Lecture 1

Fundamental of Power Plant

1.1 CONCEPT OF POWER PLANT

A **power plant** may be defined as a machine or assembly of equipment that generates and delivers a flow of mechanical or electrical energy. The main equipment for the generation of electric power is generator. When coupling it to a prime mover runs the generator, the electricity is generated. The type of prime move determines, the type of power plants. The Steam Power Plant, Diesel Power Plant, Gas Turbine Power Plant and Nuclear Power Plants are called **THERMAL POWER PLANT,** because these convert heat into electric energy.

1.2 CLASSIFICATION OF POWER PLANTS

Power Plant

- Conventional
  - Steam Engines Power Plants
  - Steam Turbine Power Plants
  - Diesel Power Plants
  - Gas Turbine Power Plants
  - Hydro-Electric Power Plants
  - Nuclear Power Plants
- Non-conventional
  - Thermoelectric Generator
  - Therm-ionic generator
  - Fuel-cells Power Plants
  - Photovoltaic solar cells Power System
  - MHD Power Plants
  - Fussion Reactor NPP Power System
  - Biogas, Biomass Energy Power system
  - Geothermal Energy
  - Wind Energy Power System
  - Ocean Thermal energy conversion (OTEC)
  - Wave and Tidal Wave
  - Energy Plantation Scheme

1.3 ENERGY

Energy is the ability to do work. **Work** is done when a force moves an object.

$W=F\times D$ while $F=M\times G$

Where: - W: work, F: force, D: distance, M: mass, and G: gravity.

- **Heat** is energy that changes the **temperature** or **state** of a substance. Example: melting ice into water or boiling water into steam.
- **Radiation** is energy in the form of **light or waves** that travel at the speed of light.

Energy can be measured in different units:

- **Calorie** – energy needed to raise the temperature of 1 gram of water by 1°C.
- **Kilocalorie (kcal)** – energy needed to raise 1 kilogram of water from 14.5°C to 15.5°C.
- **Joule (J)** – the standard SI unit of energy.
- **Quad** – a large unit used for national energy statistics.

1.4 SOURCES OF ENERGY

The various sources of energy are:

1. Fossil Fuels: Coal, Oil, and Natural Gas are the most common traditional sources. They are burned to produce heat, which generates steam to run turbines and produce electricity.

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2. Nuclear Energy: Uses **uranium, Plutonium , or thorium** as fuel.

- Energy is released through controlled **splitting (fission) or combining (fusion) of atomic nuclei**, producing heat that generates steam for turbines.
- Produces large amounts of power with low carbon emissions but involves radioactive waste and high safety requirements.

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3. Hydropower

- Utilizes the **potential and kinetic energy of water** stored in dams or flowing rivers.
- The moving water drives turbines connected to generators.
- Renewable, reliable, and clean, though dependent on site conditions and can affect ecosystems.

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4. Solar Energy

  - **Solar Photovoltaic (PV):** Converts sunlight directly into electricity using semiconductor panels.
  - **Solar Thermal (Concentrated Solar Power, CSP):** Uses mirrors/lenses to concentrate sunlight, heat a fluid, and produce steam for turbines.
- Environmentally friendly and abundant, but intermittent (depends on sunlight hours and weather).

5. Wind Energy

- Converts the **kinetic energy of moving air** into mechanical power using wind turbines.
- Clean, renewable, and increasingly cost-effective, though output depends on wind availability.

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6. Geothermal Energy

- Exploits the **heat stored inside the Earth**.
- Wells are drilled to tap hot water or steam reservoirs, which drive turbines to generate electricity.
- Provides reliable base-load power with low emissions, but locations are geographically limited.

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7. Biomass Energy

- Involves burning **organic matter** (wood, agricultural waste, biogas) to produce steam and electricity.
- Renewable if managed sustainably, though combustion can still produce emissions.

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8. Tidal Power

- Harnesses the **kinetic and potential energy of ocean tides**.
- Methods include tidal stream generators (like underwater wind turbines) and tidal barrages (dams across estuaries).
- Highly predictable and renewable, though limited to coastal sites and can impact marine ecosystems.

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9. Thermoelectric Power

- Converts **heat energy directly into electricity** using the **Seebeck effect** (temperature difference across a material produces voltage).
- Can use waste heat from industrial processes or solar heat.
- Useful for small-scale or niche applications; still less efficient compared to other large-scale power plant technologies.

👉 With this, you now have **all major conventional + renewable sources** summarized:

- **Conventional**: Fossil fuels, Nuclear, Thermoelectric (emerging).
- **Renewable**: Hydro, Wind, Solar, Tidal, Geothermal, Biomass.

Notes:

. **Thermal Energy :-** Comes from the random motion of atoms and molecules. Includes both **kinetic** (movement) and **potential** (vibration) energy at the microscopic level.

- **Mechanical Energy (Potential + Kinetic):-** Combination of potential energy (stored) and kinetic energy (motion). **Potential Energy (PE)** exists when an object has mass and height. **Kinetic Energy (KE)** is energy of motion (moving objects).

- $PE = m \times g \times h$
  where m = mass (kg), g = gravity (9.81 m/s^2), h = height (m).
  $KE = \frac{1}{2} m v^2$
  where m = mass (kg), v = velocity (m/s).
  - Forms of KE: Vibrational (oscillations), Rotational (spinning motion), and Translational (movement from one place to another).

Power (P) is the rate of doing work. It shows how much **energy** is used per unit of **time**.

1.5 POWER

- $P = \frac{E}{t}$, Where P: power, E:energy, and t:time.
- **1 Watt (W) = 1 Joule per second**
- **1 Horsepower (hp) ≈ 746 W**

1.6 THERMODYNAMICS LAWS

Thermodynamics is the science that explains how energy changes from one form to another. It provides a set of principles that help us **track and understand energy transformations**.

1.6.1. Zeroth Law of Thermodynamics: *If two bodies are each in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.* **Thermal equilibrium** means no net heat transfer occurs between the bodies.

1.6.2. First Law of Thermodynamics (Law of Energy Conservation): Energy cannot be created or destroyed. It can only change from one form to another, while the total energy remains constant.

1.6.3. Second Law of Thermodynamics (Law of Entropy): *No energy conversion process can be 100% efficient.* Some energy is always lost as heat or unusable energy. Entropy is a measure of disorder in a system. When entropy increases, disorder increases. This law explains why all real processes involve some energy degradation.

16.4. Third Law of Thermodynamics:- *At absolute zero (0 Kelvin), the entropy of a perfect crystal is zero.* Absolute zero cannot be reached in practice, only approached. This law reminds us that there are **absolute physical limits**, just like maximum engine efficiency is limited.

1.7 CLASSIFICATION OF POWER PLANT CYCLE

Power plants cycle generally divided in to the following groups,

1. **Vapour Power Cycle:** (Carnot cycle, Rankine cycle, Regenerative cycle, Reheat cycle, Binary vapour cycle)

2. **Gas Power Cycles:** (Otto cycle, Diesel cycle, Dual combustion cycle, Gas turbine cycle.)

1.7.1 CARNOT CYCLE

This cycle is of great value to heat power theory although it has not been possible to construct a practical plant on this cycle. It has high thermodynamics efficiency. It is a standard of comparison for all other cycles.

The thermal efficiency (η) of Carnot cycle is as follows:

$\eta = (T_1 - T_2)/T_1$

where, T_1 = Temperature of heat source, T_2 = Temperature of receiver

1.7.2 RANKINE CYCLE

Steam engine and steam turbines in which steam is used as working medium follow Rankine cycle. This cycle can be carried out in four pieces of equipment joint by pipes for conveying working medium as shown in Fig. 1.1. The cycle is represented on Pressure Volume P-V and S-T diagram as shown in Figs. 1.2 and 1.3 respectively.

