MODULE 5

Distribution System

That 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 substation fed by the Transmission system and the consumer's meters. It generally consists of feeders, distributors, and service mains.

CLASSIFICATION OF DISTRIBUTION SYSTEMS

A distribution system may be classified according to ;

i) **Nature of current**

According to nature of current, distribution system may be classified as

a) d.c. Distribution system
b) a.c. Distribution system

Now-a-days, a.c. system is universally adopted for distribution of electric power as it is simpler and more economical than direct current method

ii) **Type of construction**

According to type of construction distribution system may be classified as

a) Overhead system
b) Underground system.

The overhead system is generally employed for distribution as it is 5 to 10 times cheaper than the equivalent underground system. In general, the underground system is used at places where overhead con struction is impracticable or prohibited by the local laws

(iii) **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

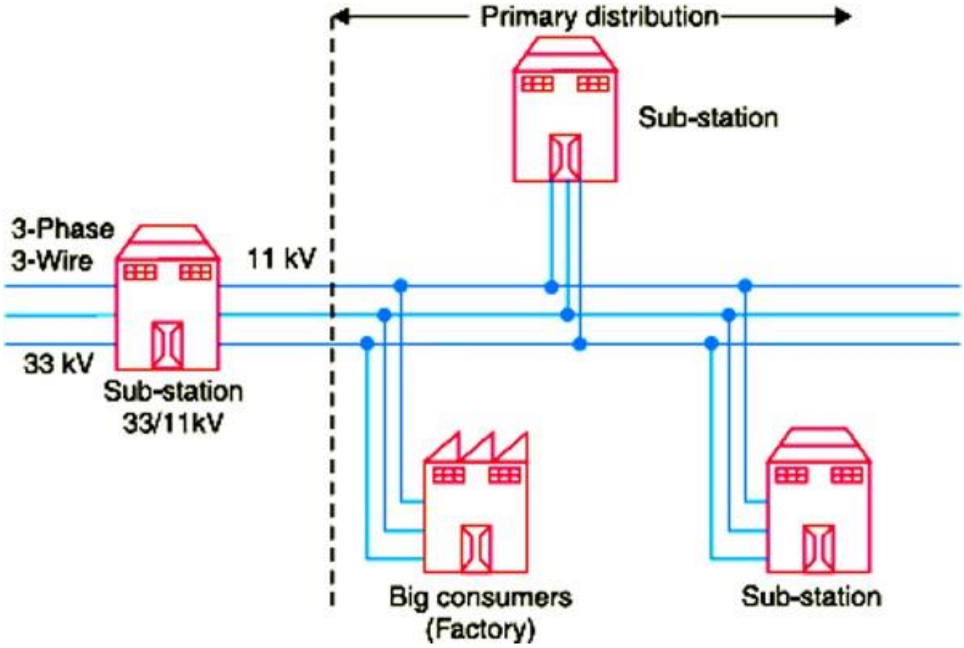
AC DISTRIBUTION

Now-a-days electrical energy is generated, transmitted and distributed in the form of alternating cur-rent. One important reason for the widespread use of alternating current in preference to direct current is the fact that alternating voltage can be conveniently changed in magnitude by means of a transformer. Transformer has made it possible to transmit a.c. power at high voltage and utilise it at a safe potential. High transmission and distribution voltages have greatly reduced the current in the conductors and the resulting line losses. There is no definite line between transmission and distribution according to voltage or bulk capacity. However, in general, the a.c. distribution system is the electrical system between the step- down substation fed by the transmission system and the consumers' meters. The a.c. distribution system is classified into

i. primary distribution system and
ii. Secondary distribution system.

