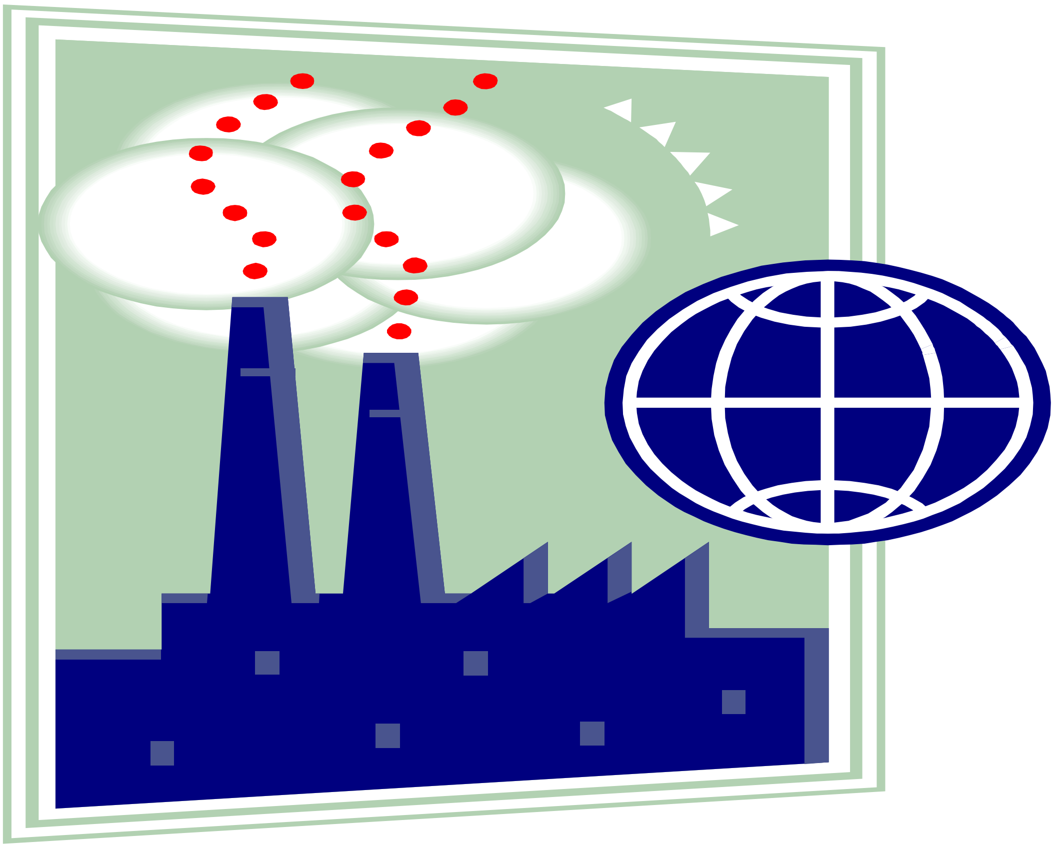
POWER PLANT FAMILIARIZATION



SINGRUALI SUPER THERMAL POWER STATION, NTPC

Shaktinagar, Sonbhadra (distt.) –U.P.

PREFACE

In today's world, electricity has an important role to play. Man, today, rely on electricity for the fulfillment of even his basic needs comfortable living.

Electricity contributes the largest share to a country's economic growth. It is the most powerful resource and has brought industrial revolution world wide. It has resulted in social changes too and raised the standard of living.

In India, several organizations like NHPC, UPSEB, and other state electricity boards etc. are engaged in electricity generation. NTPC is one of the largest among these with an honourable contribution of 26% of India's total generated power.

ACKNOWLEDGEMENT

I oblige to acknowledge my heartiest gratitude to all honourable people who helped me during my summer training at NTPC, Shaktinagar, Singrauli.

I would like to thank Mr. Ashok Kumar, Sr. Manager, HR, for granting me the permission for doing my summer training at this project.

I am also thankful to, Mr.R.K.Panda, Sr. Supdt. (O&M,Elec.)for providing the necessary guidance. I would like to thanks Mr. V.K.Sinha, Sr. Supdt. (O&M,Elec.) for giving their valuable guidance during my training period. I would like to thank Mr.R.V.Patnayak, Sr. Supdt.(O&M,Elec.) and Mr.Jayant Aggarwal, Dy. General Mgr. (O&M,Elec.), for providing me the knowledge about the work. I would also thank MrV.B.Srivastava, Mr.Dinesh Singh, Mr.M.S.Das for encouraging and providing the necessary details. I am also grateful to all SSTPS staff that helped me directly or indirectly.

I would co-heartedly thank Mrs. Manju Khatrri, Placement Officer, T & P Cell, and Prof. Gajendra Singh, HOD, Electrical & Electronics Engg., for allowing me to do my training at this place.

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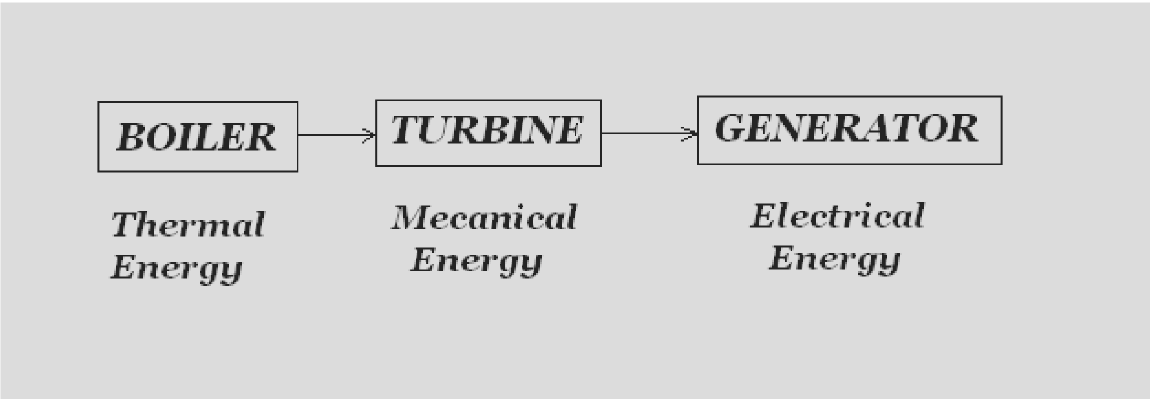
INTRODUCTION

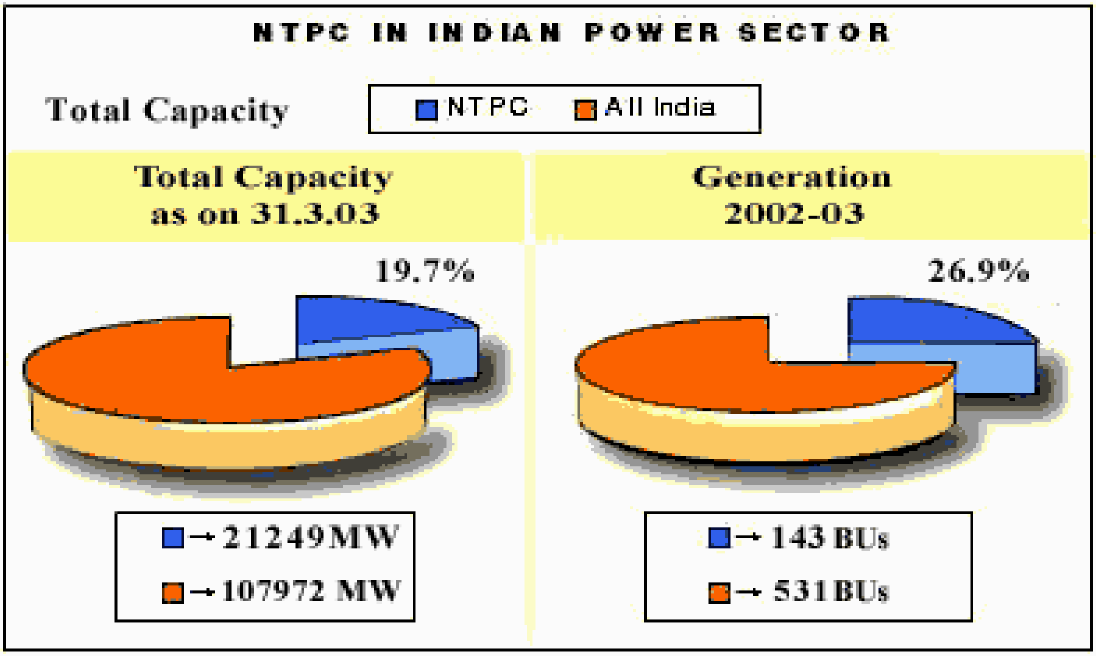
Everybody must be having a thought that a thermal power plant is a place where electricity is produced. But do you know how it is produced?

The chemical energy stored is converted to heat energy which forms the input of power plant and electrical energy produced by the generator is the output. Power is the single most important necessity for the common people and industrial development of a nation. In a convectional power plant the energy is first converted to a mechanical work and then is converted to electrical energy. Thus the energy conversions involved are:



The first energy conversion takes in what is called a Boiler or Steam Generator, the second in what is called a Turbine and the last conversion takes place in the Generator.

National Thermal Power Corporation has been the power behind India's sustainable power development since November 1975. Contributing 26% of country's entire power generation, it has placed itself in the Nav - Ratan companies of Indian government and hence is the public sector company.



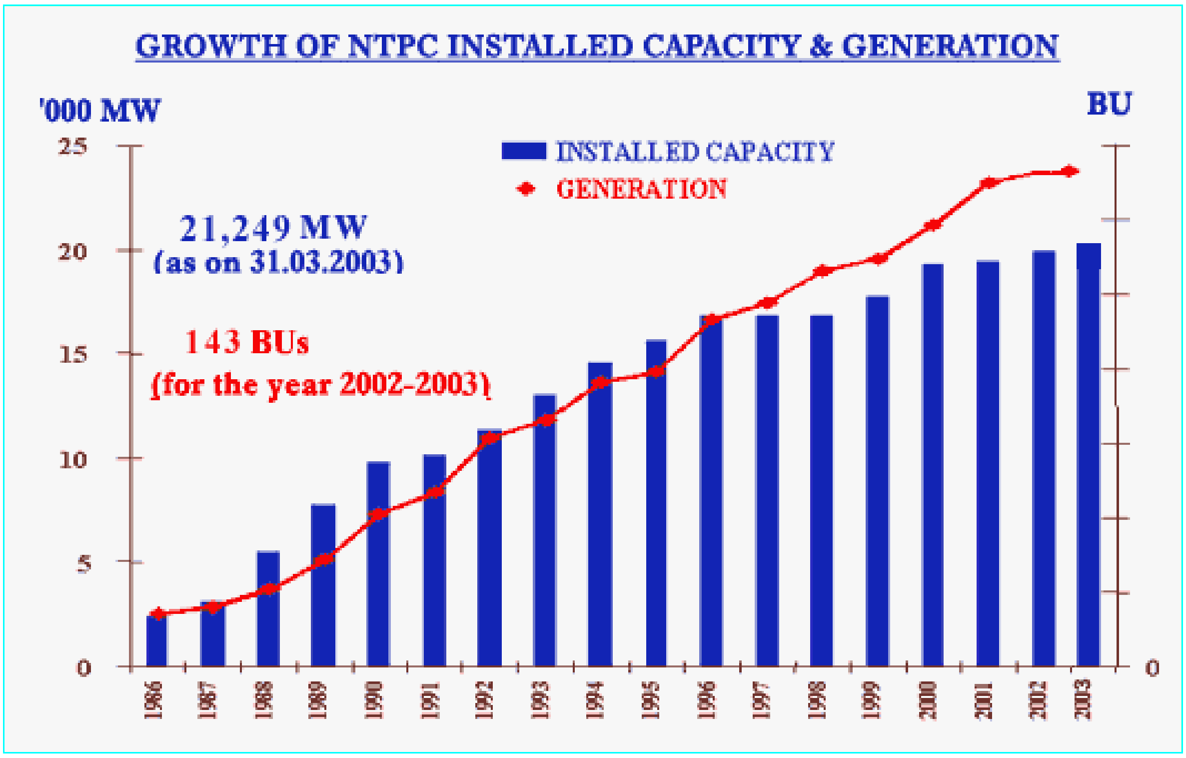
An ISO 9001:2000 certified company, it is world's 6th largest thermal power generators and 2nd most efficient in capacity utilization.

With ambitious growth planes to become a 40,000 MW plus company by 2012, NTPC — the largest power utility has already diversified into hydro sector. Further initiatives for the great organizational transformation have been approved under the PROJECT DISHA.

NTPC was ranked 3rd best employer and the No.1 Public sector undertaking among 220 major companies in India by Business Today - Hewitt Association Best Employers Survey 2003.

The total installed capacity of NTPC, as on 10th November, '03, is as follows

Fuel used	***Plants***	***Capacity(MW)***
Coal based	13	17,480
Gas/Liquid fuel	7	3,955
JV Coal	3	314
Total	**23**	**21,749**



The detailed description of various plants, projects and stations of NTPC, in a zone-wise manner, is given in the following table:

Northern & National Capital Region

Details	*Hydro*	*Coal based*					*Gas/liquid fuel based*			
Project (state)	Koldam (Himachal Pradesh)	Singrauli (Uttar Pradesh)	Rihand (Uttar Pradesh)	Unchahar (Uttar Pradesh)	Dadri (Uttar Pradesh)	Tanda (Uttar Pradesh)	Anta (Raj-asthan)	Auraiya (Uttar Pradesh)	Dadri (Uttar Pradesh)	Farid-abad (Har-yana)
Capaci-ty(MW)	800	2000	2000	840	840	440	413	652	817	430
Units Comm-ssioned	----	5x200+ 2x500	2x500	4x210	4x210	4x110	3x88+ 1x149	4x112+ 2x102	4x131+ 2x146.5	2x143 +1x 144
Units to be commi-ssioned	4x200	----	2x500	----	----	----	----	----	----	----
Energy source	----	Jayant/ Bina	Amlori	North Karanpu-Ra	North Karanp-ura	North Karan-pura	HBJ	HBJ	HBJ	HBJ
Water source	River Satluj	Rihand Dam	Rihand Dam	Sharda Sahayak Canal	Mat branch canal/ Hindon River	Saryu River	Anta Kota Right Canal	Auraiya Etawa Canal	Hindon River	Gurgan Canal
Benefi-ciaries	Northern Region states & UT's	U.P., Uttaranchal, J&K, H.P., Chandigarh, Rajasthan, Haryana, Punjab, Delhi			Delhi, U.P.	U.P.	U.P., Uttaranchal, J&K, H.P., Chandigarh, Punjab, Delhi, Haryana, Rajasthan, Railways			Haryana

WESTERN REGION

Project (state)	Korba (Chhatisgarh)	Vindhyachal (Madhya Pradesh)	Kawas (Gujrat)	JHANOR GANDHAR(GUJARAT)
Capacity(MW)	2100	3260	645	648
Units commissioned	3x200+3x500	6x200+2x500	4x106+2x110.5	3x131+1x255
Units to be commissioned	----	2x500	----	-----
Energy source	Kusmunda Block	Nigahi	HBJ	Gandhar Gas Fields
Water source	Hasdeo River	Discharge canal of Singrauli	Hazira Branch canal	Narmada River

