UNIT -1

GENERATION OF ELECTRIC POWER

Conventional sources

1.Steam power plant

2.Hydro power plant.

3.Nuclear power plant.

4.Gas turbine plant.

Non conventional sources

1.Solar energy .

2.Wind energy

3.Fuel cells.

4.Ocean energy.

5.Tidal energy.

6.Wave energy .

7.Energy conservation and storage.

Steam Power Station (Thermal Station)

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

A steam power station basically works on the Rankine cycle.

Arrangement of Steam Power Station

1.Coal and ash handling arrangement.

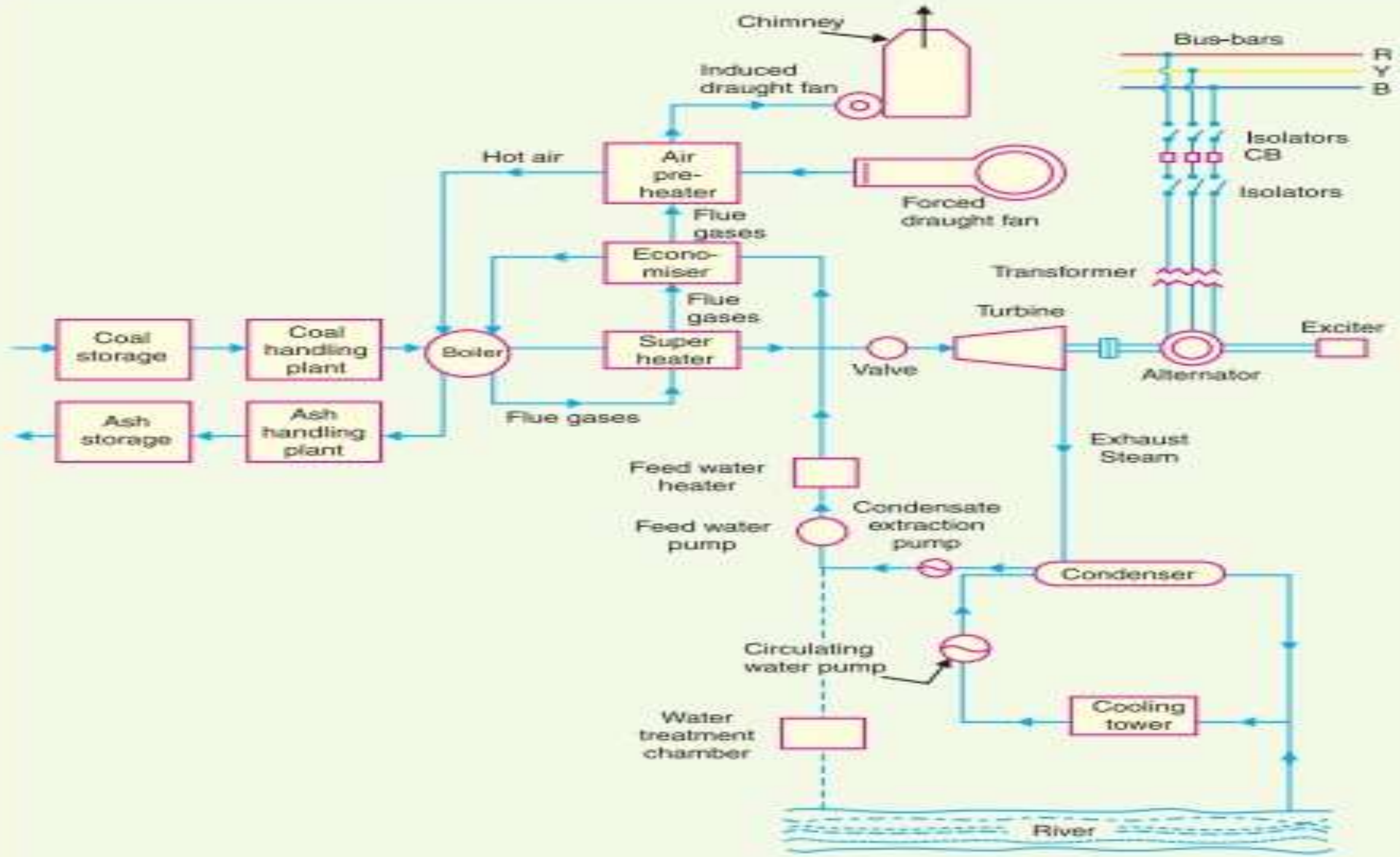
2. Steam generating plant.

3. Steam turbine

4. Alternator

5.Feed water.

6.Cooling arrangement



Schematic arrangement of Steam Power Station

Choice of Site for Steam Power Stations

1.Supply of fuel.

2. Availability of water.

3.Transportation facilities

4. Cost and type of land.

5. Nearness to load centres.

6. Distance from populated area.

Advantages

1.The fuel (*i.e.*, coal) used is quite cheap.

2.Less initial cost as compared to other generating stations.

3.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.

4.It requires less space as compared to the hydroelectric power station.

5.The cost of generation is lesser than that of the diesel power station.

Disadvantages

1.It pollutes the atmosphere due to the production of large amount of smoke and fumes.

2.It is costlier in running cost as compared to hydroelectric plant.

Hydro-electric Power Station

A generating station which utilises the potential energy of water at a high level for the generation of electrical energy is known as a **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. In a hydro-electric 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 into mechanical energy at the turbine shaft. The turbine drives the alternator which converts mechanical energy into electrical energy.

Constituents of Hydro-electric Plant

(1) hydraulic structures

(2) water turbines and

(3) electrical equipment.

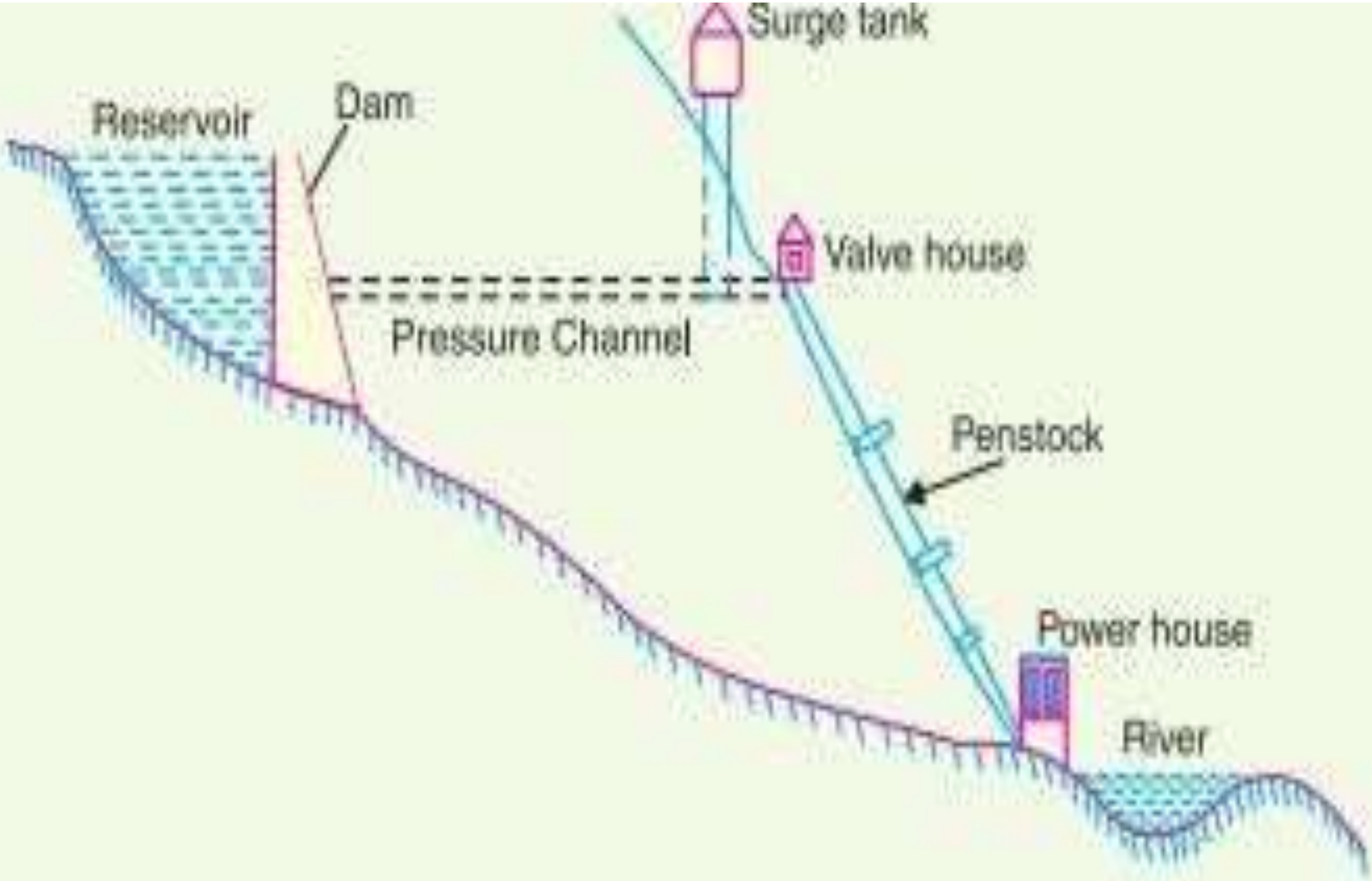
Hydraulic structures.

1.Dam.
2.Spillways.
3.Headworks.
4.Surge tank.
5.Penstocks.

Water turbines.

Impulse turbines

Reaction turbines



Schematic arrangement of a Hydro-electric plant

Fig. 2.2

Choice of Site for Hydro-electric Power Stations

1. *Availability of water.*
2. *Storage of water*
3. *Cost and type of land.*
4. *Transportation facilities.*

Advantages

1.It requires no fuel as water is used for the generation of electrical energy.

2.It is quite neat and clean as no smoke or ash is produced.

3.It requires very small running charges because water is the source of energy which is available free of cost.

4It is comparatively simple in construction and requires less maintenance.

5.It does not require a long starting time like a steam power station. In fact, such plants can be put into service instantly.

6.It is robust and has a longer life.

7.Such plants serve many purposes. In addition to the generation of electrical energy, they also help in irrigation and controlling floods.

8.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

1.It involves high capital cost due to construction of dam.

2.There is uncertainty about the availability of huge amount of water due to dependence on weather conditions

3.Skilled and experienced hands are required to build the plant

4.It requires high cost of transmission lines as the plant is located in hilly areas which are quite away from the consumers

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 (U235) or Thorium (Th232) are subjected to nuclear fission* in a special apparatus known as a *reactor*. The heat energy thus released is utilised 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.

