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**Sources of energy - Thermal power generation**

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**Objectives:** At the end of this lesson you shall be able to

- explain conventional and non-conventional energy source
  - state the various source of energy
  - state the type of fuels used for power generation
  - explain the working principle of thermal power station - coal and nuclear based
  - explain schematic arrangement and constituents of thermal, diesel and gas turbine power plants.
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**Introduction of power generation**

Energy is the basic necessity for the economic development of a country and it exists in different forms in nature. But the most important form is the electrical energy. The modern society is fully depend on the electrical energy and it has close relationship with standard of living. The per capita consumption of energy is the measure of standard of living of people.

**Sources of electrical energy**

Since electrical energy is produced from energy available in various forms in nature, it is desirable to look into the various sources of energy. The natural sources of energy which are used to generate the electricity are :

- i Sun
- ii Wind
- iii Water
- iv Fuels
- v Nuclear energy
- vi Tidal

Out of these sources, the energy due to Sun and wind has not been utilized on large scale due to a number of limitations. At present, the other three sources viz, water, fuels and nuclear energy are primarily used for the generation of electrical energy.

- i Sun :** The Sun is the primary source of energy. .Solar cells are the one of the methods which uses the heat energy of the sun to generate the electrical energy in present days. this method came into large application of solar cells to produce electricity,however, than the limitations as:
  - a) It requires a large area for the generation of even a small amount of electric power.
  - b) It cannot be used in cloudy days or at night
  - c) It is an uneconomical method compared to conventional method
- ii Wind:** This method can be used where wind flows for a considerable length of time. The wind energy is used to run the wind mill which drives a small generator.

In order to obtain the electrical energy from a wind mill continuously, the generator is arranged to charge the batteries which supply the energy even the wind stops. This method has the advantages that maintenance and generation costs are negligible. However, drawbacks of the method are that it is unreliable because of uncertainly about wind pressure and power generated is quite small.

- iii Water:** When water is stored at a suitable place, it possesses potential energy because of the head created. This water energy can be converted into mechanical energy with the help of water turbines. The water turbine drives the alternator which converts mechanical energy into electrical energy. This method of generation of electrical energy has become very popular because it has low production and maintenance costs.
- iv Fuels:** The main sources of energy are fuels viz. solid fuel as coal, liquid fuel as oil and gas fuel as natural gas. The heat energy of the fuels is converted into mechanical energy by suitable prime movers such as steam engines, steam turbines, internal combustion engines etc. The prime mover drives the alternator which covers mechanical energy into electrical energy. Although fuels continue to enjoy the place of chief source for the generation of electrical energy, yet their reserves are diminishing day by day. Therefore, the present trend is to harness water power which is more or less a permanent source of power.
- v Nuclear energy:** Towards the end of Second world War, it was discovered that large amount of heat energy is liberated by the fusion of uranium and other fissionable materials. It is estimated that heat produced by 1 Kg of nuclear fuel is equal to that produced by 27,50,000 kg of coal. The heat produced due to nuclear fission can be utilized to raise steam with suitable arrangements. The steam can run the steam turbine which in turn can drive the alternator to produce the electrical energy.

**Comparison of energy sources**

The main sources of energy used for the generation of electrical energy are water, fuels and nuclear energy. Below is given their comparison in a tabular form in Table 1.

Table 1

SI.No	Terms	Water Power	Fuels	Nuclear Energy
1	Initial cost	High	Low	Highest
2	Running cost	Less	High	Least
3	Reserves	Permanent	Exhaustible	Inexhaustible
4	Cleanliness	Cleanest	Dirtiest	Clean
5	Simplicity	Simplest	Complex	Most complex
6	Reliability	Most reliable	Less reliable	More reliable

### Types of fuels used for power generations

Fuels are categorized into Three; They are

- 1 Solid fuels
- 2 Liquid fuels
- 3 Gaseous fuels

#### Solid Fuels

This can further be classified an

- a Natural solid fuel
- b Artificial solid fuel

The natural solid fuels are wood and different variation of coal, while the artificial solid fuels are charcoal, coke and pulverized fuel.

#### Liquid Fuels

This can replace coal for the production of steam. The major petroleum products, considered an liquid fuels are the following.

- 1 Gasoline (Petrol)
- 2 Kerosene
- 3 Gas oil
- 4 Diesel

#### Gaseous Fuels

This fuel can be divided in the following categories.

- 1 Natural Gas - It is obtained from soil by mean of dup wells and it is pumped out.
- 2 Producer Gas - This is a mixture of CO and H<sub>2</sub> with a little CO<sub>2</sub>.
- 3 By product gases - This gas is obtained from blast furnace and coke ovens.

#### Advantages and disadvantages of liquid fuel

##### Advantages

- i The design and layout of the plant where liquid fuel is used are quite simple and it occupies less space as the number and size of the auxiliaries are small.

- ii Liquid fuel plant can be started quickly and can pick up the load in a short time.
- iii There are no stand by losses.
- iv The overall cost is much less than that of coal.
- v The thermal efficiency is higher than that of a coal.
- vi It requires less operating staff.

##### Disadvantages

- i The plant where liquid fuel is used has high running cost as the fuel (i.e. diesel) used is costly.
- ii The plant can generate only low power.

#### Advantage and disadvantage of solid fuel :-

##### Advantages

- i The fuel (i.e coal) used in quite cheap.
- ii The coal can be transported to the site of plant by rail or road.
- iii Solid fuel plant requires less space as compared to the hydro-electric power station.
- v The cost is lesser than that of diesel.

##### Disadvantages

- i It pollutes the atmosphere due to the production of large amount of smoke and fumes.
- ii It's handling cost is high.

#### Types of electrical power generation

Basically power generation are of two types

##### a Conventional power generation

Power generations by using non- renewable sources of energy through various methods such as hydro, thermal and nuclear etc is called conventional power generation. It contributes to the major power requirement.

##### b Non conventional power generation

Power generation by using renewable energy sources such as wind, Tide and sun etc, is called non-conventional power generation. They are small scale power generation used for specific purpose.

## Generating stations

Bulk electric power is produced by special plants known as generating station or power plants. A generating station employs a prime mover coupled with an alternator or generator for the production of electric power. The generated power is further transmitted and distributed to the customers.

Depending upon the form of energy converted into electrical energy the generating station are classified into,

- 1 Steam power stations /Thermal power stations
- 2 Hydro - electric power stations
- 3 Diesel power stations
- 4 Nuclear power stations
- 5 Gas - turbine power stations

### 1 Thermal /steam power station

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

The scheme of generation can be divided into two phases (i) Formation of steam in the boiler house (ii) Generation of electrical power in the generator room.

In the boiler the fuel is burnt and the water is converted into high pressure steam which is further super heated in a super - heater. The super - heated steam is passed in to the turbine to rotate the turbine blades, thus it converts the heat energy into electrical energy.

The turbine in the generation room acts as a prime mover of the alternator which generates electric energy. The alternator is connected through the circuit breaker to the bus bars.

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

### 2 Hydro - electric power station

A generating station which converts the energy possessed by the water into the electrical energy is known as hydro-electric power station.

Water is a great source of energy. There are two types of energies which the water can possess. The flowing water in stream may have only kinetic energy. The flowing stream of water may have both kinetic as well as potential energy or simply potential energy at some elevation with respect to a lower datum level. The practical examples of which are water - falls or water stored at the back of a dam. The water stored in the reservoir is allowed to fall on the blades of a water turbine placed at the foot of the dam.

The initial cost of harnessing water and converting the potential energy into electrical energy is quite high but recurring expenses etc. are quite less. So, the overall system will be very economical.

## 3 Nuclear Power Station

A generating station which converts the nuclear energy into the electric energy is called as nuclear power station.

The nuclear power obtained by nuclear fission is fast entering into arena of energy sources. The heat produced by nuclear fission of atomic material is utilized in special heat exchangers to produce steam to run steam turbines. The atomic materials utilized for nuclear fission are thorium and uranium. Another reason of fast development of nuclear power is that the natural resources of coal and petroleum will exhaust early if the pace of industrial development remained so fast.

## 4 Non conventional energy

It is evident that all energy resources based on fossil fuels has limitations in availability and will soon exhaust. Hence the long term option for energy supply lies only with non-conventional energy sources. These resources are in-exhaustible/do not deplete for the next hundreds of thousands of years.

For example electrical energy from solar energy, Bio-energy, Wind energy, Geothermal energy, Wave, Tidal and Micro-hydro.

### Choice of site for steam power stations

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

- Supply of fuel :** The steam power station should be located near the coal mines so that transportation costs of fuel is minimum. However, if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.
- 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.
- Transportation facilities :** A modern steam power station often requires the transportation of materials and machinery. Therefore, adequate transportation facilities must exist. i.e., the plant should be well connected to other parts of the country by rail, road etc.
- 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.

