

UNIT - 1

CONVENTIONAL ENERGY GENERATION METHODS

Thermal Power 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 utilising 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. This type of power station is suitable where coal and water are available in abundance and a large amount of electric power is to be generated.

Advantages

- (i) The fuel (*i.e.*, coal) used is quite cheap.
- (ii) Less initial cost as compared to other generating stations.
- (iii) It can be installed at any place irrespective of the existence of coal. The coal can be transported to the site of the plant by rail or road.
- (iv) It requires less space as compared to the hydroelectric power station.
- (v) The cost of generation is lesser than that of the diesel power station.

Disadvantages

- (i) It pollutes the atmosphere due to the production of large amount of smoke and fumes.
- (ii) It is costlier in running cost as compared to hydroelectric plant.

Schematic Arrangement of Steam Power Station

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 is shown in Fig. 2.1. The whole arrangement can be divided into the following stages for the sake of simplicity :

- | | |
|--------------------------------------|------------------------|
| | Steam generating |
| 1. Coal and ash handling arrangement | 2. plant |
| 3. Steam turbine | 4. Alternator |
| 5. Feed water | 6. Cooling arrangement |

Coal and ash handling plant. The coal is transported to the power station by road or rail and is stored in the coal storage plant. Storage of coal is primarily a matter of protection against coal strikes, failure of transportation system and general coal shortages. From the coal storage plant, coal is delivered to the coal handling plant where it is pulverised (*i.e.*, crushed into small pieces) in order to increase its surface exposure, thus promoting rapid combustion without using large quantity of

excess air. The pulverised coal is fed to the boiler by belt conveyors. The coal is burnt in the boiler and the ash produced after the complete combustion of coal is removed to the ash handling plant and then delivered to the ash storage plant for disposal. The removal of the ash from the boiler furnace is necessary for proper burning of coal.

It is worthwhile to give a passing reference to the amount of coal burnt and ash produced in a modern thermal power station. A 100 MW station operating at 50% load factor may burn about 20,000 tons of coal per month and ash produced may be to the tune of 10% to 15% of



coal fired *i.e.*, 2,000 to 3,000 tons. In fact, in a thermal station, about 50% to 60% of the total operating cost consists of fuel purchasing and its handling.