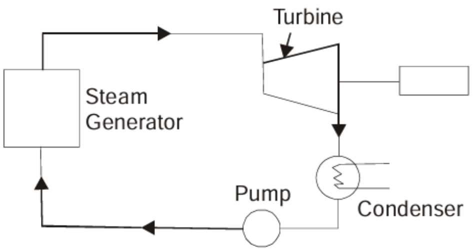

Fig. 1.1

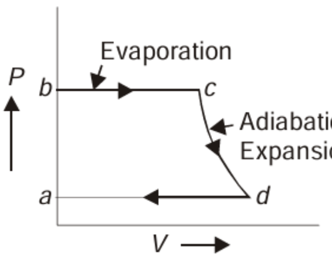

Fig. 1.2

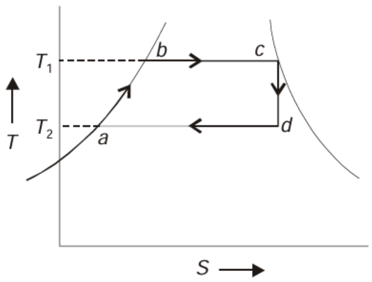

Fig. 1.3

Efficiency of Rankine cycle = $(H_1 - H_2)/(H_1 - H_{w2})$

where,

H_1 = Total heat of steam at entry pressure

H_2 = Total heat of steam at condenser pressure (exhaust pressure)

H_{w2}= Total heat of water at exhaust pressure

1.7.3 REHEAT CYCLE

In this cycle steam is extracted from a suitable point in the turbine and reheated generally to the original temperature by flue gases. Reheating is generally used when the pressure is high say above 100 kg/cm^2. The various advantages of reheating are as follows:

(*i*) It increases dryness fraction of steam at exhaust so that blade erosion due to impact of water particles is reduced.

(*ii*) It increases thermal efficiency.

(*iii*) It increases the work done per kg of steam and this results in reduced size of boiler.

The disadvantages of reheating are as follows:

(*i*) Cost of plant is increased due to the reheater and its long connections.

(*ii*) It increases condenser capacity due to increased dryness fraction.

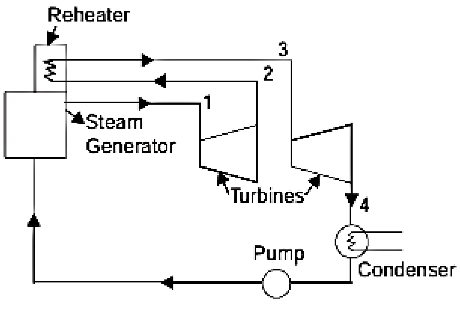

Fig. 1.4

Fig. 1.4 shows flow diagram of reheat cycle. First turbine is high-pressure turbine and second turbine is low pressure (L.P.) turbine. This cycle is shown on T-S (Temperature entropy) diagram (Fig. 1.5).

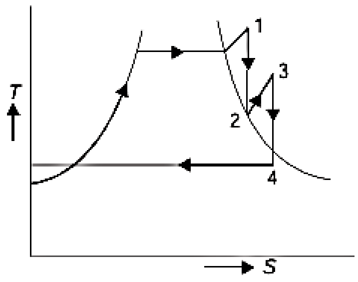

Fig. 1.5

If,

H_1 = Total heat of steam at 1

H_2 = Total heat of steam at 2

H_3 = Total heat of steam at 3

H_4 = Total heat of steam at 4

H_{w4} = Total heat of water at 4

Efficiency = $\{(H_1 - H_2) + (H_3 - H_4)\}/\{H_1 + (H_3 - H_2) - H_{w4}\}$

1.7.4 REGENERATIVE CYCLE (FEED WATER HEATING)

The process of extracting steam from the turbine at certain points during its expansion and using this steam for heating for feed water is known as Regeneration or Bleeding of steam. The arrangement of bleeding the steam at two stages is shown in Fig. 1.6.

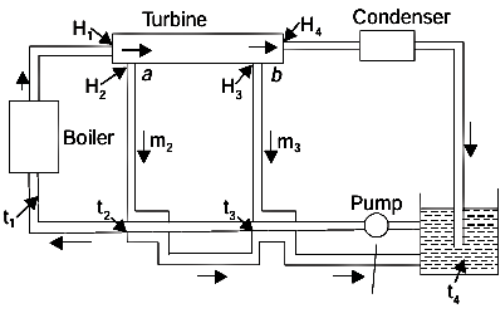

Fig. 1.6

Let,

m_2 = Weight of bled steam at a per kg of feed water heated

H_1 = Enthalpies of steam and water in boiler

H_{W1} = Enthalpies of steam and water in boiler

H_2, H_3 = Enthalpies of steam at points *a* and *b*

t_2, t_3 = Temperatures of steam at points *a* and *b*

H_4, H_{w4} = Enthalpy of steam and water exhausted to hot well. Work done in turbine per kg of feed water between entrance and $a = H_1 - H_2$

Work done between a and $b = (1 - m_2)(H_2 - H_3)$

Work done between b and exhaust $= (1 - m_2 - m_3)(H_3 - H_4)$

Total heat supplied per kg of feed water $= H_1 - H_{w2}$

Efficiency (η) = Total work done/Total heat supplied

$= \{(H_1 - H_2) + (1 - m_2)(H_2 - H_3) + (1 - m_2 - m_3)(H_3 - H_4)\}/(H_1 - H_{w2})$

1.7.5 BINARY VAPOUR CYCLE

In this cycle two working fluids are used. Fig. 1.7 shows Elements of Binary vapour power plant. The mercury boiler heats the mercury into mercury vapours in a dry and saturated state.

These mercury vapours expand in the mercury turbine and then flow through heat exchanger where they transfer the heat to the feed water, convert it into steam. The steam is passed through the steam super heater where the steam is super-heated by the hot flue gases. The steam then expands in the steam turbine.

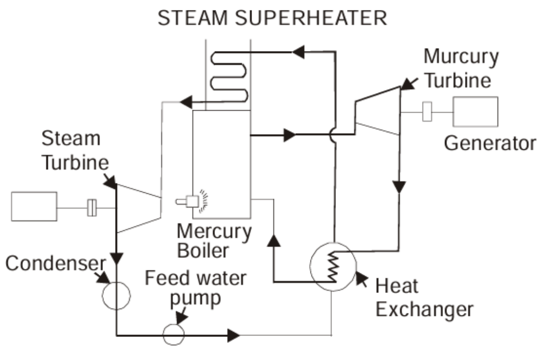

Fig. 1.7

1.7.6 REHEAT-REGENERATIVE CYCLE

In steam power plants using high steam pressure reheat regenerative cycle is used. The ther- mal efficiency of this cycle is higher than only re- heat or regenerative cycle. Fig. 1.8 shows the flow diagram of reheat regenerative cycle. This cycle is commonly used to produce high pressure steam (90 kg/cm^2) to increase the cycle efficiency.