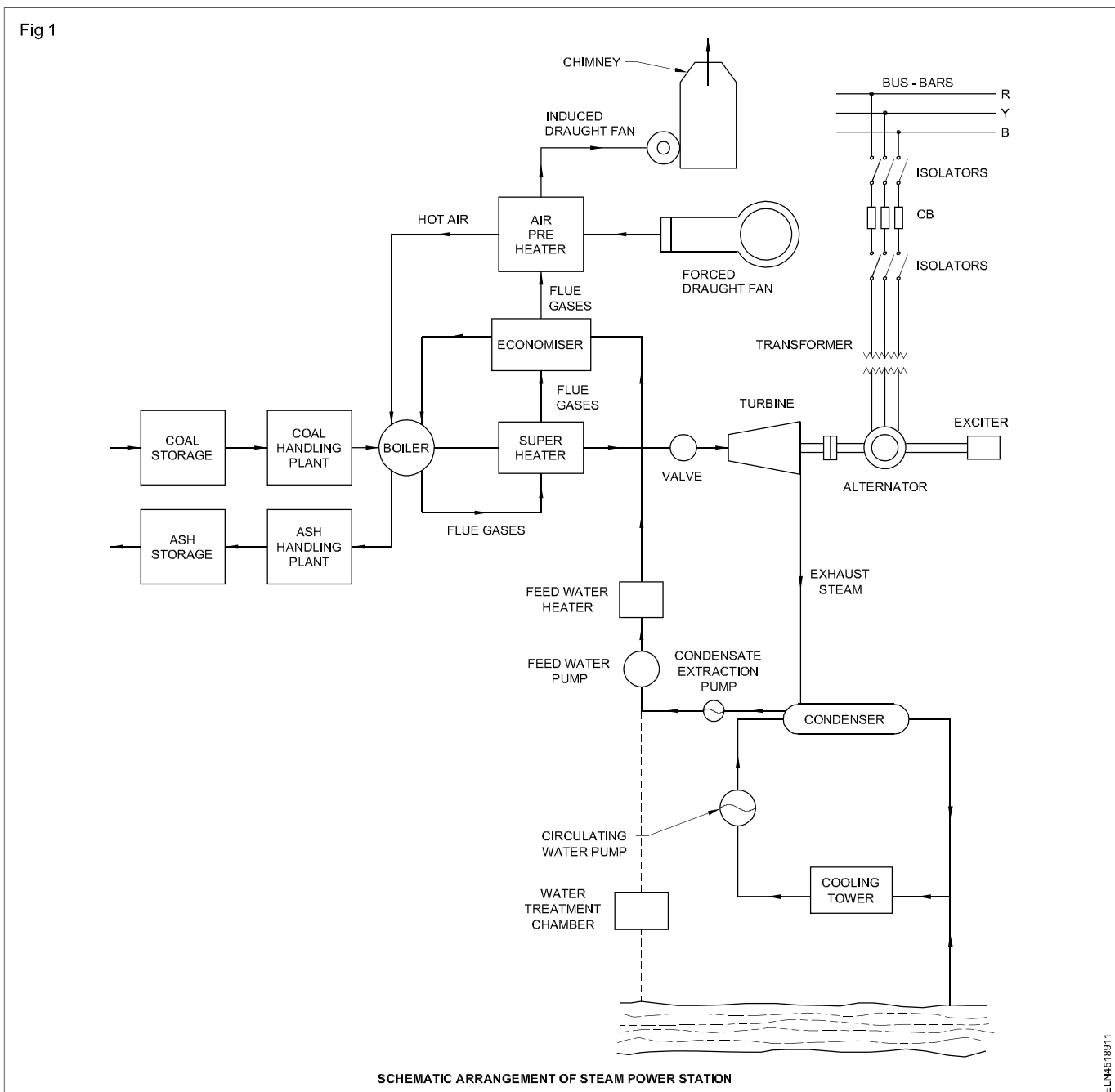
v **Nearness to load centers:** In order to reduce the transmission cost, the plant should be located near the center of the load. This is particularly important if DC supply system is adopted. However, if AC supply system, is adopted, this factor becomes relatively less important. It is because AC power can be transmitted at high voltages with consequent reduced transmission cost. Therefore, it is possible to install the plant away from the load centers, provided other conditions are favourable.

vi **Distance from populated area :** As huge amount of coal is burnt in a steam power station, therefore, smoke and fumes pollute the surrounding areas. This necessitates that the plant should be located at a considerable distance from the populated areas.

**Conclusion :** It is clear that all the above factors cannot be favorable at one place. However, keeping in view the fact that now- a -days the supply system in AC and more importance is being given to generation than transmission, a site away from the towns may be selected. In particular, a site by river side where sufficient water is available and fuel can be transported economically, may perhaps be an ideal choice.

### Schematic arrangement of steam power station

Although steam power station simply involves the conversion of heat of coal combustion into electrical energy, yet it embraces many arrangements for proper working and efficiency. The schematic arrangement of a modern steam power station is in Fig.1. 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

### Constituents in steam power station

A modern steam power station is highly complex and has numerous equipment and auxiliaries. However, the most important constituents of a steam power station are :

- 1 Steam generating equipment
- 2 Condenser
- 3 Prime mover
- 4 Water treatment plant
- 5 Electrical equipment

#### 1 Steam generating equipment

This is an important part of steam power station. It is concerned with the generation of superheated steam and includes such items as boiler, boiler furnace, super heater, economizer, air pre-heater and other heat reclaiming devices.

- i Boiler :** A boiler is closed vessel in which water is converted into steam by utilizing the heat of coal combustion. Steam boilers are broadly classified into the following two types.
- a Water tube boilers
  - b Fire tube boilers

In a water tube boiler, water flows through the tubes and the hot gases of combustion flow over these tubes. On the other hand, in a fire tube boiler, the hot products of combustion pass through the tubes surrounded by water. Water tube boilers have a number of advantages over fire tube boilers viz. require less space, smaller size of tubes and drum, high working pressure due to small drum, less liable to explosion etc. Therefore, the use of water tube boilers has become universal in large capacity steam power stations.

- ii Boiler furnace :** A boiler furnace is a chamber in which fuel is burnt to liberate the heat energy. In addition, it provides support and enclosure for the combustion equipment i.e burners. The boiler furnace walls are made of refractory materials such as fire clay, silica, kaolin etc. These materials have the property to resist change of shape, weight or physical properties at high temperatures.

The size of furnace has to be limited due to space, cost and other considerations. This means that furnace of a large plant should develop more kilo calories per square

metre of furnace which implies high furnace temperature.

- iii Super heater :** A super heater is a device which super heats the steam (i.e) it further raises the temperature of steam. This increases the overall efficiency of the plant. A super heater consists of a group of tubes made of special alloy steels such as chromium-molybdenum. The steam produced in the boiler is led through the super heater where it is superheated by the heat of flue gases. Super heaters are mainly classified into two types according to the system of heat transfer from flue gases of steam viz.

- a Radiant super heater
- b Convection super heater

- iv Economiser :** It is a device which heats the feed water on its way to boiler by deriving heat from the flue gases. This results in raising boiler efficiency, saving in fuel and reduces stresses in the boiler due to high temperature of feed water. An economizer consists of a large number of closely spaced parallel steel tubes connected by headers or drums. The feed water flows through these tubes and the flue gases flow outside. A part of heat of flue gases is transferred to feed water, thus raising the temperature of the latter.

- v Air Pre-heater :** Super heaters and economizers generally cannot fully extract the heat from flue gases. Therefore, pre - heaters are employed which recover some of the heat in the escaping gases. The function of an air pre-heater is to extract heat from the flue gases and give it to the air being supplied to furnace for coal combustion. This raises the furnace temperature and increases the thermal efficiency of the plant. Depending upon the method of transfer of heat from flue gases to air, air pre-heaters are divided into the following classes.

- a Recuperative type
- b Regenerative type

#### 2 Condensers

A condenser is a device which condenses the steam and the exhaust of turbine. It serves two important functions. Firstly, it creates a very low pressure at the exhaust of turbine, thus permitting expansion of the steam in the prime mover to a very low pressure. This helps in converting heat energy of steam into mechanical energy in the prime mover. Secondly, the condensed steam can be used as feed water to the boiler. There are two types of condensers, namely

- a Jet condenser
- b Surface condenser

#### 3 Prime movers

The prime mover converts steam energy into mechanical energy. There are two types of steam prime mover viz., steam engines and steam turbines. A steam turbine has several advantages over a steam engine as a prime mover

viz., high efficiency, simple construction, higher speed, less floor area requirement and low maintenance cost. Therefore, all modern steam power stations employ steam turbines as prime movers.

Steam turbines are generally classified into two types according to the action of steam on moving blades viz.

- a Impulse turbines
- b Reaction turbines

In an impulse turbine, the steam expands completely in the stationary nozzles (or fixed blades), the pressure over the moving blades remaining constant. In doing so, the steam attains a high velocity and the impulsive force on the moving blades which sets the rotor rotating.

In a reaction turbine, the steam is partially expanded in the stationary nozzles, the remaining expansion take place during its flow over the moving blades. The results is that the momentum of the steam causes a reaction force on the moving blades which sets the rotor in motion.

#### 4 Water treatment plant

Boilers require clean and soft water for longer life and better efficiency. However, the source of boiler feed water is generally a river or lake which may contain suspended and dissolved impurities, dissolved gases etc. Therefore, it is very important that water is first purified and softened by chemical treatment and then delivered to the boiler

The water from the source of supply is stored in storage tanks. The suspended impurities are removed through sedimentation, coagulation and filtration. Dissolved gases etc, are removed by aeration and degasification. The water is then 'softened' by removing temporary and permanent hardness through different chemical processes. The pure and soft water thus available is fed to the boiler for steam generation.

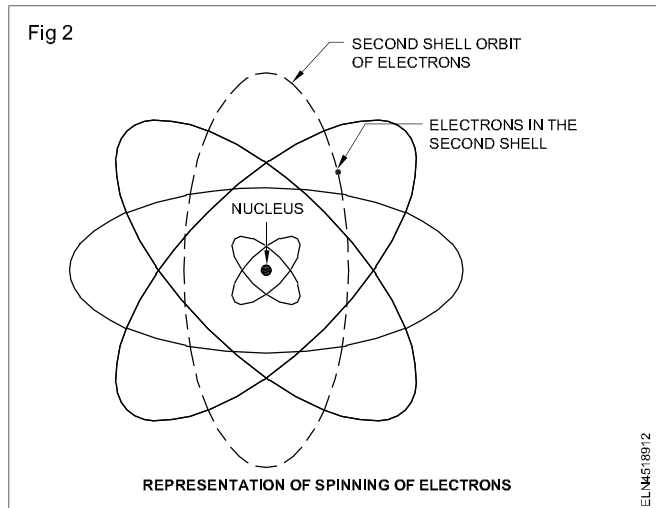
#### Nuclear based thermal power stations

##### Composition of an atomic nucleus

A matter is said to be composed of small particles called atoms and the atom itself is composed protons, neutrons and electrons, arranged in a particular fashion. The centre of the atom consists of a very dense nucleus formed by protons and neutrons. Around the nucleus the electrons revolve in orbit. The system so formed is similar to that of planetary system as shown in Fig 2. The radius of the nucleus is about  $10^{-12}$  cm. While that of electron orbit is about  $10^{-5}$  cm.

