ADITYA ENGINEERING COLLEGE (A)

DISTRIBUTION SYSTEMS

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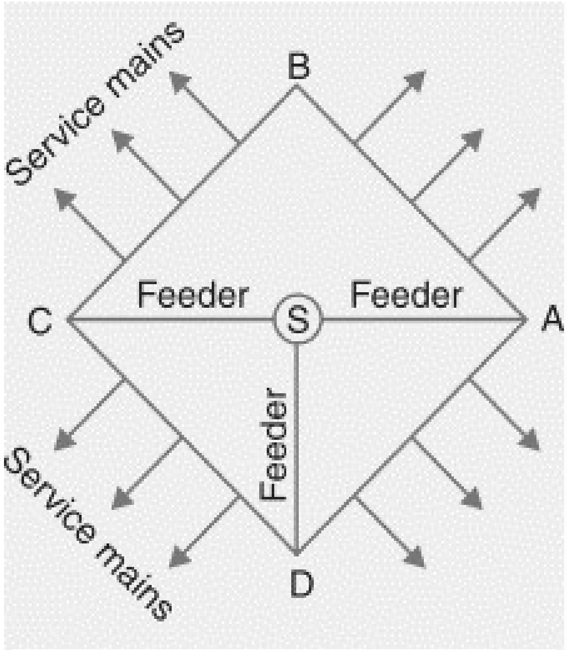
UNIT-2 DISTRIBUTION SYSTEMS (INTRODUCTION)

- **Electrical system has three important components:**
  - **Generation System:**
    - 11kV
  - **Transmission System:**
    - Primary Transmission-132kV
    - Secondary Transmission-33kV
  - **Distribution System:**
    - Primary (or High voltage) distribution system:
      - ✓ 3-phase, 3-wire system
      - ✓ 11kV, 6.6kV and 3.3kV
    - Secondary (or Low voltage) distribution system:
      - ✓ 3-phase, 4-wire system
      - ✓ 230V, 400V

ELEMENTS OF DISTRIBUTION SYSTEM

- **Distribution system is subdivided in three parts:**
  - **Feeders:**
    - No tapping's
    - Current carrying capacity
  - **Distributors:**
    - Tapping's allowed
    - Voltage drop
  - **Service mains:**
    - Connects distributor to consumers.