Southern Region

Details	***Coal based***		***Gas/liquid based***
Project (state)	Ramagundam (Andhra Pradesh)	Simhadari (Andhra Pradesh)	Kayamkulam (Kerala)
Capacity(MW)	2600	1000	350
Units commissioned	3x200+3x500	2x500	3x115+1x120
Units to be commissioned	1x500	----	----
Energy source	South Godavari	Talcher	Naphtha
Water source	Pochampad Dam	Sea water	Achankovil River
Beneficiaries	Andhra Pradesh, Tamilnadu, Kerala, Goa, Pondichery	Andhra Pradesh	Kerala, Tamilnadu

Eastern Region				
Details	***Coal based***			
Project (state)	Farakka (West Bengal)	Khalgaon (Bihar)	Talcher Kaniha (Orissa)	Talcher Thermal (Orissa)
Capacity(MW)	1600	2340	3000	460
Units commissioned	3x200+2x500	4x210	2x500	4x60+2x110
Units to be commissioned	----	3x500	4x500	----
Energy source	Rajmahal	Rajmahal	Talcher	Talcher
Water source	Farakka Feeder Canal	Ganga River	Samal Barrage	Bhramani River
Beneficearies	West Bengal, Bihar, Jharkhand, Orissa, Sikkim, Assam, Damodar Veally Corporation & Southern region states.			Orissa

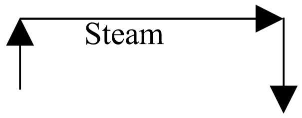
PRINCIPLE OF OPERATION

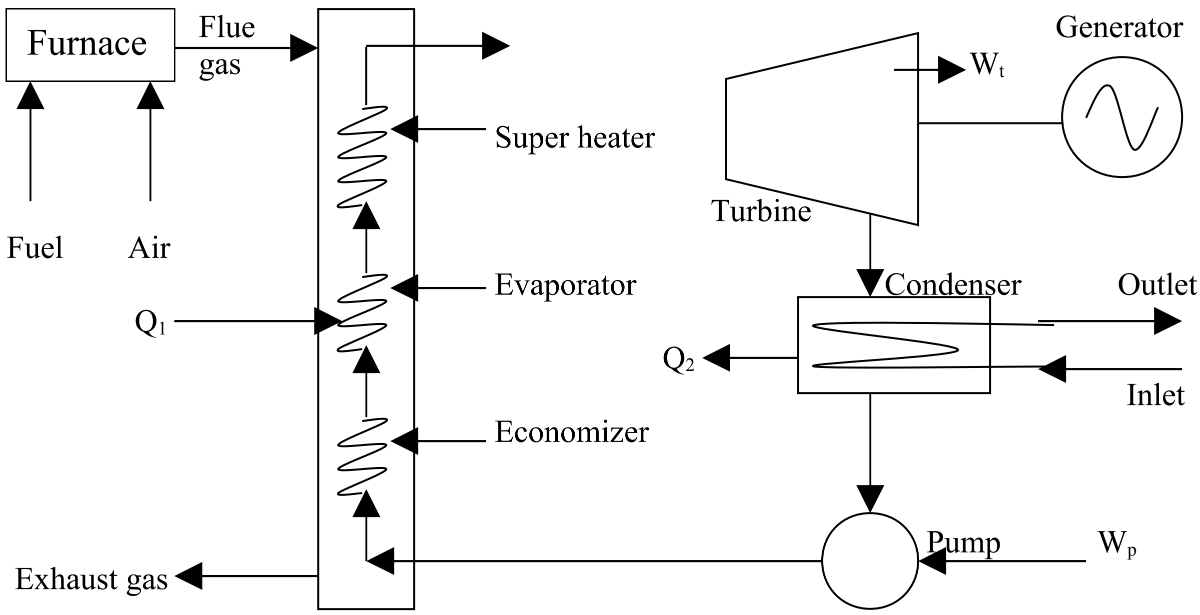
For each process in a vapour power cycle, it is possible to assume a hypothetical or ideal process which represents the basis intended operation and do not produce any extraneous effect like heat loss.

1. For steam boiler, this would be a reversible constant pressure heating process of water to form steam.
2. For turbine, the ideal process would be a reversible adiabatic expansion of steam.
3. For condenser, it would be a reversible a constant pressure heat rejection as the steam condenser till it becomes saturated liquid.
4. For pump, the ideal process would be the reversible adiabatic compression of liquid ending at the initial pressure.

When all the above four cycles are combined, the cycle achieved is called RANKINE CYCLE. Hence the working of a thermal power plant is based upon Rankine cycle with some modification.

<u>Flow diagram</u>:





where, Q_1 – Heat supplied

Q_2 – Heat ejected

W_t – Work obtained form turbine

W_p – Work supplied to pump

Cycle's efficiency = $(W_t - W_p)/Q_1$

A PULVERIZED COAL FUELED POWER PLANT

A typical pulverized coal fueled power plant is based on Rankine Thermodynamic cycle. "A Rankine cycle is a vapour cycle

that relies on the isentropic expansion of high pressure gas to produce work". Let us see a superheat Rankine cycle:

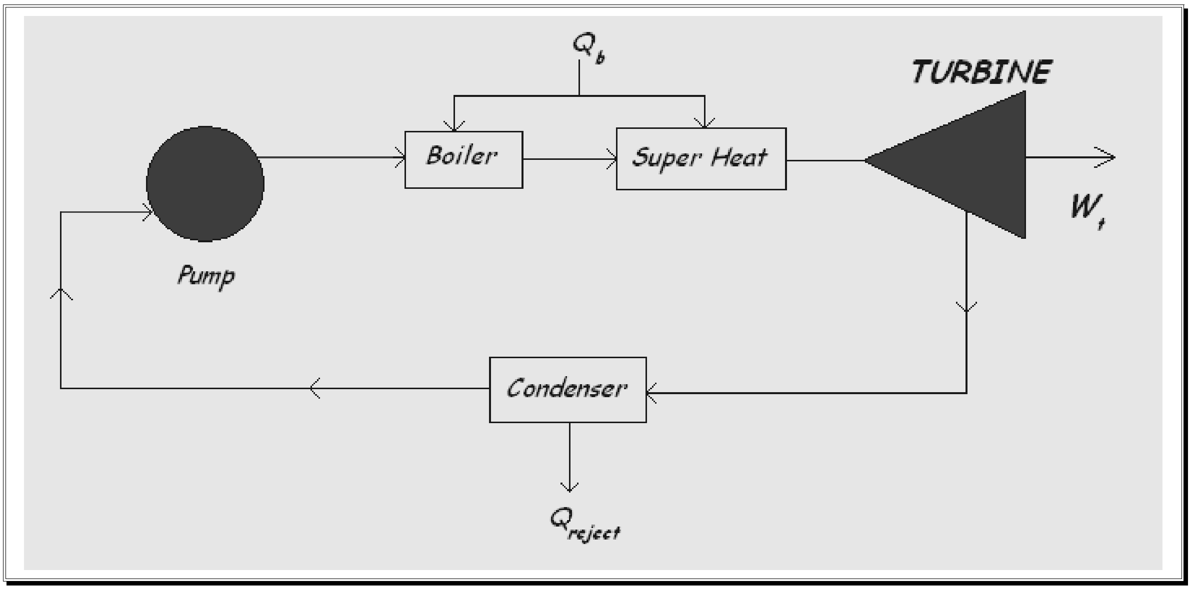


Fig: Super Heat Rankine cycle

Where,

W_t – mechanical power produced by turbine

This facility first produces steam in a boiler (steam generator). This steam is used to rotate turbine which is connected to a shaft of generator. Hence electricity is produced here. The used steam is then condensed in a condenser, and the condensed liquid is used again in the steam generator. This is a simple phenomenon, understood by everybody.

For all this we need a fuel. As the name suggest here coal is used as fuel. Coal is one of the cheapest and most preferred fossil fuel used as a key to most of the power plants. Usually delivered by train from Mines to the Coal Handing Plant (CHP). The CHP unloads this it become more economical to unload the coal. Then the coal stacked, reclaimed, crushed, and conveyed it to the storage silos near the steam generator. Then it is fed through the Feeder to the Pulverizer. Feeder is mainly used to weight the amount of coal going to the Pulverizer per hour. From the Feeder the coal is fed to the Pulverizer which powders it and then it is carried to the steam generator using pressurized air. Within the steam generator the

coal is atomized and burned and the heat energy produced is used for producing steam. Here two types of steam namely superheated & reheated steam are produced in a cycle.

The steam turbine generator converts the thermal energy of superheated and reheated steam to electrical energy. The first energy conversion is carried in Boiler or steam generator; the second is carried out in Turbine and the last one carried out in the Generator.

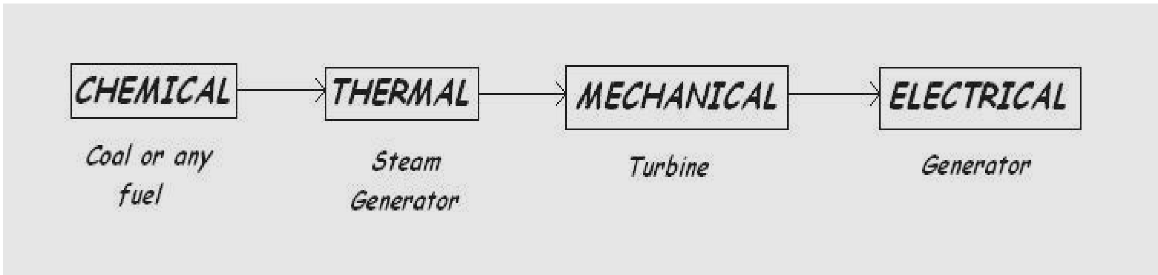


Fig: Energy conversion flow diagram.

Initially the superheated steam is fed to High Pressure (HP) turbine. It has a temperature of 540° C (approx.) and a pressure of about 140 Kg/cm^2. Then the exhausted steam from it is taken to the reheater so that it can be reheated and fed back to Intermediate Pressure (IP) turbine. Here the temperature is maintained the same as that of superheated steam but pressure is reduced to 35 Kg/cm^2. Then the exhausted steam is directly fed to Low Pressure (LP) turbine having the reduced temperature and pressure of about 1 Kg/cm^2.

Then the exhausted steam from the LP section is condensed in the condenser. The condensed liquid is moved from condenser by Condensate Pumps through Low Pressure Regenerative Feedwater heaters to a Deaerator. Boiler Feed Pumps (BFPs) moves the deaerated liquid through HP heaters to the steam generators. Extraction steam is supplied to the LP & HP regenerative heaters to improve cycle efficiency.

Then comes to the system of fans which keeps the system working by providing the valuable air where required. There are three pairs of fans, namely, Forced Draft (FD) fan, Induced Draft

(ID) fan, Primary Air (PA) fan. FD fans supplies combustion air to the steam generator and PA fans transports the coal into the steam generator. ID fans remove the flue gases from the steam generator and exhaust it through chimney. Cooling water for the condenser is supplied by the circulating water system, which takes the heat removed from the condenser and rejects it to the cooling towers or other heat sink.

This all working is controlled from a single place called control room. It enables the operator to direct the plant operation for reliable and efficient production of electrical energy. This is achieved by the control system installed by the C & I group. These are DAS (Data Acquisition System), ACS (Analog Control System), FSSS (Furnace Safeguard Supervisory System), and other relays governing numerous activities.

Last but not the least is the switching and transmission methods used here. The generated power cannot be transmitted as such. It is stepped up to 132 KVA or 400 KVA then passed through a series of three switches an isolator, a circuit breaker and an isolator. Three phase system is used for the power transmission. Each generator has its own switchyard and transmission arrangement.

PROCEDURE

The basic understanding of the modern thermal power station in terms of major systems involved can be done under three basic heads viz. generating steam from coal, conversion of thermal energy to mechanical power and generation & load dispatch of electric power.

1. Coal to Steam:

- The coal is burnt at the rate up to 200 tonnes per hour.
- From coal stores, the fuel is carried on conveyor belts to bunkers through coal tipper.
- It then falls in to coal pulverizing mill, where it is grounded into powder as fine as flour.
- Air is drawn in to the boiler house by drought fan and passed through Preheaters.
- Some air is passed directly to bunker and rest, through primary air fan, to pulverizing mill where it is mixed with powdered coal.
- The mixture is then carried to bunker of furnace where it mixes with rest of the air and burns to great heat.
- This heats circulating water and produces steam, which passes to steam drum at very high pressure.
- The steam is then heated further in the Superheater and fed to high pressure cylinder of steam turbine.
- The steam is then passed to other cylinders of turbine through reheater.
- The spent steam is sent to condenser, where it turns back to water called condensate.
- Condensate is sent to lower part of steam drum through feed heater and economizer.
- The flue gases leaving boiler are used for heating purpose in feed heater, economizer, and air Preheater.
- *The flue gases are then passed to electro-static precipitator and then, through draught fan, to chimney.*

2. Steam to Mechanical Power:

- *Steam first enters the high pressure cylinder of turbine where it passes over a ring of stationary/fixed blades which acts as nozzle and directs steam onto a ring of moving blades.*

- *Steam passes to the other cylinders through reheater and the process is repeated again and again.*
- *This rotates the turbine shaft up to 3000 rpm.*
- *At each stage, steam expands, pressure decreases and velocity increases.*

3. Mechanical to Electrical Power:

- The shaft is connected to an alternator's armature.
- Thus the armature is rotated and electric current is produced in the stator's windings.
- The generated electricity is of order 25,000 volts.

4. Switching and Transmission:

- Electricity generated can not be transmitted as such.
- It is fed to one side of generator's transformer and stepped up to 132000, 220000, or 400000 volts.
- It is then passed to a series of three switches an isolator, a circuit-breaker, and another isolator.
- From circuit-breaker, current is taken to bus bars and then to another circuit-breaker with it's associated isolator before being fed to the main Grid.
- Each generator has its own switching and transmission arrangement.
- Three-phase system is used for power transmission.

5. Control and instrumentation

Control and Instrumentation (C & I) systems are provided to enable the power station to be operated in a safe and efficient manner while responding to the demands of the national grid system. These demands have to be met without violating the safety or operational constraints of the plants. For example, metallurgical limitations are important as they set limits on the maximum

permissible boiler metal temperature and the chemical constituents of the Feed water.

The control and Instrumentation system provides the means of the manual and automatic control of plant operating conditions to:

- *Maintain an adequate margin from the safety and operational constraints.*
- *Monitor these margins and the plant conditions, and provide immediate indications and permanent records.*
- *Draw the attention of the operator by an alarm system to any unacceptable reduction in the margins.*
- *Shut down the plant if the operating constraints are violated.*

TYPES OF INSTRUMENTS

The different types of instruments normally used are given below:

- ***Indicators** – These are of two categories, namely local and remote. Local indicators are self contained and self operative and are mounted on the site. The Remote indicators are used for telemeter purposes and mounted in the centralized control room or control panel. The indicators are sometimes provided with signaling contacts where ever required. The Remote indicators depend on electricity, electronics, pneumatic or hydraulic system for their operation and accordingly they are named. The indicator can be classified as analogue or digital on the basis of final display of the reading.*
- ***Recorders** – These are necessary wherever the operating history is required for analyzing the trends and for any future case studies or efficiency purposes. Recorders can be of single point measuring a single parameter or multipoint measuring a number of parameters by single instruments. Multipoint recorders are again categorized as multipoint continuous or multipoint dot recorders. The multipoint dot recorders select the point one after the other in a sequence*

where as the continuous recorders measure simultaneously all the points.