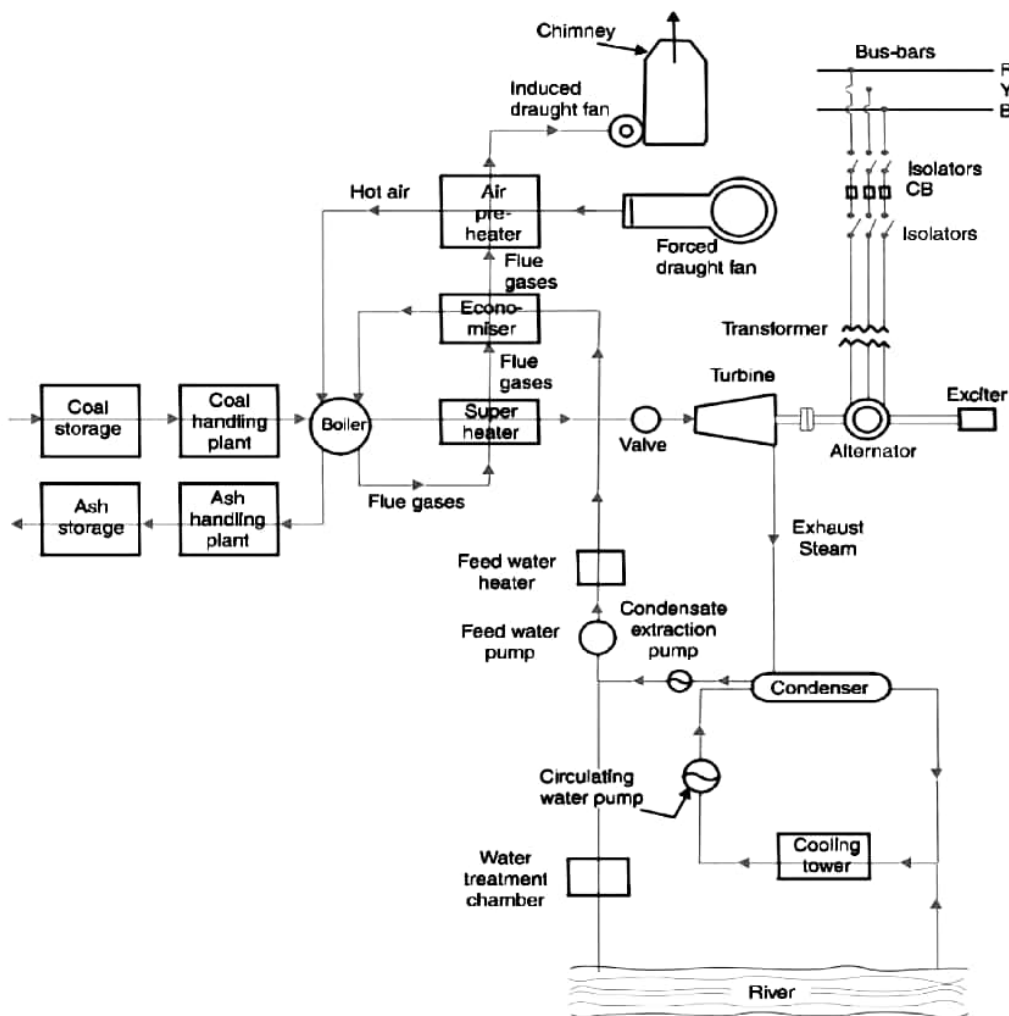
Steam generating plant. The steam generating plant consists of a boiler for the production of steam and other auxiliary equipment for the utilisation of flue gases.

(i) **Boiler.** The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through super-heater, economiser, air pre-heater and are finally exhausted to atmosphere through the chimney.

(ii) **Superheater.** The steam produced in the boiler is wet and is passed through a superheater where it is dried and superheated (*i.e.*, steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits. Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve.

(iii) **Economiser.** An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat of flue gases to increase the feed water temperature.

(iv) **Air preheater.** An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are : increased thermal efficiency and increased steam capacity per square metre of boiler surface.



Schematic arrangement of Steam Power Station

Fig. 2.1

Steam turbine. The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy to the turbine, the steam is exhausted to the *condenser* which condenses the exhausted steam by means of cold water circulation.

Alternator. The steam turbine is coupled to an alternator. The alternator converts mechanical energy of turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators.

Feed water. The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economiser. This helps in raising the overall efficiency of the plant.

Cooling arrangement. In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed* by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year, *cooling towers* are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

2.4 Choice of Site for Steam Power Stations

In order to achieve overall economy, the following points should be considered while selecting a site for a steam power station :

- (i) *Supply of fuel.* The steam power station should be located near the coal mines so that transportation cost of fuel is minimum. However, if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.
- (ii) *Availability of water.* As huge amount of water is required for the condenser, therefore, such a plant should be located at the bank of a river or near a canal to ensure the continuous supply of water.
- (iii) *Transportation facilities.* A modern steam power station often requires the transportation of material and machinery. Therefore, adequate transportation facilities must exist *i.e.*, the plant should be well connected to other parts of the country by rail, road. etc.
- (iv) *Cost and type of land.* The steam power station should be located at a place where land is cheap and further extension, if necessary, is possible. Moreover, the bearing capacity of the ground should be adequate so that heavy equipment could be installed.
- (v) *Nearness to load centres.* In order to reduce the transmission cost, the plant should be located near the centre of the load. This is particularly important if *d.c.* supply system is adopted. However, if *a.c.* supply system is adopted, this factor becomes relatively less important. It is because *a.c.* power can be transmitted at high voltages with consequent reduced transmission cost. Therefore, it is possible to install the plant away from the load centres, provided other conditions are favourable.
- (vi) *Distance from populated area.* As huge amount of coal is burnt in a steam power station, therefore, smoke and fumes pollute the surrounding area. This necessitates that the plant should be located at a considerable distance from the populated areas.