Arrangement of Nuclear Power Station

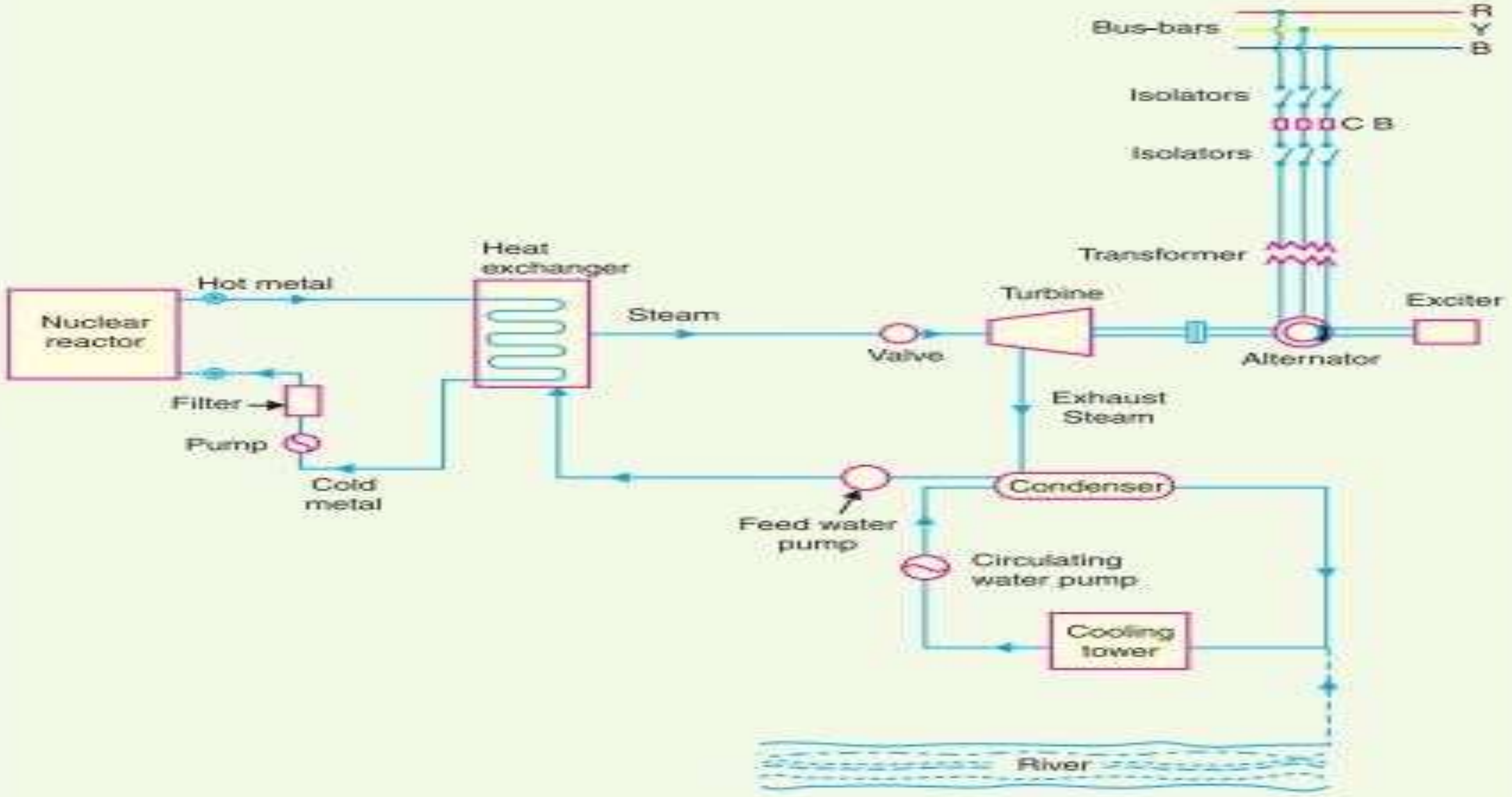
The whole arrangement can be divided into the following main stages :

1. Nuclear reactor.

2. Heat exchanger.

3. Steam turbine.

4. Alternator.



Schematic arrangement of Nuclear Power Station

Fig. 2.7

Selection of Site for Nuclear Power Station

1.Availability of water
2.Disposal of waste.
3.Distance from populated areas.
4.Transportation facilities

Advantages

1.The amount of fuel required is quite small. Therefore, there is a considerable saving in the cost of fuel transportation.
2.A nuclear power plant requires less space as compared to any other type of the same size.

3.It has low running charges as a small amount of fuel is used for producing bulk electrical energy.

4.This type of plant is very economical for producing bulk electric power.

5.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.

6.It ensures reliability of operation.

Disadvantages

1.The fuel used is expensive and is difficult to recover.

2.The capital cost on a nuclear plant is very high as compared to other types of plants.

3.The erection and commissioning of the plant requires greater technical know-how.

4.The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.

5. The fission by-products are generally radioactive and may cause a dangerous amount of radioactive pollution.

6.Nuclear power plants are not well suited for varying loads as the reactor does not respond to the load fluctuations efficiently.

7.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.

Gas Turbine Power Plant

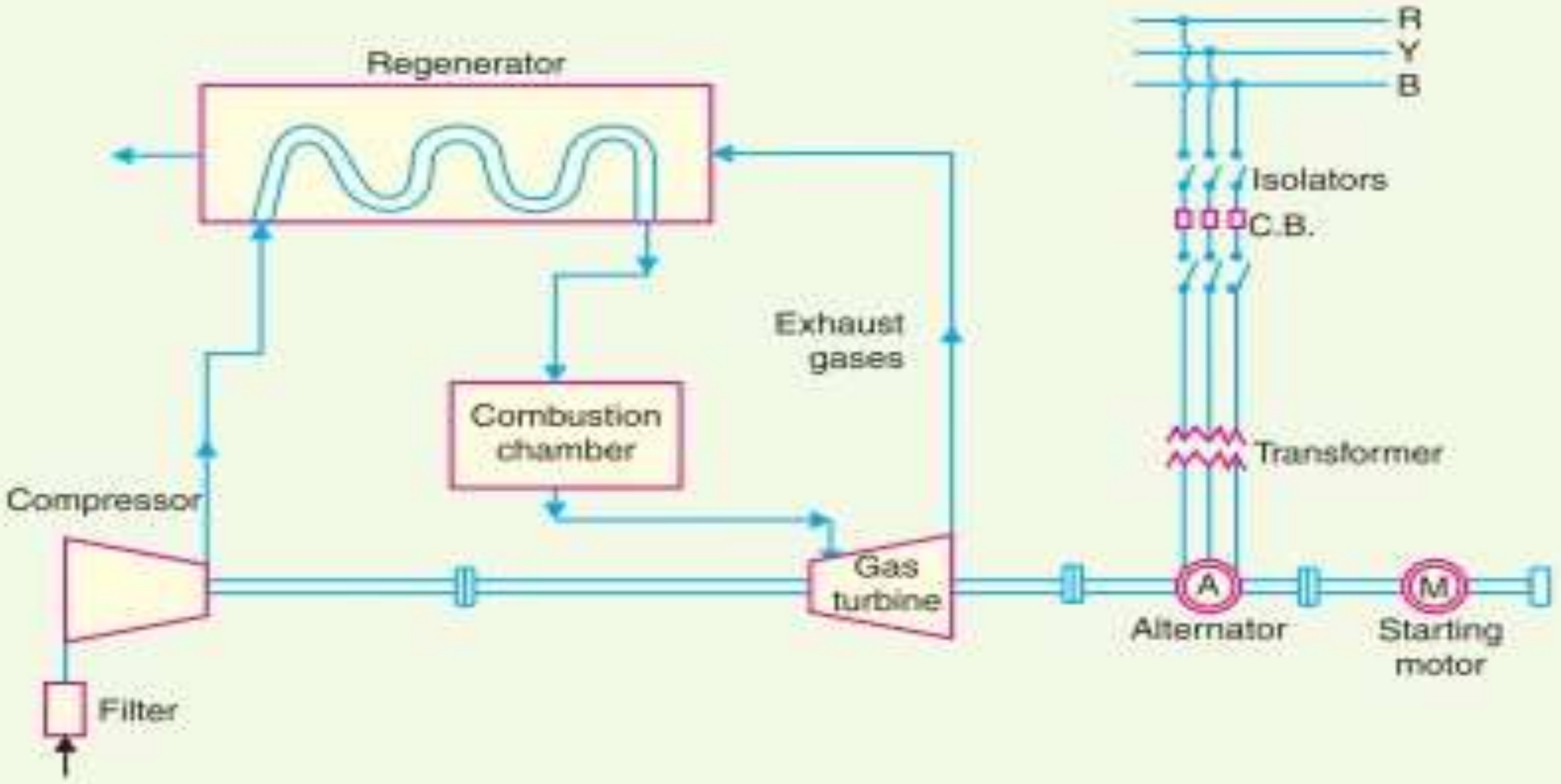
A generating station which employs gas turbine as the prime mover for the generation of electrical energy is known as a **gas turbine power plant**

In a gas turbine power plant, air is used as the working fluid. The air is compressed by the compressor and is led to the combustion chamber where heat is added to air, thus raising its temperature. Heat is added to the compressed air either by burning fuel in the chamber or by the use of air heaters. The hot and high pressure air from the combustion chamber is then passed to the gas turbine where it expands and does the mechanical work. The gas turbine drives the alternator which converts mechanical energy into electrical energy

Arrangement of Steam Power Station:

The main components of the gas turbine plant are

1. Compressor
2. Regenerator
3. Combustion chamber
4. Gas turbine
5. Alternator
6. Starting motor



Schematic arrangement of gas turbine power plant.

Fig. 2.9

Advantages

1.Gas turbines are much simpler in construction and operation than steam turbines.

2.It is simple in design as compared to steam power station since no boilers and their auxiliaries are required.

3.It is much smaller in size as compared to steam power station of the same capacity. This is expected since gas turbine power plant does not require boiler, feed water arrangement etc.

4.It requires comparatively less water as no condenser is used.

5.The maintenance charges are quite small.

6.It can be started quickly form cold conditions.

7.There are no standby losses. However, in a steam power station, these losses occur because boiler is kept in operation even when the steam turbine is supplying no load.

Disadvantages

1.There is a problem for starting the unit. It is because before starting the turbine, the com pressor has to be operated for which power is required from some external source. How ever, once the unit starts, the external power is not needed as the turbine itself supplies the necessary power to the compressor.

2.Since a greater part of power developed by the turbine is used in driving the compressor, the net output is low.

3.The overall efficiency of such plants is low (about 20%) because the exhaust gases from the turbine contain sufficient heat.

4.The temperature of combustion chamber is quite high (3000o F) so that its life is comparatively reduced.

CONCLUSION

UNIT -2

ECONOMICS OF POWER GENERATION

INTRODUCTION

Load Curves

The curve showing the variation of load on the power station with respect to time is known as **load curve.**

1.Connected Load

2.Maximum Demand

3.Demand Factor

4.Diversity Factor

5.Load Duration Curve

Connected load : It is the sum of continuous ratings of all the equipments connected to supply system.

