Electric Power Distribution Systems II

EME410

Spring 21-22

Lecture 9

D.C. Distribution

INSTRUCTOR

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➢ Contents

Introduction

- In the beginning of the electrical age, electricity was generated as a direct current 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.
- With the development of the transformer, a.c. has taken over the load formerly supplied by d.c.
- Now-a-days, electrical energy is generated, transmitted and distributed in the form of a.c. as an economical proposition.

➢ Introduction (cont.)

- ➢ However, for certain applications, d.c. supply is absolutely necessary.
- ➢ For example, d.c. supply is required for the operation of variable speed machinery (e.g. d.c. motors), electrochemical work and electric traction.
- ➢ For this purpose, a.c. power is converted into d.c. power at the sub-station by using converting machinery e.g. mercury are rectifiers, rotary converters and motor-generator sets.
- ➢ The d.c. supply from the sub-station is conveyed to the required places for distribution. In this part, we shall confine our attention to the various aspects of d.c. distribution.

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:

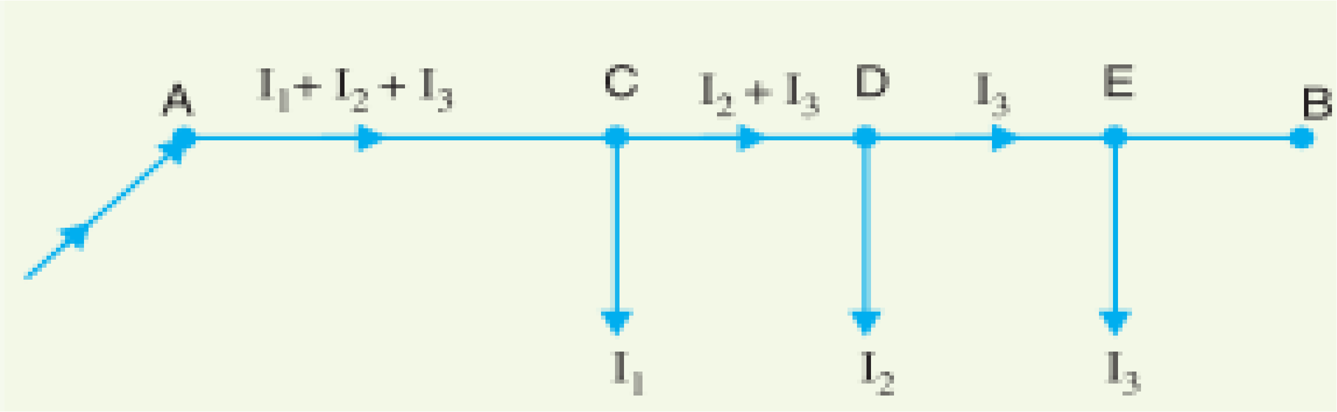
  (i) Distributor fed at one end

  (ii) Distributor fed at both ends

  (iii) Distributor fed at the center

  (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 points along the length of the distributor.
- The last figure 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 I1, I2 and I3 tapped off at points C, D and E respectively.

➢ (i) Distributor fed at one end (cont.)

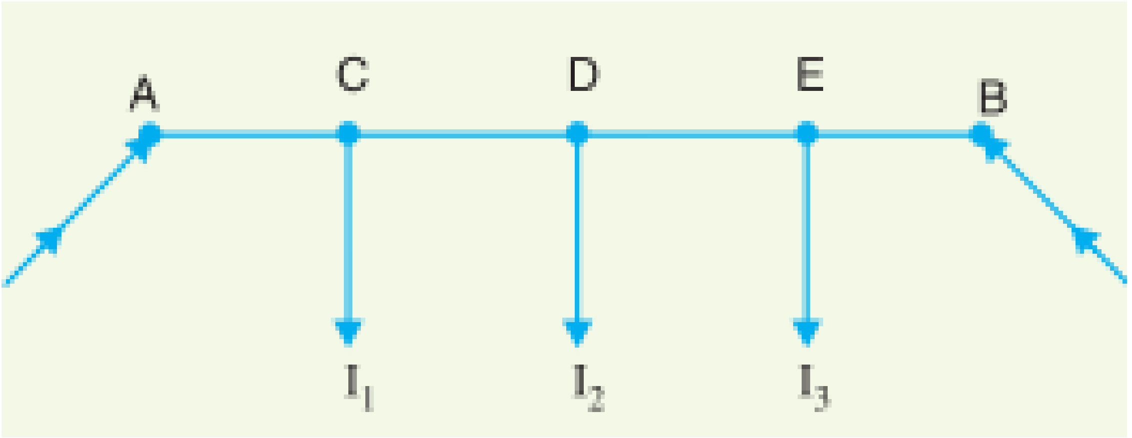
The following points are worth noting in a singly fed distributor :

