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Chapter #01 Introduction

Mangla Dam Project was actually conceived in 1950's as a multipurpose project to be constructed at a place called Mangla on river Jhelum located about 30 km upstream of Jhelum city (120 km from Capital Islamabad). The initial investigation and its feasibility studies were completed in 1958. Later on the project was included in the Indus Basin Project. The construction of Mangla Dam was started in 1962 and completed in 1967.

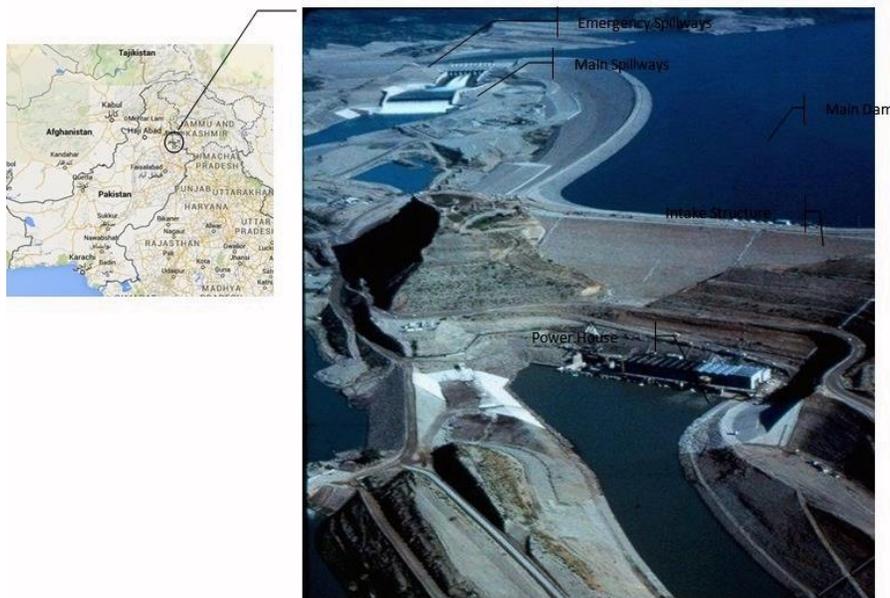


Figure 1: Biographical Location of Mangla Dam

1.1 Mangla Dam project:

As a consequence of the partition of Indo-Pakistan Sub –Continent, in 1947 India & Pakistan became two independent sovereign states. The irrigation system which existed at that time was divided between the two countries without any regards to the irrigation boundaries which resulted in an international water dispute which was finally resolved by signing of the INDUS WATER TREATY in 1960 under the aegis of World Bank. The treaty assigned to India the three Eastern Rivers (Ravi , Beas & Sutlej) and to Pakistan the three western rivers (Indus, Jhelum & Chenab) and provided for construction of replacement works which were called Indus Basin Projects for transfer of irrigation

supplies from the western rivers to the areas in Pakistan formerly served by the eastern rivers. The Works proposed under the treaty were two dams, five barrages, one syphon and eight inter-river link canals. Mangla Dam on river Jhelum and Tarbela Dam on river Indus were the two dams.

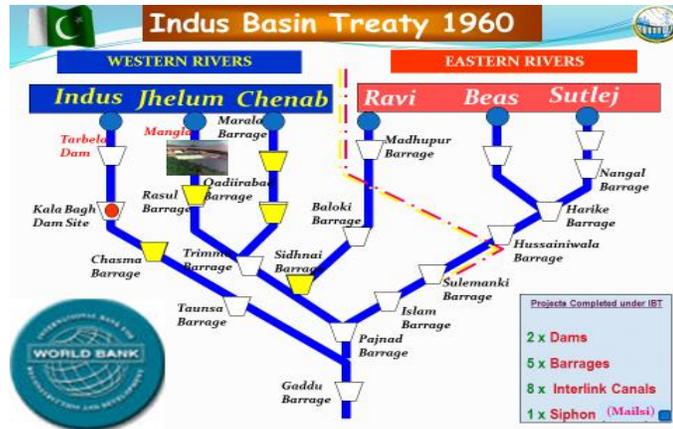


Figure 2: Mangla dam project background

Mangla Dam Project is a multipurpose project designed to conserve & control the flood water of river Jhelum through significant reduction in flood peaks and volumes at downstream by incidental use of the available storage space. The other by products are Power Generation to meet the power demand of the country, Fish culture to provide protein rich diet, Tourism to provide healthy recreation facilities to the people and Navigation. The Project is located on river Jhelum in District Mirpur of Azad Kashmir about 106 Kilometer from capital Islamabad.

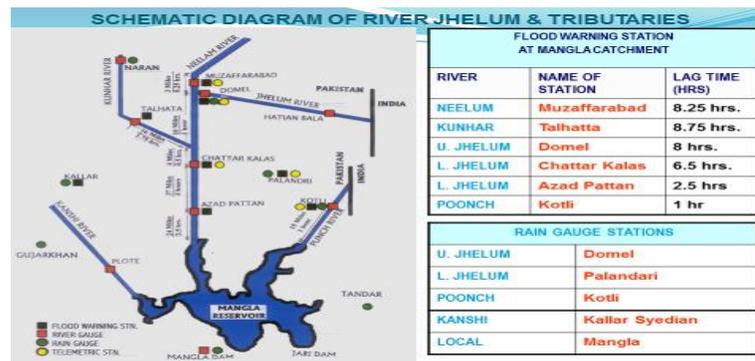


Figure 3: Jhelum River

The construction of Mangla Dam project was started in 1962 and completed in 1967. The project consists of two dams (Main Dam & Jari Dam), two dykes (Sukian & Kakra) to contain reservoir, two

Spillways (Main Spillway & Emergency Spillway) for out flow regulations, Intake structure with five tunnels (each 1600feet long with internal diameters varying between 26 feet & 30 feet), Power Station (rated capacity of 1000MW with 10 generating units each of 100 MW) and Tailrace canal (length of 25000 feet with discharge capacity of 49000 cusecs). Mangla Dam Project was inaugurated on 23rd November, 1967 by the then President of Pakistan Field Marshal Muhammad Ayub Khan.

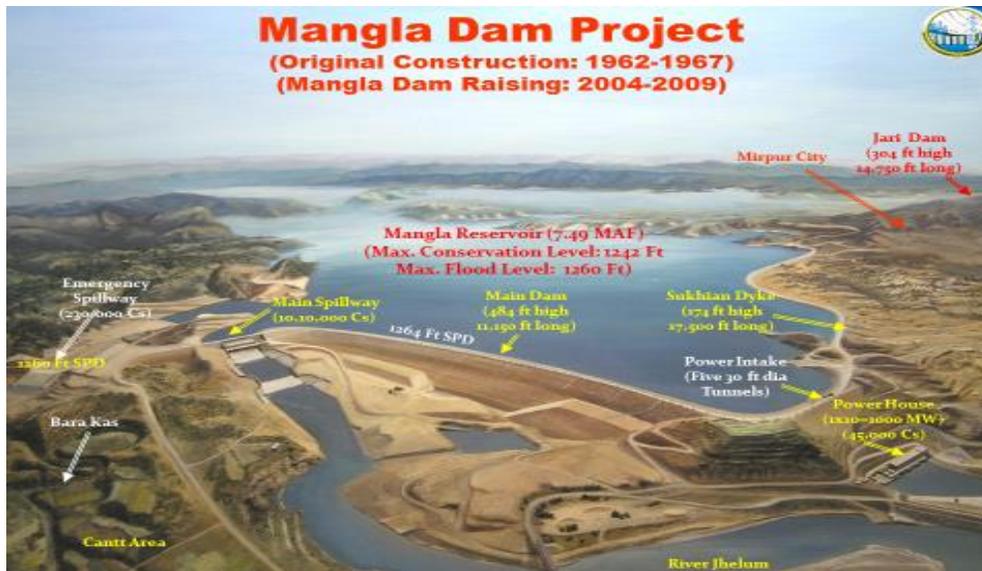


Figure 4: Mangla Reservoir

Feasibility Report Requested	1952
Feasibility Report Presented	May, 1954
Consultant Engineers Appointed	Dec, 1957
Report by Consultant Engineers	Dec, 1958
Tenders Invited For Civil Works	June, 1961
Tenders Received	Nov, 1961
Contractors Appointed	Jan, 1962
Date of Completion	June, 1967
Period	Years

Table 1: History of mangla dam project

Unit No.	DATE
1	03-07-1967
2	14-07-1967
3	07-03-1968
4	17-06-1969
5	29-12-1973
6	11-03-1974
7	25-05-1981
8	22-07-1981
9	24-09-1993
10	06-07-1994

Table 2: Commissioning dates of generating units

Total Cost of the Dam Project including Power Units 1-3 (1967)	3,200
Cost of 4th Power Unit (1969)	43
Cost of Power Units 5 & 6 (1973-74)	120
Cost of Power Units 7 & 8 (1981)	519
Cost of Power Units 9 & 10 (1992)	2,700
TOTAL COST	6,587

Table 3: Cost (IN Million rupees)

1.2 Power station Mangla:

The existing Power Station is located at downstream of five tunnels. Its building comprises the machine hall accommodating Generating Unit (1 to 10), eastern loading bay; western loading bays, control block and Admin block building. The Power Station accommodates 10 generation units on five tunnels each of 100 MW capacities. The Rotary exciter of unit 1 to 6 (static exciter for remaining units) is located at 865.5' SPD floor and connected to the rotor of generator through an upper shaft coupling with the turbine at 840.5' SPD. The generated power is transmitted to national grid through

220/132 KV bus bars at switchyard. Mangla is also capable of controlling system frequency; all Units can be selected for this purpose. While on Remote Control (SCADA), these units receive direct pulses from NPCC (National Power Control Centre) Islamabad.

Two electric overhead traveling cranes each with lifting capacity of 200 ton and 30 ton auxiliary hoist range over the power station super structure. These are provided with a lifting beam and other paralleling facilities to give a combined lifting capacity of 400 tons at the centre of the beam. An electric Gantry crane 35/25 ton capacity with 3 ton auxiliary hoist runs on downstream deck of power station. It is used to lift and pull irrigation valves and draft tube gates.



Figure 5: Power Station Internal

The downstream galleries of the power station building include battery rooms, various stores and service rooms. The upstream galleries include LV Switch Board, Cable gallery and ventilation duct. The control block is at the east end of power station building and comprises control room, air conditioning plant room, cable flat, 11 KV switchgear room, relay room and different offices while admin block is at the west end of power station building and comprises R.E (P) office, Auditorium, Telephone Exchange and different Admin & Accounts Offices. Generator transformers are sited on ground level upstream side of power station. A cable tunnel runs between power station and switchyard, distance of 0.8 KM carrying power, control and communication cables.

1.3 Main Function:

- Water control & store
- Generation
- Switching
- Transmission & distribution

1.3.1 Water control & store:

First main function of dam is water store and control for irrigation purpose. Most of the rivers have non-uniform run-offs. During rainy period is high but the power requirements are low because of the absence of irrigation load. It is necessary to store water during excess flow periods so that the same may be used during lean flow period in most of the streams. The flow is deficient during the part of the year regulation through artificial storage is necessary The main function of storage is to make more water available deficient flow times thus increase the firm capacity of the station

1.3.2 Generation:

The second main function of dam is production of electrical energy. Hydro-electric project harness water power for generation of electrical energy. When water drops through a height it energy is able to rotate turbines which are coupled to alternators

1.3.3 Switching:

Third main function is switching and controlling of different circuit during working & fault condition

1.3.4 Transmission & distribution:

All generated power transmits & distribute toward the load in 220 KV 132KV LINES

Chapter #02 Hydraulic structure

A hydraulic structure is a structure submerged or partially submerged in any body of water, which disrupts the natural flow of water. They can be used to divert, disrupt or completely stop the flow.

