An electric power system is a network of electrical components deployed to supply, transfer, and use electric power. An example of a power system is the electrical grid that provides power to homes and industry within an extended area. The electrical grid can be broadly divided into the generators that supply the power, the transmission system that carries the power from the generating centers to the load centers, and the distribution system that feeds the power to nearby homes and industries. Smaller power systems are also found in industry, hospitals, commercial buildings and homes. The majority of these systems rely upon three-phase AC power—the standard for large-scale power transmission and distribution across the modern world. Specialized power systems that do not always rely upon three-phase AC power are found in aircraft, electric rail systems, ocean liners, submarines and automobiles.

## Evolution of Electric Power Systems

The commercial use of electricity began in the late 1870s when arc lamps were used for lighthouse illumination and street lighting. The history of the evolution of electric power system is discussed in this article.

### First Complete Electric Power System – 1882

The first complete electric power system (comprising a generator, cable, fuse, meter, and loads) was built by *Thomas Alva Edison* – the historic Pearl Street Station in New York City which began operation in September 1882.

This was a dc system consisting of a steam-engine-driven dc generator supplying power to 59 customers within an area roughly 1.5 km in radius. The load, which consisted entirely of incandescent lamps, was supplied at 110 V through an underground cable system. Within a few years similar systems were in operation in most large cities throughout the world. With the development of motors by Frank Sprague in 1884, motor loads were added to such systems. This was the beginning of what would develop into one of the largest industries in the world.

### Introduction of AC Systems – 1886

In spite of the initial widespread use of dc systems, they were almost completely superseded by ac systems. By 1886, the limitations of dc systems were becoming increasingly apparent. They could deliver power only a short distance from the generators.

To keep transmission power losses and voltage drops to acceptable levels, voltage levels had to be high for long-distance power transmission. Such high voltages were not acceptable for generation and consumption of power; therefore, a convenient means for voltage transformation became a necessity.

The development of the transformer and ac transmission by L. Gaulard and J.D. Gibbs of Paris, France, led to ac electric power systems. George Westinghouse secured rights to these developments in the United States.

In 1886, William Stanley, an associate of Westinghouse, developed and tested a commercially practical transformer and ac distribution system for 150 lamps at Great Barrington, Massachusetts.

With the development of polyphone systems by Nikola Tesla, the ac system became even more attractive.

By 1888, Tesla held several patents on ac motors, generators, transformers, and transmission systems. Westinghouse bought the patents to these early inventions, and they formed the basis of the present-day ac systems.

### Frequency – 50Hz vs. 60Hz

In the early period of ac power transmission, frequency was not standardized. Many different frequencies were in use: 25, 50, 60, 125, and 133 Hz.

This posed a problem for interconnection. Eventually 60 Hz was adopted as standard in North America, although many other countries use 50 Hz.

### HVDC Transmission Systems – 1950s

With the development of mercury arc valves in the early 1950s, high voltage dc (HVDC) transmission systems became economical in special situations.

- The HVDC transmission is attractive for transmission of large blocks of power over long distances. The cross-over point beyond which dc transmission may become a competitive alternative to ac transmission is around 500 km for overhead lines and 50 km for underground or submarine cables.
- HVDC transmission also provides an asynchronous link between systems where ac interconnection would be impractical because of system stability considerations or because nominal frequencies of the systems are different.

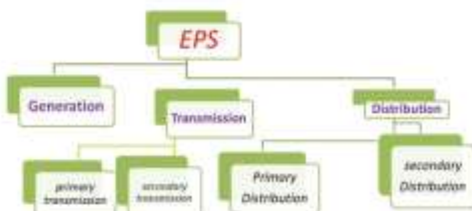
The first modern commercial application of HVDC transmission occurred in 1954 when the Swedish mainland and the island of Gotland were interconnected by a 96 km submarine cable.
With the advent of thyristor valve converters, HVDC transmission became even more attractive. The first application of an HVDC system using thyristor valves was at Eel River in 1972 – a back-to-back scheme providing an asynchronous tie between the power systems of Quebec and New Brunswick.
With the cost and size of conversion equipment decreasing and its reliability increasing, there has been a steady increase in the use of HVDC transmission.

- Interconnection of neighbouring utilities usually leads to improved system security and economy of operation. Improved security results from the mutual emergency assistance that the utilities can provide. Improved economy results from the need for less generating reserve capacity on each system.
- In addition, the interconnection permits the utilities to make economy transfers and thus take advantage of the most economical sources of power. These benefits have been recognized from the beginning and interconnections continue to grow.