(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 end

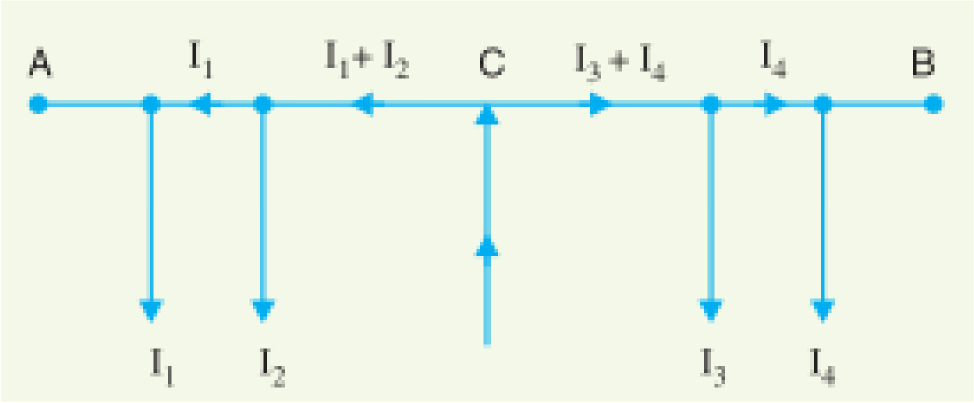


- The distributor is connected to the supply mains at both ends and loads are tapped off at different points along the length of the distributor.
- The voltage at the feeding points may or may not be equal. Fig. shows a distributor A B fed at the ends A and B and loads of I1, I2 and I3 tapped off at points C, D and E respectively.

(ii) Distributor fed at both end (cont.)

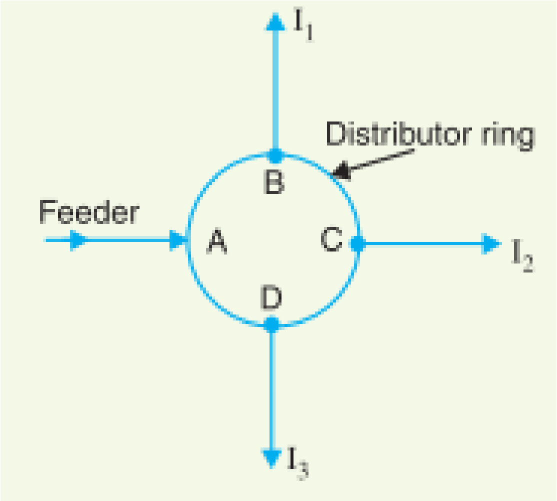
- Here, the load voltage goes on decreasing as we move away from one feeding point say A, reaches minimum value and then again starts rising and reaches maximum value when we reach the other feeding point B.
- The minimum voltage occurs at some load point and is never fixed. It is shifted with the variation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

(iii) Distributor fed at the center.



- the center 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.

D.C. Distribution Calculations

- In addition to the methods of feeding discussed above, 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.

➢ D.C. Distribution Calculations

- 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 distributor at equal distances.