Parts of hydraulic structure

- Reservoir
- Dam
- Screen
- Intake
- Penstock
- Guide or stay vanes
- Spiral casing
- Spillway
- Draft-Tube
- Irrigation valve

2.1 Reservoir:

Most of the rivers have non-uniform run-offs. During rainy period is high but the power requirements are low because of the absence of irrigation load. It is necessary to store water during excess flow periods so that the same may be used during lean flow period. The storage reservoir thus helps in supplying water to the turbines according to the load on the plant. Low head plants require very big storage reservoirs. The storage capacity of mangla reservoir is



Figure 6: reservoir

RESERVOIR	BEFORE RAISING OF CREST (1234 ft SPD)	AFTER RAISING OF CREST BY 30 ft (1264 ft SPD)
Normal Maximum Conservation Level	1202 ft. (366.5 m)	1242 ft. (378.7 m)
Minimum Operation Level	1040 ft. (317.1 m)	1040 ft. (317.1 m)
Storage Capacity	5.88 MAF	7.475 MAF
Crest Length	84,00 Ft	11,000 Ft
MAIN AND INTAKE EMBANKMENT		
Maximum Height	454 ft. (138.5 m)	484 ft. (147.6 m)
Crest Length	10,300 ft. (3,350 m)	11,150 ft. (3,400 m)
POWER INTAKE		
Elevation of Control Structure	1234 ft. (376.2 m)	1266 ft. (386 m)
No of Intake gates	05	05
PROJECT BENEFITS		
Additional avg. Annual Water Availability		Additional avg. Annual Water Availability is equal to 2.88 MAF
Additional avg. Annual Hydro-Electric Power		644 GWh
PROJECT COST		US\$ 1 Billion

Table 4: Reservoir specification

At the time of initial construction of Dam, provision was kept for 40ft rising at Additional Cost of US \$ 18 million. Since the reservoir capacity had reduced to 4.674 MAF from 5.88 MAF due to sediment

deposition, rising of Mangla Dam by 30 ft. was taken in hand which has been now completed. The Project has provided additional water storage of 2.88 MAF, increase in water head by 40 ft. and additional power generation of 644 GWh per annum and further flood alleviation.

2.2 Dam:

A dam is a man-made structure built across a river. Most dams are built to control river flow, improve navigation, and regulate flooding. However, some dams are built to produce hydroelectric power.

The function of dam in hydro electric project; is to create artificial head and storage

Diverts the flow of water so the same could used for generation of power. It is most expensive and important part of hydro project



Figure 7: dam

The dam also helps in increasing the working head of the power plant. Dams are generally built to provide necessary head to the power plant.

2.3 Screen:

The water intake from the dam or from the fore bay is provided with trash rack. The main function of trash rack is to prevent the entry of any debris which may damage the wicket gates and turbine runners or choke-up the nozzles of impulse turbine. During winter season when water forms ice, to

prevent the ice from clinging to the trash racks, they are often heated electrically. Sometimes air bubbling system is provided in the vicinity of the trash racks which bring warmer water to the surface of the trash racks.



Figure 8: Intake screen

Screen is a filter that use for the filtration of water and remove the sedimentation from water the screen use at mangla

Length	57' – 8"
Radius	16' – 4"
Width	32' - 10"
Thickness of bar	½"
Bar to bar distance	6 "

Table 5: Screen Specification

2.4 Intake:

The function of intake is to provide a passage to water to flow into the conduit, channel or penstock. Intake structure has to be provided with trash racks, screens and bottom to divert and prevent entry debris and ice in to the turbines Intake can be classified in two main i.e. high pressures intake and low pressure intake ones are used in the cause of big storage reservoirs. A low pressure intakes is used for small ponds meant to store small quantity for daily and weekly load variations

Manufacture:	VOEST WAAGNER_BIRO. AUSTRIA
Year of Construction:	1963
No of Gates.	5
Bottom of Screen Rail	953.17 ft SPD
Sill level of Gate	953.17 ft SPD
Size of Gate:	35.6' x 18'
Weight of each Gate:	100 Tons

Table 6: Intake Gates specification

2.5 Penstock:

Penstock carries water from the water storage system to the turbine. It may be a low pressure type. A low pressure penstock may be a canal flume or a steel pipe. The high pressure penstocks consist of thick steel pipes. Diameter may be up to a few meters for large units. Each turbine has separate penstock. Small size plants have concrete pent

2.6 Guide or stay vanes:

The primary function of the guide or stay vanes is to convert the pressure energy of the fluid into the momentum energy. It also serves to direct the flow at design angles to the runner blades.

2.7 Spiral casing:

The spiral casing around the runner of the turbine is known as the volute casing or scroll case. Throughout its length, it has numerous openings at regular intervals to allow the working fluid to impinge on the blades of the runner. These openings convert the pressure energy of the fluid into momentum energy just before the fluid impinges on the blades. This maintains a constant flow rate despite the fact that numerous openings have been provided for the fluid to enter the blades, as the cross-sectional area of the is casing decreases uniformly along the circumference

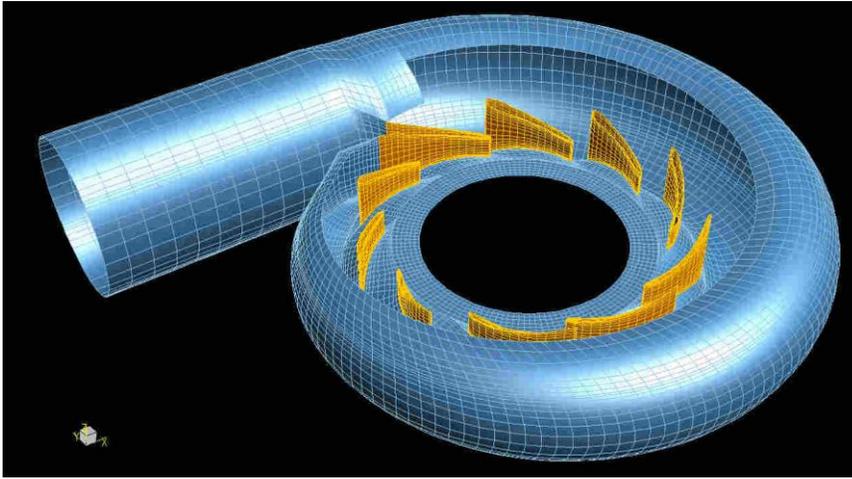


Figure 9: Spiral causing

2.8 Draft-tube:

The draft tube is a conduit that connects the runner exit to the tail race where the water is discharged from the turbine. Its primary function is to reduce the velocity of discharged water to minimize the loss of kinetic energy at the outlet. This permits the turbine to be set above the tail water without appreciable drop of available head. A draft tube is required to discharge the water, living the turbine, in to the river. It is necessary that the draft tube must remain water sealed all the time. Impulse turbine doesn't need draft tube and discharge water directly. The design and size of the draft tube should be such that water has free existed and the jet of the water, after it leave turbine, has unimpeded passage.

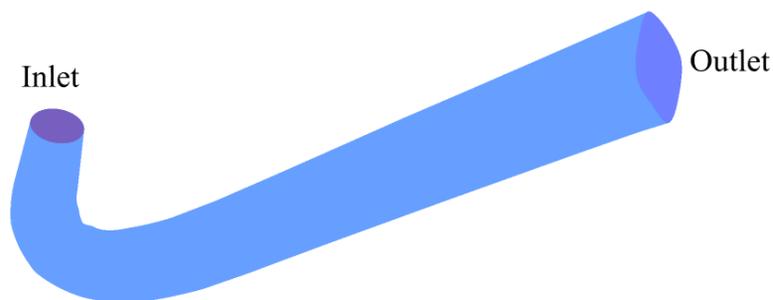


Figure 10: Draft Tube

2.9 Irrigation valve:

Irrigation valve is a relief valve that is an emergency water exit way in case emergency unit shut down. Another purpose of the irrigation valve is use extra removal of water for irrigation. These are the valves that turn on and off the sprinklers; they also may be used for drip irrigation systems. Other names sometime used for them are irrigation valve



Figure 11: Irrigation valve

Type of Irrigation Valve	Howell Bunger	
Manufacturer	MITSUBISHI Japan	Unit 1 to 8
	CKD Blansko Skoda	Unit 9 & 10
Diameter	8.53 Ft	
Weight of Body	24 Ton	
Weight of Sleeve	10 Ton	
Total Weight with Accessories	42 Ton	
No. of Vanes	05 Nos.	

Table 7: Irrigation Valve Specification

2.10 Spillway:

Every dam is provided with an arrangement to discharge excess water during floods. This arrangement may be a spillway or a by-pass tunnel or conduit. The spillway should be so designed as to discharge the major flood water with damage to the dam but at the same time maintain a

predetermined head. A spillway is a structure used to provide the controlled release of flows from a dam or levee into a downstream area, typically the riverbed of the dammed river itself. In the UK they may be known as overflow channels. Spillways ensure that the water does not overflow and damage or destroy the dam.



Figure 12: Spillway

A spillway is located at the top of the reservoir pool. Dams may also have bottom outlets with valves or gates which may be operated to release flood flow, and a few dams lack overflow spillways and rely entirely on bottom outlets.

There are two main types of spillways: controlled and uncontrolled.

A controlled spillway has mechanical structures or gates to regulate the rate of flow. This design allows nearly the full height of the dam to be used for water storage year-round, and flood waters can be released as required by opening one or more gates.

Previous Sill Level	EL 1086
Present Sill Level	EL 1091
Discharge Capacity	9, 41, 000 cusecs at 1242 ft SPD
	1, 011, 000 cusecs at 1260 ft SPD
Type	Submerged orifice
Top Seal Level of Radial Gates	1126 ft SPD
Gate top level	1138 ft SPD
Bottom Sill Level	EL 1069
Top Level on Placing all the 10 segments	EL 1129.83
Height of Each Segment	1854 mm (6.08ft)
Stilling basin	45 ft deep at 1000 ft SPD

Table 8: Main Spillway specification

An uncontrolled spillway, in contrast, does not have gates; when the water rises above the lip or crest of the spillway it begins to be released from the reservoir. The rate of discharge is controlled only by the depth of water above the reservoir's spillway. Storage volume in the reservoir above the spillway crest can only be used for the temporary storage of floodwater; it cannot be used as water supply storage because it is normally empty.

EMERGENCY SPILLWAY	
Type	Unregulated Weir
Capacity at 1260 SPD	2,30,000 Cusecs
Width	500 ft

Table 9: Emergency spillway specification

Chapter #03 Prime mover

An initial source of motive power (such as a windmill, waterwheel, turbine, or internal combustion engine) designed to receive and modify force and motion as supplied by some natural source and apply them to drive machinery

3.1 Turbine:

Turbine is a rotary machine that converts kinetic energy and potential energy of water into mechanical work. Water turbines were developed in the 19th century and were widely used for industrial power prior to electrical grids. Now they are mostly used for electric power generation. Water turbines are mostly found in dams to generate electric power from water kinetic energy. Flowing water is directed on to the blades of a turbine runner, creating a force on the blades. Since the runner is spinning, the force acts through a distance (force acting through a distance is the definition of work). In this way, energy is transferred from the water flow to the turbine



Figure 13: Francis vertical shaft turbine

The Francis turbine is a type of water turbine that was developed by James B. Francis in Lowell, Massachusetts. It is an inward-flow reaction turbine that combines radial and axial flow concepts.

Francis turbines are the most common water turbine in use today. They operate in a water head from 40 to 600 m (130 to 2,000 ft) and are primarily used for electrical power production. The electric generators that most often use this type of turbine have a power output that generally ranges from just a few kilowatts up to 800 MW, though mini-hydro installations may be lower. Penstock (input pipes) diameters are between 3 and 33 ft (0.91 and 10 m). The speed range of the turbine is from 75 to 1000 rpm. A wicket gate around the outside of the turbine's rotating runner controls the rate of water flow through the turbine for different power production rates. Francis turbines are almost always mounted with the shaft vertical to isolate water from the generator. This also facilitates installation and maintenance. The Francis turbine is a type of reaction turbine, a category of turbine in which the working fluid comes to the turbine under immense pressure and the energy is extracted by the turbine blades from the working fluid. A part of the energy is given up by the fluid because of pressure changes occurring in the blades of the turbine, quantified by the expression of Degree of reaction, while the remaining part of the energy is extracted by the volute casing of the turbine. At the exit, water acts on the spinning cup-shaped runner features, leaving at low velocity and low swirl with very little kinetic or potential energy left. The turbine's exit tube is shaped to help decelerate the water flow and recover the pressure.

TURBINE	UNITS 1,2,3,4	UNITS 5 & 6	UNITS 7 & 8	UNITS 9 & 10
Manufacturer	Mitsubishi Japan	Skoda Czechoslovakia	ACEC Belgium	Skoda Czechoslovakia
Type	Francis Vertical Shaft	Francis Vertical Shaft	Francis Vertical Shaft	Francis Vertical Shaft
Rated out Put	1,38,000 BHP/ 103MW	1,38,000 BHP/ 103MW	1,38,000 BHP/ 103MW	1,38,000 BHP/ 103MW
Maximum Out Put	1,98,000 BHP/ 148MW	1,98,000 BHP/ 148MW	1,98,000 BHP/ 148MW	1,98,000 BHP/ 148MW
Net Head	295 Feet	295 Feet	295 Feet	295 Feet
Discharge	4550 Cusecs	4515 Cusecs	4306 Cusecs	4515 Cusecs
Speed	166.7 RPM	166.7 RPM	166.7 RPM	166.7 RPM
Runner Vanes	17	15	14	15
Guide Vanes	24	24	26	24
M.G.B Pads	2 Sleeves	12	2 Sleeves	12
L.G.B Pads	24	24	22	24
T.B Oil Injection Pads	10	10	14	10
U.G.B Pads	16	8	12	12
No of Brake Pads	10	10	8	10
No. of Jacks	10	10	8	10

Table 10: Turbines Specification

Chapter#04 Electrical equipments

Electrical equipment includes any machine powered by electricity. It usually consists of an enclosure, a variety of electrical components, and often a power switch. Examples of these include

- Generator
- Transformer
- Motor

4.1 Generator:

Generator is a device that converts mechanical energy to electrical energy for use in an external circuit.

