A
Project Report
On
Practical Training Undergone At
"BHARAT HEAVY ELECTRICALS LIMITED"
Submitted For
Partial fulfilment for the award of the degree for
Bachelor of Technology
In
Electrical Engineering

Submitted by: HARSHIT BHANDARI
B.TECH. 3rdYEAR
ELECTRICAL ENGG.

JODHPUR INSTITUTE OF ENGINEERING & TECHNOLOGY
JODHPUR

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CHAPTER-1

INTRODUCTION

In 1953, India took a major step towards the establishment of its heavy engineering industry when Bharat Heavy Electrical Ltd., the first heavy electrical manufacturing unit of the country was setup at Bhopal. It progressed rapidly and three more factories went into production in 1965. The main aim of establishing BHEL was to meet the growing power requirement of the country. BHEL appeared on the power map of India in 1969 when the first unit supplied by it was commissioned at the Basin Bridge Thermal Power Station in Tamil Nadu. Within a decade, BHEL had commissioned the 100 unit at Santali. West Bengal,BHEL had taken India from a near total dependence on imports to complete self-reliance in this vital area of power plant equipment BHEL has supplied 97% of the power generating equipment. BHEL has already supplied generating equipment to various utilities capable of generating over 18000 MW power. Today BHEL can produce annually; equipment capable of generating 6000MW. This will grow further to enable BHEL to meet all of India's projected power equipment requirement. As well as sizeable portion of export targets

Probably the most significant aspect of BHEL's growth has been its diversification. The constant reorientation of the organization to meet the varied needs in time with time a philosophy that has led to the development of a total capability from concepts to commissioning not only in the field of energy but also in industry and transportation. In the world power scene, BHEL ranks among the top ten manufactures of power plant equipment and in terms of the spectrum of products and services offered, it is right on top. BHEL's technological excellence and turnkey capabilities have won it worldwide recognition. Over 40 countries in the world over have placed orders with BHEL covering individual equipment to complete power stations on a turnkey basis. In 1978-79 export earnings reached Rs.122 crores, the highest for any one-year. BHEL has its headquarters at New Delhi. Its operations are spread over 11 manufacturing plants and number of engineering and service divisions located across the country the service divisions includes a network of regional branch offices throughout India.

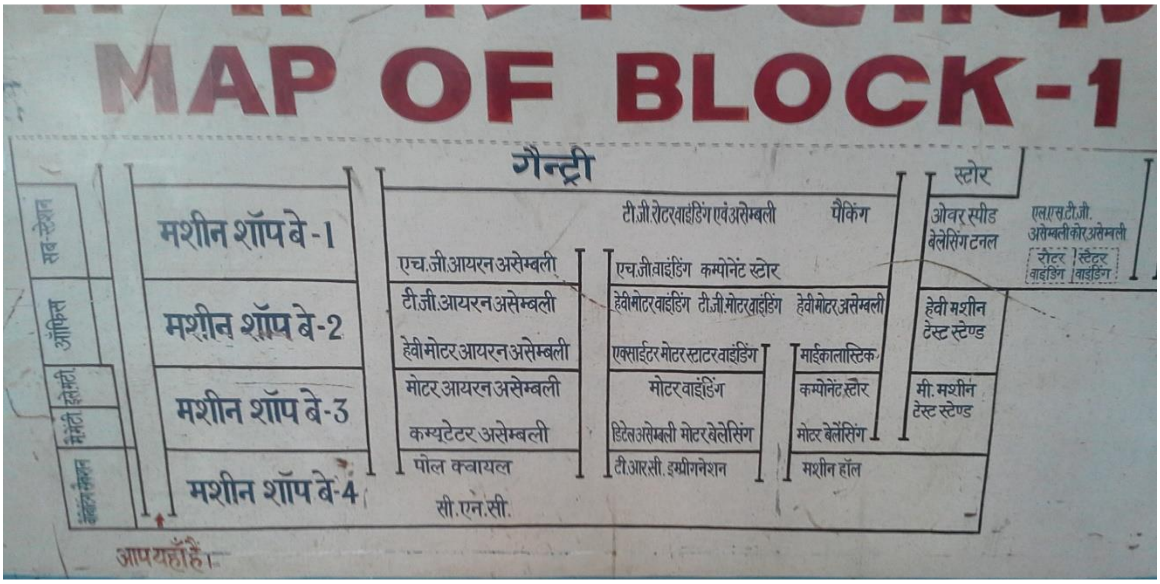

Fig 1: Layout of Block I

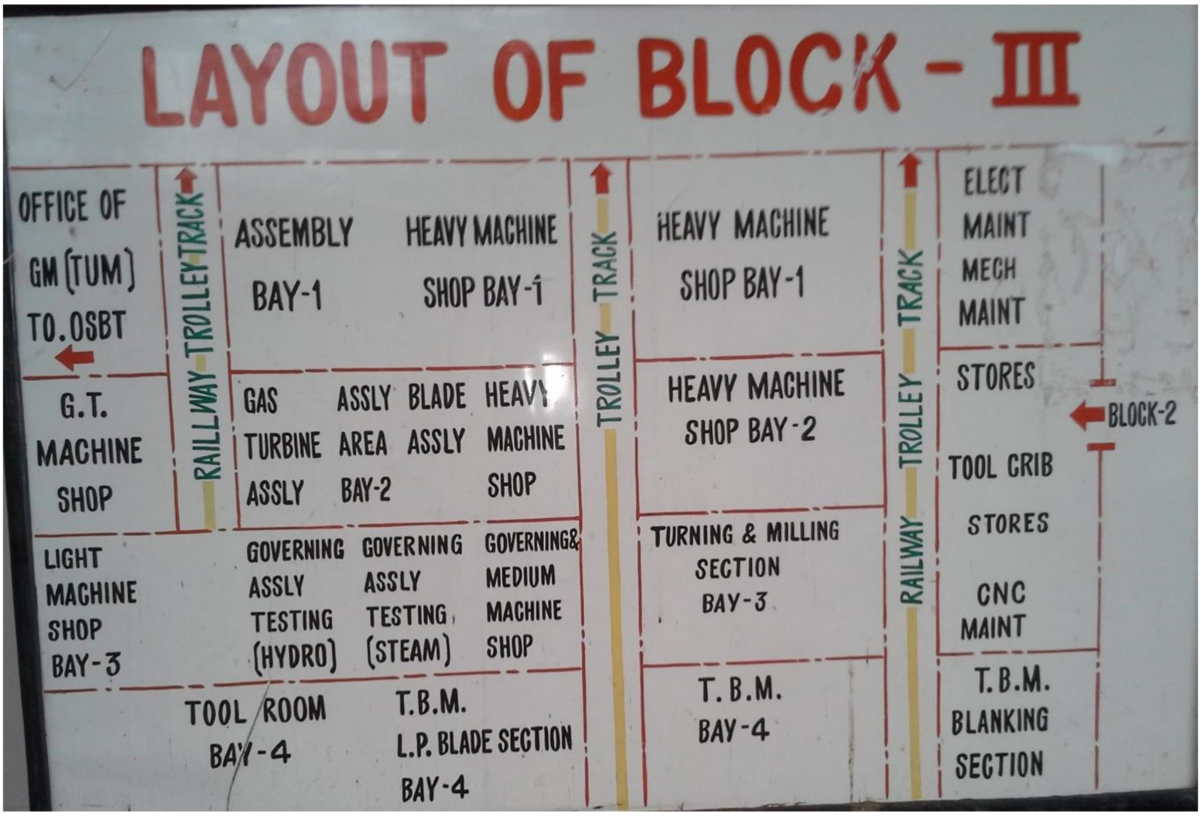

Fig2: Layout Of Block III(Turbine Shop)

