4. POWER PLANTS

In power plants, energy available in different forms (fossil fuels, hydel energy, nuclear energy, etc.) is converted into electrical energy. Major classification are:
a) steam power plant b) hydro-electric power plant c) nuclear power plant d) diesel engine power plant and e) gas turbine power plant.

4.1 Steam power plant

4.1.1 Description

The fuel used in a steam power plant is coal. Coal contains elements which get oxidised during reaction with oxygen, supplied by air in the furnace of the steam generator, with the release of a large amount of energy. The large amount of energy released during the reaction is transferred to water which is converted to high pressure steam. This high pressure steam is made to undergo expansion to low pressure in a turbine, thereby effecting a conversion of low grade heat energy into high grade mechanical work which is manifested as 'Torque' at the turbine shaft.

This torque is transferred directly to the rotor of the electrical generator. Electrical energy is thus produced. The potential of the electrical energy is then raised by transformers.

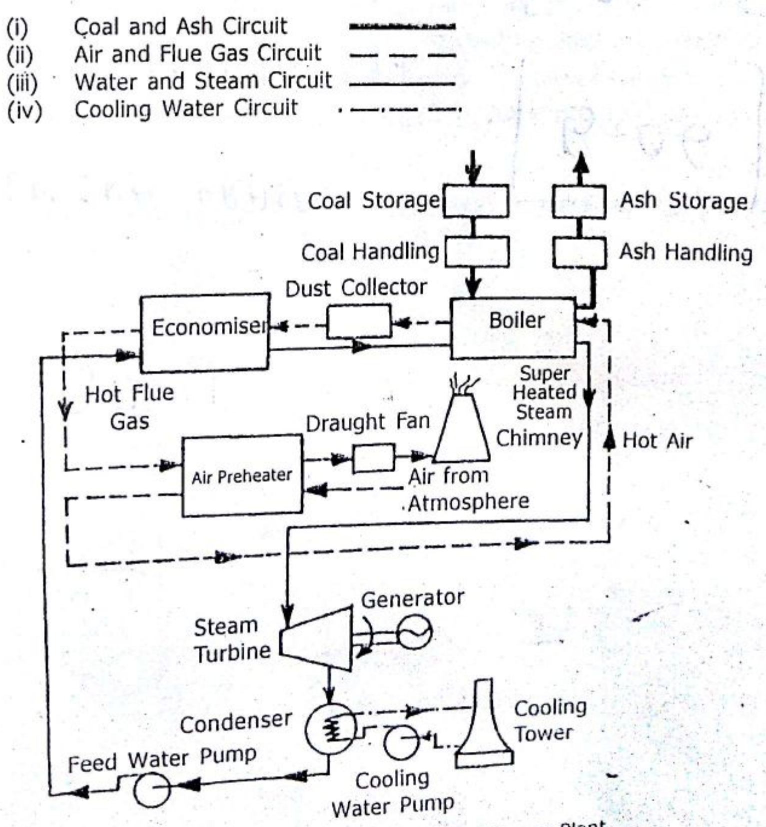

Fig.4.1 Layout of Steam (Thermal) Power Plant

To improve the efficiency of the power plant, numerous auxiliary equipments are used. Although they are expensive and add to the cost of the plant, their utilization is justified on economic grounds. In order that the boiler-turbine-condenser group perform their functions efficiently, safely and economically, it is supplied with a large number of auxiliaries or accessories such as air preheater, economiser, superheater, feed water pump, and draught fan. These auxiliaries fall under two categories: first, those associated with the flow of the working medium (water and steam); second, those associated with combustion of fuel and the flow of gases of combustion. These categories are respectively known as water and gas loops (circuits).

The condenser, cooling tower and cooling water pump form the cooling water circuit. Storage facilities and handling equipments for coal and ash constitute the coal and ash circuit.

4.1.2 Working

Refer to figure 4.1. Coal, which is the fuel for steam power plant is transported by rail, road or water from coal mines to the coal storage yard of the steam power plant. Here, the coal required for steam power plant is stored and then drawn when needed. The coal is then carried by conveyors (belt conveyors, bucket elevators, magnetic separators) to the coal preparation centre. Here, the coal is pulverised in order to increase its surface area which promotes rapid combustion. This increases the rate of heat transfer. The products of combustion (flue gases) formed transfer the heat to the water in the boiler and then pass through an economiser and an air pre-heater before they are let out high into the atmosphere through a chimney. The pressure difference necessary for the flow of flue gases is established by an induced draught fan placed before the chimney as shown. This is the gas loop mentioned in the previous section.