4.1.1 Main generator:

Generator is a device that converts mechanical energy to electrical energy for use in an external circuit. Sources of mechanical energy include steam turbines, gas turbines, water turbines, internal combustion engines and even hand cranks. The first electromagnetic generator, the Faraday disk, was built in 1831 by British scientist Michael Faraday. Generators provide nearly all of the power for electric power grids. According to the Faraday's law of electromagnetic induction,

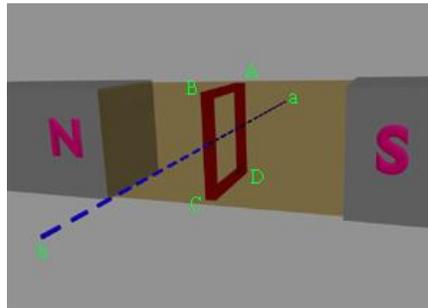


Figure 14: Generator internal EMF inducing

Whenever a conductor moves in a magnetic field EMF gets induced across the conductor. If the close path is provided to the conductor, induced emf causes current to flow in the circuit.

The working principle of alternator is very simple. It is just like basic principle of DC generator. It also depends upon Faraday's law of electromagnetic induction which says the current is induced in the conductor inside a magnetic field when there is a relative motion between that conductor and the magnetic field. For understanding working of alternator let's think about a single rectangular turn placed in between two opposite magnetic pole as shown above.

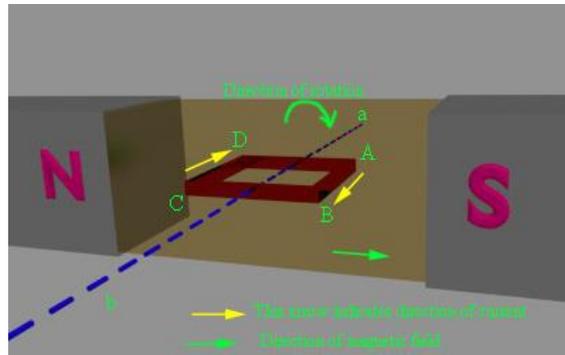


Figure 15: Generator internal EMF inducing

Say this single turn loop ABCD can rotate against axis a-b. Suppose this loop starts rotating clockwise. After 90° rotation the side AB or conductor AB of the loop comes in front of S-pole and conductor CD comes in front of N-pole. At this position the tangential motion of the conductor AB is just perpendicular to the magnetic flux lines from N to S pole. Hence rate of flux cutting by the conductor AB is maximum here and for that flux cutting there will be an induced current in the conductor AB and direction of the induced current can be determined by Fleming's right hand rule. As per this rule the direction of this current will be from A to B. At the same time conductor CD comes under N pole and here also if we apply Fleming's right hand rule we will get the direction of induced current and it will be from C to D.

Now after clockwise rotation of another 90° the turn ABCD comes at vertical position as shown below. At this position tangential motion of conductor AB and CD is just parallel to the magnetic flux lines; hence there will be no flux cutting that is any current in the conductor. While the turn ABCD comes from horizontal position to vertical position, angle between flux lines and direction of motion

of conductor, reduces from 90° to 0° and consequently the induced current in the turn is reduced to zero from its maximum value.

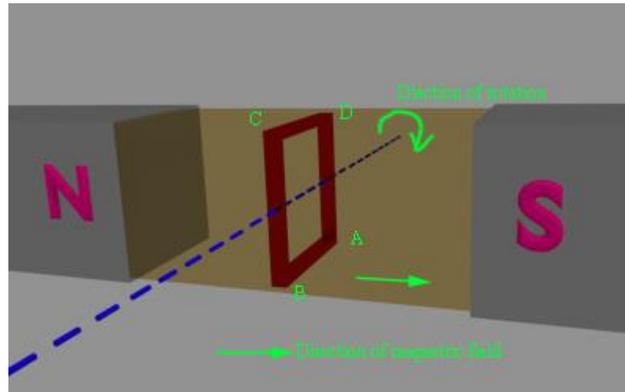


Figure 16: Generator internal EMF inducing

After another clockwise rotation of 90° the turn again come to horizontal position and here conductor AB comes under N-pole and CD comes under S-pole, and here if we again apply Fleming's right hand rule, we will see that induced current in conductor AB, is from point B to A and induced current in the conductor CD is from D to C.

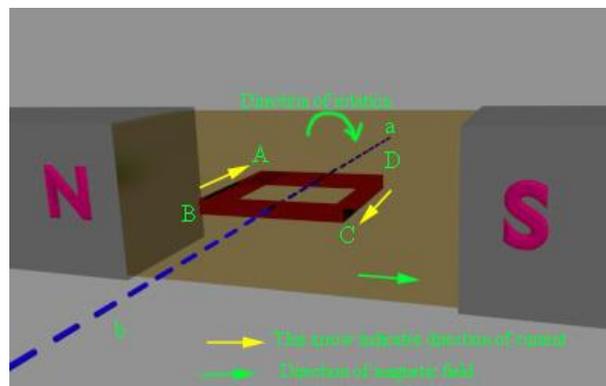


Figure 17: Generator internal EMF inducing

As at this position the turn comes at horizontal position from its vertical position, the current in the conductors comes to its maximum value from zero. That means current is circulating in the close turn from point B to A, from A to D, from D to C and from C to B. Just reverse of the previous horizontal position when the current was circulating as $A \rightarrow B \rightarrow C \rightarrow D \rightarrow A$.

While the turn further proceeds to its vertical position the current is again reduced to zero. So if the turn continues to rotate the current in the turn continually alternate its direction. During every full revolution of the turn, the current in the turn gradually reaches to its maximum value then reduces to zero and then again it comes to its maximum value but in opposite direction and again it comes to zero. In this way the current completes one full sine wave form during each 360o revolution of the turn. So we have seen how an alternating current is produced in a turn is rotated inside a magnetic field. From this, we will now come to the actual working principle of alternator.

Now we cut the loop and connect its two ends with two slip rings and stationary brush is placed on each slip ring. If we connect two terminals of an external load with these two brushes, we will get an alternating current in the load. This is our elementary model of alternator.

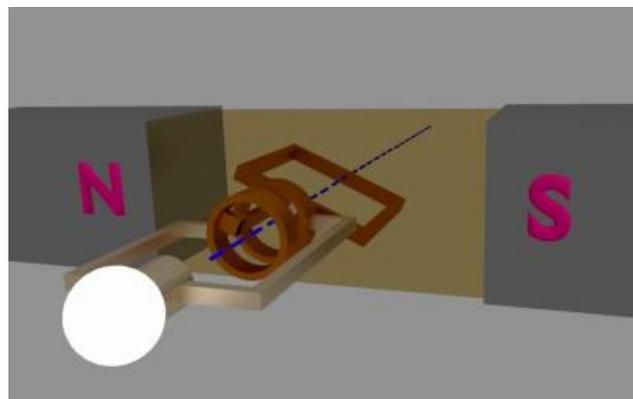


Figure 18: Simple Generator

Having understood the very basic principle of alternator, let us now have an insight into its basic operational principal of a practical alternator. During discussion of basic working of o, we have considered that the magnetic field is stationary and conductors (armature) are rotating. But generally in practical construction of alternator, armature conductors are stationary and field magnets rotate between them. The rotor of an alternator or a synchronous generator is mechanically coupled to the shaft or the turbine blades, which on being made to rotate at synchronous speed N_s under some mechanical force results in magnetic flux cutting of the stationary armature conductors housed on the stator. As a direct consequence of this flux cutting an induced EMF and current starts to flow through

the armature conductors which first flow in one direction for the first half cycle and then in the other direction for the second half cycle for each winding with a definite time lag of 120° due to the space displaced arrangement of 120° between them as shown in the figure below. These particular phenomena results in 3ϕ power flow out of the alternator which is then transmitted to the distribution stations for domestic and industrial uses

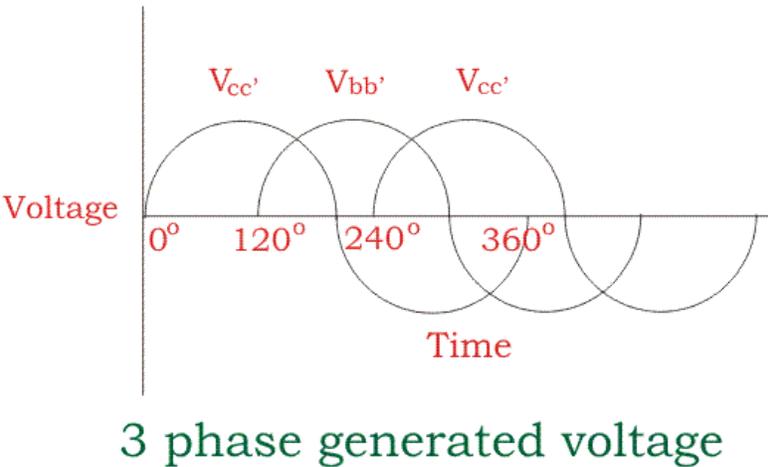


Figure 19: 3 phase power phase angle

4.1.1.1 Salient pole type alternator:

Main parts of the alternator obviously consist of stator and rotor. But, the unlike other machines, in most of the alternators, field exciters are rotating and the armature coil is stationary.

4.1.1.2 Stator:

Unlike in DC machine stator of an alternator is not meant to serve path for magnetic flux. Instead, the stator is used for holding armature winding. The stator core is made up of lamination of steel alloys or magnetic iron, to minimize the eddy current losses.



Figure 20: Generator stator

At high voltages, It easier to insulate stationary armature winding. Which may be as high as 30 kV or more. The high voltage output can be directly taken out from the stationary armature. Whereas, for a rotary armature, there will be large brush contact drop at higher voltages, also the sparking at the brush surface will occur. Field exciter winding is placed in rotor, and the low dc voltage can be transferred safely. The armature winding can be braced well, so as to prevent deformation caused by the high centrifugal force.

4.1.1.3 Rotor:

There are two types of rotor used in an AC generator / alternator:

- Salient type
- Cylindrical type

Salient pole type: Salient pole type rotor is used in low and medium speed alternators. Construction of AC generator of salient pole type rotor is shown in the figure above. This type of rotor consists of large number of projected poles (called salient poles), bolted on a magnetic wheel. These poles are also laminated to minimize the eddy current losses. Alternators featuring this type of rotor are large in diameters and short in axial length.

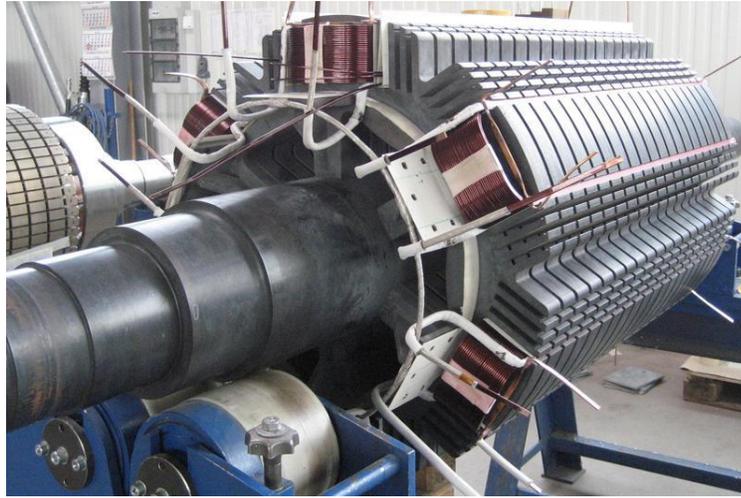


Figure 21: Generator rotor

4.1.1.4 Cylindrical type:

Cylindrical type rotors are used in high speed alternators, especially in turbo -alternators. This type of rotor consists of a smooth and solid steel cylinder having slots along its outer periphery. Field windings are placed in these slots. The DC supply is given to the rotor winding through the slip rings and brushes arrangement

4.1.1.5 Governor system:

Governing system or governor is the main controller of the hydraulic turbine. The governor varies the water flow through the turbine to control its speed or power output. Generating units speed and system frequency may be adjusted by the governor

- a) Speed sensing elements
- b) Governor control actuators
- c) Hydraulic pressure supply system
- d) Turbine control servomotors-these are normally supplied as part of turbine

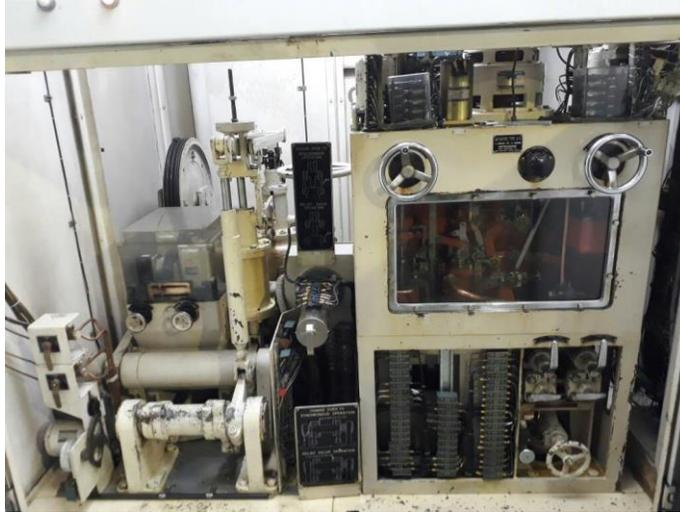


Figure 22: Governor Cabinet internal

The primary functions of the hydraulic turbine governor are as follows:

- i. To start maintain and adjust unit speed for synchronizing with the running units/grid.
- ii. To maintain system frequency after synchronization by adjusting turbine output to load changes.
- iii. To share load changes with the other units in a planned manner in response to system frequency error.
- iv. To adjust output of the unit in response to operator or other supervisory commands.
- v. To perform normal shut down or emergency over speed shut down for protection.