➢ D.C. Distributor Fed at one End —Concentrated Loading

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* $= r_1 (I_1 + I_2 + I_3 + I_4)$

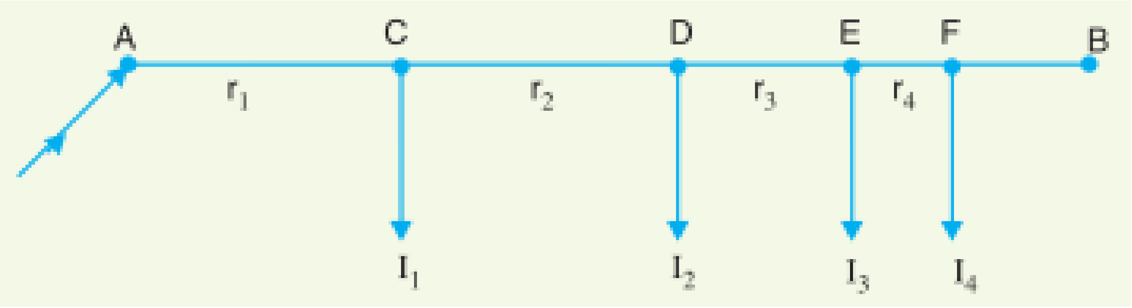
Voltage drop in section *CD* $= r_2 (I_2 + I_3 + I_4)$

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 distributor

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



It is easy to see that the minimum potential will occur at point *F* which is farthest from the feeding point *A*.

➢ Example 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 p.d. at each load point if a p.d. of 300 V is maintained at point A.

Resistance per 1000 m of distributor $= 2 \times 0{\cdot}01 = 0{\cdot}02\,\Omega$

Resistance of section AC, $R_{AC} = 0{\cdot}02 \times 500/1000 = 0{\cdot}01\,\Omega$

Resistance of section CD, $R_{CD} = 0{\cdot}02 \times 500/1000 = 0{\cdot}01\,\Omega$

Resistance of section DE, $R_{DE} = 0{\cdot}02 \times 600/1000 = 0{\cdot}012\,\Omega$

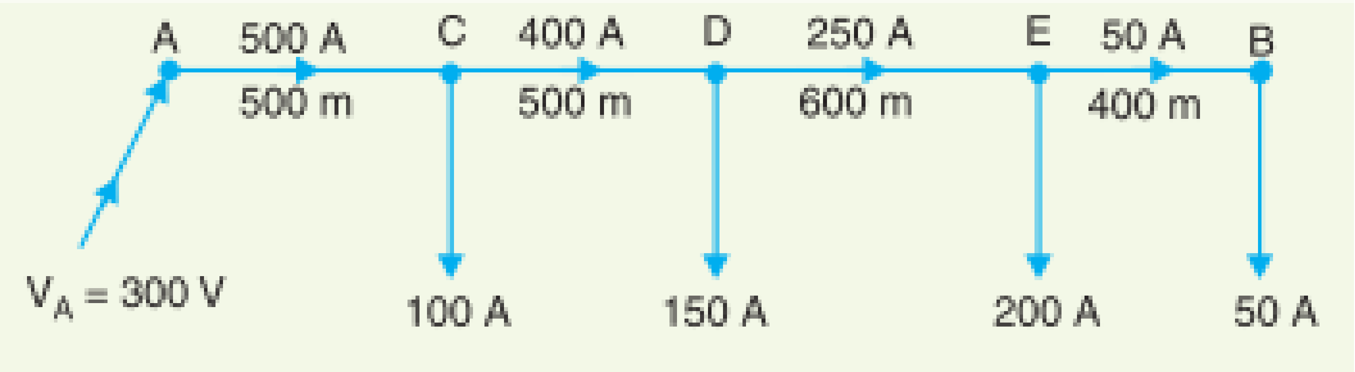
Resistance of section EB, $R_{EB} = 0{\cdot}02 \times 400/1000 = 0{\cdot}008\,\Omega$

Referring to Fig. 13.6, the currents in the various sections of the distributor are :

$I_{EB} = 50$ A ; $I_{DE} = 50 + 200 = 250$ A

$I_{CD} = 250 + 150 = 400$ A ; $I_{AC} = 400 + 100 = 500$ A

➢ Example 1 (cont.)



