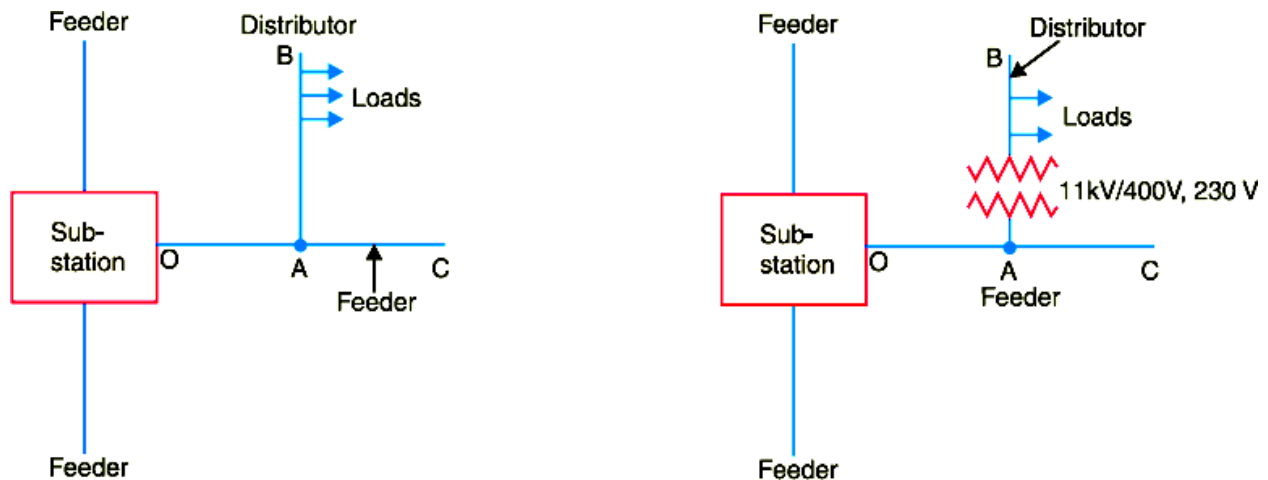


CONNECTION SCHEMES OF DISTRIBUTION SYSTEM

All distribution of electrical energy is done by constant voltage system. In practice, the following distribution circuits are generally used :

(i) Radial System.

In this system, separate feeders radiate from a single substation and feed the distributors at one end only. Fig. shows a single line diagram of a radial system for d.c. distribution where a feeder OC supplies a distributor A B at point A . Obviously, the distributor is fed at one end only i.e., point A is this case. Fig (ii) shows a single line diagram of radial system for a.c. distribution. The radial system is employed only when power is generated at low voltage and the substation is located at the centre of the load.



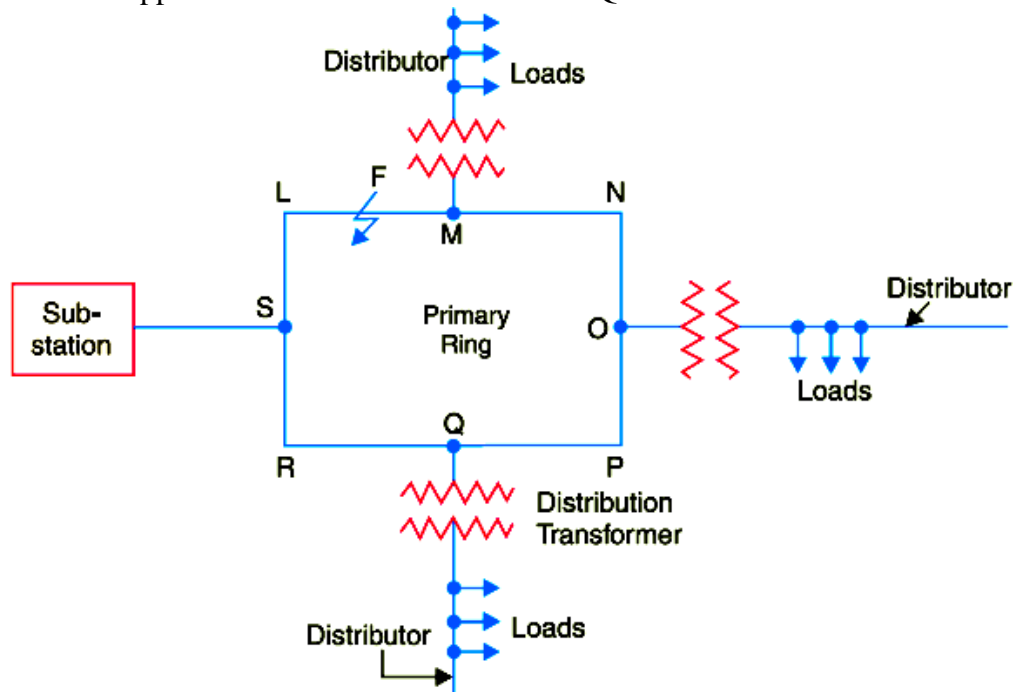
This is the simplest distribution circuit and has the lowest initial cost. However, it suffers from the following drawbacks :