In isolated systems the governor controls frequency. In large system it may be needed for load operation control for the system. A block diagram is shown in figure 6.1. Digital electronic load governor are now employed. Mechanical analogue electronic governors used in earlier plants are also briefly discussed. In small hydro units digital governors are employed for plant control and protection also which is discussed in detail in Vol. II - Control and Protection. Basic Control System Governor control system for Hydro Turbines is basically a feed back control system which senses the speed and power of the generating unit or the water level of the fore bay of the hydroelectric installation etc. and takes control action for operating the discharge/load controlling devices in accordance with the

deviation of actual set point from the reference point. Governor control system of all units controls the speed and power output of the hydroelectric turbine. Water level controlled power output controllers can be used for grid connected units.

Basic Governor Control System. The control section may be mechanical; analogue electronic or digital electronic. Actuator can be hydraulic controlled, mechanical (motor) or load actuator. Load actuator are used in micro hydro range; mechanical (motor operated) actuators may be used say up to about 1000 kW unit size. Hydraulic actuators are mostly used. Actuator system compares the desired turbine actuator position command with the actual actuator position. In most of the hydroelectric units reaction turbines are used. In these turbines it requires positioning of wicket gates, including turbine blades in Kaplan units. In Peloton units it requires positioning of spear and deflector. Pressure oil system with oil servomotor is most commonly used actuator. In micro hydro electronic loads controllers are used and shunt load bank is adjusted

4.1.1.6 AVR (Automatic voltage regulator) cabinet:

Automatic voltage regulator on a generator stops fluctuation of voltage produced by it during various load conditions. I will try and explain it in simple manner. The principle of voltage generation requires a source of magnet which is in a relative motion with conductors. When magnetic lines of forces cut the conductors, current is produced. The magnet here is not a permanent magnet but an electro magnet which draws a small current from produced current which induces the electromagnet. Greater the amount of current drawn from circuit, greater the electromagnetic power will be produced, and so a greater voltage will be produced at the generator output. So something should be responsible for regulating the amount of current given to electromagnet to produce a particular set voltage, say 440 V. This particular thing is known as AVR. As you switch on a heavier load say a motor, a voltage dip occurs (you can notice this by watching light bulbs going dim for a short period,

1–4 seconds). The AVR senses this drop in voltage and increases the feed current through an electronic circuit into the electromagnet present



Figure 23: AVR (Automatic voltage regulator)

AC GENERATOR	UNITS 1,2,3,4	UNITS 5 & 6	UNITS 7 & 8	UNITS 9 & 10
Manufacturer	Hitachi Japan	SKODA Czechoslovakia	Hitachi Japan	SKODA Czechoslovakia
Type	Vertical Shaft, Salient pole, Umbrella type			
MVA Rating	125 MVA	125 MVA	125 MVA	125 MVA
Rated Out Put	100 MW	100 MW	100 MW	100 MW
Maximum Out Put	115%	115%	115%	115%
Power Factor	0.8	0.8	0.8	0.8
No. of Phases	3	3	3	3
No. of Coolers	12	12	12	12
No. of Poles	36	36	36	36
No. of Brake Pads	10	10	8	10
Speed	166.7 RPM	166.7 RPM	166.7 RPM	166.7 RPM
Frequency	50 HZ	50 HZ	50 HZ	50 HZ
Voltage	13.2 KV	13.2 KV	13.2 KV	13.2 KV
Current	5467 A	5465 A	5467 A	5467 A
Excitation Voltage	261 V	343 V	440 V	325 V
Excitation Current	990 A	1040 A	1363 A	1430 A
Insulation class	B	F	B	F

Table 11: Main Generator specification

On the rotor of the generator, so as to reach the set voltage i.e. 440V again and power is regulated.

Various types of AVR are present today. Modern AVRs based on auto transformer principle have produced better results in reducing the recovery time (during drop of voltage) to less than 3 sec

4.1.2 Exciter Generator:

Exciter generator is a dc generator that use for the field excitation of main generator. It coupled with main generator shaft and produced DC current. It self-excited generator. Due to residual magnetism present in the poles of the stator self-excited DC generators can able to produce their own magnetic field ones it is started.



Figure 24: Exciter Generator internal

These are simple in design and no need to have the external circuit to vary the field excitation. Again these self-excited DC generators are classified into shunt, series, and compound generators.

EXCITER	UNITS 1,2,3,4	UNITS 5 & 6	UNITS 7 & 8	UNITS 9 & 10
Manufacturer	Hitachi Japan	SKODA Czechoslovakia	Hitachi Japan	SKODA Czechoslovakia
Type	Rotary	Rotary	Static	Static
Power	600 KW	600 KW	-----	-----
Speed	166.7 RPM	166.7 RPM	-----	-----
Full Load Voltage	440 V	420 V	470 V	400 V
Full Load Current	1364 A	1430 A	3 bridges Each bridge consists of 6 Thrusters 1363 A	5 bridges Each bridge consists of 6 Thrusters 1363 A
Insulation Class	Class B	Class F	-----	-----

Table 12: Exciter Generator specification

4.1.3 PMG (Permanent Magnet Generator):

A permanent magnet synchronous generator is a generator where the excitation field is provided by a permanent magnet instead of a coil. The term synchronous refers here to the fact that the rotor and magnetic field rotate with the same speed, because the magnetic field is generated through a shaft mounted permanent magnet mechanism and current is induced into the stationary armature. PMG use for the speed regulation. It coupled the main generator shaft. They are known as synchronous generators because f , the frequency of the induced voltage in the stator (armature conductors) conventionally measured in hertz, is directly proportional to RPM, the rotation rate of the rotor usually given in revolutions per minute (or angular speed). It supply give the reaction motor.



Figure 25: PMG (permanent magnet generator)

4.1.4 HTD (Hitachi tune Dynamo):

HTD is a dc generator that use field for the file excitation when requirement is high. It is a induction motor drive generator work as simple dc generator. It supply give to the AVR (Automatic voltage regulator) cabinet

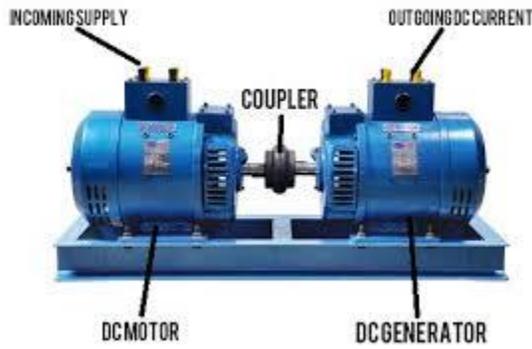


Figure 26: HTD (Hitachi tune dynamo)

4.2 Transformer:

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction

4.2.1 Power Transformer:

A transformer is an electrical device that transfers electrical energy between two or more circuits through electromagnetic induction. Electromagnetic induction produces an electromotive Force within a conductor which is exposed to time varying magnetic fields. Transformers are used to Increase or decrease the alternating voltages in electric power applications.

These are the basic components of a transformer.

1. Laminated core
2. Windings
3. Insulating materials
4. Transformer oil

5. Tap changer
6. Conservator
7. Breather
8. Cooling tubes
9. Buchholz Relay
10. Explosion vent

4.2.1.1 Core

The core is used to support the windings in the transformer. It also provides a low reluctance path to the flow of magnetic flux. It is made of laminated soft iron core in order to reduce eddy current loss and Hysteresis loss. The composition of a transformer core depends on such factors as voltage, current, and frequency. The diameter of the transformer core is directly proportional to copper loss and is inversely proportional to iron loss. If the diameter of the core is decreased, the weight of the steel in the core is reduced, which leads to less core loss of the transformer and the copper loss increase. When the diameter of the core is increased, the opposite occurs.

4.2.1.2 Windings:

There are two windings wound over the transformer core that are insulated from each other. Windings consist of several turns of copper coils bundled together, and each bundle is connected in series to form a winding.

Windings can be classified in two different ways:

1. Based on the input and output supply
2. Based on the voltage range

Within the input/output supply classification, windings are further categorized:

1. Primary windings - These are the windings to which the input voltage is applied.

2. Secondary windings - These are the windings to which the output voltage is applied.

Within the voltage range classification, windings are further categorized:

1. High voltage winding - These are made of copper coil. The number of turns is the multiple of the number of turns in the low voltage windings. The copper coils are thinner than those of the low voltage windings.

2. Low voltage windings - These have fewer turns than the high voltage windings. It is made of thick copper conductors. This is because the current in the low voltage windings is higher than that of high voltage windings. Transformers can be supplied from either low voltage (LV) or high voltage (HV) windings based on the requirement.

4.2.1.3 Insulating Materials:

Insulating paper and cardboard are used in transformers to isolate primary and secondary windings from each other and from the transformer core. Transformer oil is another insulating material. Transformer oil can actually have two functions: in addition to insulating it can also work to cool the core and coil assembly. The transformer's core and windings must be completely immersed in the oil. Normally, hydrocarbon mineral oils are used as transformer oil. Oil contamination is a serious problem because contamination robs the oil of its dielectric properties and renders it useless as an insulating medium.

4.2.1.4 Conservator:

The conservator conserves the transformer oil. It is an airtight, metallic, cylindrical drum that is fitted above the transformer. The conservator tank is vented to the atmosphere at the top, and the normal oil level is approximately in the middle of the conservator to allow the oil to expand and contract as the temperature varies. The conservator is connected to the main tank inside the transformer, which is completely filled with transformer oil through a pipeline.

4.2.1.5 Breather:

The breather controls the moisture level in the transformer. Moisture can arise when temperature variations cause expansion and contraction of the insulating oil, which then causes the pressure to change inside the conservator. Pressure changes are balanced by a flow of atmospheric air in and out of the conservator, which is how moisture can enter the system. If the insulating oil encounters moisture, it can affect the paper insulation or may even lead to internal faults. Therefore, it is necessary that the air entering the tank is moisture-free. The transformer's breather is a cylindrical container that is filled with silica gel. When the atmospheric air passes through the silica gel of the breather, the air's moisture is absorbed by the silica crystals. The breather acts like an air filter for the transformer and controls the moisture level inside a transformer. It is connected to the end of breather pipe.

4.2.1.6 Tap Changer:

The output voltage may vary according to the input voltage and the load. During loaded conditions, the voltage on the output terminal decreases, whereas during off-load conditions the output voltage increases. In order to balance the voltage variations, tap changers are used. Tap changers can be either on-load tap changers or off-load tap changers. In an on-load tap changer, the tapping can be changed without isolating the transformer from the supply. In an off-load tap changer, it is done after disconnecting the transformer. Automatic tap changers are also available.

4.2.1.7 Cooling Tubes:

Cooling tubes are used to cool the transformer oil. The transformer oil is circulated through the cooling tubes. The circulation of the oil may either be natural or forced. In natural circulation, when the temperature of the oil raises the hot oil naturally rises to the top and the cold oil sinks downward.

Thus the oil naturally circulates through the tubes. In forced circulation, an external pump is used to circulate the oil.