Fig 3: Products Manufactured in Block IV

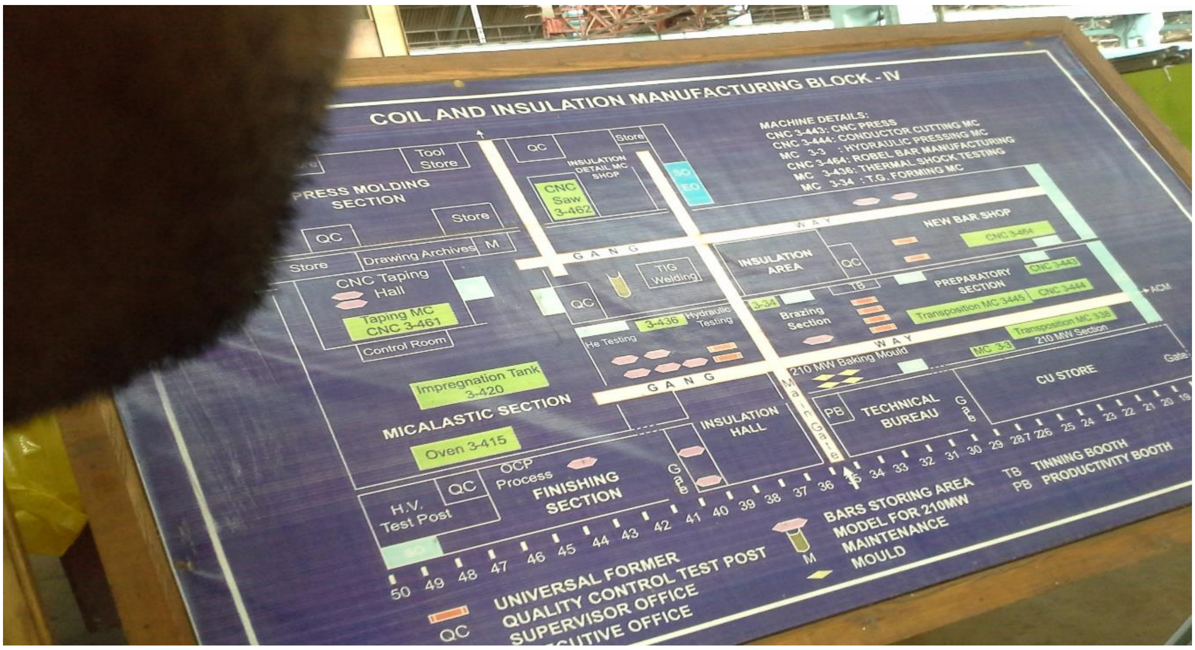

Fig 4: Layout of Block IV

CHAPTER-2
BHEL-A Brief Profile

BHEL is the largest engineering and manufacturing enterprise in India in the energy-related / infrastructure sector, today. BHEL is 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 Performa widespread value network comprising of 14 manufacturing companies, which have international recognition for its commitment towards quality. With an export presence in more than 60 countries, BHEL is truly India's ambassador to the world. BHEL's vision is to become world-class engineering enterprise, committed to enhancing stakeholder.

BHEL has:-

- Installed equipment for over 90,000MW of power generation for Utilities, captive and Industrial users.
- Supplied over 25000 Motors with Drive Control System to power projects, Petrochemicals Refineries, Steel, Aluminium, Fertilizer, Cement plant, etc.
- Supplied Traction electrics and AC/DC locos over 12000 km Railway network.
- Supplied over one million values to Power Plants and other Industries.

CHAPTER-3
BHEL - An Overview

The first plant of what is today known as BHEL was established nearly 40 years ago at Bhopal & was the genesis of the Heavy Electrical Equipment industry in India. BHEL is today the largest Engineering Enterprise of its kind in India with excellent track record of performance, making profits continuously since 1971-72.

BHEL business operations cater to core sectors of the Indian Economy like.

- ✓ Power
- ✓ Industry
- ✓ Transportation
- ✓ Transmission
- ✓ Defences etc.

Today BHEL has

- 14 Manufacturing Divisions
- 9 Service Centres
- 4 Power Sector Regional Centers

Over the years, Bharat Heavy Electrical Limited has emerged as world class engineering and Industrial giant, the best of its kind in entire South East Asia. Its business profile cuts across various sectors of engineering/power utilities and industry. The company today enjoys national and international presence featuring in the " fortune international-500" and is ranked among the top 12 companies of the world, manufacturing power generation equipment. BHEL has now 14 manufacturing division, 8 service centres and 4power power sectors regional enters besides a large number of project sites spread over India and abroad. The company is embarking upon an ambitious growth path through clear vision, mission and committed values to sustain and augment its image as a world-class enterprise.

VISION

A world-class innovating, competitive and profitable engineering enterprise providing total business solution.

MISSION

To be the leading Indian engineering enterprise providing quality products system and services in the field of energy, transportation, infrastructure and other potential areas.

VALUES

- Meeting commitments made to external & internal customers

- Foster learning creative and speed of response
- Respect for dignity and potential of individual
- Loyalty and pride in the company
- Team playing

BHEL's vision is to become world class engineering enterprise, committed to enhancing stakeholder value. The greatest strength of BHEL is its highly skilled and committed 44,000 employees. Spread all over India & abroad to provide prompt and effective service to customers.

BUSINESS SECTOR

BHEL operations are organized around business sectors to provide a strong market orientation. These business sectors are Power Indus and International operations.

POWER SECTOR

- Power sector comprises of thermal, nuclear, gas and hydro business. Today BHEL supplied sets account for nearly 65% of the total installed capacity in the country as against nil till 1969-70.
- BHEL has proven turnkey capabilities for executing power projects from concept to commissioning and manufactures boilers, thermal turbine generator set and auxiliaries up to 500MW.
- It possesses the technology and capability to procure thermal power generation equipment upto 1000MW.
- Co-generation and combined cycle plants have also been introduced.
- For efficient use of the high ash content coal-BHEL supplies circulating fluidized boiler.
- BHEL manufactures 235MW nuclear sets and has also commenced production of 500MW nuclear set. Custom-made huge hydro sets of Francis, Elton and Kaplan types for differenthead- discharge combinations are also engineered and manufactured by BHEL.

INDUSTRY SECTOR

BHEL is a major contributor of equipment and system to important industries like

- Cement
- Petrochemicals
- Fertilizers
- Steel paper
- Refineries

- Mining and Telecommunication

TRANSPORATION

BHEL supplies a wide equipment and system to Indian Railways.
Electric locomotive
Traction electric and traction control equipment

TELECOMMUNICATION

BHEL also caters to Telecommunication sector by way of small, medium and large switching system.

