



Report

# Haripur Power Plant

▶ [ Serving for a Better Bangladesh ]

## Report on Industrial Training

05 January 2003 - 30 January 2003

Haripur, Narayanganj

Department of Mechanical Engineering

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*Submitted by ...*

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## ACKNOWLEDGEMENT

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# CHAPTER 1

## BPDB & Power Plant of Bangladesh

## HISTORY OF BPDB

In 1947, for water and power resources, a common organization was established for Bangladesh (formerly East Pakistan), known as East Pakistan Water And Power Development Authority (EPWAPDA). At that time, the power generation capacity for that organization was about 200 MW.

During 1972, a Presidential Order (PO#59) divided WAPDA into two organizations - Bangladesh Water Development Board (BWDB) and Bangladesh Power Development Board (BPDB).

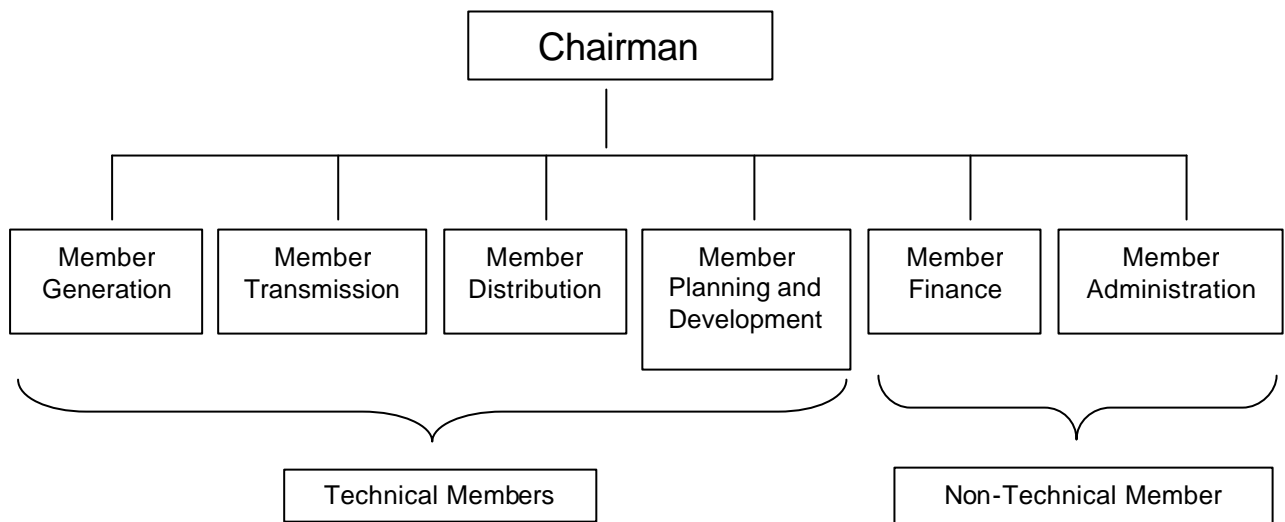
BPDB is responsible for planning, construction and operation of power generation and transmission facilities throughout Bangladesh and for distribution in urban areas except Dhaka and its adjoining areas. Total installed capacity of BPDB is 3603 MW including 302 MW generated by Independent Power Producers [Source : BPDB Annual Report 2002]. BPDB is now under the authority of Ministry of Energy and Mineral Resources.

BPDB generates electricity from both the renewable (hydro) and non-renewable sources (natural gas, furnace oil, diesel etc.). There are some places where solar photo-voltaic is used for supplying electricity to lighting and communication equipment.

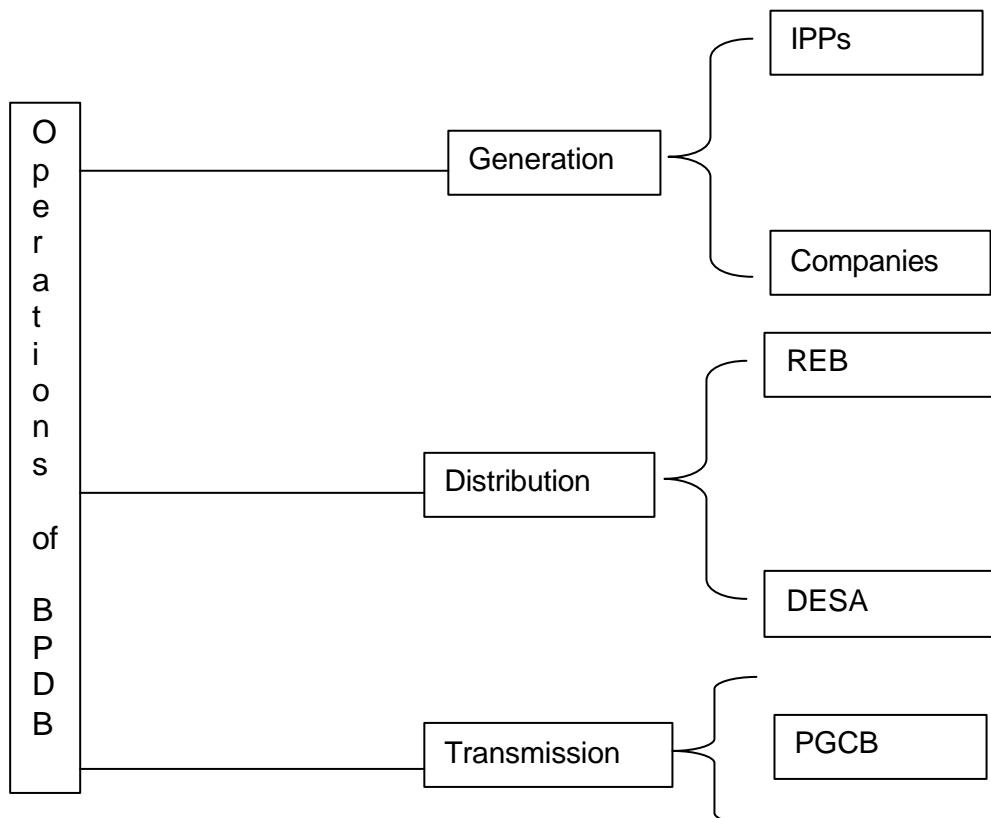
The role of BPDB is socio-economic development of the country by Power Generation and Distribution. BPDB is working as Public Limited Enterprise.

## ORGANIZATION OF BPDB

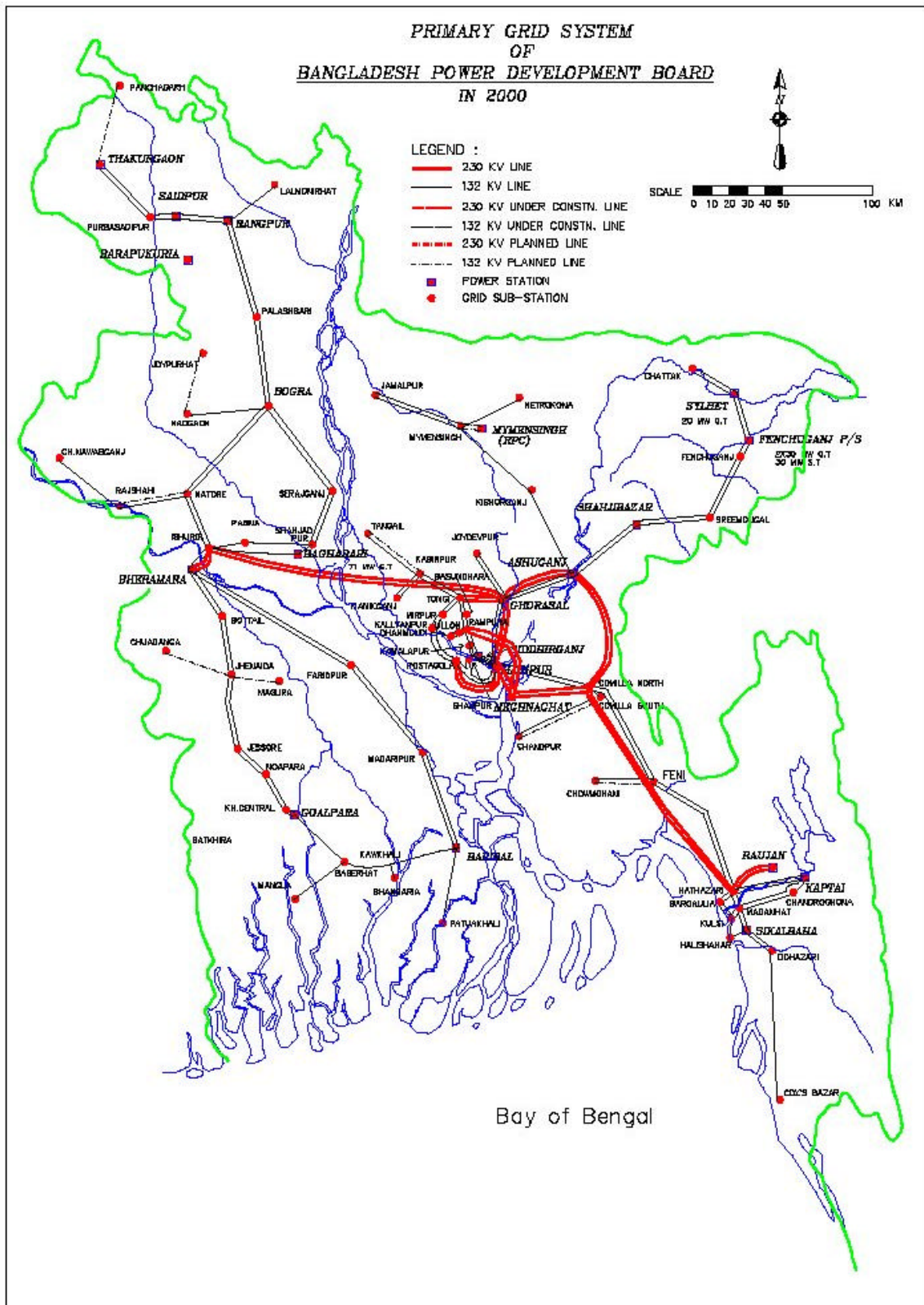
Including the Chairman there are other 7 members in the Board. The number is chosen as an odd number so that any decision can be made after voting.



