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# Power Distribution Systems

## Lecture 2

Direct Current (D.C.) Distribution

# Introduction

In the beginning of the electrical age, electricity was generated as a direct current (d.c.) and voltages were low. The resistance losses in the lines made it impracticable to transmit and distribute power for more than a few localities of the city.

Nowadays, electrical energy is generated, transmitted and distributed in the form of a.c. as an economical proposition.

However, for certain applications, d.c. sup- ply is absolutely necessary. For example,

- variable speed machinery (e.g. d.c. motors),
- electro-chemical work
- electric traction.

# 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:

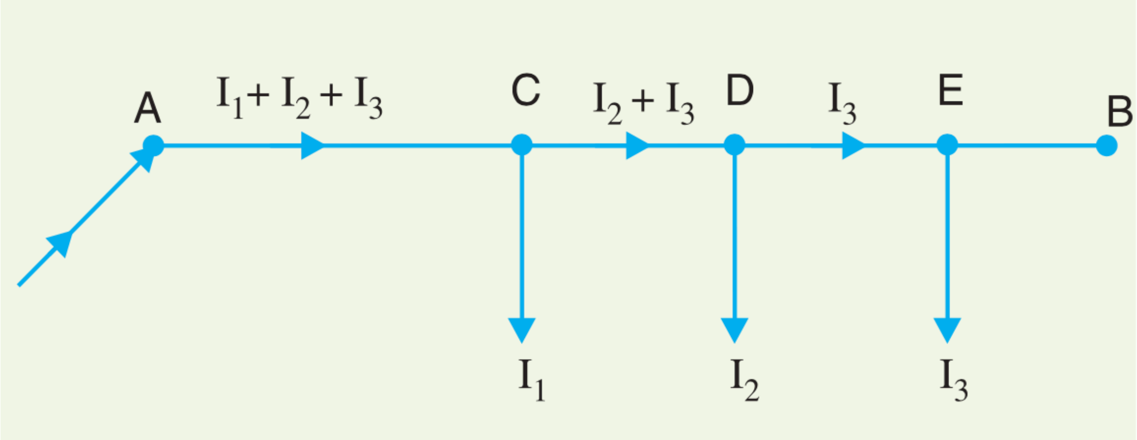
a) Distributor fed at one end
b) Distributor fed at both ends
c) Distributor fed at the center
d) Ring distributor.

# Types of D.C. Distributors

## a) Distributor fed at one end

The distributor is connected to the supply at one end and loads are taken at different points along the length of the distributor.

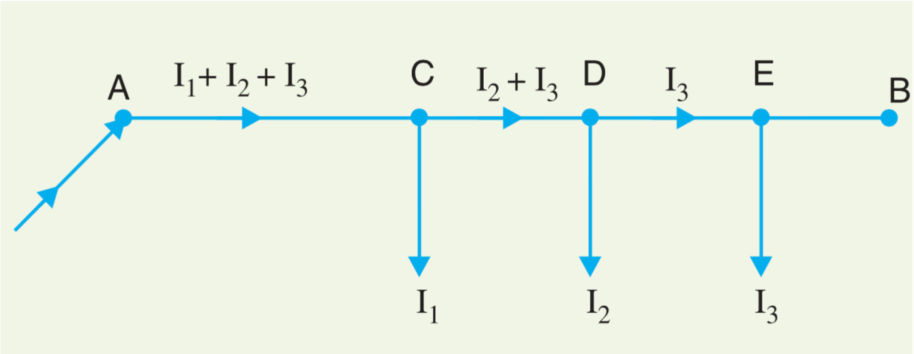
The d.c. distributor AB fed at the end A and loads $I_1$, $I_2$ and $I_3$ tapped off at points C, D and E respectively.