MANUFACTURING DIVISIONS

- Heavy Electrical Plant, Piplani, Bhopal
- Electrical Machines Repair Plant (EMRP), Mumbai
- Transformer Plant P.O. BHEL, Jhansi.
- Bharat Heavy Electrical Limited Ranipur, Hardwar
- Heavy Equipment Repair Plant, Varanasi.
- Insulator Plant, Jagdishpur, Distt. Sultanpur.
- Heavy Power Equipment Plant, Ramachandra Puram,Hyderabad
- High Pressure Boiler Plant & Seamless Steel Tube Plant,Tiruchirappalli.
- Boiler Auxiliaries Plant, Indira Gandhi Industrial Complex, Ranipet.
- Industrial Valves Plant, Goindwal.
- Electronics Division, Bangalore
- Component Fabrication Plant, Rudrapur.
- Piping Centre, Chennai.
- Heavy Electrical Equipment Plant,Hardiwar
- Regional Operations Division, New Delhi

CHAPTER-4
HEEP: AN OVERVIEW

Heavy Electrical Equipment Plant, BHEL, HARIDWAR has divided into 8 blocks:-

1). Block 1
In block one turbo generator, generator, exciter motors (A.C&D.C) are manufactured & assembled

2). Block 2
In block two large size fabricated assemblies\component for power equipment are manufactured & assembled.

3) Block 3
In block -3 steam turbine, hydro turbines, and gas turbines, turbines blade are manufactured & assembled

4) Block 4
In block -4 winding for turbo generator, hydro generator, insulation of A.C & D.C motors insulating component for turbo generator, hydro generator motors are manufactured & assembled

5) Block 5
In block -5 fabricated parts of steam turbine water box, hydro turbine turbines parts are manufactured & assembled

6) Block 6
In block -6 fabricated oil tanks hollow guide blades, rings, stator frames rotor spiders are manufactured & assembled

7) Block 7
In block -7all types of dies including stamping dies, stamping for generators & motors are manufactured & assembled

8) Block 8
In block -8 LP heaters, ejectors, steam coolers, oil coolers, ACG coolers, oil tanks are manufactured & assembled

CHAPTER-5
ELECTRICAL MACHINES BLOCK (BLOCK-I)

1. Block-I is designed to manufacture Turbo Generators.
2. The block consists of 4 bays-
Bay-I (36*482 meters), Bay-II(36*360 meters) and Bay-III and Bay-IV (Of size 24*360 meters each)
3. For handling and transporting the various components over-head crane facilities are available, depending upon the products manufactured in each Bay. There are also a number of self- propelled electrically driven transfer trolleys for the inter-bay movement of components / assemblies.
4. Testing facilities for Turbo generator are available in Bay-II.
5. There is a special test bed area for testing of T.G. of capacity of 500 MW Unit sizes.

CHAPTER-6
Types of Turbo generators

For the turbo generator the manufacturing of bars of standard capacity such as 100 MW,130MW, 150MW, 210/235MW,210/250MW. This plant has capacity and technology to manufacturing 800 MW generators.

TYPE OF GENERATORS
The generator may be classified based upon the cooling system used in the generators such as; THRI, TARI, THDI, THDD, THDF, THFF, THW
T/H ie. Turbo Generator or Hydro Generator’s
H/A/W=i.e. Hydrogen Gas, Air,Water
D/F/I=i.e. Radial, indirect, forced
W=i.e. cooling media used for cooling of stator coil

CHAPTER-7
MANUFACTURING PROCESS

Fabricated components are received in respective machine sections from fabrication blocks (Block — II, V, VI, VIII), while castings and forgings are received from sister unit CFFP and other indigenous and foreign sources for Turbo Generators. Stampings are received from stampings manufacture block, block—VI and coils, bars, insulating details and sheet metal components are received from coils and insulation manufacture and apparatus and control gear box (block — IV).

1. Turbo Generators –

a) Making of blanks is done for checking the availability of machining allowances.

b) Machining of the major components is carried out in Bay - I &Bay- II and other small components in Bay - III and Bay - IV. The boring and facing of stators are done on CNC horizontal boring machine using a rotary table. The shaft is turned on lathe having swift 2500 mm and the rotor slots are milled on a special rotor slot milling machines.

Fig 5: ***CNC PANEL***

c) In case of large size Turbo Generators core bars are welded to stator frame with the help of telescopic cantering device. The entering of core bar is done very precisely. Punching are assembled manually and cores are heated and pressed in number of stages depending on the core lengths.

d) Stator winding is done by placing stator on rotating installation. After laying of lower and upper bars, these are connected at the ends, with the help of ferrule and then soldered by resistance soldering.

e) Rotor winding assembly is carried out on special installation where coils are assembled in rotor slots. The pressing of overhang portion is carried out on special ring type hydraulic press, whereas slot portion is pressed manually with the help of rotor wedges. Coils are wedged with special press after laying and curing. The dynamic balancing of rotors is carried out on the over speed balancing installation. 500 MW Turbo Generators are balanced in vacuum balancing tunnels

Fig 6: Un-slotted Rotor

f) General assembly of Turbo Generators is done in the test bed. Rotor is inserted in the stator and assembly of end shields, bearings etc. are carried out to make generators ready for testing. Prior to test run the complete generator is hydraulically tested for leakages

g) Turbo Generators are tested as per standard practices and customer requirements.

CHAPTER-8
TURBO GENERATOR

8.1 500 MW Turbo generators at a glance -

2-Pole machine with the following features:-
• Direct cooling of stator winding with water.
•Direct hydrogen cooling for rotor.
• Moralistic insulation system
• Spring mounted core housing for effective transmission of vibrations.
•Brushless Excitation system.
• Vertical hydrogen coolers

Salient technical data–
• Rated output: 588 MVA, 500 MW
• Terminal voltage: 21 KV
• Rated stator current: 16 KA
• Rated frequency: 50 Hz
• Rated power factor: 0.85 Lag
• Efficiency: 98.55%

Important dimensions & weights –
Heaviest lift of generator stator: 255 Tons
Rotor weight: 68 Tons
Overall stator dimensions [LxBxH]: 8.83Mx4.lMx4.02M
Rotor dimensions: 1.15M dia x 12.11 M length
Total weight of turbo generator: 428 Tons

8.2 Unique installations–

Heavy Electrical Equipment Plant, Haridwar is one of the best equipped and most modern plants of its kind in the world today. Some of the unique manufacturing and testing facilities in the plant are:

TG Test Bed– New LSTG [Large Scale Turbo Generator] Test Bed has been put-up with indigenous know how in record time for testing Turbo generators of ratings 500 MW and above up to 1000 MW. It caters to the most advanced requirement of testing by employing on-line computer for data analysis.

Other major facilities are as follows –
• Major facilities like stator core pit equipped with telescopic hydraulic lift, moralistic plant for the manufacture of stator bars, thermal shocks test equipment, rotor slot milling machine etc. have been specially developed by

BHEL.12 MW/10.8 MW, 6.6 KV, 3000 RPM AC non salient pole, synchronous motor has been used for driving the 500 MW turbo generator at the TEST Bed. The motor has special features to suit the requirement of TG testing (500 MW and above). This is the largest 2- pole (3000 rpm).