### Organization Related to BPDB ▼



# POWER PLANT OF BANGLADESH



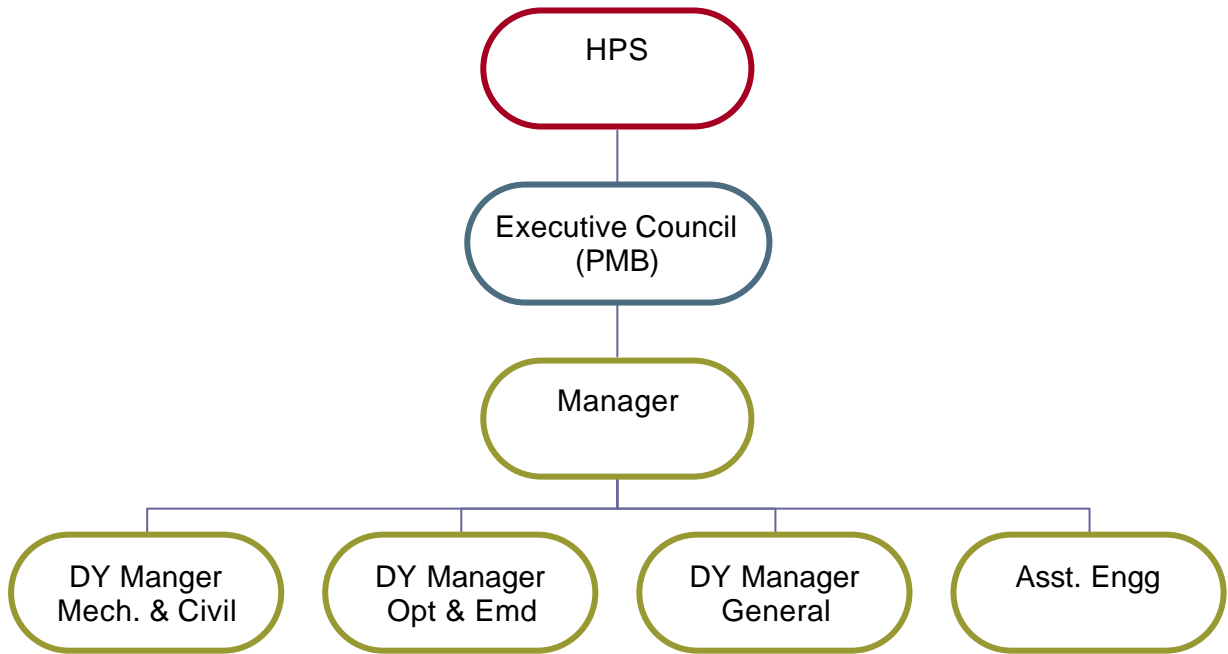
## GENERATION DATA

At present, there are about 25 Power plants in Bangladesh.

	Name of the Installation (Type)	Installed Capacity (MW)	Fuel	Efficiency
1.	Karnafuli	230	Hydro	
2.	Asujanj ST & GT & CC	724	Gas	29.01
3.	Shahjibazar GT	166	Gas	22.37
4.	Sylhet GT	20	Gas	-----
5.	Fenchuganj CC	90	Gas	41.55
6.	Ghorasal ST	950	Gas	32.40
7.	Shiddhiranj ST	50	Gas	28.21
8.	Haripur GT	99	Gas	24.29
9.	Sikhalbaha ST+Barge Mout. GT	116	Gas	37.60
10.	Rauzan ST	420	Gas	31.70
11.	Khulna ST+BMPP	226	F. Oil+Sko	26.90
12.	Baghabari GT	71	Gas+HSG	27.46
13.	Vheramara GT	60	HSG	21.00
14.	Thakurgaon Diesel	6	LDO	31.37
15.	Saidpur Diesel	23.75	F Oil + LDO + HSD	21
16.	Barisal GT + Diesel	42.6	HSD	19.75
17.	Rangpur GT	20	HSD	25.49
18.	Bhola Diesel	6	HSD + F.Oil	28.96
	IPP			
19.	Haripur BMPP	110	Gas	
20.	KPCL	110	Furnace Oil	
21.	Baghabari (WestMont)	90	Gas	
22.	RPC (Mymenshing)	140	Gas	
23.	AES Haripur	235	Gas	
	<i>Total System (IPP + BPDB)</i>	4005	-	-

# HARIPUR POWER STATION & BPDB

## Organogram for Haripur Power Station, BPDB, Narayanganj



## Objectives of Haripur Power Station (HPS)

- > To maximize power generation in a cost effective manner.
- > To ensure efficient utilization of facilities.
- > To increase the job satisfaction of employees.
- > To improve quality of performance & productivity
- > To make HPS as a profit making unit.

## TOTAL QUALITY MANAGEMENT (TQM) IN HPS

TQM in HPS is operated by nine circles between the employees. A short details is given below:

<i>Name</i>	<i>No. of person</i>	<i>Department</i>	<i>Strategy</i>
Meghdut (†gN`ȳ)	12	Operation	Operation is the key of generation
Pragati (cMwZ)	13	Operation	Generation is the key of success
Sonali (†mVbvj x)	20	Mechanical	Efficient utilization of facilities
Adarsa (Av`k)	16	Office & Store	Increase job satisfaction of employees
Rajani Prohori (i Rbx cthi x)	17	Security	Discipline is the key to success
Seba (†mev)	7	School, Medical & Mosque	Serving is our goal
Dalia (Wwj qv)	10	Civil	We will keep the power plant clean
Porimap O Niontron (cwi gvc I wqŠp)	11	Control & Instrumentation	Power generation without interruption
Torit Progoti (Zwor cMwZ)	10	Electrical	We will keep the plant working

## SBU CONCEPT

### Plant Management Board (PMB)

Consists of 9 members

- > Chairman
- > Member Generation
- > Member Transmission
- > Chief Engineer Generation
- > Controller Finance
- > Member Advisor
- > President of Chamber of Commerce & Industries, Narayanganj
- > Other 2 members

### Plant Management Committee (PMC)

Consists of the local body of the power plant containing 6 members

- > Manager
- > Deputy Manager (3 Persons)
- > Asst. Director (Admin + Security)
- > Asst. Director (Accounts)

Before SBU there were about 178 total staff and engineers in the plant but after SBU it went down to 133. Currently these employees are below 100.

## Causes For Turning Into A *S.B.U.*

- > Insufficient Maintenance planning and scheduling.
- > Insufficient Operation and Maintenance training
- > Insufficient analysis of past troubles
- > Defects in Operation and Management standard and manuals
- > Insufficient Stock of spare parts
- > Unclear responsibility for results
- > Inflexible budget system
- > Complex Procurement System
- > Difficult relation between management and labor unions
- > Lack of training opportunity for new technology acquisition
- > Rigid job rotation system.

## Options Laid Down by SAPI

A Japanese Team called Special Assistance for Project Implementation (SAPI) recommended BPDB some options. These options were :

- Owned and operated by PDB with improvement (SBU)
- Owned by PDB and operated by private company
- Owned and operated by PDB subsidiary (corporation)
- Owned by PDB subsidiary and operated by Private
- Owned and operated by private company

Haripur Power Plant was declared as SBU from January 2000 & started operated from 1st Feb, 2000.

# CHAPTER 2

## HPS : A Gas Turbine Power Plant

# GENERAL IDEA OF A OPEN CYCLE GAS TURBINE POWER PLANT

## A Simple Open Cycle Gas Turbine

Fresh atmospheric air drawn into by the compressor (Denoted by **C** in the schematic) continuously and heat is added by combustion of fuel in the working fluid (air) itself. The products of combustion are expanded through the turbine (Denoted by **T** in the schematic) and exhausted to atmosphere.

Combustion of fuel takes place either at constant volume or at constant pressure. Theoretically the thermal efficiency of the constant volume cycle is more than the constant pressure cycle. But there are some practical difficulties in the case of constant volume cycle, such as valves are necessary to isolate the combustion chambers from the compressor and the turbine. Thus combustion is intermittent and does not allow the smooth running of machine. Due to these defects this cycle has not been widely accepted. In case of constant pressure cycle, combustion is a continuous process and valves are not necessary. This system has proved to be quite satisfactory.

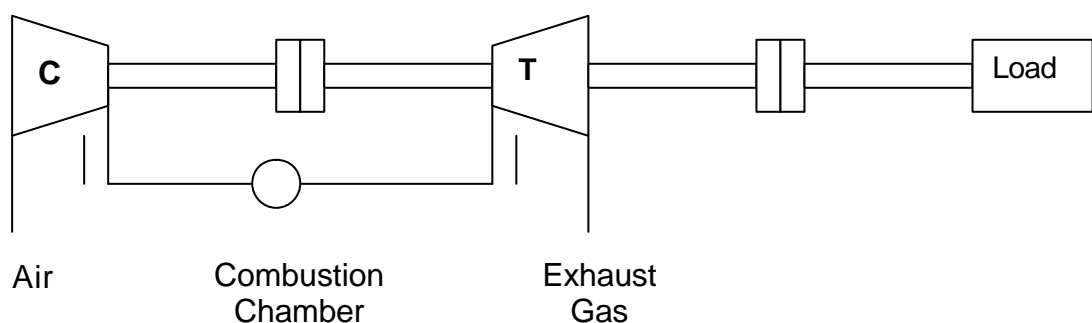


Figure : Schematic of Open Cycle Gas Turbine

## SOME MAJOR SPECIFICATIONS

### Gas Turbine

Type : Open-cycle, single-shaft, industrial type gas turbine

Model : MW-251

Compressor :

Type : Axial flow type

No. of stages : 18

Combustor :

Type : Cannular type

No. of stages : 8

Turbine

type Axial flow, reaction type

No. of stages : 3

Shaft speed 4,902.4 rpm

Direction of rotation

clockwise viewed from output coupling

Overspeed trip setting 5393±49 rpm

Heaviest piece at maintenance

gas turbine rotor approx. 15 tons

### Main reduction gear

Type Quill shaft-double helical gear

Pinion : Gear

No. of Revolutions: 4902.4 rpm / 3000rpm

No of teeth : 41 / 67

Pitch dia. : 455.56mm / 744.44mm

Reduction ratio : 0.612

### Main SSS clutch (For synchronous condenser use)

Type: Synchro-Self-Shifting clutch

Model 194T (with servo operated locking device)

### Turning gear

Turning speed : Approx. 5 rpm (Gas turbine shaft)

Turning Gear Motor

Capacity : 4.0 kW

Sync. Speed : 1500 rpm

Voltage : AC 400V

Enclosure : T.E.F.C.

Insulation Class : F

Rating : Continuous

# DESCRIPTION OF A SINGLE UNIT IN HARIPUR

## The Power Trained Diagram

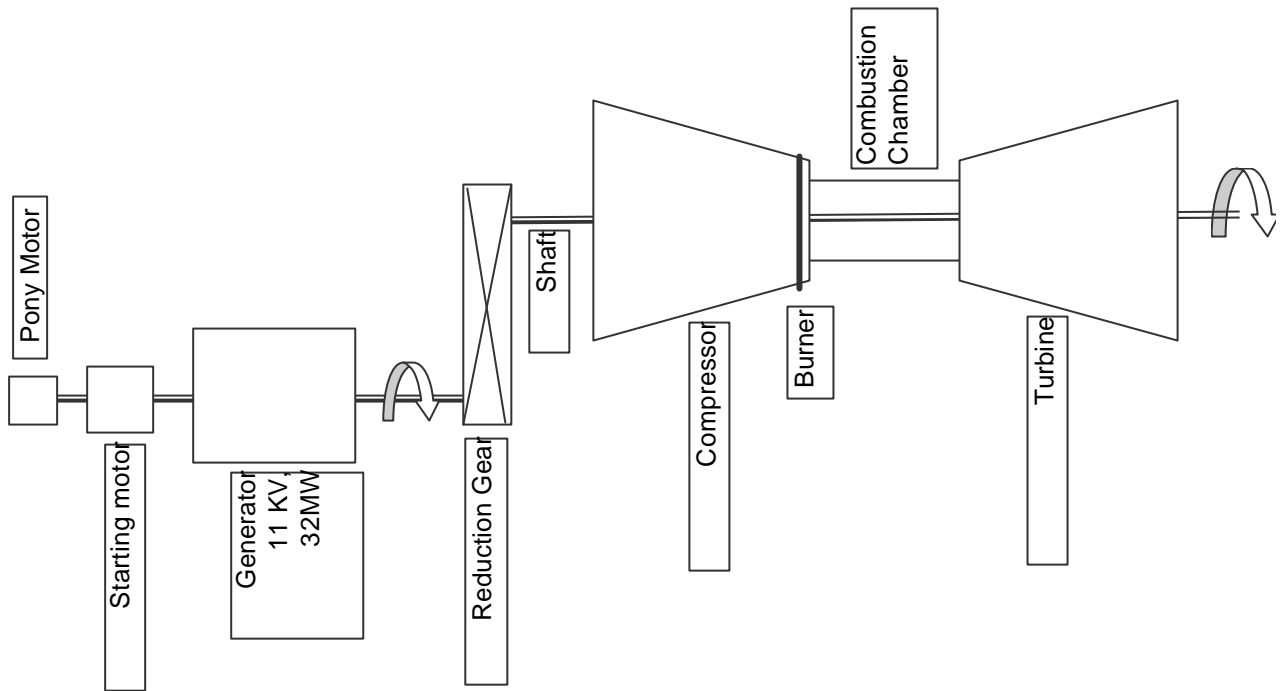


Fig : Trained Diagram of the Power Plant

## SEQUENCE PROGRESSING DURING STARTUP

Depress “GT START” button from L.C.B. (Local Control Board) or R.C.B. (Remote Control Board).