- (a) The end of the distributor nearest to the feeding point will be heavily loaded.
- (b) The consumers are dependent on a single feeder and single distributor. Therefore, any fault on the feeder or distributor cuts off supply to the consumers who are on the side of the fault away from the substation.
- (c) The consumers at the distant end of the distributor would be subjected to serious voltage fluctuations when the load on the distributor changes.

Due to these limitations, this system is used for short distances only.

(ii) Ring main system.

In this system, the primaries of distribution transformers form a loop. The loop circuit starts from the substation bus-bars, makes a loop through the area to be served, and returns to the substation. Fig. 12.9 shows the single line diagram of ring main system for a.c. distribution where substation supplies to the closed feeder LMNOPQRS.



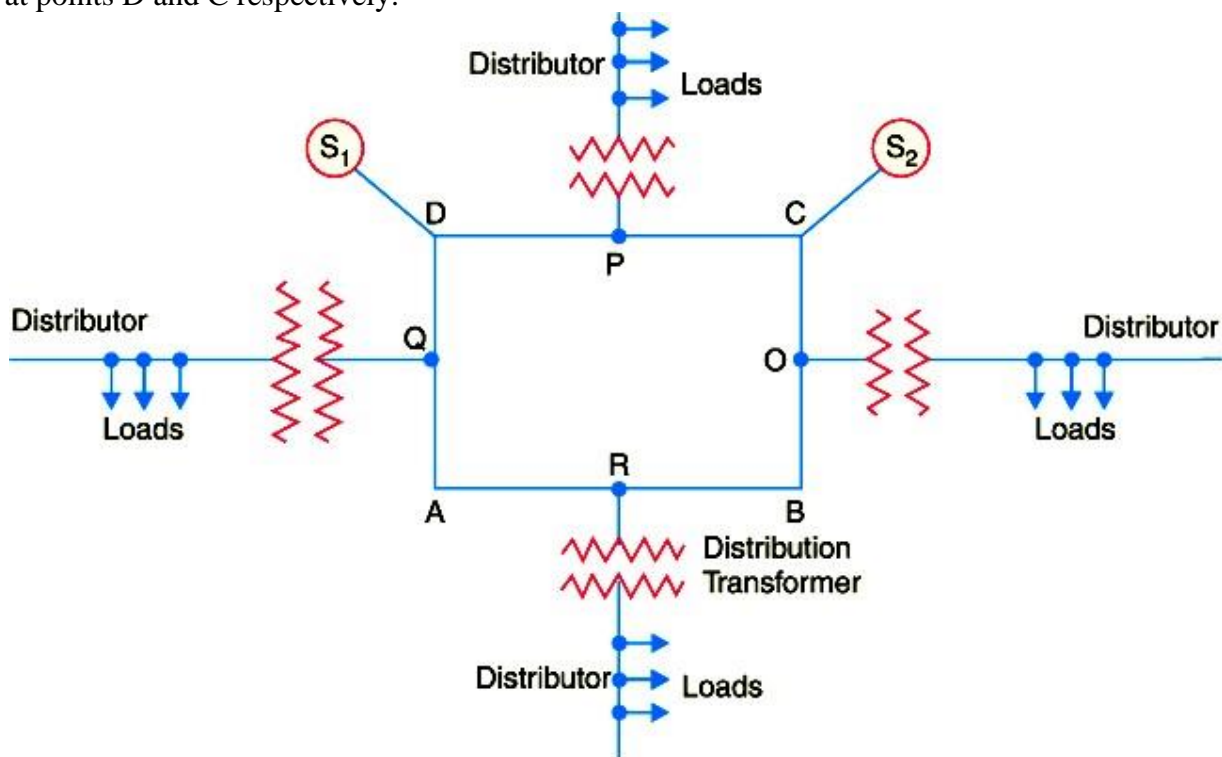
The distributors are tapped from different points M, O and Q of the feeder through distribution transformers. The ring main system has the following advantages :