Over speed Balancing vacuum tunnel –
For balancing and over speeding large flexible Turbo generators rotors in vacuum for ratings up to 1,000 MW, an over speed and balancing tunnel has been constructed indigenously. This facility is suitable for all types of rigid and flexible rotors and also high speed rotors for low and high speed balancing, testing at operational speed and for over speeding.

Generator transportation –
• Transport through 300 Tons 24-Axle carrier beam railway wagon specially designed indigenously and manufactured at Haridwar.• The wagon has been used successfully for transporting one generator -from Calcutta Port to Singrauli STPP.

CHAPTER-9
CONSTRUCTIONAL FEATURES OF STATOR BODY

1) **Stator Frame –**

Stator body is a totally enclosed gas tight fabricated structure made-up of high quality mild steel and austenitic steel. It is suitably ribbed with annular rings in inner walls to ensure high rigidity and strength .The arrangement, location and shape of inner walls is determined by the cooling circuit for the flow of the gas and required mechanical strength and stiffness. The natural frequency of the stator body is well away from any of exciting frequencies. Inner and sidewalls are suitably blanked to house for longitudinal hydrogen gas coolers inside the stator body.

2) **Pipe Connection –**

To attain a good aesthetic look, the water connection to gas cooler is done by routing stainless steel pipes; inside the stator body; which emanates from bottom and emerges out of the sidewalls. These stainless steel pipes serve as inlet and outlet for gas coolers. From sidewall these are connected to gas coolers by the means of eight U-tubes outside the stator body. For filling the generator with hydrogen, a perforated manifold is provided at the top inside the stator body.

3) **Terminal Box –**

The bearings and end of three phases of stator winding are brought out to the slip-ring end of the stator body through 9 terminal brushing in the terminal box. The terminal box is a welded construction of (non-magnetic) austenitic steel plates. This material eliminates stray losses due to eddy currents, which may results in excessive heating.

4) **Testing Of Stator Body –**

On completion of manufacture of stator body, it is subjected to a hydraulic pressure of 8 kg/cm for 30 minutes for ensuring that it will be capable of withstanding all expansion pressure, which might arise on account of hydrogen air mixture explosion. Complete stator body is then subjected to gas tightness test by filling in compressed air.

500MW Turbo Generator At Test Bed

Laying Of Water Cooled Winding In the Stator Of 500 MW Turbo Generator

Fig 7: Testing and Laying of Turbo Generator

CHAPTER-10
CONSTRUCTIONAL FEATURES OF STATOR CORE

(1) Core –

It consists of thin laminations. Each lamination made of number of individual segments. Segments are stamped out with accurately finished die from the sheets of cold rolled high quality silicon steel. Before insulation on with varnish each segment is carefully debarred. Core is stacked with lamination segments. Segments are assembled in an interleaved manner from layer to layer for uniform permeability. Stampings are held in a position by 20 core bars having do vital section. Insulating paper pressboards are also put between the layer of stamping to provide additional insulation and to localize short circuit. Stampings are hydraulically compressed during the stacking procedure at different stages. Between two packets one layer of ventilating segments is provided. Steel spacers are spot welded on stamping. These spacers from ventilating ducts where the cold hydrogen from gas coolers enter the core radial inwards there by taking away the heat generated due to eddy current losses. The pressed core is held in pressed condition by means of two massive non-magnetic steel castings of press ring. The press ring is bolted to the ends of core bars. The pressure of the pressure ring is transmitted to stator core stamping through press fringes of non-magnetic steel and duralumin placed adjacent to press ring. To avoid-heating of press ring due to end leakage flow two rings made of copper sheet are used on flux shield. The ring screens the flux by short-circuiting. To monitor the formation of hot spots resistance transducer are placed along the bottom of slots. To ensure that core losses are within limits and there are no hot spots present in the core. The core loss test is done after completion of core assembly.

2) Core Suspension –

The elastic suspension of core consists of longitudinal bar type spring called core bars. Twenty core bars are welded to inner walls of stator body with help of brackets. These are made up of spring steel having a rectangular cross section and dove-tail cut at tap, similar type of do details also stamped on to stamping and fit into that of core bar dovetail. Thus offering a hold point for stamping core bars have longitudinal slits which acts as inertial slots and helping damping the vibrations. The core bars are designed to maintain the movement of stator core with in satisfactory limits.

Fig 8: Stator Core Frame

CHAPTER-11
CONSTRUCTIONAL FEATURES OF STATOR WINDING

1) General –

The stator has a three phase, double layer, short pitched and bar type of windings having two parallel paths. Each slots accommodated two bars. The slot lower bars and slot upper are displaced from each other by one winding pitch and connected together by bus bars inside the stator frame in conformity with the connection diagram.

2) **Conductor Construction –**

Each bar consist of solid as well as hollow conductor with cooling water passing through the latter. Alternate arrangement hollow and solid conductors ensure an optimum solution for increasing current and to reduce losses. The conductors of small rectangular cross-section are provided with glass lapped strand insulation separator insulates the individual layers from each other. The transposition provides for mutual neutralization of voltage induced in the individual strands due to the slots cross field and end winding field. The current flowing through the conductor is uniformly distributed over the entire bar cross section reduced. To ensure that strands are firmly bonded together and give dimensionally stability in slot portion, a layer of glass tape is wrapped over the complete stack. Bar insulation is done with epoxy mica thermosetting insulation. This insulation is void free and possesses better mechanical properties. This type of insulation is more reliable for high voltage. This insulation shows only a small increase in dielectric dissipation factor with increasing test voltage. The bar insulation is cured in an electrically heated process and thus epoxy resin fill all voids and eliminate air inclusions.

➢ Method Of Insulation –

Bar is tapped with several layers of thermosetting epoxy tape. This is applied continuously and half overlapped to the slot portion. The voltage of machine determines the thickness of insulation. The tapped bar is then pressed and cured in electrical heated press mould for certain fixed temperature and time.

➢Corona Prevention –

To prevent corona discharges between insulation and wall of slots, the insulation in slot portion is coated with semiconductor varnish. The various test for manufacture the bar are performed which areas follows–

(a) Inter turn insulation test on stuck after consolidation to ensure absence of inter short.

(b)Each bar is subjected to hydraulic test to ensure the strength of all joints.

(c) Flow test is performed on each bar to ensure that there is no reduction in cross section area of the ducts of the hollow conductor.

(d)Leakage test by means of air pressure is performed to ensure gas tightness of all joints.
(e)High voltage to prove soundness of insulation.
(f) Dielectric loss factor measurement to establish void free insulation.

➢ Laying Of Stator Winding –

The stator winding is placed in open rectangular slots of the stator core, which are uniformly distributed on the circumference. A semiconducting spacer is placed in bottom of slots to avoid any damage to bar due to any projection. Driving in semi conducting filler strips compensates any manufacturing tolerances. After laying top bar, slot wedges are inserted. Below slots wedges, high strength glass etiolate spacers are put to have proper tightness. In between top and bottom bars, spacers are also put.