Maximum demand: It is the greatest demand of load on the power station during a given period.The load on the power station varies from time to time. The maximum of all the demands that have occurred during a given period (say a day) is the maximum demand.

Demand factor: It is the ratio of maximum demand on the power station to its connected load.

$$\text{Demand factor} = \frac{\text{Maximum demand}}{\text{Connected load}}$$

Average load The average of loads occurring on the power station in a given period (day or month or year) is known as **average load** or **average demand.**

$$\text{Yearly average load} = \frac{\text{No of units (kWh) generated in a day}}{\text{8760 hours}}$$

$$\text{Daily average load} = \frac{\text{No of units (kWh) generated in a day}}{\text{24 hours}}$$

$$\text{Monthly average load} = \frac{\text{No of units (kWh) generated in a day}}{\text{Number of hours in a month}}$$

Load factor : The ratio of average load to the maximum demand during a given period is known as **load factor.**

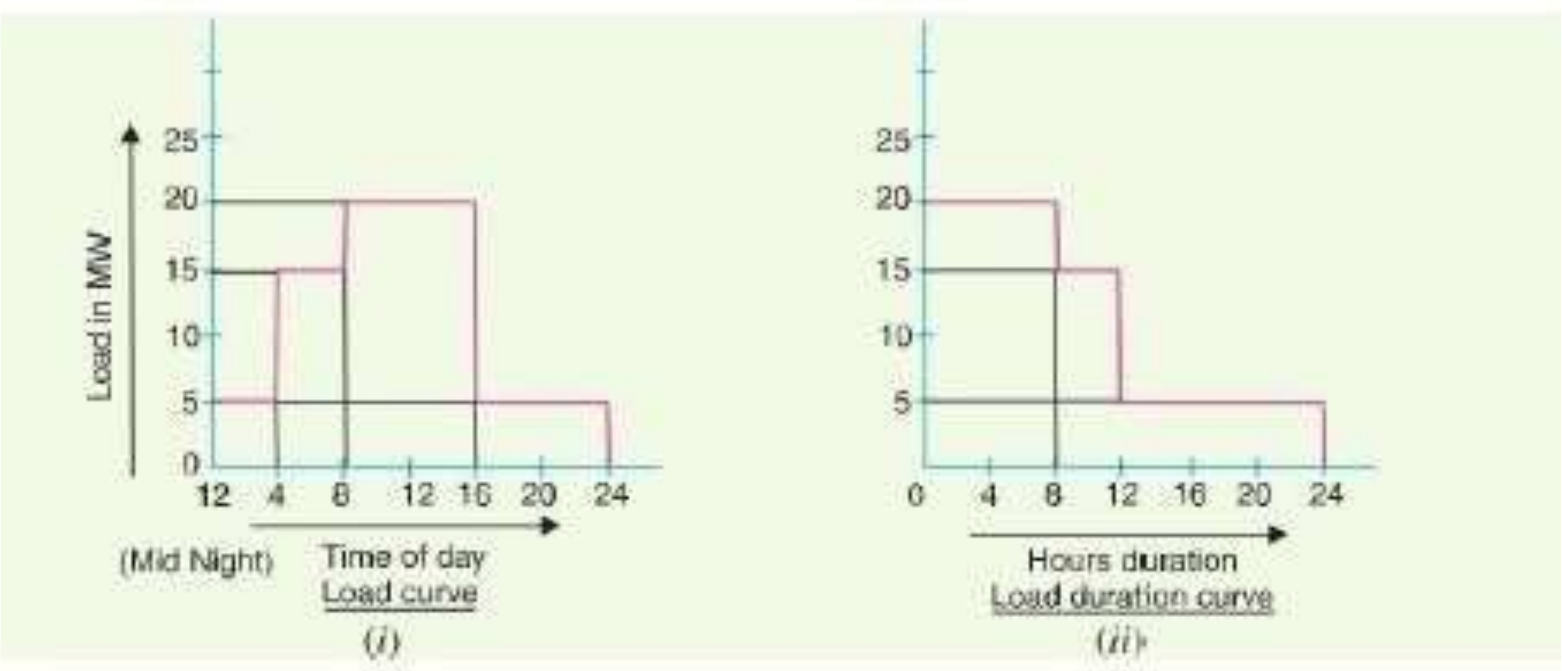
$$\text{Load factor} = \frac{\text{Average load}}{\text{Max demand}}$$

The load factor plays key role in determining the overall cost per unit generated Higher the load factor of the power station, lesser* will be the cost per unit generated.

Diversity factor : The ratio of the sum of individual maximum demands to the maximum demand on power station is known as **diversity factor.**

$$\text{Diversity factor} = \frac{\text{Sum of individual max demands}}{\text{Maximum demand on power station}}$$

Load duration curve : When the load elements of a load curve are arranged in the order of descending magnitudes, the curve thus obtained is called a **load duration curve.**



The load duration curve is obtained from the same data as the load curve but the ordinates are arranged in the order of descending magnitudes

Types of Loads

1.Domestic load

2.Commercial load

3.Industrial load

4.Municipal load

5.Irrigation load

6.Traction load

Load Curves and Selection of Generating Units

1.The load on a power station is not constant .

2.It varies from time to time. a single generating unit (ie, alternator) will not be an economical proposition to meet this varying load

3.It is because a single unit will have very poor efficiency during the periods of light loads on the power station Therefore, in actual practice, a number of generating units of different sizes are installed in a power station.

4. The selection of the number and sizes of the units is decided from the annual load curve of the station.

5.The number and size of the units are selected in such a way that they correctly fit the station load curve.

Important Points in the Selection of Units

While making the selection of number and sizes of the generating units, the following points should be kept in view:

1. The number and sizes of the units should be so selected that they approximately fit the annual load curve of the station.
2. The units should be preferably of different capacities to meet the load requirements.
3. The capacity of the plant should be made 15% to 20% more than the maximum demand to meet the future load requirements.
4. There should be a spare generating unit so that repairs and overhauling of the working Units can be carried out.
5. The tendency to select a large number of units of smaller capacity in order to fit the load curve very accurately should be avoided.

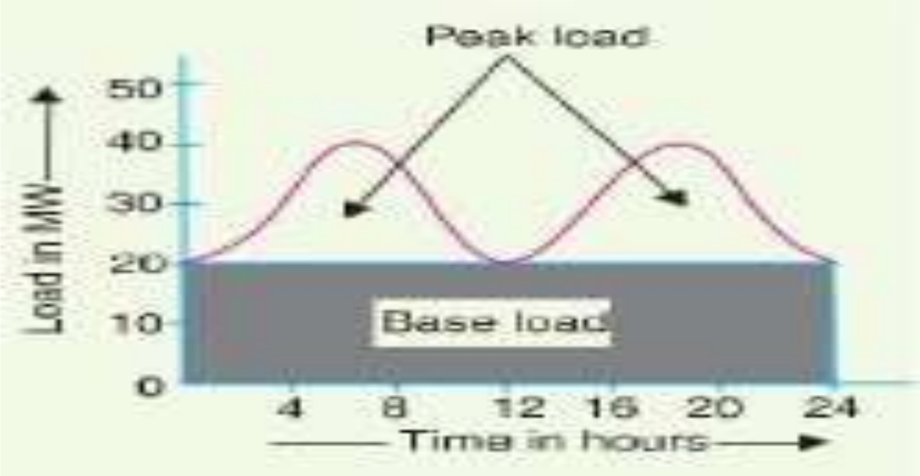
Base Load and Peak Load on Power Station

The changing load on the power station makes its load curve of variable nature Fig. shows the typical load curve of a power station. It is clear that load on the power station varies from time to time.

The load on the power station can be divided in two parts, namely;

1.Base load

2.Peak load



Base Load

The unvarying load which occurs almost the whole day on the station is known as base load.

Peak Load

The various peak demands of load over and above the base load of the station

is known as peak load.

Tariff

The rate at which electrical energy is supplied to a consumer is known as **tariff**

Objectives of Recovery of cost of producing electrical energy at the power station

1.Recovery of cost on the capital investment in transmission and distribution systems.

2.Recovery of cost of operation and maintenance of supply of electrical energy

eg, metering equipment, billing etc.

3.A suitable profit on the capital investment.

Desirable Characteristics of a Tariff

A tariff must have the following desirable characteristics:

1.Proper return.

2.Fairness.

3.Simplicity.

4.Reasonable profit.

- **CONCLUSION**

UNIT -3

OVERHEAD TRNSMISSION LINES AND OVERHEAD LINE INSULATORS

INTRODUCTION

Underground cables

An underground cable essentially consists of one or more conductors covered with suitable insulation and surrounded by a protecting cover.

Although several types of cables are available, the type of cable to be used will depend upon the working voltage and service requirements

A cable must fulfil the following necessary requirements :

1.The conductor used in cables should be tinned stranded copper or aluminium of high conductivity. Stranding is done so that conductor may become flexible and carry more current

2.The conductor size should be such that the cable carries the desired load current without overheating and causes voltage drop within permissible limits.

3.The cable must have proper thickness of insulation in order to give high degree of safety and reliability at the voltage for which it is designed.

4.The cable must be provided with suitable mechanical protection so that it may withstand the rough use in laying it.

Construction of Cables

1.Cores or Conductors

2.InsulatiOn.

3.Metallic sheath

4.Bedding.

5.rmouring.

6.Serving.

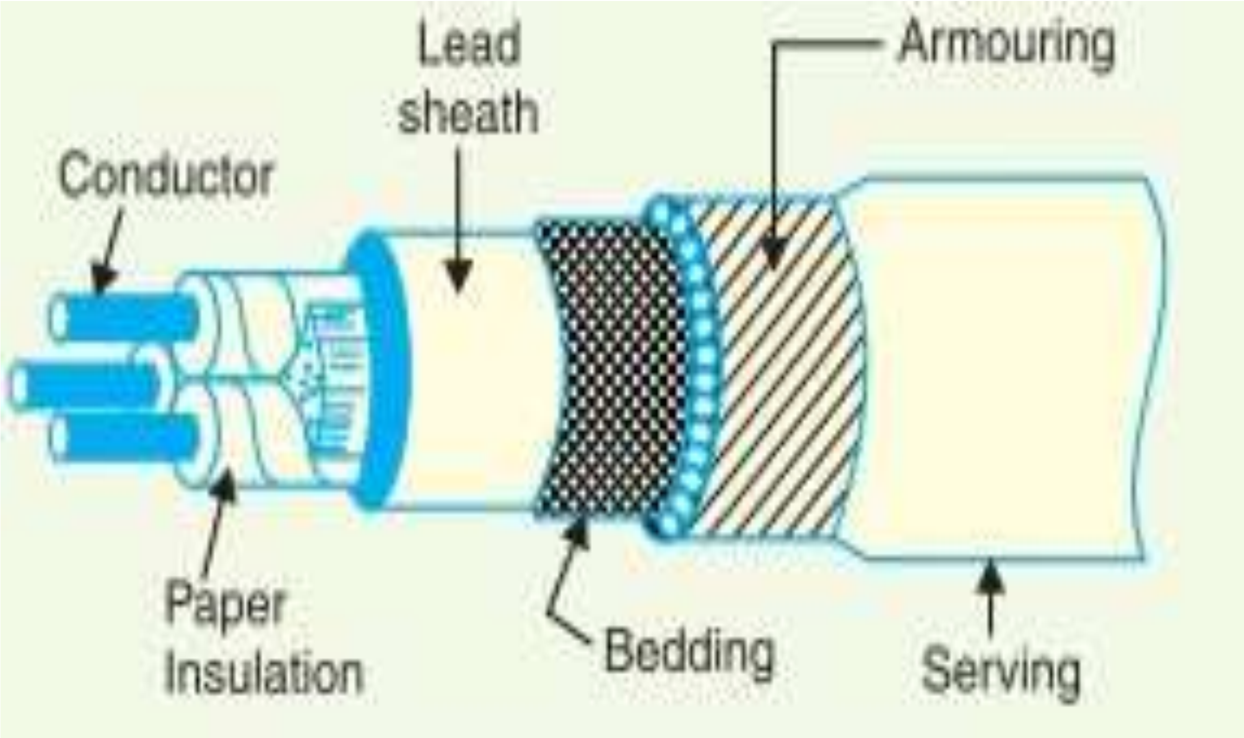


Fig. 11.1 Construction of a Cable

Insulating Materials for Cables

The satisfactory operation of a cable depends to a great extent upon the characteristics of insulation used.

