- Introduction

The power system is a network which consists generation, distribution and transmission system. It uses the form of energy (like coal and diesel) and converts it into electrical energy. The power system includes the devices connected to the system like the synchronous generator, motor, transformer, circuit breaker, conductor, etc.

The power plant, transformer, transmission line, substations, distribution line, and distribution transformer are the six main components of the power system. The power plant generates the power which is step-up or step-down through the transformer for transmission.

The transmission line transfers the power to the various substations. Through substation, the power is transferred to the distribution transformer which step-down the power to the appropriate value which is suitable for the consumers.

- Structure of Power System

The power system is the complex enterprise that may be subdivided into the following sub-systems. The subsystems of the power system are explained below in details.

- Generating Substation

In generating station the fuel (coal, water, nuclear energy, etc.) is converted into electrical energy. The electrical power is generated in the range of 11kV to 25kV, which is step-up for long distance transmission. The power plant of the generating substation is mainly classified into three types, i.e., thermal power plant, hydropower plant and nuclear power plant.

The generator and the transformer are the main components of the generating station. The generator converts the mechanical energy into electrical energy. The mechanical energy comes from the burning of coal, gas and nuclear fuel, gas turbines, or occasionally the internal combustion engine.

The transformer transfers the power with very high efficiency from one level to another. The power transfer from the secondary is approximately equal to the primary except for losses in the transformer. The step-up transformer will reduce losses in the line which makes the transmission of power over long distances.

- Transmission Substation

The transmission substation carries the overhead lines which transfer the generated electrical energy from generation to the distribution substations. It only supplies the large bulk of power to bulk power substations or very big consumers.

