressure resistant and gas tight and equipped with one stator end shield on each side. The hydrogen coolers are arranged vertically inside the turbine end stator end shield.

The generator consist of following components:

Stator:-

Stator frame

End Shields

Stator Core

Stator Winding

Hydrogen Coolers

Rotor:-

Rotor Shaft

Rotor Winding

Rotor retaining rings

Field connections

Bearings:-

Shaft Seals

Additional auxiliaries for generator operation

Oil system

Gas system

Primary Water System

Excitation system

Block-1 Production and capacity

	Name	Type	Capacity
1.	Turbogenerator	Air cooled Hydrogen cooled Water cooled	500 MW
2.	Hydrogenerator	Umbrella Semiumbrella Suspension Horizontal	250 MW
3.	Motors	AC Motors	35 MW
		DC Motors	12 MW (670 rpm)

Layout "CNC conductor cutting machine"

1. Copper storage
2. Bobbin Ready to use.
3. Tool Rack
4. Bobbin revolving machine
5. Tension device
6. Conductor cutting machine
7. Drum for plastic waste

8. Control panel
9. Operator control desk
10. Waste glass dust collector
11. Conductor shifting table