COAL HANDLING PLANT

Every thermal power plant is based on steam produced on the expanse of heat energy produced on combustion of fuel. Fuels used are coal and fuel oil. Coal is more important as oil is occasionally used. Coal is categorised as follows depending upon fixed carbon, volatile matter and moisture content:

- Anthracite having 86% fixed carbon

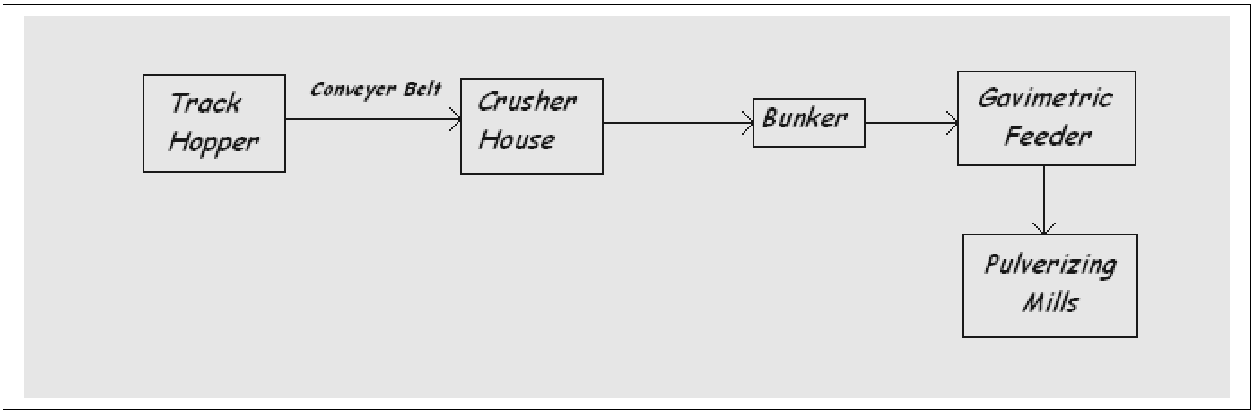
- Bituminous having 46 to 86% fixed carbon
- Lignite having 30% fixed carbon and
- Peat having 5 to 10% fixed carbon

Coal from mines is transported to CHP in railway wagons. It is unloaded in track hoppers. Each project requires transportation of large quantity of coal mines to the power station site. Each project is established near coal mine which meets the coal requirements for the span of its entire operational life. For the purpose each plant has Merry Go-Round (MGR) rail transportation system. The loading operation of the coal rake takes place while it is moving under the silo at a present speed of 0.8 Km/hr. the loading time for each wagon is one minute. For unloading of coal from the wagons an under ground track hopper is provided at the power station end.

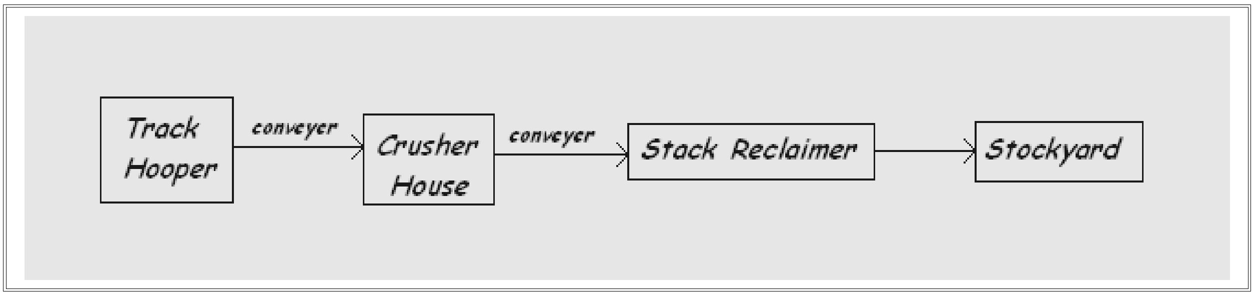
CHP then normally follows three coal paths:

1. Path A – from track hoppers to bunkers.
2. Path B – from track hoppers to stockyard.
3. Path C – from stockyard to bunkers.

<u>Path A</u>



Path B



Path C

MILLS

These are basically coal pulverizing mills. Thermal power stations use pulverized coal firing system. In this the coal is reduced to fineness such that 70 to 80% passes through a 200

mesh sieve. This fine powdered coal is called pulverized coal and is carried forward to the burner by air through pipes.

Advantage of pulverized coal firing system:-

1. Efficient utilization of low grade and cheap coal.
2. Flexibility in firing.
3. Ability to meet fluctuating load.
4. Better reaction to automatic control.
5. High efficiency of boiler.
6. Easy complete combustion.

The only disadvantage being its high initial cost.

Bowl Mill:-

The most widely used mills are bowl mills. Even SSTPS uses these kinds of mills. Bowl mill is a medium speed mill with 30 rpm speed. It pulverizes coal to a size of 200 microns with a purity of 600 micron. Bowl mills are available in varying capacities ranging from 1.7 to 100 tons per hour.

A 200 MW unit uses 6 mills of 32 tons per hour capacity, out of which 4-5 run at a time and one is in stand-by condition for emergency. A 500 MW unit uses 8 mills of 60 tons per hour capacity, out of which 6-7 run at a time.

Construction:-

Bowl mill has a bowl covered with bull rings. It is mounted on a gear called worm gear and bearings assembly. This assembly is held

in a casing filled with lubricating oil along with cooling arrangements. Worm gear is coupled to helical gear shaft which is in turn coupled to AC motors.

A bowl mill has three grinding rollers each weighing three tons. There is a 3mm clearance between bowl and roller and both are at an angle of 22° to each other. A spring mechanism with 25 kg/cm^2 tension is used to maintain the clearance. Rollers are free to rotate about their axis.

The mill has five openings at the top. Out of these, one is inlet of gravimetric feeder and rest four is outlet openings to each corner of furnace. There are classifiers around openings and scrapers around the bowl.

Working:-

Coal is fed into mill through Gravimetric feeder. When the A.C. supply is switched on the bowl rotate and due to centrifugal force, the coal moves in the outward direction. As the coal come between grinder and bowl, it gets pulverized. The unwanted material is removed through scrapers.

The pulverized coal is then carried to burners by primary air through outlet openings. The heavier particles, as they rise, collide with classifiers and fall back in mill for further grind. Sealing air is provided through seal air fan to avoid deposition of coal dust in bearings and spring mechanism.

Specifications:-

Pulverizer

- Air flow/mill ~~ 60 T/hr.

- Air temp. at mill inlet ~~ 260° C.
- Mill outlet temp. ~~ 77° C.
- Coal flow/mill ~~ 36 T/hr.
- Fineness of coal Milled ~~ 70 % through 200 mesh
- Primary air pressure inlet ~~ 650 mmwcl.
- Primary air pressure outlet ~~244 mmwcl.

DRAFT FANS

Like water circulation, air circulation is equally important in boilers. It helps in complete combustion of fuel and removal of flue

gases and ash from furnace. It also helps in maintaining furnace's pressure below atmospheric pressure.

Draft fans are used for fulfilling the above requirements. There are three types of draft fans used:-

FD FAN (FORCED DRAFT)

FD fan is located prior to furnace. It forces air to flow through furnace via pre-heater. This air helps in complete combustion of fuel. FD fan is an axial fan and has Pitch Control i.e. the pressure of forced air is controlled by rotating the blades of fan using oil control.

FD fan is run by an A.C. motor at 1490 rpm. A.C. motor used is 3 phases, squirrel cage induction motor that takes 6600V, 84.5A, 800KW supply. It is 94.5% efficient.

Specification:-

Fan

- Type & size ~~ Axial Reaction API 18/11.
- Orientation ~~ Horizontal.
- Medium handled ~~ Air.
- Location ~~ Ground level.
- No. of fans/boiler ~~ 2
- Capacity ~~ 105 m^3/sec.
- Total head ~~ 510 mmwcl.
- Temp of medium ~~ 50° C.
- Specific weight of medium ~~1.619 Kg/cm^2.
- Speed ~~ 740 rpm.
- Type of fan regulation ~~ Inlet Guide Vane.

Motor

- Type ~~ Squirrel cage induction motor.
- Rated power ~~ 1100 KW.
- Rated voltage ~~ 6.6 KV.

- Rated frequency ~~ 50 Hz.
- Lubricating system ~~ Grease lubrication.
- No. of phases ~~ 3
- Bearing type ~~ hydrodynamic ring assisted bearing.
- Speed ~~ 1480 rpm.

ID FAN (INDUCED DRAFT)

ID fan, induces a draft that helps in removal of flue gases from the furnace. It also causes the flue gases to flow through ESP and then out of chimney and ESP.

ID fan is an axial fan made of croton steel. It is driven by 3 phase squirrel cage induction motor at 744 rpm. Motor uses 6600V, 138.5A, 1300KW supply and is 95.5% efficient. ID fan has Inlet Guide Vane control pressure.

Specification:-

Fan

- Type & size ~~ Axial Impulse AN 28e6.
- Orientation ~~ Horizontal.
- Medium handled ~~ Flue gas.
- No. of fans/boiler ~~ 2
- Capacity ~~ 225 m^3/sec.
- Temp of medium ~~ 136° C.
- Specific weight of medium ~~ 7966 Kg/cm^2.
- Speed ~~ 740 rpm.
- Type of fan regulation ~~ Inlet Guide Vane.

Motor

- Type ~~ Squirrel cage induction motor.
- Rated power ~~ 1100 KW.

- Rated voltage ~~ 6.6 KV.
- Rated frequency ~~ 50 Hz.
- Lubricating system ~~ Forced oil lubrication.
- No. of phases ~~ 3
- Bearing type ~~ hydrodynamic ring assisted bearing.
- Speed ~~ 740 rpm.

PA FAN (PRIMARY AIR)

PA fan supplies primary air that carries the pulverized coal from mills to furnace. Primary air passes to mills through 2 different ducts. One duct carries air 1st to pre-heater and then to mills while the other carries directly to mills. Air through pre-heater is hot air while other is cold air. Hot air helps in removal of moisture content from pulverized coal. PA fan is a radial fan runs at 1480 rpm by an A.C. motor and has Inlet Guide Vane control.

Specification:-

Fan

- Type & size ~~ Single suction, Radial fan.
- Orientation ~~ Horizontal.
- Medium handled ~~ Air.
- No. of fans/boiler ~~ 2
- Capacity ~~ 75 m^3/sec.
- Temp of medium ~~ 50° C.
- Lubricating system ~~ Forced oil lubrication.
- Specific weight of medium ~~ 1.019 Kg/cm^2.
- Type of fan regulation ~~ Inlet Guide Vane.

Motor

- Type ~~ 3-phase, air cooled,Squirrel Cage Induction motor.
- Rated power ~~ 1250 KW.

- Rated voltage ~~ 6.6 KV.
- Rated frequency ~~ 50 Hz.
- Lubricating system ~~ Grease lubrication.
- No. of phases ~~ 3
- Speed ~~ 1480 rpm.

WATER TREATMENT PLANT

The water available can not be used in boilers as such. The objective of water treatment plant is to produce the boiler feed water so that there shall be

- No scale formation
- No corrosion
- No priming or forming problems

The treated water is called 'Dematerialized Water'. The treatment process can be divided in two sections:

1. Pre-treatment section
2. Demineralisation section

Pre-treatment section

Pre-treatment plant removes suspended solids like clay, salt, plants, micro-organisms etc form raw water to give clarified water. Suspended solids can be separable or non-separable. Separable solids are heavier & large and can easily be removed by an aerator. Non-separable solids have finer size and take long to settle down. Hence they are required to be flocculated. In this, water is first dozed with lime and alum. This forces finer particles to coagulate increasing their weight and size. Non-separable solids can now be separated in clariflocculator. The clarified water is then stored in clarified water storage tanks.

Demineralisation section

The clarified water now goes to FCA (activated carbon filter) where it de-chlorinated. Water then passes through cation exchanger where weak and strong acidic cations are removed on adding resin.

RH	+	Na	$\longrightarrow$	RNa	+	H_2SO_4
(resin)		K		K		HCl
		Ca		Ca		HNO_3
		Mg		Mg		H_2CO_3
		(in water)		(drain)		(left in water)

The water is then sent to degasser where CO_2 is removed. From degasser, water comes to anion exchanger where anions are removed.

ROH	+	H_2SO_4	$\longrightarrow$	RSO_4	+	H_2O
(Resin)		HCl		Cl		(demineralised water)
		HNO_3		NO_3		
		(From cation exchanger)		(Drain)		

Water thus achieved is the required demineralised water which is then stored in demineralised water storage tanks.

Regeneration

Recharging the exhausted form of resin i.e. regeneration employing 5% of acid/alkali as below:

Cation resin:

$$\begin{array}{ccccc} RNa & + & HCl & \longrightarrow & RH & + & NaCl \\ K & & & & \text{(fresh} & & KCl \\ Ca & & & & \text{resin)} & & CaCl_2 \\ Mg & & & & & & MgCl_2 \\ \text{(Exhausted resin)} & & & & & & \text{(removed by} \\ & & & & & & \text{rinsing)} \end{array}$$

Anion resin:

$$\begin{array}{ccccc} RSO_4 & + & NaOH & \longrightarrow & ROH & + & Na_2SO_4 \\ Cl & & & & \text{(fresh} & & NaCl \\ NO_3 & & & & \text{resin)} & & NaNO_3 \\ \text{(exhausted resin)} & & & & & & \text{(removed by} \\ & & & & & & \text{rinsing)} \end{array}$$

The fresh resin thus produced is reused in demineralisation process.

BOILER

DEFINITION:

Boiler can simply defined as the device where any liquid is boiled or Boiler may be defined as a device that is used to transfer heat energy being produced by burning of fuel to liquid, generally water, contended in it to cause its vaporization. Boiler, in simple terms, can be called "Steam Generator".

The following are factors essential for the efficient combustion usually referred as "The three T's".

a) Time – It will take a definite time to heat the fuel to its ignition temperature and having ignited, it will also take time to burn.
b) Temperature – A fuel will not burn until it reaches its ignition temperature.
c) Turbulence – Turbulence is introduced to achieve a rapid relative motion between the air and fuel particles.

CLASSIFICATION:

Boilers may be classified under different heads on different basis:-

1. Depending upon "Use"

- 1.1. Stationary (land) boilers
- 1.2. Mobile boilers
  - 1.2.1. Marine boilers
  - 1.2.2. Locomotive boilers

2. Depending upon "Tube contents"

- 2.1. Fire tube boilers
- 2.2. Water tube boilers

3. Depending upon "Tube shape"

- 3.1. Straight tube boilers
- 3.2. Bent tube boilers

3.3. Sinuous tube boilers

4. Depending upon "Tube position"

4.1. Horizontal or Vertical
4.2. Inclined

5. Depending upon "Furnace position"

5.1. Externally fired
5.2. Internally fired

6. Depending upon "Heat source"

6.1. Solid, liquid or gas
6.2. Waste of chemical process
6.3. Electrical energy
6.4. Nuclear energy

7. Depending upon "Circulation"

7.1. Natural circulation
7.2. Positive or forced circulation

SPECIFICATIONS:

Following are the specifications of the main boiler used at Singrauli Super Thermal Power Station for (200) MW:

1. **Main Boiler**

1.1 Type: Natural circulation, Dry bottom, Tangentially fired, balanced draft, Radiant Reheat type with direct fired pulverized coal system.