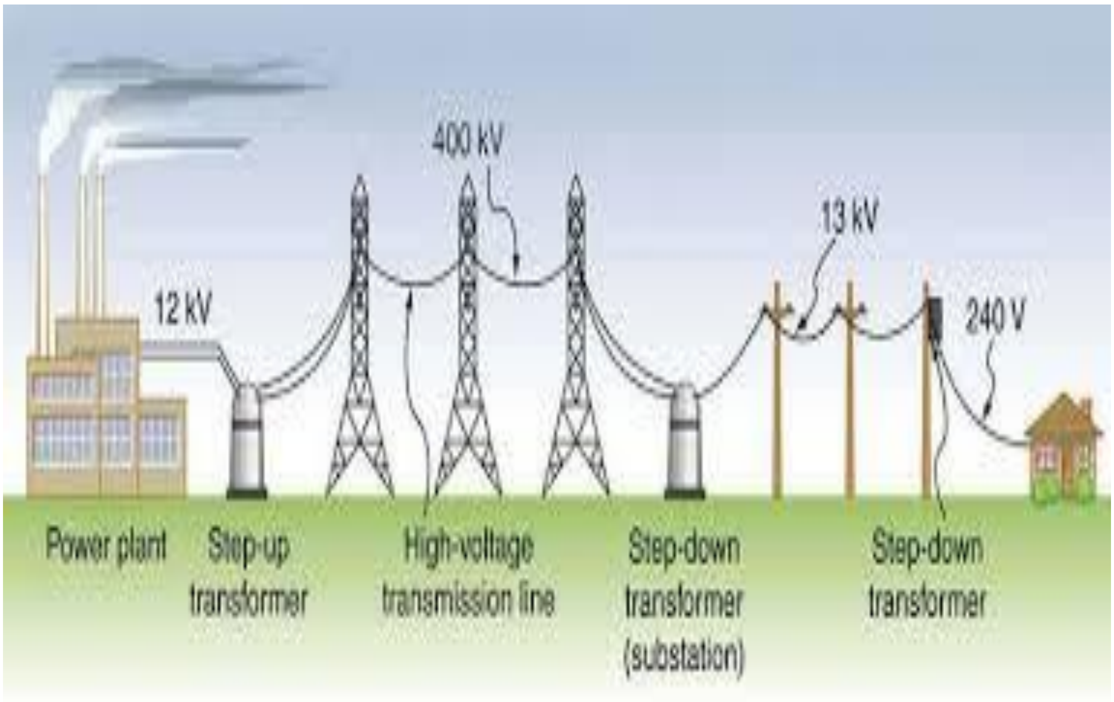


Fig 1-1 Structure of power system

- Distribution Substation

The component of an electrical power system connecting all the consumers in an area to the bulk power sources is called a distribution system. The bulk power stations are connected to the generating substations by transmission lines. They feed some substations which are usually situated at convenient points near the load centers. The substations distribute the power to the domestic, commercial and relatively small consumers. The consumers require large blocks of power which are usually supplied at sub-transmission or even transmission system.

- Power generating station

Power generating station (i.e. power plants) *is special plants* with a set of components that have the ability to generate *bulk electric power*.

A generating station essentially employs a prime mover coupled to an alternator for the production of electric power.

- The prime mover (*e.g.*, steam turbine, water turbine etc.) converts energy from some other form into mechanical energy.
- Alternator converts mechanical energy of the prime mover into electrical energy.

- The electrical energy produced by the generating station is transmitted and distributed with the help of conductors to various consumers.

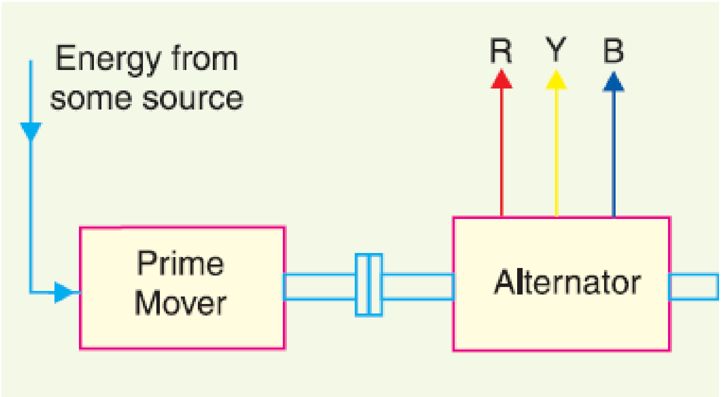


Fig.1-2 Diagram of A generating station

- Sources of electric energy

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. These sources of energy are:

(i) The Sun ***(ii)*** The Wind ***(iii)*** Water……(**Renewable energy)**
(*iv*) Fuels **(*v*)** Nuclear energy…**……..** **(Classical energy)**

Depending upon the form of energy converted into electrical energy, the generating stations are classified as under:

(i) Steam power stations
(ii) Hydroelectric power stations
(iii) Diesel power stations
(iv) Gas station
(v) Nuclear power stations
(vi) Wind power station
(vii) Solar cell (Photo voltage cell)

Types of generating stations:

1. **Steam Power Station (Thermal Station):** *A generating station which converts heat energy of coal combustion into electrical energy is known as a* **steam power station.**

A steam power station basically works on the Rankine cycle. Steam is produced in the boiler by utilizing the heat of coal combustion. The steam is then expanded in the prime mover (i.e., steam turbine) and is condensed in a condenser to be fed into

the boiler again. The steam turbine drives the alternator which converts mechanical energy of the turbine into electrical energy.
Although steam power station simply involves the conversion of heat of coal combustion into electrical energy, yet it embraces many arrangements for proper working and efficiency.
The schematic arrangement of a modern steam power station can be divided into the following stages for the sake of simplicity:
1. Coal and ash handling arrangement
2. Steam generating plant
3. Steam turbine
4. Alternator
5. Feed water
6. Cooling arrangement