(a) There are less voltage fluctuations at consumer's terminals.

(b) The system is very reliable as each distributor is fed via *two feeders. In the event of fault on any section of the feeder, the continuity of supply is maintained. For example, suppose that fault occurs at any point F of section SLM of the feeder. Then section SLM of the feeder can be isolated for repairs and at the same time continuity of supply is maintained to all the consumers via the feeder SRQPONM.

(iii) **Interconnected system.**

When the feeder ring is energised by two or more than two generating stations or substations, it is called inter-connected system. Fig. 12.10 shows the single line diagram of interconnected system where the closed feeder ring ABCD is supplied by two substations S and S at points D and C respectively.



Distributors are connected to points O, P, Q and R of the feeder ring through distribution transformers. The interconnected system has the following advantages :

(a) It increases the service reliability.

(b) Any area fed from one generating station during peak load hours can be fed from the other generating station. This reduces reserve power capacity and increases efficiency of the system.

REQUIREMENTS OF A DISTRIBUTION SYSTEM

A considerable amount of effort is necessary to maintain an electric power supply within the requirements of various types of consumers. Some of the requirements of a good distribution system are : proper voltage, availability of power on demand and reliability.

(i) Proper voltage.

One important requirement of a distribution system is that voltage variations at consumer's terminals should be as low as possible. The changes in voltage are generally caused due to the variation of load on the system. Low voltage causes loss of revenue, inefficient lighting and possible burning out of motors. High voltage causes lamps to burn out permanently and may cause failure of other appliances. Therefore, a good distribution system should ensure that the voltage variations at consumers terminals are within permissible limits. The statutory limit of voltage variations is $\pm 6\%$ of the rated value at the consumer's terminals. Thus, if the declared voltage is 230 V, then the highest voltage of the consumer should not exceed 244 V while the lowest voltage of the consumer should not be less than 216 V.

(ii) Availability of power on demand.

Power must be available to the consumers in any amount that they may require from time to time. For example, motors may be started or shut down, lights may be turned on or off, without advance warning to the electric supply company. As electrical energy cannot be stored, therefore, the distribution system must be capable of supplying load demands of the consumers. This necessitates that operating staff must continuously study load patterns to predict in advance those major load changes that follow the known schedules.

(iii) Reliability.

Modern industry is almost dependent on electric power for its operation. Homes and office buildings are lighted, heated, cooled and ventilated by electric power. This calls for reliable service. Unfortunately, electric power, like everything else that is man-made, can never be absolutely reliable. However, the reliability can be improved to a considerable extent by (a) interconnected system (b) reliable automatic control system (c) providing additional reserve facilities.

DESIGN CONSIDERATIONS IN DISTRIBUTION SYSTEM

Good voltage regulation of a distribution network is probably the most important factor responsible for delivering good service to the consumers. For this purpose, design of feeders and distributors requires careful consideration.

(i) Feeders.

A feeder is designed from the point of view of its current carrying capacity while the voltage drop consideration is relatively unimportant. It is because voltage drop in a feeder can be compensated by means of voltage regulating equipment at the substation.