1.2 Manufacturer: **BHEL**

1.3 Designed fuel: Indian Bituminous coal

1.4 Furnace type: Fusion welded

1.5 Drum:

- Material ~~ Carbon Steel SA—299
- Overall length ~~ 15.700 mtrs.
- Designed pressure ~~ 176 Kg/cm^2
- Designed metal temp. ~~ 354 °C

1.6 Water wall, Economizer, Superheater, Reheater Details:

1.6.1 No. of coils/boiler

- Low temp. Superheater ~~ 134
- Platen Superheater ~~ 29
- Final Superheater ~~ 119
- Reheater
  - Front Assembly ~~ 59
  - Rear Assembly ~~ 00
- Economizer ~~ 143

1.6.2 Superheater Attemperator (Desuperheater):

- Type ~~ Spray—mixing
- No. of stages ~~ one
- Position in steam circuit ~~ b/w Low temp. S/H & Platen S/H

1.7 Set pressure (Kg/cm^2):

- Drum ~~ 158.2, 161.0, 162.41
- Superheater ~~ 143.30, 144.00
- Electromatic Relief valve ~~ 142
- Reheater inlet ~~ 33.40,33.75,33.00,

	34.45
➢ Reheater outlet ~~	30.58

1.8 Relieving capacity (Tonnes/hr.):

➢ Drum ~~	190.04, 162.08, 195.08
➢ Superheater ~~	86.89, 86.73
➢ Electromatic Relief valve ~~	88.106
➢ Reheater inlet ~~	94.70, 136.01, 137.386, 138.76
➢ Reheater outlet ~~	114.932

2. Flow (Tonnes/hr)

		MCR	NCR
2.1	Steam:		
	➢ At final S/H outlet ~~	700	612
	➢ At R/H outlet ~~	585	535
2.2	Water:		
	➢ Feed water entering Economizer ~~	700	593
2.3	Fuel:		
	➢ Coal flow ~~	118	105
2.4	Air:		
	➢ Primary air flow to Air heater outlet ~~	131	115.7
	➢ Secondary air flow to A/H outlet ~~	629	524.5
	➢ Tempering air ~~	110	120
	➢ Total combustion air ~~	889.2	725.7

3. Temperature ($^{\circ}$C):

3.1	Steam:		
	➢ At final S/H outlet ~~	535	535
	➢ At R/H outlet ~~	535	535
	➢ At R/H inlet ~~	323	305

- Form drum ~~ 342 342

3.2 Water:

- Feed water entering Economizer ~~ 246 220
- Feed water leaving Economizer ~~ 281 27

4. <u>Pressure (kg/cm^2):</u>

4.1 Steam:

- At final S/H outlet ~~ 138 130
- At R/H outlet ~~ 24.5 18.85
- At R/H inlet ~~ 25.83 19.87
- From drum ~~ 151.5 146.1

4.2 Water:

- Feed water entering Economizer ~~ 153.2 148.4

WATER & STEAM CIRCULATION

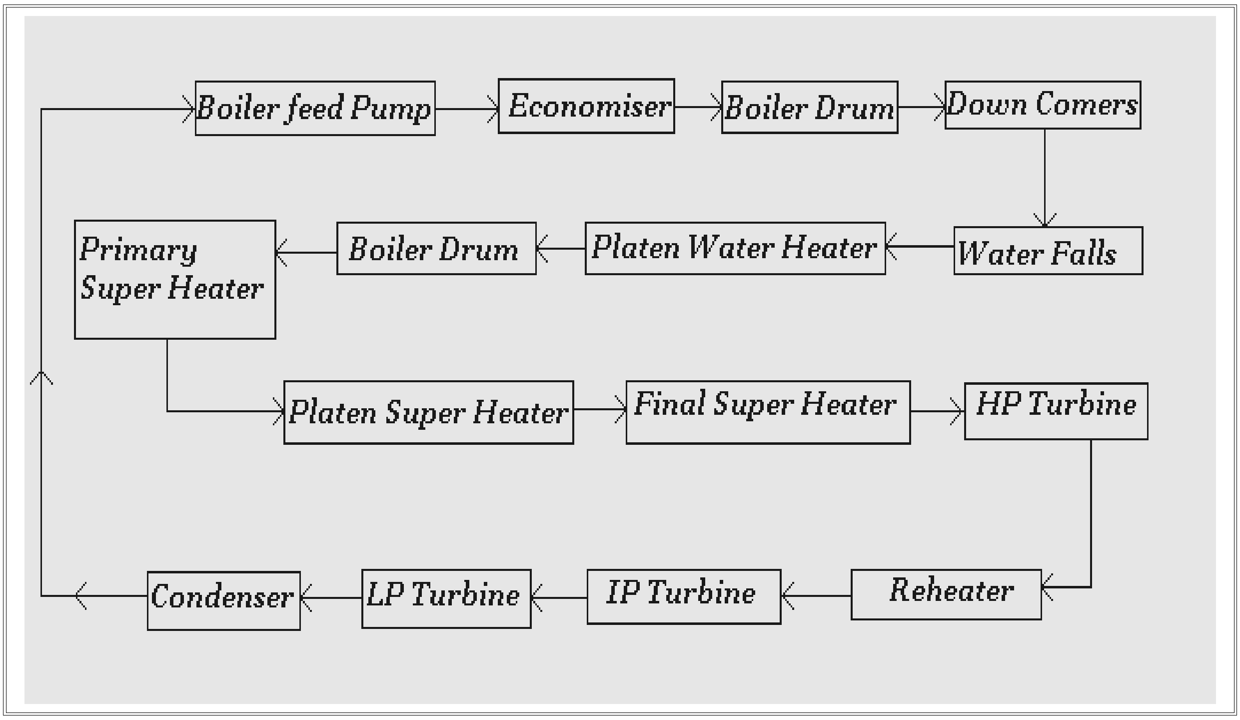


fig. – Flow diagram of water & steam circulation

BOILER AUXILIARIES

Efficiency of a system is of most concerned. Thus it is very important to maintain a system as efficient as possible. Boiler auxiliaries help in improving boiler's efficiency. Following are the important auxiliaries used:

Economizer: Its purpose is to preheat feed water before it is introduced into boiler drum by recovering heat from flue gases leaving the furnace.

Super Heater: It increases the temperature of steam to super heated region.

Reheater: It is used for heat addition and increase the temperature of steam coming from high pressure turbine to 540°.

Soot Blower: It blows off the ash deposited on the water wall surface. It uses steam for blowing purpose.

Air Preheater: It pre-heats the air entering the furnace by recovering heat from flue gases in order to ease the combustion process.

Draft Fans: They handle the supply of air and the pressure of furnace.

Oil Guns: They are used to spray oil to raise the temperature of furnace to ignition temperature of fuel.

Wind Box: It distributes the excess air uniformly through out furnace.

Boiler Mountings

These are used for the safe operation of boiler. Some examples of mountings used are water level indicator in drum, furnace temperature probe, reheat release valve, pressure gauges indicating steam pressure etc.

STEAM TURBINE

GENERAL:

At Singrauli Station 200 MW capacity turbines are of Kraft Werk Union (KWU - Germany) design and supplied by BHEL. The turbine is condensing, tandem compounded, horizontal, reheat type, single shaft machine. It has got separate high pressure, intermediate and low pressure parts. The HP part is a cylinder and IP & LP parts are double flow cylinders. The turbine rotor is rigidly coupled with each other and with generator rotor.

HP turbine has throttle control. The stream is admitted through two combined stop and control valves. The steam from reheater is admitted to IP turbine through two combined stop and control valves. Two crossover pipes connect IP and LP cylinder.

The entire turbine is provided with reaction blading. The moving blades of HPT, LPT and front rows of LPT have inverted T roots and shrouded. The last stages of LPT are twisted; drop forged moving blades with fir tree roots. They also have guide blades for proper functioning. The TG unit is mounted on six bearings HPT rotor is mounted on two bearings, a double wedged journal bearing at the front and combined thrust bearing adjacent to front IP rotor coupling.

In the 200 MW KWU turbines, single oil is used for lubrication of bearings, control oil for governing and hydraulic turbine turning gear. During start-ups, auxiliary oil pump (2 Nos.) supplies the control oil. Once the speed of the turbine crosses 90% of the rated speed, the main oil pump takes over. Under emergency, a DC oil pump can supply lubrication oil. Before the turbine is turned or barred, the Jacking Oil Pump (2 Nos.) supplies high pressure oil to jack up the turbine generator shaft to prevent boundary lubrication in bearing.

The turbine is equipped with a hydraulic turning gear assembly comprising two rows of moving blades mounted on the coupling between IP and LP rotors. The oil under pressure supplied

by the AOP strikes against the hydraulic turbine blades rotates the shaft at 110rpm (220 rpm under full vacuum condition).

Turbine shaft glands are sealed with auxiliary steam supplied by an electro-hydraulically controlled seal steam pressure control valve. A pressure of 0.01 Kg / square-cm (g) is maintained in the seals.

Above a load of 80 MW the turbine becomes self sealing. The leak off steam from HPT/IPT glands is used for sealing LPT glands.

SPECIFICATIONS

Type: The cylindrical reheat condensing turbine having:

- Single flow HP turbine with 25 reaction stages.
- Double flow IP turbine with 20 reaction stages per flow.
- Double flow LP turbine with 8 reaction stages per flow.

Rated Parameters

- Nominal rating ~~ 210 MW
- Peak loading (without HP heaters)~~ 229 MW
- Rated speed ~~ 3000 rpm
- Main steam flow at full load (with HP heater in service)~~ 630 tons per hour
- Main steam pressure /temperature at full load ~~ 147.1 kg/cm^2 535° C.
- Condenser pressure ~~ 76 mm Hg CW inlet temperature 33° C.

TURBINE GOVERING SYSTEM

In order to maintain the synchronous speed under changing load/grid or steam conditions, it is equipped with electro-hydraulic governor; fully backed-up by a hydraulic governor. The measuring and processing of electrical signal offer the advantages such as flexibility, dynamic stability and simple representation of complicated functional systems. The integration of electrical and hydraulic system is an excellent combination with following advantages:

- Exact load frequency drop with high sensitivity.
- Avoids over speeding of turbine during load throw offs.
- Adjustments of drop in fine steps, even during on load operation.

The main elements of the governing system are as follows:

- Remote trip solenoids (RTS).
- Main trip valves (Turbine trip gear).
- Starting and Load limit device.
- Speeder Gear (Hydraulic Governor).
- Aux. follow-up piston valves.
- Hydraulic amplifier.
- Follow-up piston valves.
- Electro-Hydraulic Converter (ECH).
- Sequence trimming device.
- Solenoids for load shedding relay.
- Test valve.
- Extraction valve relay.
- Oil shutoff valve.
- Hydraulic protective devices.

TURBINE PROTECTION SYSTEM

Turbine protection system performs to cover the following functions:-

a. Protection of turbine from inadmissible operating conditions.
b. In case of plant failure, protection against subsequent damages.
c. It restricts occurring failures to minimum.

Standard turbine protection system comprises the following:-

- Mechanical / hydraulic turbine protection.
- Electrical turbine protections.

The main elements of the Turbine Protection system are as follows:-

a) Emergency Governors.
b) Emergency Governor Pilot Valves.
c) Emergency stop valve (ESV) Servomotors.
d) Interceptor valve (I V) Servomotors.
e) Turbine shutdown switch.
f) Electro-hydraulic transducer.
g) Initial steam pressure unloading gear.

H.P. - L.P. BY- PASS SYSTEM

The HP By-pass system in coordination with LP By-pass enables boiler operation and loading independent of the turbine. For matching the live steam and metal temperature for a quick startup, by-pass stations have been provided, which dumps the steam to the condenser through pressure reducing station and desuperheaters, during the period the steam parameters at the boiler are being raised. This allows quick rising of parameters to a level acceptable to the turbine for rolling during startup. It helps in quick start of turbine and low noise level, also economizes the consumption of DM water.

The HP By-pass system consists of two parallel branches that divert steam from the Main Steam line to Cold Reheater line. The steam pressure on the valve upstream side can be maintained at the desired level. The steam is de-superheated in order to keep the steam temperature in cold reheat line within limits, below 345 degree Celsius. The steam downstream of the HP by-pass station is maintained by 2 nos. pf spray water temperature control valves BPE-1 and BPE-2 with valve mounted electro-hydraulic actuators.

With the use of turbine by-pass station it is possible to build up the matching steam parameters at the boiler outlet during any regime of starting, independent of the steam flow through turbine. The steam generated by boiler, and not utilized by the turbine during start-up or shutdown, is conserved within the power cycle and thus losses of steam into the atmosphere are cut down to the barest minimum. By-pass system enables to shorten the start-up time.

CONDENSATE EXTRACTION PUMP (CEP)

The condensate extraction pump (CEP) is a centrifugal type vertical pump, consisting of pump body, can, distributor housing and

the driven lantern. The pump body is arranged vertically in the can and is attached to the distributor with the rising main. The rotor is guided in bearings lubricated by the fluid pumped, is suspended from the support bearing, which is located in the bearing pedestal in the driven lantern. The shaft exit in the driver lantern is sealed off by one packed stuffing box.

The steam after condensing in the condensing in the condenser known as condensate is extracted out of the condenser hot well by condensate pump and taken to the Deaerator through ejectors, gland steam cooler and series of LP heaters. The function of these pumps is to pump out the condensate to the Deaerator through injector, gland steam cooler, and LP heaters. These pumps have four stages and since the suction is at a negative pressure, special arrangements have been made for providing sealing.

BOILER FEED PUMP (BFP)

The Weir type FK8D30 pressure stage pump is an 8 stage horizontal centrifugal pump of the barrel casing design. The pump internals are designed as a cartridge, which can be easily removed for maintenance without disturbing the suction and discharge pipe work, or the alignment of the pump and the turbo coupling. This system plays an important role in supply of feed water to the boiler at requisite pressure and steam/water ratio.

This pump is horizontal and of barrel design driven by an electric motor through a hydraulic coupling. All the bearings of pump and motor are forced lubricated by a suitable oil lubricated system with adequate protection to trip pump if the lubrication oil pressure falls below a preset value. The high pressure BFP is an expensive machine which calls for a very careful operation and skilled maintenance. The feed pump consists of the pump barrel, into which is mounted the inside stator together with rotor. The hydraulic part is enclosed by the high pressure cover along with the balancing device. The suction side of the barrel and the space in the

high pressure cover behind the balancing device are enclosed by the low pressure covers along with the stuffing box casings. The entire pump is mounted on a foundation frame. The flushing water is cooled by passing through seal coolers, and each seal coolers being circulated with clarified cooling water.

The water with the given operating temperature should flow continuously to the pump under a certain minimum pressure. It passes through the suction branch into the intake spiral and from there is directed to the first impeller. After leaving impeller it passes through the distributing passages of the diffuser and thereby gets a certain pressure rise at the same time it flows over to the guide vane to the inlet of the next impeller and the end diffuser. Thus the feed water reaching into discharge space develops the necessary operating pressure.