1. The master control will be energized and the automatic starting sequence will be preceded.
  - > Lube oil cooler fans will start
  - > Turbine cooling air cooler fans will start
  - > Air filter blower will start
  - > Package ventilating fans will start

2. Then starting pony motor will start. After 15 seconds, starting main motor will start and the lamp "STARTER ON" will be lit on. \*CV-081 is opened and \*CV-084 is closed, then lube oil is supplied to the hydraulic torque converter and starting motor is connected to the gas turbine shaft hydraulically.
  
3. Gas turbine generator will be accelerated and turning device will be disengaged automatically by the overriding mechanism of the SSS clutch for turning.  
At the 10% speed of the rated (14C10), turning motor if off.
  
4. When the gas turbine generator reaches its ignition speed (approx. 20% speed : 14CIG),
  - > At the ignition speed, pre-ignition purge is conducted for 60 second (T-14CIGT)
  - > After completion of the pre-ignition purge, igniters are on.
  - > Over speed trip solenoid valve \*UY-116 is closed and the OST pressure is established, over speed trip valve \*CV-170A is open and \*CV-170B is closed. Then the lamp "FUEL ON" is lighted.
  - > Fuel gas isolation valve \*CV-177 is open simultaneously.
  
5. Igniters spark and ignition is conducted in the combustion basket #3 and #4. Then flame propagates.
  - > Flame detectors sense flame and the lamp "FLM7/FLM8" is lighted.
  - > Flame must be detected in both combustors #7 and #8 within 30 seconds. If not, the machine will be shut down automatically.

6. When the gas turbine generator reaches approx. 70% of the rated speed :
  - > At the 70% of the rated speed (14CSD), the starting motor is off, \*CV-081 is closed and \*CV-084 is opened, then the lube oil in the hydraulic torque converter is drained out.
  
7. When the gas turbine generator reaches near the rated speed :
  - > At the 96% of the rated speed (14CM), low pressure bleed valve \*CV-016 and high pressure bleed valve \*CV-017 are closed.
  - > The limit switches sense the valve closing positions and the lamp “LP BLD CLS” & “HP BLD CLS” will be lighted.
  - > When “AUTO. SYNC” is selected, the generator field breaker will be closed and AVR will be operated automatically. The indication lamp “41E ON” will light.
  - > (NOTE) If controller is in the manual synchronization mode, refer to manual synchronization section for continuing the sequence.
  - > When the turbine speed reaches to 14CRTD (approx. 4807 rpm) and MEGAC speed control in MEGAC is operated, the indication lamp “RATED SPEED” will light.
  
8. At the rated speed :
  - > AC motor of the auxiliary lube oil pump is de-energized and auxiliary lube oil pump will be shut down.
  - > Automatic synchronization system operates and then the generator breaker is closed and initial load is taken.
  - > At this time, the indicating lamp “52G ON” will light.

# FUTURE EXTENSION PLAN AS A COMBINED CYCLE

## Combined Cycle Gas Turbine

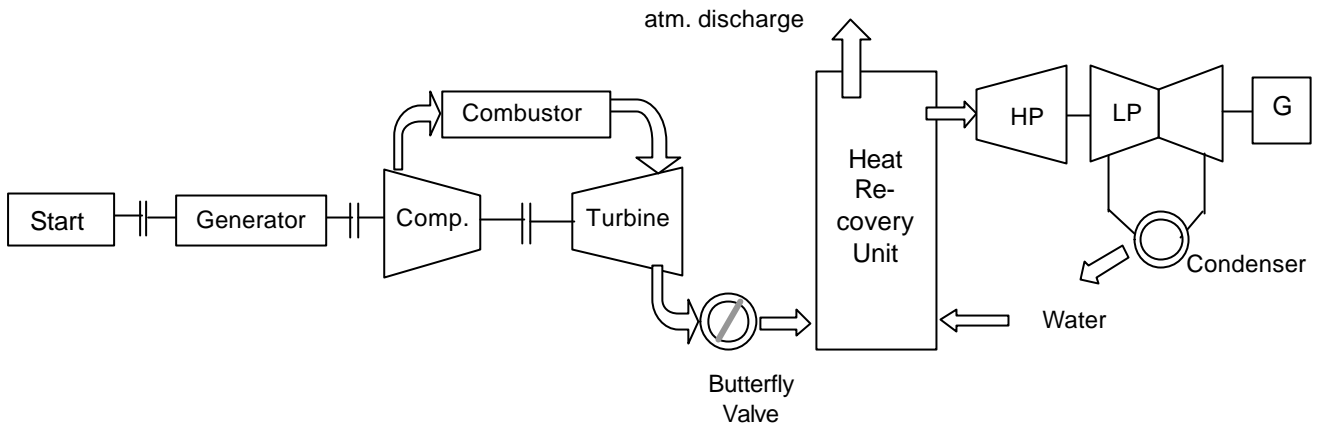


Fig : Schematic of Combined Cycle Gas Turbine

In this modification over the simple gas turbine, the exhaust gas with heat energy is used with a steam turbine. Thus very effective and efficient condition is obtained.

## Future Plan

The Future plan for haripur power plant is to convert the existing plant to a combined cycle unit. Along with it some more gas turbine is planned to setup, so that the steam turbine would be working continuously. An extension project is taken under consideration.

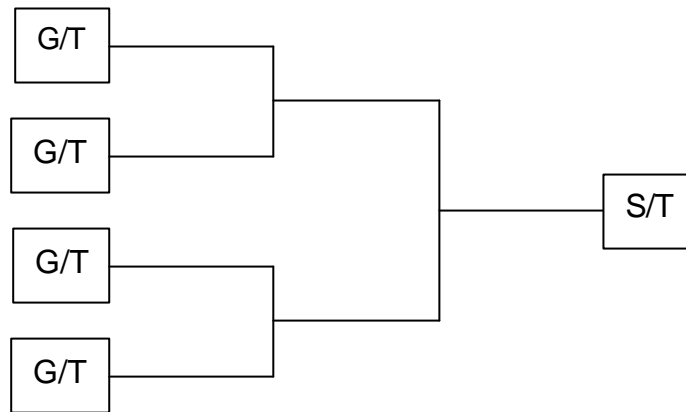


Figure : Schematic of The Plan

# CHAPTER 3

## Description of Major Equipments

# STARTING SYSTEM

## Pony Motor

It is a small type of motor that runs at 400V & 50W. It starts electrically at first. This runs the rotor which is coupled with the starting motor by rubber coupling.

## Starting Motor

Starting motor is a three-phase induction motor. It helps to rotate the rotor from initial condition to 3600 rpm.

## Specification :

### Main Starting Motor

Type Three phase induction motor

Capacity : 500 kW

Voltage : 11000V

Frequency : 50 Hz

No. of Pole : 4

Sync. Speed : 1500 rpm

Insulation class : F

Rating : 30 min

Enclosure & protection : Drip proof type, IP22

### Auxiliary Starting Motor

Type Three phase induction motor

Capacity : 40 kW

Voltage AC : 400V

Frequency : 50 hz

No. of Pole : 4

Sync. Speed : 1500 rpm

Insulation Class : F

Rating : 30 min

Enclosure : T.E.F.C.

## Torque Converter

A torque converter is a fluid and mechanical coupling . In this unit, the starting motor and the exciter is coupled by the torque converter.It is to be noted that both the starting motor and the exciter is coupled with the torque converter by the solid/rigid coupling(shafts are directly connected to one another by couplings).

### **Specification :**

#### Torque Converter

Type : 1-stage, 3-element, hydraulic type

Model : 4UGGN-2304

Capacity : 500 kW

Stall Torque Ratio Approx. 4.2

Max. Efficiency : Approx. 85%

Auxiliary Gear

Type : Single Helical Gear

Reduction Ratio

Input Side : 0.742

Output Side : 0.769

## POWER GENERATION SECTION

### Exciter

The generator needs an exciter to build up the necessary voltage on no load and then to keep it constant load, when greater excitation will be required. The exciter is a D.C generator shunt or compound. The capacity of the exciter depends on the speed, on the voltage rating of a.c. generator and on the voltage required to compensate for the drop due to load on generator.

The rating of exciter is 0.3 to 1% of the generator output. Exciters usually operate at a voltage between 115volts and 400 volts.

## GENERATOR

An electric generator is a device used to convert mechanical energy into electrical energy based on the principle of "electromagnetic induction". In this power plant, the voltage rating is 11kV with 0.8 power factor lagging. It is a 2-pole generator with a speed of 3000 rpm and their efficiency may be taken between 98% to 99%.