P.D. at load point C, V_C = Voltage at A – Voltage drop in AC

$$= V_A - I_{AC} R_{AC}$$

$$= 300 - 500 \times 0{\cdot}01 = \mathbf{295\ V}$$

P.D. at load point D, $V_D = V_C - I_{CD} R_{CD}$

$$= 295 - 400 \times 0{\cdot}01 = \mathbf{291\ V}$$

P.D. at load point E, $V_E = V_D - I_{DE} R_{DE}$

$$= 291 - 250 \times 0{\cdot}012 = \mathbf{288\ V}$$

P.D. at load point B, $V_B = V_E - I_{EB} R_{EB}$

$$= 288 - 50 \times 0{\cdot}008 = \mathbf{287{\cdot}6\ V}$$

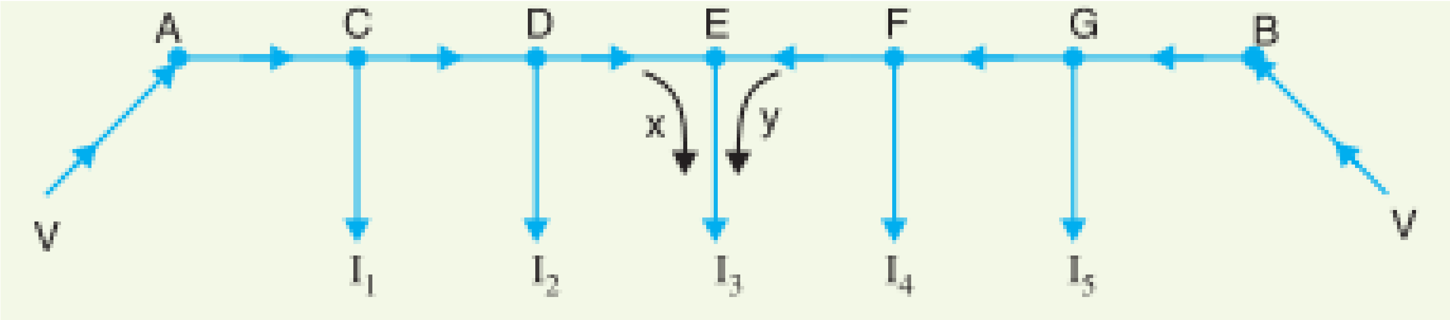
➢ Distributor Fed at Both Ends — Concentrated Loading

➢ The two ends of the distributor may be supplied with

(i) equal voltages

(ii) unequal voltages.

➢ (i) Two ends fed with equal voltages



Voltage drop between A and B = Voltage drop over AB

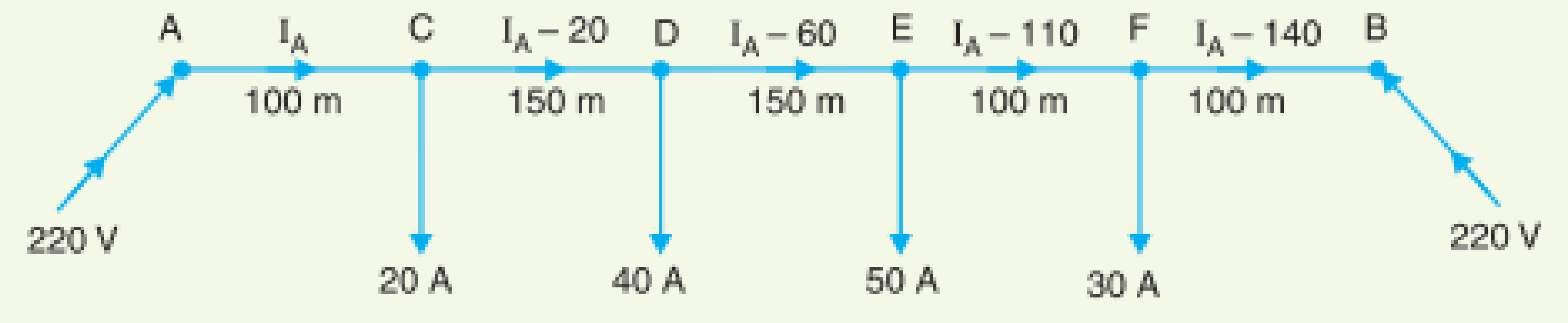
or $V - V = I_A R_{AC} + (I_A - I_1) R_{CD} + (I_A - I_1 - I_2) R_{DE} + (I_A - I_1 - I_2 - I_3) R_{EB}$