Conclusion. It is clear that all the above factors cannot be favourable at one place. However, keeping in view the fact that now-a-days the supply system is *a.c.* and more importance is being given to generation than transmission, a site away from the towns may be selected. In particular, a site by river side where sufficient water is available, no

pollution of atmosphere occurs and fuel can be transported economically, may perhaps be an ideal choice.

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 and secondly heat losses occur at various stages of the plant. The heat lost in the condenser cannot be avoided. It is because heat energy cannot be converted into mechanical energy without temperature difference. The greater the temperature difference, the greater is the heat energy converted* into mechanical energy. This necessitates to keep the steam in the condenser at the lowest temperature. But we know that greater the temperature difference, greater is the amount of heat lost. This explains for the low efficiency of such plants.

(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.*

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

The thermal efficiency of a modern steam power station is about 30%. It means that if 100 calories of heat is supplied by coal combustion, then mechanical energy equivalent of 30 calories will be available at the turbine shaft and rest is lost. It may be important to note that more than 50% of total heat of combustion is lost in the condenser. The other heat losses occur in flue gases, radiation, ash etc.

(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.*

$$\text{Overall efficiency, } \eta_{\text{overall}} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat of combustion of coal}}$$

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.

$$\text{Overall efficiency} = \text{Thermal efficiency} \times \text{Electrical efficiency}$$

Hydro-electric Power Station

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

Hydro-electric power stations are generally located in hilly areas where dams can be built conveniently and large water reservoirs can be obtained. In a hydro-electric power station, water head is created by constructing a dam across a river or lake. From the dam, water is led to a water turbine. The water turbine captures the energy in the falling water and changes the hydraulic energy (*i.e.*, product of head and flow of water) into mechanical energy at the turbine shaft. The turbine drives the alternator which converts mechanical energy into electrical energy. Hydro-electric power stations are

becoming very popular because the reserves of fuels (*i.e.*, coal and oil) are depleting day by day. They have the added importance for flood control, storage of water for irrigation and water for drink-ing purposes.

Advantages

- (i)** It requires no fuel as water is used for the generation of electrical energy.
- (ii)** It is quite neat and clean as no smoke or ash is produced.
- (iii)** It requires very small running charges because water is the source of energy which is avail-able free of cost.
- (iv)** It is comparatively simple in construction and requires less maintenance.
- (v)** It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.
- (vi)** It is robust and has a longer life.
- (vii)** Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.
- (viii)** Although such plants require the attention of highly skilled persons at the time of construc-tion, yet for operation, a few experienced persons may do the job well.

Disadvantages

- (i)** It involves high capital cost due to construction of dam.
- (ii)** There is uncertainty about the availability of huge amount of water due to dependence on weather conditions.
- (iii)** Skilled and experienced hands are required to build the plant.
- (iv)** It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers.