Each BFP is provided with a Booster pump in its suction line which is driven by the main motor of the boiler feed pump. One of the major damages which may occur to a BFP is from Cavitation or vapor bounding at the pump suction due to suction failure. Cavitation will occur when the suction pressure of the pump at the pump suction is equal or very near to the vapor pressure of the liquid to be pumped at the particular feed water temperature. By the use of the booster pump in the main pump suction line, always there will be positive suction pressure which will remove the possibility of Cavitation. Therefore all 3 feed pumps are provided with the main shaft driven booster pump in its suction line for obtaining a definite positive suction pressure.

GENERATOR AND ITS AUXILIARIES

GENERATOR:

The 200 MW generator is a 3-phase, horizontally mounted 2-pole cylindrical rotor type, synchronous machine driven by steam turbine. The stator windings are cooled by de-mineralized water flowing through the hollow conductor while the rotor winding is cooled by hydrogen gas. Fans mounted on the generator rotor facilitate the circulation of the H2 inside the machine requiring cooling. 4 coolers mounted inside the machine cool the H2 gas.

The generator winding is insulated by epoxy thermo- setting type insulation. It is provided with static excitation system. 2 H2 driers are provided to facilitate moisture removal. H2 is circulated through them via the fans in dry condition. Normally one drier is kept in service and other is in standby. Liquid Level Detectors (LLDs) are provided to indicate liquid in the generator casing, to indicate whether oil is leaking or water. It can be drained through drain valves. H2 gas purity is to be maintained at more than 99%.

The cooling water system consists of 2x100% duty AC motor driven pumps, 2x100% duty water coolers, 2x100% duty mechanical filters, 1x100% duty magnetic filter, expansion tank, polishing unit and ejector system. The stator water pump drive the water through coolers, filters and winding and finally discharges into the expansion tank situated at a height of about 5m above the TG floor. It is maintained at a vacuum of about 250mm Hg by using water ejectors. A gas trap is provided in the system to detect any traces of hydrogen gas leaking into the stator water system. To prevent leakage of hydrogen from generator housing, ring type seals are provided at the both ends of the generator. The seal ring is free to adjust its position according to shaft position.

SPECIFICATIONS

Rated Parameters:

- Maximum Continuous KVA rating ~~ 235300 KVA

- Maximum Continuous KW rating ~~ 200000 KW
- Rated Terminal Voltage ~~ 15750 V
- Rated Stator Current ~~ 9050 A
- Rated Power Factor ~~ 0.85 lag
- Excitation Voltage at MCR condition ~~ 310 V
- Excitation Voltage at MCR condition ~~ 2600 A
- Excitation voltage at no load ~~ 102 V
- Excitation current at no load ~~ 917 A
- Rated speed ~~ 3000 rpm
- Rated frequency ~~ 50 c/s
- Efficiency at MCR condition ~~ 98.49%
- Short circuit ratio ~~ 0.49
- Direction of rotation from slip ring ~~ Anti clockwise
- Phase connection ~~ Double star
- No. of terminals brought out ~~ 9(6 neutral, 3 phase)
- Generator gas volume ~~ 56 m^3
- Nominal pressure of H_2 ~~ 3.5 Kg/cm^2
- Nominal temp of cold gas ~~ 40 ^0C (Alarm)
- Purity of hydrogen ~~ > 97% (min)
- Relative humidity of H_2 ~~ 60 %
- Hot gas temp ~~ 75 ^0C
- **Stator water flow**
  1. Normal ~~ 27 $\pm$ 3 m^3 / hr
  2. Alarm ~~ 21 m^3 / hr
  3. Trip ~~ 13 m^3 / hr
- **Stator water conductivity**
  1. Normal ~~ < 5.0 μ mho/ cm
  2. High ~~ 13.3 μ mho/ cm
  3. Trip ~~ 13 m^3 / hr
- Stator water expansion tank volume ~~ 200-300 mm wcl

- **Nominal consumption of cooling water**
  1. At 35 ^0C ~~ 95 m^3 / hr
  2. At 37 ^0C ~~ 110 m^3 / hr

3. At 40 ^{0}C ~~ 130 m^{3} / hr

- **Seal oil outlet temperature**
  1. Normal ~~ 40 ^{0}C
  2. Alarm ~~ 65 ^{0}C
- Safety Valve release (AC seal oil pump) ~~ 9 Kg/cm^{2}
- Safety Valve release (DC seal oil pump) ~~ 9 Kg/cm^{2}

STATIC EXCITATION SYSTEM

Static Excitation System is used in most of the 200 MW Generator sets. The AC power is tapped off from the generator terminal and stepped down and rectified by fully controlled thyristor b ridges and then fed to generator field as excitation power, to control the generator output voltage. A high controlled speed is achieved by using an inertia free control and power electronic system. Any deviation in generator terminal voltage is sensed by an error detector and causes the voltage regulator to advance or retard the firing angle of thyristor thereby controlling the field excitation.

The static excitation system consists of:

i. Rectifier Transformer
ii. Thyristor Converter
iii. Automatic Voltage Regulator
iv. Field Flashing Circuit
v. Field breaker and field discharge equipment.

GENERATOR PROTECTION

The core of an electrical power system is generator. During operating conditions certain components of the generator are subjected to increase stress and therefore, could fail, referred to as faults. It can be internal fault or external fault depending upon whether they are inside or outside of the machine. The machine with fault must be tripped immediately. The corrective measures against generator's abnormal operation are taken care by stubborn system.

Task of the protective system:

- Detect abnormal condition or defect.
- Limit its scope by switching to isolate the defect.
- Alarm the operating staff.
- Unload and/or trip the machine immediately.

Requirement of protective devices:

- Selectivity: Only that part of the installation containing fault should is disconnected.
- Safety against faulty tripping: There should be no trip when there is no fault.
- Reliability: The device must act within the required time.
- Sensitivity: Lowest signal input value at which the device must act.
- Tripping time: There should be a clear a distinction between the tripping time of the device, considering the circumstances such as current and total tripping time for the fault.

Protective Devices

The choice of protective equipment for the generator should precisely understand the type of fault and do the necessary preventive measures for avoiding it.

Electrical protection

- Differential protection:
    - Generator differential
    - UAT differential
    - Overhead line differential
    - G.T. restricted earth fault, Main
    - Overall differential
- Earth fault protection:
- Stator earth fault
- Stator earth fault, Stand by
- Rotor earth fault
- Stator Inter turn fault
- Negative Phase Sequence Current
- Generator Backup Impedance
- Loss of excitation
- Pole slipping
- Over voltage
- Over fluxing
- Low forward power
- Reverse power
- Generator Local Breaker Backup (LLB)
- Generator Transformer Protections
- Buchholz Protection
- PRD protection
- Winding Temperature High
- Oil Temperature High
- Fire Protection
- UAT Protection
- Bus Bar Protection

ELECTROSTATIC PRECIPITATOR

(ESP)

Indian coal contains about 30% of ash. The hourly consumption of coal of a 200 MW unit is about 110 tons. With this, the hourly production of ash will be 33 tons. If such large amount of ash is discharge in atmosphere, it will create heavy air pollution thereby resulting health hazards. Hence it is necessary to precipitate dust and ash of the flue gases.

Precipitation of ash has another advantage too. It protects the wear and erosion of ID fan.

To achieve the above objectives, Electrostatic Precipitator (ESP) is used. As they are efficient in precipitating particle form submicron to large size they are preferred to mechanical precipitation.

CONSTRUCTION

An ESP has series of collecting and emitting electrons in a chamber collecting electrodes are steal plates while emitting electrodes are thin wire of 2.5mm diameter and helical form. Entire ESP is a hanging structure hence the electrodes are hung on shock bars in an alternative manner.

It has a series of rapping hammer mounted on a single shaft device by a motor with the help of a gear box at a speed of 1.2 rpm. At the inlet of the chamber there are distributor screens that distributes the gas uniformly through out the chamber.

There are transformer and rectifiers located at the roof of chamber. Hopper and flushing system form the base of chamber.

WORKING:

Flue gases enter the chamber through distributor screen and get uniformly distributed. High voltage of about 40 to 70 KV form the transformer is fed to rectifier. Here ac is converted to dc. The negative polarity of this dc is applied across the emitting electrode while the positive polarity is applied across the collecting electrodes. This high voltage produces corona effect negative (–ve) ions from emitting electrode move to collecting electrode. During their motion, they collide with ash particles and transfer their charge. On gaining this charge, ash particles too move to collecting electrode and stock to them. Similar is the case with positive (+ve) ions that moves in opposite direction.

The rapping hammers hit the shock bars periodically and dislodge the collected dust from it. This dust fall into hopper and passes to flushing system. Here it is mixed with water to form slurry which is passed to AHP.

Efficiency of ESP is approximately 99.8%.

ASH HANDLING PLANT (AHP)

The ash produced on the combustion of coal is collected by ESP. This ash is now required to be disposed off. This purpose of ash disposal is solved by Ash Handling Plant (AHP).
There are basically 2 types of ash handling processes undertaken by AHP:

- Dry ash system
- Ash slurry system

Dry ash system

Dry ash is required in cement factories as it can be directly added to cement. Hence the dry ash collected in the ESP hopper is directly disposed to silos using pressure pumps. The dry ash from these silos is transported to the required destination.

Ash slurry system

Ash from boiler is transported to ash dump areas by means of sluicing type hydraulic system which consists of two types of systems:

- Bottom ash system
- Ash water system

Bottom ash system

In this system, the ash slag discharged from the furnace is collected in water impounded scraper installed below bottom ash hopper. The ash collected is transported to clinkers by chain conveyors. The clinker grinders churn ash which is then mixed with water to form slurry.

Ash water system

In this system, the ash collected in ESP hopper is passed to flushing system. Here low pressure water is applied through nozzle directing tangentially to the section of pipe to create turbulence and proper mixing of ash with water to form slurry.

Slurry formed in above processes is transported to ash slurry sump. Here extra water is added to slurry if required and then is pumped to the dump area.

Fly ash system

Even though ESP is very efficient, there is still some ash, about 0.2%, left in flue gases. It is disposed to the atmosphere along with flue gases through chimney.

ROLE OF TRANSFORMERS:

After the electricity is generated by the turbogenerators of Unit-1 to 5 (generating 15.75KV) & Unit 6 & 7(generating 21 KV),it is sent to the Generating Transformer(G.T.) and Unit-Auxiliary Transformer(U.A.T.) at the same time.

Generating Transformer steps–up this voltage of 15.75/21 KV to a higher voltage of 400 KV (hence, working as a step-up Transformer).This voltage of 400 KV is then transmitted to switchyard.

GENERATING TRANSFORMER(G.T.)

Unit-Auxiliary Transformer(U.A.T.) steps-down this voltage of 15.75/21 KV to a comparatively lower voltage of 6.9 KV which is required to run the auxiliaries of the Main Plant such as I.D. Fan,

P.A. Fan, F.D. Fan and other auxiliary motors. Each unit has its own separate G.T. & U.A.T.

UNIT AUXILIARY TRANSFORMER(U.A.T.)

There is one more Transformer known as **Station Transformer** used only for initializing the start-up of the station (Main Plant).It is very beneficial during emergency situations such as tripping of Units, shut-down etc.

It gets the supply in its primary from 132 KV switchyard, steps-down it to 6.6 KV which is used for starting various equipments & devices used in the Main Power Plant.

STATION TRANSFORMER(S.T.)

GENERATING TRANSFORMER:

- Type of coolingO.F.W.F.
- Rating H.V.(MVA): 200

- Rating L.V.(MVA): 200
- No-load Voltage (KV):
  - H.V. 400/√3
  - L.V. 21
- Line current(Amps.):
  - H.V. 866.0
  - L.V. 9523.8
- Temperature rise(°C):
  - Oil 50
  - Windings 60
- Phase: 1
- Frequency (Hz): 50
- Connection symbol: YND11*
- Makers Serial No: 60046
- Electrical Specification No: 600626
- Year of manufacture: 1985
- Core & winding(Kg.): 123050
- Weight of Oil(Kg.): 27500
- Total weight (Kg.): 179500
- Oil quantity(l.): 29540
- Transport weight(Kg.): 138000
- Untanking weight(Kg.): 12000
- Insulation Level:
  - H.V. S.I.1050 KVp LI 1300KVp AC 38KV rms
  - L.V. L.I.125 KVp, AC 50 KV rms

*When connected in a bank of three transformers.

UNIT AUXILIARY TRANSFORMER (U.A.T.)

- Rating (KVA): 12000/16000

- Cooling: Method ONAN/ONAF
  % 75/100
- KV (At no load):
  H.V. 15.75
  L.V. 6.9
- Amperes:
  H.V. 439.8/586.53
  L.V. 1004.1/1338.8
- % Impedance:
  At 75°C Min. tap 5.63/7.50
  Normal tap 5.47/7.29
  Max. tap 5.46/7.28
- Phases: H.V. & L.V. Three
- Vector group: H.V. & L.V. DY ∩1
- Temp.rise (˚C):
  Tap oil 40
  Winding 50
- Insulation level(KVp):
  H.V. 125
  L.V. 60
- Total Mass(Kg.): 37700
- Untanking Mass(Kg.): 19200
- Mass of Oil(Kg.): 7100
- Volume of Oil(l.): 8250
- Transport Mass with Oil(Kg.): 30000
- Manufacture's Serial No: 37893
- Year of manufacture: 1982
- Frequency(Hz): 50

STATION TRANSFORMER:

- Rating(KVA): 19000/25000/31500
- Amperes:
  - H.V. 83.1/109.3/137.8
  - L.V. 1589.8/2091.8/2635.7
- **%** Impedance (At 75°C)
  - Min.tap 8.05/10.60/13.35
  - Normal tap 8.23/10.83/13.64
  - Max.tap 8.66/11.40/14.36
- KV at no-load:
  - H.V. 132
  - L.V. 6.9
- Phases: H.V. & L.V. 3
- Vector group: H.V. & L.V. YNY∩O
- Temp. rise(°C):
  - Tap Oil 40
  - Winding 55
- Frequency(Hz): 50
- Total Mass(Kg.): 63000
- Untanking Mass(Kg.): 29000
- Mass of Oil(Kg.): 17000
- Volume of Oil(l.): 19600
- Transport Mass with Oil(Kg.): 47000
- Insulation level(KVp):
  - H.V./H.V.N. 550/170
  - L.V. 60
- Cooling Methods: ONAN/ONAF/OFAF
  - **%** 60/80/100
- Manufacture’s Serial No: 37899
- Year of manufacture: 1980

POWER

TRANSMISSION

IN

SSTPS

SWITCHYARD

Switchyard is considered as the ***HEART*** of the Power Plant. Power generated can be worthful only if it is successfully transmitted and received by its consumers. Switchyard plays a very important role as a ***buffer*** between the generation and transmission. It is a junction, which carries the generated power to its destination (i.e. *consumers*).

Switchyard is basically a yard or an open area where many different kinds of equipments are located (isolator, circuit breaker etc…), responsible for connecting & disconnecting the transmission line as per requirement (e.g. any fault condition).

Power transmission is done at a higher voltage.
(*Higher transmission voltage reduces transmission losses).*
Therefore, the power generated by the Turbogenerator of 1 to 5 units is ***15.75KV*** and of 6&7 units is ***21KV*** which is further stepped-up to ***400KV*** by the ***Generating transformer*** & then transmitted to switchyard.
Switchyards can be of ***400KV, 200KV&132KV.***
In ***SSTPS*** there are two interconnected switchyards:-

(i) 400KV SWITCHYARD

(ii) 132KV SWITCHYARD

400KV SWITCHYARD:

There are on total 21 bays in this switchyard.
(A bay is basically a way for the incoming power from generator as well as outgoing power for distribution).