$I_{AC} = I_A$; $\quad I_{CD} = I_A - I_1$

$I_{DE} = I_A - I_1 - I_2$; $\quad I_{EB} = I_A - I_1 - I_2 - I_3$

➢ Example 2

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 $\rho = 1{\cdot}7 \times 10^{-6}\ \Omega$ cm.



➢ Example 2 (cont.)

Resistance of 1 m length of distributor

$$= 2 \times \frac{1 \cdot 7 \times 10^{-6} \times 100}{1} = 3 \cdot 4 \times 10^{-4}\ \Omega$$

Resistance of section AC, R_{AC} $= (3 \cdot 4 \times 10^{-4}) \times 100 = 0 \cdot 034\ \Omega$

Resistance of section CD, R_{CD} $= (3 \cdot 4 \times 10^{-4}) \times 150 = 0 \cdot 051\ \Omega$

Resistance of section DE, R_{DE} $= (3 \cdot 4 \times 10^{-4}) \times 150 = 0 \cdot 051\ \Omega$

Resistance of section EF, R_{EF} $= (3 \cdot 4 \times 10^{-4}) \times 100 = 0 \cdot 034\ \Omega$

Resistance of section FB, R_{FB} $= (3 \cdot 4 \times 10^{-4}) \times 100 = 0 \cdot 034\ \Omega$

Voltage at B = Voltage at A − Drop over length AB

or $$V_B = V_A - [I_A R_{AC} + (I_A - 20) R_{CD} + (I_A - 60) R_{DE} + (I_A - 110) R_{EF} + (I_A - 140) R_{FB}]$$

or $$220 = 220 - [0 \cdot 034 I_A + 0 \cdot 051 (I_A - 20) + 0 \cdot 051 (I_A - 60) + 0 \cdot 034 (I_A - 110) + 0 \cdot 034 (I_A - 140)]$$

$$= 220 - [0 \cdot 204 I_A - 12 \cdot 58]$$

or $$0 \cdot 204 I_A = 12 \cdot 58$$

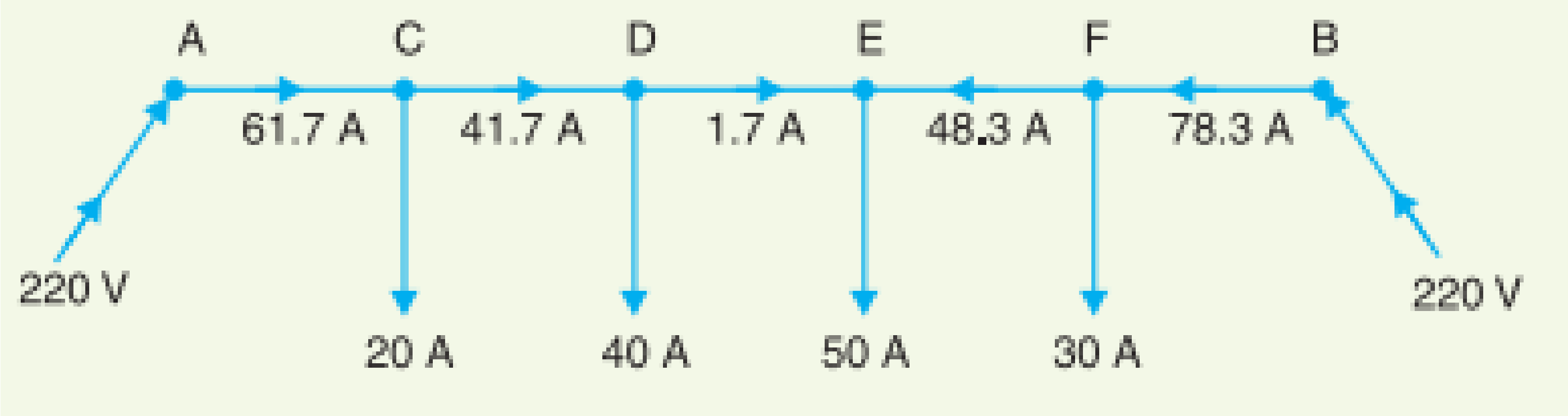
$$\therefore \quad I_A = 12 \cdot 58/0 \cdot 204 = 61 \cdot 7\ \text{A}$$