The important properties of the atomic structure are:

The mass of proton and neutrons is almost same while the mass of each electron is 1/1840 times that of a proton or neutron which shows that the mass of an atom is only due to the nucleus. From avogadro's hypothesis, the number of atoms in a gram atom is  $6.03 \times 10^{23}$  (actually its mass is 1.008 gm)



$$= \frac{1.008}{6.03 \times 10^{23}}$$

$$= 1.67 \times 10^{-24} \text{ gm} = 1.67 \times 10^{-27} \text{ kg} \dots \dots \dots (1)$$

The mass of 1 electron

$$= \frac{1.67 \times 10^{-27}}{1840} = 9.10 \times 10^{-31} \text{ kg} \dots \dots \dots (2)$$

It has been practically observed that, to deposit 1 molecule gram of hydrogen 96,493.7 coulombs of electricity are required.

So, charge on each electron

$$= \frac{96.493.7}{6.03 \times 10^{23}}$$

$$= 1.602 \times 10^{-19} \text{ coulombs} \dots \dots \dots (3)$$

The charge of proton is the same as that of electron

$$= 1.602 \times 10^{-19} \text{ coulombs} \dots \dots \dots (4)$$

The charge and mass of an electron, proton and neutron can be summarized as.

Name of atomic ingredient	Electric charge in coulomb	Mass in kilogram	Mass in atomic mass unit (a.m.u)*
1. Electron	$-1.602 \times 10^{-19}$	$9.10 \times 10^{-31}$	0.000, 548
2. Proton	$+1.602 \times 10^{-19}$	$1.67 \times 10^{-27}$	1.00,758
3. Neutron	0	$1.67 \times 10^{-27}$	1.00,898

\*1 a.m.u =  $1.6597 \times 10^{-19}$  kg.

**Atomic number and mass number:** The chemical properties of an atom depend on the number of protons present in the nucleus.

The atomic number of an atom is defined as the number of protons present in the nucleus of an atom and is represented as Z.

Let, N be equal to number of neutrons in the nucleus. The mass number (A) is given as.

$$A = Z + N$$

The advantage of atomic number and mass number is that this represents an atom uniquely. Thus, for example sodium atom is represented as  ${}_{11}^{23}\text{Na}$ , where, the prefix represents the atomic number (Z) and suffix represents mass number (A), i.e. 11 is atomic number and 23 is mass number.

The number of neutron (N) presents in the atom can be determined by

$$N = A - Z = 23 - 12$$

$$= 11$$

The atomic number, mass and number of neutrons for some elements are listed in Table 1.

Table 1

Element	Symbol	Atomic number = Z	Mass No = A	Neutrons A - Z
Hydrogen	${}_{1}\text{H}_1$	1	1	0
Helium	${}_{2}\text{He}_4$	2	4	2
Oxygen	${}_{8}\text{O}_{16}$	8	16	8
Uranium	${}_{92}\text{U}_{238}$	92	238	146

### 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 ( $\text{U}^{235}$ ) or Thorium ( $\text{Th}^{232}$ ) 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 into the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

The most important features of a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power station. Although the extracting of the nuclear fuels (i.e. Uranium and Thorium) is difficult and expensive, yet the total energy content are considerably higher than those of conventional fuel, viz. coal, and gas.

### 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 energy.
- 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 extract.
- The capital cost on a nuclear plant is very high as compared to other types of plants.
- The erection and commissioning of the requires greater technical know-how.
- The fission by products are generally radio-active 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 waste, which are radioactive, is a big problem. They should either be disposed off in a deep trench or in the sea away from the sea-shore.

### Schematic arrangement of nuclear power station

The schematic arrangement of a nuclear power station is in Fig 3. The whole arrangement can be divided into the following main stages.

- Nuclear reactor
- Heat exchanger
- Steam turbine
- Alternator
- Nuclear reactor :** It is an apparatus in which nuclear fuel ( $\text{U}^{235}$ ) is subjected to nuclear fission. It controls the chain reaction that starts once the fission is done. If the chain reaction is not controlled, the result will be an

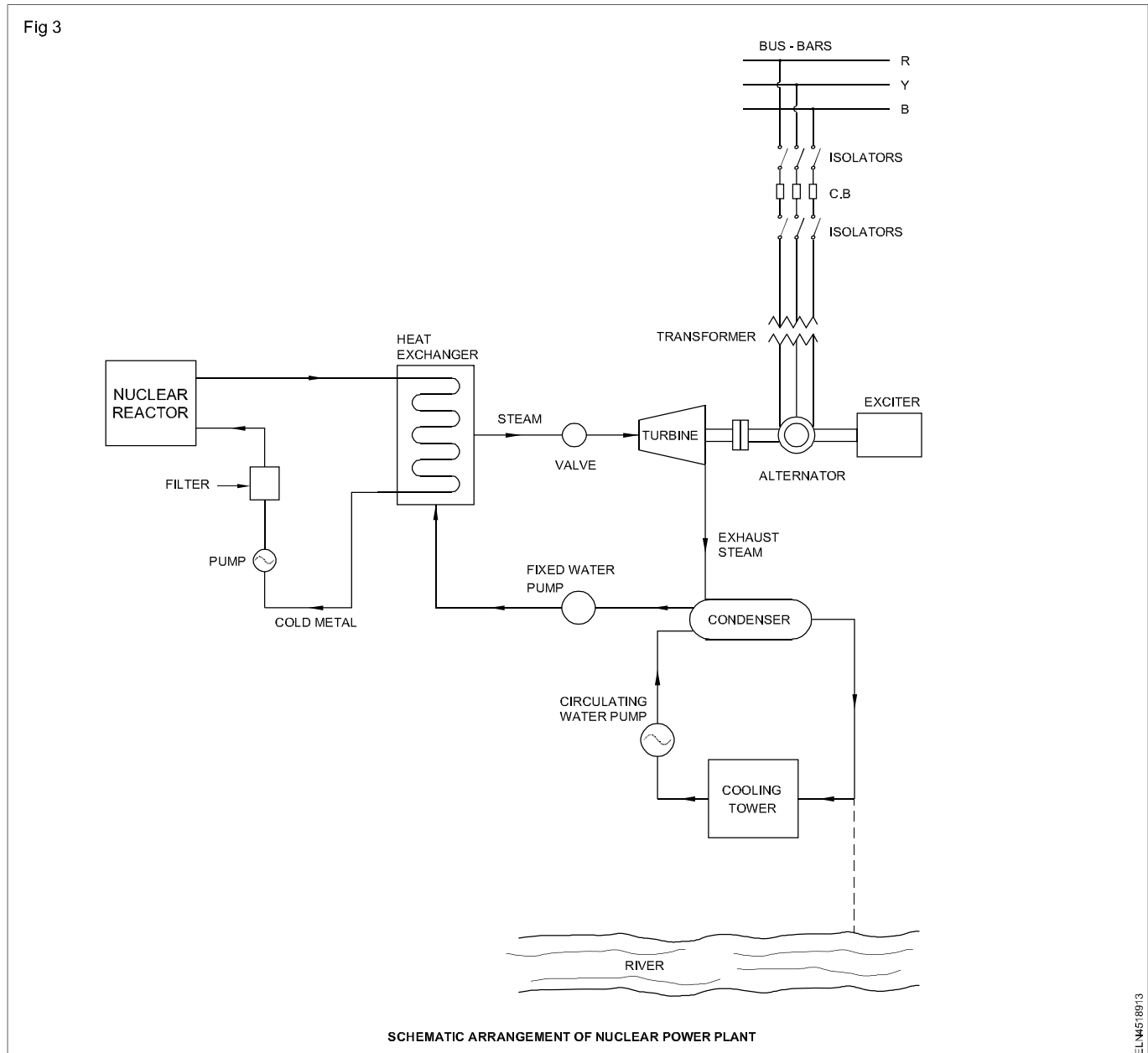
explosion due to the fast increase in the energy released.

A nuclear reactor is a cylindrical stout pressure vessel and houses fuel rods of Uranium, moderator and control rods (Fig 4).

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 central rods is accomplished automatically according to the requirement of rod. The heat produced in the reactor is removed by the coolant, generally in a sodium metal. The coolant carries the heat to the heat exchanger.

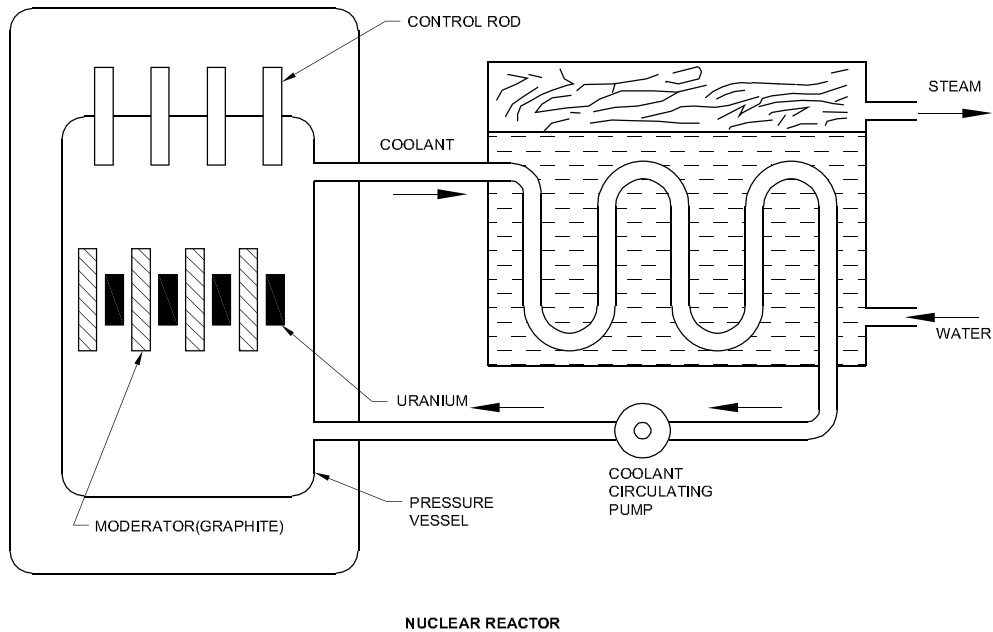


ii **Heat exchanger** : The coolant gives up heat to the heat exchanger which is utilized in raising the steam. After giving up heat, the coolant is again fed to the reactor.