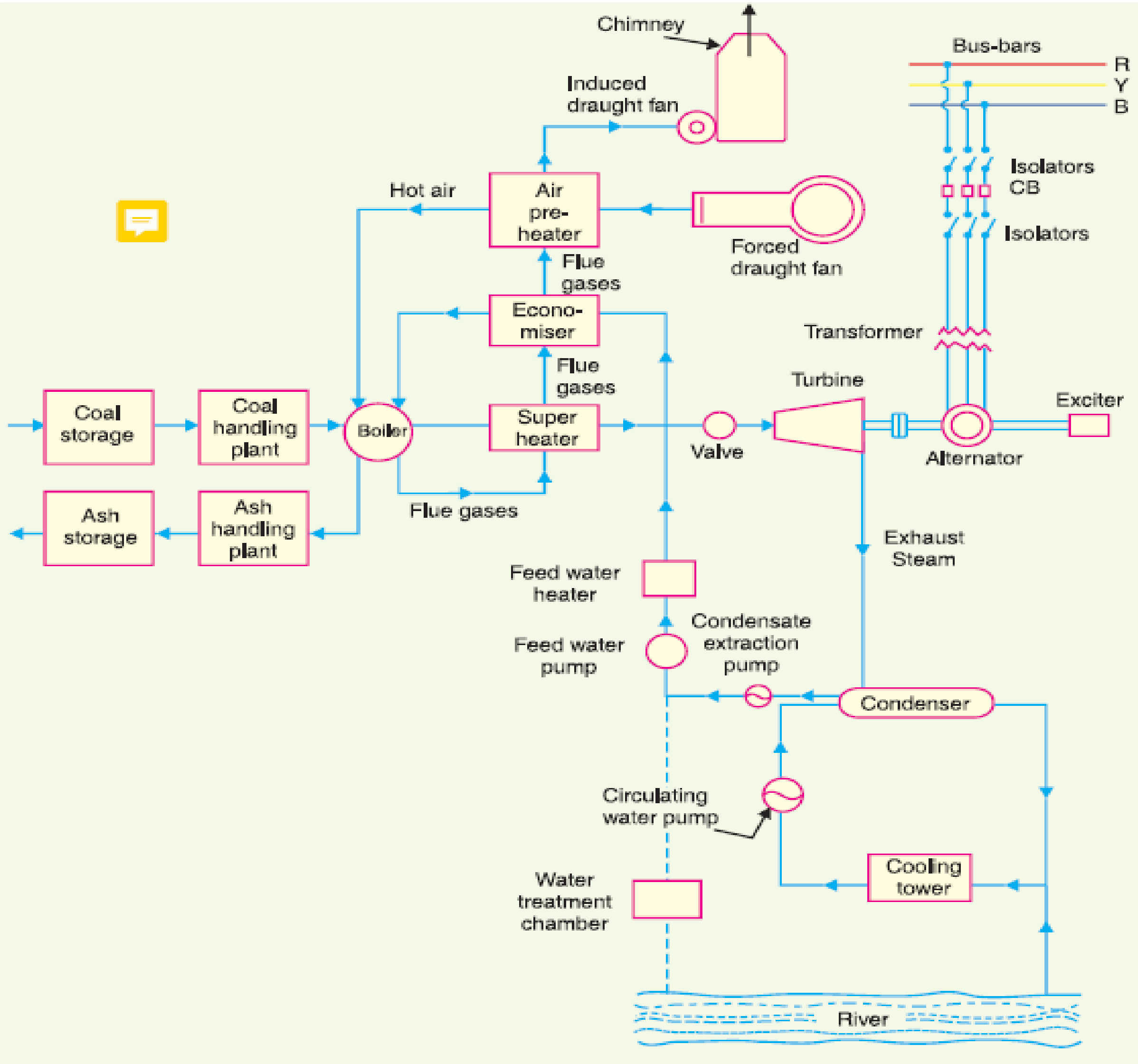


Fig. 1-3 Schematic arrangement of steam station

Efficiency of Steam Power Station

The overall efficiency of a steam power station is quite low (about 29%) due mainly to two reasons.