4.2.1.8 Buchholz Relay:

The Buchholz Relay is a protective device container housed over the connecting pipe from the main tank to the conservator tank. It is used to sense the faults occurring inside the transformer. It is a simple relay that operates by the gases emitted due to the decomposition of transformer oil during internal faults. It helps in sensing and protecting the transformer from internal faults.

4.2.1.9 Explosion Vent:

The explosion vent is used to expel boiling oil in the transformer during heavy internal faults in order to avoid the explosion of the transformer. During heavy faults, the oil rushes out of the vent. The level of the explosion vent is normally maintained above the level of the conservatory tank

Function of power transformer in power station

Power transformer has a small number of turns (LV side) while the transformer secondary side has many number of turns (HV side). That means an energy flows from the LV to HV side.



Figure 27: Step up power transfer

The most important application of step-up transformer is a generator step-up (GSU) transformer which is used in all generating plants. Those transformers usually have large turn's ratio value. The voltage value produced in energy generation is increased and prepared to the long distance energy transmission. The energy produced in generating plant is characterized by allow voltage and high current value. Depending on the generating plant type, the GSU transformer has nominal primary voltage value from 113.2 up to 220 kV. The nominal voltage value of GSU secondary side can be 132 kV, 220 kV, depending on energy transmission system which is connected to the GSU secondary side

132 KV Transformers	Unit 1	Unit No. 2	Spare
Manufacturer	Savigliano Italy	Savigliano Italy	SKODA Czechoslovakia
Year of Manufacturing	1966	1966	1992
Serial No.	58926	58927	965359
Rating	138 MVA	138 MVA	138 MVA
Voltage Ratio	12.5/132 KV	12.5/132 KV	12.5/132 KV
Frequency	50 Hz	50 Hz	50 Hz
Impedance	12.5%	11.41%	12.66%
Vector Group	Yd 11	Yd 11	Y N d 11
Oil (Gallons)	6400	6400	8300
No. Of Taps	5	5	5
Alarm	95 C°	95 C°	95 C°
Trip	110 C°	110 C°	110 C°

Table 13: 132kv step up power transformers specification

220 KV Transformers	Unit 3, 8, 9 & 10	Unit No. 4, 5 & 6	Unit No. 7	Spare
Manufacturer	SKODA Czechoslovakia	Savigliano Italy	Italtrafo Italy	Savigliano Italy
Year of Manufacturing	1994	1967	1978	1967
Serial No. (unit wise)	966736 963670 963671 963672	58928 60236 60235	1H7103-1	58666
Rating	144 MVA	138 MVA	144 MVA	138 MVA
Voltage Ratio	12.5/220 KV	12.5/220KV	12.5/220 KV	12.5/220 KV
Frequency	50 Hz	50 Hz	50 Hz	50 Hz
Impedance % (unit wise)	15.9 15.52 15.7 15.64	13.8 13.75 13.74	15.59	13.87
Vector Group	YNd 11	Yd 11	Yd 11	Yd 11
Oil (Gallons)	8127	9200	7410	9200
No. Of Taps	5	5	5	5
Alarm	95 C°	95 C°	95 C°	95 C°
Trip	110 C°	110 C°	110 C°	110

Table 14: 220kv step up power transformers specification

4.2.2 Interconnector Transformer:

The function of the interconnecting transformer-as the name suggests interconnecting two systems at different voltages. Normally, they will be either 220KV/132KV or 220KV of say about 138 MVA. They are bidirectional .During the plant start-up; they import power from grid either at 132KV or 220KV and step down to220KV or 132KV to supply the station auxiliaries. Once the plant is started and synchronized to the grid, the same transformer can now be used to export power to the grid.



Figure 28: Interconnector transformer

They are normally auto-transformers and they will have a delta connected tertiary winding, for providing a circulating path for the Zero sequence currents. Then the Transformer rating will be 132/220, 138 MVA. Transformers are a critical and expensive component of the power system. Due to the long lead time for repair of and replacement of transformers, a major goal of transformer protection is limiting the damage to a faulted transformer. Some protection functions, such as over excitation protection and temperature-based protection may aid this goal by identifying operating conditions that may cause transformer failure. The comprehensive transformer protection provided by multiple function protective relays is appropriate for critical transformers of all applications

INTERCONNECTOR TRANSFORMERS	I/C T/F No. 1	I/C T/F No. 2	I/C T/F No. 3	Spare
Manufacturer	Savigliano Italy	Savigliano Italy	Lueng Chemming Shandong, China	ABB Germany
Year of Manufacturing	1965	1973	2007	1990
Rating	138 MVA	138 MVA	138 MVA	138 MVA
Voltage Ratio	220/132 KV	220/132 KV	220/132 KV	220/132 KV
LV Current	604.3 Amp	604.3 Amp	603.59 Amp	603.6 Amp
Frequency	50 Hz	50 Hz	50 Hz	50 Hz
Impedance	9.11 %	9.28 %	9.11 %	9.7 %
Vector Group	Yyo (d11)	Yyo (d11)	YNa od1	YNao (d11)
Volume of Oil (Tons)	40	40	55	35
Alarm	95 C°	95 C°	88 C°	95 C°
Trip	110 C°	110 C°	105 C°	110 C°
Type of Cooling	OFB	OFB	ONAF2	OFAF
No. of Cooling Fan Groups	3	3	3	2
No. of Cooling Fan	2 Fans in each group	2 Fans in each group	2 groups of 7 fans 1 group of 4 fans	3 Fans in each group
Total No. Of Cooling Fans	6	6	18	6

Table 15: Interconnector Transformer

4.2.3 Station Transformer:

Station transformer is the step down transformer which is generally used in the generation station. It is mounted before the generator transformer. It takes the supply from the generator output and step down it to 11KV which is supplied to the auxiliary panel. So it is use to power the auxiliaries in the power plant. When it comes to the power system, it serves the same purpose but instead provide supply to the substation situated in that area.

STATION TRANSFORMERS	
Manufacturer	Savigliano Italy
Year of Manufacturing	1965
Rating	7.5 MVA
Voltage Ratio	132/11 KV
LV Current	394 Amp
Frequency	50 Hz
Impedance (St. T/F-1, St. T/F2)	7.8%, 7.76 %
Vector Group	Yyo
Weight of Oil	10.5 Tons
Volume of Oil	-----
Alarm	95 C°
Trip	110 C°
No. Of Taps	19
Type of Cooling	ON

Table 16: Station transformer specification

4.2.4 Excitation Transformer:

Excitation transformers are used to magnetize generators. Generator terminal voltage gives the excitation transformer input and converts to step down voltage from 13.2kv/440v for generator field excitation



Figure 29: Excitation transformer

4.2.5 Auxiliary Transformer:

Auxiliary transformer is used to supply low voltage for AC power system inside substation such as lighting, air conditioners and other AC supply system and DC power system such as protection relays, batteries, SCADA & telecom system and other DC supply system

AUXILIARY TRANSFORMERS	
Manufacturer	PEL Pakistan
Type	IDA 316-11
Year of Manufacturing	1966
Rating	300 KVA
Voltage Ratio	11/0.4 KV
LV Current	415 Amp
Frequency	50 Hz
Impedance	4.98 %, 4.88%
Vector Group	DY 11
Weight of Oil	0.41 Ton
Volume of Oil	-----
No. Of Taps	5
Type of Cooling	O.N

Table 17: Auxiliary transformer specification

4.3 Motor:

An electrical motor is such an electromechanical device which converts electrical energy into a mechanical energy.

4.3.1 Servo Motor:

Servomotor is a rotary actuator or linear actuator that allows for precise control of angular or linear position, velocity and acceleration. It consists of a suitable motor coupled to a sensor for position feedback. It also requires a relatively sophisticated controller, often a dedicated module designed specifically for use with servomotors. A servomotor is a closed-loop servomechanism that uses position feedback to control its motion and final position. The input to its control is a signal (either analogue or digital) representing the position commanded for the output shaft. The motor is paired with some type of encoder to provide position and speed feedback. In the simplest case, only the position is measured. The measured position of the output is compared to the command position, the external input to the controller. If the output position differs from that required, an error signal is generated which then causes the motor to rotate in either direction, as needed to bring the output shaft to the appropriate position. As the positions approach, the error signal reduces to zero and the motor stops. The very simplest servomotors use position-only sensing via a potentiometer and bang-bang control of their motor; the motor always rotates at full speed (or is stopped). This type of servomotor is not widely used in industrial motion control, but it forms the basis of the simple and cheap servos used for radio-controlled models. More sophisticated servomotors use optical rotary encoders to measure the speed of the output shaft and a variable-speed drive to control the motor speed. Both of these enhancements, usually in combination with a PID control algorithm, allow the servomotor to be brought to its commanded position more quickly and more precisely, with less

4.3.2 Induction Motor:

An electrical motor is such an electromechanical device which converts electrical energy into a mechanical energy. In case of three phase AC operation, most widely used motor is three phase induction motor as this type of motor does not require any starting device or we can say they are self.

Induction motor use for oil circulating pump and water circulating pump and other function

Chapter #05 Control & switching

Condition monitoring systems are a basic data provider for advanced asset management strategies, focusing on system reliability or risk. They allow consistently accessing the health status of your switchgear and thus can be used to increase maintenance efficiency. To reflect the asset specific importance and your individual needs, our monitoring offering is graded, starting from SF₆ monitoring up to full circuit-breaker monitoring.

5.1 D.C Control System:

DC step-up system controls the AC input from the household power supply and boosts the voltage to that required by the battery using a DC/DC circuit. The MCU performs both PFC* control and control of the DC/DC step-up circuit. In addition to battery cell monitor MCUs, Rennes's supplies analog and power devices suitable for battery charger/DC-DC control systems.

5.1.1 D.C Battery system:

D.C Battery system is the lifeline for any control or protection system. The Battery System of the Power Station is therefore of great importance. Two types of Battery Voltage have been used in the Power Station. 230V system for protection and control and 50 V systems for indications and alarms. There are two battery rooms in the Power Station, each having 2 sets of 230V and 50V batteries along with charger. There is a separate 230V D.C system in the Switchyard, which is similar to those installed in the Power Station. The rating of 230V and 50V Battery Systems installed in power house is 107 Ampere Hours.

5.1.2 230V System:

Each 230V D.C system has 2 sets of batteries. The two sets, each comprising of 115 cells are connected in parallel to increase the reliability and Ampere Hour rating of the battery system. A 3

phase input battery charger (Rectifier) has been provided in parallel with the battery sets. The rated voltage of one cell (without charger) is 2 volts. 115 cells are therefore required for one set. There will therefore be 230 cells for the two sets in a 230V system. In charged condition the voltage of one cell is 2.3 to 2.4V therefore in the event when the charger is working, the number of cells required for maintaining 230V is 103. The remaining 12 cells are called booster cells. These cells remain out of circuit when the charger is working. Upon failure of the charger the booster cells come into circuit automatically to make up the loss of voltage.

5.1.3 110V System

Besides 230V DC battery system in switchyard there is a 110V DC battery system for the control and protection of - 1 bay. The rating of 110V battery system is 300 ampere hour. A three phase input battery charger (rectifier) has been provided in parallel with this system. There are 55 cells with 2V rated voltage of each in this battery system.

5.1.4 50V System

50V systems are similar to 230V system described above except that number of cells are different. 50 V battery charger works on single phase A.C.

Total No. of Cells in one set = 25

No. of Main Cells = 22

No. of Booster Cells = 3

The following points should be noted regarding the operation of Battery Systems. Whenever the indication 'Battery Volts Low' is received in Control Room during supply change over, the battery volts should always be checked in the charger Room/E.C.D in order to ascertain whether the booster cells have come in circuit or not. In case the booster cells have not come in circuit or if the indication does not vanish after two minutes, the concerned section should immediately be informed. While

recording the battery reading of set No. 1 the reading of two volt meters which show whether there is some grounding or not, should also be recorded. Battery reading of switchyard should also be recorded in station log book as follows..

Power House	Set No. 1	230 V/20A	G.V= \pm 115V
		50 V/20A	= \pm 25V
	Set No. 2	230 V/9A	G.V= \pm 115V
		50 V/3A	
Switchyard	Set No. 3	230 V/8A	
		110 V/2A	

The voltmeter of 230V D.C has been installed on E.C.D to enable the Shift Engineers to keep a continuous watch over the battery readings. In case of failure of A.C supply, or after any changeover of supply, the voltage should be checked and if it is low, the fuse of booster cells should be checked and replaced, if required. For Battery Set No. 2 indication "230 V Battery Set No. 2 earth Fault" appears in control room when grounding occurs. Ground volt meters have also been installed. When the indication appears and persists or if it repeatedly appears, the concerned Maintenance Engineer must be immediately informed. Shift Engineer on duty should visit Battery Charger Rooms at least once a shift and see that the fan and air conditioner are working. Also the ambient Temp should be noted from the thermometer already installed and the temp recorded in the Governor Cabinet Log Sheet and Station Log.