- 7 for unit Generating Transformer.
- 7 for various distribution lines such as:
  Lucknow line;
  Allahabad #1 line;
  Anpara line;
  Allahabad #2 line;
  Rihand #1 line;
  VSTPP line;
  Rihand #2 line;
- 2 for Bus coupler.
- 2 for TBC.
- 2 for ICT.
- 1 for the Bus Section.

There are on total ***6 buses*** in 400KV switchyard.

- Bus-1
- Bus-2
- Bus-3
- Bus-4

There are two transfer buses:

- Transfer bus-1
- Transfer bus-2

Transfer buses are kept spare and remain idle and are used only for emergency purposes.

Bus-1 & Bus-3, Bus-2 & Bus-4; both are joined together by ***BUS SECTION (1 & 2)*** respectively.

BUS COUPLER-1 & BUS COUPLER-2 interconnects Bus-1 & Bus-2, Bus-3 & Bus-4 respectively. Bus couplers are very beneficial as they help in *load sharing* between the different buses.

TBC (TRANSFER BUS COUPLER):

TBC is a bus coupler, which uses transfer bus when there is any defect in the equipments used (circuit breakers & isolators) in any of the bay. Thus, it offers a closed path through transfer bus for the flow of power in the respective bus.

There are two TBC bays: TBC#1 bay used for stage-1 (200MW) & TBC#2 bay used for stage-2 (500MW).

ICT BAY:

ICT#1 & ICT#2 bay interconnect 400KV & 132KV switchyard.

132KV SWITCHYARD:

There are 15 bays in 132KV switchyard.

- 4 for Station Transformer.
- 4 for C.W. Transformer.
- 2 for Colony Transformer.
- 2 for I.C.T.
- 1 for S-V-R line.
- 1 for Pipri line.
- 1 for Bus Coupler.

There are only ***2 buses*** in 132KV switchyard.
Bus-1 is arranged in ***U-shape*** configuration
Whereas Bus-2 is a single straight line inserted in between U-shaped Bus-1.

BUS COUPLER is used to couple Bus-1 & Bus-2.

Station Transformer Bay:

There are 4 Station Transformer connected with 132KV switchyard.
(S.T. #1, S.T. #2, S.T. #3 & S.T. #4) rated at
50 MVA.

S.T. #1 & S.T. #2 are used for stage-1 (200 MW) and S.T. #3 & S.T. #4 used for stage-2 (500 MW).

The main purpose of the Station Transformer is to step-down the system voltage of 132 KV to 6.6KV, which is used to start-up the Station (Main Plant).

C.W.Transformer Bay:

There are 4 C.W.Transformer connected with 132 KV switchyard.
(C.W. #1, C.W. #2, C.W. #3, C.W. #4) rated at 25 MVA.

The main purpose of C.W. Transformer is to step-down the system voltage of 132 KV to 6.9 KV, which is required for C.W. Pump Motor used for condensing the water.

Colony Transformer Bay:

There are 2 Colony Transformer connected with 132KV switchyard. (Colony Transformer#1 & Colony Transformer#2) rated at 12.5 MVA.

The purpose of Colony Transformer is to step-down the system voltage of 132 KV to 11 KV for supplying the electricity to colonies for domestic purposes.

ICT BAY:

ICT#1 & ICT#2 bay interconnect 400KV & 132KV switchyard.

Pipri Line:

In the case of emergency, e.g. total grid failure we take the power from Pipri line for the initial starting of the station (Main Plant). Though Pipri comes in NORTHERN REGION itself but since it is a HYDEL Power Plant, it requires very less time (about 5 to 10 mins.) to get start-up again.

S-V-R Line:

S-V-R line stands for Singrauli-Vindhyachal-Rihand line and it connects all the three.
In case of emergency, e.g. total grid failure of NORTHERN REGION we take Power from VSTPP (as it comes under WESTERN REGION) for the initial starting of the system.
Switchyard mainly consists of:

- **(i) Outdoor equipments.**
- **(ii) Protection and Control panels.**
- **(iii) P.L.C.C (Power Line Carrier Communication).**

OUTDOOR EQUIPMENTS:

1. *Lightening Arrestor:*

It is a protective device, which protects the costly equipments such as overhead lines, poles or towers, transformer etc. against lightening. As the name suggests it arrests the lightening of very high voltage (crores of KV) and dump it into the ground.

It works on the principle of ***easy path for the flow of current.***

L.A. is connected in parallel with the line with its lower end connected and the upper end projected above the pole of tower.

2. *Lightening Most:*

It is present at the highest point, at the topmost tower of the switchyard and is connected together by wires forming a web. The reason for its presence at the topmost point is to grasp the lightening before it can come, fall and damage the costly equipments present in the switchyard.

3. *Wave Trap:*

It is an equipment used to trap the high *carrier frequency* of 500 KHz and above and allow the flow of *power frequency* (50 Hz).
High frequencies also get generated due to capacitance to earth in long transmission lines.
The basic principle of wave trap is that it has low inductance (2 Henry) & negligible resistance, thus it offers high impedance to *carrier frequency* whereas very low impedance to *power frequency* hence allowing it to flow in the station.

4. *CIRCUIT BREAKER:*

It is an automatic controlling switch used in power house, substation & workshop as well as in power transmission during any unwanted condition (any fault condition-earth fault, over-current, flashover, single phasing,).

During such condition it cuts down the supply automatically by electromagnetic action or thermal action. It can be used in **off-load** as well as **on-load** condition.

When a circuit breaker is operated by sending an impulse through relay, C.B. contact is made or broken accordingly. During this making and breaking, an arc is produced which has to be quenched; this is done by air, oil, SF6 gas etc….

Depending on the medium being used C.B.s can be categorized into various types.In SSTPS for 400 KV/132 KV switchyard only 4 main types are being used:-

- ***ABCB (Air operated circuit breaker):-*** operated as well as arc quenched through air.
- ***Air operated SF6 circuit breaker:-*** operated through air but arc quenching done through SF6 gas.
- ***MOCB (Minimum oil circuit breaker):-***operated through spring action but arc quenching done through oil (Aerosol fluid oil).
- ***Hydraulic operated SF6 circuit breaker:-*** operated through hydraulic oil and arc quenching done through SF6 gas.

Hydraulic operated SF6 circuit breaker is the most efficient due to following reasons:-

1. Less maintenance.
2. Arc quenching capability of SF6 gas is more effective than air.
3. Heat transfer capacity is better in this C.B.

5. ISOLATOR:

An isolator is also a switching device used to disconnect the line. As the name suggests it isolate the line from the supply. It is always used in *OFF-LOAD* condition.

Whenever any fault occurs in the equipments present in the line, in order to remove the fault or replace the device first of all supply is disconnected. But even after the disconnection of the supply, the line remains in charged mode so before working on the device (to remove fault) isolator should be made open.

Depending on the structure there are mainly two types of isolators:-

- **Pentagraph isolator.**
- **Centre-break isolator** (also known as **Sequential isolator**).

Pentagraph is generally used in buses whereas Centre-break (Sequential) is used in line.

Isolators may be operated in air (pneumatic), electrically or even manually.

6. C.V.T (Capacitance Voltage Transformer):

This Transformer performs mainly two major functions:-

- Used for *voltage measurement*. The high voltage of 400 KV is impossible to measure directly. Hence a C.V.T is used, (connected in parallel with the line) which *step-downs* the voltage of 400 KV to 110 KV, comparatively easy to measure.
- The other most important function of C.V.T is that it *blocks* power frequency of 50Hz and *allows the flow of carrier frequency for communication.*

7. P.T (Potential Transformer):

This Transformer is connected in parallel with the line with one end earthed. It is only used for *voltage measurement by stepping-down the voltage to the required measurable value.*

8. C.T (Current Transformer):

This Transformer is used for basically two major functions: -

- *Metering which means current measurement.*
- *Protection such as over current protection, overload earth fault protection, Bus-bar protection, Bus differential protection.*

NOTE:- *Secondary of the C.T should be kept shorted* because (when secondary is kept open) even the presence of a very small voltage in the primary of C.T will prove to be harmful as it will start working as a step-up Transformer & will increase the voltage to such a high value that primary would not be able to bear it & will get burned.

CONTROL AND PROTECTION PANELS

The control and relay panels associated with 400KV & 132KV switchyard are installed in a control room. The equipments housed here are:-

- Air compressors for compressed air supply to 400KV/132KV switchyard where pneumatically operated isolators and ABCB are installed. The compressors develop a pressure of 60 Kg.
- Two independent D.C. batteries of 300 AH capacity, 220V each along with separate battery chargers and distribution boards.
- One P.L.C.C. battery of 400AH capacity, 50V with separate battery charger.
- P.L.C.C. Panels.
- A.C. distribution board for 415V A.C. supply inside the switchyard.

The control and relay panels installed in this room are:-

(i) ***Duplex type control and relay panels*** for 400/132KV feeders. The protective relays of 400/132KV feeders such as control relays, local breaker back-up relays, energy-meters, auto-reclose relays for line feeders and breakers, pole discrepancy relays are housed on the back of the relay panels.

(ii) ***Simplex type protection panels*** for 400KV feeders. On these panels protective relays of line feeders are mounted.

The common bus bar protection panels in a separate section house all the bus bar protection scheme relays except the C.T. zone switchyard relays that are mounted in weather proof relay panel for each bay located in the switchyard.

Besides the above, the protection relays of generator feeders are located in a section of simplex protection panels located in the unit control room for each generator.

Power Line Carrier communication

(P.L.C.C.)

As the name suggests, P.L.C.C. is basically a method in which the line used for power transmission is also being used for communication.
P.L.C.C is employed for performing following two functions:

(i) Communication purposes.
(ii) Line tripping.

Communication Purpose:

There are two types of electrical signals which flow in a line- 50Hz power signal & 20 KHz of carrier signal. In order to isolate these two signals (so that they do not hinder each other) tapping of the signals is done as per the requirement. Since in the buses and bays we need only power signal, wave traps are being used to block high frequency carrier signals. C.V.T. blocks the power frequencies and due to the capacitance present it allows the high frequency carrier signals to pass through co-axial cables.

Line Tripping:

Transmission line between two sub-stations is bi-directional. When a fault occurs and a trip command is given at one end, the breaker gets opened. Now the other end breaker should also be opened to completely isolate the line from supply. For this the other end should also give the trip command. This is when the P.L.C.C. comes into play.

From the P.L.C.C. room present at the tripping end along with the carrier signal, a signal of a lesser frequency is superimposed and sent to the P.L.C.C. room present at the other end. Now this will be demodulated and the other end will come to know that tripping has occurred. Now it will give a command, which will energize the relay, contact will be made and the breaker will operate.

STATIC EXCITATION SYSTEM OF SSTPS

–

INTRODUCTION

The static excitation system has been provided in 5x200MW units of stage1 of S.S.T.P.S.

Generation of electricity in thermal power station is the process of conversion of thermal energy to electrical energy.
Thermal energy is transformed into rotational energy by the means of process up to turbine in thermal power stations and conversion of rotational energy to electrical form is achieved by means of generator.

This process requires mainly;

1. A conductor or coil in which the electrical power is developed i.e. stator coil.
2. A magnetic field as an intermediatory in conversion processes either a permanent magnet or an electromagnet created by the means of excitation system.
3. Relative motion between coil and field achieved through rotational power input by turbine.

Thus the generator converts the rotational energy input at its rotor shaft to electrical energy at stator terminals by the means of magnetic coupling between stator and rotor achieved through excitation system. The excitation system achieves this by application of DC voltage at its rotor winding.

Main Features:

1. It is designed as very fast response system with response time of approx. 40 msec.

2. Fast de-excitation is achieved by provision of F.D.R.[Field Discharge Resistor] and also the inverter action of thyristors.
3. Fully static, therefore most reliable.
4. AC to DC converting stage can be replaced during running condition in view of redundancy.

CIRCUIT CONFIGURATION

The complete installation can be divided into 4 main sections:

- Excitation transformer

- Converter
- Excitation build-up and de-excitation facility
- Regulation and control unit.

WORKING

It can be described in following steps:

1. The generator terminal voltage (15.75KV) is tapped and stepped down to 575V by the means of excitation transformer.

2. This is fed to generator field winding after controlled rectification through 4 fully controlled thyristor bridges with the help of A.V.R. panel, grid control panel, pulse amplifiers and gate circuit.

For initial voltage build up

1. When generator terminal voltage in not available, the power is taken from auxiliary 415V AC (or DC) supply.

2. And it is fed through a step down transformer and uncontrolled full wave rectifier to generator field winding.

3. During starting, as soon as the field breaker is closed, field flashing contractor also closes and field voltage builds up. Field flashing is capable of building up generator voltage to 70% of rated value.

4. As soon as 30% of generated terminal voltage is reached, the normal mode of excitation
System i.e. through fully controlled thyristor bridges (from rectifier transformer) becomes active.

5. As soon as 70% of generator terminal voltage is reached, field flashing contactor goes off and auxiliary source function is now inactive, excitation function being solely taken over by normal source.

6. If within 20sec. voltage build up does not take place and field flashing contactor is not switched off, then field breaker trips.

Various subsystems of normal mode of excitation system are:

(i)Rectifier Transformer:

It is a 3-phase,2500KVA,15.75KV/575V drycast resin transformer installed just below main generator terminal and housed in and enclosed cubicle.

Normally the transformer has DYn5 vector group connections because it facilitates easy manufacturing activities.

The main **function** of this transformer is:
To supply the rated excited current at rated voltage continuously.

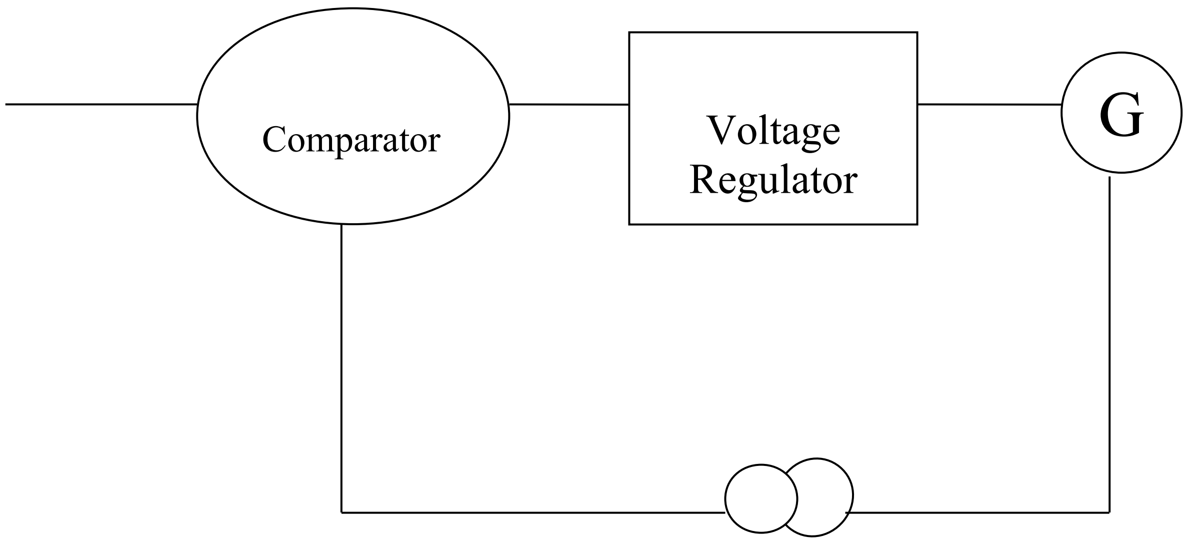
Advantages:

- *High overload capacity.*
- *Short circuit & Moisture proof.*
- Resistance against temp. fluctuations.
- *High impulse strength.*
- *Immediate switch on.*
- *Maintenance free.*

(ii)Automatic Voltage Regulator (AVR):

When excitation is kept on auto mode, the AVR comes into the picture. It generates constant generator terminal voltage under all operating conditions like load variations,frequency variations, grid voltage variations & fault conditions by controlling the supply of DC to the main generator rotor winding.