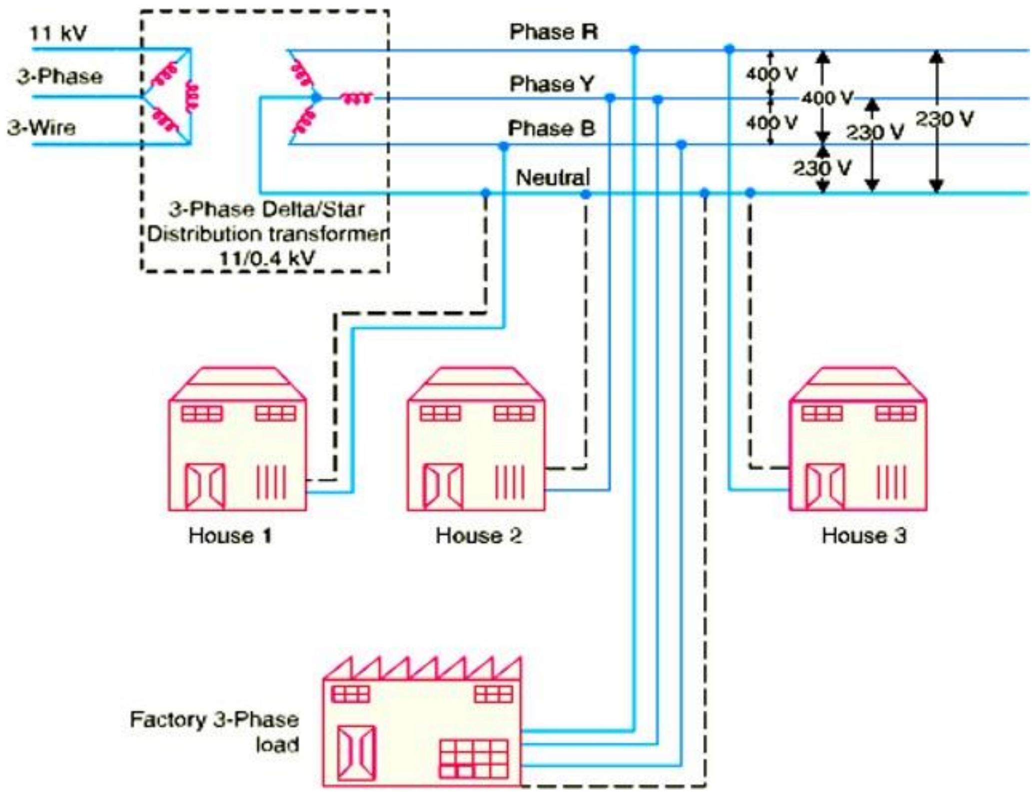
i) Primary distribution system.

It is that part of a.c. distribution system which operates at voltages somewhat higher than general utilization and handles large blocks of electrical energy than the average lowvoltage consumer uses. 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. The most commonly used primary distribution voltages are 11 kV, 6·6 kV and 3·3 kV. Due to economic considerations, primary distribution is carried out by 3- phase, 3-wire system Fig. shows a typical primary distribution system Electric power from the generating station is transmitted at high voltage to the substation located in or near the city.



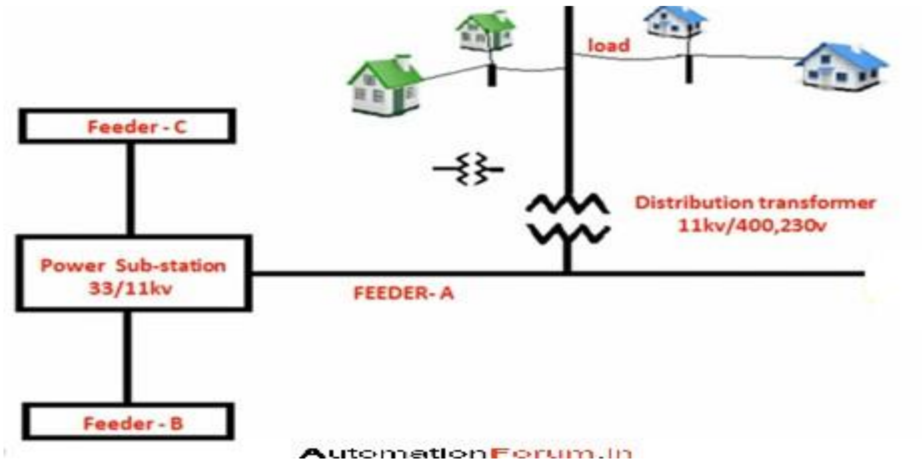
ii) Secondary distribution system

It is that part of a.c. distribution system. The secondary distribution employs 400/230V, 3phase, 4wire system. Fig shows a typical secondary distribution system. 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. At each distribution substation, the voltage is stepped down to 400Vandpowerisdeliveredby 3-phase, 4wire a.c. system. The voltage between any two phasesis 400V and between any phase and neutralize 230V.The single phase domestic loads are connected between any one phase and the neutral, where as 3phase 400V motor loadsareconnectedacross3- phase lines directly.



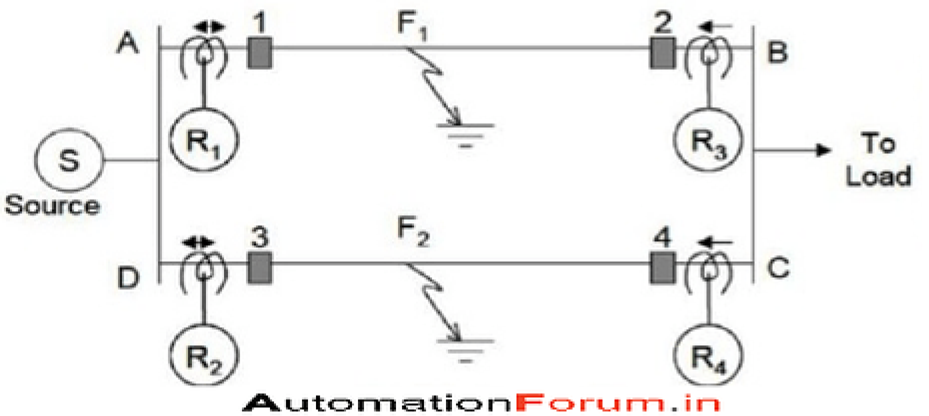
RADIALFEEDERS

It is used for many distribution processes it is really cheap and simple it is only used when the substation or the generating stations are located at the center of the consumers in this type feeder will radiate from the generating stations or substations and it will reach the distributors at one end. Thus the power flow is in one direction