The feed water is pumped to the boiler by a feed pump. This feed water enters an economiser where it is preheated by the heat of the flue gases from the boiler. This pre – heating of the feed water results in savings in fuel consumption. This feed water which has been preheated then enters the boiler. Here water is converted into high pressure, high temperature steam (super heated steam). This superheated steam then drives a turbine coupled to a generator. The steam drives the turbine, to produce a 'Torque' at the turbine shaft which drives the generator to produce electricity. The steam on coming out of the turbine is in an 'energy – lost' state and is condensed in a condenser, the condensate is then discharged into the well or water storage tank.

Cold water is the coolant used for condensing the steam in the condenser. The coolant is kept in circulation by a coolant pump as shown in the figure. The coolant, on absorbing heat from the steam coming out of the turbine, passes on to the top of a cooling tower from where it is sprayed through nozzles. It is cooled by a current of cold air entering along the periphery of the cooling tower, from the bottom, and travelling in the upward direction. The hot coolant giving up its heat to the air, becomes cool and gets collected at the bottom of the tower. The cold water is once again circulated by the coolant pump to the condenser. Water required for condensing the steam may be taken from sources such as river or lake.

The ash formed during combustion of fuel is disposed off by ash – handling equipments.

4.1.3 Advantages of Thermal Power Plant

1. The initial cost of establishing a thermal power plant is low when compared with that of a hydro-electric power plant.
2. The plant may be located near the load centre so that transmission losses and transmission cost are low.
3. The erection and commissioning of a thermal power plant consumes lesser time when compared with hydro – electric power plant.

4.1.4 Disadvantages

1. The possibility of depletion of fuel (coal or oil) is not ruled out since it is a non-renewable source of energy.
2. It cannot meet the rapid variations of loads as its part load efficiency decreases rapidly with decreasing load.
3. In case the plant is located away from the coal fields, then transportation is a major problem.
4. The smoke produced by the burning of the fuel causes air-pollution.
5. The cost of power generation is high when compared with that of the hydro – electric plant.
6. The life of thermal power plant (25 years) is less than that of hydro – electric power plant ([illegible] years)

4.1.5 Thermal Power stations in India

There are about 26 thermal power stations in India. Their capacities varies from 50 to 600 MW. In Tamilnadu, we have 6 thermal power stations.

In order to face the persisting power crisis, super thermal power plants with installed capacity of 2000 – 3000 MW have been put to use. The major super thermal power plants are at Singrauli, Korba, Ramagundam, Neyveli, Talcher and Farakka.

4.2 Hydro– electric power plant

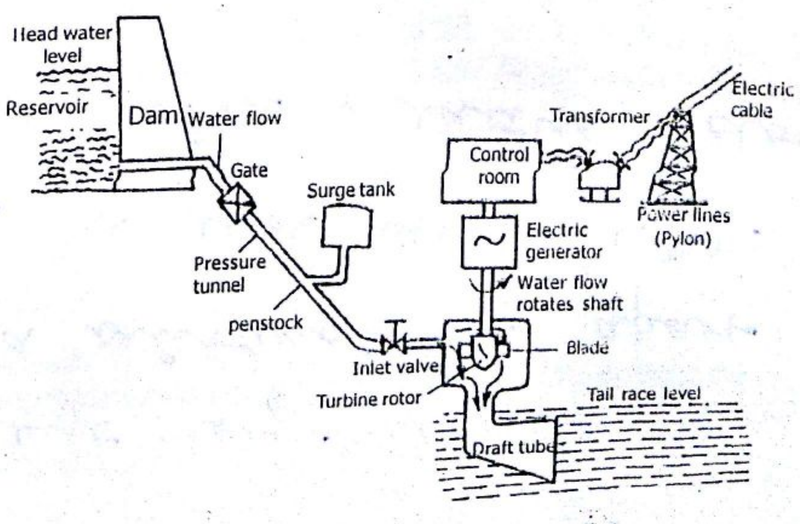

Fig 4.2

Description

'Hydro' means water. In a hydro electric power plant water power is used for generating electricity. The water stored in a dam has potential energy on account of its position or height above the ground level. As the water falls through a certain height, it is capable of doing work. In a hydro electric power plant, the force exerted by water is used to drive a turbine coupled to an alternator which generates electric power.

