

Session 2

A thermal power plant, also known as a steam power plant, generates electricity by using heat energy produced from the combustion of fossil fuels or nuclear reactions to convert water into steam. The steam then drives a turbine connected to a generator, producing electrical power. Here is a general layout of a thermal power plant:

1. **Boiler:** The boiler is the main component of a thermal power plant. It is where fossil fuels, such as coal, oil, or natural gas, are burned to generate heat. The heat energy is used to convert water into high-pressure steam. The boiler consists of a combustion chamber, fuel supply system, air supply system, and exhaust system.
2. **Turbine:** The high-pressure steam produced in the boiler is directed to a turbine. The turbine converts the thermal energy of the steam into mechanical energy by causing the turbine blades to rotate. There are various types of turbines used in thermal power plants, including steam turbines and gas turbines.
3. **Generator:** The rotating shaft of the turbine is connected to a generator. As the turbine spins, it drives the generator, which converts the mechanical energy into electrical energy. The generator produces alternating current (AC) electricity.
4. **Condenser:** After passing through the turbine, the steam enters the condenser. The condenser is a heat exchanger that cools down the steam by transferring its heat to a coolant, such as water from a nearby river or cooling towers. The steam condenses back into water, creating a vacuum that improves the turbine's efficiency.
5. **Cooling System:** Thermal power plants require a cooling system to dissipate excess heat and maintain proper operating temperatures. This can be achieved through various methods, including cooling towers that use evaporation to remove heat or direct contact cooling systems that use water from natural sources.
6. **Fuel Storage and Handling:** Thermal power plants require storage and handling facilities for the fossil fuels they use. This includes storage areas for coal, oil tanks, or gas pipelines, as well as equipment for fuel preparation and feeding into the boiler.
7. **Environmental Control Systems:** Thermal power plants incorporate various environmental control systems to minimize air and water pollution. This includes systems for removing particulate matter, sulfur dioxide (SO₂), nitrogen oxides (NO_x), and other pollutants from the flue gases before they are released into the atmosphere.
8. **Control Room and Monitoring:** A thermal power plant typically has a control room where operators monitor and control various aspects of plant operations, including

boiler temperature and pressure, turbine speed, and electrical output. Advanced control systems and automation are used to optimize power generation and ensure safe and efficient operation.

9. **Transmission Lines:** The electricity generated in the power plant is transmitted through high-voltage transmission lines to distribution networks, where it can be distributed to homes, businesses, and industries.

It's important to note that the specific layout and design of a thermal power plant can vary depending on factors such as the type and capacity of the plant, fuel type, environmental regulations, and site constraints. Additionally, some thermal power plants may incorporate additional components, such as a steam generator in nuclear power plants or advanced pollution control systems for emissions reduction.

Almost two third of electricity requirement of the world is fulfilled by **thermal power plants** (or **thermal power stations**). In these [power stations](#), steam is produced by burning some fossil fuel (e.g. coal) and then used to run a steam turbine. Thus, a thermal power station may sometimes called as a **Steam Power Station**. After the steam passes through the steam turbine, it is condensed in a condenser and again fed back into the boiler to become steam. This is known as **Ranking cycle**. This article explains **how electricity is generated in thermal power plants**. As majority of thermal power plants use coal as their primary fuel, this article is focused on a **coal fired thermal power plant**.

Typical Layout And Working Of A Thermal Power Plant

A simplified **layout of a thermal power station** is shown below.