➢Ending Winding –

In the end winding, the bars are arranged close to each other. Any gaps due to design or manufacturing considerations are fitted with curable prepay with spacer in between. The prepay material is also placed between the brackets and binding rings. Lower and upper layers are fixed with epoxy glass ring made in segment and flexible spacer put in between two layers. Bus bars are connected to bring out the three phases and six neutrals. Bus bars are also hollow from inside. These bus bars are connected with terminal bushing. Both are water cooled. Brazing the two lugs properly makes connection.

CHAPTER-12
CONSTRUCTIONAL FEATURES OF ROTOR

The rotor comprises of following component:
1) Rotor shaft
2) Rotor winding
3) Rotor wedges and other locating parts for winding
4) Retaining ring
5) Fans
6) Field lead connections

1) **Rotor Shaft** –

The rotor shaft is a single piece solid forging manufactured from a vacuum casting. Approximately 60 % of the rotor body circumference is with longitudinal slots, which hold the field winding. The rotor shaft is a long forging measuring more than 9m in length and slightly more than one meter in diameter. The main constituents of the steel are chromium, molybdenum, nickel and vanadium. The shaft and body are forged integral to each other by drop forging process. Following tests are done: -
(a)Mechanical test
(b)Chemical analysis
(c)Magnetic permeability test
(d)Micro structure analysis
(e)Ultrasonic examination
(f) Baroscopic examination
On 2/3 of its circumference approximately the rotor body is provided with longitudinal slot to accommodate field winding. The slot pitch is selected in such a way that two solid poles displaced by180 C are obtained. For high accuracy the rotor is subjected to 20% over speeding for two minutes. The solid poles are provided with additional slots in short lengths of two different configurations. One type of slots served as an outlet for hydrogen which has cooled the overhang winding and other type used to accommodate finger of damper segments acting as damper winding.

2) **Rotor Winding**

After preliminary turning, longitudinal slots are milled unsophisticated horizontal slot milling machine. The slot house the field winding consists of several coils inserted into the longitudinal slots of rotor body-
2.1. Copper Conductor –
The conductors are made of hard drawn silver bearing copper. The rectangular cross section copper conductors have ventilating duct son the two sides thus providing a channel for hydrogen flow. Two individual conductors placed-one over the other are bent to obtain half turns. Further these half turns are brazed in series to form colon the rotor model.

2.2. Insulation –

The individual turns are insulated from each other by layer of glass prepay strips on turn of copper and baked under pressure and temperature to give a monolithic inter turn insulation.The coils are insulated from rotor body by U-shaped glass laminate module slot through made from glass cloth impregnated with epoxy varnish. At the bottom of slot D-shaped liners are put to provide a plane seating surfaces for conductors and to facilitate easy flow of gas from one side to another. These liners are made from moulding material. The overhang winding is separated by glass laminated blocks called liners. The overhang winding are insulated from retaining rings segments having L-shape and made of glass cloth impregnated by epoxy resin.

2.3. Cooling Of Winding –

The rotor winding are cooled by means of direct cooling method of gap pick-up method. In this type of cooling the hydrogen in the gapes sucked through the elliptical holes serving as scoop on the rotor wedges and is directed to flow along lateral vent ducts on rotor The cantering rings are shrinking fitted at the free end of retaining ring that serves to reinforce the retaining ring, securing, end winding in axial direction at the same time. To reduce stray losses, the retaining rings are made of non-magnetic, austenitic steel and cold worked, resulting in high mechanical strength.

3**) Fans –**

Two single stage axial flow propeller type fans circulate the generator cooling gas. The fans are shrink fitted on either sides of rotor body. Fans hubs are made of alloy steel forging with three peripheral grooves milled on it. Fan blades, which are precision casting with special alloy, are machined in the tail portion so that they fit into the groove of the fan hub.

4) **Field Lead Connections –**

4.1 Slip Rings –

The slip ring consists of helical grooved alloy steel rings shrunk on the body shaft and insulated from it. The slip rings are provided with inclined holes for self-ventilation. The helical grooves cut on the outer surfaces of the slip rings improve brush performance by breaking the pressurized air pockets that would otherwise get formed between the brush and slip rings.

4.2 Field Lead –

The slip rings are connected to the field winding through semi flexible copper leads and current-carrying bolts placed in the shaft. The radial holes with current carrying bolts in the rotor shafts are effectively sealed to prevent the escape of hydrogen.

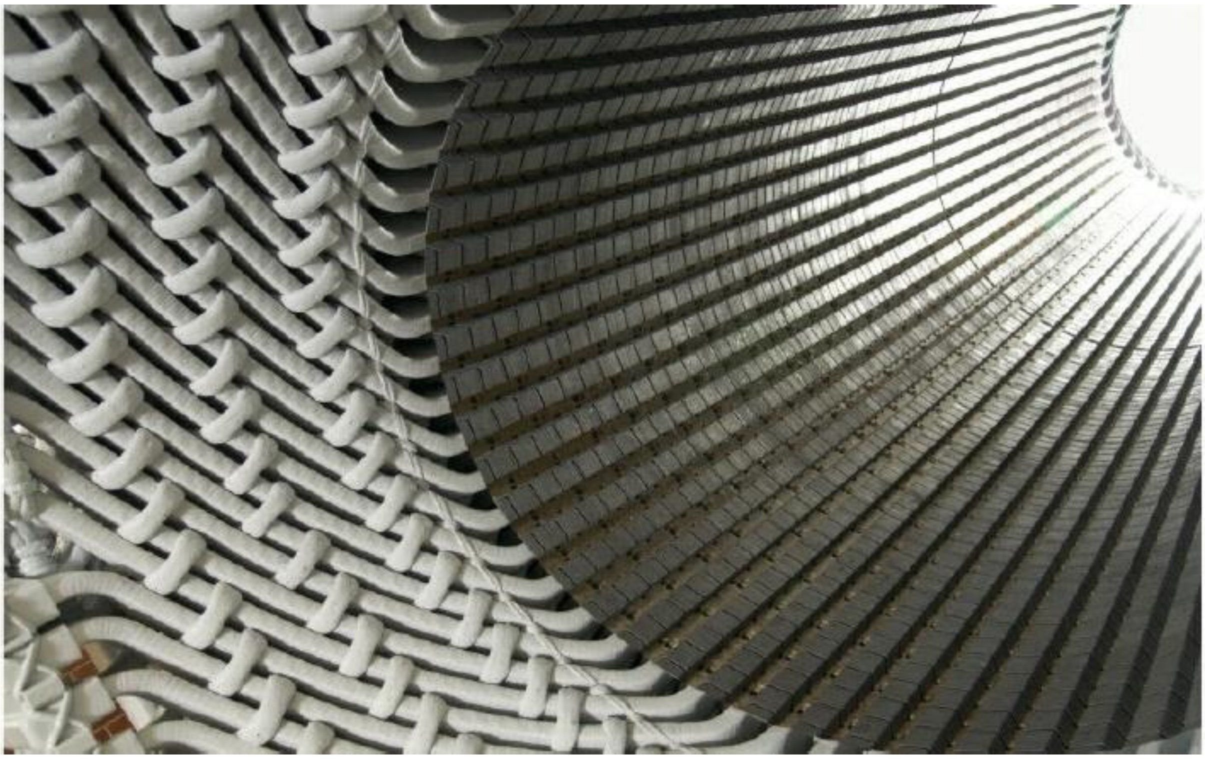

Fig 9: Completed Winding

CHAPTER 13
COOLING SYSTEM

Heat losses arising in generator interior are dissipated to secondary coolant (raw water, condensate etc.) through hydrogen and Primary water. Direct cooling essentially eliminates hot spots and differential temperature between adjacent components, which could result in mechanical stresses, particularly to the copper conductors, insulation, and rotor body and stator core.