Working

Refer to figure 4.2. The water collected from the catchment area is stored in a reservoir behind a dam. This catchment area gets its supply of water from rain and rivers. Perennial supply of water is essential for a hydro-electric plant. The level of water in the reservoir is called "Head water level or Head race level". The dam regulates the out going flow of water. It also helps to increase the level of water carried by it, called the "Head", to generate the required quantity of power. However, excessive accumulation of water also causes instability to the dam. In order to prevent the outflow or over flow of water during rainy seasons, spillways are provided which keep the level of water in the dam constant by letting out excessive water accumulated to a different area. A gate is used to regulate the quantity of water flowing out of the dam. The water from the reservoir is carried by a pressure tunnel to the surge tank.

Water hammer

When the load on the turbine is suddenly reduced, the inlet valves supplying the water to the turbine must be closed suddenly. This sudden closure of the valve brings the water in the immediate vicinity of the valve to a standstill but the long column of water in the inlet pipe is still moving. The momentum of this water column causes a sudden increase of pressure in the pipe. This sudden rise of water pressure is called water hammer. Surge tank helps in dissipating and releasing this excess pressure above the normal value existing in the penstock (pipe lines).

A "surge-tank" is a small reservoir or tank into which water flows in or from which water flows out due to sudden variations of pressure. It also performs an additional function. It serves as a "supply – tank" delivering additional water when the water in the pipe is accelerated due to the increased demand or load on the turbine, and as a "storage tank" collecting water when the water is decelerated due to the reduced load on the turbine. The water under pressure is supplied to the turbine by the penstock made of steel or concrete, through the inlet valve. The valve is a flow – regulating device which also regulates the pressure of water entering the turbine. The hydraulic turbine converts the energy of water into mechanical energy. The torque available on the turbine shaft is transferred to an alternator which generates electricity. The voltage of the electricity is then increased by means of a step – up transformer. Now, the electric power is distributed through distribution lines.

The water, after transferring the major part of its energy, enters a draft tube with remaining kinetic energy, which is quite considerable. All this energy will be lost, if this water is allowed to discharge freely. So, by passing the water at the turbine exit through a draft tube, the velocity is significantly reduced with a corresponding increase in pressure and therefore the net head on the turbine increases and hence the output of the turbine.

The draft tube is a metallic pipe or concrete tunnel having a gradually increasing area of section towards its outlet so that little or no energy is left in the water as it discharges into the tail race.

The draft tube allows the turbine to be placed above the tail race level. Tail race is a water way which leads the water discharged from the draft tube to the river.

4.2.4 Advantages

1. This type of power plant depends on supply of water which is a renewable source of energy. Hence there is no fuel cost as in the case of steam, nuclear and diesel power plants, which use non-renewable source of energy as fuel. Water is a gift of nature and available in plenty.
2. Since water is directly received from rain in the catchment area, there is no problem associated with the transportation of fuel as in the case of thermal power plant.
3. No ash is produced as a by product. Hence there is no pollution problem and problem associated with the disposal of ash.
4. Apart from power generation, they also help in irrigation, flood control and fishery and serve as a centre of tourist attraction.
5. Since hydro-electric power plants operate at ambient temperatures, they have longer lives as compared to thermal power plants which operate at very high temperatures (500 – 700°C).
6. A hydro-electric plant can meet the rapid variations of load.

4.2.5 Disadvantages

1. High initial cost.
2. Erection and commissioning of hydro – electric power plants takes a long time.
3. These plants are usually located in the hilly areas far away from the places of demand. Hence they require long transmission lines to deliver power to the load centres. So the cost of transmission and transmission losses are high.
4. The satisfactory operation of the plant requires sufficient availability of water which in turn depends on the rainfall. If the rainfall is deficit, the plant cannot work to full capacity.

4.2.6 Hydro – Electric Power Plants in India

There are about 28 Hydro – electric power plants in India. Their capacities are ranging from 25 MW – 1500 MW. In Tamilnadu, we have the following hydro – electric power projects.

1. Kodayar Hydro – Electric Project - Kodayar.
2. Kundah Basin Development Project - Kundah Basin
3. Mettur Basin Development Project - Mettur.
4. Periyar Basin Development Project - Periyar.

4.3 Nuclear Power Plant

4.3.1 Description

There is strategic as well as economic necessity for Nuclear power. The strategic importance lies in the fact that more than 50,000 barrels of oil per day could be saved by one large nuclear plant. The unit cost per kWh for nuclear energy is equal to or even lower than unit cost of coal in most plants of the world. There are no problems associated with mine safety, labour and transportation of fuel.

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A nuclear power plant uses Nuclear energy (or) Atomic energy. Nuclear power plant derives its energy from Nuclear fission. This energy is used to heat the water in the steam generator. Thus steam is produced which then drives a steam turbine which in turn drives an alternator to produce electricity.