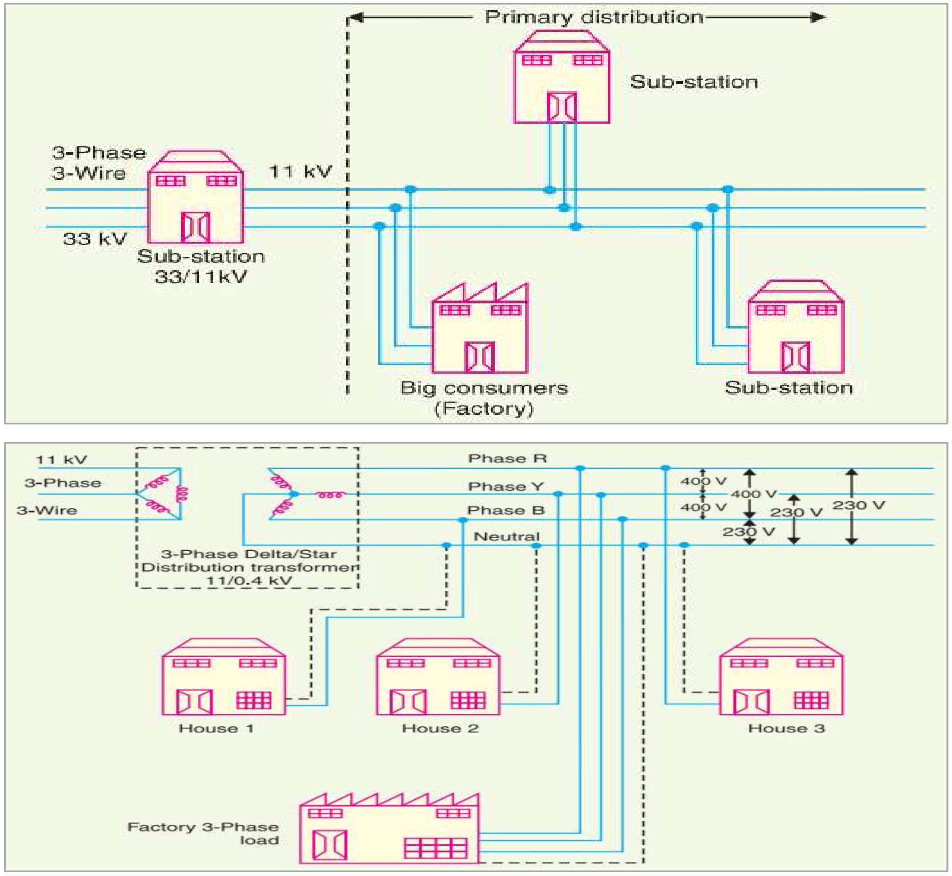
S = Substation or generating station

CLASSIFICATION OF DISTRIBUTION SYSTEM

According to 'nature of current'	• A.C Distribution system • D.C Distribution system
According to 'type of construction'	• Overhead system • Underground system
According to 'scheme of construction'	• Radial system • Ring main system • Interconnected system
According to 'number of wires'	• Two-wire system • Three-wire system • Four-wire system

A.C DISTRIBUTION

- A.C distribution systems are classified as:
- Primary distribution system
  - 11kV, 6.6kV and 3.3kV
  - 3-phase, 3-wire system
- Secondary distribution system
  - 400V and 230V
  - 3-phase, 4-wire system



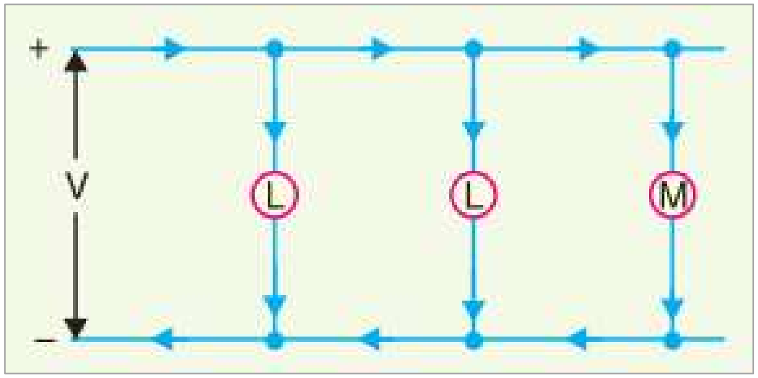
D.C DISTRIBUTION

❖ **2-wire d.c system:**

➢Outgoing and return wire (+ve & -ve)

➢Low efficiency

➢Lamps and motors.



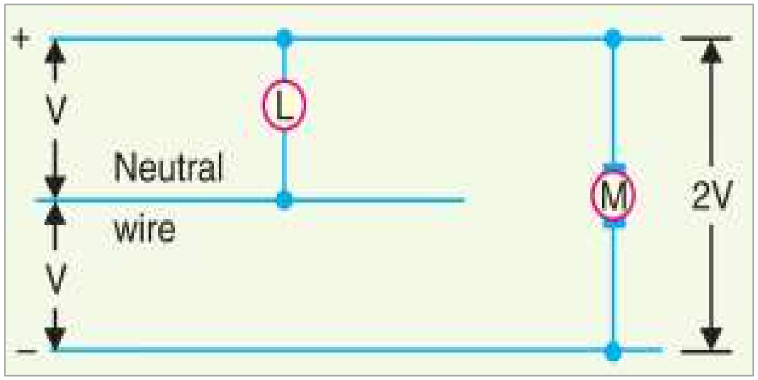
❖ **3-wire d.c system:**

➢Two outers and a middle

➢Two voltages are available (2V &V)