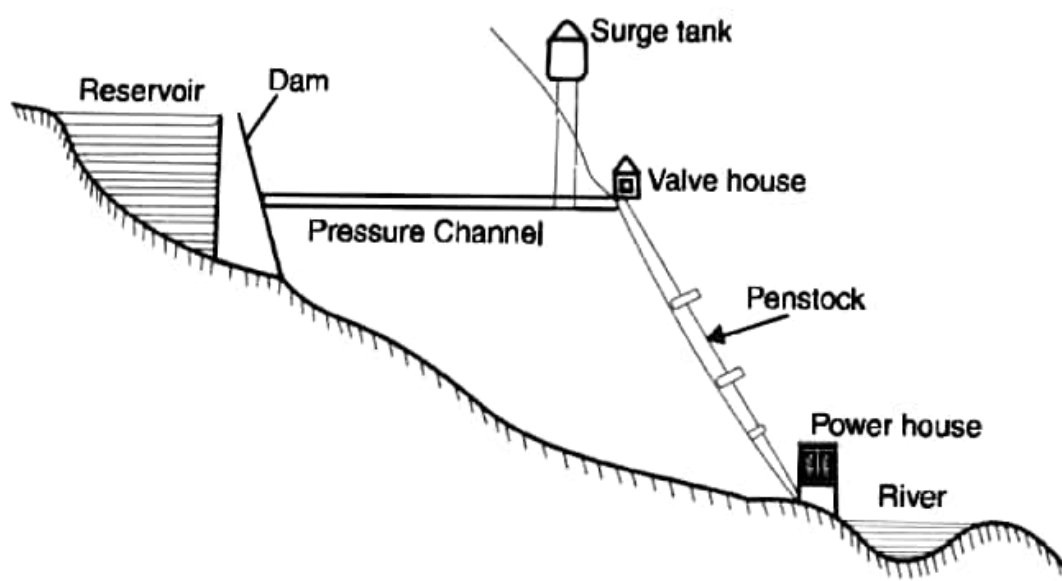
Schematic Arrangement of Hydro-electric Power Station

Although a hydro-electric power station simply involves the conversion of hydraulic energy into electrical energy, yet it embraces many arrangements for proper working and efficiency. The schematic arrangement of a modern hydro-electric plant is shown in Fig. 2.2.

The dam is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a reservoir. A pressure tunnel is taken off from the reservoir and water brought to the valve house at the start of the penstock. The valve house contains main sluice valves and automatic isolating valves. The former controls the water flow to the power house and the latter cuts off supply of water when the penstock bursts. From the valve house, water is taken to water turbine through a huge steel pipe known as *penstock*. The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

A surge tank (open from top) is built just before the valve house and protects the penstock from bursting in case the turbine gates suddenly close* due to electrical load being thrown off. When the

gates close, there is a sudden stopping of water at the lower end of the penstock and consequently the penstock can burst like a paper log. The surge tank absorbs this pressure swing by increase in its level of water.



Schematic arrangement of a Hydro-electric plant

Fig. 2.2

The following points should be taken into account while selecting the site for a hydro-electric power station :

- (i) **Availability of water.** Since the primary requirement of a hydro-electric power station is the availability of huge quantity of water, such plants should be built at a place (*e.g.*, river, canal) where adequate water is available at a good head.
- (ii) **Storage of water.** There are wide variations in water supply from a river or canal during the year. This makes it necessary to store water by constructing a dam in order to ensure the generation of power throughout the year. The storage helps in equalising the flow of water so that any excess quantity of water at a certain period of the year can be made available during times of very low flow in the river. This leads to the conclusion that site selected for a hydro-electric plant should provide adequate facilities for erecting a dam and storage of water.
- (iii) **Cost and type of land.** The land for the construction of the plant should be available at a reasonable price. Further, the bearing capacity of the ground should be adequate to with-stand the weight of heavy equipment to be installed.
- (iv) **Transportation facilities.** The site selected for a hydro-electric plant should be accessible by rail and road so that necessary equipment and machinery could be easily transported.

It is clear from the above mentioned factors that ideal choice of site for such a plant is near a river in hilly areas where dam can be conveniently built and large reservoirs can be obtained.

Constituents of Hydro-electric Plant

The constituents of a hydro-electric plant are (1) hydraulic structures (2) water turbines and electrical equipment. We shall discuss these items in turn.

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. Dams are built of concrete or stone masonry, earth or rock fill. The type and arrangement depends upon the





topography of the site. A masonry dam may be built in a narrow canyon. An earth dam may be best suited for a wide valley. The type of dam also depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards. At most of sites, more than one type of dam may be suitable and the one which is most economical is chosen.