Parallel feeder

There is a disadvantage in radial feeders if there is any fault occur during the transmission there will be no supply for many customers so this can be changed by using parallel feeder if there is any fault occurs only one line of the feeder will be affected the other will do the work the cost is high due to increase in feeder number it can be used to transfer heavy loads



Interconnected distribution system:

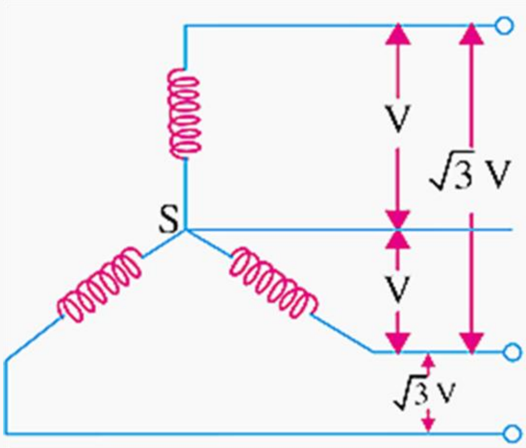
When a ring main feeder is energized by two or more substations or generating stations, it is called as an interconnected distribution system. This system ensures reliability in an event of transmission failure. Also, any area fed from one generating stations during peak load hours can be fed from the other generating station or substation for meeting power requirements from increased load.

Distribution of AC power

AC power transmission is always at high voltage and mostly by **3-phase system**. The use of single-phase system is limited to single-phase electric railways. Single-phase power transmission is used only for short distances and for relatively low voltages.

Three-phase, 4-wire system

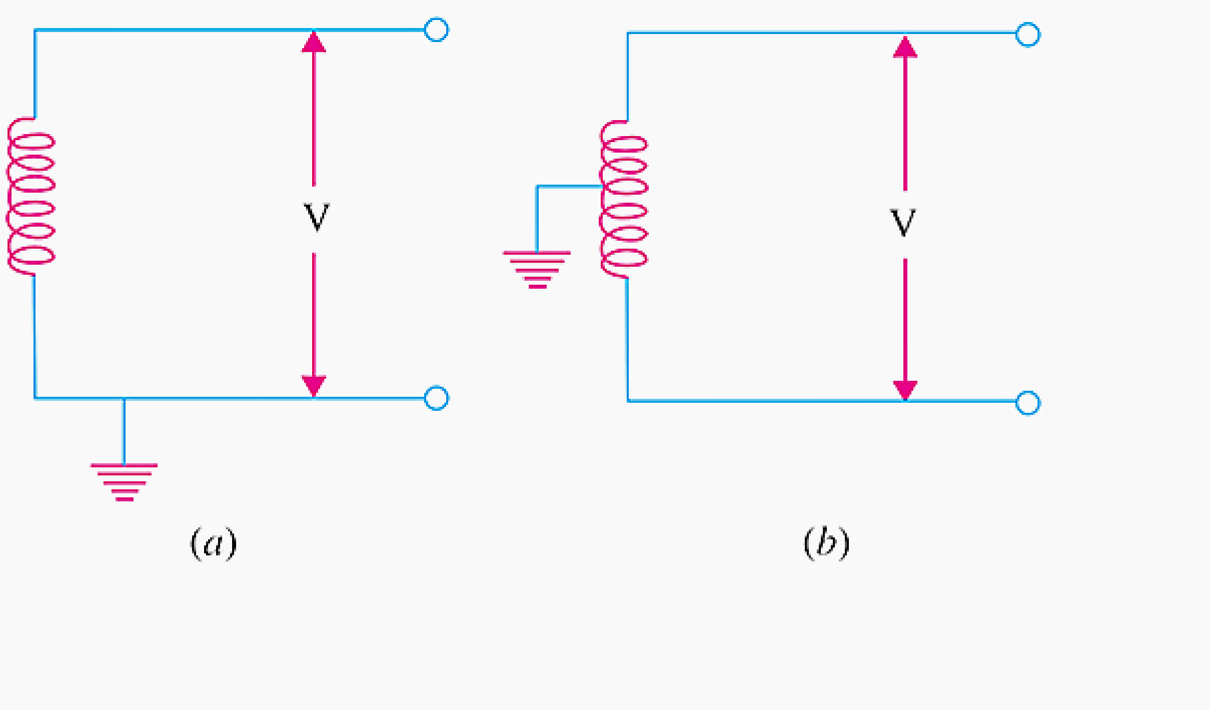
The 4th or neutral wire is taken from the star point of the star-connection as shown in Figure 6 and is of half the cross-section of the outers or line conductors. If V is the voltage of each winding, then line voltage is **3 V**. Usually, phase voltage i.e. voltage between any outer and the neutral for a symmetrical system is **230V** so that the voltage between any two lines or outers is **3×230=400V**.