Hydrogen Cooling Circuit:

The hydrogen is circulated in the generator interior in a closed-circuit by one multistage axial flow fan arranged on the rotor at the turbine end. Hot gases is drawn by the fan from the air gap and delivered to the coolers where it is recoiled and then divided into three flow paths after each cooler:

Flow path I:

Flow path I is directed into the rotor at the turbine end below the fan hub for cooling of the turbine end half of the rotor.

Flow path II:

Flow path II is directed from the cooler to the individual frame compartments for cooling of the stator core.

Flow path III:

Flow path III is directed to the stator end winding space at the exciter end through guide ducts in the frame of cooling of the exciter end half of the rotor and of the core end portion. The three flow paths miss the air gaps. The gas is then returned to the coolers via the axial flow fan. The cooling water flow through the hydrogen coolers should automatically control to maintain a uniform generator temperature level for various loads and cold-water temperature.

CHAPTER 14.
Cooling Of Rotors:

For direct cooling of rotor winding cold gas is directed to the rotor end wedges at the turbine and exciter ends. The rotor winding is symmetrical relative to generator centreline and pole axis. Each coil quarter is divided into two cooling zones consists of the rotor end winding and the second one of the winding portion between the rotor body end and the midpoint of the rotor. Cold gas is directed to each cooling zone through separate openings directly before the rotor body end. The hydrogen flows through each individual conductor is closed cooling ducts. The heat removing capacity is selected such that approximately identical temperature is obtained for all conductors. The gas of the first cooling zone is discharged from the coils at the pole centre into a collecting compartment within the pole area below the end winding from the hot gases passes into air gap through the pole face slots at the end of the rotor body. The hot gas of the second cooling zone is discharged into the air gap at the mid length of the rotor body through radial openings in the hollow conductors and wedges.

CHAPTER 15.
Cooling of stator core:

For cooling of the stator core, cold gas is passes to the individual frame compartment via separate cooling gas ducts. From these frames compartment the gas then flow into the air gap through slots and the core where it absorbs the heat from the core. To dissipate the higher losses in core ends the cooling gas section. To ensure effective cooling. These ventilating ducts are supplied from end winding space. Another flow path is directed from the stator end winding space paste the clamping fingers between the pressure plate and core section into the air gap along either side of flux shield. All the flows mix in the air gap and cool the rotor body and stator bore surfaces. The air gap is then returned to the coolers via the axial flow fan. To ensure that the cold gas directed to the exciter end cannot be directly discharged into the air gap. Air gap chokers arranged with in the stator end winding cover and the rotor retaining rings at the exciter end.

Primary Cooling Water Circuit in the Generators:

The treated water used for cooling of the stator winding, phase connectors and bushings is designated as primary water in order to distinguish it from the secondary coolant (raw water, condensate etc.). The primary water is circulated in a closed circuit and dissipates the absorbed heat to the secondary cooling in the primary water cooler. The pump is supplied with in primary water cooler.

The pump is supplied with in the primary water tank and delivers the water to the generator via the following flow paths:

Flow path I:

Flow path I cools the stator winding. This flow path passes through water manifold on the exciter end of the generator and from there to the stator bars via insulated bar is connected to the manifold by separate hose. Inside the bars the cooling water flows through hollow strands. At the turbine end, the water is passed through the similar hoses to another water manifold and then return to the primary water tank. Since a single pass water flow through the stator is used, only a minimum temperature rise is obtained for both the coolant and the bars. Relatively movements due to the different thermal expansions between the top and the bottom bars are thus minimized.

Flow Path II: Flow path II cools the phase connectors and the bushings. The bushing and the phase connectors consist of the thick walled copper tubes through which the cooling water is circulated. The six bushings and phase connectors arranged in a circle around the stator winding are hydraulically interconnected so that three parallel flow paths are obtained. The primary water enters three bushings and exits from the three remaining bushings. The secondary water flow through the primary water cooler should be controlled automatically.

CHAPTER 16
EXCITATION SYSTEM:

In large synchronous machines, the field winding is always provided on the rotor, because it has certain advantages they are: It is economical to have armature winding on the stator and field winding on the rotor. Stationary armature windings can be insulated satisfactorily for higher voltages, allowing the construction of high voltage synchronous machines.

• Stationary armature winding can be cooled more efficiently.
• Low power field winding on the rotor gives a lighter rotor and therefore low centrifugal forces. In view of this, higher rotor speeds are permissible, thus increasing the synchronous machine output for given dimensions.

Design features

The excitation system has a revolving field with permanent magnet poles. The three-phase ac output of this exciter is fed to the field of the main exciter via a stationary regulator & rectifier unit. Three- phase ac induced in the rotor of the main exciter is rectified by the rotating Rectifier Bridge & supplied to the field winding of the generator rotor through the dc lead in the rotor shaft. A common shaft carries the rectifier wheels, the rotor of the main exciter &PMG rotor. The shaft is rigidly coupled to the generator rotor. The generator & exciter rotors are supported on total three bearings.

Three Phase Pilot Exciter

It is a six-pole revolving field unit. The frame accommodates the laminated core with the three-phase winding. Each pole consists of separate permanent magnets that are housed in a non-magnetic metallic enclosure.

Three phase main exciter

The three phase main exciter is a six-pole armature-revolving unit. The field winding is arranged on the laminated magnetic poles. At the pole shoe, bars are provided which are connected to form a damper winding. Between the two poles, a quadrature-axis coil is provided for inductive measurement of the field current. After completing the winding & insulation etc., the complete rotor is shrunk on the shaft.

Rectifier wheels

The silicon diode is the main component of the rectifier wheels, which are arranged in a three-phase bridge circuit. With each diode, a fuse is provided which serves to cut off the diode from the circuit if it fails. Form suppression of the momentary voltage peaks arising from commutation, R-C blocks are provided in each bridge in parallel with each set of diodes. The rings, which form the positive& negative side of the bridge, are insulated from the rectifier wheel which in turn is shrunk on the shaft. The three phase connections between armature & diodes are obtained via copper conductors arranged on the shaft circumference between the rectifier wheels & the main exciter armature.

Voltage regulator

The voltage regulator is intended for the excitation and control of generators equipped with alternator exciters employing rotating uncontrolled rectifiers. The main parts of the regulator equipment are two closed-loop control systems including a separate gate control set and thyristor set, field discharge circuit, an open loop control system for exchanging signal between the regulator equipment and the control room, and the power supply circuits.

CHAPTER 17
MOTOR WINDING

17.1 Technical Requirements

(1) Count the coil groups in the anti-clock wise direction locking from the connection end.

(2)Leads of the coils groups lying on the outer periphery of the overhang position shall be the finish and those lying on the inner periphery shall be the start to coil groups.

(3) Leads shall be taken form the coil side lying at inner periphery of slot No.1.