## Reduction Gear

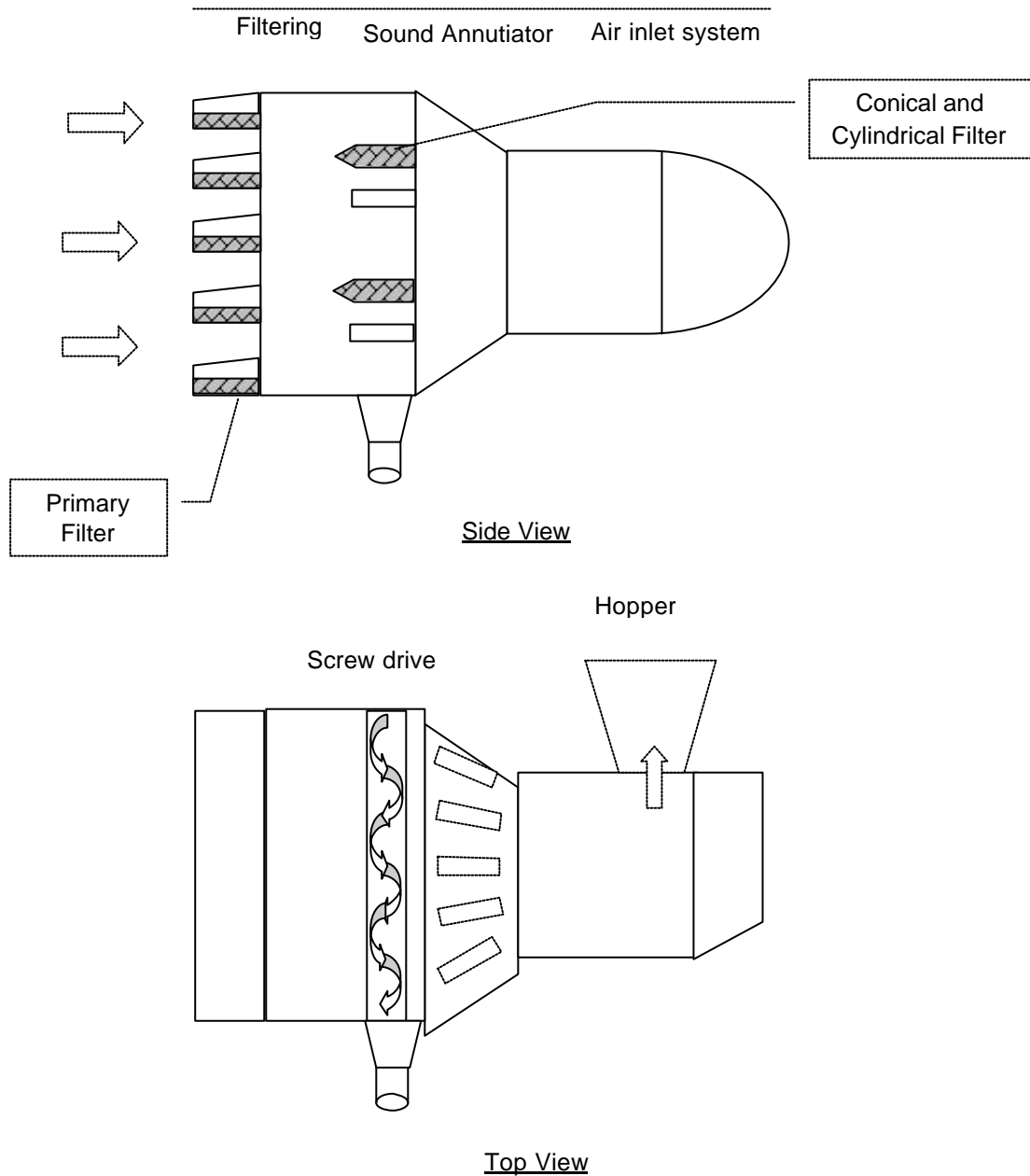
It is a double helical gear which reduces the turbine speed from 4902 rpm to 3000 rpm. It resides between generator and compressor-turbine. It consists of three gears due to which the rotation of the shafts is in the same direction.

### Specification :

Main reduction gear			
double helical gear			
Pinion	Gear		
No. of Revolutions	4902.4 rpm	3000rpm	
No of teeth	41	67	
Pitch dia.	455.56mm	744.44mm	
Reduction ratio	0.612		

# Air Filter

## Intake Air System of Open Cycle G/T Power Plant



The Filtering system was installed by :

Donaldson Company Inc. USA

Serial 7630, Model OSM, 38930-01, Manufactured : Feb 95

## Importance of Filtering

- To reduce pitting of compressor and turbine blades from entering coarse particles.
- To prevent the entry of moisture.

## COMPRESSOR/ COMBUSTOR SECTION

The combustion cycle, to remain efficient, requires large quantities of air which is derived from an axial flow compressor. The compressor produce a high compression ratio while maintaining the added advantages of being compact and presenting a relatively small frontal area. The air is confined to the space between the rotating stages and the diaphragms, where it is compressed by alternate rotating and stationary airfoil-shaped blades.

The combustor section, which contains the combustor baskets, is designed to burn a mixture of fuel and compressed air, then deliver the resulting gases to the turbine section. The igniters housed in the upstream end of the combustor basket, must add sufficient heat energy to the fuel/air mixture to ignite it and accelerate their mass enough to produce the desired power for the turbine. No burning should occur after the gases leave the basket outlet, which means that complete combustion must take place within the combustor basket. The gases must have satisfactory temperature distribution and acceptable maximum temperature distribution and acceptable maximum temperature as they enter the turbine section.

The compressor/combustor cylinder is fabricated in halves from steel castings and plate and joined at the horizontal center line for simplify of assembly, inspection, and maintenance.

## Compressor

Air in the compressor flow in the axial direction through a series of rotating blades and stationary vanes which are concentric with the axial of rotation. The flow path of an axial compressor decreases in cross-sectional area in the direction of flow. The incoming air passes through a set of inlet guide vanes which sets the initial flow angle for the first rotating stage. As the air passed through the various stages of compression, the pressure, temperature and flow increases until it reaches its maximum levels at the exit of the compressor. From the compressor exit it is expelled into the combustor cavity.

The compressor/combustor cylinder forms the outer casing of the subject section. The entire compressor casing is divided into two sections: 1) the forward section, which is actually part of the inlet casing, contains the inlet guide vanes, and the first and second stage diaphragms; 2) the aft section, which is part of the compressor/combustor section, contains the remaining diaphragms. The cylinder also incorporates the sixth to eleventh stage bleed air manifolds and accommodates the combustion chamber.

## Compressor diaphragms

The chrome steel stationary vanes are rolled and twisted airfoil sections welded into inner and outer shroud rings to form diaphragms which are machined to fit into grooves in the compressor cylinder cover at the horizontal joint. Sealing between stages is accomplished by seal strips attached to the inner diameter of the inner shroud rings. Corresponding seal lands are machined on the compressor discs. The stationary blade diaphragms are removable with the rotor in place so that all blading may inspected without removing the rotating elements.

## Combustor

The combustor section consists of combustor baskets, transition pieces, fuel nozzles, ignition cross-flame tube housing with flame detectors and torque tube seals. This section is designed to burn a mixture of fuel and compressed air, and deliver the resultant hot gases to the turbine section.

The MW-251 gas turbine employs an arrangement that takes individual baskets and places them side by side in an annular chamber. The chamber in which these baskets are enclosed forms a relatively low velocity plenum into which compressor discharge air flows. There are eight combustor basket assemblies, each being numbered clockwise from one through eight beginning at the top and looking in the direction of flow. Combustion gases from each combustor basket are directed to the first row turbine vanes by means of a transition piece. The connection of each combustor basket to its transition piece is made by means of a flanged sleeve which permits unhindered thermal expansion. The flanged part of the transition is fixed to the combustor cylinder by a bolted steel plate, the down stream end of the combustor basket is supported by the inner and outer peripheries of the sleeve. The upstream end of the combustor baskets by means of nozzles which are accessible for easy removal at the compressor end of the combustor shell. Ignition of the fuel is initiated by means of igniters located at the upstream end of numbers three and four combustor baskets.

Cross-flame tube between all baskets except seven and eight serve to propagate the flame from fired to unfired baskets until flame has reached the last basket on each side position seven and eight.

No cross-flame tube exists between seven and eight. This is to ensure that all baskets between igniters and each end are ignited. Ultra-violet (UV) flame detectors monitor flame in baskets seven and eight. Loss of flame causes a shutdown.

## Combustor Basket

The structure of the combustor basket is relatively small in diameter and it is made of cold rolled nickel base chromium alloy. The combustor has an inherent resistance to buckling when subjected to high pressure at operating temperatures. The upstream end of the combustor basket consists of several cylindrical sleeves arranged in such a manner that each section is spaced from the adjoining section by means of a corrugated cylinder so as to form a slotted annular opening between each section. These slots admit the relatively cool compressed air, from the axial compressor, in a longitudinal direction so as to form a sheath of air around the inner periphery of the combustor basket. This compressed air acts to protect the combustor walls. The combustor basket walls contain several rows of holes which admit air in a radial pattern to form a turbulent mixture of gases in the basket. The holes in the upstream section is used for introducing combustion or primary air while the holes in the last section are for the admission of diluent or secondary air. This secondary air serves to reduce the temperature of the basket terminates in a conical dome which is bolted to the cover plate. The nozzle housing and swirl plate assembly injects a cone spray of air/fuel mixture into each combustor basket. Each cover plate provides access to a manhole and entrance to the combustor section.

## Transition Pieces

Eight transition pieces direct the hot gases from the circular end of each separate combustor basket into a segmental inlet opening leading to the first row turbine vanes. The upstream end of the transition pieces fit over the downstream end of the sleeve. The transition pieces are tilted to the blade ring to maintain alignment and clearances as specified in the assembly instructions.

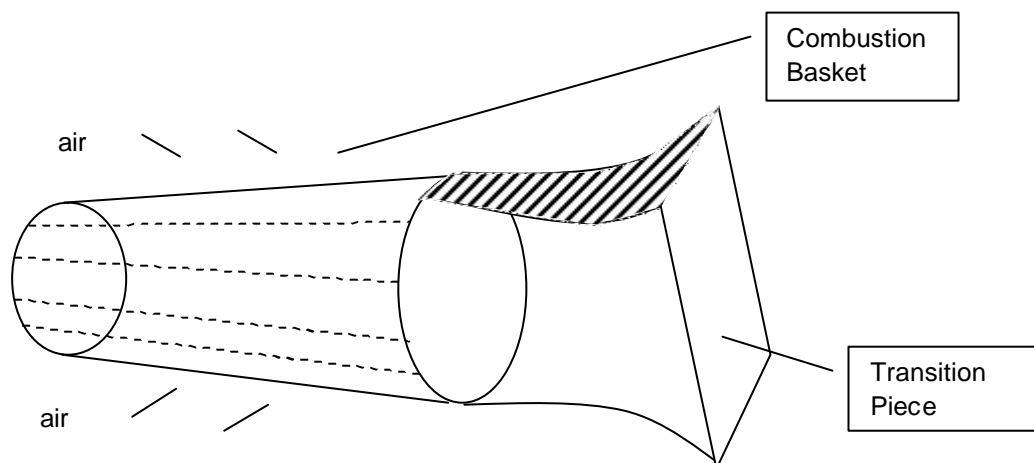


Figure : Combustor Basket and Transition Piece

## Igniters

Combustion of the fuel/air mixture is initiated by spark plug igniters located in the combustor some where fuel and air proportions are suitable during light off conditions. Two of the combustors are fitted with a tube serving as an entry to the dome for the spark plug. Each igniter, assembled into the combustor coverplate, consists of a spark plug mounted in a spring loaded piston. The spark plug during start-up is held in its inner most position by the piston spring thereby placing the electrode in the most ideal location for igniting the fuel/air mixture. It is supplied with high voltage direct current from an ignition transformer which has an inbuilt rectifier through a shielded cable and will continually discharge high voltage for a pre-determined time. At this pre-determined set point the igniters are deenergized whether ignition is completed or not. After ignition occurs, the combustor pressure on the piston becomes sufficient to compress the spring and move the spark plug to its outmost position, thus removing the electrodes from the combustion area and protecting them from burning.

## Cross Flame Tubes

To assure positive firing in all combustors, interconnecting tubes are located on the upstream end of the baskets. When one combustor lights, the pressure difference between a fired and unfired combustor is sufficient to carry transient flame through the interconnecting tube to immediately fire an unfired combustor. The propagation of flame to all combustors is virtually instantaneous. The cross flame tubes are held to each combustor flange by a V-shaped coupling. No special tool is required for assembly and disassembly of the cross flame tubes.

## Flame Detector

The four ultra-violet flame scanners mounted on two combustor cover plates are designed to give a high speed response to a flame \out condition in the combustor basket, thus giving maximum protection during such an occurrence. The lenses are kept clean by a difference of air pressure, which is drawn through openings in the scanner tube.