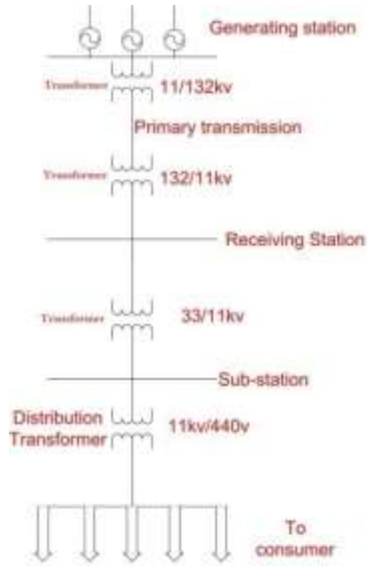
Almost all the utilities in the United States and Canada are now part of one interconnected system. The result is a very large system of enormous complexity. The design of such a system and its secure operation are indeed challenging problems.

**Structure of power system**

The electrical power system is divided into 3 parts as shown




Electricity is generated at generating station; there is a different type of generating station such as thermal power plant, hydropower plant, nuclear power plant etc. Then the power is transmitted through the transmission line by step up or step down the voltage level to the consumer by means of distribution.
Now-a-days, 3-phase, 3-wire a.c. the system adopted for generation and transmission of electric power as an economical proposition. However, distribution of electric power is done by 3-phase, 4-wire a.c. system. The underground system is more expensive than the overhead system. Therefore, in our country, the overhead system is adapted for transmission and distribution of electric power.
Fig showed below the structure of the electrical power system-




(i) **Generating station**

The electricity is generated in the power system by the alternator which operates in parallel with each other. The voltage usually generated by the alternator is about 11kv; for economical operation of power system the voltage is step up by means of a step-up transformer up to 132kv from 11kv.

(ii**) Primary transmission**

After generation of electricity from generating station by the alternator of 11kv is step up to 132kv by step-up transformer then it is transmitted by 3 phase 3 wire overhead line in the form of primary transmission.

(iii) Secondary transmission

After primary transmission, the primary transmission line is terminated at receiving station. At the receiving station, the voltage level of 132kv is reduced to 33kv by means of the step-down transformer. At the station, 33kv is transmitted to the various substation in form of secondary transmission.

(iv**) Primary distribution**

After the complete journey of secondary transmission, the secondary transmission line is terminated at the substation where the voltage level down by step down transformer from 33kv to 11kv.

**(v) Secondary distribution**

The secondary voltage level of primary distribution (11kv) is given to the secondary distribution, where the voltage is down up to 400v by means of the step-down distribution transformer by 3 phase 4 wire system to the consumer.

**Conventional sources of Electrical Energy**

Energy is one of the major parts of the economic infrastructure, being the basic input needed to sustain economic growth. There exists a strong relationship between economic development and energy consumption.

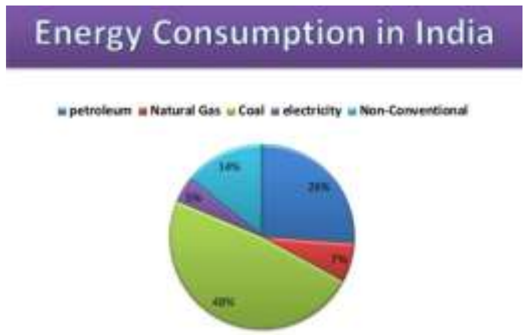
The more developed is a country; the higher is the per capita of energy consumption and vice-versa. Human civilization relies on different sources of energy.

**The two major sources of energy can be classified under:**

- Conventional Sources
- Non-Conventional Sources

**What is a conventional source of energy?**

When we cannot reuse a source of energy after using it once we call them **"**conventional sources of energy" or **"**non-renewable energy resources"**.** They are the most important conventional sources of energy. These include coal, petroleum, natural gas and nuclear energy. Oil is the most widely used source of energy. Coal, petroleum and natural gas account for about 90% of world's production of commercial energy and hydroelectric and nuclear power account for about 10%.




**Coal:**Coal is the most abundant conventional source of energy which could last for at least 200 years. It is a black-brown sedimentary rock. Formation of coal occurs when the remains of plants convert into lignite and then into anthracite. This involves a long process that takes place over a long period of time. Coal helps for various proposes such as heating of the house, as fuel for boilers and steam engines and for generation of electricity by thermal plants. It constitutes about 70% of total commercial energy consumption in the country.