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



Fig 4



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**iv Alternator :** The steam turbine drives the alternator which converts mechanical energy into electrical energy. The output from the alternator is delivered to the bus-bars through transformer, circuit breaker and isolators.

**Selection of site for nuclear power station**

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

- i Availability of water :** As sufficient water is required for cooling purposes, therefore, the plant site should be located where ample quantity of water is available e.g. across a river or by sea - side.
- ii Disposal of waste :** The waste produced by fission in a nuclear power station is generally radioactive which must be disposed off properly to avoid health hazards. The waste should either be buried in a deep trench or disposed off in the sea quite away from the sea shore. Therefore, the site selected for such a plant should have adequate arrangement for the disposal of radioactive waste.
- iii Distance from populated areas :** The site selected for a nuclear power station should be quite away from the populated areas as there is a danger of presence of radio - activity in the atmosphere near the plant.

However, as the precautionary measure, a dome is used in the plant which does not allow the radioactivity to spread by wind or underground waterways.

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

From the above mentioned factors it becomes apparent that ideal choice for a nuclear power station would be near

sea or river and away from thickly populated areas.

**Nuclear reactors**

Nuclear reactors may be classified on the following basis.

- A) On the basis of neutron energy
  - 1 Thermal reactors
  - 2 Fast breeder reactors
- B) On the basis of fuel used
  - 1 Natural uranium
  - 2 Enriched uranium
- C) On the basis of moderator used
  - 1 Graphite reactors
  - 2 Beryllium reactors
- D) On the basis of coolant used
  - 1 Water cooled reactors (ordinary or heavy)
    - i Boiling water reactor
    - ii Pressurized water reactor
  - iii Heavy water cooled and moderated reactor
  - 2 Gas cooled reactors
  - 3 Liquid metal cooled reactors
  - 4 Organic liquid cooled reactors
- E) On the basis of type of core used
  - 1 Homogenous reactors
  - 2 Heterogeneous reactors

**Boiling water reactor (BWR)**

In this reactor fuel used is enriched uranium. Water is used as both the moderator and coolant. As is clear from its name it utilizes light water as a coolant. In this case the

steam is generated in the reactor itself. Feed water enters the reactor tank at the bottom and takes up the heat generated due to the fission of fuel and gets converted into steam.

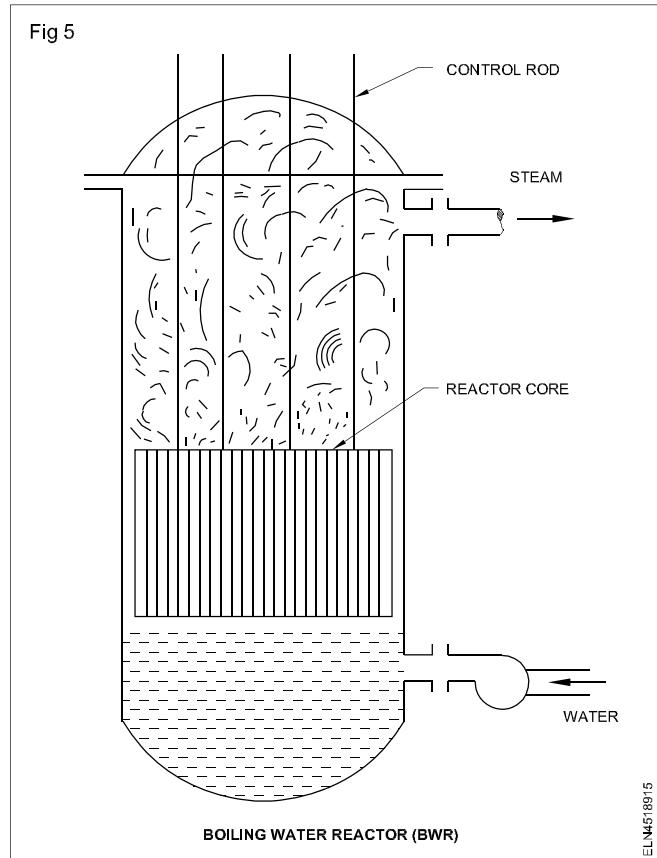
Steam leaves the reactor at the top and flows into the turbine. Uranium fuel elements are arranged in a particular lattice form inside the pressure vessel containing water. Feed water passes through fuel elements in the core as coolant and also as moderator. Fig 5 shows a boiling water reactor.

### Advantages

- 1 Heat exchanger circuit is eliminated and as a result there is reduction in cost and gain in thermal efficiency (30% to 20% for a pressure water reactor (PWR)).
- 2 As water is allowed to boil inside the reactor the pressure inside the reactor vessel is considerably lower than in the case of a PWR. As a result the reactor vessel can be made much lighter reducing its cost considerably.
- 3 The BWR cycle is more efficient than the PWR cycle since for a given containment pressure the outlet temperature of steam is appreciably higher in a BWR.
- 4 The metal surface temperature is lower than in the case of a PWR since boiling of water is inside the reactor.
- 5 A BWR is more suitable than a PWR, (In fact BWR is commonly known as a self - controlled reactor)

### Disadvantages

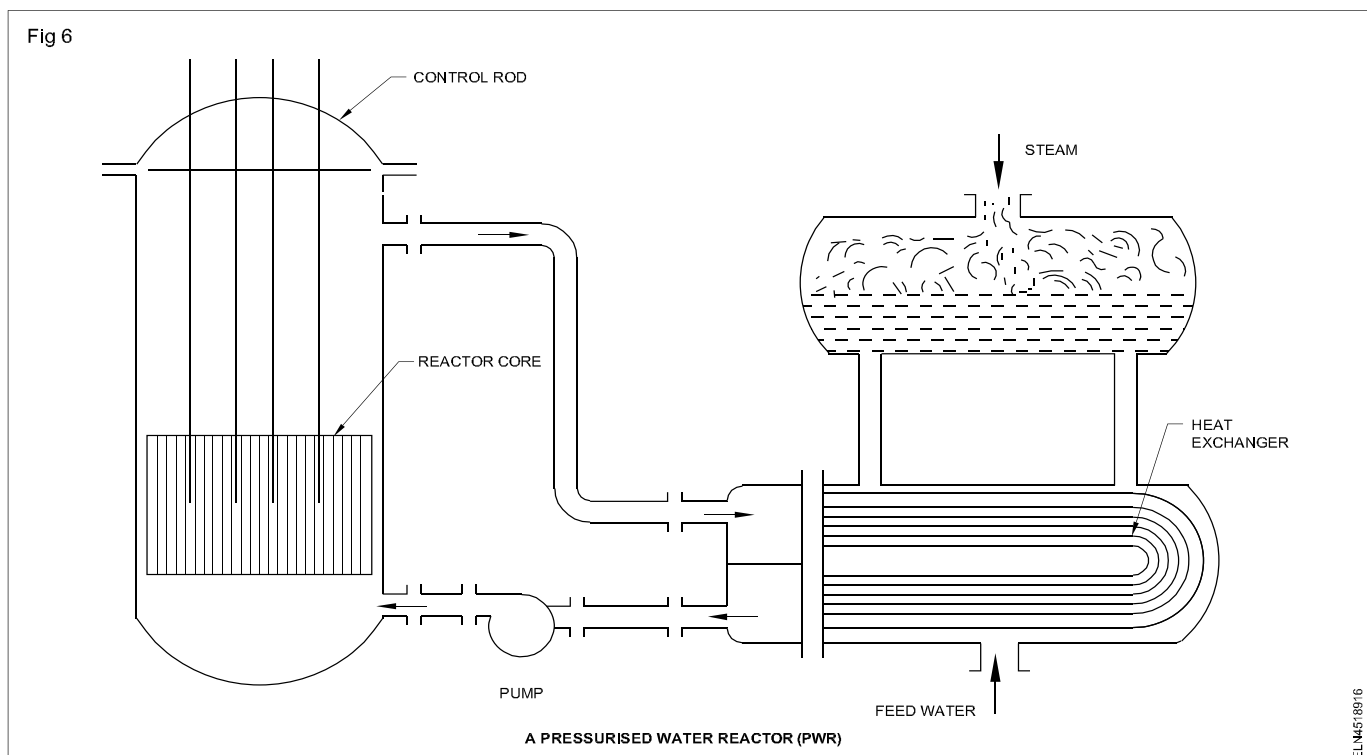
- 1 There is a possibility of radio - active contamination in the turbine mechanism should there occur any failure of fuel elements. Therefore more elaborate safety measures are needed. This increases the cost.

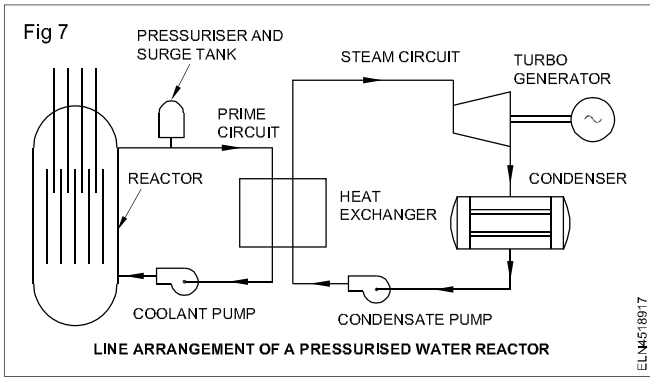


- 2 There is wastage of steam resulting in lowering of thermal efficiency on part load operation.

### Pressurized Water Reactor (PWR)

A pressurized water reactor is in Fig 6. The line arrangement of such a reactor with heat exchanger in circuit is in Fig 7.





The fuel used is enriched uranium clad with stainless steel or zirconium alloy and water under pressure is used as both moderator and coolant. This type of reactor is designed to prevent the boiling of the water coolant in the uranium core. A pump circulates water at high pressure (as high as 140 Kg/cm<sup>2</sup>) round the core so that water in liquid state absorbs heat from the uranium and transfer it to the secondary loop-the boiler. The boiler has a heat exchanger and a steam drum.

A pressuriser and surge tank tapped into the pipe loop maintains constant pressure in the water system throughout the load range. An electric heating coil in the pressuriser boils the water to form steam which is collected in the dome; this steam pressurizes the entire coolant circuit. Water spray is used to condense the steam when pressure is desired to be reduced.