Single-phase residential lighting loads or single-phase motors which run on **230 V** are connected between the neutral and any one of the line wires. These loads are connected symmetrically so that line wires are loaded equally. Hence, the resultant current in the neutral wire is **zero or at least minimum.**The three phase induction motors requiring higher voltages of 400 V or so are put across the lines directly.

Single-phase, 2-wire System

It is shown in Figure 1 (a) and (b). In Figure 1 (a), one of the two wires is earthed whereas in Figure 1 (b) **mid-point of the phase winding is earthed**.



What happens when neutral wire is disconnected?

When the neutral wire in a 3 – phase, 4 – wire system is disconnected, the loads which are connected between any two line conductors and the neutral are get connected in series and the potential difference across the combined load becomes equal to the line voltage. The potential difference across each load is changed according to the rating of theload

Illustration: The effect of disconnecting neutral wire in a 3 – phase 4 -wire system can be explained more clearly by the following illustration:

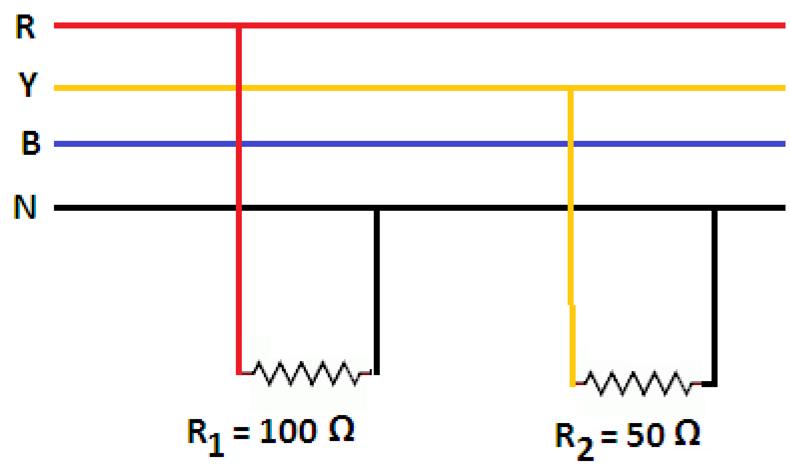


Figure A

Suppose a resistance of 100 Ω is connected between R – phase and neutral and a resistance of 50 Ω is connected between Y – phase and neutral in a 3 – phase, 4 wire supply as shown in Figure (a). The simplified diagram is shown in Figure (b).