The insulating materials used in cables should have the following properties :

1. High insulation resistance to avoid leakage current.
2. High dielectric strength to avoid electrical breakdown of the cable.
3. High mechanical strength to withstand the mechanical handling of cables.
4. Non-hygroscopic i.e., it should not absorb moisture from air or soil.

The moisture tends to decrease the insulation resistance and hastens the breakdown of the cable

1. Non-inflammable
2. Low cost so as to make the underground system a viable proposition
3. Unaffected by acids and alkalies to avoid any chemical action.

The principal insulating materials used in cables are.

1. Vulcanised India Rubber (V.I.R.).
2. Impregnated paper
3. Varnished cambric.
4. Polyvinyl chloride (PVC).

Classification of Cables

Cables for underground service may be classified in two ways according to

(i) the type of insulating material used in their manufacture

(ii) the voltage for which they are manufactured.

1. Low-tension (L.T.) cables — upto 1000 V
2. High-tension (H.T.) cables — upto 11,000 V
3. Super-tension (S.T.) cables — from 22 kV to 33 kV
4. Extra high-tension (E.H.T.) cables — from 33 kV to 66 kV
5. Extra super voltage cables — beyond 132 kV

A cable may have one or more than one core depending upon the type of service for which it is intended.

It may be (i) single-core (ii) two-core (iii) three-core (iv) four-core

For a 3-phase service, either 3-single-core cables or three-core cable can be used depending upon the operating voltage and load demand

underground cables are generally required to deliver 3-phase power.

Types of cables are generally used for 3-phase service :

1. Belted cables — upto 11 kV
2. Screened cables — from 22 kV to 66 kV
3. Pressure cables — beyond 66 kV.

INSULATORS

The overhead line conductors should be supported on the poles or towers in such a way that currents from conductors do not flow to earth through supports i.e., line conductors must be properly insulated from supports.

The insulators provide necessary insulation between line conductors.

In general, the insulators should have the following desirable properties

1.High mechanical strength in order to withstandconductor load, wind load etc

2.High electrical resistance of insulator material in order to avoid leakage currents to earth

3.High relative permittivity of insulator material in order that dielectric strength is high.

4.The insulator material should be non-porous, free from impurities and cracks otherwise the permittivity will be lowered.

5.High ratio of puncture strength to flashover

Types of insulators

1.Pin type insulators

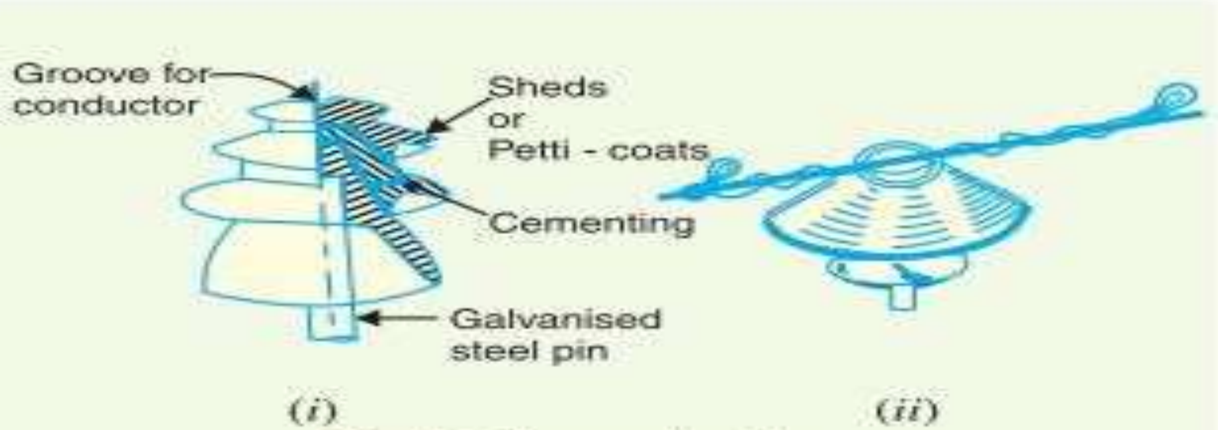


Fig. 8.5. Pin-type insulator

2.Suspension type insulators.

3.Strain insulators

4.Strain insulators

Potential Distribution over Suspension Insulator String

A string of suspension insulators consists of a number of porcelain discs connected in series through metallic links. Fig shows 3-disc string of suspension insulators. The porcelain portion of each disc is in between two metal links.

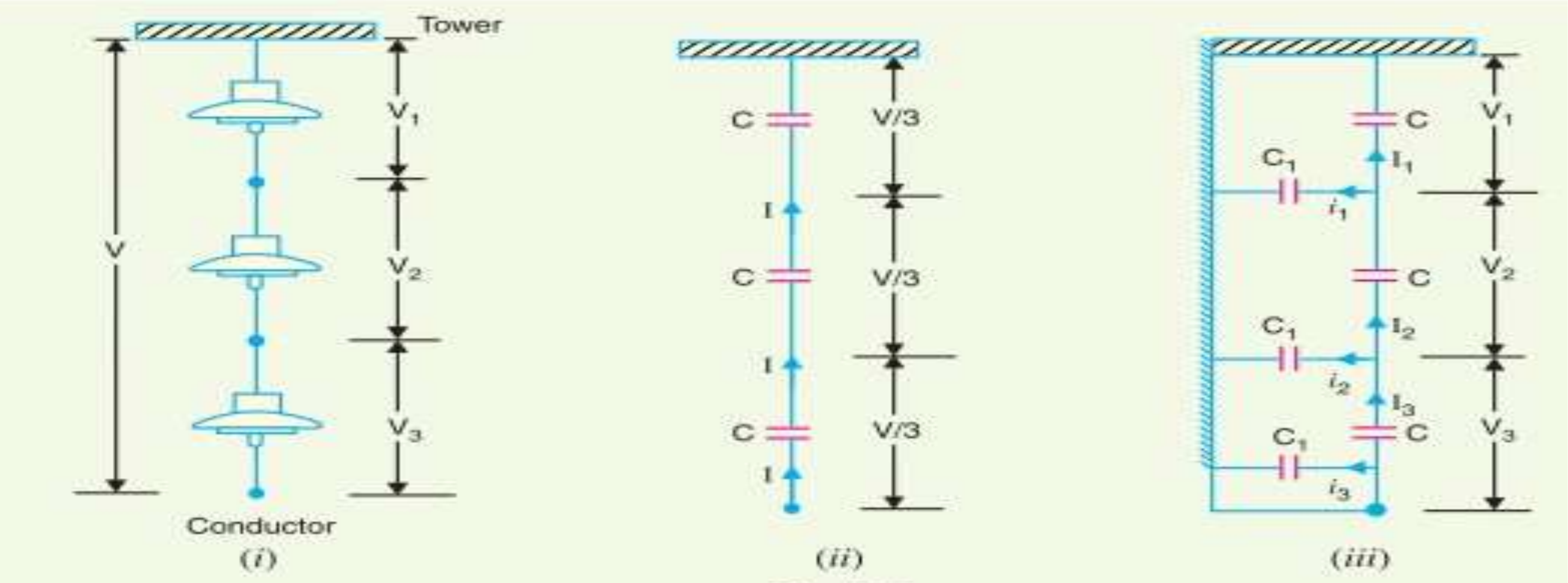


Fig. 8.10

String Efficiency:

The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency.

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to conductor}}$$

where n = number of discs in the string.

Potential at a charged single conductor.

Consider a long straight cylindrical conductor A of radius r metres. Let the conductor operate at such a potential (VA) that charge QA coulombs per metre exists on the conductor. It is desired to find the expression for VA

$$E = \frac{Q_A}{2\pi x \varepsilon_0} \text{ volts/m}$$

where Q_A = charge per metre length

ε_0 = permittivity of free space

As x approaches infinity, the value of E approaches zero. Therefore, the potential difference between conductor A and infinity distant * neutral plane is given by :

$$\dagger V_A = \int_r^\infty \frac{Q_A}{2\pi x \varepsilon_0} dx = \frac{Q_A}{2\pi\varepsilon_0} \int_r^\infty \frac{dx}{x}$$

Capacitance of a Single Phase capacitance of a Single Phase Two-wire Line

Consider a single phase overhead transmission line con sisting of two parallel conductors A and B spaced d metres apart in air.

Suppose that radius of each conductor is r metres. Let their respective charge be + Q and − Q coulombs per metre length.

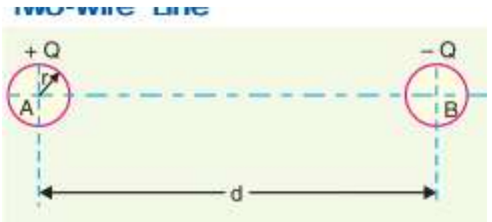


Fig. 9.21

$$V_A = \int_r^\infty \frac{Q}{2\pi x \varepsilon_0} dx + \int_d^\infty \frac{-Q}{2\pi x \varepsilon_0} dx$$

$$= \frac{Q}{2\pi \varepsilon_0}\left[\log_e \frac{\infty}{r} - \log_e \frac{\infty}{d}\right] \text{volts} = \frac{Q}{2\pi \varepsilon_0} \log_e \frac{d}{r} \text{ volts}$$

Similarly, p.d. between conductor B and neutral "infinite" plane is

$$V_B = \int_r^\infty \frac{-Q}{2\pi x \varepsilon_0} dx + \int_d^\infty \frac{Q}{2\pi x \varepsilon_0} dx$$

$$= \frac{-Q}{2\pi \varepsilon_0}\left[\log_e \frac{\infty}{r} - \log_e \frac{\infty}{d}\right] = \frac{-Q}{2\pi \varepsilon_0} \log_e \frac{d}{r} \text{ volts}$$

Both these potentials are *w.r.t.* the same neutral plane. Since the unlike charges attract each other, the potential difference between the conductors is

$$V_{AB} = 2V_A = \frac{2Q}{2\pi \varepsilon_0} \log_e \frac{d}{r} \text{ volts}$$

∴ Capacitance, $$C_{AB} = Q/V_{AB} = \frac{Q}{\frac{2Q}{2\pi \varepsilon_0} \log_e \frac{d}{r}} \text{ F/m}$$

∴ $$C_{AB} = \frac{\pi \varepsilon_0}{\log_e \frac{d}{r}} \text{ F / m} \qquad ...(i)$$

Capacitance of a 3-Phase Overhead Line

In a 3-phase transmission line, the capacitance of each conductor is considered instead of capacitance from conductor to conductor.Here, again two cases arises.