- (ii) **Spillways.** There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down-stream side of the dam, spillways are used. Spillways are constructed of concrete piers on the top of the dam. Gates are provided between these piers and surplus water is discharged over the crest of the dam by opening these gates.
- (iii) **Headworks.** The headworks consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris, sluices for by-passing debris and sediments and valves for controlling the flow of water to the turbine. The flow of water into and through headworks should be as smooth as possible to avoid head loss and cavitation. For this purpose, it is necessary to avoid sharp corners and abrupt contractions or enlargements.
- (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. A surge tank is located near the beginning of the conduit. When the turbine is running at a steady load, there are no surges in the flow of water through the conduit *i.e.*, the quantity of water flowing in the conduit is just sufficient to meet the turbine requirements. However, when the load on the turbine decreases, the governor closes the gates of turbine, reducing water supply to the turbine. The excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement. Hence, a surge tank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on the turbine.

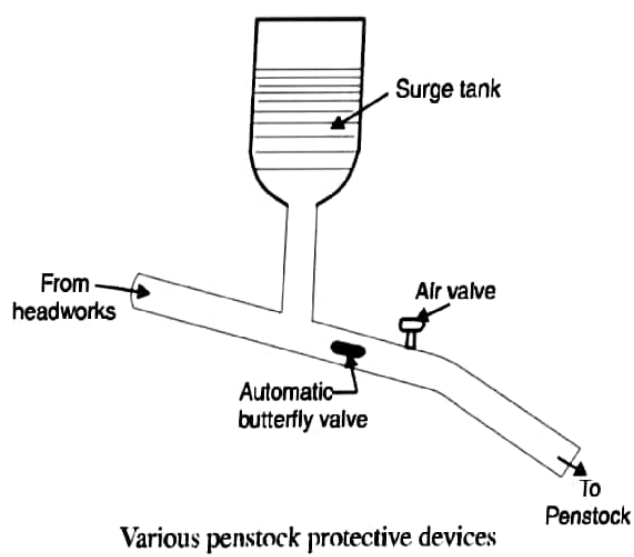


Fig. 2.3

(v) Penstocks. Penstocks are open or closed conduits which carry water from the headworks to the turbines. They are generally made of reinforced concrete. Concrete penstocks are suitable for low

heads (< 30 m) as greater pressure causes rapid deterioration of steel pen-stocks can be designed for any head; the thickness increases with the head or working pressure.

Various devices such as automatic butterfly valve, air valve and surge tank (Fig. 2.3) are provided for the protection of penstocks. Automatic butterfly valve allows water flow through the penstock promptly if it ruptures. Air valve maintains the pressure inside the penstock equal to outside atmospheric pressure. When the water flows out of a penstock faster than it enters, a vacuum is created which may cause the penstock to collapse. Under such situations, air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

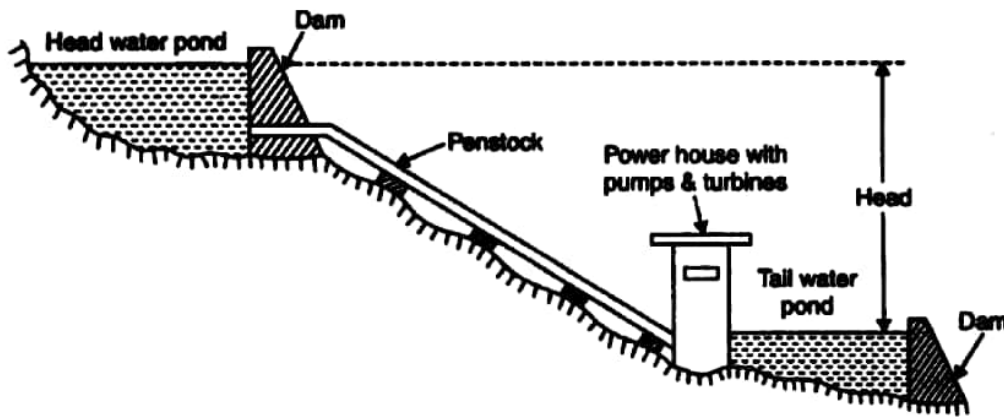


Fig. 5.5. Pumped storage plant.