*__Firstly,__ a huge amount of heat is lost in the condenser.

*__Secondly__ heat losses occur at various stages of the plant.

(i) **Thermal efficiency.** The ratio of heat equivalent of mechanical energy transmitted to the turbine shaft to the heat of combustion of coal is known as thermal efficiency of steam power station.

$$\text{Thermal efficiency, } \eta_{thermal} = \frac{\text{Heat equivalent of mech. energy transmitted to turbine shaft}}{\text{Heat of coal combustion}}$$

(ii) Overall efficiency. The ratio of heat equivalent of electrical output to the heat of combustion of coal is known as overall efficiency of steam power station i.e. Overall efficiency,

The overall efficiency of a steam power station is about 29%. It may be seen that overall efficiency is less than the thermal efficiency. This is expected since some losses (about 1%) occur in the alternator. The following relation exists among the various efficiencies.

Overall efficiency = Thermal efficiency . Electrical efficiency

Example 2.5. *A 100 MW steam station uses coal of calorific value 6400 kcal/kg. Thermal efficiency of the station is 30% and electrical efficiency is 92%. Calculate the coal consumption per hour when the station is delivering its full rated output.*

Solution.

Overall efficiency of the power station is

$$\eta_{overall} = \eta_{thermal} \times \eta_{elect} = 0{\cdot}30 \times 0{\cdot}92 = 0{\cdot}276$$

$$\text{Units generated/hour} = (100 \times 10^3) \times 1 = 10^5 \text{ kWh}$$

$$\text{Heat produced/hour, } H = \frac{\text{Electrical output in heat units}}{\eta_{overall}}$$

$$= \frac{10^5 \times 860}{0{\cdot}276} = 311{\cdot}6 \times 10^6 \text{ kcal} \qquad (\because\ 1 \text{ kWh} = 860 \text{ kcal})$$

$$\therefore \quad \text{Coal consumption/hour} = \frac{H}{\text{Calorific value}} = \frac{311{\cdot}6 \times 10^6}{6400} = \mathbf{48687\ kg}$$

2. Hydro-electric Power Station

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a **hydro-electric power station.**

Constituents of Hydro-electric Plant

The constituents of a hydro-electric plant are
(1) Hydraulic structures
(2) Water turbines and
(3) Electrical equipment. We shall discuss these items in turn.

1. Hydraulic structures. Hydraulic structures in a hydro-electric power station include dam, spillways, headworks, surge tank, penstock and accessory works

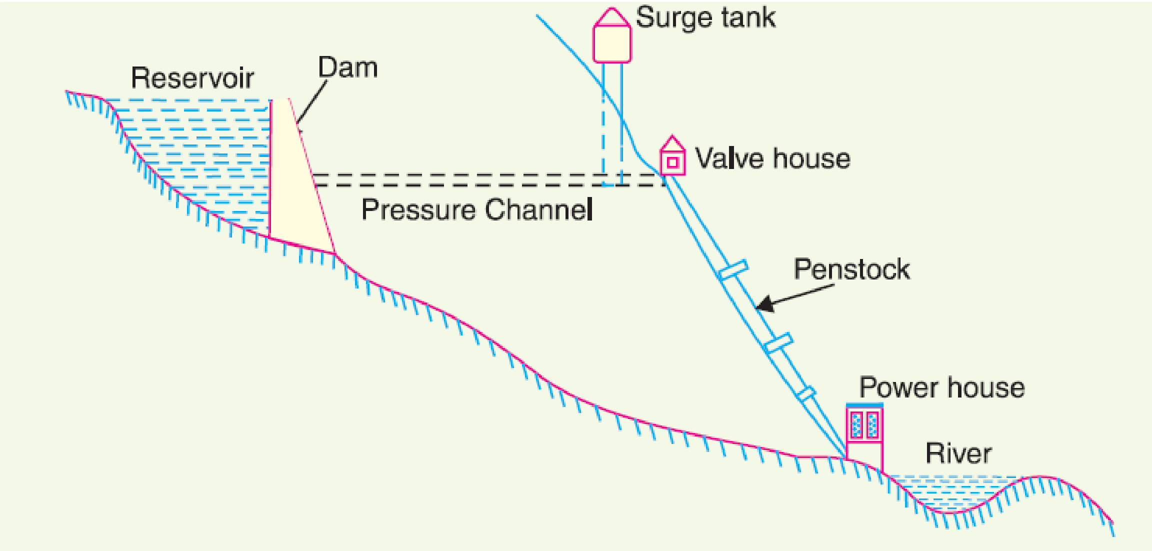
(i) *Dam*. A dam is a barrier which stores water and creates water head.
(ii) *spillways* are constructed of concrete piers on the top of the dam, used to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam.
(iii) *Headworks*. The headworks consists of the diversion structures at the head of an intake. They generally include valves for controlling the flow of water to the turbine.
(iv) *Surge tank*. Open conduits leading water to the turbine require no* protection. However, when closed conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, closed conduits are always provided with a surge tank. A surge tank is a small reservoir or tank (open at the top) in which water level rises or falls to reduce the pressure swings in the conduit.