1.symmetrical spacing and

2.unsymmetrical spacing

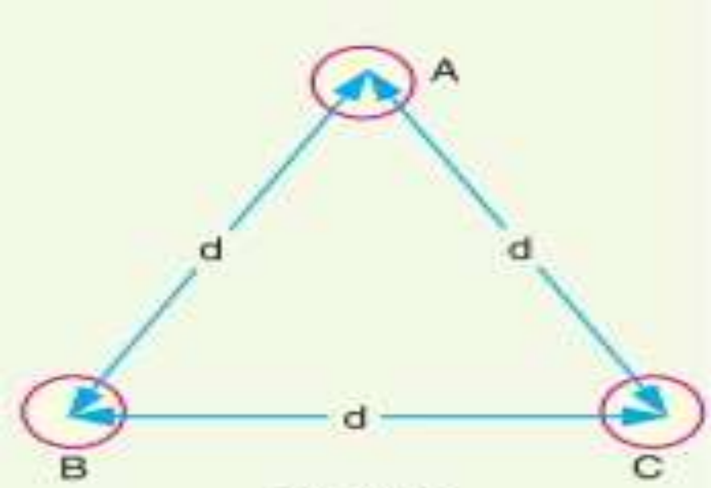


Fig. 9.24

Symmetrical Spacing. Fig. 9.24 shows the three conductors A, B and C of the 3-phase overhead transmission line having charges QA, QB and QC per metre length respectively. Let the conductors be equidistant (d metres) from each other

$$V_A = \int_r^\infty \frac{Q_A}{2\pi x \varepsilon_0} dx + \int_d^\infty \frac{Q_B}{2\pi x \varepsilon_0} dx + \int_d^\infty \frac{Q_C}{2\pi x \varepsilon_0} dx$$

$$= \frac{1}{2\pi \varepsilon_0}\left[Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d} + Q_C \log_e \frac{1}{d}\right]$$

$$= \frac{1}{2\pi \varepsilon_0}\left[Q_A \log_e \frac{1}{r} + (Q_B + Q_C) \log_e \frac{1}{d}\right]$$

Assuming balanced supply, we have, $Q_A + Q_B + Q_C = 0$

$\therefore \quad Q_B + Q_C = -Q_A$

$$\therefore \quad V_A = \frac{1}{2\pi \varepsilon_0}\left[Q_A \log_e \frac{1}{r} - Q_A \log_e \frac{1}{d}\right] = \frac{Q_A}{2\pi\varepsilon_0} \log_e \frac{d}{r} \text{ volts}$$

$\therefore$ Capacitance of conductor A w.r.t neutral,

$$C_A = \frac{Q_A}{V_A} = \frac{Q_A}{\frac{Q_A}{2\pi \varepsilon_0} \log_e \frac{d}{r}} \text{ F/m} = \frac{2\pi \varepsilon_0}{\log_e \frac{d}{r}} \text{ F/m}$$

$$\therefore \quad C_A = \frac{2\pi \varepsilon_0}{\log_e \frac{d}{r}} \text{ F/m}$$

Unsymmetrical spacing. Fig. 9.25 shows a 3-phase transposed line having unsymmetrical spacing. Let us assume balanced conditions i.e. QA + QB + QC = 0

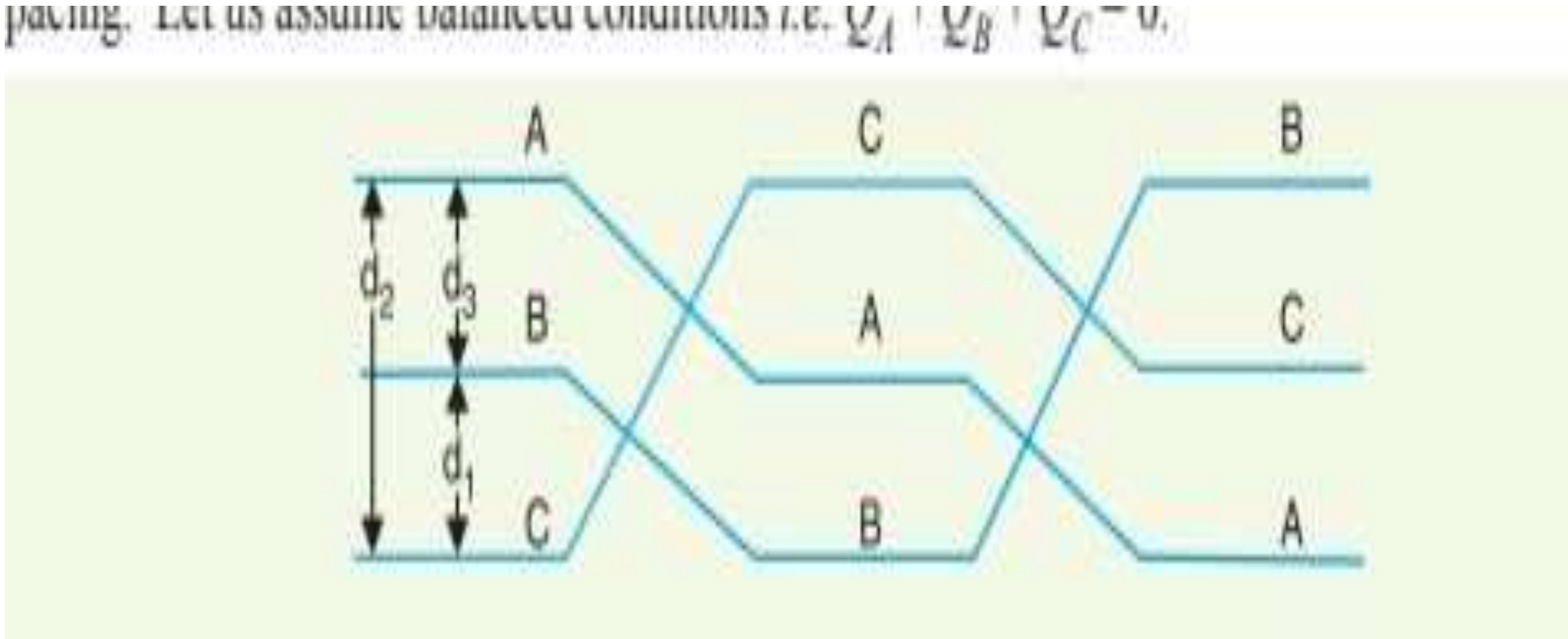


Fig. 9.25

Potential of 1st position, $V_1 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_3} + Q_C \log_e \frac{1}{d_2}\right)$

Potential of 2nd position, $V_2 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_1} + Q_C \log_e \frac{1}{d_3}\right)$

Potential of 3rd position, $V_3 = \frac{1}{2\pi\varepsilon_0}\left(Q_A \log_e \frac{1}{r} + Q_B \log_e \frac{1}{d_2} + Q_C \log_e \frac{1}{d_1}\right)$

Average voltage on condutor A is

$$V_A = \frac{1}{3}(V_1 + V_2 + V_3)$$

$$= \frac{1}{3 \times 2\pi\varepsilon_0} * \left[Q_A \log_e \frac{1}{r^3} + (Q_B + Q_C)\log_e \frac{1}{d_1 d_2 d_3}\right]$$

As $Q_A + Q_B + Q_C = 0$, therefore, $Q_B + Q_C = -Q_A$

$$\therefore \quad V_A = \frac{1}{6\pi\varepsilon_0}\left[Q_A \log_e \frac{1}{r^3} - Q_A \log_e \frac{1}{d_1 d_2 d_3}\right]$$

Capacitance from conductor to neutral is

$$C_A = \frac{Q_A}{V_A} = \frac{2\pi\varepsilon_0}{\log_e \frac{\sqrt[3]{d_1 d_2 d_3}}{r}} \; F/m$$

Skin effect

The tendency of alternating current to concentrate near the surface of a conductor is known as skin effect.

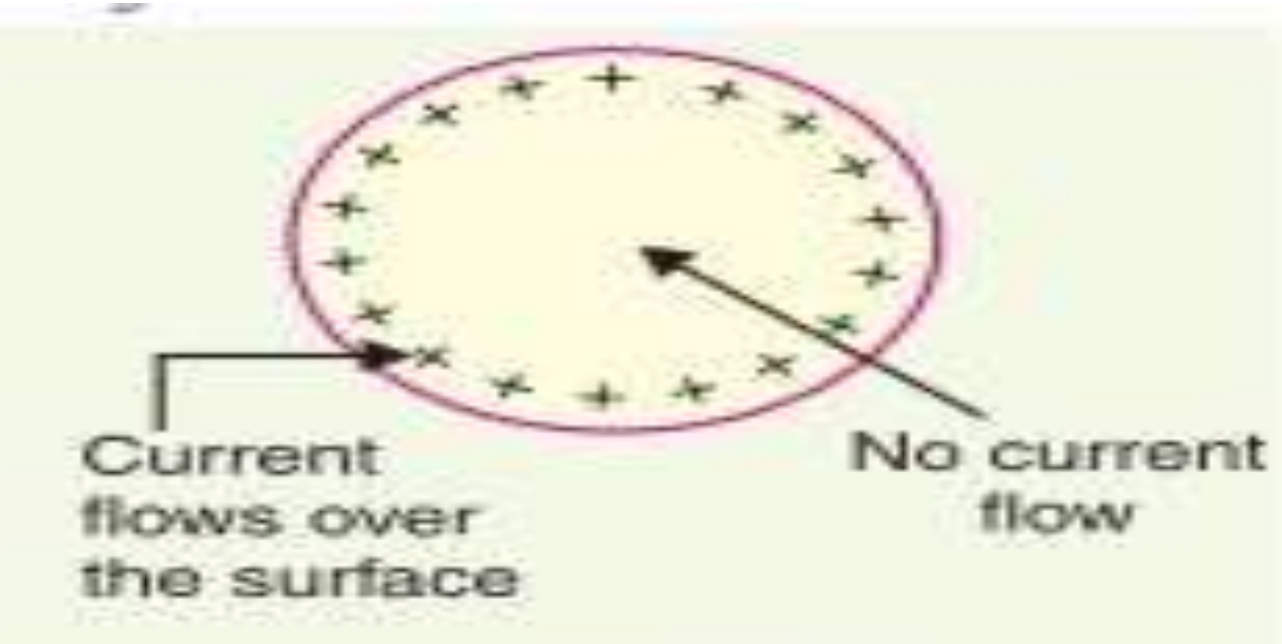


Fig. 9.3

Due to skin effect, the effective area of cross-section of the conductor through which current flows is reduced the resistance of the conductor is slightly increased when carrying an alternating current.