Since water is passing through the reactor becomes radio - active the entire primary circuit including heat exchanger has to be shielded.

### Advantages

- 1 A PWR is relatively compact in size compared with other types.
- 2 There is a possibility of breeding plutonium by providing a blanket of U-238.
- 3 The reactor has a high power density.
- 4 Due to use of heat exchanger containment of fission products is possible.
- 5 An inexpensive substance (light water) can be used as moderator - cum-coolant-cum-refractor.
- 6 The reactor responds to supply more power when the load increases. (The positive power demand co-efficient makes this almost automatic)

### Disadvantages

- 1 The moderator remains under high pressure; a strong pressure vessel is required.
- 2 Expensive cladding material is required to prevent corrosion.
- 3 There is heat loss due to use of heat exchanger.
- 4 In comparison to other types more elaborate safety devices are required.

- 5 The reactor lacks flexibility; this requires the reactor to be shut down before recharging and there is difficulty in fuel element design and fabrication.
- 6 The thermal efficiency of a PWR is as low as 20%

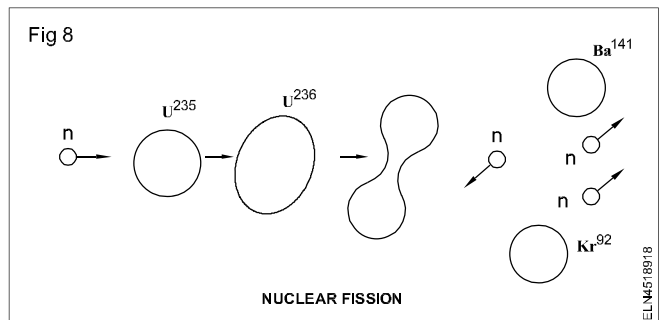
Less compared with that required for PWRs and BWRs. Amongst disadvantages are : the extremely high cost of heavy water, problem of leakage and very high standard of design etc.

### Nuclear fission and fusion

Nuclear fission : When an uranium nucleus is bombarded with a slow moving neutron, it exploded into two nearly equal fragments of Barium and Krypton.

The process of breaking up of the nucleus of a heavy atom into two fragments with the release of large amount of energy is known as fission. The fission is accompanied by the release of three neutrons and energy in the form of  $\gamma$ -rays.

Fig 8 shows that the compound nucleus undergoes distortion due to the excitation energy to attain the shape of a dumb-bell and finally splits up into fission products Ba<sup>141</sup> and Kr<sup>92</sup> with the release of three neutrons.



It was observed that Barium and krypton were not the only products of fission, the isotopes of different elements in the atomic number range from 34 to 58 were also obtained as the fission products.

### Chain reaction

The process of nuclear fission usually results in the emission of two or three free neutrons per fission besides the other fission fragments.

When  ${}_{92}\text{U}^{235}$  nucleus splits up, it generally release three neutrons. One of the neutrons may escape without hitting any other uranium nucleus and thus get lost. The other two may strike against other fissionable nuclei to produce further fission, accompanied by the release of still more neutrons and so on. Thus more than one neutron per fission is produced on the average.

The number of fissions taking place at each successive stage goes on increasing at a rapid rate, giving rise to what is called chain reaction. A chain reaction can be set up only if the mass of the fissionable material is greater than a critical mass.

## Hydel power plants

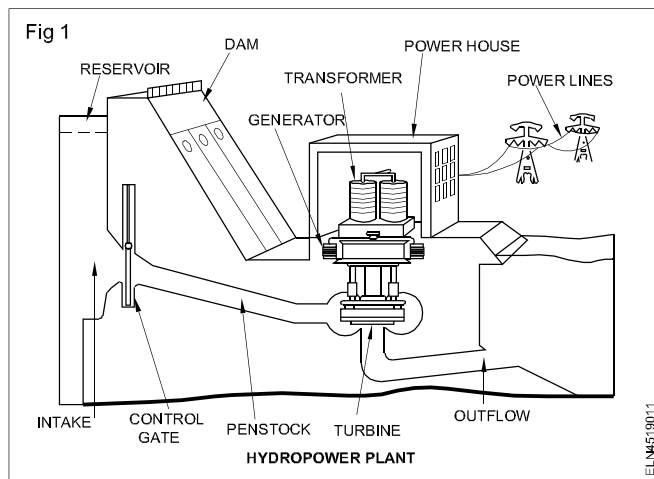
**Objectives:** At the end of this lesson you shall be able to

- state the types of hydro- electric power station
- state the advantage & disadvantage of hydro electric power station over thermal power station
- list out the reason for selecting the site of a hydro electric power station
- explain the schematic arrangement of hydro electric power station
- state the turbines used in hydro electric power station with suitable reasons
- state the classification of hydro electric power station.

### Hydro - electric power stations

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as "Hydro-electric power station".

A basic model of a H.E.P generation is illustrated in Fig 1 is known as hydro - electric power station.



Hydro - electric power stations are generally located in hilly areas where dams can be built conveniently and large water reservoirs can be obtained. From the dam, water is led to a water turbine. The water turbine captures the energy in the falling water and changes the hydraulic energy (i.e product of head and flow of water) into mechanical energy at the turbine shaft.

The turbine drives the alternator which converts mechanical energy into electrical energy. Hydro electric power stations are becoming very popular because the reserves of fuels (i.e coal and oil) are depleting day by day.

### 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 cost.
- It is comparatively simple in construction and requires less maintenance.

- It does not requires 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.
- Although such plants require the attention of highly skilled persons at the time of construction, yet for operation, a few experienced persons may do the job well.

### Disadvantages

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

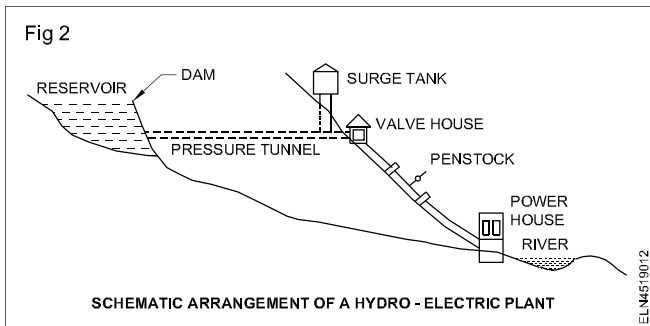
### Choice of site for hydro - electric power stations

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

- Availability of water :** Since the primary requirement of a hydro - electric power stations is the availability of huge quantity of water, such plants should be built at a place (e.g. river, canal) where adequate water is available at the 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.
- 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 withstands the weight of heavy equipment to be installed.

**vi Transportation facilities :** The site selected for hydro - electric plant should be accessible by rail and road so that necessary equipment and machinery could be easily transported

**Schematic arrangement of hydro - electric power station :** (Fig 2)



The schematic arrangement of a modern hydro - electric plant is shown in Fig. 2. The dam is constructed across a river or lake and water from the catchment area collects at the back of the dam to form a reservoir. A pressure tunnel is taken off from the reservoir and water brought to the valve house at the start of the Penstock.

The valve house contains main sluice valves and automatic isolating valves. The former controls the water flow to the power house and the latter cuts off supply of water flow to the power house when the penstock bursts. From the valve house, water is taken to water turbine through a huge steel pipe known as penstock . The water turbine converts hydraulic energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy.

**Constituents of Hydro - Electric Plant**

The constituents of hydro - electric plant are (1) hydraulic structures (2) water turbines and (3) electrical equipment.

**1 Hydraulic Structures**

Hydraulic structures in a hydro electric power station include dam, spillways, headworks, surge tank, penstock and accessory works.

- i Dam :** A dam is a higher barrier which stores water and creates water head. Dams are built of concrete or stone masonry, earth or rock fill. The type and arrangement depends upon the topography of the site. The type of dam also depends upon the foundation conditions, local materials and transportation available, occurrence of earthquakes and other hazards.
- ii Spillways :** There are times when the river flow exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down - stream side of the dam, spillways are used.
- iii Headworks :** The headworks consists of the diversion structures at the head of an intake. They generally

include booms and racks for diverting floating debris, sluices for by - passing the debris and sediments and valves for controlling the flow of water to the turbine. The flow of water into and through head works should be as smooth as possible to avoid the head loss and cavitation. For this purpose, it is necessary to avoid sharp corners and abrupt contractions or enlargements.

**iv Surge tank :** Open conduits which leading the water to the turbine require no protection. However, when closed conduits are used, protection becomes necessary to limit the abnormal pressure in the conduit. For this reason, closed conduits are always provided with a surge tank. a surge tank is a small reservoir or tank (open at the top) in which water level rises or falls to reduce the pressures 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 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.

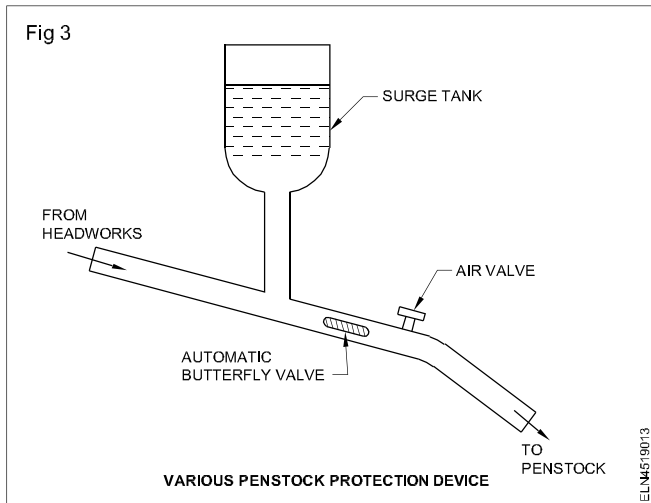
The excess water at the lower end of the conduit rushes back to the surge tank and increases its water level. Thus the conduit is prevented from bursting. On the other hand, when load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirement. Hence, a surge tank overcomes the abnormal pressure in the conduit when load on the turbine falls and acts a reservoir during increase of load on the turbine.

**(v) Penstocks :** Penstocks are open or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel. The thickness of the Penstock increases with the head or working pressure

Various devices such as automatic butterfly valve, air valve and surge tank are provided for the protection of penstocks. Automatic butterfly valve shuts off water flow through the penstocks promptly of its ruptures. Air valve maintains the air pressure inside the penstock equal to outside atmospheric pressure.