4.3.2 Nuclear Fission

The fuel used in nuclear reactor is uranium. There are two common isotopes of uranium namely U^{235} and U^{238}. U^{238} is fissionable only by high energy neutrons whereas U^{235} is fissionable by neutrons of all energies. The isotope U^{235} is highly unstable.

When a slow moving neutron collides with U^{235} nucleus, it splits up into two fragments of nearly equal masses namely Barium and Krypton along with 3 fast neutrons, one is used to sustain the chain reaction by colliding again with another U^{235} nucleus, second neutron combines with U^{238} forming Plutonium–239. The third neutron escapes from the reactor. All the three neutrons emanating from the reaction have very high kinetic energies. Moderators are provided to slow down the neutrons. However they should not absorb the neutrons.

4.3.3 Moderators

In any chain reaction, the neutrons produced are fast moving neutrons. These are less effective in causing fission of U^{235} and they try to escape from the reactor. It is thus implicit that speed of these neutrons must be reduced if their effectiveness in carrying out fission is to be increased. This is done by making these neutrons collide with lighter nuclei of other materials, which does not absorb these neutrons but simply scatter them. Each collision causes loss of energy and thus the speed of neutrons is reduced. Such a material is called a 'Moderator'. The neutrons thus slowed down are easily captured by the fuel element and the chain reaction proceeds slowly.

4.3.4 Reflectors

Some of the neutrons produced during fission will be partly absorbed by the fuel elements, moderator, coolant and other materials. The remaining neutrons will try to escape from the reactor and will be lost. Such losses are minimised by surrounding (lining) the reactor core with a material called a reflector which will reflect the neutrons back to the core. They improve the neutron economy. Example: Graphite, Beryllium.

4.3.5 Shielding

During Nuclear fission, α, β, γ particles and neutrons are also produced. They are harmful to human life. Therefore it is necessary to shield the reactor with thick layers of Lead, or concrete to protect both the operating personnel as well as the environment from radiation hazards.

4.3.6 Cladding

In order to prevent the contamination of the coolant by fission products, the fuel element is covered with a protective coating. This is known as cladding.

Control rods are used to control the reaction to prevent it from becoming violent. They control the reaction by absorbing neutrons. These rods are made of Boron or Cadmium. Whenever the reaction needs to be stopped, the rods are fully inserted and placed against their seats and when the reaction is to be started the rods are pulled out.

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There are two kinds of fission reactors
1. Thermal
2. Fast.

Thermal reactor power plants are those which use thermal reactors as a heat source. Thermal reactors are those in which fission is primarily caused by thermal neutrons. Therefore they need a moderator to slow down or thermalize the neutrons, as well as a coolant to carry away the heat produced during the fission reaction. The same material can serve both as a coolant and moderator as in the case of heavy water (D_2O) or different materials could be used for moderator (graphite) and coolant (Helium or CO_2). Some common thermal reactors are,
1. Pressurised Water Reactor (PWR)
2. Boiling Water Reactor (BWR)

4.3.7 Pressurised Water Reactor

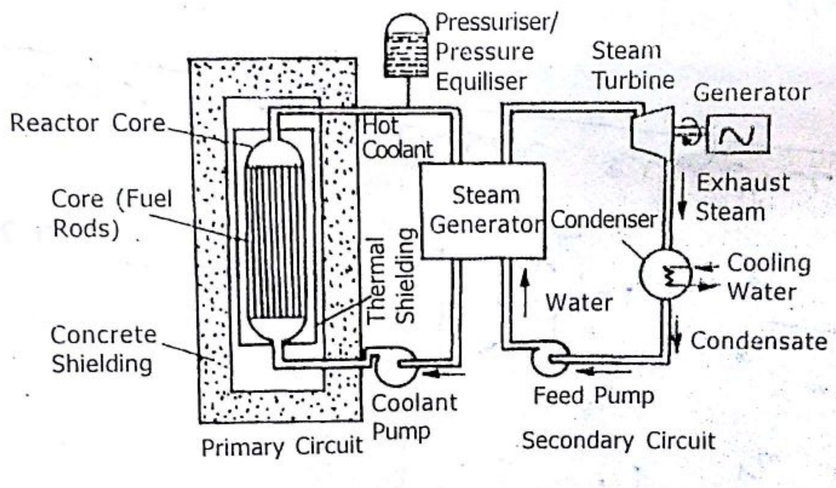

Fig. 4.3

A PWR power plant contains two loops in series. One is called the coolant loop or primary loop and the other is called the water – steam or working fluid loop. Nuclear reactor is the housing inside which energy release due to nuclear fission takes place. This energy is transferred to the coolant which circulates in the nuclear reactor. The coolant then transfers its energy to the working fluid (water) in the heat exchanger. The water upon absorption of heat gets converted into steam which drives a turbine – alternator assembly thereby generating electricity. The steam after doing work in the turbine is then recirculated by a pump back to the heat exchanger after condensation in a condenser and preheating in a feed water heater. The condensate is preheated by mixing with steam bled from a suitable section of the turbine.