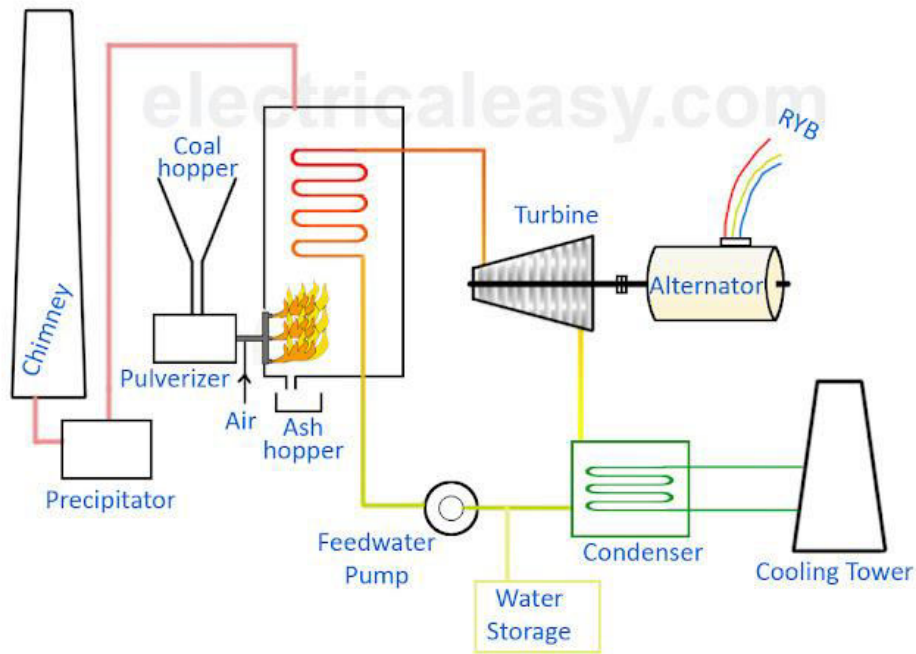


Figure 1 Thermal Power Plant Layout

Coal: In a coal based thermal power plant, coal is transported from coal mines to the generating station. Generally, bituminous coal or brown coal is used as fuel. The coal is stored in either 'dead storage' or in 'live storage'. Dead storage is generally 40 days backup coal storage which is used when coal supply is unavailable. Live storage is a raw coal bunker in boiler house. The coal is cleaned in a magnetic cleaner to filter out if any iron particles are present which may cause wear and tear in the equipment. The coal from live storage is first crushed in small particles and then taken into pulverizer to make it in powdered form. Fine powdered coal undergoes complete combustion, and thus pulverized coal improves efficiency of the boiler. The ash produced after the combustion of coal is taken out of the boiler furnace and then properly disposed. Periodic removal of ash from the boiler furnace is necessary for the proper combustion.

Boiler: The mixture of pulverized coal and air (usually preheated air) is taken into boiler and then burnt in the combustion zone. On ignition of fuel a large fireball is formed at the center of the boiler and large amount of heat energy is radiated from it. The heat energy is utilized to convert the water into steam at high temperature and pressure. Steel tubes run along the boiler walls in which water is converted in steam. The flue gases from the boiler make their way

through superheater, economizer, air preheater and finally get exhausted to the atmosphere from the chimney.

- **Superheater:** The superheater tubes are hanged at the hottest part of the boiler. The saturated steam produced in the boiler tubes is superheated to about 540 °C in the superheater. The superheated high pressure steam is then fed to the steam turbine.
- **Economizer:** An economizer is essentially a feed water heater which heats the water before supplying to the boiler.
- **Air pre-heater:** The primary air fan takes air from the atmosphere and it is then warmed in the air pre-heater. Pre-heated air is injected with coal in the boiler. The advantage of pre-heating the air is that it improves the coal combustion.

Steam turbine: High pressure super heated steam is fed to the steam turbine which causes turbine blades to rotate. Energy in the steam is converted into mechanical energy in the steam turbine which acts as the prime mover. The pressure and temperature of the steam falls to a lower value and it expands in volume as it passes through the turbine. The expanded low pressure steam is exhausted in the condenser.

Condenser: The exhausted steam is condensed in the condenser by means of cold water circulation. Here, the steam loses it's pressure as well as temperature and it is converted back into water. Condensing is essential because, compressing a fluid which is in gaseous state requires a huge amount of energy with respect to the energy required in compressing liquid. Thus, condensing increases efficiency of the cycle.

Alternator: The steam turbine is coupled to an alternator. When the turbine rotates the alternator, electrical energy is generated. This generated electrical voltage is then stepped up with the help of a [transformer](#) and then transmitted where it is to be utilized.

Feed water pump: The condensed water is again fed to the boiler by a feed water pump. Some water may be lost during the cycle, which is suitably supplied from an external water source.

This was the **basic working principle of a thermal power station** and its typical components. A practical thermal plant possess more complicated design and multiple stages of turbine such as High Pressure Turbine (HPT), Intermediate Pressure Turbine (IPT) and Low Pressure Turbine (LPT).

Advantages And Disadvantages Of A Thermal Power Plant

Advantages:

- Less initial cost as compared to other generating stations.
- It requires less land as compared to hydro power plant.
- The fuel (i.e. coal) is cheaper.
- The cost of generation is lesser than that of diesel power plants.

Disadvantages:

- It pollutes the atmosphere due to the production of large amount of smoke. This is one of the causes of global warming.
- The overall efficiency of a thermal power station is low (less than 30%).

Efficiency Of A Thermal Power Station

A huge amount of heat is lost in various stages of the plant. Major part of heat is lost in the condenser. That is why the efficiency of thermal plants is quite low.

1. **Thermal Efficiency:** The ratio of 'heat equivalent of mechanical energy transmitted to the turbine shaft' to the 'heat of coal combustion' is called as thermal efficiency.

$$\text{Thermal Efficiency} = \frac{\text{Heat equivalent of mech. energy transmitted to the turbine shaft}}{\text{Heat produced by coal combustion}}$$

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Thermal efficiency of modern thermal power stations is about 30%. It means, if 100 calories of heat are produced by coal combustion, the mechanical energy equivalent of 30 calories will be available at the turbine shaft.