(ii) Distributors.

A distributor is designed from the point of view of the voltage drop in it. It is because a distributor supplies power to the consumers and there is a statutory limit of voltage variations at the consumer's terminals ($\pm 6\%$ of rated value). The size and length of the distributor should be such that voltage at the consumer's terminals is within the permissible limits.

A.C. DISTRIBUTION -INTRODUCTION

In the beginning of electrical age, electricity was generated, transmitted and distributed as direct current. The principal disadvantage of d.c. system was that voltage level could not readily

be changed, except by the use of rotating machinery, which in most cases was too expensive. With the development of transformer by George Westinghouse, a.c. system has become so predominant as to make d.c. system practically extinct in most parts of the world. The present day large power system has been possible only due to the adoption of a.c. system. Now-a-days, electrical energy is generated, transmitted and distributed in the form of alternating current as an economical proposition. The electrical energy produced at the power station is transmitted at very high voltages by 3-phase, 3-wire system to step-down sub-stations for distribution. The distribution system consists of two parts viz. primary distribution and secondary distribution. The primary distribution circuit is 3-phase, 3-wire and operates at voltages (3.3 or 6.6 or 11kV) somewhat higher than general utilization levels. It delivers power to the secondary distribution circuit through distribution transformers situated near consumers' localities. Each distribution transformer steps down the voltage to 400 V and power is distributed to ultimate consumers' by 400/230 V, 3-phase, 4-wire system. In this chapter, we shall focus our attention on the various aspects of a.c. distribution.

A.C. DISTRIBUTION CALCULATIONS

A.C. distribution calculations differ from those of d.c. distribution in the following respects :

(i) In case of d.c. system, the voltage drop is due to resistance alone. However, in a.c. system, the voltage drops are due to the combined effects of resistance, inductance and capacitance.

(ii) In a d.c. system, additions and subtractions of currents or voltages are done arithmetically but in case of a.c. system, these operations are done vectorially.

(iii) In an a.c. system, power factor (p.f.) has to be taken into account. Loads tapped off from the distributor are generally at different power factors. There are two ways of referring power factor viz

(a) It may be referred to supply or receiving end voltage which is regarded as the reference vector.

(b) It may be referred to the voltage at the load point itself.

There are several ways of solving a.c. distribution problems. However, symbolic notation method has been found to be most convenient for this purpose. In this method, voltages, currents and impedances are expressed in complex notation and the calculations are made exactly as in d.c. distribution.

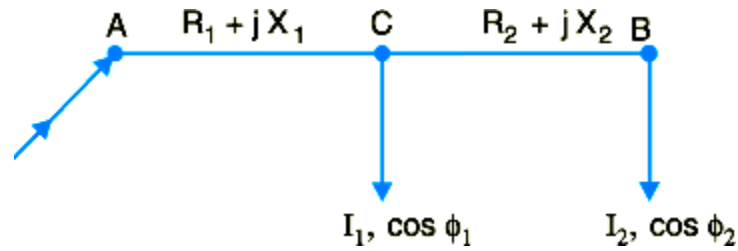
METHODS OF SOLVING A.C. DISTRIBUTION PROBLEMS

In a.c. distribution calculations, power factors of various load currents have to be considered since currents in different sections of the distributor will be the vector sum of load currents and not the arithmetic sum. The power factors of load currents may be given (i) w.r.t. receiving or sending end voltage or (ii) w.r.t. to load voltage itself. Each case shall be discussed separately.

(i) Power factors referred to receiving end voltage.

Consider an a.c. distributor AB with concentrated loads of I_1 and I_2 tapped off at points C and B as shown in Fig. Taking the receiving end voltage V_B as the reference vector, let

lagging power factors at C and B be $\cos \phi_1$ and $\cos \phi_2$ w.r.t. V_B . Let R_1, X_1 and R_2, X_2 be the resistance and reactance of sections AC and CB of the distributor.