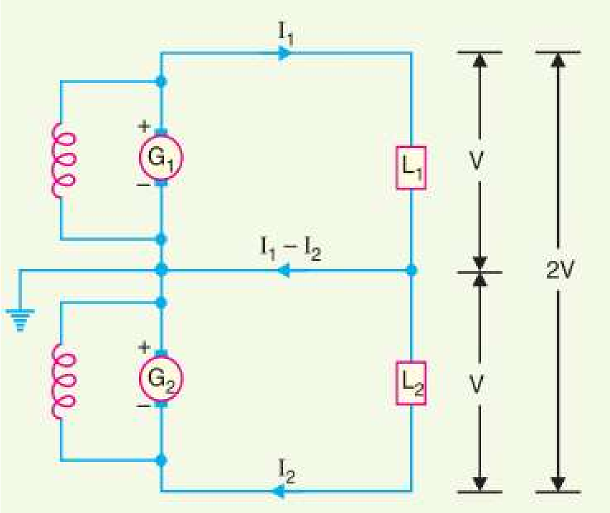
➢H.V are connected across the outers

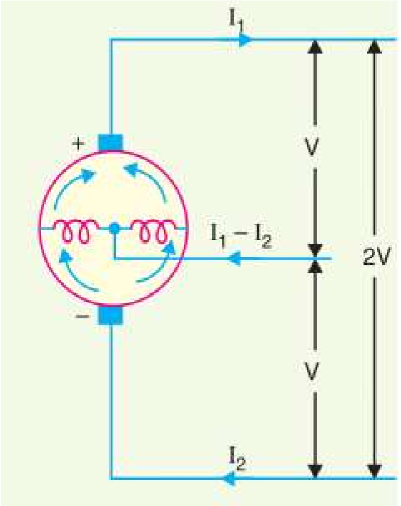
➢L.V are connected between either outer and neutral.

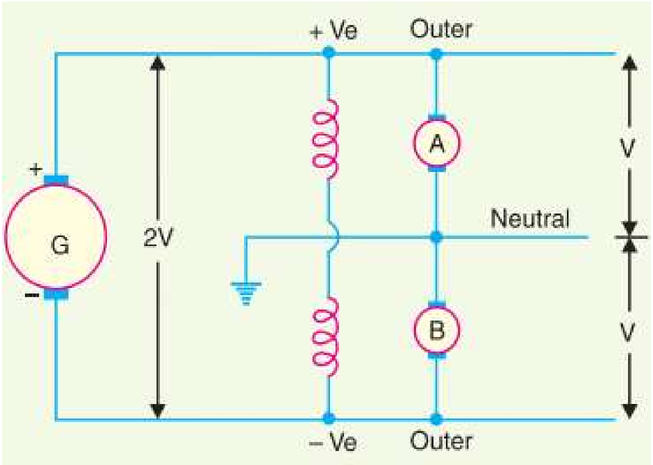


METHODS OF OBTAINING THREE WIRE D.C SYSTEM

- i) Two generator method
- ii) 3-wire d.c generator method
- iii) Balancer set







OVERHEAD VERSUS UNDERGROUND SYSTEM

❖ **The choice between UG and OH depend upon the different factors:**

- Public safety
- Initial cost
- Flexibility
- Faults
- Appearance
- Fault location and repairs
- Current carrying capacity and voltage drop
- Useful life
- Maintenance cost
- Interference with communication circuits