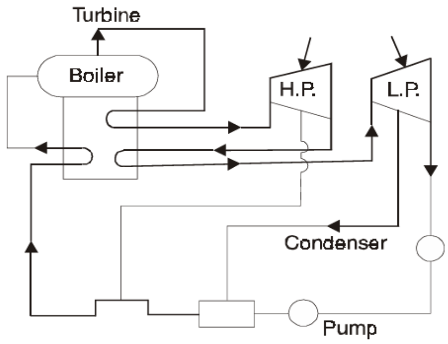

Fig. 1.8

1.7.7 FORMULA SUMMARY

1. Rankine efficiency
   $= (H_1 - H_2)/(H_1 - H_{w2})$
2. Efficiency ratio or Relative efficiency
   = Indicated or Brake thermal efficiency/Rankine efficiency
3. Thermal efficiency $= 3600/m(H_1 - H_{w2})$, m = steam flow/kw hr
4. Carnot efficiency $= (T_1 - T_2)/T_1$

1.8 THERMODYNAMICS CYCLES RELATED TO POWER PLANTS

Steam Power Plants – Work on a **modified Rankine cycle** (steam engines, impulse and reaction turbines).

- **Internal Combustion Engines (Diesel Plants)** – Work on the **Otto cycle**, **Diesel cycle**, or **Dual cycle**.
- **Gas Turbine Plants** – Work on the **Brayton cycle**.
- **Nuclear Plants** – Operate based on **Einstein's equation (E = mc²)** and the principles of **nuclear fission/fusion**.
- **Non-conventional Energy Systems** – Use various principles, such as **thermoelectric** or **thermionic conversion**, depending on the system type.

SOLVED EXAMPLES

Example 1. *Steam at a pressure of 15 kg/cm² (abs) and temperature of 250°C. is expanded through a turbine to a pressure of 5 kg/cm² (abs.). It is then reheated at constant pressure to a temperature of 200°C after which it completes its expansion through the turbine to an exhaust pressure of 0.1 kg/cm²(abs). Calculate theoretical efficiency.*

(a) *Taking reheating into account*

(b) *If the steam was expanded direct to exhaust pressure without reheating.*

Solution. From Mollier diagram

H_1 = Total heat of steam at 15 kg/cm² and 250°C = 698 Kcal/kg

H_2 = Total heat of steam at 5 kg/cm² = 646 Kcal/kg

Now steam is reheated to 200°C at constant pressure

H_3 = Heat in this stage = 682 Kcal/kg

This steam is expanded to 0.1 kg/cm²

H_4 = Heat in this stage = 553 Kcal/kg

H_{w4} = Total Heat of water at 0.1 kg/cm² = 45.4 Kcal/kg

$$\text{Theoretical efficiency} = \frac{\{(H_1 - H_2) + (H_3 - H_4)\}}{\{H_1 + (H_3 - H_2) - H_{w4}\}}$$

Example 2. *Determine the thermal efficiency of the basic cycle of a steam power plant (Rankine Cycle), the specific and hourly steam consumption for a 50 mW steam turbine operating at inlet conditions: pressure 90 bar and temperature 500°C. The condenser pressure is 0.40 bar.*

Solution. From Mollier diagram

H_1 = Total heat of steam at point 1 = 3386.24 kJ/kg

H_2 = Total heat of steam at point 2 = 2006.2 kJ/kg

H_{w2} = Total Heat of water at point 2 = 121.42 kJ/kg

$$(a)\ \text{Thermal efficiency} = \frac{(H_1 - H_2)}{(H_1 - H_{w2})}$$

(b) Specific steam consumption is the amount of steam in kg per kW-hr.

Now 1 kW-hr = 3600 kJ

$$\text{Specific steam consumption} = \frac{3600}{(H_1 - H_2)} = \frac{3600}{(3386.24 - 2006.2)}$$

$$= 2.61 \text{ kg/kW-hr}$$

(c) Hourly steam consumption = 2.61 × Kilowatts

$= 2.61 \times 50{,}000 =$ **1.305 Tonnes/hr Ans.**

Example 3. *A steam power plant, operating with one regenerative feed water heating is run at the initial steam conditions of 35.0 bar and 440°C with exhaust pressure of 0.040 bar. Steam is bled from the turbine for feed water heating at a pressure of 1.226 bar. Determine*

(1) Specific heat consumption

(2) Thermal efficiency of the cycle

(3) Economy percentage compared with the cycle of a simple condensing power plant.

Solution. From Mollier diagrams and steam table,

$H_1 = 3314$ kJ/kg

$H_2 = 2560$ kJ/kg

$H_3 = 2100$ kJ/kg

$H_{w2} = 439.43$ kJ/kg

$H_{w3} = 121.42$ kJ/kg

From the heat balance for the feed water heater

$$m(H_2 - H_{w2}) = (1 - m)(H_{w2} - H_{w3})$$

$$m(2560 - 439.43) = (1 - m)(439.43 - 121.42)$$

On solving, we get $m = 0.1304$ kg

Total work done $= 1 \times (H_1 - H_2) + (1 - m)(H_2 - H_3)$

$= (3314 - 2460) + (1 - 0.1304)(2560 - 2100)$

$= 1154$ kJ/kg

(1) Specific steam consumption $= \dfrac{3600}{1154} =$ **3.12Kg/kW-hr. Ans.**

(2) Thermal efficiency $= \dfrac{1154}{(3314 - 439.43)} =$ **40.15%. Ans.**

(3) With out regeneration feed water heating the work done will be

$H_1 - H_2 = 3314 - 2100 = 1214$ kJ/kg

$$\text{Steam consumption} = \frac{3600}{1214} = 2.94 \text{ kg/kW-hr}$$

Without regeneration heating, the thermal efficiency

$$\eta = \frac{(H_1 - H_3)}{(H_1 - H_{w3})}$$

Now from the steam tables

$$H_{w3} = 121.42 \text{ kJ/kg}$$

$$\eta = \frac{(3314 - 2100)}{(3314 - 121.42)} = 0.38$$

Increase in thermal efficiency due to regeneration feed water heating is

$$= \frac{(0.4015 - 0.38)}{0.4015} = \mathbf{5.5\ \%\ Ans.}$$

THEORETICAL QUESTIONS

1. What is the concept of Power plant?

2. Define the types of energy.

3. Define different types of power cycle.

Lecture 2

STEAM POWER PLANT

2.1 Introduction

Steam is an important medium for producing mechanical energy. Steam is used to drive steam engines and steam turbines. Steam has the following advantages.

1. Steam can be raised quickly from water which is available in plenty.
2. It does not react much with materials of the equipment used in power plants.
3. It is stable at temperatures required in the plant.

2.2 Equipment of a Steam Power Plant

A steam power plant must have the following equipment.

1. A furnace for burning the fuel.
2. A steam generator or boiler for steam generation.
3. A power unit like an engine or turbine to convert heat energy into mechanical energy.
4. A generator to convert mechanical energy into electrical energy.
5. Piping system to carry steam and water.

2.3 Circuits of a Steam Power Plant

Figure 2.1 shows a schematic layout of a steam power plant. The working of a steam power plant can be explained in four circuits.

1. Fuel (coal) and ash circuit.
2. Air and flue gas circuit.
3. Feed water and steam flow circuit.
4. Cooling water flow circuit.