Pumped storage plants are employed at the places where the quantity of water available for power generation is *inadequate*. Here the water passing through the turbines is stored in 'tail race pond'. During low load periods this water is pumped back to the head reservoir using the extra energy available. This water can be again used for generating power during peak load periods. Pumping of water may be done seasonally or daily depending upon the conditions of the site and the nature of the load on the plant.

Such plants are *usually interconnected* with steam or diesel engine plants so that off peak capacity of interconnecting stations is used in pumping water and the same is used during peak load periods. Of course, the energy available from the quantity of water pumped by the plant is *less* than the energy input during pumped operation. Again while using pumped water the *power available is reduced* on account of losses occurring in primemovers.

Advantages. The pump storage plants entail the following *advantages* :

1. There is substantial increase in peak load capacity of the plant at comparatively low capital cost.
2. Due to load comparable to rated load on the plant, the operating efficiency of the plant is high.
3. There is an improvement in the load factor of the plant.
4. The energy available during peak load periods is higher than that of during off peak periods so that inspite of losses incurred in pumping there is *over-all gain*.
5. Load on the hydro-electric plant remains uniform.
6. The hydro-electric plant becomes partly independent of the stream flow conditions.

Under pump storage projects almost 70 percent power used in pumping the water can be recovered. In this field the use of "*Reversible Turbine Pump*" units is also worth noting. These units can be used as turbine while generating power and as pump while pumping water to storage. The generator in this case works as motor during reverse operation. The efficiency in such case is high and almost the same in both the operations. With the use of reversible turbine pump sets, additional capital investment on pump and its motor can be saved and the scheme can be worked more economically.

Nuclear Power Station

generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station, heavy elements such as Uranium (U^{235}) or Thorium (Th^{232}) are sub-jected to nuclear fission* in a special apparatus known as a *reactor*. The heat energy thus released is utilised in raising steam at high temperature and pressure. The steam runs the steam turbine which

converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

The most important feature of a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations. It has been found that complete fission of 1 kg of Uranium (U^{235}) can produce as much energy as can be produced by the burning of 4.500 tons of high grade coal. Although the recovery of principal nuclear fuels (*i.e.*, Uranium and Thorium) is difficult and expensive, yet the total energy content of the estimated world reserves of these fuels are considerably higher than those of conventional fuels, *viz.*, coal, oil and gas. At present, energy crisis is gripping us and, therefore, nuclear energy can be successfully employed for producing low cost electrical energy on a large scale to meet the growing commercial and industrial demands.

Advantages

- (i)** The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.
- (ii)** A nuclear power plant requires less space as compared to any other type of the same size.
- (iii)** It has low running charges as a small amount of fuel is used for producing bulk electrical energy.
- (iv)** This type of plant is very economical for producing bulk electric power.
- (v)** It can be located near the load centres because it does not require large quantities of water and need not be near coal mines. Therefore, the cost of primary distribution is reduced.
- (vi)** There are large deposits of nuclear fuels available all over the world. Therefore, such plants can ensure continued supply of electrical energy for thousands of years.
- (vii)** It ensures reliability of operation.