(4) The coil group No.1 shall Lie at top with its axes coinciding with the vertical axis of the frame.

(5) Take out terminal leads 02 U2, V2, W2 for left hand side terminal box and 02 U1, V1, W1 for right hand side terminal box. When looking form the connection end.

17.2 CIRCUIT DIAGRAM

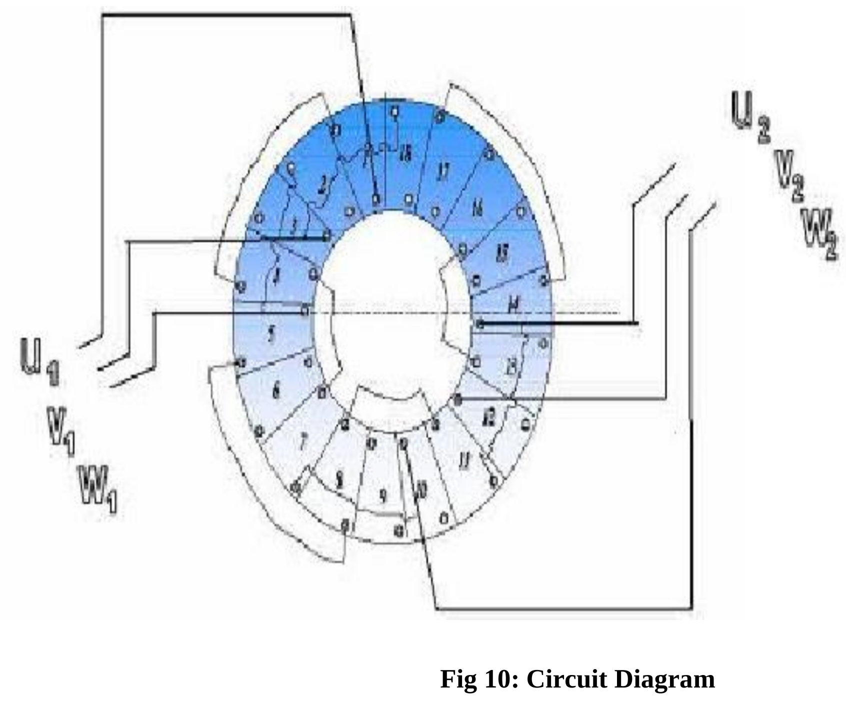

Fig 10: Circuit Diagram

CONNECTION DIAGRAM:

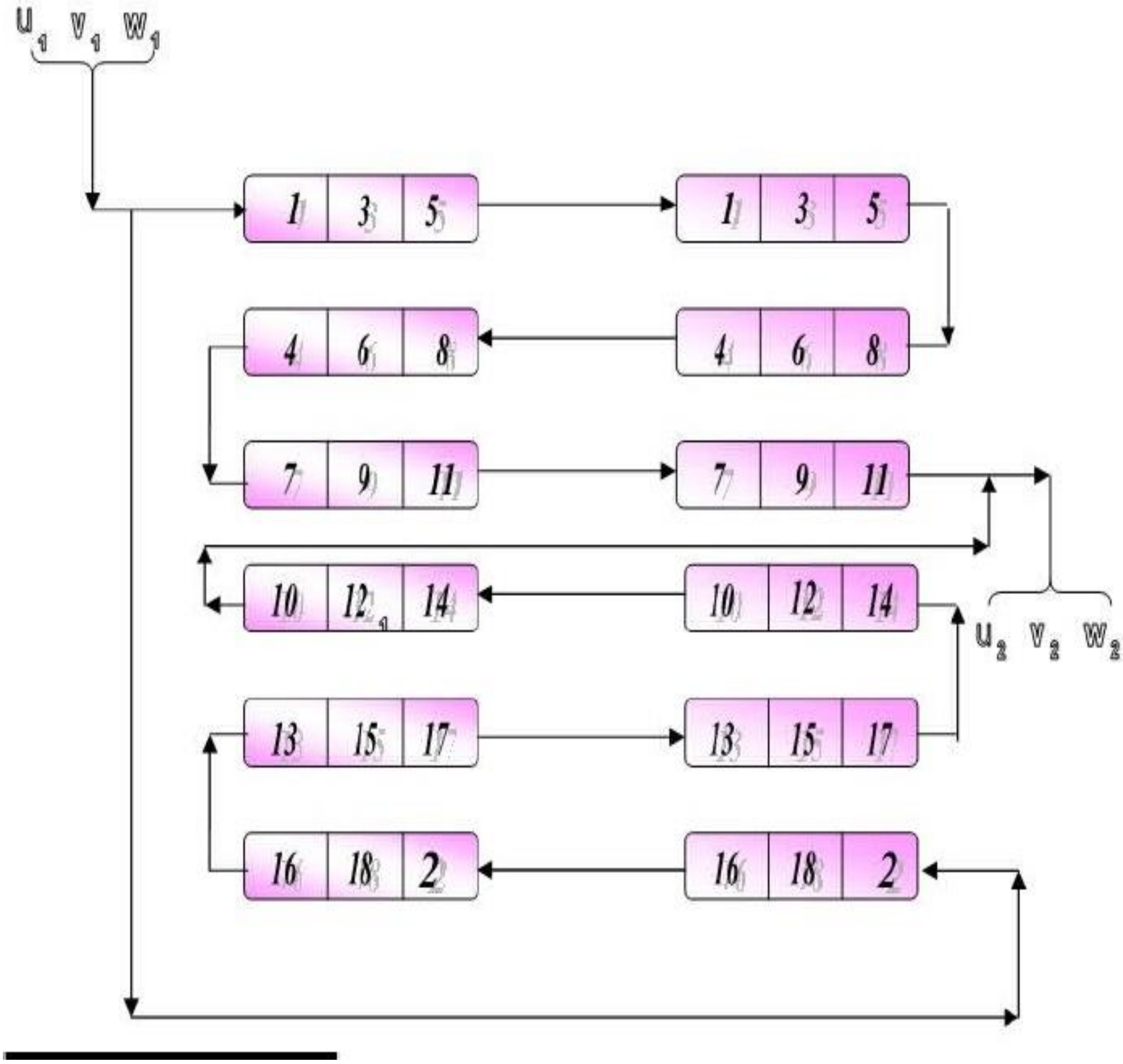

Fig 11: Circuit Diagram

CHAPTER 18
TURBINES AND AUXILIARY

18.1 GENERAL

Block-III manufactures Steam Turbines, Hydro Turbines, Gas Turbines and Turbines Blades. Special Tooling for all products are also manufactured in the Tool Room located in the same block. Equipment layout plan is a per Drawing appended in Section III. Details of facilities are given in Section II.
 The Block consists of four Bays, namely, Bay-I and II of size 36x378 metres and 36x400 metres respectively and Bay-III and IV of size 24x402 metres and 24x381 metres respectively. The Block is equipped with the facilities of EOT Cranes, compressed air, Steam, Over speed Balancing Tunnel, indicating stands for steam turbine, rotors, one Test stand for testing 210 MW steam turbines Russian Design, one Test Stand for Hydro Turbine Guide Apparatus and two separate Test Stands for the testing of Governing Assemblies of Steam and Hydro Turbines. All the parts are conserved, painted and packed before dispatch.