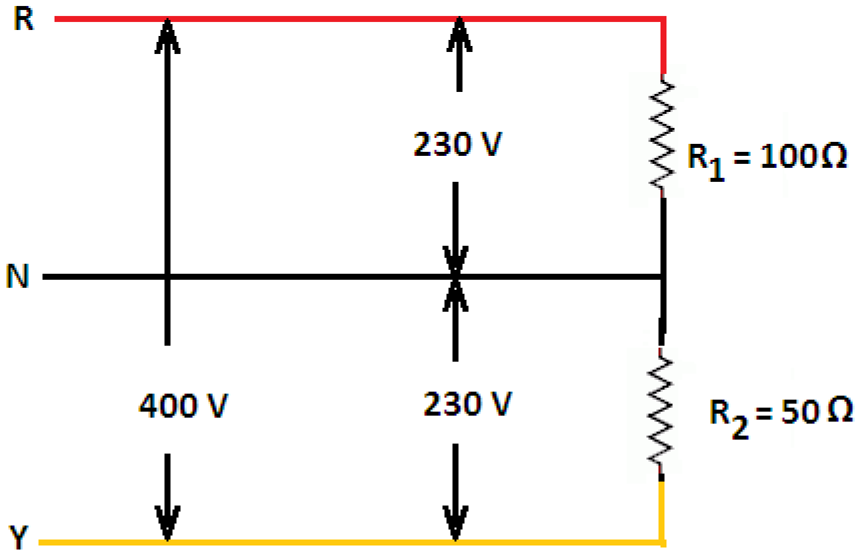


Figure B

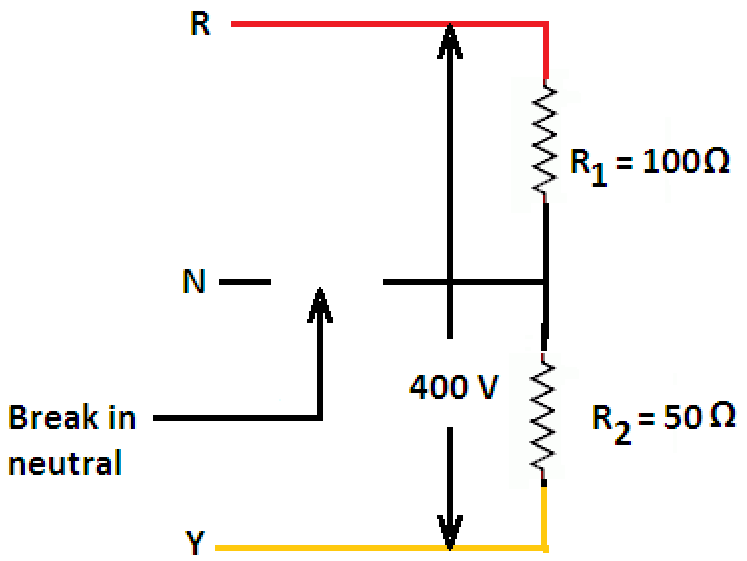


Figure C

If the neutral wire is disconnected, the two loads R_1 and R_2 are get connected in series and the potential difference across them becomes equal to the line voltage i.e. 400 V.

Therefore,

current through loads, $I = V_L/(R_1 + R_2)$

$= 400 /(100 + 50) = 2.67$ A

Therefore,

potential difference across the resistance $R_1 = I*R_1$

$= 2.67*100 = 267$ V

Similarly,

potential difference across the resistance $R_2 = I*R_2$

$= 2.67*50 = 133$ V

It is clear from the above illustration that if the neutral wire is disconnected in a 3 – phase, 4 – wire system the potential difference across the high resistive load is increased and the potential difference across the low resistive load is decreased. In this process, the voltage across the high resistive load may rise more than the designed value and may damage the high resistive load**.**

Reliability and Quality of Distribution System:

Definition of Reliability: **Reliability** of a power **distribution system** is defined as the ability to deliver uninterrupted service to customer. **Distribution system reliability** indices can be presented in many ways to reflect the **reliability** of individual customers, feeders and **system** oriented indices related to substation.

Limitation of Distributed System

Distributed System is a collection of self-governing computer systems efficient of transmission and cooperation among each other by the means of interconnections between their hardware and software. It is a collection of loosely coupled processor that appears to its users a single systematic system. Distributed systems has various limitations such as in distributed system there is not any presence of a global state. This differentiates distributed system computing from databases in which a steady global state is maintained.

Distributed system limitations have the impact on both design and implementation of distributed systems.

POWER QUALITY

Good **power quality** saves money and energy. Direct savings to consumers come from lower energy cost and reactive power tariffs. Indirect savings are gained by avoiding circumstances such as damage and premature aging of equipment, loss of production or loss of data and work. Mainly the power quality problems are-high harmonic in distribution system, low power factor, voltage transients, voltage flicker, active power and reactive power. Due to poor power quality the performance of various sensitive loads is very poor. Power Quality Standards: An Industry Update. Power quality is a worldwide issue, and keeping related standards current is a never-ending task. It typically takes years to push changes through the process Most of the ongoing work by the IEEE in harmonic standards development has shifted to modifying Standard 519-1992.

DC Distribution Calculation:

In addition to the methods of feeding discussed above, a DC Distribution Calculation may have

1. **concentrated loading**
2. **uniform loading**
3. **both concentrated and uniform loading.**

The concentrated loads are those which act on particular points of the distributor. A common example of such loads is that tapped off for domestic use. On the other hand, distributed loads are those which act uniformly on all points of the distributor. Ideally, there are no distributed loads. However, a nearest example of distributed load is a large number of loads of same wattage connected to the DC Distribution Calculation at equal distances.

In DC Distribution Calculation, one important point of interest is the determination of point of minimum potential on the distributor. The point where it occurs depends upon the loading conditions and the method of feeding the distributor. The distributor is so designed that the minimum potential on it is not less than 6% of rated voltage at the consumer's terminals. In the next sections, we shall discuss some important cases of d.c. distributors separately.

DC Distributor Fed at one End—Concentrated Loading:

Fig. 13.5 shows the single line diagram of a 2-wire d.c. distributor AB fed at one end A and having concentrated loads I_1, 1_2, 1_3 and 1_4 tapped off at points C, D, E and F respectively.

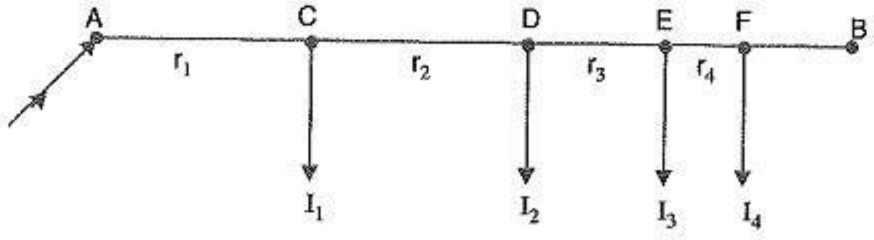


Fig. 13.5

Let r_1, r_2, r_3 and r_4 be the resistances of both wires (go and return) of the sections AC, CD, DE and EF of the distributor respectively.