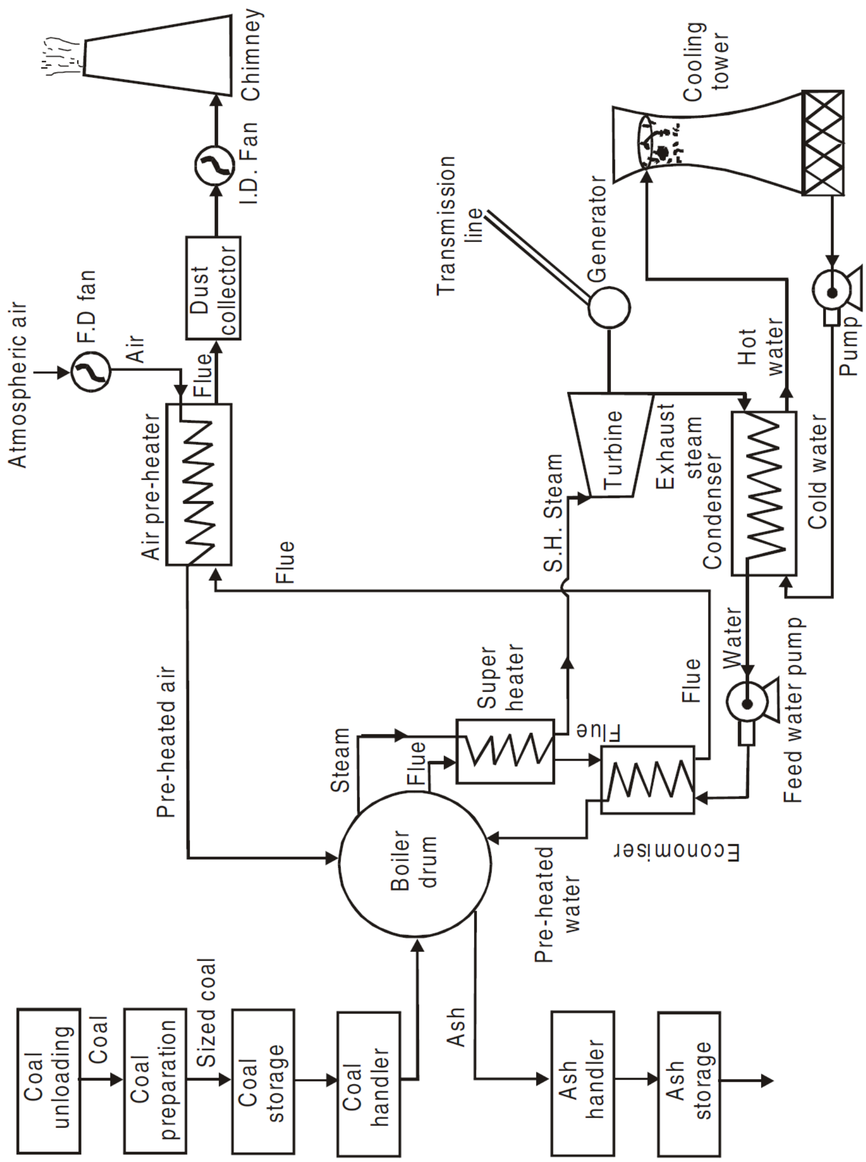

Figure 2.1: Layout of a steam power plant.

1. Coal and Ash circuit

This includes coal delivery, preparation, coal handling, boiler furnace, ash handling and ash storage. The coal from coal mines is delivered by ships, rail or by trucks to the power station. This coal is sized by crushers, breakers etc. The sized coal is then stored in coal storage (stock yard). From the stock yard, the coal is transferred to the boiler furnace by means of conveyors, elevators etc.

The coal is burnt in the boiler furnace and ash is formed by burning of coal. Ash coming out of the furnace will be too hot, dusty and accompanied by some poisonous gases. The ash is transferred to ash storage. Usually, the ash is quenched to reduced temperature, corrosion and dust content.

There are different methods empolyed for the disposal of ash. They are hydraulic system, water jetting, ash sluice ways, pneumatic system etc. In large power plants hydraulic system is used. In this system, ash falls from the furnace grate into high velocity water stream. It is then carried to the slumps. A line diagram of coal and ash circuit is shown separately in figure 2.1 and 2.2.

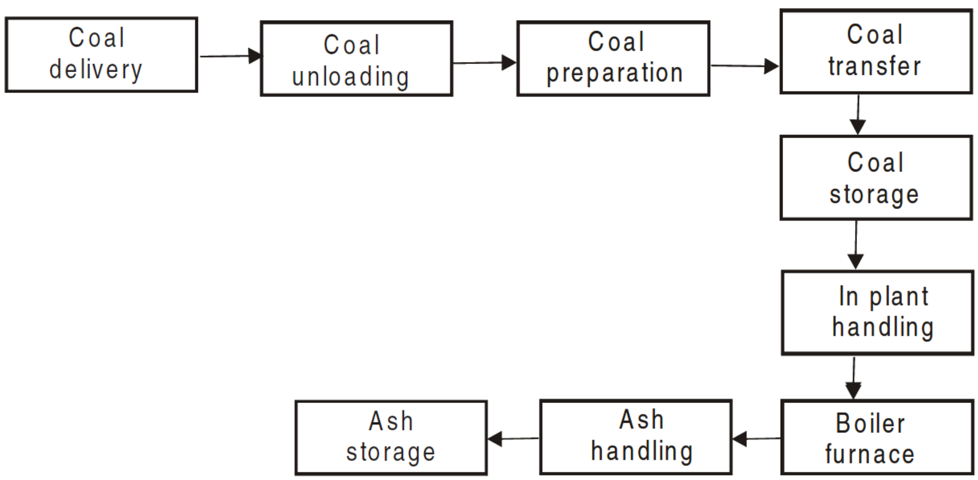

Figure 2.2: Fuel (coal) and ash circuit.

2. Water and Steam circuit

It consists of feed pump, economiser, boiler drum, superheater, turbine condensor etc. Feed water is pumped to the economiser from the hot well. This water is preheated by the flue gases in the economiser. This preheated water is then supplied to the boiler drum. Heat is transferred to the water by the burning of coal. Due to this, water is converted into steam.

The steam raised in boiler is passed through a superheater. It is superheated by the flue gases. The superheated steam is then expanded in a turbine to do work. The turbine drives a generator to produce electric power. The expanded (exhaust) steam is then passed through the condenser. In the condenser, the steam is condensed into water and recirculated. A line diagram of water and steam circuit is shown separately in figure 2.3.

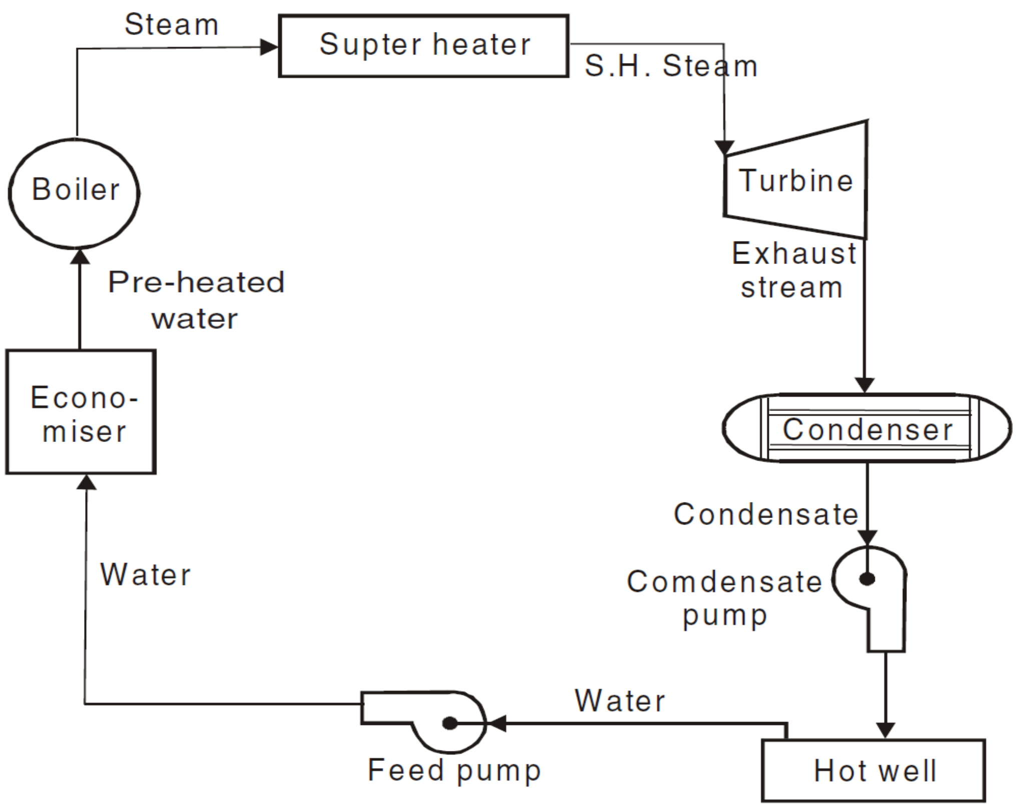

Figure 2.3: Water and Steam circuit.