## Torque Tubes

Filtered cooling air is supplied to the torque tube seal housing by means of a pipe connected to the turbine cylinder section. The cooling air filter bleed piping is brought back into the cycle by piping in the torque tube cylinder on the compressor side of the torque tube seals. The cooling air is employed to cool the first stage turbine. A pair of thermocouples is used to monitor the air in each of the two zones.

## Fuel Nozzles

The gas fuel nozzle consists of an annular flow passage which distributes gaseous fuel to accurately machined orifice jets and injects the gas into the upstream end of each combustor basket. The gas fuel nozzle consists of nozzle holder, which includes the gas fuel connection, and nozzle welded as a unit.

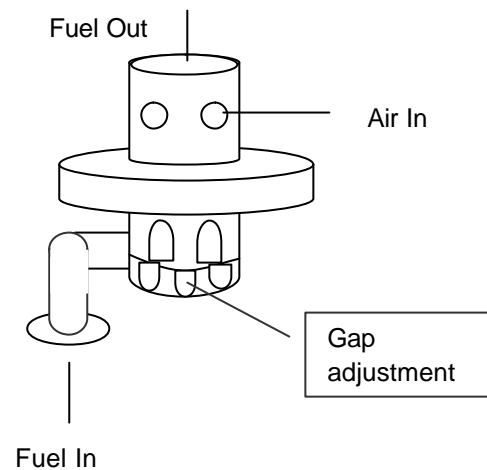


Figure : Fuel Nozzle

## TURBINE SECTION

The turbine section extracts kinetic energy from the high temperature gases discharged from the combustion section, converting it into useful output plus power to drive the compressor and accessories.

### Casing

For simplicity of assembly, inspection and maintenance, the turbine cylinder is made in halves joined at the horizontal center line forming a base and cover. The cylinder, fabricated from carbon steel plated, provides a housing for the turbine vanes. The structural shape of the cylinder and method of support is especially designed to permit free expansion and contraction in response to temperature changes, while minimizing the possibility of distortion and misalignment. The exhaust cylinder is secured to the outlet end of the turbine section cylinder where it collects the exhaust gases and directs them through a flanged, rectangular outlet opening.

### Turbine Vanes and Blade Ring

The transition pieces, through which the gases pass from the combustor baskets, are located upstream of the first stage turbine vanes. The turbine vanes are cast in segments, integral with the inner and outer shroud, from a high heat resistant alloy. These vane segments, which direct the flow of gas through the turbine section, are held in position by pinning the outer shroud to the blade ring with orifice pins. Small gaps between the segments allow for differential expansion between the segments and blade ring during temperature changes.

The blade ring made in halves, are secured to the turbine cylinder by keys and angular torque pins. Enclosing the blade ring is an air chamber into which cooled air is continuously piped. This cooled air, that has been extracted from the combustor shell, is passed through an external heat exchanger and filter before being introduced into the air chamber.

The first stage vanes are cooled by air passing through spanwise holes within the vane wall. The spanwise holes terminate in a cavity below the vanes from where air is channeled into the vane core and exits by slots in the trailing edge of each vane.

The second stage vanes are cooled using an airfoil shaped insert that fits closely to the vane cavity. Cooling air exits through small holes in the insert to impinge on the vane walls at the vane leading edge as well as other selected areas around the vane. This air flows in the narrow passages between the insert and the vane walls, and exits through holes in the vane near the trailing edge.

Also, cooling air flows through the holes in the end of the insert to the upstream side of the sealing structure.

The third stage vanes, unlike the first and second, does not require cooling. But within the core of these vanes is a tube insert to channel cooling air to the upstream side of the sealing structure.

Leakage past each seal area is reduced to a minimum by a sealing structure consisting of a seal and support ring radially keyed to the vane segments. The upstream cooling air flow 1) supplies the demand of the seals, thereby keeping the disc cavity at the proper environment temperature level and preventing the upstream hot gases from entering the seal area, 2) maintains the seal rings at an optimum operating temperature. Two vane segments, in each of stage and three disc cavities, are equipped with thermocouples to continuously monitor this temperature.

## EXHAUST SECTION

After passing through the turbine section, the combustion gases and cooling air enter the exhaust cylinder section. It is here that the temperature and pressure of the gases, that have been reduced in the turbine section, are discharged into the exhaust manifold and eventually into the atmosphere.

### Casing

The exhaust cylinder is a fabrication consisting of a bearing housing, inner and outer exhaust diffuser cone, and an outer casing ,all joined together by means of a strut system.

The strut system, consists of six bearing struts equally spaced around the circumference, but disposed tangentially with respect to the bearing housing. These struts run from the bearing housing to the other casing. In the hot gas section of the exhaust diffuser, the bearing struts are shielded inside another set of hollow struts which also serves as supports for the exhaust diffuser cones. Thus the bearing struts are protected from the hot exhaust gas by envelopes of cooler air around them, resulting in a strut system that is less sensitive to transient temperatures. The system

provides a low stress rigid support which is capable of holding the bearing on center for all variations of load and temperature.

## Bearing

The exhaust end of the spindle is supported by a journal bearing, housed in the exhaust casing. It is similar to the inlet journal bearing . Therefore refer to the inlet casing section for a complete description of the journal bearing.

## Support

The exhaust end of the turbine is mounted on its base by a relatively flexible trunnion support located on each side of the exhaust cylinder section. The support is shimmed, as required to align the gas turbine, and bolted to the bed-plate. The rigid support, located at the inlet end, fixes this point while the trunnion support allows for thermal growth of the gas turbine without incurring undue misalignment with the driven equipment. Trunnion bearing joints are provided at the point of connection between the trunnion supports and exhaust casing. This allows the support to rotate slightly as the unit “ grows” in an aft direction due to thermal expansion. Oil is pumped through internal passages in the support to it, thereby minimizing thermal growth in the vertical direction.

# CHAPTER 4

## Control Unit of the Power Plant

## Control Unit

The Control Unit is the place from where the total plant can be monitored and controlled. There are indicators for individual plants for all the desired operations. Each operation of the plant can be done full automatically. Also there are provisions for manual controls in some individual operations.

Round the clock there are engineers in the control room to ensure that everything runs in order. If anything goes wrong they can take immediate steps.

The control can be done from the centralized control center. Also each instrument can be controlled from the spots with individual metering and gauges.

## VIBRATION MONITORING SOFTWARE

The Control Unit of the Haripur Power Plant is very modern. For unit 2 there is fully vibration monitoring system integrated with computerized software. Also the other two units are to be computerized very soon. The software installed is developed by Bently Nevada. It shows and monitors bearing vibrations at different points of the plant.

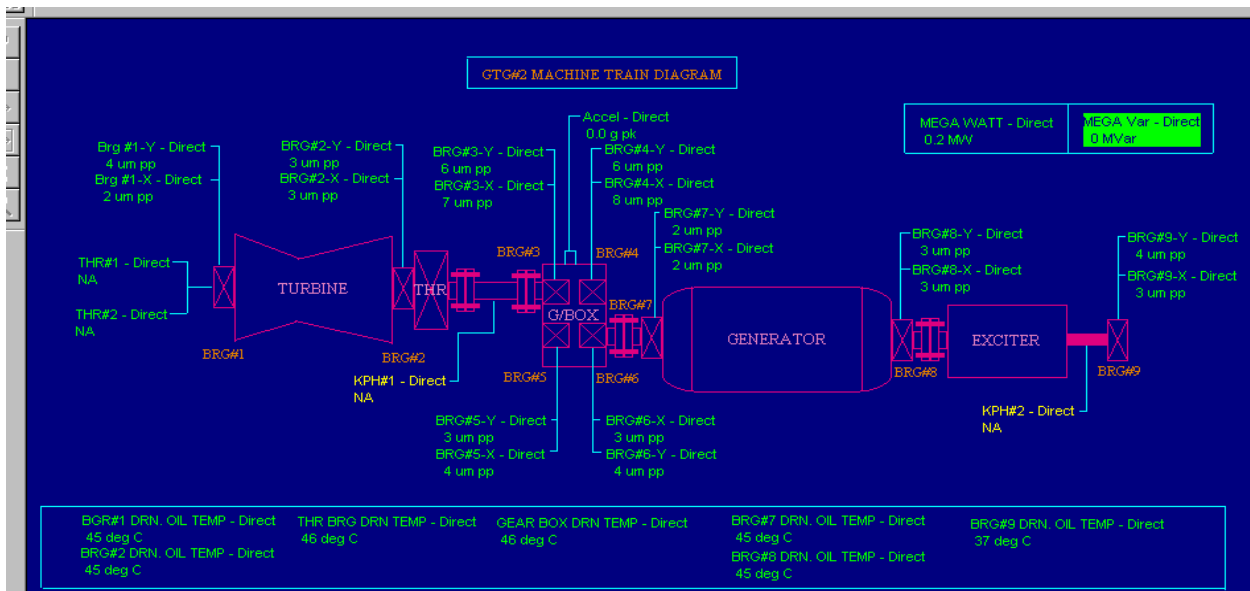


Figure : Vibration Monitoring Software by BENTLY NEVADA

## Control and Protection system

In Haripur Power Plant the following instruments are used for control and protection system:

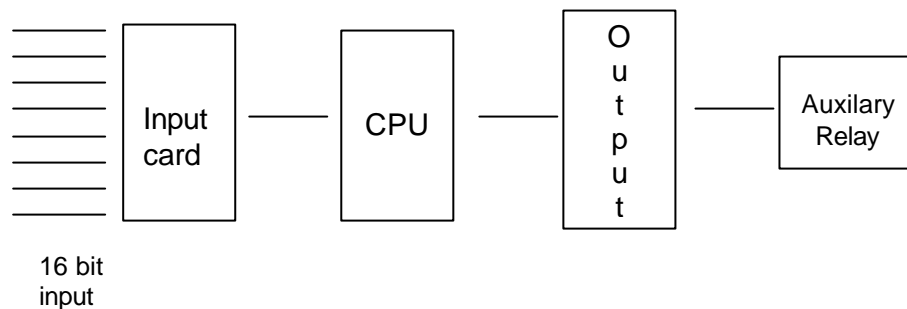
### A. Control System

1. Programmable logic control unit

Brand name

Mitsubishi Programmable Logic Control Unit – 300

(MELPLAC-300)



*Figure : Schematic Diagram*

### Main Control Parameters

- P.V. (Process Parameter)
- S.P. (Set Point)
- C.O. (Control Output)

### Control Logic

When,  $P.V. - S.P. = 0$ , then  $C.O. = 0$

$P.V. - S.P. = \text{Max}^m$ , then  $C.O. = 100\%$

The range of  $C.O. = 4 - 20 \text{ mA}$ .