The *actual distribution of currents in the various sections of the distributor is shown in Fig. 13.18. It is clear that currents are coming to load point E from both sides *i.e.* from point D and point F. Hence, E is the point of minimum potential.

∴ Minimum consumer voltage,

$$V_E = V_A - [I_{AC} R_{AC} + I_{CD} R_{CD} + I_{DE} R_{DE}]$$

➢ Example 2 (cont.)



$$= 220 - [61{\cdot}7 \times 0{\cdot}034 + 41{\cdot}7 \times 0{\cdot}051 + 1{\cdot}7 \times 0{\cdot}051]$$

$$= 220 - 4{\cdot}31 = \mathbf{215{\cdot}69\ V}$$

➢ Example 3

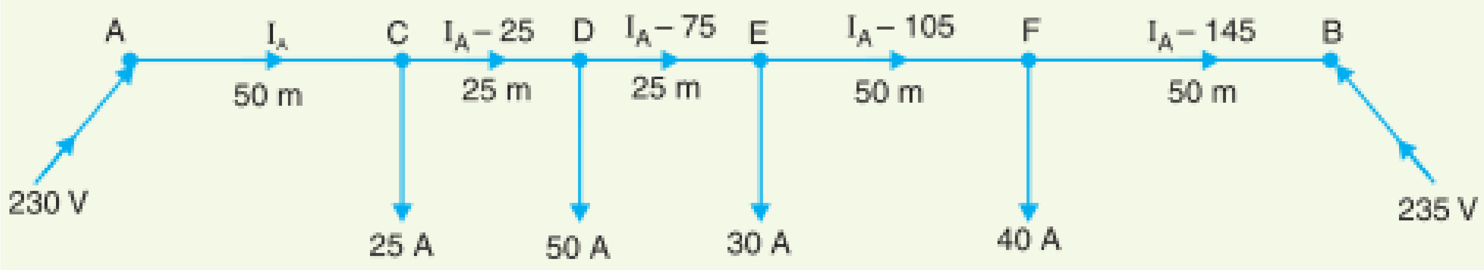
A 2-wire d.c. distributor AB is fed from both ends. At feeding point A, the voltage is maintained as at 230 V and at B 235 V. The total length of the distributor is 200 meters and loads are tapped off as under : 25 A at 50 meters from A ; 50 A at 75 meters from A 30 A at 100 meters from A ; 40 A at 150 meters from A The resistance per kilometer of one conductor is 0·3 Ω.

Calculate :

(i) currents in various sections of the distributor

(ii) minimum voltage and the point at which it occurs

➢ Example 3 (cont.)