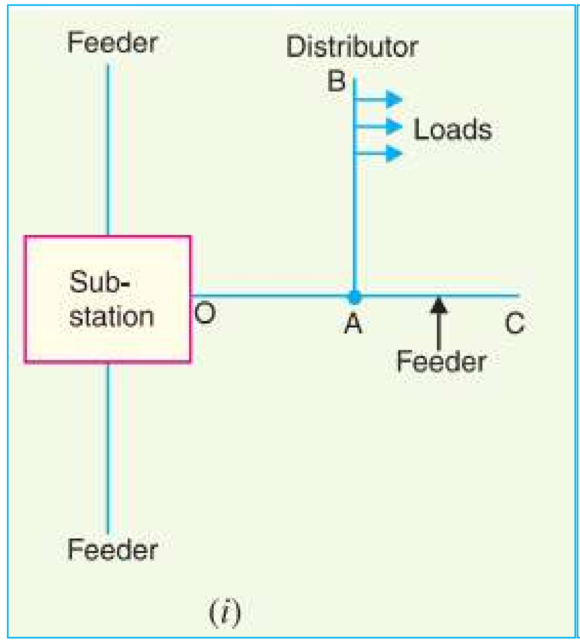
RADIAL DISTRIBUTION SYSTEM

❖ **Advantages:**

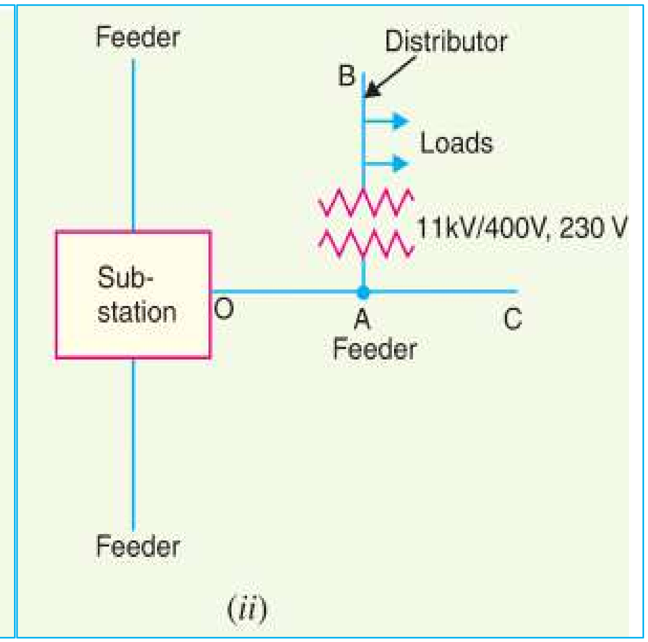
- Circuit is simple
- Initial cost is less

❖ **Disadvantages:**

- End portion of the distributor nearest to the feeding point will be heavily loaded
- Consumers depend on single distributor and single feeder
- Voltage fluctuations are high.



D.C distributor



A.C distributor

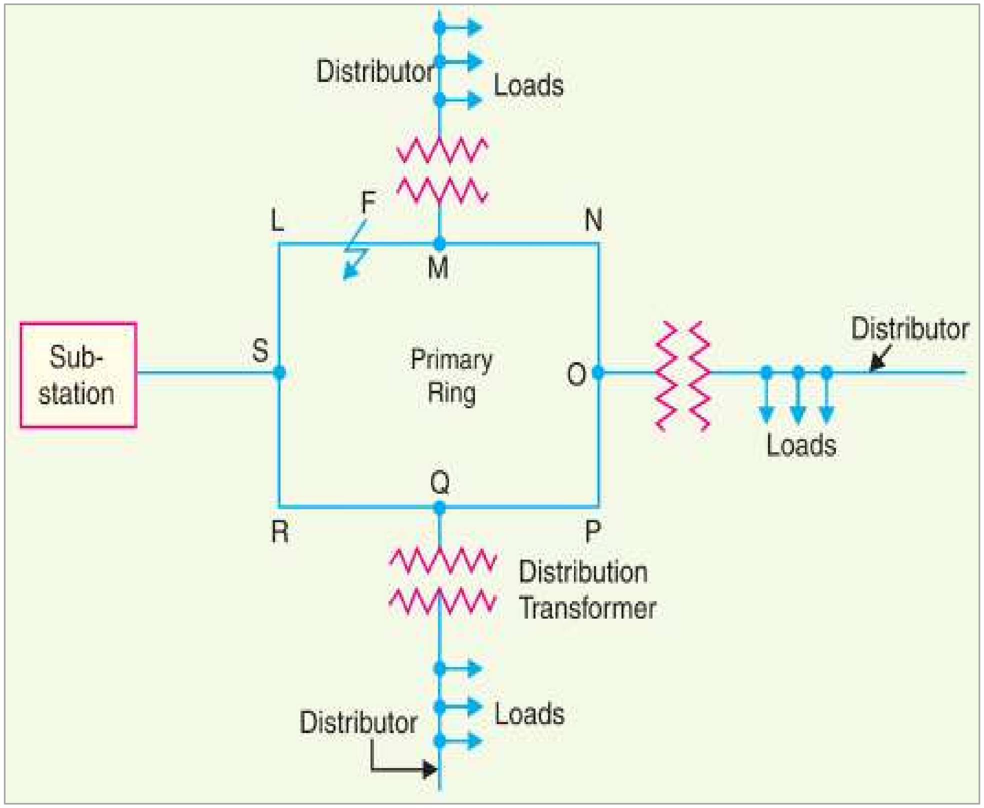
RING MAIN DISTRIBUTION SYSTEM

❖ **Advantages:**

- Voltage fluctuations are less
- The system is very reliable
- Less copper is required