3. *Air and Flue gas circuit*

It consists of forced draught fan, air preheater, boiler furnace, superheaterer, economiser, dust collector, induced draught fan, chimney etc. Air is taken from the atmosphere by the action of a forced draught fan. It is passed through an air pre-heater. The air is pre- heated by the flue gases in the pre-heater. This pre-heated air is supplied to the furnace to aid the combustion of fuel. Due to combustion of fuel, hot gases (flue gases) are formed.

The flue gases from the furnace pass over boiler tubes and superheater tubes. (In boiler, wet steam is generated and in superheater the wet steam is superheated by the flue gases.) Then the flue gases pass through economiser to heat the feed water. After that, it passes through the air pre-heater to pre-heat the incoming air. It is then passed through a dust catching device (dust collector). Finally, it is exhausted to the atmosphere through chimney. A line diagram of air and flue gas circuit is shown separately in figure 2.4.

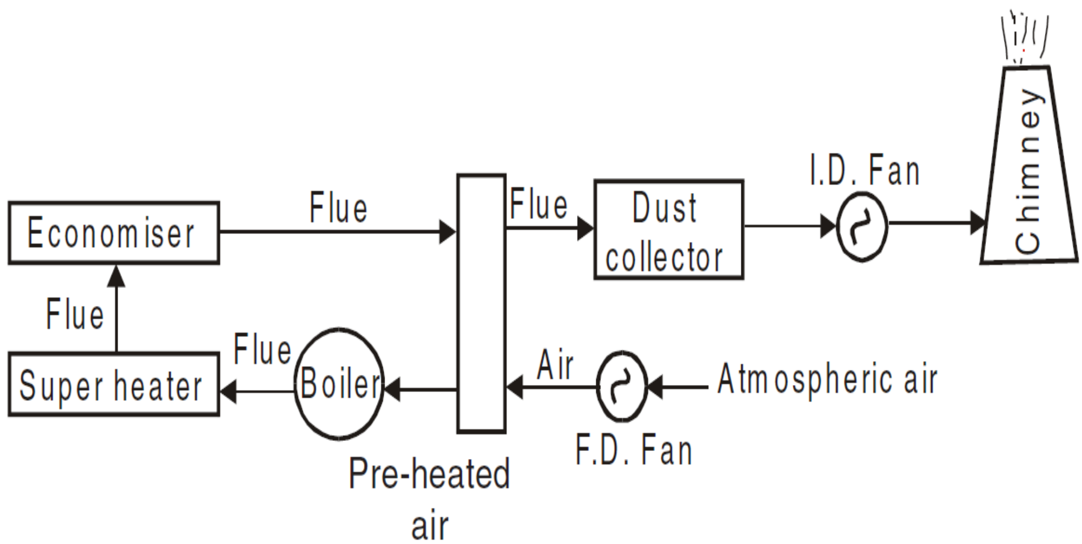

Figure 2.4: Air and flue gas circuit.

4. Cooling water circuit

This circuit includes a pump, condenser, cooling tower etc. The exhaust steam from the turbine is condensed in a condenser. In the condenser, cold water is circulated to condense the steam into water. The steam is condensed by losing its latent heat to the circulating cold water.

Thus the circulating water is heated. This hot water is then taken to a cooling tower. In cooling tower, the water is sprayed in the form of droplets through nozzles. The atmospheric air enters the cooling tower from the openings provided at the bottom of the tower. This air removes heat from water. Cooled water is collected in a pond (known as cooling pond). This cold water is again circulated through the pump, condenser and cooling tower. Thus the cycle is repeated again and again. Some amount of water may be lost during the circulation due to vaporisation etc. Hence, make up water is added to the pond by means of a pump. This water is obtained from a river or lake. A line diagram of cooling water circuit is shown in figure 2.5 separately.

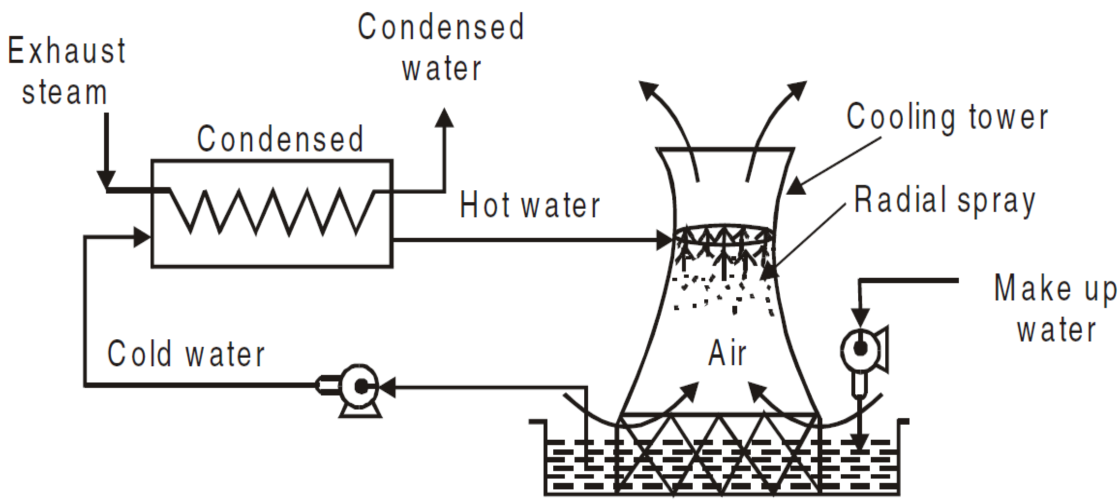

Figure 2.5: Cooling water current.

2.4 Advantages of a Thermal Power Plant

The unit capacity of a thermal power plant is more. The cost of unit decreases with the increase in unit capacity.

1. Life of the plant is more (25-30 years) as compared to diesel plant (2-5 years).
2. Repair and maintenance cost is low when compared with diesel plant.
3. Initial cost of the plant is less than nuclear plants.
4. Suitable for varying load conditions.
5. No harmful radioactive wastes are produced as in the case of nuclear plant.
6. Unskilled operators can operate the plant.
7. The power generation does not depend on water storage.
8. There are no transmission losses since they are located near load centres.

2.5 Disadvantages of thermal power plants

1. Thermal plants are less efficient than diesel plants.
2. Starting up the plant and bringing into service takes more time.
3. Cooling water required is more.
4. Space required is more.
5. Storage required for the fuel is more.
6. Ash handling is a big problem.
7. Not economical in areas which are remote from coal fields.
8. Fuel transportation, handling and storage charges are more.