Resistance of 1000 m length of distributor (both wires)

$$= 2 \times 0{\cdot}3 = 0{\cdot}6\,\Omega$$

Resistance of section AC, $R_{AC} = 0{\cdot}6 \times 50/1000 = 0{\cdot}03\,\Omega$

Resistance of section CD, $R_{CD} = 0{\cdot}6 \times 25/1000 = 0{\cdot}015\,\Omega$

Resistance of section DE, $R_{DE} = 0{\cdot}6 \times 25/1000 = 0{\cdot}015\,\Omega$

Resistance of section EF, $R_{EF} = 0{\cdot}6 \times 50/1000 = 0{\cdot}03\,\Omega$

Resistance of section FB, $R_{FB} = 0{\cdot}6 \times 50/1000 = 0{\cdot}03\,\Omega$

Voltage at B = Voltage at A – Drop over AB

or $$V_B = V_A - [I_A R_{AC} + (I_A - 25) R_{CD} + (I_A - 75) R_{DE} + (I_A - 105) R_{EF} + (I_A - 145) R_{FB}]$$

or $$235 = 230 - [0{\cdot}03\,I_A + 0{\cdot}015\,(I_A - 25) + 0{\cdot}015\,(I_A - 75) + 0{\cdot}03\,(I_A - 105) + 0{\cdot}03\,(I_A - 145)]$$

or $$235 = 230 - [0{\cdot}12\,I_A - 9]$$

$\therefore$ $$I_A = \frac{239 - 235}{0{\cdot}12} = 33{\cdot}34\text{ A}$$

(*i*) $\therefore$ Current in section AC, $I_{AC} = I_A =$ **33·34 A**

Current in section CD, $I_{CD} = I_A - 25 = 33{\cdot}34 - 25 =$ **8·34 A**

➢ Example 3 (cont.)

Current in section DE, I_{DE} = $I_A - 75 = 33{\cdot}34 - 75 = -41{\cdot}66$ A *from D to E*

= **41·66 A** ***from E to D***

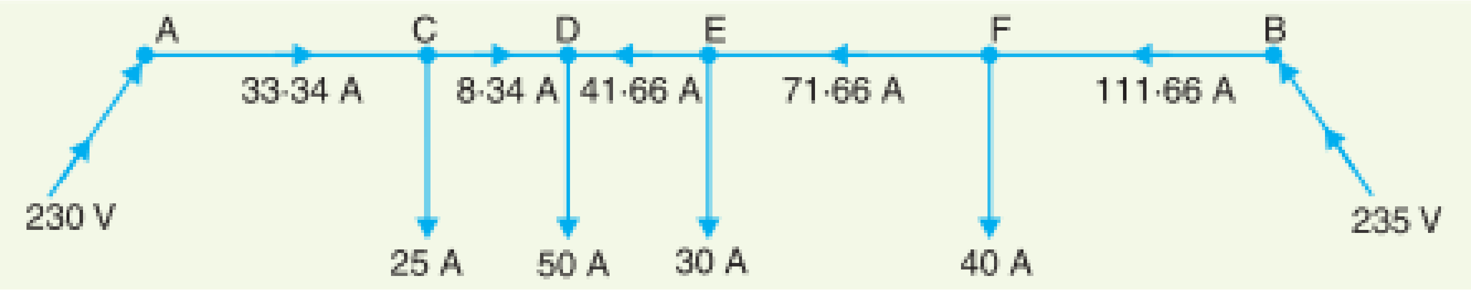
Current in section EF, I_{EF} = $I_A - 105 = 33{\cdot}34 - 105 = -71{\cdot}66$ A *from E to F*

= **71·66 A** ***from F to E***

Current in section FB, I_{FB} = $I_A - 145 = 33{\cdot}34 - 145 = -111{\cdot}66$ A *from F to B*

= **111·66 A** ***from B to F***

(*ii*) The actual distribution of currents in the various sections of the distributor is shown in Fig. 13.20. The currents are coming to load point *D* from both sides of the distributor. Therefore, load point *D* is the point of minimum potential.



$$\text{Voltage at } D,\ V_D = V_A - [I_{AC} R_{AC} + I_{CD} R_{CD}]$$
$$= 230 - [33{\cdot}34 \times 0{\cdot}03 + 8{\cdot}34 \times 0{\cdot}015]$$
$$= 230 - 1{\cdot}125 = \mathbf{228{\cdot}875\ V}$$


Thank you