It is a closed loop electronic controller which uses a signal proportional to the generator terminal voltage and compares it with steady reference voltage. The difference voltage is used to control generator output voltage.



If the load on the generator changes the generator terminal voltage also changes. It compares the actual generator voltage with the reference and the error signal is processed to form grid control voltage. This grid voltage decides the firing angle of thyristor bridges. Apart from reference voltage, the influence of limiter and PSS also act on this AVR module. Limiter operation overrides the AVR action.

(iii)<u>Gate Control Circuit:</u>

The grid control voltage formed by AVR or in case of manual operation, the manual grid control voltage formed by the

manual reference set by the desk engineer acts on this module to generate a series of pulse train placed at definite intervals(determined by firing angle)suitable for firing a fully controlled full wave thyristor bridge. These pulses of very low power are amplified at intermediate and final pulse stage amplifiers of respective thyristor bridges and then are applied to the gate circuit of thyristor bridges. The pulse output of intermediate pulse amplifier is monitored by supervision unit.

Separate intermediate amplifier and gate control units are provided for auto and manual channels. Whereas the pulse final stage amplifier is provided at individual thyristor bridge panels and a common for both the channels.

Follow Up Circuits:

Normally, excitation system is run in auto mode. In case of any problem in auto mode, there is a provision of automatic "Protective changeover to manual". Thus, in case of fault in auto channel, the excitation system automatically changes over to manual. For this it is essential that manual channel reference potentiometer should always follow auto channel reference so that in case of sudden changeover to manual due to auto fault, there is no jerk on generator voltage and smooth changeover is insured. This is achieved by follow up control. Therefore, whenever the system is on auto mode manual follows auto channel and therefore always the AVR balance meter continues to show "Zero" value. Whenever protective changeover to manual takes place, an alarm comes in UCB.

It must be noted that even when it is desired to change the channel either from manual to auto or vice-versa manually, the desk operator must insure AVR balance meter is at zero during changeover. If it is not at zero, zero condition is to be achieved by changing either auto or manual reference potentiometers.

Limiters and PSS:

The basic function of the limiters is to intervene whenever the generator operating point goes beyond its capability.

It should be noted that limiters *do not cause any protective tripping*. Another aspect to be noted is that limiters are functional only during auto channel operation of excitation system.

The various types of limiters employed are:

1. Stator Current Limiter:

Its function is to limit stator current by acting on AVR. It acts both in under-excited as well as over-excited region. In under-excited region the limiter acts without time delay whereas in overexcited region, it acts with time delay through an integrator to avoid limiter intervention during transient conditions. This delay is dependent on the rate and amount by which stator current has exceeded the limit.

2. Rotor Current Limiter:

It comes into action whenever field current goes beyond set value of 100 to 105% of rated generator field current. It instantaneously limits the field current to 150% of rated generator field current and gradually brings it down to set value of 100 to 105%.This is done to avoid limiter to intervene in

transient conditions when there is additional requirement of excitation current.
E.g. in case of external faults in the network when generator terminal voltage tends to fall. AVR tends to boost excitation so as to maintain generator voltage till the time fault is cleared by protective relays. This action called *field forcing* is essential to prevent generator falling out of step. This limiter operates only in overexcited region of machine operation.

3. Load Angle Limiter:

It limits the angle between grid load centre and rotor axis. Thus prevents the generator to go in unstable limit.

PSS (Slip Stabilization):

The function of limiter is to intervene in AVR operation and stabilize the generator operating point at the time of low frequency oscillations in active power caused by external network.

DRAWBACKS

It is well known that the excitation system forms a vital subsystem in electrical power generation. But excitation system has many in built redundancy features. The common problems experienced are:

1. Problems in voltage build up and related problems in field flashing and field breakers.

2. Problems in auto and manual channels and electronic circuit due failure of electronic sub assemblies.

3. Thyristor block problems.

4. PSS problems.

5. Transformer thermistor failure (used for temp. protections of rectifier transformer): Thermistors are being replaced to overcome this.

REMEDIAL MEASURES

1. Daily monitoring.

2. Periodic P/M: The optimum frequency of P/M for the system is once in 3-4 months. By implementing this schedule most of the problems have been overcomed.

3. Extensive testing during unit overhauls.

4. Maintaining proper air-conditioning of regulation cubicle.

With effective implementation of above, failures and consequent delays/trippings have been minimized.

BRUSHLESS EXCITATION

SYSTEM

IN

500 MW

INTRODUCTION

In 500 MW Turbo-generator, brushless excitation system is provided. Brushless exciter consists of a 3-phase permanent magnet pilot exciter the output of which is rectified and controlled by Thyristor Voltage Regulator to provide a variable D.C. for the main exciter.

The three phases are induced in the rotor of the main exciter and is rectified by the rotating diodes and fed to the field winding of generator rotor through the D.C. leads in the rotor shafts.

Since the rotating rectifier bridge is mounted on the rotor, the slip rings are not required and the output of the rectifier is connected directly to the field winding through generator rotor shaft.

A common shaft carries the *rectifier wheels, the rotor of the main exciter* and *permanent magnet rotor of the pilot exciter.*

RECTIFIER WHEELS

The main components of rectifier wheels are the silicon diodes which are arranged in a three phase bridge circuit.
The basic elements of the rectifier wheels are:

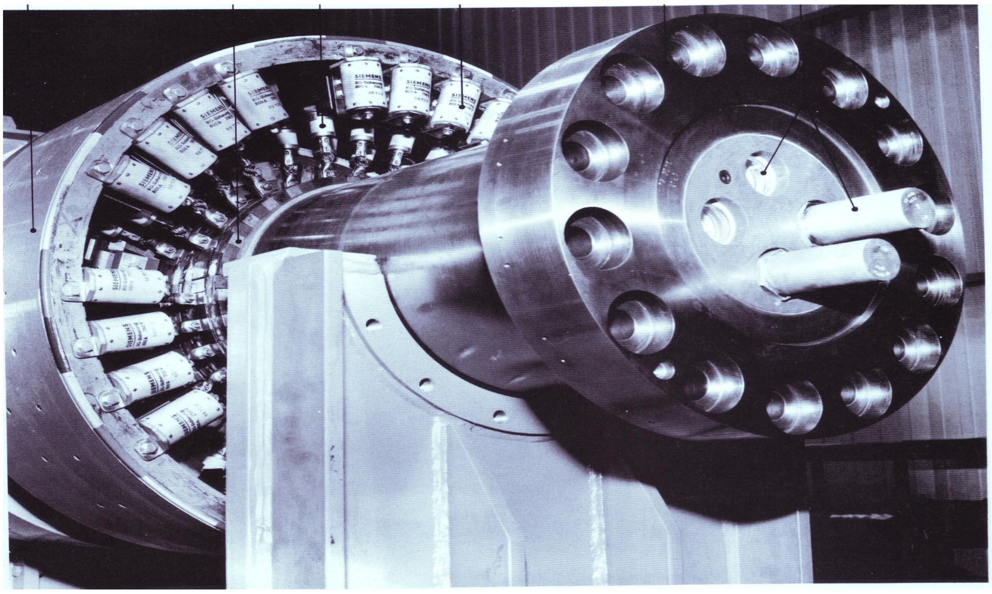
- *Rectifier wheel.*
- *Three phase lead.*
- *Heat sink.*
- *Diode.*

- *Fuse.*
- *Multi contact plug-in-bolt.*

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 of which is combined in a single resin-encapsulated unit.

The insulated and shrunken rectifier wheels serve as D.C. buses for the negative and positive sides of the rectifier bridge. The direct current from the rectifier wheels is fed to the D.C. leads arranged in the central bore of the shaft via radial bolts.

The 3-phase alternating current is obtained via copper conductors arranged on the shaft circumference between the rectifier wheels and the 3-phase main exciter.



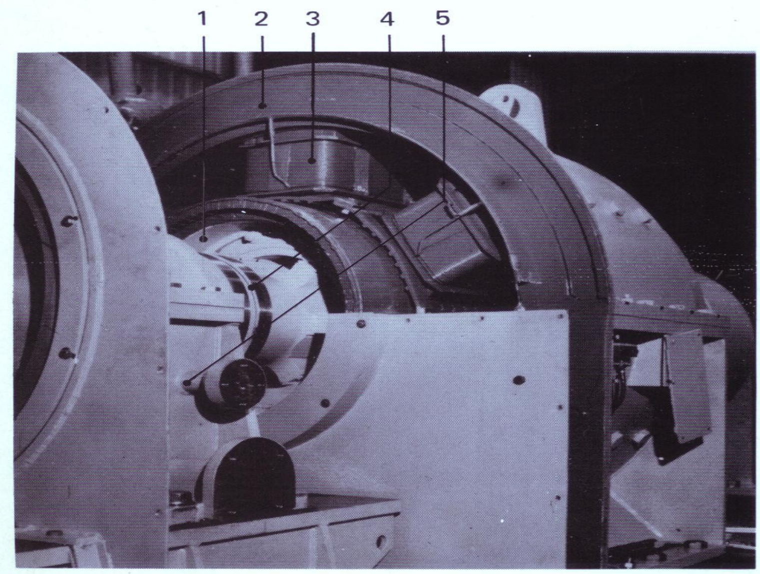
THREE-PHASE MAIN EXCITER

The main components of 3-phase exciter are:

- *Stator.*
- *Rotor.*
- *Magnetic pole.*
- *Slip rings for ground fault detection.*
- *Bearing housing.*

The 3-phase main exciter is a 6 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.

The rotor consists of stacked laminations which are compressed by bolts over compression rings. The three-phase winding is inserted in the slots of the laminated rotor. The winding ends are run to a bus ring system to which the 3-phase leads to the rectifier wheels are also connected.

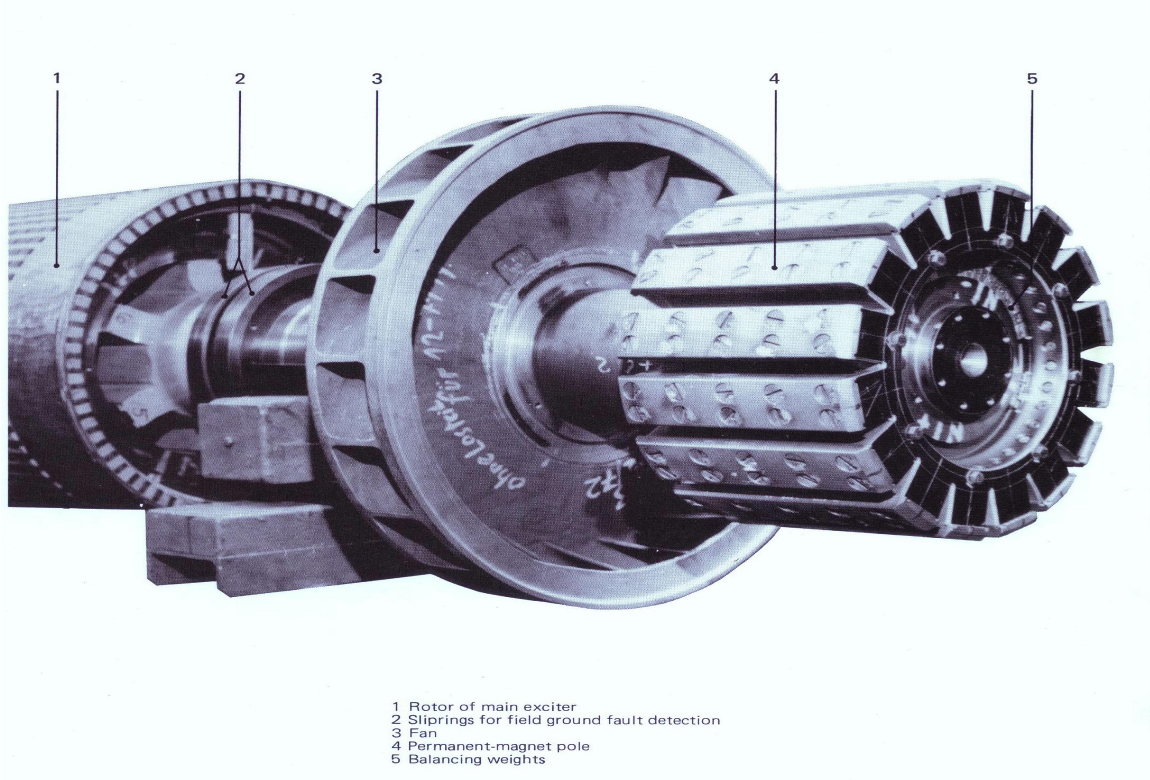


1 Rotor
2 Stator
3 Magnetic pole
4 Sliprings for ground fault detection
5 Bearing housing

Fig. 5 Main Exciter

THREE-PHASE PILOT EXCITER

The three-phase pilot exciter is a16 pole revolving-field unit. The frame accommodates the laminated core with the three phase winding. Each pole consists of 10 separate permanent magnets which are housed in a non magnetic metallic enclosure.



COOLING OF EXCITER

The exciter is air cooled. The cooling air is circulated in a closed circuit and re-cooled in two cooler sections arranged along side the exciter. The complete exciter is housed in an enclosure through which the cooling air circulates.

In the event of cooler failure, emergency cooling is provided to permit continued operation.

AUTOMATIC VOLTAGE REGULATOR

Voltage Regulating System

1. Type Thyrisiem 04-2

2. Maximum Output Voltage 250 V

3. Output Current for field 152 A
forcing

4. Output Current for rated 88 A
generator load

5. Auxiliary Voltage from 3-phase, 220V
Pilot exciter for Thyristor sets

6. D.C. Voltage from station 220V
battery for conductor&drive

7. Power input continuously 0.1KW

8. Power input short time 1KW

9. DC current from station Max.15A positive
battery 224V for control Max.6A
and regulation

10. Rated secondary current 120V

11. Power input of voltage 2VA
transformer per phase

12. Rated secondary current 5A

13. Power input of current   6.5VA
Transformer per phase

14 Accuracy of control   better than 0.5%

15. Setting range of voltage 5-10%of nominal   set point
potentiometer   Gen. Voltage

16. Setting range of droop compensation or compounding 0-10% dependent on the setting of the potentiometer and proportional to reactive current.

STRUCTURAL SET-UP

The THYRISIEM 04-2 voltage regulator is designed for excitation and control brushless generators. The machine set consists of the generator and a direct coupled exciter unit with a 3-phase main exciter, rotating rectifiers and a permanent magnet auxiliary exciter.