When water run out of a penstock faster than it enters, a vacuum is created which may cause the penstocks to collapse. Under such situations, air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure. A typical penstock protective device is in Fig 3.

**(vi) Tail race :** The tail race is the channel which carries water (known as tail water) away from the power house after it has passed through the turbine. It may be the natural stream channel or a specially excavated channel entering the natural stream at some point down stream from the power house. The water surface in the tail race is known as tail race level or simply the tail race.



**(vii) Draft tube :** In the case of a reaction turbine there is a pressure difference existing between water in the turbine and atmosphere. Therefore this type turbine must be completely enclosed. Accordingly it is necessary to connect the turbine outlet by means of a pipe or a passage of gradually increasing cross sectional area up to tail race level.

A draft tube has two important purposes to serve.

- 1 It permits a negative or suction head to be established at the runner exit thus making it possible to install the turbine above the tail race level without loss of head.
- 2 It converts a large proportion of the velocity energy rejected from the runner into useful pressure head i.e it acts as a recuperator of pressure energy.

## 2 Water turbine

Water turbines are used to convert the energy of falling water into mechanical energy. The principal types of water turbines are :

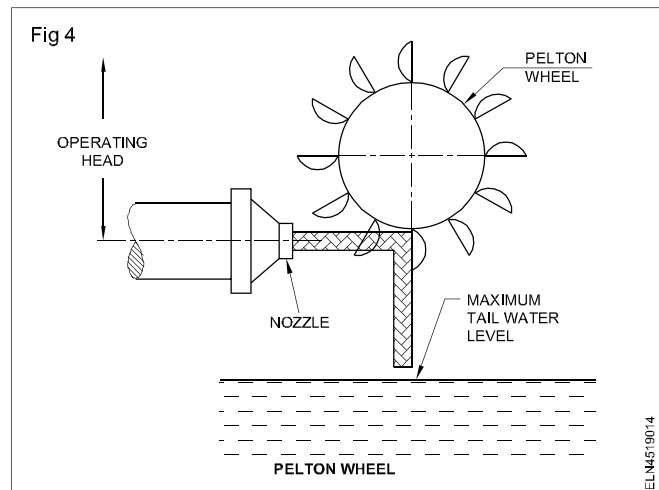
- i Impulse turbines
- ii Reaction turbines

**i Impulse turbines :** Such turbines are used for high heads. In an impulse turbines, the entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel i.e, pelton wheel as in Fig 4. It consists of a wheel fitted with elliptical buckets along its periphery. The force of water jet striking the bucket on the wheel drives the turbine. The quantity of water jet falling on the turbine is controlled by means of needle or spear (not shown in the figure) placed in the tip of the nozzle.

The movement of the needle is controlled by the governor. If the load on the turbine decreases the governor pushes the needle into the nozzle, thereby reducing the quantity of water striking the bucket. Reverse action takes place if the load on the turbine increases.

**ii Reaction turbines :** Reaction turbines are used for low and medium heads. In a reaction turbine water enters the runner partly with pressure energy and

partly with velocity head. The important types of reaction turbine are.



- a. Francis turbines
- b. Kaplan turbines

A Francis turbine is used for low to medium heads. It consists of an outer ring of stationary guide blades for the turbine casing and an inner ring of rotating blades forming the runner. The guide blades control the flow of water to the turbine. Water flows radially inwards and changes to a downward direction while passing through the runner. As the water passes over the rotating blades of the runner, both pressure and velocity of water are reduced. This causes a reaction force which drives the turbine.

A Kaplan turbine is used for low heads and large quantities of water. It is similar to a Francis turbine except that the runner of a Kaplan turbine receives water axially. Water flows radially inwards through regulating gates all round the sides, changing direction in the runner to axial flow causes a reaction force which drives the turbine.

## 3 Electrical equipment

The electrical equipment of a hydro - electric power plant includes alternators, transformers, circuit breaker and switching and protective devices.

### Types of hydro - electric plants

There are three different methods of classifying the electric plants. The classification may be based on,

- a Quantity of water available
- b Available head
- c Nature of load

### Classification of Hydro - electric plants according to quantity of water available.

According to this classification, the plants may be divided into.

- i Run - off river plants without pondage

ii Run - off river plants with pondage

iii Reservoir plants

**i Run off river plants without pondage**

As the name indicates this type of plant does not store water. The plant uses water as it comes. The plant can use water only as and when available.

**ii Run- off river plants with pondage**

Usefulness of a run - off river plant is increased by pondage. Pondage permits storage of water during the off - peak periods and use of this water during the peak periods.

**iii Reservoir plants**

Water is stored behind the dam and is available to the plant with control as required. Such a plant has better capacity and can be used efficiently throughout the year.

**Classification of hydro - electric plants according to available head**

Hydro - electric plants may be classified into high - head, medium - head and low head plants. A plant may be classified as high - head if operating on a head above 300 meters. Low - head plants work under heads below 30 metres. Medium - head plants are those lying between the above two classes.

In the case of high - head plants water in due to rains or melting of snow is stored at high elevation. A low - head plant stores water by the construction of a dam across a river and the power plant is installed near the base of the dam of the down - stream side. The medium - head plant is similar to the low - head plant but works on a head of about 30 to 300 m.

**Classification of Hydro- electric plants according to nature of load**

Hydro - electric plants may be classified in to base load peak load and pumped storage plants for peak load.

## **Visiting of electrical substation**

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**Objectives:** At the end of this lesson you shall be able to

- **state the initial preparatory work before commencing the visit**
  - **explain the individual trainees main areas and its importance for preparation**
  - **list out the supporting materials to carry for visit**
  - **prepare a list of do's and dont's during visit.**
- 

### **Introduction**

A industrial visit is a very important step to tap actual working environments. During practical exercises practicing in the lab or workshop never provides actual working condition because it is a part of structure training planned to complete within a stipulated time and a assessment at later stage.

### **Initial preparatory work**

The trainees should be in a position to interact well at the actual site. Every industry technical experts execute the work on a team and produce better results. The technician or operator concerned will be able to give a clear idea of working or procedure of a particular work and you have to extract it fully

To understand the whole process from the concerned technician or operator, you must have a sound knowledge of that particular object or process. You should prepare well to meet the challenge whenever you go industrial visit in a factory or work place.

### **Preparation areas and its importance**

If the process is complicated or multi level procedure involved; in that case trainees should be made small batches to interact or involve the whole process. In such cases each batch should be formed in advance and decided the section or part to be interacted. Finally all the batches together to make the end result.

### **Supporting materials**

When the visit is at generating stations, have must collect the following:

- 1 Installed capacity of the plant.
- 2 Maximum load demand .
- 3 Load factor .
- 4 Distance of the nearest sub station.
- 5 Total number of alternators installed and its working conditions.

- 6 Details of the fuel used (Coal- Nuclear - Its availability, quality etc) and the daily expenditure for fuel.
- 7 Solutions to meet extra fuel in case of environmental emergency.
- 8 Location Map of the plant and its surroundings.
- 9 Gather maximum information regarding generation and distribution techniques other than guided or studied.
- 10 Maximum hazardous Area - PPE facility Emergency root in case of emergency.

### **Do's & Dont's**

#### **Do's**

- 1 Wear uniform with name badge.
- 2 Ensure the protective gadgets are available otherwise carry them.
- 3 Follow the safety norms imposed in the particular areas, listen the instruction carefully.
- 4 Carry materials to record your findings and assessments to make then and their.
- 5 Follow strict discipline and punctuality .
- 6 Obey all the instructions and rules.
- 7 Walk in the prescribed areas only.

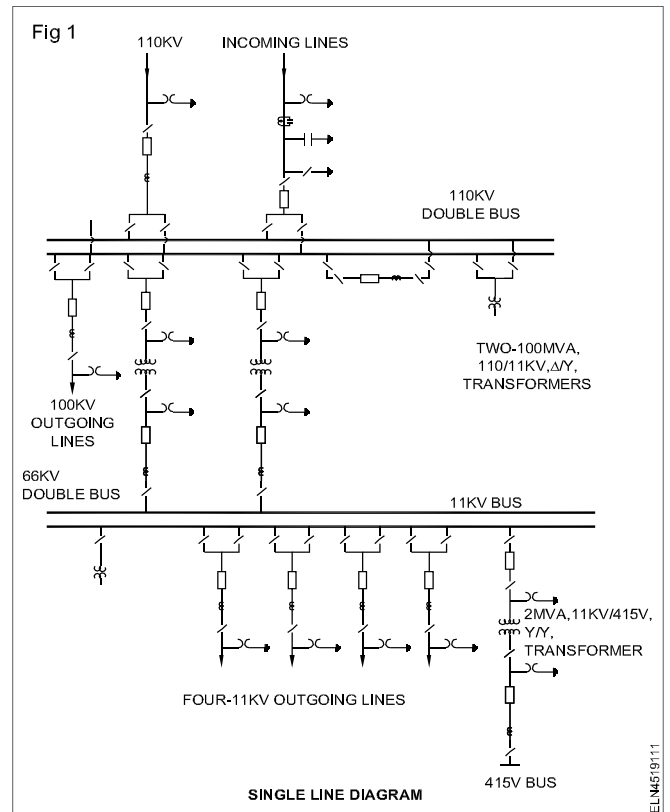
#### **Dont's**

- 1 Avoid wearing loose clothes and ornaments.
- 2 Not to carry any bag or attachments.
- 3 Do not cross-over any prohibited areas .
- 4 Do not operate, touch or play with any part or machine you pass over.
- 5 Do not sit or learn over any machine or place you come accross.
- 6 Do not shout or make any unusual noises when the visit is in progress or inside the factory.
- 7 Do not involve any kind of horse play at the time of visiting various sections, areas.
- 8 Do not avoid or neglect any instruction passed on you at any time.



- 9 Do not indulge any horse play or encourage others to do. The person responsible for leading the visit has to arrange the programme well in advance and informs all concerned. Taking permission to visit and arrange transportation to reach in time. Arrangement may also be done to carry or provide hospitality is also the responsibility of the person concerned.

Fig 1 shows a typical single line layout diagram of a transmission and distribution substation.