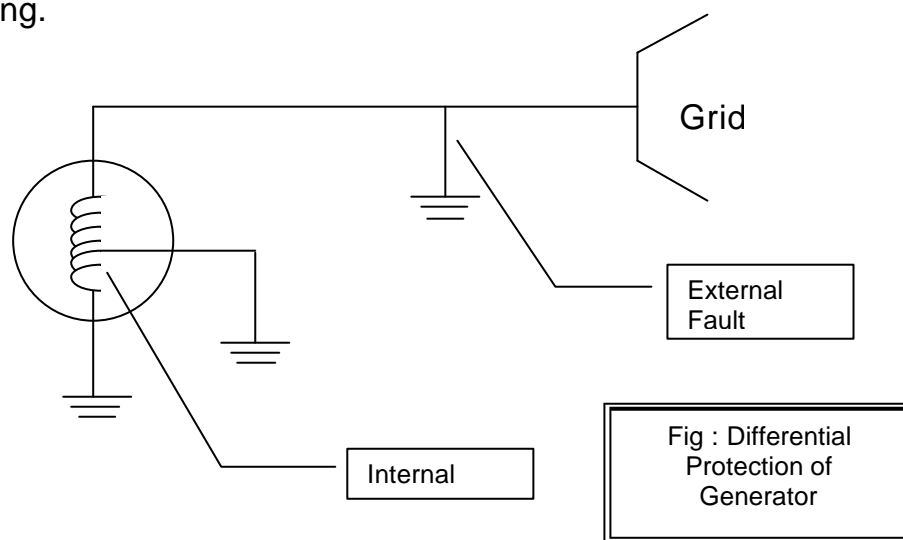
## B. Protection System

In the generator the following protection conditions are encountered

- ❖ Over current protection
- ❖ Over Voltage protection
- ❖ Under Frequency protection
- ❖ Over Frequency protection
- ❖ Differential protection Generator

### Differential protection of Generator

This sort of protection is required to overcome any sort of fault inside the generator. For example, if any part of the generator is earthen suddenly then this sort of protection is essential to keep the generator working.



### Over Current Protection

This situation is avoided by allowing the current through the transformer.

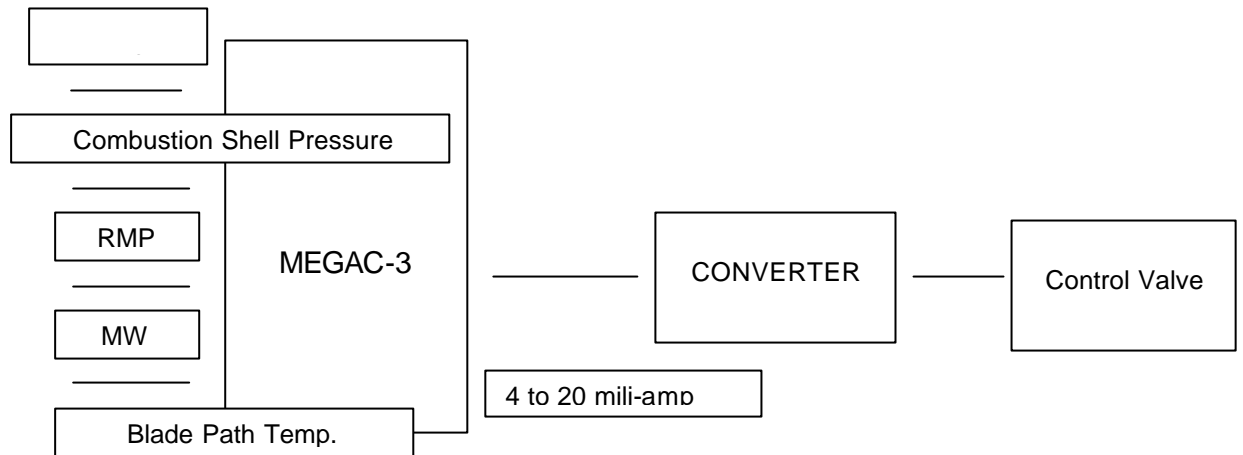
### Over Voltage Protection

To avoid this situation potential transformer is used.

## Gas Analog Controller

### Brand name

Mitsubishi Electronic Gas Analog Controller-3 (MEGAC -3)



Nowadays we use Microprocessor based control instead of previously used Relay Circuit. The main disadvantage of Relay was that it used Mechanical Contact which is subjected to wear and tear. The microprocessor based control system does not require any moving parts, so the chance of mechanical failure is omitted.

Transmitted output in a control mechanics is from 4 to 20 mili-amp.

**Conventional Relay:**

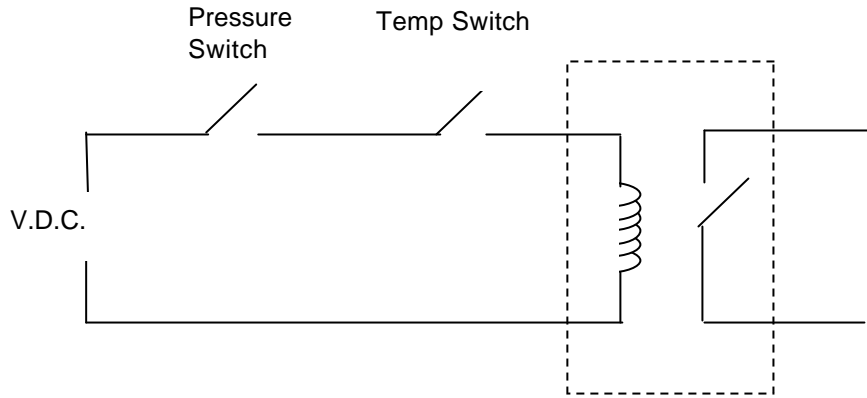


Fig: Conventional Relay Circuit (Previously Used)

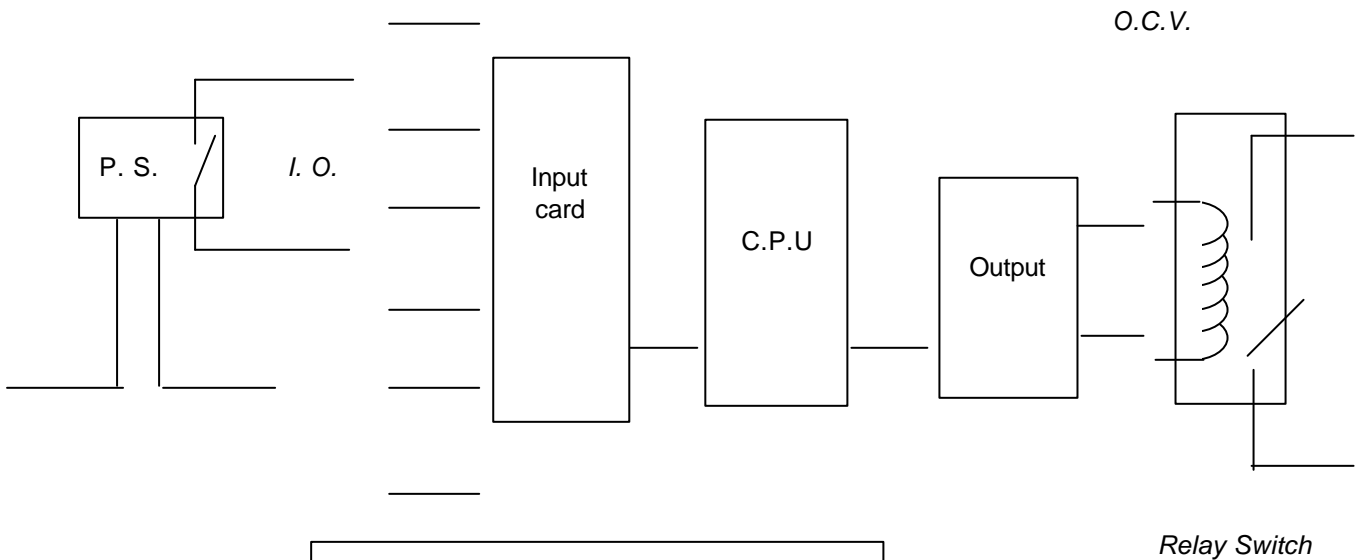


Fig: PLC - Programmable Logic Control

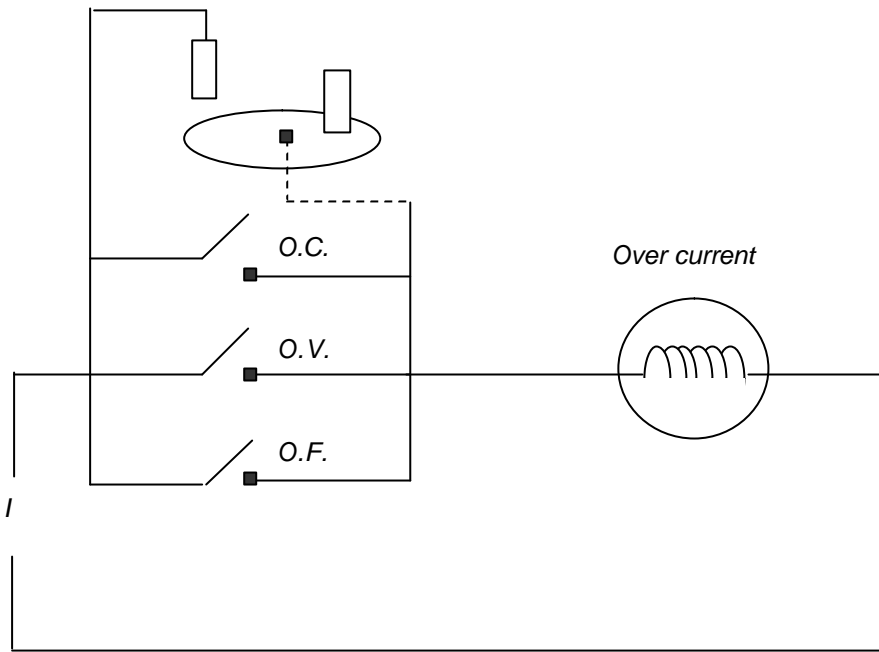


Fig: Protection Logic System

# CHAPTER 5

## The Auxiliary System

## Lubrication System

The Lubrication system is very important in the power plant. Even when the plant is not generating power, the lubrication system works to ensure journal and shafts are lubricated. As huge temperature is generated in the plant, the lubrication system is very critical so that no part is damaged. The lubrication system not only lubricates the part but also take out extreme temperature from the remote parts of the plant.

The lube oils are fed with lube-oil pump connected with lube-oil motor. Generally it runs on A.C. power. So there is a D.C. motor for emergency lube oil feeding as a backup.

### Lube oil system specification :

#### Lube Oil reservoir

Capacity 11m<sup>3</sup>

Initial Fill Approx. 12.5 m<sup>3</sup>

Lube oil heater AC 400 V, 5.5 kW Sheathed heater x 2

#### Main Lube Oil Pump

#### Pump :

Type : Horizontal, positive displacement, screw type pump with three spindles

Model : GH-RIT-949

Design Capacity : 1960 l/min

Discharge Pressure : 7.0 kg/cm<sup>2</sup>g

Suction Head : -0.5 m

Speed : 2307 rpm

Liquid to be pumped : Lube oil

Driver : Auxiliary Gear

Safety Valve Setting : 7.5 kg/cm<sup>2</sup>g

## Auxiliary Lube Oil Pump :

### Pump :

Type : Vertical, single-suction, single stage, centrifugal type.

Model : CSS-150

Design Capacity : 2000 l/min

Discharge Pressure : 7.0 kg/cm<sup>2</sup>g

Speed (Synchro.) : 3000 rpm

Liquid to be pumped : Lube Oil

### Motor :

Capacity : 55kW

No. of Poles : 2

Voltage : AC 400V

Frequency : 50 Hz

Enclosure : T.E.F.C.

Insulation Class : F

Rating : Continuous

## Emergency Lube oil pump

### Pump :

Type : Vertical, single-suction, single-stage, centrifugal types.