**Oil**

Out of all the conventional sources of energy, oil is used abundantly all over. Considering, oil is one of the most important conventional sources of energy in India, the resources for same are even smaller. The extraction of oil from deposits is known as **oil resources.**

**Petroleum and Natural Gas:**

Petroleum is the mixture of hydrocarbons like alkanes and cycloalkanes. In crude form black liquid is known as petroleum and the formation of a natural gas occurs when the gas comes in contact with petroleum layer. Natural gas is a mixture of 50-90% of Methane, Ethane, Propane, Butane, and Hydrogen sulphide. After refining and purifying crude petroleum, it is available as petrol, diesel, lubricating oil, plastic etc. Natural gas is also making a significant contribution to the household sector. It causes less air pollution as compared to other fossil fuel.

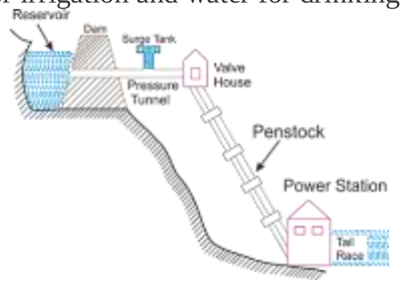
**Fuel Woods:**

Rural people use the fuel wood for their day to day cooking which comes from natural forests and plantations. The availability of fuel wood has become difficult due to rapid deforestation. We can avoid this problem by planting more trees on degraded forest land, culturable wasteland, and barren land grazing land.

**Nuclear energy:**

A small amount of radioactive substance can produce a lot of energy through the nuclear substances all over the world. In order to obtain nuclear energy, nuclear reactions are essential and there are about 300 nuclear reactions. Nuclear energy is one of the most environmentally friendly conventional sources of energy as it produces fewer greenhouse gas emissions during the production of electricity in comparison to sources like coal power plants. Although in case of accidents, this same nuclear energy releases in high amount in the environment. Also, the nuclear waste that remains is radioactive and hazardous.

**Hydroelectric Power Generation:** A Generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a Hydroelectric Power Station .Hydroelectric Power Station stations are generally located in hilly areas where dams can be built conveniently and large water reservoirs can be obtained. In a Hydroelectric 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. Hydroelectric Power Station is 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 drinking purposes.




**<u>Constituents of hydro power plant</u>**

**Dam.** A dam is a barrier which stores water and creates water head. Dams are built of concrete or stone masonary, earth or rock fill. The type and arrangement depends upon the topography of the site. A masonary 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.

**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.

**Headworks.** The headwork 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 though headwork should be as smooth as possible to avoid head loss and cavitations. For this purpose, it is necessary to avoid sharp corners and abrupt contractions or enlargements.

**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 .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.

**Penstocks.** Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. Concrete penstocks are suitable for low heads (< 30 m) as greater pressure causes rapid deterioration of concrete. The steel penstocks can be designed for any head; the thickness of the penstock increases with the head or working pressure.

**Water turbines**. Water turbines are used to convert the energy of falling water into mechanical energy. The principal types of water turbines are
(i) Impulse turbines
(ii) Reaction turbines

Impulse turbines are used for high heads Reaction turbines are used for low and medium heads

**Advantages:**

- It requires no fuel as water is used for the generation of electrical energy.
- It is quite neat and clean as no smoke or ash is produced.
- It requires very small running charges because water is the source of energy which is available free of cost.
- It is comparatively simple in construction and requires less maintenance.
- It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.
- It is robust and has a longer life.
- Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.

**Choice of Site for Hydro electric Power Stations:**

The following points should be taken into account while selecting the site for a Hydroelectric Power Station:

- **Availability of water.** Since the primary requirement of a Hydroelectric Power Station is the availability of huge quantity of water, such plants should be built at a place (e.g., liver, canal) where adequate water is available at a good head.
- **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 equalizing 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
- **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 withstand the weight of heavy equipment to be installed.
- **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.