5.2 Switchyard:

The apparatus used for switching, controlling and protecting the electrical circuits and equipment is known as switchyard the switchgear equipment is essentially concerned with switching and

interrupting currents either under normal or abnormal operating conditions. The tumbler switch with ordinary fuse is the simplest form of switchgear and is used to control and protect lights and other equipment in homes, offices etc. For circuits of higher rating, a high-rupturing capacity (H.R.C.) fuse in conjunction with a switch may serve the purpose of controlling and protecting the circuit. However, such a switchgear cannot be used profitably on high voltage system (3.3 kV) for two reasons. Firstly, when a fuse blows, it takes some time to replace it and consequently there is interruption of service to the customers. Secondly, the fuse cannot successfully interrupt large fault currents that result from the faults on high voltage system.

With the advancement of power system, lines and other equipments operate at high voltages and carry large currents. When a short circuit occurs on the system, heavy current flowing through the equipment may cause considerable damage. In order to interrupt such heavy fault currents, automatic circuit breakers (or simply circuit breakers) are used. A circuit breaker is switchgear which can open or close an electrical circuit under both normal and abnormal conditions. Even in instances where a fuse is adequate, as regards to breaking capacity, a circuit breaker may be preferable. It is because a circuit breaker can close circuits, as well as break them without replacement and thus has wider range of use altogether than a fuse.

5.2.1 Features of Switchyard:

A substation is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

5 Substations may be owned and operated by an electrical utility, or may be owned by a large industrial or commercial customer. Generally substations are unattended, relying on SCADA for remote supervision and control.

5.2.1.1 Complete reliability:

With the continued trend of interconnection and the increasing capacity of generating stations, the need for reliable switchgear has become of paramount importance. This is not surprising because switchgear is added to the power system to improve the reliability. When fault occurs on any part of the power system, the switchgear must operate to isolate the faulty section from the remainder circuit.

5.2.1.2 Absolutely certain discrimination:

When fault occurs on any section of the power system, the switchgear must be able to discriminate between the faulty section and the healthy section. It should isolate the faulty section from the system without affecting the healthy section. This will ensure continuity of supply.

5.2.1.3 Quick operation:

When fault occurs on any part of the power system, the switchgear must. Operate quickly so that no damage is done to generators, transformers and other equipment by the short-circuit currents. If fault is not cleared by switchgear quickly, it is likely to spread into healthy parts, thus endangering complete shutdown of the system.

5.2.1.4 Provision for manual control:

Switchgear must have provision for manual control. In case the electrical (or electronics) control fails, the necessary operation can be carried out through manual control.

5.2.1.5 Provision for Instruments:

There must be provision for instruments which may be required. These may be in the form of ammeter or voltmeter on the unit itself or the necessary current and voltage transformers for connecting to the main switchboard or a separate instrument panel.

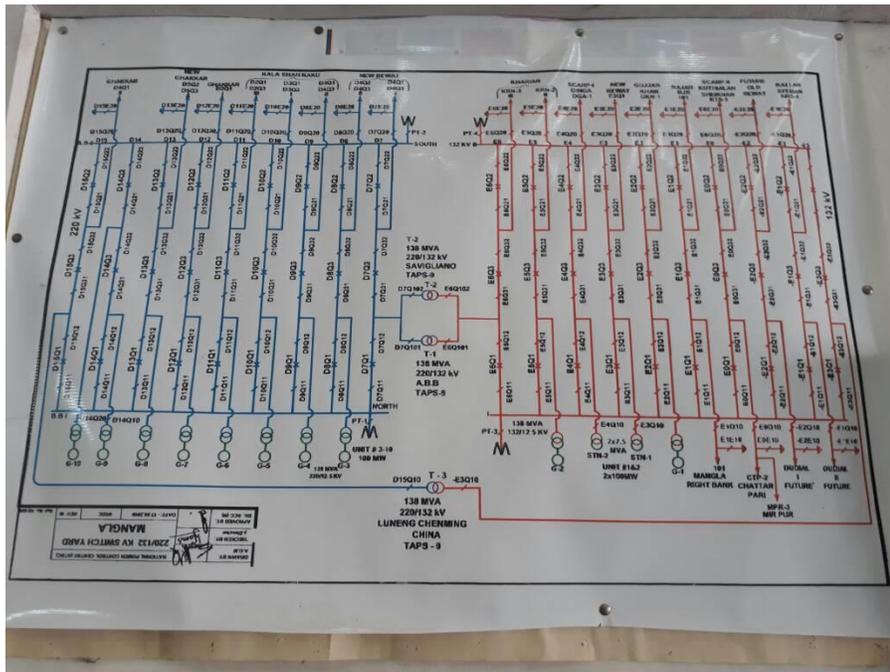


Figure 30: Switch yard

5.3 Fuses:

A fuse is a short piece of wire or thin strip which melts when excessive current flows through it for sufficient time. It is inserted in series with the circuit to be protected. Under normal operating conditions the fuse element is at a temperature below its melting point. Therefore, it carries the normal load current without overheating. However when a short circuit or overload occurs, the current through the fuse element increases beyond its rated capacity. This raises the temperature and the fuse element melts (or blows out), disconnecting the circuit protected by it. In this way, a fuse protects the machines and equipment from damage due to excessive currents. It is worthwhile to note that a fuse performs both detection and interruption functions.



Figure 31: Fuse

5.4 Earth Switch:

Earth switch connect the live parts/ line conductors and earth. This switch is normally open. Earth switch is used to earth the live parts during maintenance and during testing. During maintenance although circuit is open still there are some voltages on line, due to which capacitance between line and earth is charged. Before proceeding to maintenance work the voltage s discharged to earth, by closing the earth switch

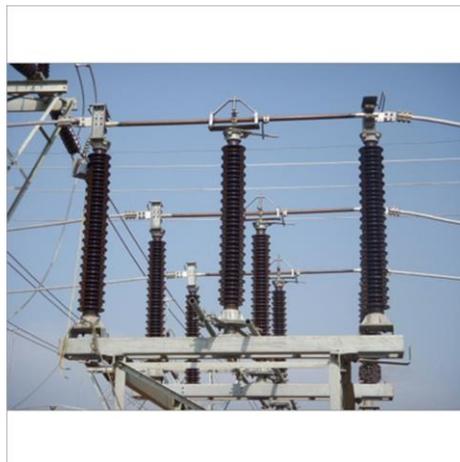


Figure 32: Earth switch

- .1. Maintenance Earth Switch: These are two or three pole units with a manual operating mechanism.
2. High Speed Earth Switch: These are operated by spring energy. Spring is charged by motor-mechanism.

5.5 Isolator:

Circuit breaker (C.B) always trip the circuit but open contacts of breaker cannot be visible physically from outside of the breaker and that is why it is recommended not to touch any electrical circuit just by switching off the circuit breaker. So for better safety there must be some arrangement so that one can see open condition of the section of the circuit before touching it. Isolator is a mechanical switch which isolates a part of circuit from system as when required.



Figure 33: Isolator switch

Electrical isolators separate a part of the system from rest for safe maintenance works. Bus side isolator: the isolator is directly connected with main bus. Line side isolator: the isolator is situated at line side of any feeder. Transfer bus side isolator: the isolator is directly connected with transformer.

5.6 Surge Arrester:

A surge arrester is a device used to protect electrical equipment from over-voltage transients caused by external (lightning) or internal (switching) events. This class of device is used to protect equipment in transmission and distribution system.



Figure 34: Surge Arrester

5.7 SF6 Gas Circuit Breaker:

The sulphur hexafluoride gas (SF₆) is an electronegative gas and has a strong tendency to absorb free electrons. The contacts of the breaker are opened in a high pressure flow of Sulphur hexafluoride gas and an arc is struck between them. The gas captures the conducting free electrons in the arc to form relatively immobile negative ions. This loss of conducting electrons in the arc quickly builds up enough insulation strength to extinguish the arc. A gas blast applied to the arc must be able to cool it rapidly so that gas temperature between the contacts is reduced from 20,000 K to less than 2000 K in a few hundred microseconds, so that it is able to withstand the transient recovery voltage that is applied across the contacts after current interruption. Sulfur hexafluoride is generally used in present high-voltage circuit breakers at rated voltage higher than 52 kV. There are mainly three types of SF₆ CB depending upon the voltage level of application. Single interrupter SF₆ CB applied for up to 245

KV systems. Two interrupter SF6 CB applied for up to 420KV systems. Four interrupter SF6 CB applied for up to 800KV systems.



Figure 35: SF6 Circuit breaker

5.8 Air Blast Circuit Breaker:

Air blast circuit breakers employ a high-pressure air blast as an arc quenching medium. Under normal condition the contacts are closed. When a fault occurs, contacts are opened and an arc is struck between them. The opening of contacts is done by a flow of air blast established by the opening of blast valve (located between air reservoir and arcing chamber). The air blast cools the arc and sweeps away the arcing products in to the atmosphere. Thus, the dielectric strength of the medium is increased, prevents from re-establishing the arc. The arc gets extinguished and flow of current is interrupted. Air blast circuit breakers were used for the system voltage of 245 KV, 420 KV and even more, especially where faster breaker operation was required. Air blast circuit breaker has some specific Advantages over oil circuit breaker which are listed as follows. There is no chance of fire hazard caused by oil. The breaking speed of circuit breaker is much higher during operation of air blast circuit breaker. Arc quenching is much faster during operation of air blast circuit breaker. The

duration of arc is same for all values of small as well as high currents interruptions. As the duration of arc is smaller, so lesser amount of heat realized from arc to current carrying contacts hence the service life of the contacts becomes longer. The stability of the system can be well maintained as it depends on the speed of operation of circuit breaker. Requires much less maintenance compared to oil circuit breaker. There are also some disadvantages of air blast circuit breakers. In order to have frequent operations, it is necessary to have sufficiently high capacity air compressor. Frequent maintenance of compressor, associated air pipes and automatic control equipment is also required. Due to high speed, current interruption there is always a chance of high rate of rise of re-striking voltage and current chopping. There also a chance of air pressure leakage from air pipes junctions.



Figure 36: Air Blast Circuit Breaker

5.9 Outgoing transmission line:

Sr. No.	132 KV Transmission Lines	Length (KM)	Conductor
1	Mangla Right Bank	2.12	Wolf
2	Gujar Khan	55	Zegalo
3	Jhelum-II	86.91	Zegalo
4	Rajar	48	Wolf

5	New Bong Escape –I	7	Zegalo
6	New Bong Escape –II	7	Zegalo
7	Dinga	71	Cukoo
8	Kuthialan Sheikhan	109	Cukoo
9	Mirpur	7.79	Lynux
10	Kallar syedan	78	Lynux
11	Dudyal-I	36.6	Rail
11	Dudyal-II	36.6	Rail
13	Old Rawat-II	78	

Table 18: 132kv outgoing circuits from mangla power station

Sr. No.	220 KV Transmission Lines	Length (KM)	Conductor
1	Ghakar-1	114.9	Rail
2	Ghakar-2	113.7	Rail
3	New Ghakar	145	Rail
4	Kala Shah Kaku-1	173	Rail
5	Kala Shah Kaku-2	173	Rail
6	Kala Shah Kaku-3	172	Rail
7	Mangla New Rawat-1	79	Rail
8	Mangla New Rawat-2	79	Rail

Table 19: 220kv outgoing circuits from mangla power station

Chapter #06 P&I (Protection & Instrumentation)

6.1 Current Transformers:

A current transformer (CT) is an electric device that produces an alternating current (AC) in its secondary which is proportional to the AC in its primary. Current transformers, together with voltage transformers (VTs) or potential transformers (PTs), which are designed for measurement, are known as instrument transformers. When a current is too high to measure directly or the voltage of the circuit is too high, a current transformer can be used to provide an isolated lower current in its secondary which is proportional to the current in the primary circuit. The induced secondary current is then suitable for measuring instruments or processing in electronic equipment. Current transformers also have little effect on the primary circuit. Often, in electronic equipment, the isolation between the primary and secondary circuit is the important characteristic. Current transformers are used in electronic equipment and are widely used for metering and protective relays in the electrical power industry.



Figure 37: Current Transformers

6.2 Potential Transformers:

Voltage transformers (VT), also called potential transformers (PT), are a parallel connected type of instrument transformer, used for metering and protection in high-voltage circuits or phasor phase shift isolation. They are designed to present negligible load to the supply being measured and to have an accurate voltage ratio to enable accurate metering. A potential transformer may have several secondary windings on the same core as a primary winding, for use in different metering or protection circuits. The primary may be connected phase to ground or phase to phase. The secondary is usually grounded on one terminal. There are three primary types of voltage transformers (VT): electromagnetic, capacitor, and optical. The electromagnetic voltage transformer is a wire-wound transformer. The capacitor voltage transformer uses a capacitance potential divider and is used at higher voltages due to a lower cost than an electromagnetic VT. An optical voltage transformer exploits the electrical properties of optical materials. Measurement of high voltages is possible by the potential transformers.