## Electrical substations

**Objectives:** At the end of this lesson you shall be able to

- state the functions and purpose of electrical substations
- classify the different types of substation
- list out the equipment and components used in substation
- state the single line diagram of electrical substation with symbols.

### Substations

Electric power is produced at the power generating stations, which are generally located far away from the load centers. Between the power generating station and consumers a number of transformations and switching stations are required. These are generally known as substations.

Substations are important part of power system and form a link between generating stations, transmission systems and distribution systems. It is an assembly of electrical components such as bus-bars, switch gear apparatus, power transformers etc.

### Function

Their main functions are to receive power transmitted at high voltage from the generating stations and reduce voltage for switching operations of transmission lines. Substations are provided with safety devices to disconnect equipment or circuit at the time of faults.

Substations are the convenient place for installing synchronous condensers for the purpose of improving power factor and it provides facilities for making measurements to monitor the operation of the various parts of the power system.

### Classification of substation

The substations may be classified in according to service requirements and constructional features. According to service requirements they are classified in to transformer substations, switching substations and converting substations.

**1 Transformer substations :** Majority of the substations in the power system are in this type. They are used to transform the power from one voltage level to another voltage level. Transformer is the main component in such substations. Transformer substations are further classified into step-up substations, primary grid substations, secondary substations and distribution substations.

**a Step-up substations :** These substations are usually located at the generating stations. Generating voltage of the order of 11KV needs to be stepped up to a primary transmission voltage level of the order of 220KV or 400KV.

**b Primary grid substations :** These substations are located at the end of primary transmission lines and the primary voltage is stepped down to suitable secondary voltages of the order of 66KV or 33KV.

- c **Secondary substations** : The voltage is further stepped down to 11KV. Large consumers are supplied with power at 11KV.
- d **Distribution substations** : These substations are located near the consumer localities to supply power at 415V three phase or 240V single phase to the consumers.
- 2 **Switching substations** : These substations are meant for switching operations of power lines without transforming the voltage. Different connections are made between the various transmission lines.
- 3 **Converting substation** : Such substations are meant for either converting AC to DC or vice versa. Some are used to change the frequency from higher to lower or vice versa for industry utilizations.

According to constructional features substations are classified into indoor substations, outdoor substations, underground substations and pole mounted substations.

- 1 **Indoor substations** : All equipment of the substation are installed within the station buildings.
- 2 **Outdoor substations** : All equipments such as transformers, circuit breakers, isolators, etc, are installed outdoors.
- 3 **Underground substations** : In thickly populated areas where the space is the major constraint, and cost of land is higher, under such situation the substations are laid underground.
- 4 **Pole mounted substations** : This is an outdoor substation with equipment installed overhead of a H pole or 4 pole structure.

The substations can also be classified in several ways including the following.

- 1 **Classification based on voltage levels** : eg. AC substation : EHV, HV, MV, LV : HVDC substation.
- 2 **Classification based on outdoor or indoor** : Outdoor substation is in open air. Indoor substation is inside a building.
- 3 **Classification based on configuration**
  - Conventional air insulated outdoor substation or
  - SF<sub>6</sub> Gas insulated substation (GIS)
  - Composite substations having combination of the above two.
- 4 **Classification based on application**
  - **Step up substation** : Associated with generating station as the generating voltage is low.
  - **Primary Grid substation** : Created at suitable load centre along primary transmission lines. It receive the power from EHV lines at 400KV, 220 KV, 132KV and transform the voltage to 66KV, 33KV or 22KV ( 22KV is uncommon) to suit the local requirements in respect of both load and distance of ultimate consumers.

These are also referred to EHV substations.

- **Secondary substation** : Along secondary transmission line. It receive the power at 66/33KV which is stepped down usually to 11KV.
- **Distribution substation** : Created where the transmission line voltage is stepped down to supply voltage.
- **Bulk supply and industrial substation** : Similar to distribution substation but created separately for each consumer.
- **Mining substation** : Needs special design consideration because of extra precaution for safety needed in the operation of electric supply.
- **Mobile substation** : For emergency replacement of transformer etc.
- **Distribution substations** : It receive power at 11KV, 6.6 KV and step down to a volt suitable for LV distribution purposes, normally at 415 volts.

### The parts, equipment and components installed in substation

Each substation has the following parts and equipment.

#### 1 Outdoor switchyard

- Incoming lines
- Outgoing lines
- Busbar
- Transformers
- Bus post insulator & string insulators
- Substation equipment such as circuit-breakers, isolators, earthing switches, surge arresters, CTs, PTs neutral grounding equipment
- Station earthing system comprising ground mat, risers, auxiliary mat, earthing strips, earthing spikes & earth electrodes.
- Overhead earthwise shielding against lightning strokes.
- Galvanized steel structures for lower equipment supports.
- PLCC equipment including line trap, tuning unit, coupling capacitor, etc.
- Power cables
- Control cables for protection and control
- Road, cable trenches
- Station illumination system

#### 2 Main office building

- Administrative building
- Conference room etc.

#### 3 6.6/11/22/33/66/132 KV switch gear LV

- Indoor switch gear

#### 4 Switchgear and control panel building

- Low voltage AC switchgear
- Control panels, protection panels

#### 5 Battery room and DC distribution system

- DC battery system and charging equipment
- DC distribution system

#### 6 Mechanical, electrical and other auxiliaries

- Fire fighting system
- D.G (Diesel Generator) set
- Oil purification system

An important function performed by a substation is switching, which is the connecting and disconnecting of transmission lines or other components to and from the system. A transmission line or other component may need to be de-energized for maintenance or for new construction, for adding or removing a transmission line or a transformer. All work to be performed, from routine testing to adding new substations, must be done while keeping the whole system running.

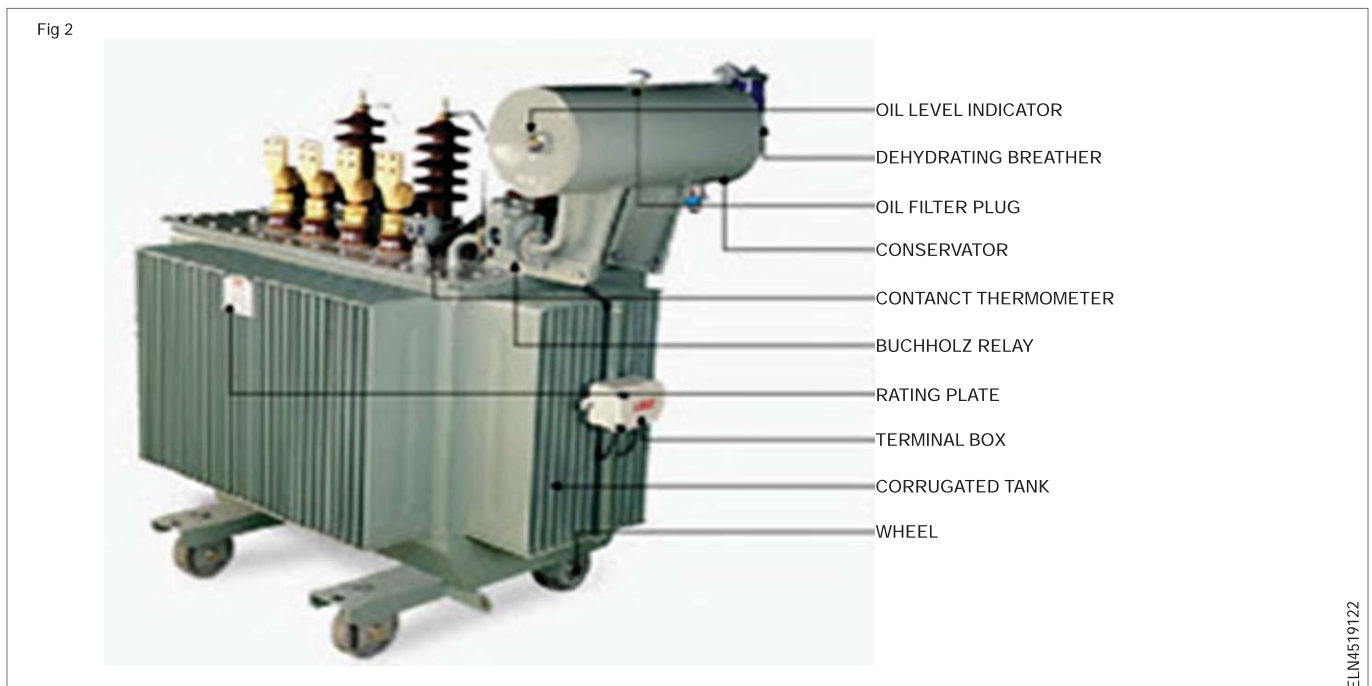
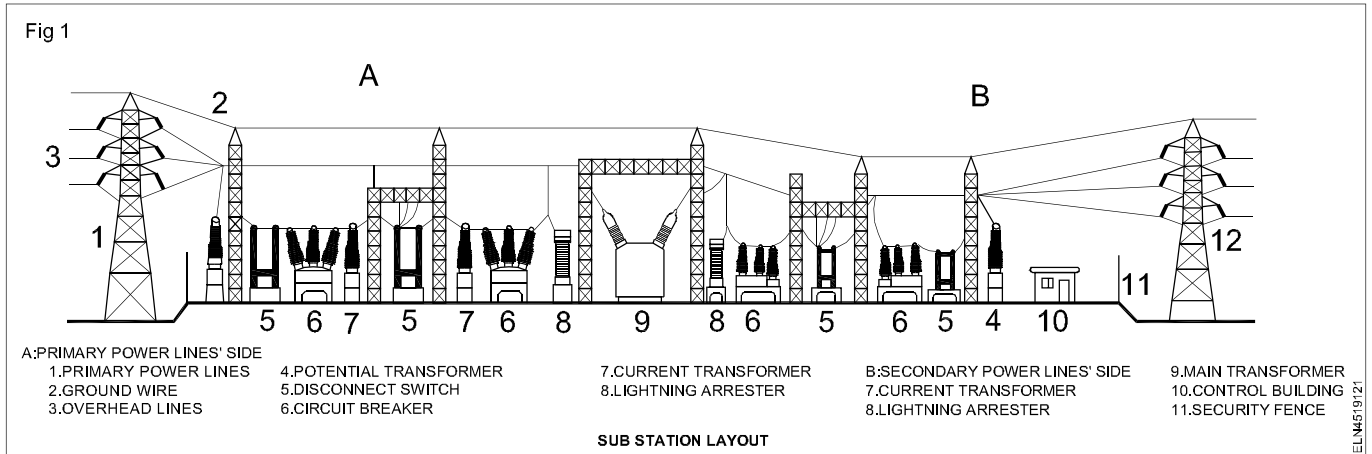
A fault may develop in a transmission line or any other component. Some examples of this a line is hit by lightning and develops an arc, or a tower is down by a high wind. The function of the substation is to isolate the faulty portion of the system within the shortest possible time.