Current fed from point *A*	$= I_1 + I_2 + I_3 + I_4$
Current in section *AC*	$= I_1 + I_2 + I_3 + I_4$
Current in section *CD*	$= I_2 + I_3 + I_4$
Current in section *DE*	$= I_3 + I_4$
Current in section *EF*	$= I_4$
Voltage drop in section *AC*	$= r_1 (I_1 + I_2 + I_3 + I_4)$
Voltage drop in section *CD*	$= r_2 (I_2 + I_3 + I_4)$
Voltage drop in section *DE*	$= r_3 (I_3 + I_4)$
Voltage drop in section *EF*	$= r_4 I_4$

Total voltage drop in the DC Distribution Calculation is

Total voltage drop in the DC Distribution Calculation is

$$= r_1 (I_1 + I_2 + I_3 + I_4) + r_2 (I_2 + I_3 + I_4) + r_3 (I_3 + I_4) + r_4 I_4$$

Uniformly Loaded Distributor Fed at One End:

Fig 13.11 shows the single line diagram of a 2-wire d.c. distributor AB fed at one end A and loaded uniformly with i amperes per metre length. It means that at every 1 m length of the distributor, the load tapped is i amperes. Let l metres be the length of the distributor and r ohm be the resistance per metre run.

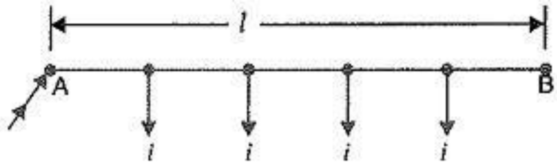


Fig. 13.11

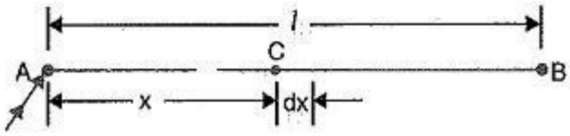


Fig. 13.12

Consider a point C on the distributor at a distance x metres from the feeding point A as shown in Fig. 13.12. Then current at point C is

$$= i\,l - i\,x \text{ amperes} = i\,(l - x) \text{ amperes}$$

Now, consider a small length dx near point C. Its resistance is r dx and the voltage drop over length dx is

$$dv = i\,(l-x)\,r\,dx = i\,r\,(l-x)\,dx$$

Total voltage drop in the distributor upto point C is

$$v = \int_0^x i\,r\,(l-x)\,dx = i\,r\left(l\,x - \frac{x^2}{2}\right)$$

The voltage drop upto point B (i.e. over the whole distributor) can be obtained by putting x = l in the above expression.

Voltage drop over the distributor AB

$$= i\,r\left(l \times l - \frac{l^2}{2}\right)$$

$$= \frac{1}{2}\,i\,r\,l^2 = \frac{1}{2}\,(i\,l)\,(r\,l)$$

$$= \frac{1}{2}\,I\,R$$

$i\,l = I$, the total current entering at point A

$r\,l = R$, the total resistance of the distributor

Thus, in a uniformly loaded distributor fed at one end, the total voltage drop is equal to that produced by the whole of the load assumed to be concentrated at the middle point.

Distributor Fed at Both Ends — Concentrated Loading:

Whenever possible, it is desirable that a long distributor should be fed at both ends instead of at one end only, since total voltage drop can be considerably reduced without increasing the cross-section of the conductor. The two ends of the distributor may be supplied with (i) equal voltages (ii) unequal voltages.

1. **Two ends fed with equal voltages:** Consider a distributor AB fed at both ends with equal voltages V volts and having concentrated loads I_1, I_2, I_3, I_4 and I_5 at points C, D, E, F and G respectively as shown in Fig. 13.14. As we move away from one of the feeding points, say A, p.d. goes on decreasing till it reaches the minimum value at some load point, say E, and then again starts rising and becomes V volts as we reach the other feeding point B.