Figure 38: (PT) Potential Transformer

6.3 Capacitor Coupled Voltage Transformer (CCVT):

A capacitor voltage transformer (CVT or CCVT), is a transformer used in power systems to step down extra high voltage signals and provide a low voltage signal, for metering or operating a protective relay



Figure 39: (CCVT) Capacitor Coupled Voltage Transformer

In its most basic form, the device consists of three parts: two capacitors across which the transmission Line signal is split, an inductive element to tune the device to the line frequency, and a voltage transformer to isolate and further step down the voltage for the metering devices or protective relay.

The tuning of the divider to the line frequency makes the overall division ratio less sensitive to changes in the burden of the connected metering or protection devices. The device has at least four terminals: a terminal for connection to the high voltage signal, a ground terminal, and two secondary terminals which connect to the instrumentation or protective relay. In practice, capacitor C1 is often constructed as a stack of smaller capacitors connected in series. This provides a large voltage drop across C1 and a relatively small voltage drop across C2. As the majority of the voltage drop is on C1, this reduces the required insulation level of the voltage transformer. This makes CVTs more

economical than the wound voltage transformers under high voltage, as the later one requires more winding and materials.

6.4 RTD (Resistance Temperature Detectors):

Resistance temperature detectors (RTDs), are sensors used to measure temperature. Many RTD elements consist of a length of fine wire wrapped around a ceramic or glass core but other constructions are also used. The RTD wire is a pure material, typically platinum, nickel, or copper. The material has an accurate resistance/temperature relationship which is used to provide an indication of temperature. As RTD elements are fragile, they are often housed in protective probes.

RTDs, which have higher accuracy and repeatability Common RTD sensing elements constructed of platinum, copper or nickel have a repeatable resistance versus temperature relationship (R vs. T) and operating temperature range. The R vs. T relationship is defined as the amount of resistance change of the sensor per degree of temperature change. The relative change in resistance (temperature coefficient of resistance) varies only slightly over the useful range of the sensor.



Figure 40:(RTD) Resistance Temperature Detectors

6.5 RELAYS:

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits), or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. Relays were used extensively in telephone exchanges and early computers to perform logical operations.

- Latching relay
- Buchholz relay
- Overload protection relay
- Differential Relays
- Split phase relay
- Under frequency Relay
- Asymmetrical Relay
- Distance Relay
- Over current Relay
- Directional Relay

6.5.1 Latching relay:

A latching relay (also called "impulse", "keep", or "stay" relays) maintains either contact position indefinitely without power applied to the coil. The advantage is that one coil consumes power only for an instant while the relay is being switched, and the relay contacts retain this setting across a power outage. A latching relay allows remote control of building lighting without the hum that may be produced from a continuously (AC) energized coil. In one mechanism, two opposing coils with an

over-centre spring or permanent magnet hold the contacts in position after the coil is de-energized. A pulse to one coil turns the relay on and a pulse to the opposite coil turns the relay off. This type is widely used where control is from simple switches or single-ended outputs of a control system and such relays are found in avionics and numerous industrial applications. Another latching type has a remnant core that retains the contacts in the operated position by the remnant magnetism in the core. This type requires a current pulse of opposite polarity to release the contacts. A variation uses a permanent magnet that produces part of the force required to close the contact; the coil supplies sufficient force to move the contact open or closed by aiding or opposing the field of the permanent magnet. A polarity controlled relay needs changeover switches or an H bridge drive circuit to control it. The relay may be less expensive than other types, but this is partly offset by the increased costs in the external circuit



Figure 41: Latching Relay

6.5.2 Buchholz relay:

A Buchholz relay is a safety device sensing the accumulation of gas in large oil- filled transformers, which will alarm on slow accumulation of gas or shut down the transformer if gas is produced rapidly in the transformer oil. The contacts are not operated by an electric current but by the pressure of accumulated gas or oil flow. Depending on the model, the relay has multiple methods to detect a

failing transformer. On a slow accumulation of gas, due perhaps to slight overload, gas produced by decomposition of insulating oil accumulates in the top of the relay and forces the oil level down. A float switch in the relay is used to initiate an alarm signal. Depending on design, a second float may also serve to detect slow oil leaks. If an electrical arc forms, gas accumulation is rapid, and oil flows rapidly into the conservator. This flow of oil operates a switch attached to a vane located in the path of the moving oil. This switch normally will operate a circuit breaker to isolate the apparatus before the fault causes additional damage. Buchholz relays have a test port to allow the accumulated gas to be withdrawn for testing. Flammable gas found in the relay indicate some internal fault such as overheating or arcing, whereas air found in the relay may only indicate low oil level or a leak.



Figure 42: Buchholz .Relay

6.5.3 Overload protection relay:

Electric motors need over current protection to prevent damage from over-loading the motor, or to protect against short circuits in connecting cables or internal faults in the motor windings. The overload sensing devices are a form of heat operated relay where a coil heats a bimetallic strip, or where a solder pot melts, releasing a spring to operate auxiliary contacts. These auxiliary contacts are in series with the coil. If the overload senses excess current in the load, the coil is de-energized.

This thermal protection operates relatively slowly allowing the motor to draw higher starting currents before the protection relay will trip. Where the overload relay is exposed to the same environment as

the motor, a useful though crude compensation for motor ambient temperature is provided. The other common overload protection system uses an electromagnet coil in series with the motor circuit that directly operates contacts. This is similar to a control relay but requires a rather high fault current to operate the contacts. To prevent short over current spikes from causing nuisance triggering the armature movement is damped with a dashpot. The thermal and magnetic overload detections are typically used together in a motor protection relay. Electronic overload protection relays measure motor current and can estimate motor winding temperature using a "thermal model" of the motor armature system that can be set to provide more accurate motor protection. Some motor protection relays include temperature detector inputs for direct measurement from a thermocouple or resistance thermometer sensor embedded in the winding.



Figure 43: Overload protection relay

6.5.4 Differential Relays:

The differential relay is one that operates when there is a difference between two or more similar electrical quantities exceeds a predetermined value. In differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit. The relays used in power system protection are of different types. Among them differential relay is very commonly used relay for protecting transformers and generators from localized faults. Differential relays are very sensitive to the faults occurred within the zone of protection but they are least sensitive to the faults that occur outside the protected zone. Most of the relays operate when any quantity exceeds beyond a

predetermined value for example over current relay operates when current through it exceeds predetermined value. But the principle of differential relay is somewhat different. It operates depending upon the difference between two or more similar electrical quantities



Figure 44: Differential Relay

6.5.5 Distance relay:

Distance relays differ in principle from other forms of protection in that their performance is not governed by the magnitude of the current or voltage in the protected circuit but rather on the ratio of these two quantities. Distance relays are actually double actuating quantity relays with one coil energized by voltage and other coil by current. The current element produces a positive or pick up torque while the voltage element produces a negative or reset torque. The relay operates only when the V/I ratio falls below a predetermined value (or set value). During a fault on the transmission line the fault current increases and the voltage at the fault point decreases. The V/I ratio is measured at the location of CTs and PTs. The voltage at the PT location depends on the distance between the PT and the fault. If the measured voltage is lesser, that means the fault is nearer and vice-versa. Hence the protection called Distance relay.



Figure 45: Distance Relay

6.5.6 Directional Relay:

A directional relay uses an additional polarizing source of voltage or current to determine the direction of a fault. Directional elements respond to the phase shift between a polarizing quantity and an operate quantity. The fault can be located upstream or downstream of the relay's location, allowing appropriate protective devices to be operated inside or outside of the zone of protection.



Figure 46: Directional Relay

6.5.7 Over current Relay:

An Over current relay is a type of protective relay which operates when the load current exceeds a pickup value. Instantaneous over current (IOC) or a Definite Time Over current (DTOC) In a typical application the over current relay is connected to a current transformer and calibrated to operate at or above a specific current level. When the relay operates, one or more contacts will operate and energize to trip (open) a circuit breaker. The Definite Time Over current Relay (DTOC) has been used extensively in the United Kingdom but its inherent issue of operating slower for faults closer to

the source led to the development of the IDMT relay. The ANSI device number for (TOC) or (IDMT) protection is 51.



Figure 47: Over current relay

6.5.8 Split Phase relay:

The stator winding of a hydro generator is often made up of coils with multiple turns in the same slot. It is therefore possible for faults to develop between adjacent turns on the same phase (turn-to turn faults). These faults cannot be detected by the stator differential protection because there is no difference between the neutral- and terminal-side currents. Split-phase protection, an over current element responding to the difference between the currents in the winding parallel branches, is typically provided to detect these faults. Ideally, the split-phase element should be sensitive enough to detect a single shorted turn. Despite the fact that the current in this turn can be six to seven times the machine nominal current, the current seen by the split-phase protection can be quite small, in the order of one-twentieth of the generator full-load current. In addition, a spurious split-phase current can be measured due to current transformer (CT) errors, saturation during external faults in particular. Therefore, primary considerations in the application of split-phase protection are the method of measuring the difference in the currents between the parallel branches and the proper selection of the CT used for this purpose.



Figure 48: Split phase Relay

6.5.9 Asymmetrical Relay:

Asymmetrical is a condition in which the three-phase voltages in the system differ by an amount (Amplitude) or if the angle between each two phases is 120° . A measure of the asymmetry of the voltage is defined as the ratio of the inverse and direct component. The asymmetry in distribution networks is caused by the uneven distribution of loads in stages or by a malfunction. Asymmetrical relay is use for the asymmetrical fault identification is system



Figure 49: Asymmetrical relay

6.5.10 Under frequency relay:

Under frequency refers to a condition where the frequency of the AC supply drops to a value that is lower than its defined value such as 50 Hz or 60 Hz. Under frequency is usually caused by overloading a power source or problems with a prime mover such as engines or turbines.

The low-frequency relay is works to protect the load on the frequency of the event generator that falls below the preset limits. It is activated when the frequency decreases to 49 hertz for 50 hertz operation. When actuated, the contacts within the relay are approached to signal the annunciate, and are opened to de-energize the generator switch (contactor), resulting in a display of the fault condition and the elimination of the generator load.



Figure 50: Under frequency relay

Chapter # 07 Power house elevation:

The elevation of a geographic location is its height above or below a fixed reference point, most commonly a reference geoids a mathematical model of the Earth's sea level as

an equip gravitational surface (see Geodetic system, vertical datum). Elevation, or geometric height, is mainly used when referring to points on the Earth's surface, while altitude or geo potential height is used for points above the surface, such as an aircraft in flight or a spacecraft in orbit, and depth is used for points below the surface.