**Nuclear Power Station:**

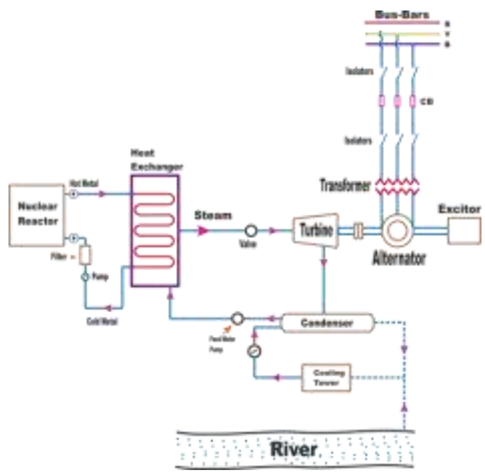
A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station, heavy elements such as Uranium ($U^{235}$) or Thorium ($Th^{232}$) are subjected to nuclear fission in a special apparatus known as a reactor**.** The heat energy thus released is utilized 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.

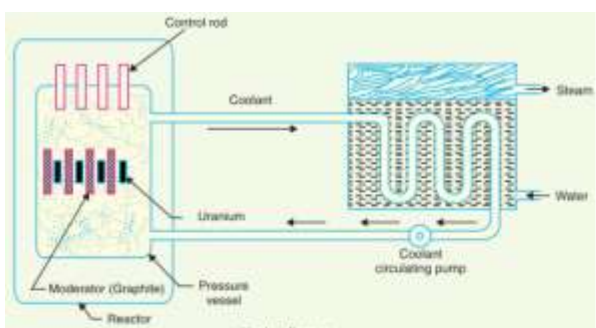
**Schematic Arrangement of Nuclear Power Station:**

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

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




**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.




Nuclear Reactor

A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods . 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

**Heat exchanger:** The coolant gives up heat to the heat exchanger which is utilized in raising the steam. After giving up heat, the coolant is again fed to the reactor.

**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.

**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 transformer, circuit breakers and isolators.

**Advantages:**

- The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.
- A nuclear power plant requires less space as compared to any other type of the same size.
- It has low running charges as a small amount of fuel is used for producing bulk electrical
- This type of plant is very economical for producing bulk electric power.
- It can be located near the load centers because it does not require large quantities of water and need not be near coal mines. Therefore, the cost of primary distribution is reduced.
- 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.
- It ensures reliability of operation.

**Disadvantages:**

- The fuel used is expensive and is difficult to recover.
- The capital cost on a nuclear plant is very high as compared to other types of plants.
- The erection and commissioning of the plant requires greater technical know-how.
- The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.
- Maintenance charges are high due to lack of standardization. Moreover, high salaries of specially trained personnel employed to handle the plant further raise the cost.
- Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.
- 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.

**Selection of Site for Nuclear Power Station**

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

- **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, g., across a river or by sea-side.
- **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.
- **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.

- **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.

## Thermal power station

A generating station which converts heat energy of coal combustion into electrical energy is known as a steam power station.

## Schematic Arrangement of Steam Power Station

The whole arrangement can be divided into the following stages for the sake of simplicity:

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

**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.

**2. 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 superheater, 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) Economise:** 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 preheate:** 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.

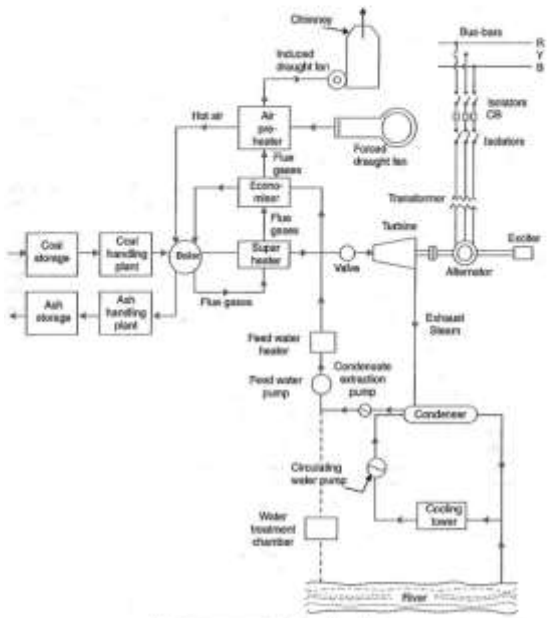
The principal benefits of preheating the air are: increased thermal efficiency and increased steam capacity per square meter of boiler surface.

**3. 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.

**4. 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.

**5. 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.

**6. 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 it 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.




Schematic arrangement of Steam Power Station

**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

(vi) 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.

**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

**<u>Choice of Site for Steam Power Stations</u>**

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.

**(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.

**(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 centers**. In order to reduce the transmission cost, the plant should be located near the centre of the load.

**(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