9. Number of persons for operating the plant is more than that of nuclear plants. This increases operation cost.
10. For large units, the capital cost is more. Initial expenditure on structural materials, piping, storage mechanism is more.

Lecture 3

HYDRO-ELECTRIC POWER PLANT

3.1 Introduction

'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. 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.

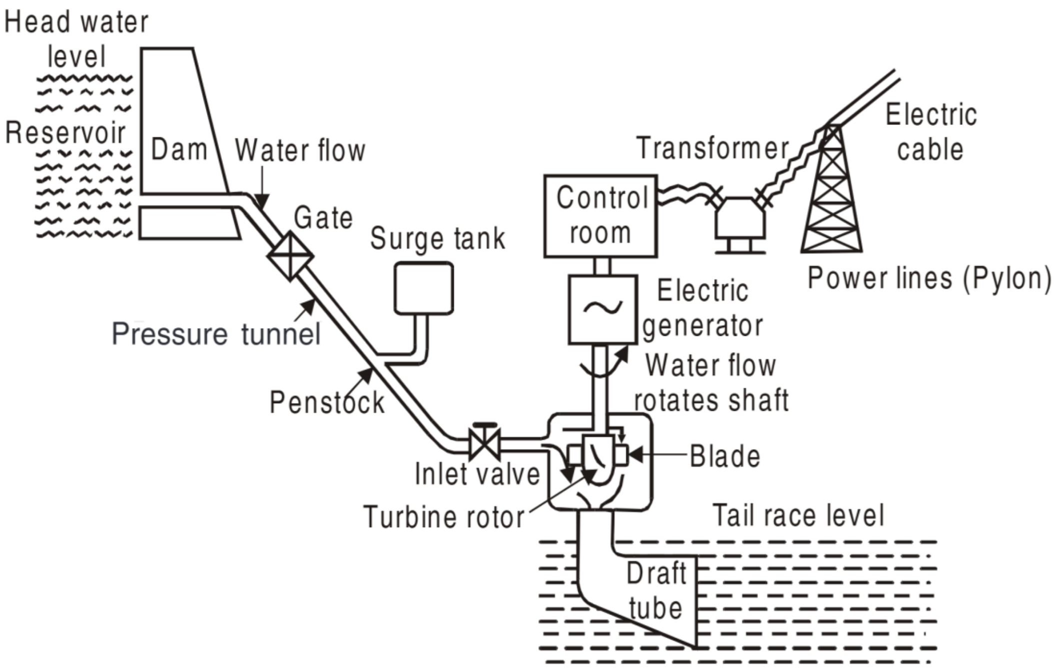

Figure 3.1: Layout of hydro-electric power plant.

3.2 Working Principle

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 outgoing 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 overflow of water during rainy seasons, spillways are provided which keep the level of water in the dam constant by letting out excess 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.

3.3 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 (pipelines).

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 voltages of the electricity is then increased by means of a step-up transformer. Now, the electric power is distributed through distribution lines.

3.4 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 plants.
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 centre of tourist attaction.
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 – 700ºC).
6. A hydro-electric plant can meet the rapid variations of load.

3.5 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.

Lecture 4

NUCLEAR POWER PLANT

4.1 Introduction

The main components of a nuclear power plant are shown in figure 4.1. It consists of nuclear reactor, heat exchanger (steam generator), turbine, electric generator, condenser and pumps for circulating, feed water and coolant.

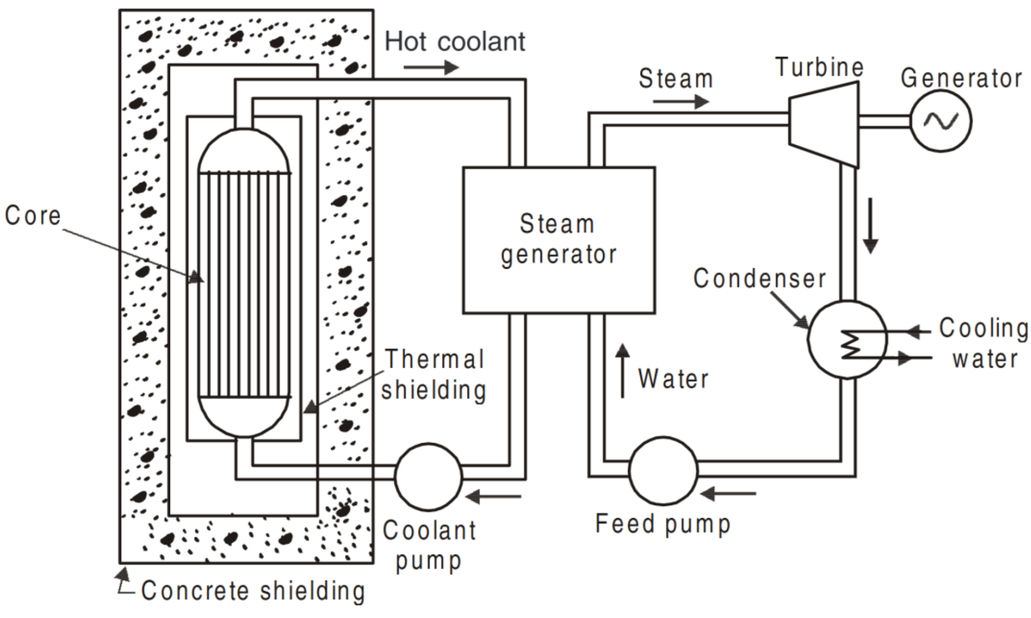

Figure 4.1: Layout of Nuclear power plant.

4.2 Working Principle

The reactor of a nuclear power plant is similar to the furnace of a steam power plant. Here, a large amount of heat energy is produced by the nuclear fission of the fuel. The heat liberated is carried by the coolant circulating through the reactor core. The hot coolant then flows through the tubes of steam generator. The steam generator is a boiler where the hot coolant transfer its heat to the feed water producing steam. The steam thus produced passes through the turbine and work is done by the expansion of steam in the turbine. The generator coupled to the turbine produces power. The exhaust steam leaves the turbine and flows to the condenser. A coolant pump is provided to circulate coolant and a feed pump is provided to circulate feed water in the plant.

4.4 Advantages

1. **No greenhouse gas emissions:** Nuclear power plants do not release greenhouse gases or pollutants into the atmosphere, making them a cleaner alternative to fossil fuels.
2. **High energy density:** A small amount of nuclear fuel can produce a large amount of energy, making it very efficient.
3. **Reliable power:** Nuclear plants can operate continuously for long periods, providing a steady and reliable source of base load power that is not dependent on weather conditions.
4. **Less land use:** Nuclear power plants require a relatively small physical footprint compared to other energy sources like solar or wind farms.
5. **Lower operating costs:** Once built, nuclear plants have relatively low operating and fuel costs compared to fossil fuel plants.

4.5 Disadvantages

1. **Radioactive waste:** The process creates long-lasting radioactive waste that is difficult and expensive to store and dispose of safely.
2. **High initial costs:** Building nuclear power plants is extremely expensive and takes a significant amount of time.
3. **Risk of accidents:** Although rare, nuclear accidents can be catastrophic, releasing large amounts of radiation and posing severe safety risks.
4. **Water usage:** Nuclear plants use large amounts of water for cooling, which can affect local ecosystems, especially when discharged at elevated temperatures.
5. **Non-renewable fuel:** The fuel used, such as uranium, is a finite resource.