2. Water turbines. Water turbines are used to convert the energy of falling water into mechanical energy. The principal types of water turbines are :

(*i*) Impulse turbines **(*ii*)** Reaction turbines
(*i*) *Impulse turbines*. Such turbines are used for high heads.

(ii) Reaction turbines. Reaction turbines are used for low and medium heads.
The important types of reaction turbines are :
(*a*) Francis turbines is used for low to medium heads.
(*b*) Kaplan turbines is used for low heads and large quantities of water.

3. **Electrical equipment.** The electrical equipment of a hydro-electric power station includes alternators, transformers, circuit breakers and other switching and protective devices.



Schematic arrangement of a Hydro-electric plant

Fig. 1-5 Schematic arrangement of steam station

Example 2.8. *Water for a hydro-electric station is obtained from a reservoir with a head of 100 metres. Calculate the electrical energy generated per hour per cubic metre of water if the hydraulic efficiency be 0·86 and electrical efficiency 0·92.*

Solution.

Water head, $H = 100\text{ m}$; discharge, $Q = 1\text{ m}^3/\text{sec}$; $\eta_{overall} = 0{\cdot}86 \times 0{\cdot}92 = 0{\cdot}79$

Wt. of water available/sec, $W = Q \times 1000 \times 9{\cdot}81 = 9810\ N$

Power produced $= W \times H \times \eta_{overall} = 9810 \times 100 \times 0{\cdot}79$ watts

$= 775 \times 10^3$ watts $= 775$ kW

$\therefore$ Energy generated/hour $= 775 \times 1 =$ **775 kWh**

Example 2.6. *A hydro-electric generating station is supplied from a reservoir of capacity 5×10^6 cubic metres at a head of 200 metres. Find the total energy available in kWh if the overall efficiency is 75%.*

Solution.

Weight of water available is

$$W = \text{Volume of water} \times \text{density}$$
$$= (5 \times 10^6) \times (1000) \qquad (\because \text{ mass of } 1\text{m}^3 \text{ of water is 1000 kg})$$
$$= 5 \times 10^9 \text{ kg} = 5 \times 10^9 \times 9{\cdot}81 \text{ N}$$

Electrical energy available $= W \times H \times \eta_{overall} = (5 \times 10^9 \times 9{\cdot}81) \times (200) \times (0{\cdot}75)$ watt sec

$$= \frac{(5 \times 10^9 \times 9\cdot 81) \times (200) \times (0\cdot 75)}{3600 \times 1000} \text{kWh} = \mathbf{2.044 \times 106\ kWh}$$