7.1 Ground level (865.5 FT SPD):

- Generator Transformer
- Exciters
- Loading Bays
- 11KV Switchgear
- Relay Room
- Ventilation Plants

7.2 Machine hall (852 FT SPD)

- Machine Hall
- Generator
- Generator/ Exciter Control cubical/ Governor cabinets/AVR
- LV switchgear
- Irrigation valve (853 FT SPD)
- 50V & 230V Battery rooms

7.3 Cooling water gallery (842 FTSPD):

- Cooling water Feed Point/ CW distribution gallery
- Normal tail race level (Minimum 835.5ft SPD & Maximum 846ft SPD)

7.4 Compressor area (837 FT SPD):

- Compressor Area

- Turbine pits
- Governor oil pumps
- Excitation Transformers
- HTDs
- Grease Pumps
- Mechanical Workshop

7.5 827 FT SPD:

- Spiral case
- Turbine Runner (825 FT SPD)

7.6 810 FT SPD

- Inlet Valve sump tanks/pumps
- Draft tube windows
- Drainage pits
- Dewatering Drainage Pumps
- Ventilation pumps
- S/By cooling water pump
- Rotary& Mitsubishi Air Compressors
- Draft Tube Exhaust fans

7.7 900 FT SPD

- Power House Crane
- Draft Tube Gantry crane
- Control Building

7.8 Elevation level (Spillway)

- Spillway sill Level 1091 FT SPD
- Bottom Sill Level 1069 FT SPD
- Top Seal Level of Radial gates 1126 FT SPD
- Gate Top Level 1138 FT SPD

7.9 Elevation level (Intake)

- Sill level 953 FT SPD
- Main Intake Control Building 1266 FT SPD
- Locking Device 1228 FT SPD

Chapter # 08 Schedule of Training

Week No.	Work Perform
1	MME(Mechanical maintenance engineers) Section
2	MME(Mechanical maintenance engineers) Section
3	EME(Electrical maintenance engineers) Section
4	EME(Electrical maintenance engineers) Section
5	Auxiliary Section
6	Auxiliary Section
7	P&I(Protections & Instrumentation) Section
8	P&I(Protections & Instrumentation) Section
9	Switchyard
10	Switchyard
11	Operation Section
12	Operation Section
13	Operation Section
14	Operation Section
15	Operation Section
16	Operation Section

Table 20 Training schedule

Chapter # 09 Skills Gained

9.1 Technical Skills acquired:

- Power Station Technologies and Operations & maintenance.
- Transmission systems technologies and operations & maintenance,
- Distribution system technologies and operations & maintenance,
- Energy Efficiency
- Energy Environment Interface
- Rural Electrification

9.2 Interpersonal Communication Skills:

During my internship period the Interpersonal skills, which are the life skills I use every day to how I communicate with others, but also I got confidence and my ability to listen and understand. Problem solving, decision making and personal stress management are also considered interpersonal skills. Through this internship, I found that I matured and I gained many new perspectives, such as problem solving skill, diversity, effective communication, team work and service recovery, attention to detail, time management, personal empowerment, self-confidence, responsibility and cultural sensitivity. My supervisor was so kind to answer with patience and teach me much that made this internship so enjoyable. I had gotten a wonderful internship that spent such a happy moment with all of them. Though, still have so much to learn, I think this challenge was what should include in my career. This helped much on my future planning

9.3 Team Playing Skills:

In the section of the company I had been working, most of the time I had work with my supervisor though gained in terms of improving my team playing skill during my internship period in Mangla Power Plant

9.4 Leadership Skills:

Leadership skills are the tool, behaviors, and capabilities that a person needs in order to be successful at motivating and directing others. Yet true leadership skills involve something more; the ability to help people grow in their own abilities. It can be said that the most successful leaders are those that drive other to active their own success. I gained leadership skills from my supervisor during the internship period which include managing time, motivating individuals, giving feedback and building teams

9.5 Work Ethics Related Issue:

An internship is an opportunity to learn the skills and behaviors along with the work values that are required for success in the workplace. Workplace ethics are established codes of conduct that reflect the values of the organization or company where you are employed. I have seen possess willingness to work hard from my supervisor during my internship period. In addition to working hard it is also important to work smart. This means I acquired the most efficient way to complete tasks and finding ways to save time while completing daily assignments. It's also important to care about my job and complete all projects while maintaining a positive attitude.

9.6 Entrepreneurship Skills:

Entrepreneurship is the ability to “create and build something from practically nothing. It is initiating, doing, achieving and building an enterprise or organization, rather than just watching, analyzing or describing one. It is the knack of sensing an opportunity where others see chaos, contradiction and confusion. It is the ability to build a founding team to complement your own skills and talents. It is the know-how to find, marshal and control resources and to make sure you don't run out of money when you need it most. Finally, it is the willingness to take calculated risks, both personal and financial, and then to do everything possible to get the odds in your favor.”

An entrepreneurship education program consists of wide-ranging subjects, and in every entrepreneurship education program, learning something at outside classroom like internship in accompany plays an important role, as well as normal lectures in classroom. Of course, in this respect, the good relationship between educational institutions and business society is very important for the purpose of implementing an internship program as a part of curriculum. Interns gain firsthand understanding of entrepreneurship along with enhanced technical, professional, and communication skills. In this internship I have gained self confidence, information seeking, problem seeking and sees and acts on opportunities of business in networking. Though helping me to clarify my vision and decided whether or not to forge ahead with the idea.

Conclusion:

After going through the whole period of internship as an intern I've observed so many professional activities and learnt as well. This internship was very fruitful to me because I had to cover many different fields. I also learnt new concepts and new ways of working. During this internship period I acquired practical experience to complement the theoretical content of my study for campus

Abbreviations

NPCC	National Power Control Centre
MME	Mechanical maintenance engineers (Section)
EME	Electrical maintenance engineers (Section)
P&I	Protections & Instrumentation (Section)
R.E (P)	Resident Engineer (Power)
AVR	Automatic voltage regulator
PMG	permanent magnet generator
HTD	Hitachi tune dynamo
H.R.C	High-rupturing capacity
C.B	Circuit breaker
CT	Current transformer
AC	Alternating current
VT	Voltage transformers
PT	Potential transformers
CCVT	Capacitor Coupled Voltage Transformer
RTD	Resistance Temperature Detectors
IOC	Instantaneous over current
DTOC	Definite Time Over current

References

1. Maximum data take from Mangla Power Station Operation Section
2. https://en.wikipedia.org/wiki/Hydraulic_structure
3. <https://www.merriam-webster.com/dictionary/prime%20mover>
4. <http://new.abb.com/high-voltage/monitoring>
5. <https://www.renesas.com/en-us/solutions/automotive/hev-ev/battery-charger.html>
6. https://en.wikipedia.org/wiki/Electrical_substation
7. <https://en.wikipedia.org/wiki/Elevation>
8. [https://www.google.com.pk/search?q=spiral+casing&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiJsrf4wqHWAhVKbxQKHSngD1IQ_AUICigB&biw=1348&bih=633#imgrc=8SbUCIVjuGDbM:](https://www.google.com.pk/search?q=spiral+casing&source=lnms&tbm=isch&sa=X&ved=0ahUKEwiJsrf4wqHWAhVKbxQKHSngD1IQ_AUICigB&biw=1348&bih=633#imgrc=8SbUCIVjuGDbM)
9. <http://www.wapda.gov.pk/index.php/projects/hydro-power/o-m/mangla>
10. <http://www.wapda.gov.pk/index.php/projects/hydro-power/o-m/mangla/item/66-mangla-dam-raising-project>
11. <http://www.wapda.gov.pk/index.php/projects/hydro-power/o-m/mangla/item/65-mangla-dam-raising-project>
12. <https://www.electrical4u.com/signal-generator/>
13. https://www.slideshare.net/KeithVaugh/hydropower-11538342?qid=9d5bfaee-8bc5-4150-a47e-4619f98e6e56&v=&b=&from_search=22
14. <https://energy.gov/eere/water/types-hydropower-plants>
15. <https://water.usgs.gov/edu/hyhowworks.html>
16. [https://www.google.com.pk/search?biw=1348&bih=633&tbm=isch&sa=1&q=dam+screen&oq=dam+screen&gs_l=psy-ab.3..0i13k114.3076.10832.0.12371.14.13.1.0.0.0.928.2737.4-1j2j1.4.0....0...1.1.64.psy-ab..9.5.2742...0j0i67k1.jyrzO8kj530#imgrc=IZku93KPky3vzM:](https://www.google.com.pk/search?biw=1348&bih=633&tbm=isch&sa=1&q=dam+screen&oq=dam+screen&gs_l=psy-ab.3..0i13k114.3076.10832.0.12371.14.13.1.0.0.0.928.2737.4-1j2j1.4.0....0...1.1.64.psy-ab..9.5.2742...0j0i67k1.jyrzO8kj530#imgrc=IZku93KPky3vzM)

17. <https://www.quora.com/What-is-function-of-a-draft-tube-in-a-turbine-Why-is-it-tapering-and-not-cylindrical>
18. <https://www.quora.com/What-is-the-purpose-of-a-spillway>
19. <http://www.electronics-tutorials.ws/transformer/transformer-basics.html>
20. <http://www.jameco.com/jameco/workshop/howitworks/how-servo-motors-work.html>
21. www.electronics-tutorials.ws › Input/Output Devices

Control Room data sheets

PAKISTAN WATER & POWER DEVELOPMENT AUTHORITY
MANGLA HYDRO-ELECTRIC GENERATING STATION
CONTROL ROOM LOG SHEET

132 K.V. TRANSMISSION LINES

1.535

180-24-4
255-16-4
100-16-4
115-20-4
125-22-4
115-20-4

TIME	DADYAL		OLDRAWAT-2		K.T.S		MIRPUR		RAJAR		MIRB		GURDIP KHAN		JHEELUM-2		DINGII		NBE-2		NBE-1			
	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN	AMPS	MIN		
0100	250	50	15	-	NIL	-	120	24	-02	270	60	02	110	20	-06	190	44	08	280	56	10	170	36	18
0200	220	45	15	-	-	-	110	22	-02	230	52	06	100	16	-08	170	40	04	260	46	16	150	32	12
0300	200	45	15	-	-	-	145	28	-12	250	56	02	100	20	-06	125	30	-	240	50	08	115	24	08
0400	200	45	15	-	-	-	140	26	-12	255	56	04	110	24	-02	110	36	06	250	50	08	110	22	10
0500	160	40	10	-	-	-	140	26	-12	265	60	04	105	20	-04	140	34	02	235	50	08	120	26	12
0600	200	40	15	-	-	-	115	22	06	255	56	02	90	16	-06	110	26	-	210	46	08	120	26	12
0700	200	40	15	-	-	-	110	22	04	245	54	02	100	18	-06	120	30	-	200	42	08	120	24	12
0800	200	40	15	-	-	-	110	22	04	245	54	02	100	18	-06	120	30	-	200	42	08	120	24	12
0900	180	40	15	-	-	-	100	18	-06	235	52	02	80	12	-08	125	32	-	225	48	08	120	24	12
1000	180	40	15	-	-	-	100	18	-06	235	52	02	80	12	-08	125	32	-	225	48	08	120	24	12
1100	160	35	15	-	-	-	115	24	-02	200	46	04	80	12	-00	115	28	04	185	40	08	50	10	08
1200																								
1300																								
1400																								
1500																								
1600																								
1700																								
1800																								
1900																								
2000																								
2100																								
2200																								
2300																								
2400																								

Figure 51: 132kv Lines Data sheet

WEDNESDAY DATE 26/4/17

220 K.V. TRANSMISSION LINES NEWQUIK

LINE	MNR-1		MNR-2		KSK-2		KSK-1		KSK-3		GHK-1		GHK-2		GHK-3		TIME
	AMPS	MIN															
1	120	10	120	10	120	10	120	10	120	10	120	10	120	10	120	10	0100
2	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	0200
3	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	0300
4	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	0400
5	120	20	120	20	120	20	120	20	120	20	120	20	120	20	120	20	0500
6	100	10	100	10	100	10	100	10	100	10	100	10	100	10	100	10	0600
7	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	0700
8	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	0800
9	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	0900
10	100	20	100	20	100	20	100	20	100	20	100	20	100	20	100	20	1000
11	130	40	130	40	130	40	130	40	130	40	130	40	130	40	130	40	1100
12	130	40	130	40	130	40	130	40	130	40	130	40	130	40	130	40	1200
13	230	75	230	75	230	75	230	75	230	75	230	75	230	75	230	75	1300
14																	1400
15																	1500
16																	1600
17																	1700
18																	1800
19																	1900
20																	2000
21																	2100
22																	2200
23																	2300
24																	2400

Figure 52: 220kv Transmission Lines

UNIT No.	TRANSFORMER		FIRE PROTECTION		PRESSURE AND TAP POSITION		PEAK HOURS LOADING		DAILY GENERATION ABSTRACT (0000 - 2400 HRS)												
	NIGHT SHIFT - A WATER PRESS. (KG/CM ²)	AIR PRESS. (KG/CM ²)	TAP POSITION	MORNING SHIFT WATER PRESS. (KG/CM ²)	AIR PRESS. (KG/CM ²)	TAP POSITION	EVENING SHIFT WATER PRESS. (KG/CM ²)	AIR PRESS. (KG/CM ²)	TAP POSITION	TIME	MIN	MAX	MIN	MAX	SYSTEM PEAK (W)	SYSTEM PEAK (T)	IPV	SYSTEM PEAK (TOTAL)	AVERAGE DISCHARGE	AVERAGE IN FLOW	AVERAGE BUT FLOW
1	8.5	8.5	5.0	5.0	5.0	5.0	5.0	5.0	1715	1930											
2	10.3	10.3	5.0	5.0	5.0	5.0	5.0	5.0	1730	1945											
3	8.7	8.7	5.0	5.0	5.0	5.0	5.0	5.0	1745	2015											
4	11.0	11.0	5.0	5.0	5.0	5.0	5.0	5.0	1815	2030											
5	7.6	7.6	6.0	6.0	6.0	6.0	6.0	6.0	1830	2045											
6	-	10.7	5.0	5.0	5.0	5.0	5.0	5.0	1845	2115											
7	-	5.0	5.0	5.0	5.0	5.0	5.0	5.0	1915	2130											
8	-	5.0	5.0	5.0	5.0	5.0	5.0	5.0													
9	-	4.0	4.0	4.0	4.0	4.0	4.0	4.0													
10	-	4.0	4.0	4.0	4.0	4.0	4.0	4.0													

Figure 56: Flow Discharge Data Sheet