2. **Overall Efficiency:** The ratio of 'heat equivalent of electrical output' to the 'heat of coal combustion' is called as overall efficiency.

$$\text{Overall Efficiency} = \frac{\text{Heat equivalent of electrical output}}{\text{Heat produced by coal combustion}}$$

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The overall efficiency of a thermal plant is about 29% (slightly less than the thermal efficiency).

A **hydroelectric power plant**, also known as a hydro power plant, generates electricity by utilizing the gravitational force of falling or flowing water to drive a turbine connected to a generator. Here is a general layout of a hydro power plant:

1. **Dam:** The first component of a hydro power plant is a dam, which is built across a river or a water source to create a reservoir. The dam serves to raise the water level, creating a potential energy difference between the reservoir and the lower river or downstream.
2. **Intake Structure:** The intake structure is located at the base of the dam or on its side. It consists of gates or openings that control the flow of water into the power plant. The intake structure prevents debris and sediment from entering the power plant, ensuring clean water for power generation.
3. **Penstock:** The penstock is a large pipe or conduit that carries the water from the reservoir to the power plant. It is designed to withstand high water pressure. The penstock may be made of concrete, steel, or other materials depending on the size and capacity of the power plant.
4. **Turbine:** The water from the penstock is directed towards the turbine. The turbine converts the kinetic energy of the flowing water into mechanical energy by causing the turbine blades to rotate. There are different types of turbines used in hydro power plants, such as Francis turbines, Pelton turbines, and Kaplan turbines, depending on the head (height difference) and flow rate of the water.
5. **Generator:** The rotating shaft of the turbine is connected to a generator. As the turbine spins, it drives the generator, which converts the mechanical energy into electrical energy. The generator produces alternating current (AC) electricity.
6. **Transformer:** The electricity produced by the generator is initially at a relatively low voltage. It is then stepped up to a higher voltage using transformers. Higher voltage is advantageous for efficient transmission of electricity over long distances.
7. **Transmission Lines:** The electricity generated in the hydro power plant is transmitted through high-voltage transmission lines to distribution networks, where it can be distributed to homes, businesses, and industries.

8. **Control Room and Monitoring:** A hydro power plant typically has a control room where operators monitor and control various aspects of plant operations, including water flow, turbine speed, and electrical output. Advanced control systems and automation are used to optimize power generation and ensure safe and efficient operation.
9. **Spillway:** The spillway is an essential safety feature of a hydro power plant. It allows excess water from the reservoir to flow safely downstream, preventing overtopping of the dam during periods of high water flow or flooding.

It's important to note that the specific layout and design of a hydro power plant can vary depending on factors such as the type and capacity of the plant, head and flow rate of the water, environmental considerations, and site constraints. Additionally, some hydro power plants may incorporate additional components, such as fish passages or environmental monitoring systems, to minimize their impact on aquatic ecosystems.

Hydroelectric power plant

Working principle

Hydroelectric power plant (Hydel plant) utilizes the potential energy of water stored in a dam built across the river. The potential energy of the stored water is converted into kinetic energy by first passing it through the penstock pipe. The kinetic energy of the water is then converted into mechanical energy in a water turbine. The turbine is coupled to the electric generator. The mechanical energy available at the shaft of the turbine is converted into electrical energy by means of the generator. Because gravity provides the force which makes the waterfall, the energy stored in the water is called gravitational potential energy.

Water reservoir:

In a reservoir the water collected from the catchment area during the rainy season is stored behind a dam. Catchment area gets its water from rains and streams. Continuous availability of water is a basic necessity for a hydroelectric power plant. The level of the water surface in the reservoir is called the Headwater level. The water head available for power generation depends on the reservoir height.

Dam:

the purpose of the dam is to store the water and to regulate the out going flow of water. The dam helps to store all the incoming water. It also helps to increase the head of the water. In order to generate a required quantity of power, it is necessary that a sufficient head is available.

Spillway:

Excess accumulation of water endangers the stability of dam construction. Also in order to avoid the overflow of water out of the dam especially during rainy seasons spillways are provided. This prevents the rise of the water level in the dam. Spillways are passages that allow the excess water to flow to a different storage area away from the dam.

Gate:

A gate is used to regulate or control the flow of water from the dam.

Pressure tunnel:

It is a passage that carries water from the reservoir to the surge tank.

Surge tank:

A surge tank is a small reservoir or tank in which the water level rises or falls due to sudden changes in pressure. There may a sudden increase of pressure in the penstock pipe due to sudden backflow of water, as the load on the turbine is reduced. This sudden rise of pressure in the penstock pipe is known as water hammer.