Model : CSS-100

Design Capacity : 1100 l/min

Discharge Pressure : 1.2 kg.cm<sup>2</sup>g

Speed (Synchro.) : 1500 rpm

Liquid to be pumped : Lube oil

### Motor

Capacity	5.5 kW
Speed	1500 rpm
Voltage	DC 125V
Enclosure	T.E.F.C.
Insulation Class	F
Rating	Continuous

## Lube Oil Cooler

### Design Condition

Fluid	Lube Oil	Air
Flow Rate	2000 /min	52.9 m <sup>3</sup> /s
Inlet temp.	76.4°C	45°C
Outlet temp.	60°C	62.3°C
Heat Exchanger	816,000 kcal/Hr.	

### Heat Exchanger

Type	Copper tubes with fins
Model	EKV 5700/1596
Quantity	100% duty x 2 units
No. of passes	2

### Fan

Type	Axial flow type
Quantity	2 sets/ 1 unit

### Fan Motor

Capacity	11 kW (each one)
Quantity	2 sets/ 1 unit
No. of poles	10
Voltage	AC 400 V
Frequency	50 Hz.
Enclosure	T.E.F.C
Insulation Class	F
Rating	Continuous

### (6) Lube Oil Filter

Type	Duplex, mesh wire type
Quantity	1
Deg. of Filtration	200 mesh

### (7) Lube Oil Filter (Emergency Lube Oil Line)

Type	Simplex, mesh wire type
Quantity	1
Deg of Filtration	100 mesh

## Air Cooling System

There is a cooling system to cool down the bearing and turbine blades. The hot air is taken out from the plant, cooled with the help of two motor connected induced draft fans. The coolant used here is natural air.

## GAS Intake

In the plant the main fuel is natural gas. In order to take in the gas, there is a separate mechanism. First the gas is fed from the TITAS Gas Substation. Here the gas pressure is high so it is reduced in the Pressure Reducing Station. From there the gas is fed into the combustion chamber through another gas pressure monitoring mechanism.

## Emergency System

There are some emergency system provided in the plant in order to meet emergency situation. Basically the emergency systems ensures the plant to be operated at safe conditions and thus electricity is generated. There are some auxiliary systems which ensures that the plant works well and emergency system also make sure of that.

The emergency system consists of:

**a) *Emergency Diesel Generator***

**b) *DC Lube Oil Pump***

Dc Lube Oil Pump is an emergency pump which works on Direct Current in case Alternating Current supply fail to the main Lube Oil Pump. As the moving shafts and other parts require continuous supply of Lubrication oil, the role of Lube Oil Pump is very important. Even when the plant does not generate power, the shaft is on turning at very low rpm. Even at idle time the lubrication oil pump need to be operating. The operator can not afford to stop the pump even for a small fraction of time. The Lube oil pump at the same time lubricates and also keeps the temperature of the machine parts low.

### Specification of Emergency Lube Oil Pump

#### **Pump**

Type	: Vertical, single-suction, single-stage, centrifugal types.
Model	: CSS-100
Design Capacity	: 1100 l/min
Discharge Pressure	: 1.2 kg.cm <sup>2</sup> g
Speed (Synchro.)	: 1500 rpm
Liquid to be pumped	: Lube oil

#### **Motor**

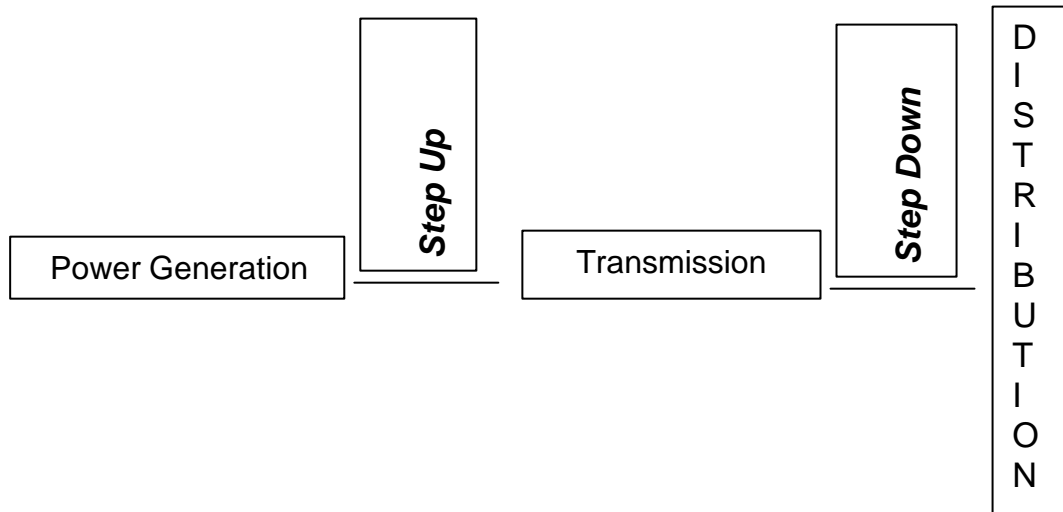
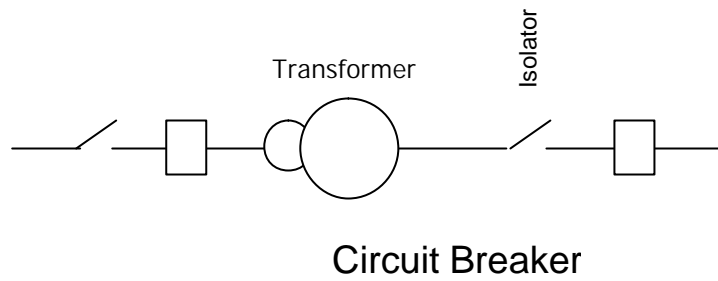
Capacity	: 5.5 kW
Speed	: 1500 rpm
Voltage	: DC 125V
Enclosure	: T.E.F.C.
Insulation Class	: F
Rating	: Continuous

# CHAPTER 6

## Grid & Transmission

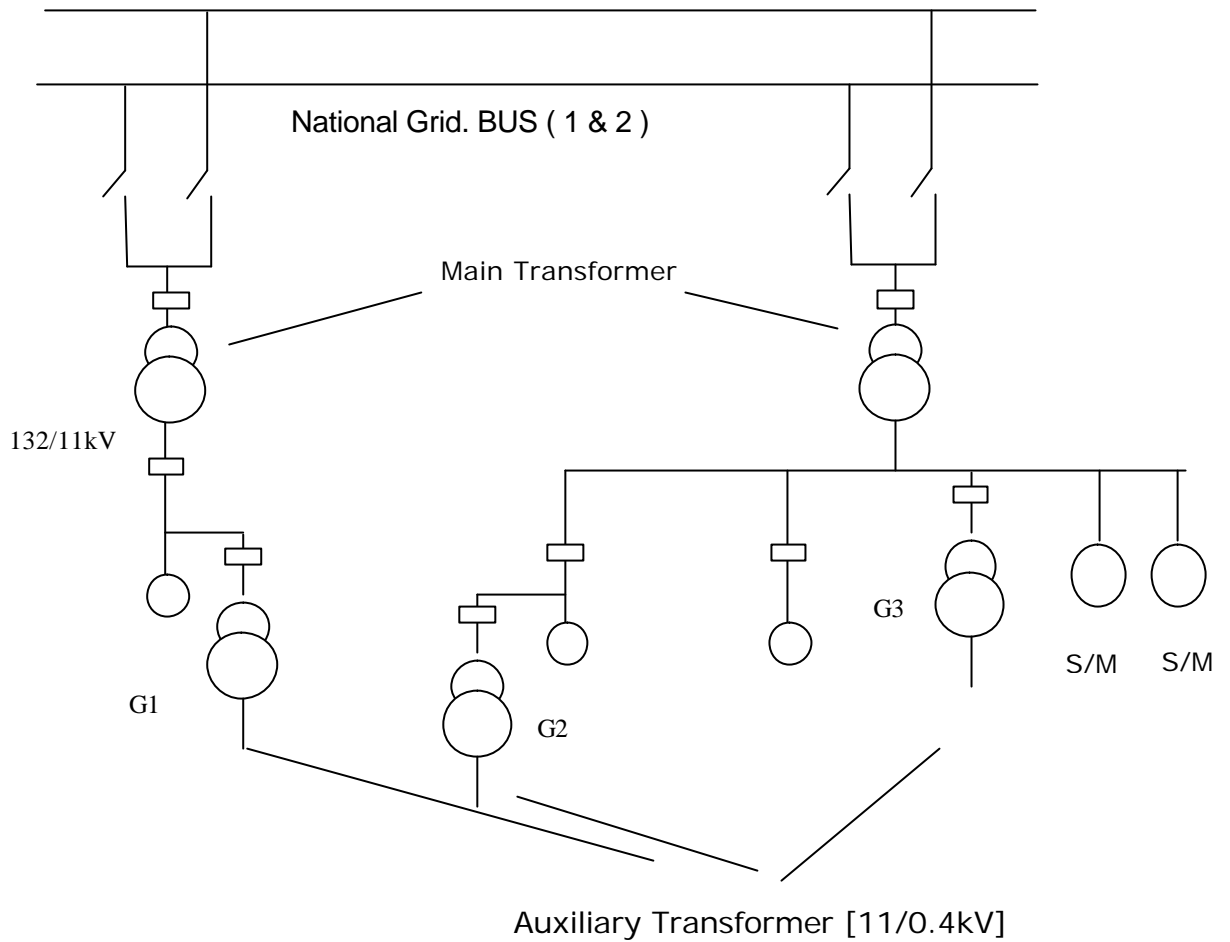
# How Power Distribution Grids Work

Basic mechanism of transmission:



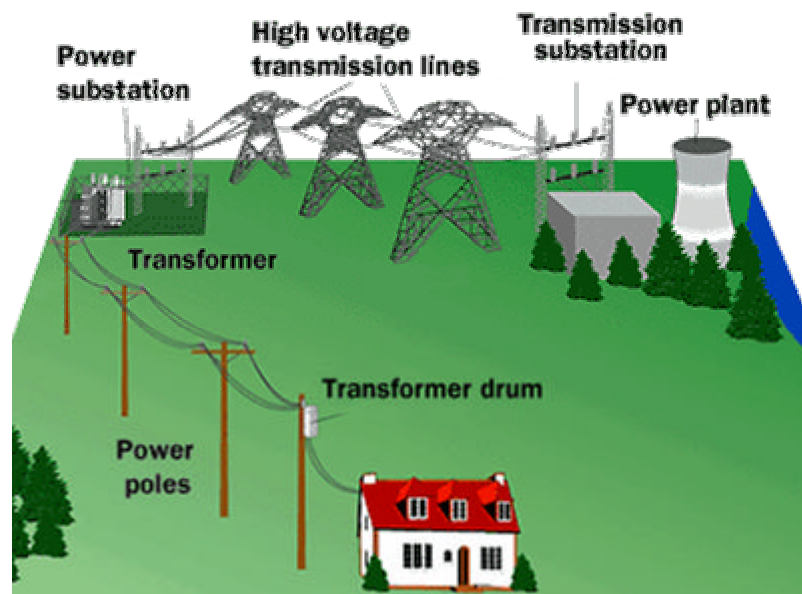
Simplified Distribution Flowchart

## The Way HPS Connects to the National Grid



## Grid Distribution Flowchart

Power travels from the power plant to our house through an amazing system called the **power distribution grid**.



## The Distribution Grid

For power to be useful in a home or business, it comes off the transmission grid and is **stepped-down** to the distribution grid. This may happen in several phases. The place where the conversion from "transmission" to "distribution" occurs is in a **power substation**. A power substation typically does two or three things:

- It has transformers that step transmission voltages (in the tens or hundreds of thousands of volts range) down to distribution voltages (typically less than 10,000 volts).
- It has a "bus" that can split the distribution power off in multiple directions.
- It often has circuit breakers and switches so that the substation can be disconnected from the transmission grid or separate distribution lines can be disconnected from the substation when necessary.