## a) Distributor fed at one end

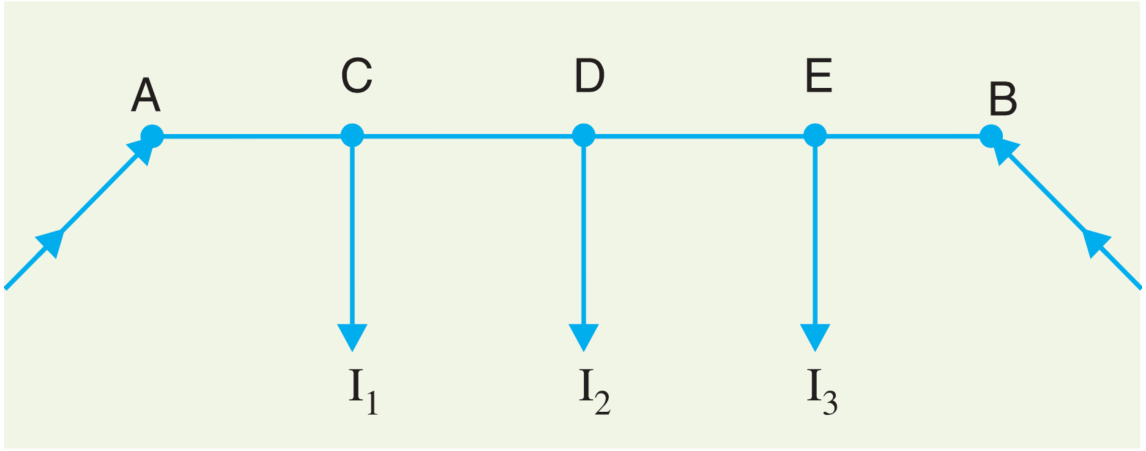
The features of topology;

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



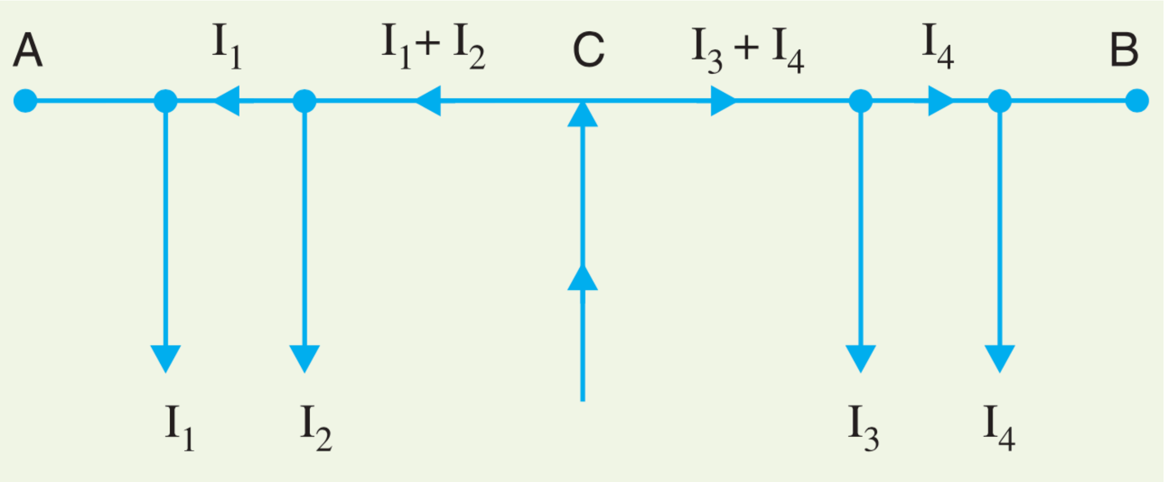
## b) Distributor fed at both ends

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.
The distributor AB fed at the ends A and B and loads of loads $I_1$, $I_2$ and $I_3$ tapped off at points C, D and E respectively.
The load voltage goes on decreasing as we move away from each feeding point A or B. The minimum voltage occurs at some load point and is never fixed.