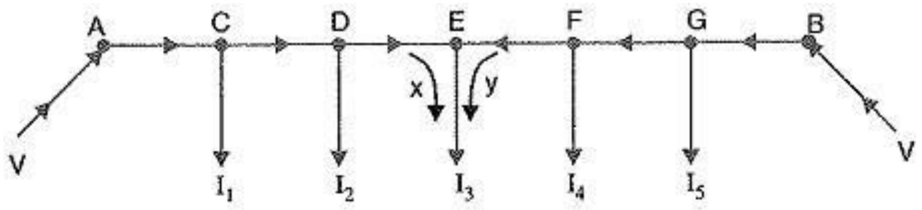


Fig. 13.14

All the currents tapped off between points A and E (minimum p.d. point) will be supplied from the feeding point A while those tapped off between B and E will be supplied from the feeding point B. The current tapped off at point E itself will be partly supplied from A and partly from B. If these currents are x and y respectively, then,

$$I_3 = x + y$$

Therefore, we arrive at a very important conclusion that at the point of minimum potential, current comes from both ends of the DC Distribution Calculation.

(i) Point of minimum potential. It is generally desired to locate the point of minimum potential. There is a simple method for it. Consider a distributor AB having three concentrated loads I_1, I_2 and I_3 at points C, D and E respectively. Suppose that current supplied by feeding end A is I_A. Then current distribution in the various sections of the distributor can be worked out as shown in Fig. 13.15 (i). Thus

$$I_{AC} = I_A \; ; \qquad I_{CD} = I_A - I_1$$
$$I_{DE} = I_A - I_1 - I_2 \; ; \qquad I_{EB} = I_A - I_1 - I_2 - I_3$$

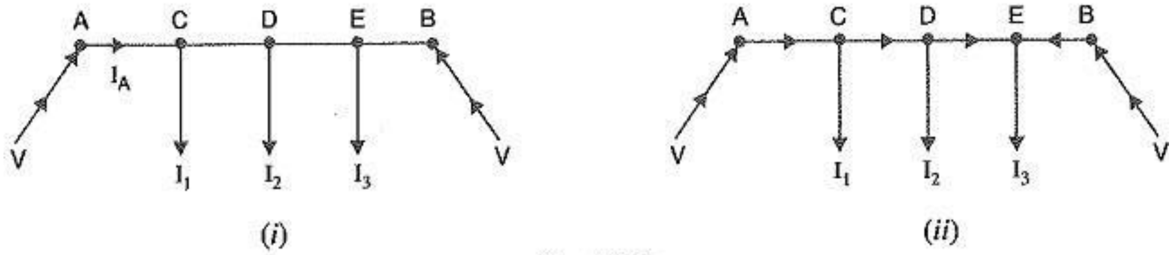


Fig. 13.15

Voltage drop between A and B = Voltage drop over AB

or $\quad V - V = I_A R_{AC} + (I_A - I_1) R_{CD} + (I_A - I_1 - I_2) R_{DE} + (I_A - I_1 - I_2 - I_3) R_{EB}$

From this equation, the unknown I_A can be calculated as the values of other quantities are generally given. Suppose actual directions of currents in the various sections of the distributor are indicated as shown in Fig. 13.15 (ii). The load point where the currents are coming from both sides of the distributor is the point of minimum potential i.e. point E in this case

(ii) Two ends fed with unequal voltages. Fig. 13.16 shows the distributor AB fed with unequal voltages ; end A being fed at V_1 volts and end B at V_2 volts. The point of minimum potential can be found by following the same procedure as discussed above. Thus in this case,

Voltage drop between A and B = Voltage drop over AB

or $\quad V_1 - V_2$ = Voltage drop over AB

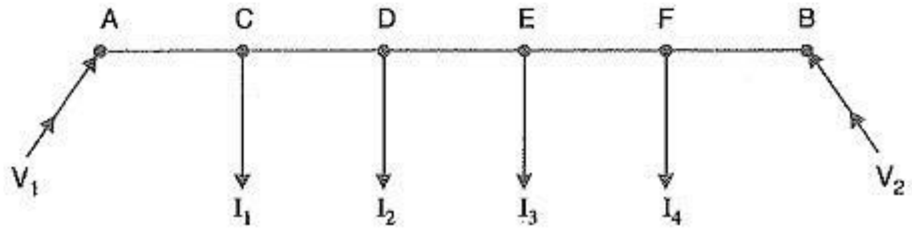


Fig. 13.16

Uniformly Loaded Distributor Fed at Both Ends:

We shall now determine the voltage drop in a uniformly loaded distributor fed at both ends. There can be two cases viz the distributor fed at both ends with

(i) equal voltages (ii) unequal voltages.

The two cases shall be discussed separately.

(i) Distributor fed at both ends with equal voltages. Consider a distributor AB of length l metres, having resistance r ohms per metre run and with uniform loading of i amperes per metre run as shown in Fig. 13.24. Let the DC Distribution Calculation be fed at the feeding points A and B at equal voltages, say V volts. The total current supplied to the distributor is i l. As the two end voltages are equal, therefore, current supplied from each feeding point is i l/2 i.e.