18.2 MANUFACTURING FACILITIES

18.2.1 HYDRO TURBINES

For manufacturing of Hydro Turbines, Bay-I has the following sections:
(a) Circular Components Machining Section – This section is equipped with a number of large/ heavy size Horizontal and Vertical Boring Machines, Drilling Machines, Centre Lathes, Marking Table and Assembly Bed. The major components machined in this section are Spiral Casing with Stay Ring, Spherical and Disc Valve bodies and Rotors.

(b) Runner and Servo Motor Housing Machining Section – This section is equipped withNC/CNC and conventional machines comprising Heavy and Medium size vertical and Horizontal Boring Machines, Centre Lathes, Grinding machines and Drilling Machines, Marking Table, Assembly Bed, Assembly Stands for Steam Turbine and Gas Turbine assemblies and Wooden Platform for overturning heavy components. Hydro Turbine Runners, Servomotors, cylinders, Labyrinth Ring, Regulating Ring, Stay Ring, Turbine Cover, Lower Ring, Kaplan Turbine Runner Body and Blades are machined here.
(c) Guide Vanes and Shaft Machining Section – This section is equipped with Heavy duty Lathe machines upto 16 metres bed, CNC turning machines, Horizontal Boring Machine, Heavy planer, Deep Drilling Machine, Boring Machines, marking Table, Marking Machines and Assembly Beds. Turbine

shafts, Guide Vanes, Journals and Rotors of Spherical and Disc Valves are machined here. Rotors of Steam Turbines are
also machined in this section.
(d) Assembly Section – In this section, assembly and testing of Guide Apparatus, Disc Valve, Spherical Valves, Servo motor shaft and combined Boring of coupling holes are done.
(e) Preservation and Packing Section – Final preservation and packing of all the Hydro Turbine components / assemblies is done here.
(f) Small components Machining Section – This is equipped with Planetary Grinding Machine, Cylindrical Grinding Machines, small size Lathes, Planers, Vertical and Horizontal Boring Machines. Small components like Bushes, Levers, Flanges etc. and Governing assemblies and machines here.
(g) Governing Elements Assembly and Test Stand Section – This section is equipped with facilities like oil Pumping Unit, Pressure Receiver, Servomotors etc. for assembly and Testing of Governing Elements.

Fig 12:High Pressure Turbine

18.2.2 STEAM TURBINES

The facilities and parts manufactured in the various sections of Steam Turbine manufacture are as follows:
(a) Turbine casing Machining Section – It is equipped with large size Planer, Drilling, Horizontal Boring, Vertical Boring, CNC Horizontal and Vertical

Boring machines etc. Fabrication work like casings, Pedestals etc. are received from Fabrication Block-
II.
(b) Rotor Machining Section – It is equipped with large size machining tools like Turning Lathe, CNC Lathes, Horizontal Boring Machines, special purpose Fir tree Groove Milling Machine etc. Some rotor forgings are imported from Russia and Germany and some are indigenously manufactured at CFFP, BHEL, Hardwar.
(c) Rotor Assembly Section – This is equipped with Indicating Stand, Small size Grinding, Milling, Drilling, machines, Press and other devices for fitting Rotors and Discs. Machined Rotor, Discs and Blades are assembled here. Balancing and over speeding of Rotor is done on the dynamic balancing machine.
(d) Turbine casing Assembly Section – Machined casings are assembled and hydraulically tested by Reciprocating Pumps at two times the operating pressure.
(e) Test Station - Test station for testing of 210 MW USSR Steam Turbine at no load is equipped with condensers, Ejector, Oil Pumps, Oil containers Steam Connections etc, required for testing. Over speed testing is done for emergency Governor. Assembly Test Stands for different modules of Siemens design are equipped with accessory devices.
(f) Painting Preservation and Packing Section – All the parts are painted, preserved and
packed here for final dispatch.
(g) Bearings and Miscellaneous Parts Machining Section – This section is equipped with small and medium size basic machine tools, e.g., lathes, Milling M/c, Horizontal Borer, Vertical Borer, drilling M/c etc. for manufacture of bearings and other miscellaneous parts of turbine.
(h) Sealing and Diaphragm Machining Section – It is equipped with medium size Vertical Boring, Horizontal Boring, Planning, Drilling Machines etc. wherein castings of sealing Housings, Liner housings, Forgings of Rotor Discs, castings and fabricated Diaphragms and components are machined. It is also equipped with CNC machining center.
Precision Horizontal Boring, Plano-Milling machines etc, are for manufacture of Governing Casting, Servo Casings and other medium parts of governing and Main Turbine assemblies.
(i) Governing Machining Section – This section is equipped with medium size and small size lathes, medium CNC lathe, Milling, Grinding, Drilling, Slotting and Honing
Machines. Governing assembly parts are machined here.
(j) Diaphragm and Governing Assembly Section – It is equipped with deflection testing equipment for Diaphragms, Dynamic Balancing Machine for balancing Impeller of Centrifugal Oil Pumps and small fittings and

assembly equipment. Governing test stand is equipped with the facilities like Oil Pumping Unit, Pressure Receiver, Servomotor, overspeed testing of Emergency Governor etc.
(k) Light machine shop – In addition to normal conventional machine tools it is equipped
with CNC Lathes, CNC Milling, CNC Vertical Boring, Precision Milling, planetary grinding machines etc. for manufacture of small and medium precision components of governing and other turbine parts.

18.2.3 **GAS TURBINE**

All the components of Gas Turbine are machined and assembled using the facilities available for manufacturing of steam and hydro turbines except the following facilities which are procured exclusively for the manufacturing of Gas Turbine and are installed in the areas specified for gas turbine manufacturing.
a) Hydraulic Lifting Platform
This facility is used for assembly and disassembly of G.T. Rotor. This is a hydraulically operated platform which travels upto 10 M height to facilitate access to different stages of Rotor. This is installed in Bay-I assembly area.
b) CNC Creep Feed Grinding M/c.
This is installed in Gas Turbine machining area Bay-II Extn. This M/c grinds the hearth serration on rotor disc faces. Hirth serrations are radial grooves teeth on both the faces of rotor discs. Torque is transmitted trough these serrations, which are veryaccurately ground.
c) External Broaching Machine
This machine is installed in GT machining area and is used to make groove on the outer dia of rotor discs for the fitting of moving blades on the discs.

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CONCLUSIONS

The 30 days industrial training at BHEL , Haridwar provided important knowledge in the field of construction of turbo alternators and their components. This year it has a projected target of producing 800 MW turbo alternator. Besides the production of new alternators the plant also repairs damage done’s. With the ever increasing pressure of industry BHEL is striving hard to continue leading in this era of fierce competition. The construction of new blade shop having four and five axis computer numerical controllers (CNC) represent the most recent technologies used here which are comparable with other large companies of the world. But there are few factors that require special mention. Training is not paid due attention. It is recommended that there should be projectors especially for trainees where presence of authorities is ensured

A separate training in charge should be made in each department which can help us getting through that department very well. Though technicians are helpful but sometimes due to work load we have to be satisfied just by viewing the scenario. However the training has cleared our perception about practical implementation of theoretical concepts and make us realize the working culture of BHEL where sun never dawns.