**A typical small substation**

The box in the foreground is a large transformer. To its left (and out of the frame but shown in the next shot) are the incoming power from the transmission grid and a set of switches for the incoming power. Toward the right is a distribution bus plus three voltage regulators.



**The transmission lines entering the substation  
and passing through the switch tower**



**The switch tower and the main transformer**

Now the distribution bus comes into the picture.

## Distribution Bus

The power goes from the transformer to the distribution bus:



In this case, the bus distributes power to two separate sets of distribution lines at two different voltages. The smaller transformers attached to the bus are stepping the power down to standard line voltage (usually 132kV) for one set of lines, while power leaves in the other direction at the higher voltage of the main transformer. The power leaves this substation in two sets of three wires, each headed down the road in a different direction:



**The wires between these two poles are "guy wires" for support. They carry no current.**



In the typical scene pictured on the right, the three wires at the top of the poles are the three wires for the 3-phase power. The fourth wire lower on the poles is the ground wire. In some cases there will be additional wires, typically phone or cable TV lines riding on the same poles.

As mentioned above, this particular substation produces two different voltages. The wires at the higher voltage need to be stepped down again, which will often happen at another substation or in small transformers somewhere down the line. For example, you will often see a large green box (perhaps 6 feet/1.8 meters on a side) near the entrance to a subdivision. It is performing the step-down function for the subdivision.

## Regulator Bank

Regulator banks can also be located along the line, either underground or in the air. They regulate the voltage on the line to prevent undervoltage and overvoltage conditions.



**A typical regulator bank**

Up toward the top are three switches that allow this regulator bank to be disconnected for maintenance when necessary:

At this point, we have typical line voltage at something like 132000 volts running through the neighborhood on three wires (with a fourth ground wire lower on the pole):

## Taps

A house needs only one of the three phases, so typically three wires running down a main road, and **taps** for one or two of the phases running off on side streets. Pictured below is a 3-phase to 2-phase tap, with the two phases running off to the right:

Here is a 2-phase to 1-phase tap, with the single phase running out to the right:



## At the House

Finally we are down to the wire that brings power to your house! Past a typical house runs a set of poles with one phase of power (at **7,200 volts**) and a ground wire (although sometimes there will be two or three phases on the pole, depending on where the house is located in the distribution grid). At each house, there is a **transformer drum** attached to the pole, like this:

In many suburban neighborhoods, the distribution lines are **underground** and there are green transformer boxes at every house or two. Here is some detail on what is going on at the pole:

The transformer's job is to reduce the 132000 volts down to the **240 volts** that makes up normal household electrical service. Let's look at this pole one more time, from the bottom, to see what is going on:



There are two things to notice in this picture:

- There is a bare wire running down the pole. This is a grounding wire. Every utility pole on the planet has one. If you ever watch the power company install a new pole, the end of that bare wire is stapled in a coil to the base of the pole and therefore is in direct contact with the earth, running 6 to 10 feet (1.8 to 3 m) underground. It is a good, solid ground connection. If you examine a pole carefully, you will see that the ground wire running between poles (and often the guy wires) is attached to this direct connection to ground.
- There are two wires running out of the transformer and three wires running to the house. The two from the transformer are insulated, and the third one is bare. The bare wire is the ground wire. The two insulated wires each carry 120 volts, but they are 180 degrees out of phase so the difference between them is 240 volts. This arrangement allows a homeowner to use both 120-volt and 240-volt appliances. The transformer is wired in this sort of configuration:

The 240 volts enters our house through a typical **watt-hour meter** .The meter lets the power company charge you for putting up all of these wires.

## Fuses and Circuit Breakers

Fuses and circuit breakers are safety devices. Let's say that we did not have fuses or circuit breakers in your house and something "went wrong." What could possibly go wrong? Here are some examples:

- A fan motor burns out a bearing, seizes, overheats and melts, causing a direct connection between power and ground.
- A wire comes loose in a lamp and directly connects power to ground.
- A mouse chews through the insulation in a wire and directly connects power to ground.
- Someone accidentally vacuums up a lamp wire with the vacuum cleaner, cutting it in the process and directly connecting power to ground.
- A person is hanging a picture in the living room and the nail used for said picture happens to puncture a power line in the wall, directly connecting power to ground.

When a 120-volt power line connects directly to ground, its goal in life is to pump as much electricity as possible through the connection. Either the device or the wire in the wall will burst into flames in such a situation. (The wire in the wall will get hot like the element in an electric oven gets hot, which is to say very hot!). A **fuse** is a simple device designed to overheat and burn out extremely rapidly in such a situation. In a fuse, a thin piece of foil or wire quickly vaporizes when an overload of current runs through it. This kills the power to the wire immediately, protecting it from overheating. Fuses must be replaced each time they burn out. A **circuit breaker** uses the heat from an overload to trip a switch, and circuit breakers are therefore re-settable.

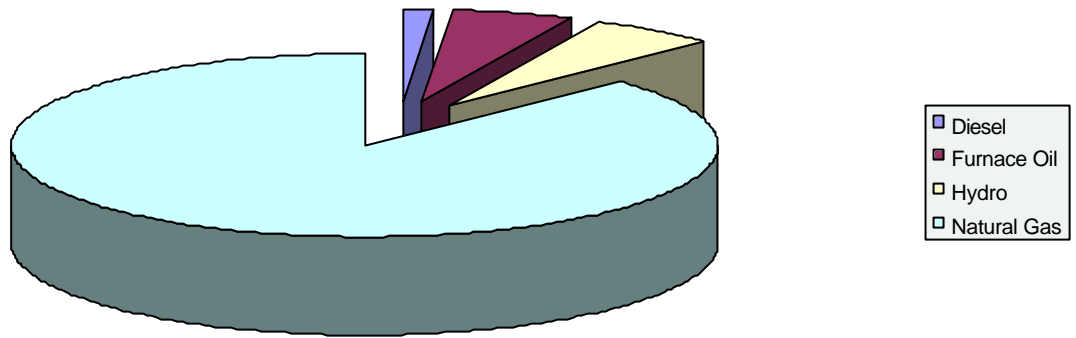
The power then enters the home through a typical **circuit breaker panel**. Inside the circuit breaker panel there is two primary wires from the transformer entering the **main circuit breaker** at the top. The main breaker lets one to cut power to the entire panel when necessary. Within this overall setup, all of the wires for the different outlets and lights in the house each have a separate circuit breaker or fuse:

If the circuit breaker is on, then power flows through the wire in the wall and makes its way eventually to its final destination, the outlet.

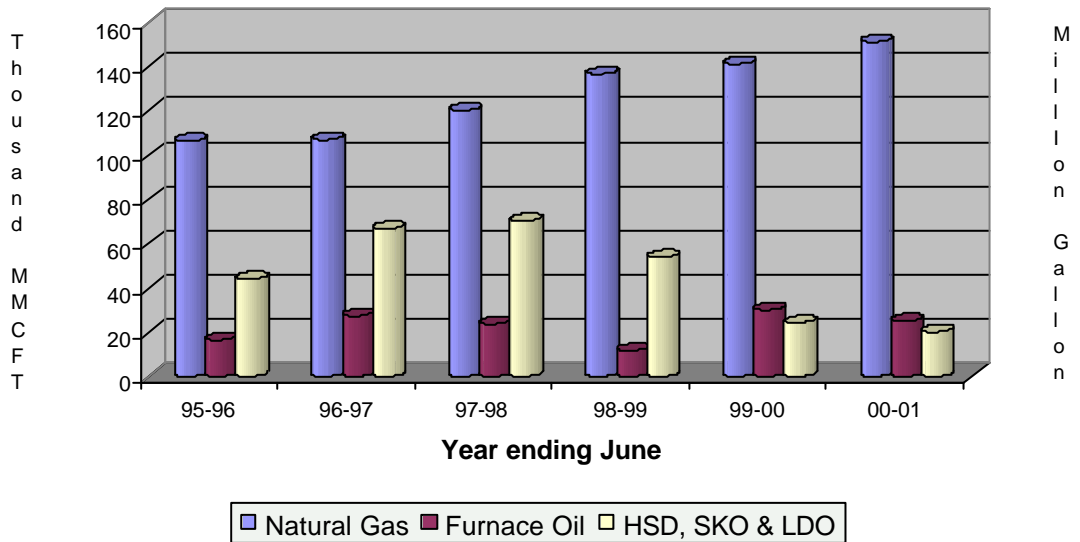
# CHAPTER 7

## Tables and Figures

## Generation Pattern of 2001

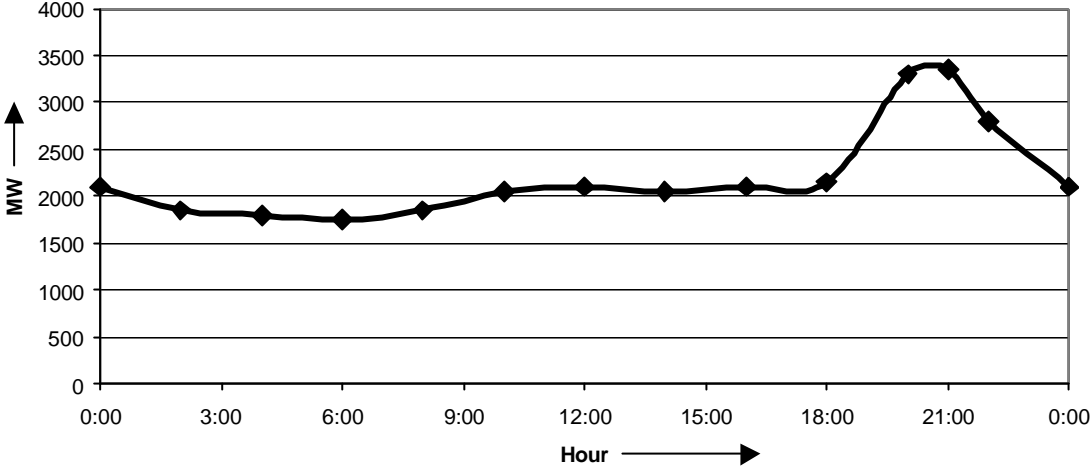


## BPDB Fuel Consumption



# Daily Load Curve

7 th June, 2001



**Table : Average Billing Rate**

Fiscal Year	Average Billing Rate	Percentage Increase over the preceding year
95-96	1.87	0
96-97	1.96	4.81
97-98	2.07	5.36
98-99	2.08	0.76
99-00	2.2	5.73
00-01	2.25	2.27

# APPENDIX

Reference

## Reference

- BPDB Annual Report 2000-2001
- Haripur Power Station Extension Engineering Report
- Mitsubishi Technical Manual
- Thermal Engineering – R. S. Khurmi
- Heat Engineering – V. P. Vasandani
- Power Plant Engineering – G. R. Nagpal
- cvl qvi c:~U BwÄwloqwi s - wekpv\_ gRg` vi

## Internet Links

- ❖ <http://www.howstuffworks.com>
- ❖ <http://www.qsl.net>
- ❖ <http://www.transmission-crafters.com/prod.htm>
- ❖ <http://www.wvic.com/default.htm>
- ❖ <http://www.converter.cc/index.html>

# APPENDIX

## Images