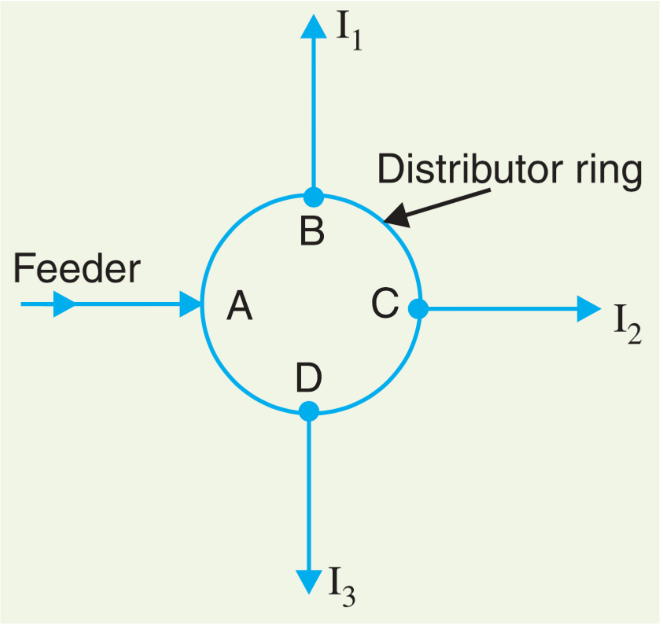
## c) Distributor fed at the center

The center of the distributor is connected to the supply mains. It is equivalent to two distributors fed at one end, each distributor having a common feeding point and length equal to half of the total length.



## d) Ring Mains

The distributor is in the form of a closed ring. 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.



# D.C. Distribution Calculations

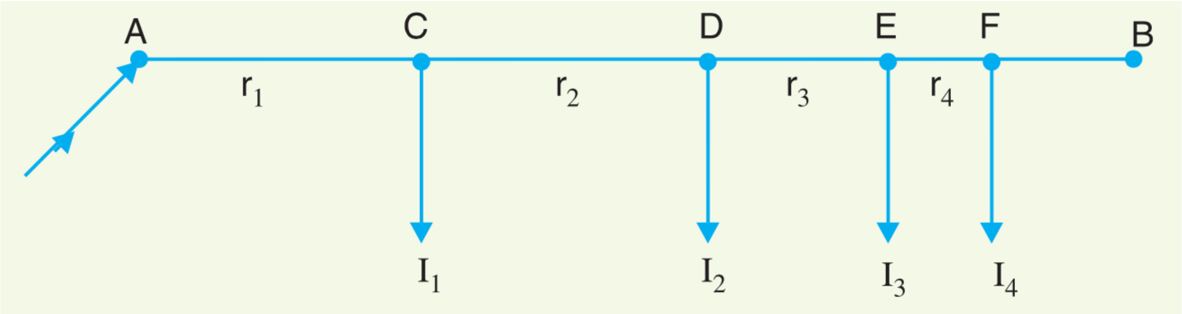
A distributor may have
(i) Concentrated loading
(ii) Uniform loading
(iii) Both concentrated and uniform loading.

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.

In d.c. distribution calculations, 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.

# D.C. Distributor Fed at One End-Concentrated Loading

The following figure shows the single line diagram of a 2-wire d.c. distributor AB fed at one end A and having concentrated loads $I_1$, $I_2$, $I_3$ and $I_4$ tapped off at points C, D, E and F respectively.




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 $AC = I_1 + I_2 + I_3 + I_4$    Voltage drop in section $AC = r_1 (I_1 + I_2 + I_3 + I_4)$

Current in section $CD = I_2 + I_3 + I_4$    Voltage drop in section $CD = r_2 (I_2 + I_3 + I_4)$

Current in section $DE = I_3 + I_4$    Voltage drop in section $DE = r_3 (I_3 + I_4)$

Current in section $EF = I_4$    Voltage drop in section $EF = r_4 I_4$

Total voltage drop in the distributor; $r_1 (I_1 + I_2 + I_3 + I_4) + r_2 (I_2 + I_3 + I_4) + r_3 (I_3 + I_4) + r_4 I_4$

# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.1** *A 2-wire d.c. distributor cable AB is 2 km long and supplies loads of 100A, 150A,200A and 50A situated 500 m, 1000 m, 1600 m and 2000 m from the feeding point A. Each conductor has a resistance of 0.01 Ω per 1000 m. Calculate the voltage at each load point if 300 V is maintained at point A.*

# D.C. Distributor Fed at One End-Concentrated Loading

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**Example 2.2** *A 2-wire d.c. distributor AB is 300 meters long. It is fed at point A. The various loads and their positions are given below :*

| *At point* | *distance from A in meters* | *concentrated load in amperes* |
|---|---|---|
| C | 40 | 30 |
| D | 100 | 40 |
| E | 150 | 100 |
| F | 250 | 50 |

*If the maximum permissible voltage drop is not to exceed 10 V, find the cross-sectional area of the distributor. Take resistivity $\rho = 1.78 \times 10^{-8}\ \Omega m$.*

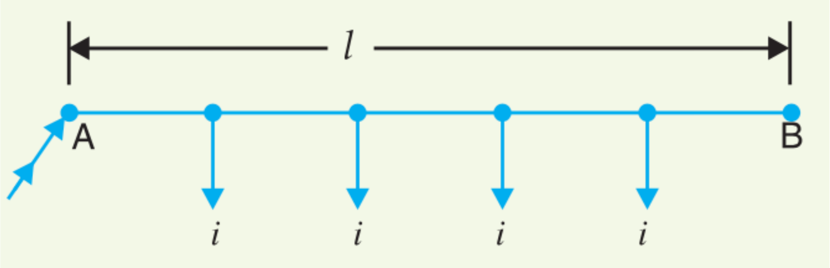
*$R = \rho L / A$ [Ω]*
*L: length of conductor [m]*
*A: cross-sectional area of conductor [$m^2$]*

# D.C. Distributor Fed at One End-Concentrated Loading

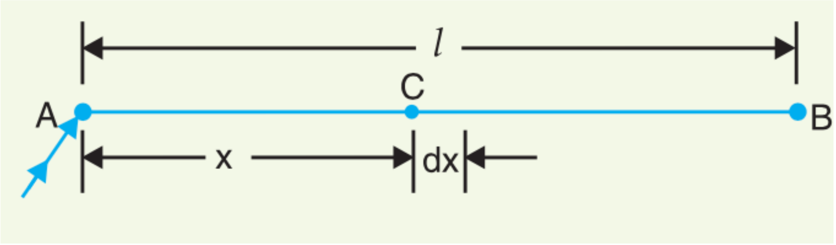
<u>**Example 2.3**</u> *Two tram cars (A & B) 2 km and 6 km away from a sub-station return 40 A and 20 A respectively to the rails. The sub-station voltage is 600 V d.c. The resistance of trolley wire is 0·25 Ω/km and that of track is 0·03 Ω/km. Calculate the voltage across each tram car.*

# Uniformly Loaded Distributor Fed at One End

The following figure 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 meter length. It means that at every 1 m length of the distributor, the load tapped is *i* amperes.




Let $l$ meters be the length of the distributor and r ohm be the resistance per meter run. Consider a point *C* on the distributor at a distance *x* meters from the feeding point *A* as shown in figure below.




Then current at point *C* is = $il - ix$ Amps=$i(l-x)$ Amps

# Uniformly Loaded Distributor Fed at One End

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 up to 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*

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

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

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

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 <u>concentrated at the middle point.</u>

# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.4** *A 2-wire d.c. distributor 200 meters long is uniformly loaded with 2A/meter. Resistance of single wire is 0.3 Ω/km. If the distributor is fed at one end, calculate :*

a) *the voltage drop up to a distance of 150 meters from the feeding point*

b) *the maximum voltage drop*

# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.5** *A uniform 2-wire d.c. distributor 500 meters long is loaded with 0.4 ampere/ meter and is fed at one end. If the maximum permissible voltage drop is not to exceed 10 V, find the cross-sectional area of the distributor conductor. Take* $\rho = 1.7 \times 10{-}6\ \Omega$ *cm.*

# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.6** *A 250 meter , 2-wire d.c. distributor fed from one end is loaded uniformly at the rate of 1.6 A/meter. The resistance of each conductor is 0.0002 Ω per meter. Find the voltage necessary at feed point to maintain 250 V*

*a) at the far end*

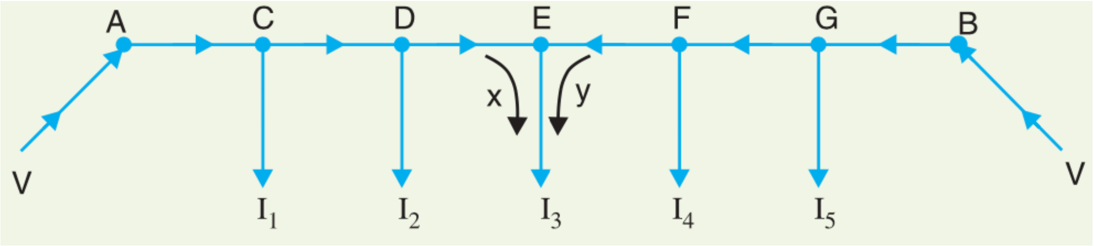
*b) at the mid-point of the distributor.*

# Distributor Fed at Both Ends-Concentrated Loading

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

a) equal voltages
b) unequal voltages.

**a) Two ends fed with equal voltages.** Consider a distributor *A B* 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 we move away from one of the feeding points, *say A* , voltage 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*.

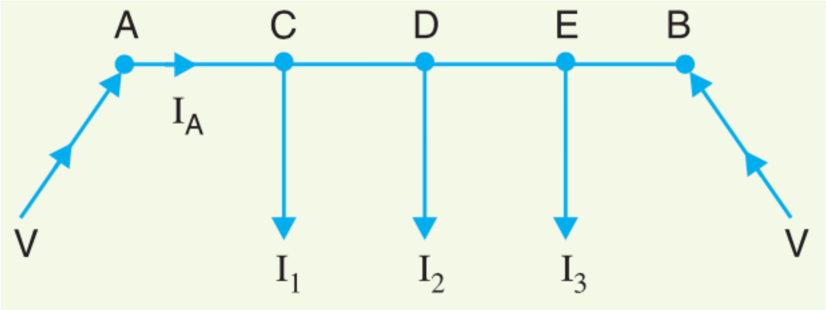



The currents between points *A* and *E*, $I_1$, $I_2$, will be supplied from the feeding point *A* while the currents $I_4$ and $I_5$ will be supplied from the feeding point *B*. at point *E* itself will be partly supplied from *A* and partly from *B*. If these currents are *x* and *y* respectively, then,

$$I_3 = x + y$$

# Distributor Fed at Both Ends-Concentrated Loading

**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 *A B* 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.

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

Voltage drop between *A* and *B* = Voltage drop over *A B*

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

From this equation, the unknown $I_A$ can be calculated as the values of other quantities are generally given.

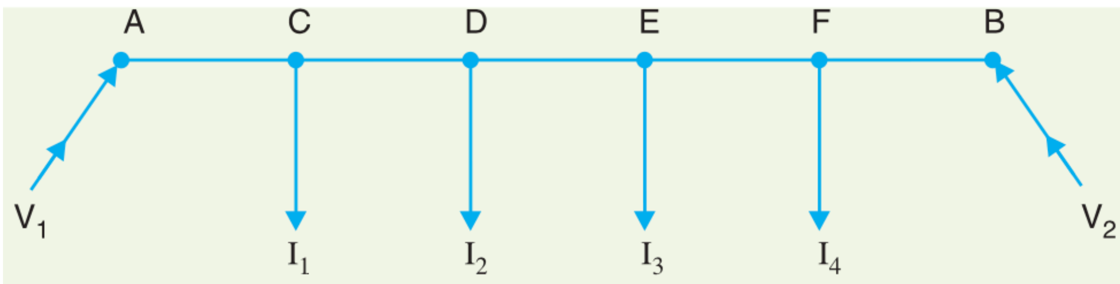
# Distributor Fed at Both Ends-Concentrated Loading