Lecture 5

DIESEL POWER PLANT

5.1 Introduction

Diesel engine power plants are suitable for small and Medium outputs

1. They are quite suitable for mobile power generation and are widely used in land, air and marine transportation.
2. They can be used as stand-by power plants.
3. They can be used for generating power up to 50 MW.
4. Diesel power plants have high overall efficiency.

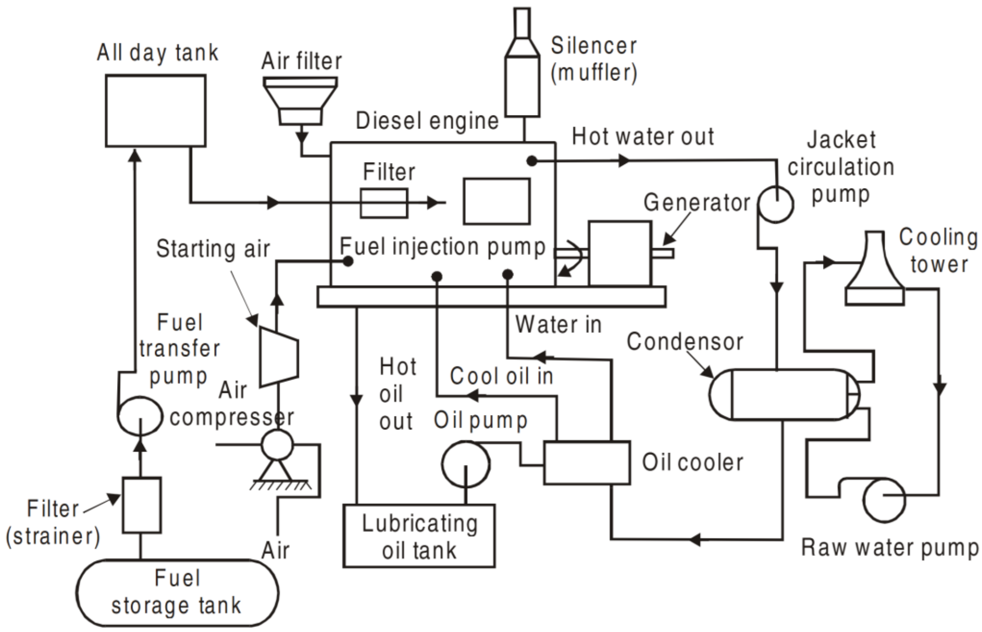

Figure 5.1: Layout of diesel power plant.

5.2 Construction and Working Principle

The diesel engine power plant consists of the following parts:-

i) *Diesel engine*

ii) *Starting system*

iii) *Fuel supply system*

iv) *Air intake system*

v) *Exhaust system*

vi) *Cooling system*

vii) *Lubricating system*

i) Diesel engine

It is the central, power producing element in the power plant. It is a compression ignition engine. The engine may be of two or four strokes, but the two-stroke engine is favoured. Usually multi-cylinder engines are used.

Atmospheric air enters the cylinders of the diesel engine and is then compressed. At the end of compression, the temperature and pressure of air reach high values. The fuel (diesel) is now injected into the cylinder through the fuel injectors and ignited. The fuel burns and the products of combustion expand and exert force on the piston, which reciprocates inside the cylinder. This motion is converted into rotary motion of the crankshaft and fly wheel. The engine is directly coupled to the alternator. The torque available at the engine shaft rotates the alternator thereby generating electricity. The gases after expansion, are expelled from the cylinder by the piston. These gases then pass through a silencer, which reduces the noise of the gases before they are let out into the atmosphere.

ii) Starting system

A compressed air system is used for starting the engine. The high compression rations involved in a diesel engine makes starting by hand-cranking difficult and so mechanical cranking must be resorted to. Generally compressed air, electric cranking motors and auxiliary gasoline engines are employed for this purpose. Large stationary diesel power plants are generally started using compressed air.

Two or more compressed air-storage tanks or ‘bottles’ are provided and another emergency compressor is usually installed for the purpose of recharging these tanks. Starting air pressure is to be maintained at 20 bar.

During the starting period, compressed air is injected to one or more cylinder. This air exerts thrust on the piston moving it down. At the same time some other cylinders may be starting their suction strokes, to which the compressed air is injected and the same sequence of events follow. Once the engine gains sufficient momentum due to the thrust of the injected air, the air supply is cut off and oil injection is started and the engine ‘drifts’ on its momentum.

iii) Fuel supply system

Liquid fuels are used in diesel engines (IC engines) on account of their high calorific value and ease of storage and handling. The amount of fuel to be stored depends on the service hours (running hours of the power plant) and is different for different installations. The fuel delivered to the power plant is received in storage tanks. Pumps draw the oil from the storage tanks and supply it to ‘day tanks’ which supply the day-to-day oil requirements of the engine. The day tank is placed at greater elevation than the engine so that fuel flows by gravity, unassisted by external power. The fuel from the day tank passes through a filter which removes the impurities present in the fuel before it is injected into the cylinder of the engine.

iv) Air intake system

A large diesel engine requires considerable amount of air for combustion. The atmospheric air will vary in temperature and dust content. The air system is provided with a filter to remove dirt which may otherwise cause excessive wear of the engine. The filters may be of oil-impingement, oil-bath or dry type.

The oil-impingement type consists of a wire frame coated with special oil so that air passing through the frame is broken up into a number of small filaments intimately in contact with oil whose property is to seize or hold any dust or impurity carried by air. In oil-bath type of cleaner, the air is swept over a pool of oil so that the impurities get coated. This air is then made to pass through a filter which retains the oil coated dust particles. The dry type of filter is made of felt, wool and cloth, which catch the dirt by causing these impurities to cling to the filter material. Light weight steel pipe is the material used for intake ducts.

v) Exhaust system

An exhaust manifold is provided to the diesel engine for conveying the exhaust gases to the atmosphere. The exhaust system should silence the exhaust noise to requisite levels. The muffling of the exhaust noise is met by using silencers. The gases must be discharged sufficiently high above the ground level to avoid low level pollution of air.

vi) Cooling system

The temperatures existing in the engine cylinder due to the burning of the fuel are in the order of 1500ºC–2000ºC. These temperatures may cause uneven expansion of the engine parts such as cylinder head, walls piston and exhaust valves. In the extreme, it may even cause breakdown of the lubricating oil. Thus a well designed cooling system is essential for proper cooling of the engine and for a long life of the engine but at the same time it should not provided excessive cooling of the engine.

Cooling water is kept in circulation around the cylinders by the jacket circulating pump. The water, on absorbing the heat from the cylinder passes on to a heat exchanger where it gives up its heat to the raw water and this raw water is subsequently cooled in a cooling tower before being once again sent back to the engine cylinders.

vii) Lubricating system

This is essential to reduce the wear and tear of the moving parts. Lubricating system is also used to cool the engine to a certain extent.

In a lubricating system, the oil which is hot after lubricating the various parts of the engine returns to the lubricating tank. The hot lubricating oil is then sent to the oil cooler where it is cooled by the cold water coming out of the heat exchanger. From the oil cooler, it enters the diesel engine for the purpose of lubrication.

5.3 Advantages

1. Handling of fuel is easy and only small space for fuel storage is required.
2. It can be located near the load centre.
3. It can start quickly.
4. The plant is smaller in size than a steam power plant of the same capacity.
5. Operation of the plant is easy and requires less number of personnel.

6. The thermal efficiency of diesel engine is higher than that of steam power plants.
7. It requires less amount of water for cooling.

5.4 Disadvantages

1. Diesel oil is costly.
2. The overload response of the plant is not satisfactory for longer periods.
3. Lubricating cost is high.
4. They are of limited capacity. (Maximum 50 MW).