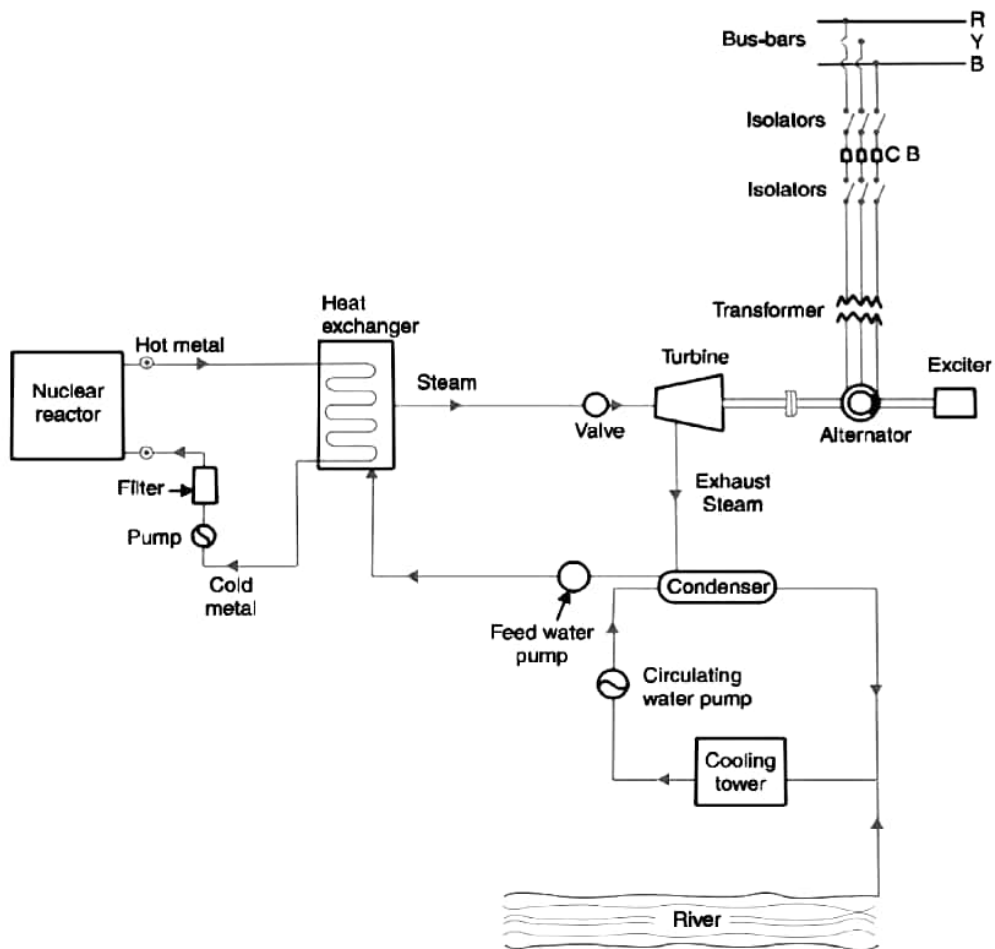
Disadvantages

- (i)** The fuel used is expensive and is difficult to recover.
- (ii)** The capital cost on a nuclear plant is very high as compared to other types of plants.
- (iii)** The erection and commissioning of the plant requires greater technical know-how.
- (iv)** The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.
- (v)** Maintenance charges are high due to lack of standardisation. Moreover, high salaries of specially trained personnel employed to handle the plant further raise the cost.
- (vi)** Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.
- (vii)** The disposal of the by-products, which are radioactive, is a big problem. They have either to be disposed off in a deep trench or in a sea away from sea-shore.

Schematic Arrangement of Nuclear Power Station

The schematic arrangement of a nuclear power station is shown in Fig. 2.7. The whole arrangement can be divided into the following main stages :

- (i) Nuclear reactor (ii) Heat exchanger (iii) Steam turbine (iv) Alternator.