Impedance of section AC , $\vec{Z}_{AC} = R_1 + jX_1$

Impedance of section CB , $\vec{Z}_{CB} = R_2 + jX_2$

Load current at point C , $\vec{I}_1 = I_1 (\cos \phi_1 - j \sin \phi_1)$

Load current at point B , $\vec{I}_2 = I_2 (\cos \phi_2 - j \sin \phi_2)$

Current in section CB , $\vec{I}_{CB} = \vec{I}_2 = I_2 (\cos \phi_2 - j \sin \phi_2)$

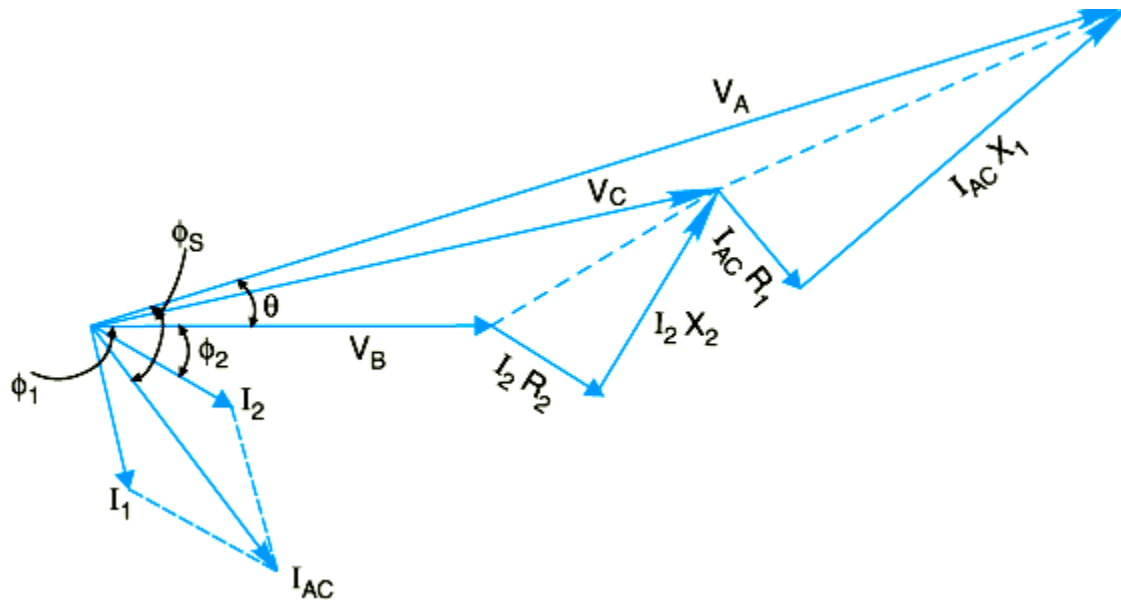
Current in section AC , $\vec{I}_{AC} = \vec{I}_1 + \vec{I}_2$
 $= I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)$

Voltage drop in section CB , $\vec{V}_{CB} = \vec{I}_{CB} \vec{Z}_{CB} = I_2 (\cos \phi_2 - j \sin \phi_2) (R_2 + jX_2)$

Voltage drop in section AC , $\vec{V}_{AC} = \vec{I}_{AC} \vec{Z}_{AC} = (\vec{I}_1 + \vec{I}_2) Z_{AC}$
 $= [I_1 (\cos \phi_1 - j \sin \phi_1) + I_2 (\cos \phi_2 - j \sin \phi_2)] [R_1 + jX_1]$