A solid conductor may be thought to be consisting of a large number of strands, each carrying a small part of the current.

The inductance of each strand will vary according to its position.

The skin effect depends upon the following factors :

1.Nature of material

2.Diameter of wire – increases with the diameter of wire.

3.Frequency – increases with the increase in frequency.

4.Shape of wire – less for stranded conductor than the solid conductor.

- **CONCLUSION**

UNIT -4

SUBSTATIONS

25.1 Sub-Station

The assembly of apparatus used to change some characteristic (e.g. voltage, a.c. to d.c., frequency, p.f. etc.) of electric supply is called a **sub-station.**

Sub-stations are important part of power system. The continuity of supply depends to a considerable extent upon the successful operation of sub-stations. It is, therefore, essential to exercise utmost care while designing and building a sub-station. The following are the important points which must be kept in view while laying out a sub-station :

(*i*) It should be located at a proper site. As far as possible, it should be located at the centre of gravity of load.

(*ii*) It should provide safe and reliable arrangement. For safety, consideration must be given to the maintenance of regulation clearances, facilities for carrying out repairs and maintenance, abnormal occurrences such as possibility of explosion or fire etc. For reliability, consideration must be given for good design and construction, the provision of suitable protective gear *etc.*

(*iii*) It should be easily operated and maintained.

(*iv*) It should involve minimum capital cost.

25.2 Classification of Sub-Stations

There are several ways of classifying sub-stations. However, the two most important ways of classifying them are according to (1) service requirement and (2) constructional features.

1. According to service requirement. A sub-station may be called upon to change voltage level or improve power factor or convert a.c. power into d.c. power etc. According to the service requirement, sub-stations may be classified into :

(i) **Transformer sub-stations.** Those sub-stations which change the voltage level of electric supply are called transformer sub-stations. These sub-stations receive power at some voltage and deliver it at some other voltage. Obviously, transformer will be the main component in such sub-stations. Most of the sub-stations in the power system are of this type.

(ii) **Switching sub-stations.** These sub-stations do not change the voltage level *i.e.* incoming and outgoing lines have the same voltage. However, they simply perform the switching operations of power lines.

(iii) **Power factor correction sub-stations.** Those sub-stations which improve the power factor of the system are called power factor correction sub-stations. Such sub-stations are generally located at the receiving end of transmission lines. These sub-stations generally use synchronous condensers as the power factor improvement equipment.

(iv) **Frequency changer sub-stations.** Those sub-stations which change the supply frequency are known as frequency changer sub-stations. Such a frequency change may be required for industrial utilisation.

(v) **Converting sub-stations.** Those sub-stations which change a.c. power into d.c. power are called converting sub-stations. These sub-stations receive a.c. power and convert it into d.c. power

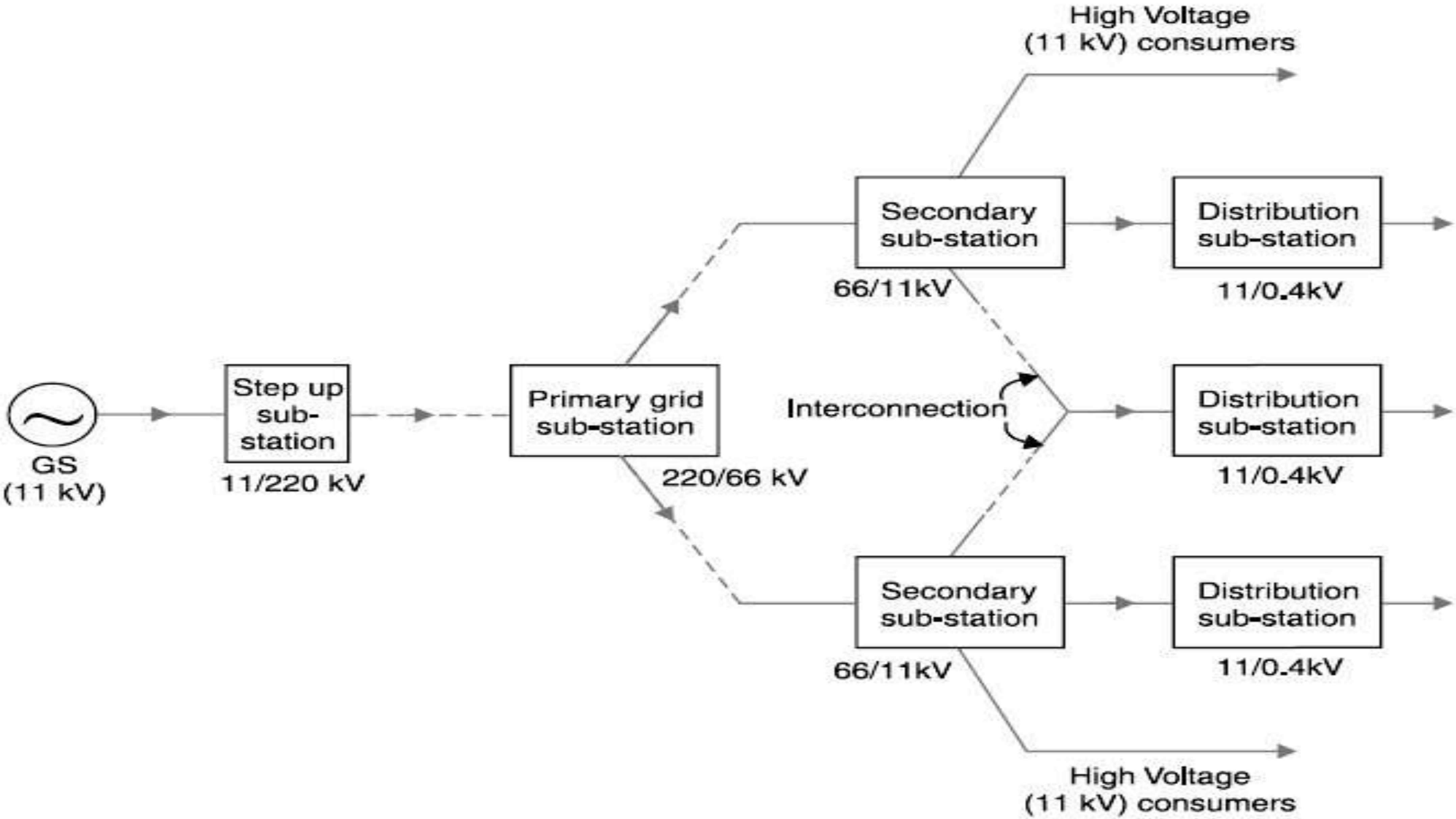
Transformer Sub-Stations

(*i*) Step-up sub-station

(*ii*) Primary grid sub-station

(*iii*) Secondary sub-station

(*iv*) Distribution sub-station



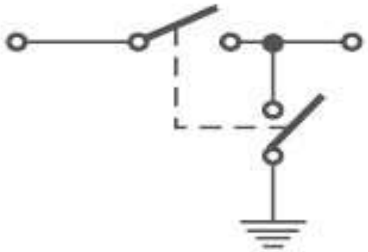
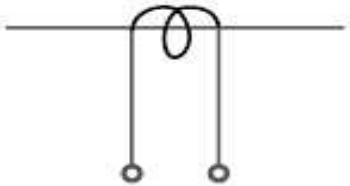
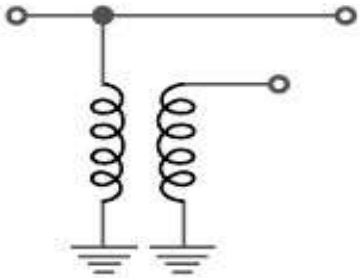
High Voltage
(11 kV) consumers
Secondary
sub-station
Distribution
sub-station
66/11kV
11/0.4kV
Step up
sub-
station
Primary grid
sub-station
Interconnection
Distribution
sub-station
GS
(11 kV)
11/220 kV
220/66 kV
11/0.4kV
Secondary
sub-station
Distribution
sub-station
66/11kV
11/0.4kV
High Voltage
(11 kV) consumers

(*i*) **Step-up sub-station.** The generation voltage (11 kV in this case) is stepped up to high voltage (220 kV) to affect economy in transmission of electric power. The sub-stations which accomplish this job are called step-up sub-stations. These are generally located in the power houses and are of outdoor type.

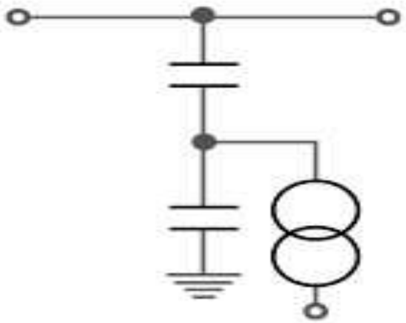
(*ii*) **Primary grid sub-station.** From the step-up sub-station, electric power at 220 kV is transmitted by 3-phase, 3-wire overhead system to the outskirts of the city. Here, electric power is received by the primary grid sub-station which reduces the voltage level to 66 kV for secondary transmission. The primary grid sub-station is generally of outdoor type.

(*iii*) **Secondary sub-station.** From the primary grid sub-station, electric power is transmitted at 66 kV by 3-phase, 3-wire system to various secondary sub-stations located at the strategic points in the city. At a secondary sub-station, the voltage is further stepped down to 11 kV. The 11 kV lines run along the important road sides of the city. It may be noted that big consumers (having demand more than 50 kW) are generally supplied power at 11 kV for further handling with their own sub-stations. The secondary sub-stations are also generally of outdoor type.

(iv) **Distribution sub-station.** The electric power from 11 kV lines is delivered to distribution sub-stations. These sub-stations are located near the consumers localities and step down the voltage to 400 V, 3-phase, 4-wire for supplying to the consumers. The voltage between any two phases is 400V and between any phase and neutral it is 230 V. The single phase residential lighting load is connected between any one phase and neutral whereas 3-phase, 400V motor load is connected across 3-phase lines directly. It may be worthwhile to mention here that majority of the distribution sub-stations are of pole-mounted type.