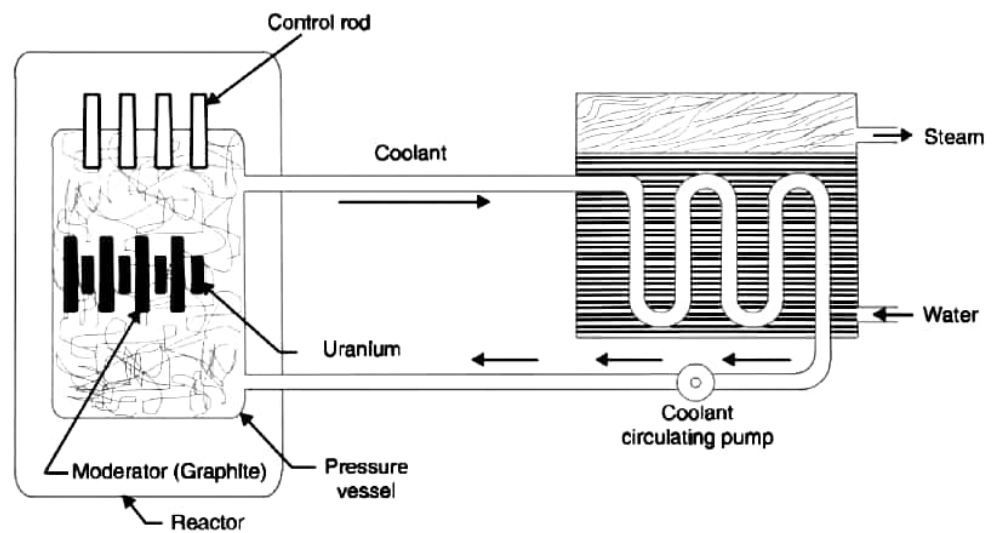
Schematic arrangement of Nuclear Power Station

Fig. 2.7

- (i) **Nuclear reactor.** It is an apparatus in which nuclear fuel (U^{235}) is subjected to nuclear fission. It controls the *chain reaction** that starts once the fission is done. If the chain reaction is not controlled, the result will be an explosion due to the fast increase in the energy released.



A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods (See Fig. 2.8). The fuel rods constitute the fission material and release huge amount of energy when bombarded with slow moving neutrons. The moderator consists of graphite rods which enclose the fuel rods. The moderator slows down the neutrons before they bombard the fuel rods. The control rods are of cadmium and are inserted into the reactor. Cadmium is strong neutron absorber and thus regulates the supply of neutrons for fission. When the control rods are pushed in deep enough, they absorb most of fission neutrons and hence few are available for chain reaction which, therefore, stops. However, as they are being withdrawn, more and more of these fission neutrons cause fission and hence the *intensity* of chain reaction (or heat produced) is increased. Therefore, by pulling out the control rods, power of the nuclear reactor is increased, whereas by pushing them in, it is reduced. In actual practice, the lowering or raising of control rods is accomplished automatically according to the requirement of load. The heat produced in the reactor is removed by the coolant, generally a sodium metal. The coolant carries the heat to the heat exchanger.



Nuclear Reactor
Fig. 2.8

(ii) Heat exchanger. The coolant gives up heat to the heat exchanger which is utilised in raising the steam. After giving up heat, the coolant is again fed to the reactor.

(iii) Steam turbine. The steam produced in the heat exchanger is led to the steam turbine through a valve. After doing a useful work in the turbine, the steam is exhausted to condenser. The condenser condenses the steam which is fed to the heat exchanger through feed water pump.

(iv) Alternator. The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through trans through trans- former, circuit breakers and isolators.

Selection of Site for Nuclear Power Station

The following points should be kept in view while selecting the site for a nuclear power station :

- (i) Availability of water.** As sufficient water is required for cooling purposes, therefore, the plant site should be located where ample quantity of water is available, *e.g.*, across a river or by sea-side.

- (ii) Disposal of waste.** The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards. The waste should either be buried in a deep trench or disposed off in sea quite away from the sea shore. Therefore, the site selected for such a plant should have adequate arrangement for the disposal of radioactive waste.

- (iii) Distance from populated areas.** The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radioactivity in the atmosphere near the plant. However, as a precautionary measure, *a dome* is used in the plant which does not allow the radioactivity to spread by wind or underground waterways.

- (iv) Transportation facilities.** The site selected for a nuclear power station should have adequate facilities in order to transport the heavy equipment during erection and to facilitate the movement of the workers employed in the plant.

From the above mentioned factors it becomes apparent that ideal choice for a nuclear power station would be near sea or river and away from thickly populated areas.