Sending end voltage, $\vec{V}_A = \vec{V}_B + \vec{V}_{CB} + \vec{V}_{AC}$

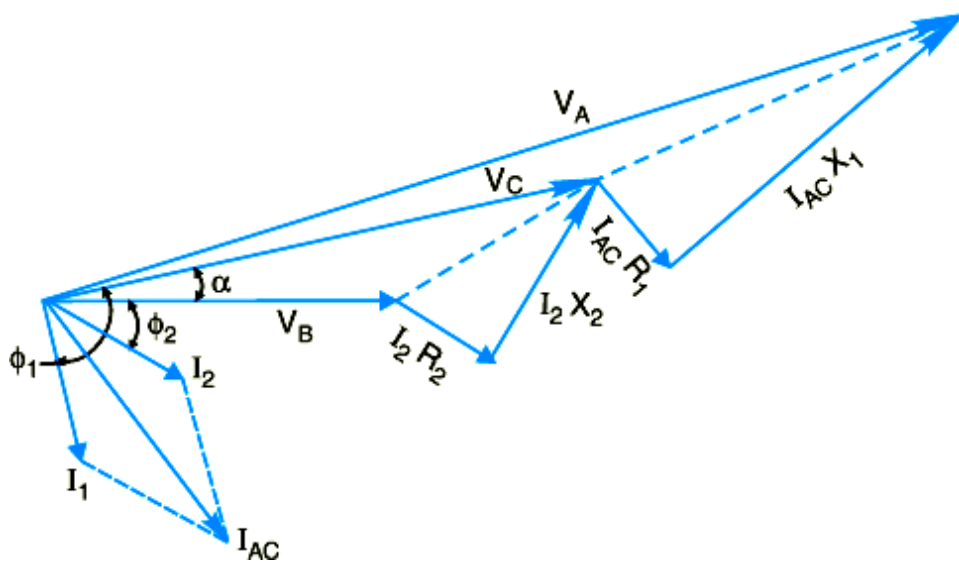
Sending end current, $\vec{I}_A = \vec{I}_1 + \vec{I}_2$



The vector diagram of the a.c. distributor under these conditions is shown in Fig. Here, the receiving end voltage V_B is taken as the reference vector. As power factors of loads are given *w.r.t.* V_B , therefore, I_1 and I_2 lag behind V_B by ϕ_1 and ϕ_2 respectively.

(ii) Power factors referred to respective load voltages.

Suppose the power factors of loads in the previous Fig. are referred to their respective load voltages. Then ϕ_1 is the phase angle between V_C and I_1 and ϕ_2 is the phase angle between V_B and I_2 . The vector diagram under these conditions is shown in Fig



$$\text{Voltage drop in section } CB = \vec{I}_2 \vec{Z}_{CB} = I_2 (\cos \phi_2 - j \sin \phi_2) (R_2 + j X_2)$$

$$\text{Voltage at point } C = \vec{V}_B + \text{Drop in section } CB = V_C \angle \alpha \text{ (say)}$$

$$\text{Now } \vec{I}_1 = I_1 \angle -\phi_1 \text{ w.r.t. voltage } V_C$$

$$\therefore \vec{I}_1 = I_1 \angle -(\phi_1 - \alpha) \text{ w.r.t. voltage } V_B$$

$$\text{i.e. } \vec{I}_1 = I_1 [\cos(\phi_1 - \alpha) - j \sin(\phi_1 - \alpha)]$$

$$\begin{aligned} \text{Now } \vec{I}_{AC} &= \vec{I}_1 + \vec{I}_2 \\ &= I_1 [\cos(\phi_1 - \alpha) - j \sin(\phi_1 - \alpha)] + I_2 (\cos \phi_2 - j \sin \phi_2) \end{aligned}$$

$$\text{Voltage drop in section } AC = \vec{I}_{AC} \vec{Z}_{AC}$$

$$\therefore \text{Voltage at point } A = V_B + \text{Drop in } CB + \text{Drop in } AC$$

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:

- (i) Distributor fed at one end
- (ii) Distributor fed at both ends
- (iii) Distributor fed at the centre
- (iv) Ring distributor.

(i) 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 point along the length of the distributor.