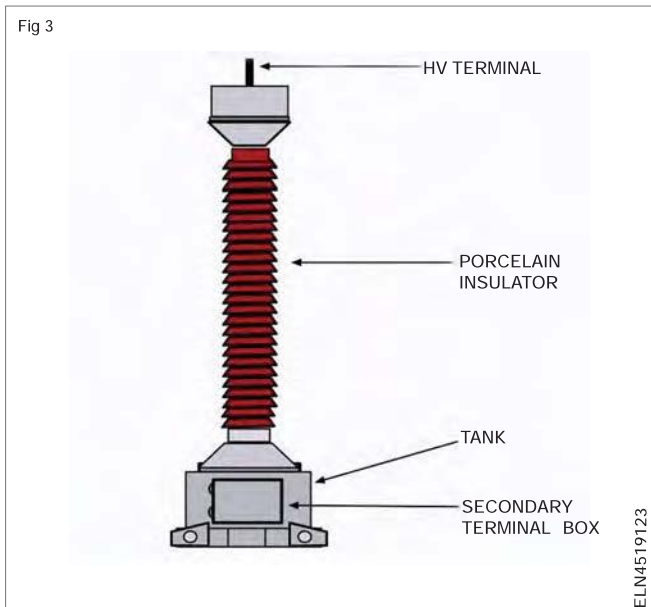
#### Substation layout and their components

Fig 1 shows the typical substation layout. It consists of the following components and explained below.

**Power transformer :** Power transformers are used for generation and transmission network for stepping-up the voltage at generating station and stepping down the voltage for distribution. Auxiliary transformers supply power to auxiliary equipment at the substations. (Fig 2).

**Current transformers (CT) :** The lines in substations carry currents in the order of thousands of amperes. The measuring instruments are designed for low value of currents. Current transformers are connected in lines to supply measuring instruments and protective relays. For example a 100/1A CT is connected in a line carrying 100A, and then the secondary current of CT is 1A. (Fig 3).





**Potential transformers (PT) :** The lines in substations operate at high voltages. The measuring instruments are designed for low value of voltages. Potential transformers are connected in lines to supply measuring instruments and protective relays.

These transformers make the low voltage instruments suitable for the measurement of high voltages. For example a 11KV/110V PT is connected to a power line and the line voltage is 11KV then the secondary voltage will be 110V. (Fig 4).



**Circuit breaker (CB) :** Circuit breakers are used for opening or closing a circuit under normal as well as abnormal (faulty) conditions. Different types of CBs which are generally used are oil circuit breaker, air - blast circuit breaker, vacuum circuit breaker and SF<sub>6</sub> circuit breaker.

**Isolators for isolating switches :** Isolators are employed in substations to isolate a part of the system for general maintenance. Isolator switches are operated only under load condition. They are provided on each side of every circuit breaker.

**Lightning arresters (LA) :** Lightning arresters are the protective devices used for protection of equipment from lightning strokes. They are located at the starting of the substation and also provided near the transformer terminals.

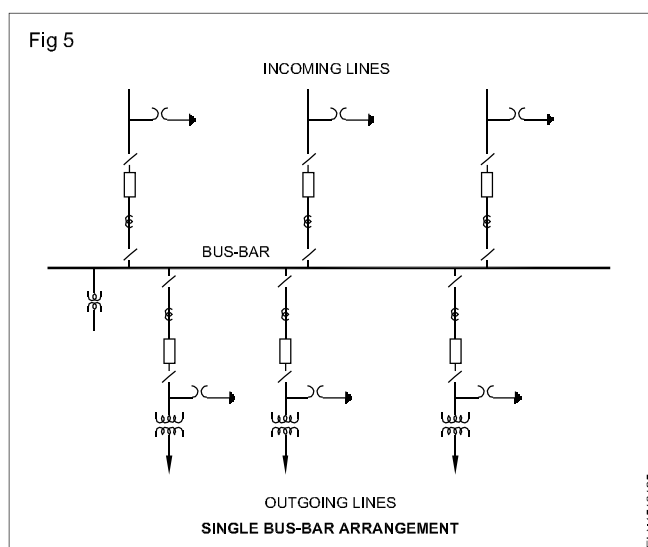
**Earth switch :** It is a switch normally kept open and connected between earth and conductor. If the switch is closed it discharges the electric charge to ground, available on the uncharged line.

**Wave trap :** This equipment is installed in the substation for trapping the high frequency communication signals sent on the line from remote substation and diverting them to the telecom panel in the substation control room.

**Coupling capacitor :** A coupling capacitor is used in substations where communication is done by AC power line. It offers very low impedance to high frequency carrier signal and allows them to enter the line matching unit and blocks the low frequency signals.

**Bus - bar :** When number of lines operating at the same voltage levels needs to be connected electrically, bus - bars are used. Bus - bars are conductors made of copper or aluminium, with very low impedance and high current carrying capacity. Different types of bus - bar arrangements are single bus bar arrangements, single bus - bar with sectionalization, double bus - bar arrangements, sectionalized double bus - bar arrangement, double main and auxiliary bus - bar arrangement, breaker and a half scheme / 1.5 Breaker scheme, and ring bus - bar scheme.

**Single bus-bar arrangement :** It consists of single bus - bar. Both incoming and outgoing lines are connected to the single bus - bar (Fig 5). The advantages of this arrangement are low maintenance, low initial cost and simple operation. The drawback of this arrangement is if any repair work is to be done on bus-bar, complete system get interrupted.



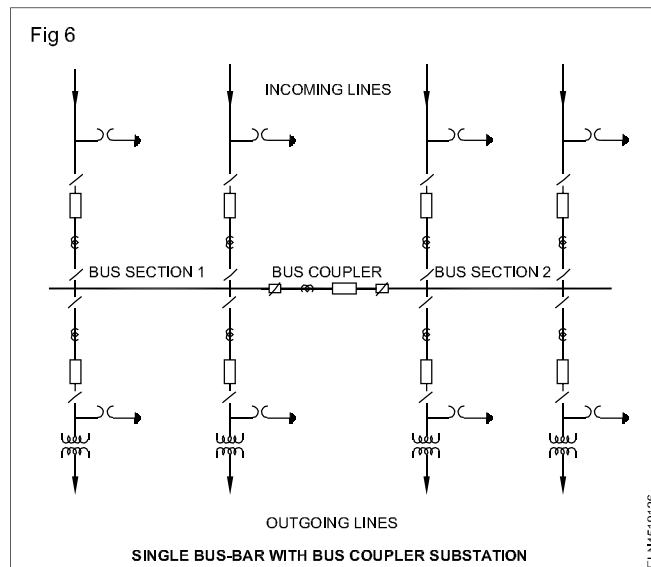
**Single bus-bar with sectionalization:** Single bus-bar is divided into sections. Any two sections are connected by circuit breaker and isolators. During fault or maintenance particular section can be de-energized. This eliminates complete shutdown of the system. Fig 6 shows that two incoming and two outgoing lines are connected bus section 1 and other two incoming and two outgoing lines are connected bus section. 2 by using bus coupler.

**Double bus - bar arrangements :** This arrangement is also known as duplicate bus-bar system. It consists of two bus-bars 'main' and a 'spare' of same capacity. Incoming line and outgoing lines can be connected to either bus by means of bus coupler breaker and isolators. Continuity of supply of the circuit can be maintained during maintenance of main bus-bar or fault occurring on it.

**Single line diagram for substation**

Any complex power system even though they are three phase circuits, can be represented by a single line diagram, showing various electrical components of power system and their interconnection. In single line

representation of substation the electrical components such as power transformers, incoming and outgoing lines, bus-bars, switching and protecting equipments, are represented by **standard symbols** and their interconnections between them are shown by line. Single line diagrams are useful in planning a substation layout.



**Standard symbols used for single line diagram of substation**

SI. No.	Electrical components	Symbol
1	AC Generator	
2	Bus bar	
3	Power transformer - Two winding	
4	Three winding transformer	
5	Current transformer (CT)	
6	Voltage transformer or Potential transformer (PT)	

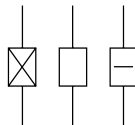

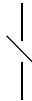

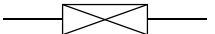
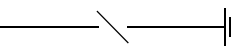
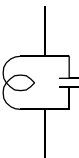
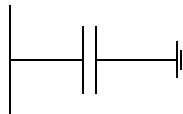
Sl. No.	Electrical components	Symbols
7	Circuit Breaker (CB)	
8	Circuit breaker with isolator	
9	Isolator or Group Operating Switch (GOS)	
10	Lightning Arrester (LA)	 
11	Earth Switch (ES)	
12	Wave or Line trap	
13	Coupling Capacitor (CC)	

Fig 7 & 8 show the examples ( 1 & 2) of substation layout drawings with all equipments represented by symbols.

### Example 1

Draw the single line diagram of substation having the following equipment.

- i Incoming lines : Two, 110KV
- ii Outgoing lines : (a) One, 110KV (b) Four, 11KV
- iii Transformers : (a) Two, 100MVA, 110/11KV,  $\Delta/Y$  (b) one, 2MVA, 11KV/ 415V, Y/Y

- iv) Bus-bars : 110KV- Duplicate bus - bar, 11KV single bus - bar shows the positions of CTs, PTs isolators, lightning and arresters, circuit breakers.

Fig 7 shows the single line diagram of the substation.

### Example - 2

Draw the single line diagram of a pole mounted substation.

Fig 8 shows the typical single line diagram of pole mounted substation.