Penstock:

Penstock pipe is used to bring water from the dam to the hydraulic turbine. Penstock pipes are made up of steel or reinforced concrete. The turbine is installed at a lower level from the dam. Penstock is provided with a gate valve at the inlet to completely close the water supply. It has a control valve to control the water flow rate into the turbine. Water turbine or hydraulic turbine (Prime mover): The hydraulic turbine converts the energy of water into mechanical energy. The mechanical energy (rotation) available on the turbine shaft is coupled

to the shaft of an electric generator and electricity is produced. The water after performing the work on the turbine blade is discharged through the draft tube.

The prime movers which are in common use are Pelton wheel, Kaplan turbine, Francis

Draft tube:

Draft tube is connected to the outlet of the turbine. It converts the kinetic energy available in the water into pressure energy in the diverging portion. Thus, it maintains a pressure of just above the atmospheric at the end of the draft tube to move the water into a tailrace. Water from the tailrace is released for irrigation purposes.

Tailrace level:

Tailrace is a water path to lead the water discharged from the turbine to the river or canal. The water held in the tailrace is called the Tailrace water level.

Power House:

The powerhouse accommodates the water turbine, generator, transformer, and control room. As the water rushes through the turbine, it spins the turbine shaft, which is coupled to the electric generator. The generator has a rotating electromagnet called a rotor and a stationary part called a stator. The rotor creates a magnetic field that produces an electric charge in the stator. The charge is transmitted as electricity. The step-up transformer increases the voltage of the current coming from the stator. The electricity is distributed through power lines.

Classification of Hydroelectric power plant

High head power plants: When the operating head of water exceeds 70 meters, the plant is known as High head power plant. Pelton wheel turbine is the prime mover used.

Medium head power plants: When the water ranges from 15 to 70 meters, then the power plant is known as a Medium head power plant. It uses Francis Turbine.

Low head power plants: When the head is less than 15 meters, the plant is named as Low head power plant. It uses Francis or Kaplan turbine as the prime mover.

Advantages of hydroelectric power plant

1. The water source is perennially available. No fuel is required to be burnt to generate electricity. It is aptly termed as 'the white coal'. Water passes through turbines to produce work and downstream its utility remains undiminished for irrigation of farms and quenching the thirst of people in the vicinity.
2. The running costs of hydropower installations are very low as compared to thermal or nuclear power stations. In thermal stations, besides the cost of fuel, one has to take into account the transportation cost of the fuel also.
3. There is no problem with regard to the disposal of ash as in a thermal station. The problem of emission of polluting gases and particulates to the atmosphere also does not exist. Hydropower does not produce any greenhouse effect, cause the pernicious acid rain and emit obnoxious NO.
4. The hydraulic turbine can be switched on and off in a very short time. In a thermal or nuclear power plant the steam turbine is put on turning gear for about two days during start-up and shut-down.
5. The hydraulic power plant is relatively simple in concept and self-contained in operation. Its system reliability is much greater than that of other power plants.
6. Modern hydropower equipment has a greater life expectancy and can easily last 50 years or more. This can be compared with an effective life of about 30 years of a thermal or nuclear station.
7. Due to its great ease of taking up and throwing off the load, hydropower can be used as the ideal spinning reserve in a system mix of thermal, hydro, and nuclear power stations.
8. Modern hydro-generators give high efficiency over a considerable range of load. This helps in improving the system efficiency.
9. Hydro-plants provide ancillary benefits like irrigation, flood control, afforestation, navigation, and aqua-culture.
10. Being simple in design and operation, the hydro-plants do not require highly skilled workers. Manpower requirement is also low.

Disadvantages of Water Power

1. Hydro-power projects are capital-intensive with a low rate of return. The annual interest of this capital cost is a large part of the annual cost of hydropower installations.
2. The gestation period of hydro projects is quite large. The gap between the foundation and completion of a project may extend from ten to fifteen years.

3. Power generation is dependent on the quantity of water available, which may vary from season to season and year to year. If the rainfall is in time and adequate, then only the satisfactory operation of the plant can be expected.
4. Such plants are often far away from the load center and require long transmission lines to deliver power. Thus the cost of transmission lines and losses in them are more.
5. Large hydro-plants disturb the ecology of the area, by way of deforestation, destroying vegetation and uprooting people. Strong public opinion against. The erection of such plants is a deterrent factor. The emphasis is now more on small, mini and micro hydel stations.

Hydroelectric power plant in India

- Srisaillam Hydel power plant – AP – 770 MW
- Upper sileru Hydor electric project – AP – 120
- Kodayar hydro electric power plant – TN – 100 MW
- Iddiki hydel project – Kerala – 800 MW