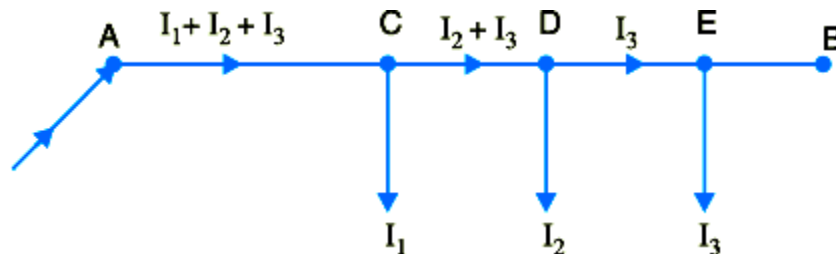


Fig. shows the single line diagram of a d.c. distributor A B fed at the end A (also known as singly fed distributor) and loads I_1 , I_2 and I_3 tapped off at points C, D and E respectively.

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

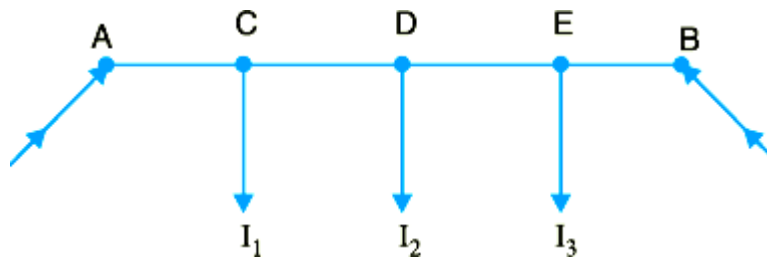
(a) The current in the various sections of the distributor away from feeding point goes on decreasing. Thus current in section AC is more than the current in section CD and current in section CD is more than the current in section DE.

(b) The voltage across the loads away from the feeding point goes on decreasing. Thus in Fig. the minimum voltage occurs at the load point E.

(c) 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.

(ii) 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. shows a distributor A B fed at the ends A and B and loads of I_1 , I_2 and I_3 tapped off at points C, D and E respectively.



Here, the load voltage goes on decreasing as we move away from one feeding point say A, reaches minimum value and then again starts rising and reaches maximum value when we reach the other feeding point B. The minimum voltage occurs at some load point and is never fixed. It is shifted with the variation of load on different sections of the distributor.

Advantages

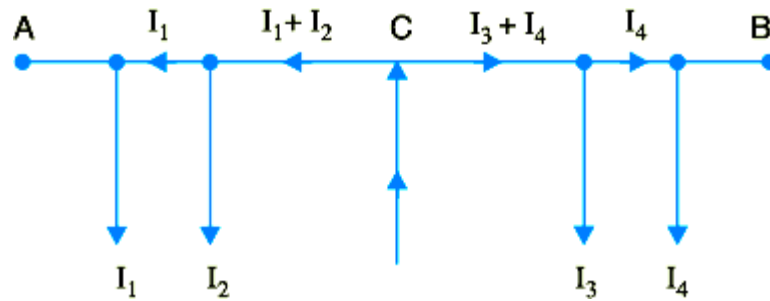
(a) If a fault occurs on any feeding point of the distributor, the continuity of supply is maintained from the other feeding point.

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

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

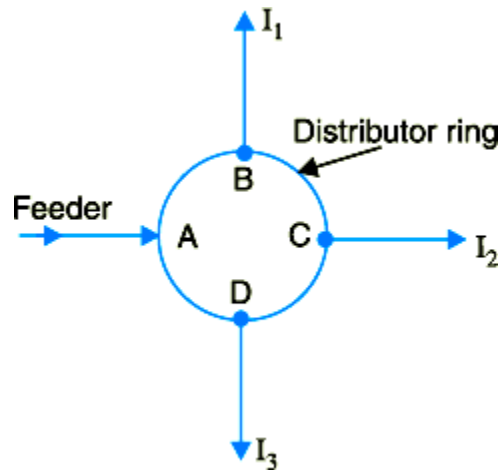
(iii) Distributor fed at the centre.

In this type of feeding, the centre of the distributor is connected to the supply mains as shown in Fig. It is equivalent to two singly fed distributors, each distributor having a common feeding point and length equal to half of the total length.



(iv)Ring mains.

In this type, the distributor is in the form of a closed ring as shown in Fig. 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. The distributor ring may be fed at one or



more than one point.