S.No.	Circuit element	Symbol
1	Bus-bar	
2	Single-break isolating switch	
3	Double-break isolating switch	
4	On load isolating switch	
5	Isolating switch with earth Blade	
6	Current transformer	
7	Potential transformer	

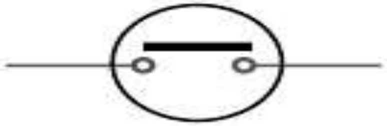
8 Capacitive voltage transformer



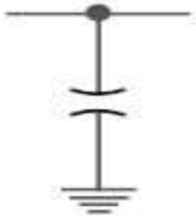
9 Oil circuit breaker

10 Air circuit breaker with overcurrent tripping device

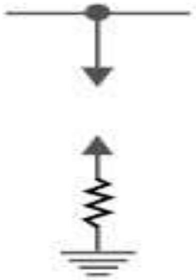
11 Air blast circuit breaker

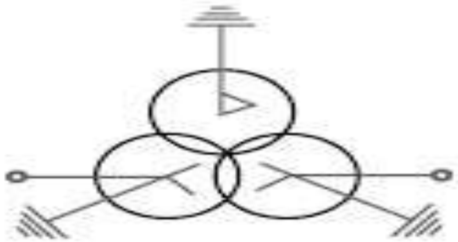
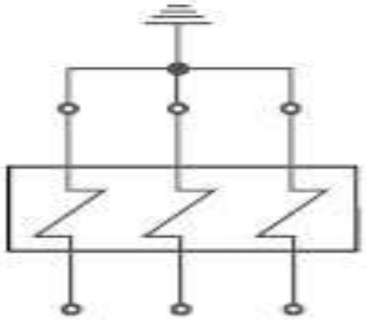
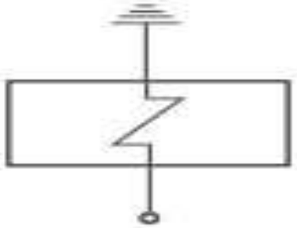


12 Lightning arrester (active gap)



13 Lightning arrester (valve type)



S.No.	Circuit element	Symbol
14	Arcing horn	
15	3-ϕ Power transformer	
16	Overcurrent relay	
17	Earth fault relay	

25.8 Equipment in a Transformer Sub-Station

The equipment required for a transformer sub-station depends upon the type of sub-station, service requirement and the degree of protection desired. However, in general, a transformer sub-station has the following main equipment :

1. Bus-bars. When a number of lines operating at the same voltage have to be directly connected electrically, bus-bars are used as the common electrical component. Bus-bars are copper or aluminium bars (generally of rectangular *x*-section) and operate at constant voltage. The incoming and outgoing lines in a sub-station are connected to the bus-bars. The most commonly used bus-bar arrangements in sub-stations are :

(*i*) Single bus-bar arrangement

(*ii*) Single bus-bar system with sectionalisation

(*iii*) Double bus-bar arrangement

A detailed discussion on these bus-bar arrangements has already been made in Art. 16.3. However, their practical applications in sub-stations are discussed in Art. 25.9.

2. Insulators. The insulators serve two purposes. They support the conductors (or bus-bars)

CONCLUSION

UNIT -5

DC DISTRIBUTION AND AC DISTRIBUTION

Distribution system:
The part of power system which distributes electric power for local use is known as distribution system**.**
In general, the distribution system is the electrical system between the sub-station fed by the transmission system and the consumers meters.
It generally consists of feeders, distributors and the service mains.

Feeders: A feeder is a conductor which connects the sub-station to the area where power is to be distributed

Distributor:A distributor is a conductor from which tappings are taken for supply to the consumers

Service mains:A service mains is generally a small cable which connects the distributor to the consumers' terminals.

Classification of Distribution Systems

1.Nature of current. According to nature of current, distribution system may be classified as
1.D.C. distribution system
2.A.C. distribution system.

Type of construction.
According to type of construction, distribution system may be classified as
1. overhead system
2.underground system.

The overhead system is gen- erally employed for distribution as it is 5 to 10 times cheaper than the equivalent underground system.

Scheme of connection.
According to scheme of connection, the distribution system may be classified as
(a) radial system
(b) ring main system
(c) inter-connected system..

A.C. distribution system is classified into

(i) primary distribution system and

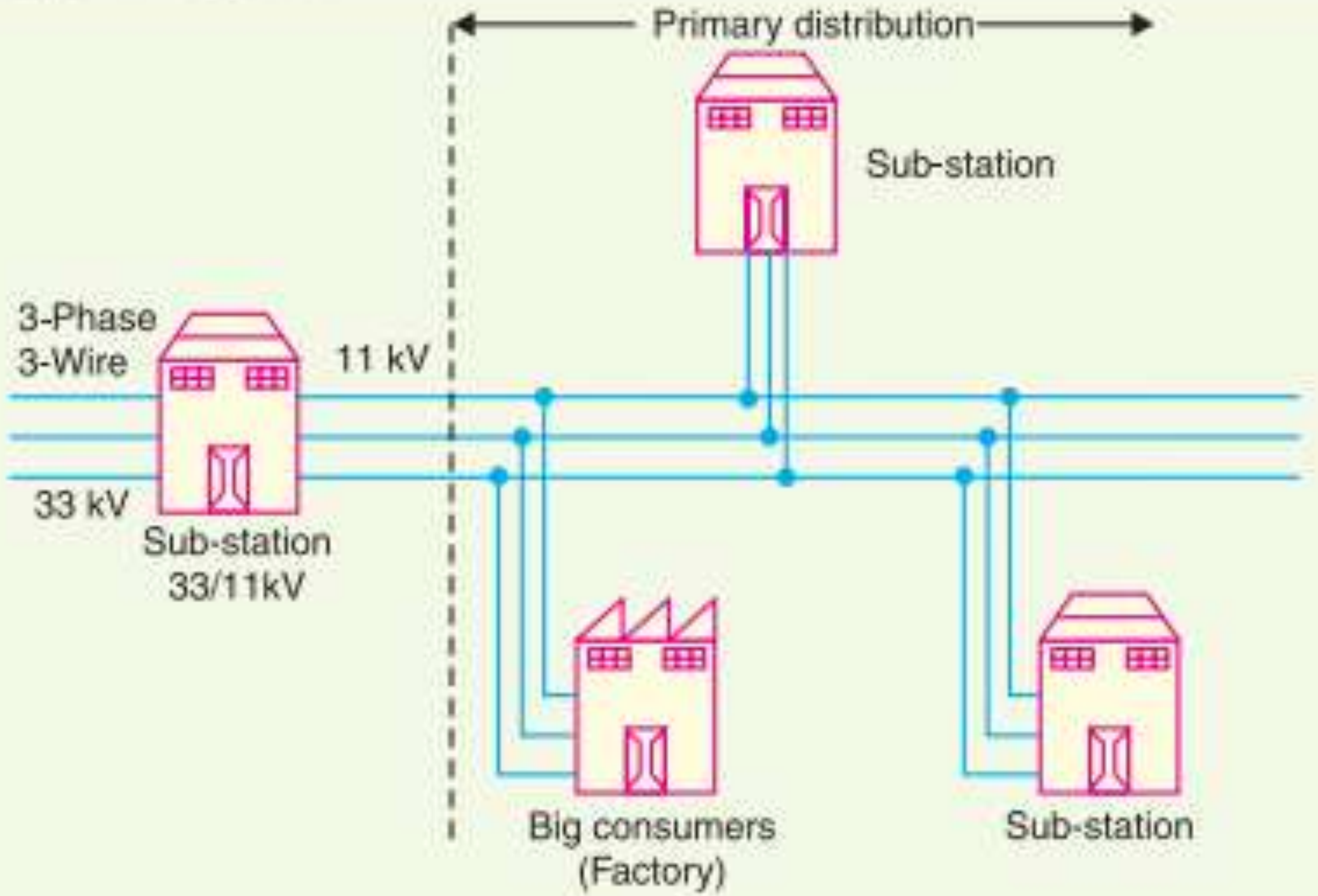
(ii) secondary distribution system.

Primary distribution system: It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilisation and handles large blocks of electrical energy than the average low-voltage consumer uses.

1.The voltage used for primary distribution depends upon the amount of power to be conveyed and the distance of the substation required to be fed.

2.The most commonly used primary distribution voltages are 11 kV, 6·6 kV and 3·3 kV.

3.Due to economic considerations, primary distribution is carried out by 3- phase, 3-wire system



Primary distribution
Sub-station
3-Phase
3-Wire
11 kV
33 kV
Sub-station
33/11kV
Big consumers
(Factory)
Sub-station

Fig. 12.2

Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.

1. At this substation, voltage is stepped down to 11 kV with the help of step-down transformer.

2.Power is supplied to various substations for distribution or to big consumers at this voltage. This forms the high voltage distribution or primary distribution.

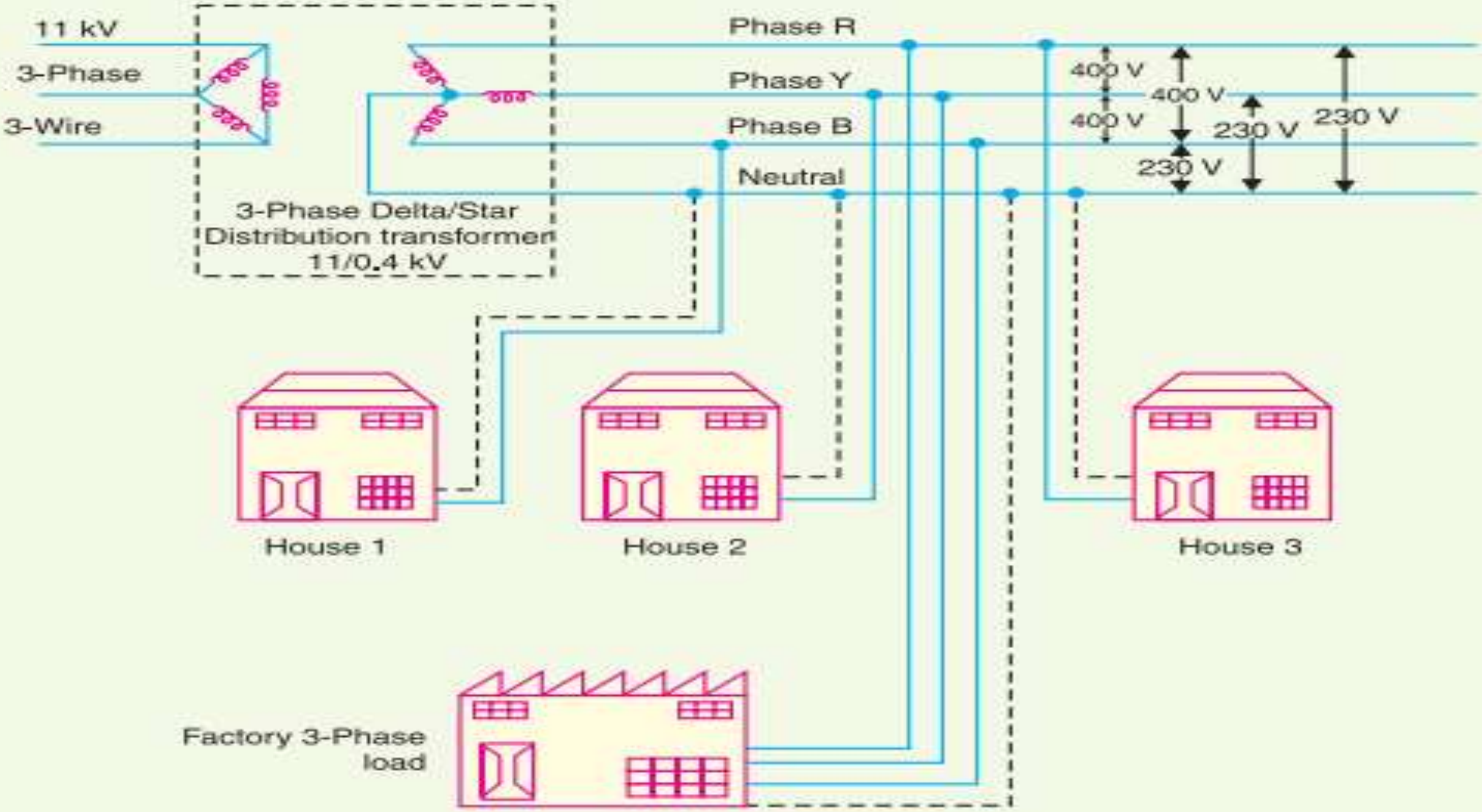
Secondary distribution system. It is that part of a.c. distribution system which includes the range of voltages at which the ultimate consumer utilises the electrical energy delivered to him.