The main components of the voltage regulator are *two closed-loop control systems each followed by a separate gate control unit, Thyristor set and a de-excitation equipment.*

CONTROL SYSTEM-1(AUTO):

COMPONENTS:

- *Generator voltage control*
- *Excitation current regulator*

- *Circuit for automatic excitation build-up during start-up and field suppression during shut-down*
- *Limiter for the under-excited range*
- *Delayed limiter for the over-excited range*

The field forcing limitation limits the output current of the thyristor sets to the maximum permissible value i.e. 1.5 times the rated excitation, when the voltage regulation calls for maximum excitation.

In the under-excited range, the under excitation limiter ensures that the minimum excitation required for stable parallel operation of the generator with the system is available and the under-excited reactive power limited accordingly.

CONTROL SYSTEM-2(MANUAL):

It mainly comprises a second excitation current regulator with separate sensing for the actual value. It is also called manual

control system because for constant generator voltage manual re-adjusting of the excitation current set-point is required when changing the generator load. The system can also be used for setting the generator excitation during normal operation when the automatic voltage is defective. Normally, the automatic voltage regulator is in service even during start-up and shut-down of the generator.

The set point adjuster of the excitation current regulator for MANUAL is tracked automatically (follow-up control) so that, in the event of faults, changeover to the MANUAL control system is possible without delay. Automatic changeover to the MANUAL initiated by some special fault conditions is possible without delay.

Both control system is coordinated with a separate gate-control and Thyristor set. Separate equipment is also provided for supplying powerto either control system.

DE-EXCITATION OF GENERATOR

To de-excite the generator during shutdown or when the generator protection system has picked up, a command is transmitted to the outputs of both control systems, driving the Thyristor to maximum negative output voltage. The negative voltage (*inverter operation*) de-excites the main exciter in less than ½ sec. The generator de-excitation is a function of the relevant effective generator time constant.

Approx. ½ sec. after receiving the de-excite command, two field suppression contractors(one being redundant) switch a *field discharge resistor* in parallel to the main exciter field winding. Subsequently an off command is issued to the field breaker via its tripping coil. In the event of failure of the electronic field suppression by inverter operation,de-excitation would be achieved with a delay of ½ sec. via the field discharge resistors.

WORKING

A common shaft carrying the rectifier wheels, rotor of the main exciter and the pilot exciter, is rigidly coupled to the generator rotor. The exciter shaft is supported on a bearing between the main and the pilot exciter.

- The 3-phase pilot exciter has a revolving field with permanent magnet poles. Due to the rotation of the rotor, 3-phase A.C. is generated in the exciter's stator winding ***(220V, 400Hz, 195amps.)***

- This is rectified and contributed by the thyrism 04.2, an Automatic Voltage Regulator (AVR) to provide a variable D.C.

- This variable D.C. supply is provided to the main exciter's stator winding and 3-phase A.C. is induced in its rotor ***(660V, 6300A)***.

- It is rectified by the rotating rectifier bridge and led to the field winding of the generator rotor through D.C. leads in the rotor shaft.

WHY BRUSHLESS EXCITATION PREFERRED????

- *It eliminates the use of* ***slip rings*** *and* ***carbon brushes*** *(worth in static excitation).*

- *It eliminates the need of an* ***excitation transformer*** *(an important component of static excitation).*

- *Requires less maintenance in comparison to static excitation.*

- *More rugged in construction.*

- *Greater life-span.*

MATCHING FOLLOW-UP CONTROL

The excitation current regulator (MANUAL) is mainly used during maintenance work and when faults occur in the AUTO system. For

this purpose, the setting of the excitation current set-point adjuster must be matched to the actual excitation state before changeover to MANUAL. Matching is to be carried out continuously by means of an automatic follow-up control system.

The excitation current may be subjected to considerable transient variations during faults. For this reason, a clear design of the matching of the follow-up control circuits is important.

Changeover from AUTO to MANUAL requires the excitation current set-point adjuster to be set to a position in which a set point corresponding to the actual exciting current is supplied. The output values of the excitation current regulators for AUTO and MANUAL are compared by an amplifier and the difference signal acts on the matching instrument and the control unit.

UNDER EXCITATION LIMITER

The under excitation limiter automatically prevents too low excitation of the generator. A reduction of the excitation may occur under the influence of the automatic voltage regulator when

the system voltage rises during low-load operation, from a faulty operation e.g. the tapping switch of the main transformer.

OVER EXCITATION LIMITER

Reduction of the system voltage due to increased reactive power requirements, switching operation or disturbances causes the voltage regulator to increase the generator excitation in order to maintain a constant generator voltage. Major system voltage reduction may result in a thermal overloading of the exciter and generator rotor unless the operator presets a lower set-point for the generator voltage or changes the ratio of the unit transformer.

In such a case the over excitation limiter limits the generator excitation by automatically reducing the generator voltage. The excitation current is measured through a current transformer with shunt and compared with a set- point. When the excitation current exceeds the set-point value, a signal appears at the output of the over excitation limiter. The resulting signal in the input amplifier of the voltage regulator causes the excitation to decrease accordingly.

The over excitation limiter has the response time inversely proportional to the difference between the actual value and the response value.

V/Hz LIMITER

Excessive magnetic flux increases thermal stressing of the unit transformer and the generator. The function of the V/Hz limiter is to issue a signal to the voltage regulation loop when a preset V/Hz limit value is exceeded and to reduce this value to permissible limit.

For this purpose the V/Hz limiter includes an element for measuring the frequency, comparing the frequency value against the generator voltage value and evaluating a correction signal.

The action of the V/Hz limiter is frequently restricted to operation with the generator being disconnected from the grid.

A

SPECIAL REPORT

ON

EXCITATION SYSTEM

IN

NTPC/SSTPS

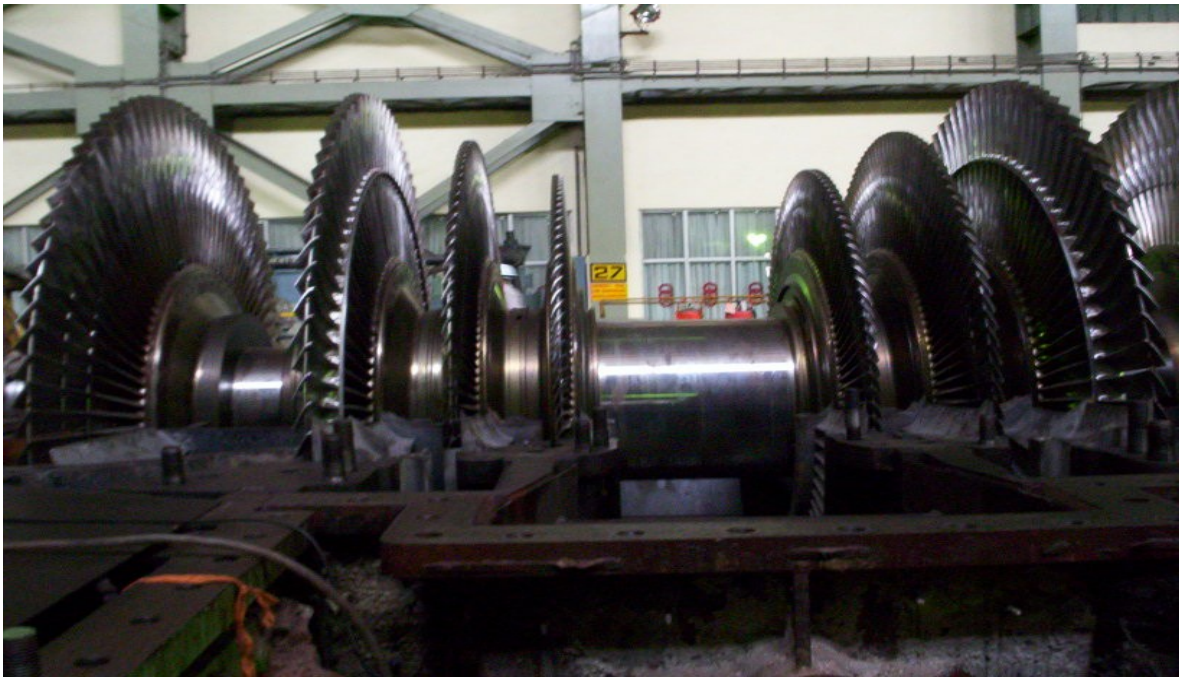
N.T.P.C.

(NATIONAL THERMAL POWER CORPORATION)

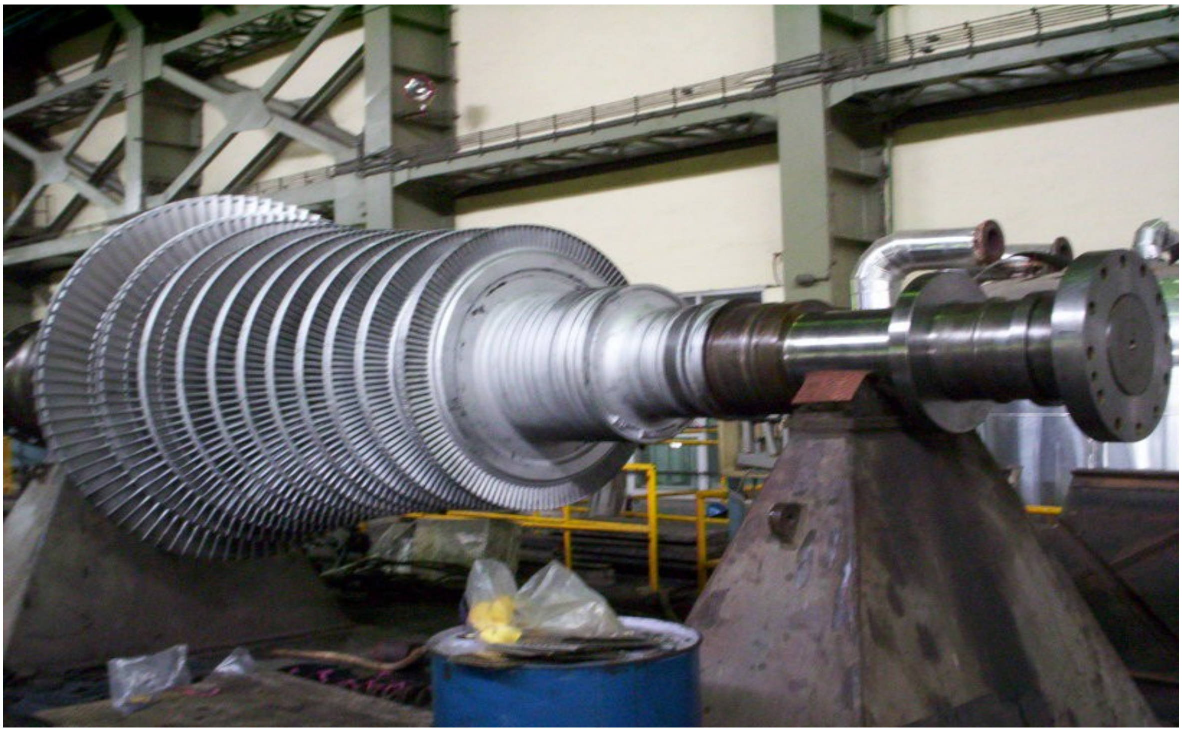
S.S.T.P.S

SHAKTINAGAR

SONEBHADRA(U.P.)

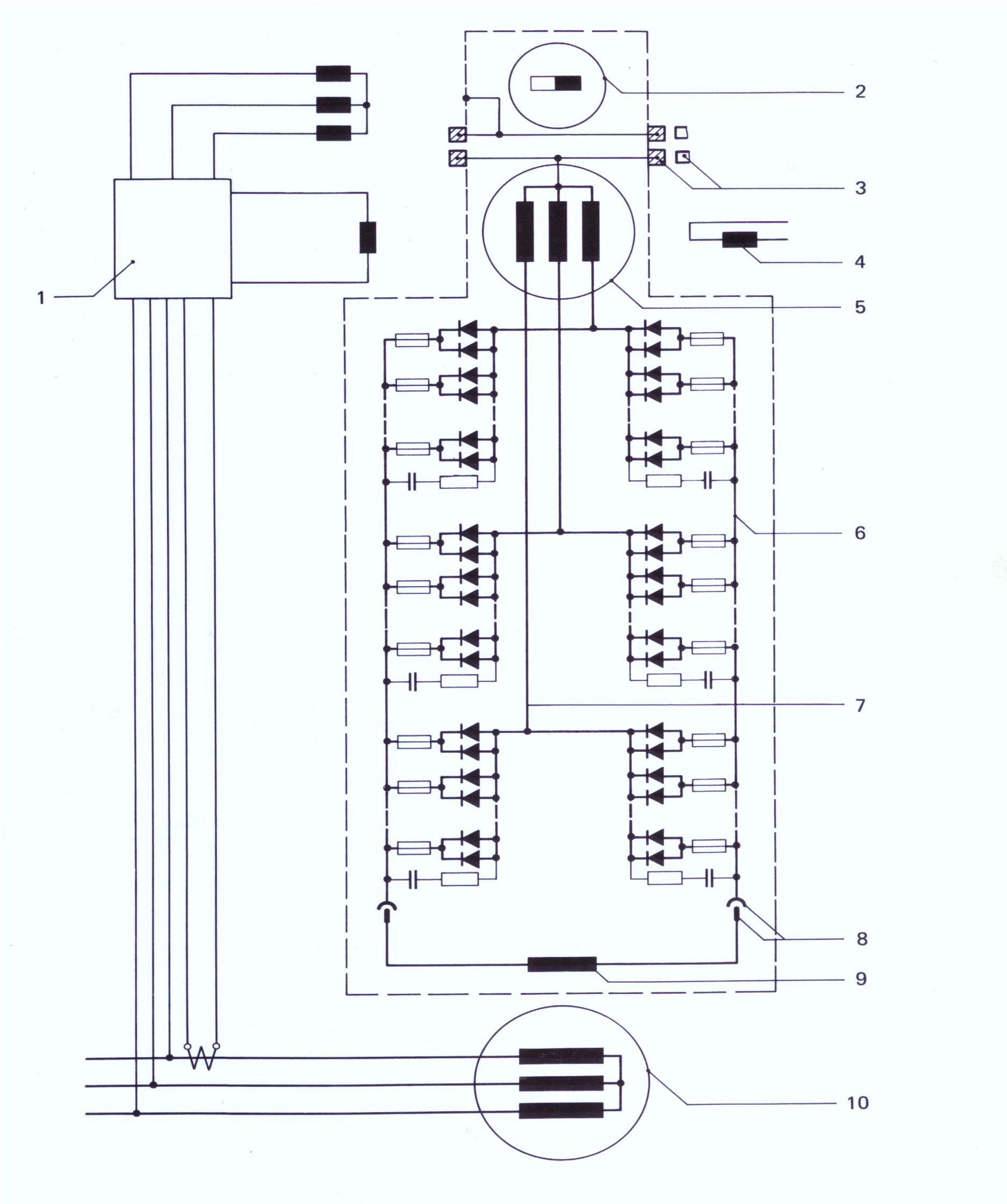


ROTOR OF L.P. TURBINE



ROTOR OF H.P. TURBINE

COAL HANDLING PLANT(C.H.P.)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