**b) Two ends fed with unequal voltages.** Consider a 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 $V - V$ = Voltage drop over *AB*



# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.7** *A 2-wire d.c. street mains AB, 600 m long is fed from both ends at 220 V. Loads of 20 A, 40 A, 50 A and 30 A are tapped at distances of 100m, 250m, 400m and 500 m from the end A respectively. If the area of X-section of distributor conductor is 1cm$^2$, find the minimum consumer voltage. Take ρ = 1.7 × 10$^{-6}$ Ω cm.*

# D.C. Distributor Fed at One End-Concentrated Loading

**<u>Example 2.8</u>** *A 2-wire d.c. distributor AB is fed from both ends. At feeding point A, the voltage is maintained as at 230 V and at B 235 V. The total length of the distributor is 200 meters and loads are tapped off as under :*

*25 A at 50 meters from A*

*50 A at 75 meters from A*

*30 A at 100 meters from A*

*40 A at 150 meters from A*

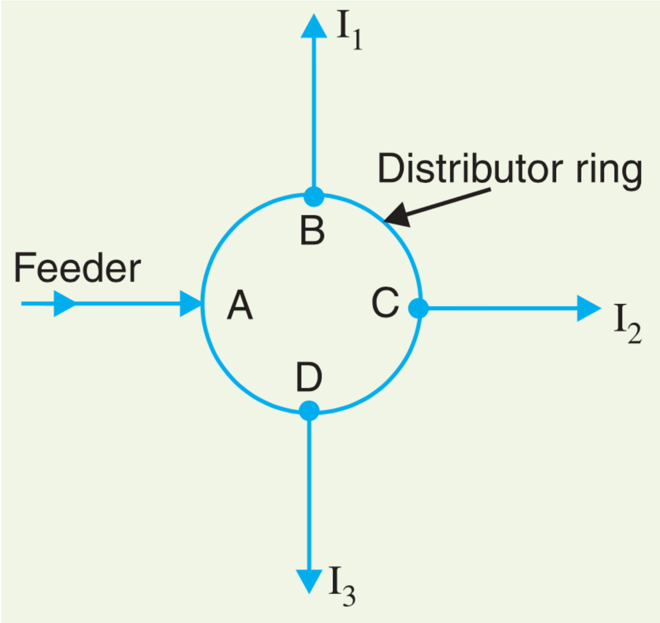
*The resistance per kilometer of one conductor is 0.3 Ω. Calculate :*

a) *currents in various sections of the distributor*

b) *minimum voltage and the point at which it occurs*

# Ring Distributor

A distributor arranged to form a closed loop and fed at one or more points is called a ***ring distributor***. Such a distributor starts from one point, makes a loop through the area to be served, and returns to the original point. For the purpose of calculating voltage distribution, the distributor can be considered as consisting of a series of open distributors fed at both ends. The principal advantage of ring distributor is that by proper choice in the number of feeding points, great economy in copper can be affected.



# D.C. Distributor Fed at One End-Concentrated Loading

**Example 2.9** *A 2-wire d.c. ring distributor is 300 m long and is fed at 240 V at point A. At point B, 150 m from A, a load of 120 A is taken and at C, 100 m in the opposite direction, a load of 80 A is taken. If the resistance per 100 m of single conductor is 0.03 Ω, find :*

a) *current in each section of distributor*

b) *voltage at points B and C*

**Example 2.10** *A 2-wire d.c. distributor ABCDEA in the form of a ring main is fed at point A at 220 V and is loaded as under :*

*10A at B ; 20A at C ; 30A at D and 10A at E.*

*The resistances of various sections (go and return) are :*

*AB = 0.1 Ω ; BC = 0.05 Ω ; CD = 0.01 Ω ; DE = 0.025 Ω and EA = 0.075 Ω. Determine :*

a) *the point of minimum potential*

b) *current in each section of distributor*