Lecture 6

GAS TURBINE POWER PLANT

6.1 Introduction

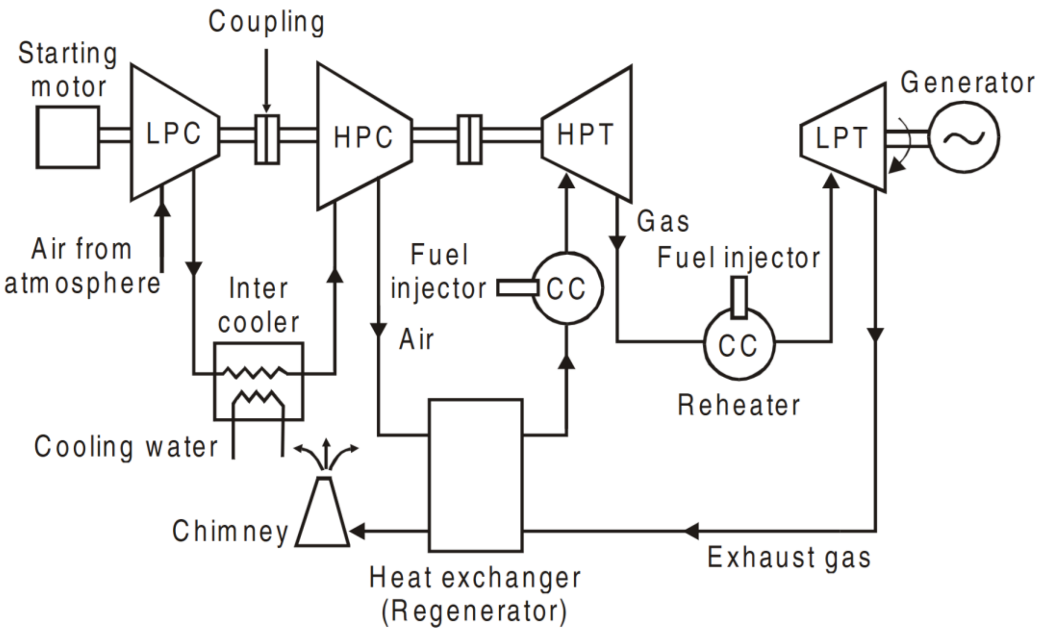

Figure 6.1: Layout of gas-turbine power plant.

6.2 Elements of Gas Turbine Power Plant and its Working Principle

1. Starting motor

For starting a gas turbine power plant, various starting devices are used. For an isolated gas turbine power plant, an electric motor energised by battery is used. For stationary plants, energy supplied by Busbars is used for staring purposes. Small internal combustion engines are also used where, the engine is first started by hand-cranking and then the momentum developed by the engine is used to start the gas turbine power plant.

2. *Low-pressure compressor*

The major function of the compressor is to compress the air. The atmospheric air is compressed to a value depending on the pressure ratio of the compressor. Only a fraction of the total pressure rise is achieved at the exit of L.P. compressor.

3. *Inter cooler*

The air at the exit of L.P. compressor is hot on account of its pressure rise. Inter- cooling is the removal of heat from compressed air between stages. This reduces the work of compression because work of compression is proportional to inlet temperature. This is achieved by using water cooled surface coolers called 'inter coolers'.

4. *High pressure compressor*

The air from the inter-cooler enters the high pressure compressor where it is compressed to the requisite, final pressure. The reason for staging the compression in H.P and L.P. stages is that high overall pressure ratios can be achieved.

5. *Regenerator or Recuperator*

The air from the H.P compressor enters a regenerator which is a type of heat exchanger. Here the air is pre-heated by the exhaust gases from the L.P. Turbine before it enters the combustion chamber. The objective of pre-heating the compressed air is to effects savings in fuel consumption (less amount of fuel needs to be injected into the air- stream for the purpose of ignition if the air is pre-heated).

6. *Combustion chamber*

It is the location where combustion takes place in the GTPP. It is called combustor. It usually contains 6 chambers. These power plants use natural gas and clean liquid fuels. Since natural gas is mostly utilized for domestic purposes and the cost of liquid hydrocarbons has also increased, residual liquid fuels, (the residue obtained after light fractions are extracted from crude) are now employed in gas turbines. Other alternatives are synthetic fuels obtained from coal gasification and liquifaction.

The fuel, pressurised and preheated, is supplied through air atomiser spray nozzles. The fuel air mixture is then ignited by spark plugs located in two chambers. The other chambers are ignited by the cross tubes connecting these chambers. Spark ignition is used only during the starting period after which combustion is self-sustaining.

7. *High pressure turbine*

The products of combustion emerging from the combustion chamber enter the H.P. turbine, where they expand transferring their momentum to the blades of the H.P. turbine. The power developed by the H.P. turbine is used to drive the compressors. Initially, a starting motor is used to drive the compressors. Then the above-mentioned sequence of events takes place, actuating the H.P. turbine which then takes care of the compressors, relieving the burden on the starting motor. The turbine is called H.P. turbine because the products of combustion which are at high pressure and temperature directly impinge on its blades. Only a part of the total expansion is carried out in the H.P. turbine.

The main objective behind staging the expansion is to increase the work output and increase the thermal efficiency of the plant. This is achieved at the cost of increased capital investment and size of the plant.

8. *Reheater or Combustion chamber*

The products of combustion, after expansion in the H.P. turbine enter the reheater, or combusin chamber, where heat is once again added to the products of combustion by adding required quantities of fuel. The inherent advantage of reheating is that the temperature at the entry of the low pressure turbine is increased thereby increasing the work output of the L.P. turbine. The torque available at the turbine shaft is supplied to the alternator causing it to rotate thereby generating electricity. However, it has to be noted that only a part of the total expansion is utilised for useful power output and the remaining part of the expansion is used for driving the compressors.

In practice, about 66% of the total power output (H.P. and L.P. turbines) is used for driving the compressors and the remaining 34% is used for generating electricity. However in the case of aircraft gas turbines, all the work output of the turbine is used for driving the compressors (i.e.,) for propulsion only and there is no need to generate electricity.

6.3 Applications

1. Gas turbines are used for powering all types of aircraft.
2. They are also used in industries for driving pumps, compressors and electric generators.
3. They are used in steam or hydro power plants for producing electric power for peak loads as well as for intermediate and base load duties.

6.4 Advantages

1. They are small in size, weigh less and have low initial cost per unit output.
2. They are easy to install within short periods.
3. They are quick-starting and smooth running.
4. They offer flexibility by supplying electricity for power generation as well as by supplying compressed air for process needs.
5. They are capable of using a range of liquid and gaseous fuels including synthetic fuels.

6. They are subjected (put) to fewer environmental restrictions than other prime movers.
7. Water consumption is less compared to steam power plant.

6.5 Disadvantages

1. An electric motor or an I.C. engine is necessary for starting the plant. The starting motor must bring the compressor well towards the operating speed. So starting is not simple as in the case of other power plants.
2. Gas turbine plants have less vibrations when compared with reciprocating engines of the same speed. However the high frequency noise from the compressor is objectionable.
3. High temperatures impose severe restriction on the servicing conditions of the plant.
4. Overall efficiency is low since two-thirds of the total power output is used for driving the compressor.
5. The blades of the turbine require special cooling methods due to the severity of operating temperatures and pressures. In practice, the temperatures at the entry of the turbine are as high as 1100ºC – 1260ºC. Hence they should be made of special metals and alloys.
6. They are incompatible with solid fuels.