Current supplied from each feeding point

$$= \frac{i\,l}{2}$$

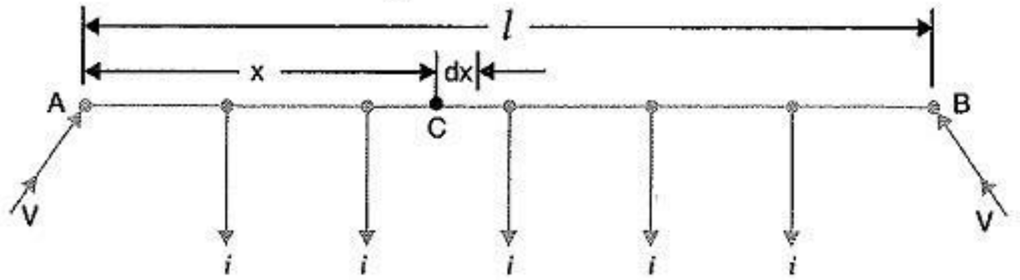


Fig. 13.24

Consider a point C at a distance x metres from the feeding point A. Then current at point C is

$$= \frac{i\,l}{2} - i\,x = i\left(\frac{l}{2} - x\right)$$

Now, consider a small length dx near point C. Its resistance is r dx and the voltage drop over length dx is

$$dv = i\left(\frac{l}{2} - x\right) r\,dx = i\,r\left(\frac{l}{2} - x\right) dx$$

$$\text{Voltage drop upto point } C = \int_0^x i\,r\left(\frac{l}{2} - x\right) dx = i\,r\left(\frac{l\,x}{2} - \frac{x^2}{2}\right)$$

$$= \frac{i\,r}{2}\left(l\,x - x^2\right)$$

Obviously, the point of minimum potential will be the mid-point. Therefore, maximum voltage drop will occur at mid-point i.e. where x =l/2.

$$\text{Max. voltage drop} = \frac{i\,r}{2}\left(l\,x - x^2\right)$$

$$= \frac{i\,r}{2}\left(l \times \frac{l}{2} - \frac{l^2}{4}\right) \qquad \text{[Putting } x =$$

$$= \frac{1}{8}\,i\,r\,l^2 = \frac{1}{8}(i\,l)(r\,l) = \frac{1}{8}\,I\,R$$

$i\,l$ = I, the total current fed to the distributor from both ends

$r\,l$ = R, the total resistance of the distributor

$$\text{Minimum voltage} = V - \frac{I\,R}{8}\ \text{volts}$$

(ii) Distributor fed at both ends with unequal voltages. Consider a distributor AB of length (metres having resistance r ohms per metre run and with a uniform loading of i amperes per metre run as shown in Fig. 13.25. Let the DC Distribution Calculation be fed from feeding points A and B at voltages V_A and V_B respectively.

Suppose that the point of minimum potential C is situated at a distance x metres from the feedingvpoint A. Then current supplied by the feeding point A will be i x.

$$\text{Voltage drop in section } AC = \frac{i\,r\,x^2}{2}\ \text{volts}$$

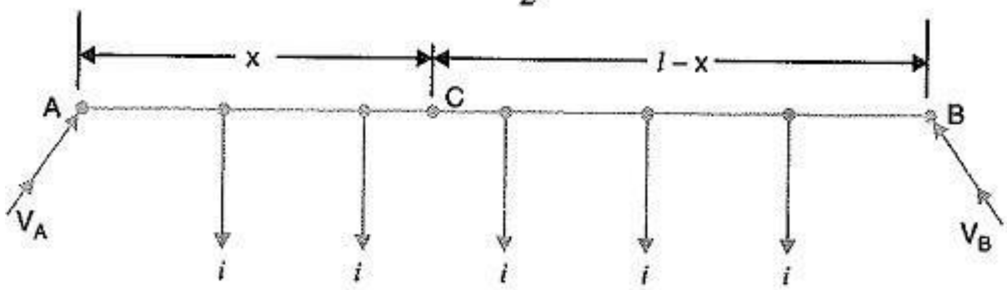


Fig. 13.25

As the distance of C from feeding point B is (1— x), therefore, current fed from B is i (l – x).

$$\text{Voltage drop in section } BC = \frac{i\,r\,(l-x)^2}{2}\ \text{volts}$$

$$\text{Voltage at point } C,\ V_C = V_A - \text{Drop over } AC$$

$$= V_A - \frac{i\,r\,x^2}{2} \qquad \text{...(i)}$$

$$\text{Also, voltage at point } C,\ V_C = V_B - \text{Drop over } BC$$

$$= V_B - \frac{i\,r\,(l-x)^2}{2} \qquad \text{...(ii)}$$

From equations (i) and (ii), we get,

$$V_A - \frac{i\,r\,x^2}{2} = V_B - \frac{i\,r\,(l-x)^2}{2}$$

Solving the equation for x, we get,

$$x = \frac{V_A - V_B}{i\,r\,l} + \frac{l}{2}$$

As all the quantities on the right hand side of the equation are known, therefore, the point on the distributor where minimum potential occurs can be calculated.