In PWR, the coolant pressure is higher than the saturation pressure corresponding to the maximum coolant temperature. The main objective of this is to ensure that no boiling of coolant takes place. Thus the coolant remains in liquid phase throughout its path in the primary loop.

Whenever the load on the reactor changes, coolant temperature changes (also its volume) also the case whenever expansion or contraction of the loop components takes place. This cause

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severe oscillatory pressure changes. Whenever the pressure increases, water flashes into steam which may disrupt the safe working of the nuclear reactor and even burnout the nuclear fuel elements.

Whenever the pressure decreases, it causes cavitation which is again harmful. To avoid these happenings, it is necessary to provide a surge chamber which will accommodate the changes in volume at the same time maintaining the pressure limits. Such a vessel is called a pressuriser.

4.3.8 Boiling Water Reactor

Refer to figure 4.4. In BWR, the coolant is in direct contact with the fuel elements and boils in the same place where the fuel element is located. Since water and vapour coexist in the core, BWR produces saturated steam. The coolant thus serves the triple function of coolant, moderator and working fluid.

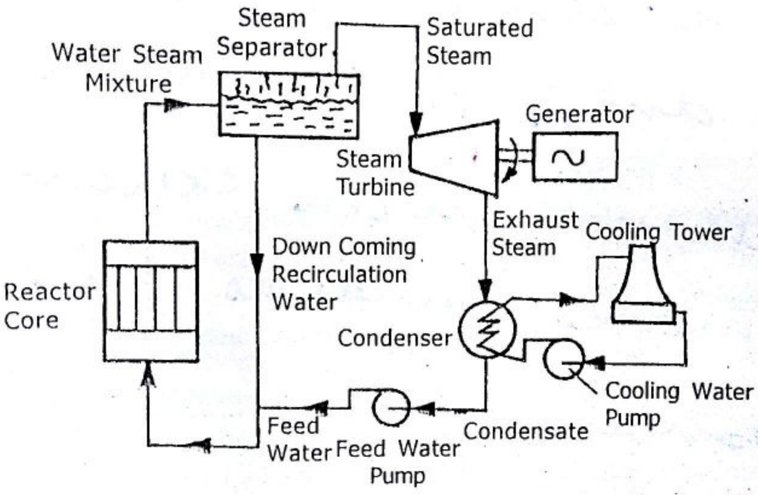

Fig 4.4

A BWR power plant consists of a reactor, a turbo – alternator, a condensor, a feed pump and other auxiliaries. The liquid coolant on entering the core receives sensible as well as latent heat and it is converted into a mixture of liquid and vapour. The vapour gets separated from the liquid in the steam separator, flows to the turbine where it does useful work and after leaving the turbine gets condensed in a condenser, the condensate is then pumped back to the reactor by the feed water pump.

The saturated liquid separated from the vapour in the steam separator flows downward through the down comers and mixes with the condensate from the feed pump before entering the reactor. The coolant flow is due to natural circulation because of the differences in density between the liquid in the down comer and the two phase mixture in the core. This situation is similar to what happens in a fossil – fuel steam generator. Modern BWR are of the internal, forced circulation type.

4.3.9 Breeder Reactors

A breeder reactor is one in which more fissionable material is produced than consumed. A breeding reaction is one in which fertile U^{238} is converted into fissionable Pu^{239}.

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In fast breeder reactor, the core containing U^{235} is surrounded by a fertile material U^{238}. In this reactor, no moderator is used. The fast moving neutrons produced during the fission of U^{235} are absorbed by U^{238} which gets converted into Pu^{239} which is a fissionable material capable of sustaining a chain reaction.

4.3.10 Advantages

1. A nuclear power plant occupies less space when compared with other conventional power plants of same size.
2. Fuel transportation cost and fuel storage facilities needed are less.
3. They are not affected by adverse weather conditions.

4.3.11 Disadvantages

1. Cost of establishing nuclear plant is more than that for a hydro or thermal power plant.
2. Sufficient care must be taken to dispose off the radio active wastes which may otherwise pose a serious problem to the health of the workers as well as to the environment.
3. Maintanence cost is high.
4. It requires skilled personnel for operation.

4.3.12 Nuclear Power Plants in India