1.The secondary distribution employs 400/230 V, 3-phase, 4-wire system.

2.The primary distribution circuit delivers power to various substations, called distribution sub-stations. The substations are situated near the consumers' localities and contain step-down transformers.

3. At each distribution substation, thevoltage is stepped down to 400V and power is delivered by 3-phase,4-wire a.c. system.

4.The voltage between any twophases is 400 V and between any phase and neutral is 230V.



11 kV
3-Phase
3-Wire
3-Phase Delta/Star
Distribution transformer
11/0.4 kV
Phase R
Phase Y
Phase B
Neutral
400 V
400 V
400 V
230 V
230 V
230 V
House 1
House 2
House 3
Factory 3-Phase load

Fig. 12.3

Overhead Versus Under versus Underground System

1.The distribution system can be overhead or underground.

2.Overhead lines are generally mounted on wooden, concrete or steel poles which are arranged to carry distribution transformers in addition to the conductors.

3.The underground system uses conduits, cables and manholes under the surface of streets and sidewalks.

4.The choice between overhead and underground system depends upon a number of widely differing factors. Therefore, it is desirable to make a comparison between the two.

Overhead Versus Under versus Underground System

1.Public safety

2.Initial cost.

3.Flexibility.

4.Faults.

5.Appearance

6. Fault location and repairs

7.Current carrying capacity and voltage drop

8.Useful life

9.Maintenance cost

10.Interference with communication circuits

Types of D.C. Distributors

The most general method of classifying d.c. distributors is the way they are fed by the feeders.

On this basis, d.c. distributors are classified as

1. Distributor fed at one end
2. Distributor fed at both ends
3. Distributor fed at the centre
4. Ring distributor.

Distributor fed at one end

In this type of feeding, the distributor is connected to the supply at one end and loads are taken at different points along the length of the distributor.

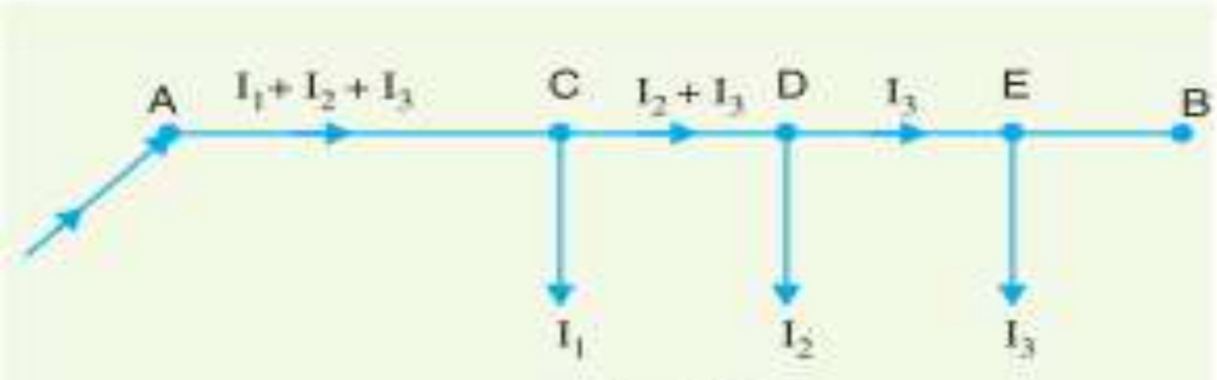


Fig. 13.1

The above fig shows the single line dia-gram of a d.c. distributor A B fed at the end A (also known as singly fed distributor) and loads I1, I2 and I3 tapped off at points C, D and E respectively.

The following points are worth noting in a singly fed distributor :

1.The current in the various sections of the distributor away from feeding point goes on decreasing. Thus current in section AC is more than the current in section CD and current in section CD is more than the current in section DE.

2.The voltage across the loads away from the feeding point goes on decreasing. Thus in Fig. 13.1, the minimum voltage occurs at the load point E.

3.In case a fault occurs on any section of the distributor, the whole distributor will have to be disconnected from the supply mains. Therefore, continuity of supply is interrupted

Distributor fed at both ends.

In this type of feeding, the distributor is connected to the supply mains at both ends and loads are tapped off at different points along the length of the distributor. The voltage at the feeding points may or may not be equal.

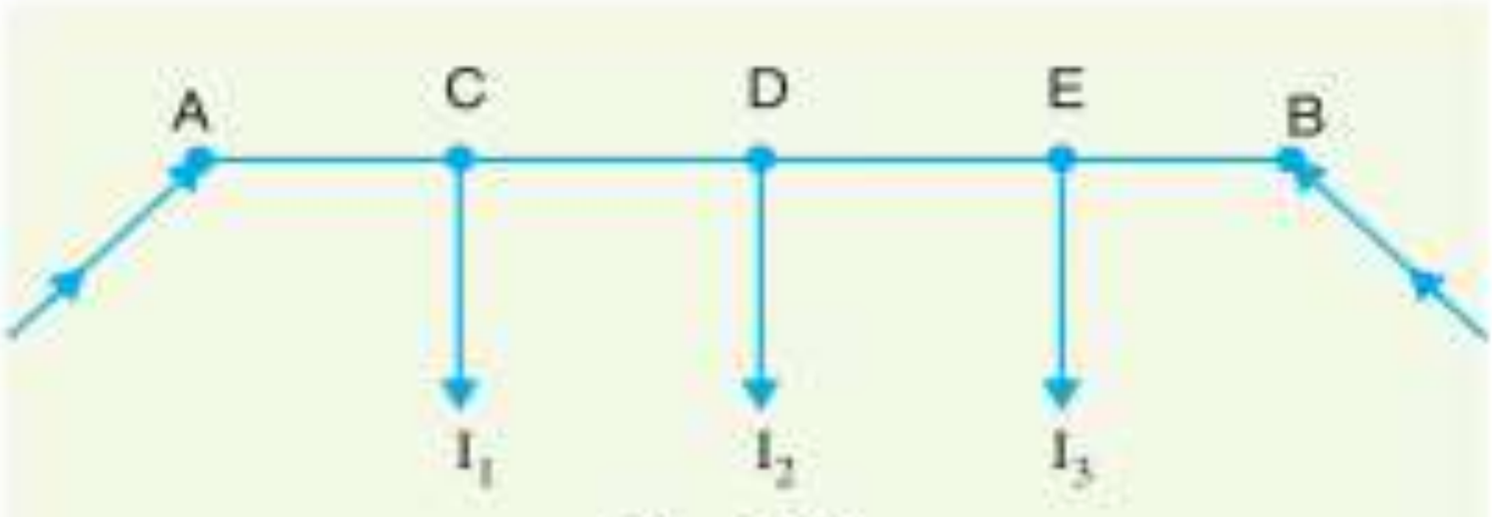


Fig. 13.2

Advantages

1.If a fault occurs on any feeding point of the distributor, the continuity of supply is main- tained from the other feeding point.

2.In case of fault on any section of the distributor, the continuity of supply is maintained from the other feeding point.

3.The area of X-section required for a doubly fed distributor is much less than that of a singly fed distributor.

Distributor fed at the centre.

In this type of feeding, the centre of the distributor is connected to the supply mains as shown in Fig. 13.3.

It is equivalent to two singly fed distributors, each distributor having a common feeding point and length equal to half of the total length.

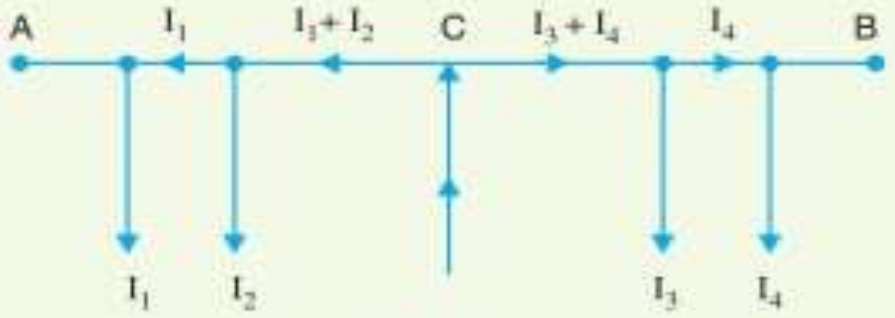


Fig. 13.3

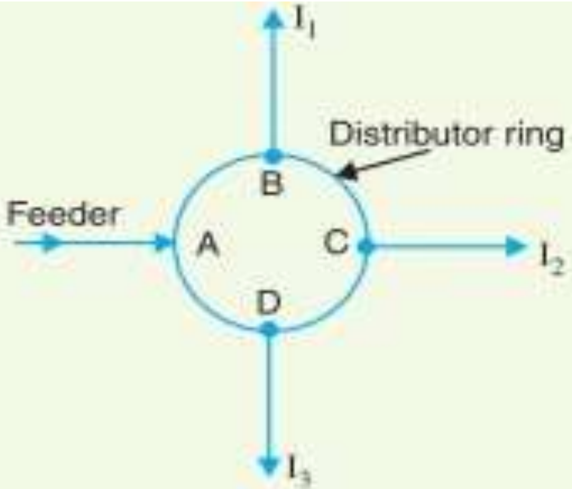


Fig. 13.4

Ring mains.

1.In this type, the distributor is in the form of a closed ring as shown in Fig.13.4.

2. It is equivalent to a straight distributor fed at both ends with equal voltages, the two ends being brought together to form a closed ring.

3.The distributor ring may be fed at one or more than one point.

- **CONCLUSION**