❖ **Disadvantages:**

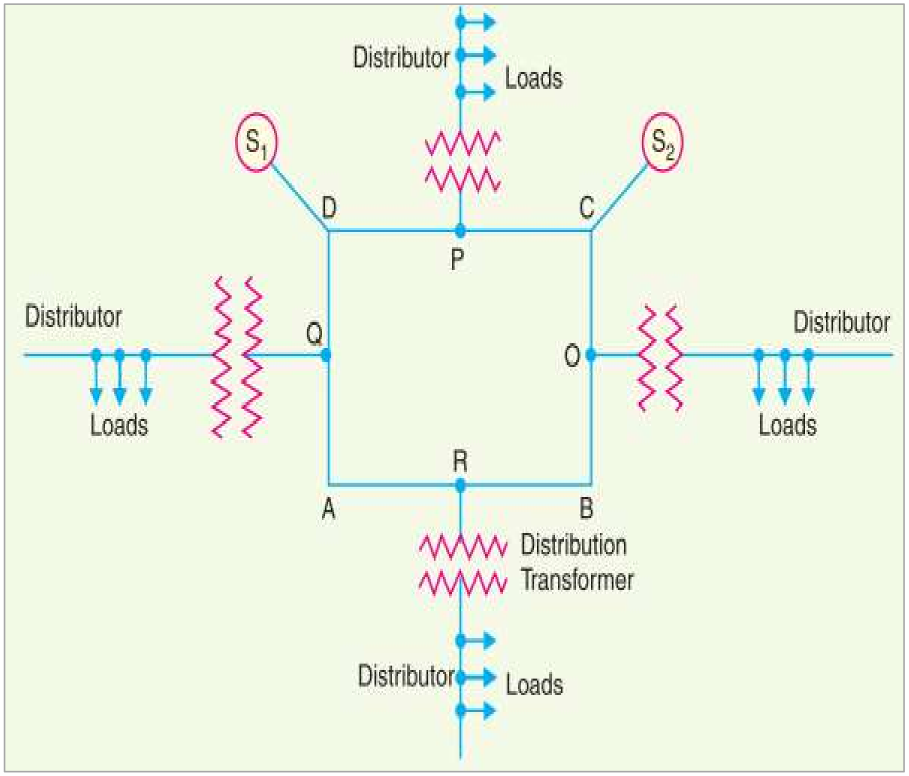
- Feeder is energized by one generating station



INTERCONNECTED DISTRIBUTION SYSTEM

❖ Advantages:

- Increases the service reliability.
- System efficiency is high
- Less copper is required
- Feeder is energized by two or more generating stations or substations



IMPORTANT FACTORS IN DISTRIBUTION SYSTEM

Requirements:

- Proper voltage (Permitted limit of voltage variations is ±6%)
- Availability of power on demand (Prepare the load schedule)
- Reliability(It is improved by interconnected system and reserves etc.,)

Design considerations:

- Feeders (Current carrying capacity)
- Distributors (The voltage drop)

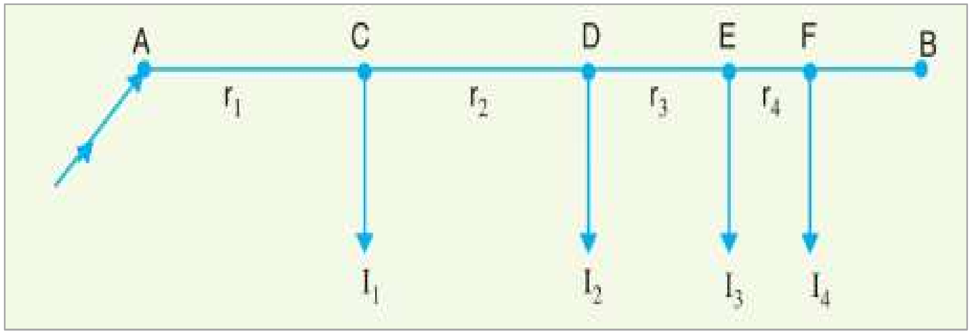
CALCULATION OF VOLTAGE DROPS IN DISTRIBUTION

- **D.C distributor:**
  - Distributor fed at one end:
    - Concentrated loading
    - Uniformly loaded distributor
  - Distributor fed at both ends:
    - Concentrated loading (two ends fed with equal and unequal voltages)
    - Uniform loading (two ends fed with equal and unequal voltages)
  - Distributor with both concentrated and uniform loading
  - Ring main distributor
  - Ring main distributor with interconnector
- **A.C distributor:** concentrated loading
  - Single-phase
  - Three-phase

D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

❖ **Single line diagram of a 2-wire d.c distributor AB fed at one end A:**

- The concentrated loads I1, I2, I3 and I4 tapped off at points C, D, E and F respectively.
- Let r1, r2, r3 and r4 be the resistances of both wires (go and return) of the sections AC, CD, DE and EF of the distributor .
- Current fed from point A = I1 + I2 + I3 + I4

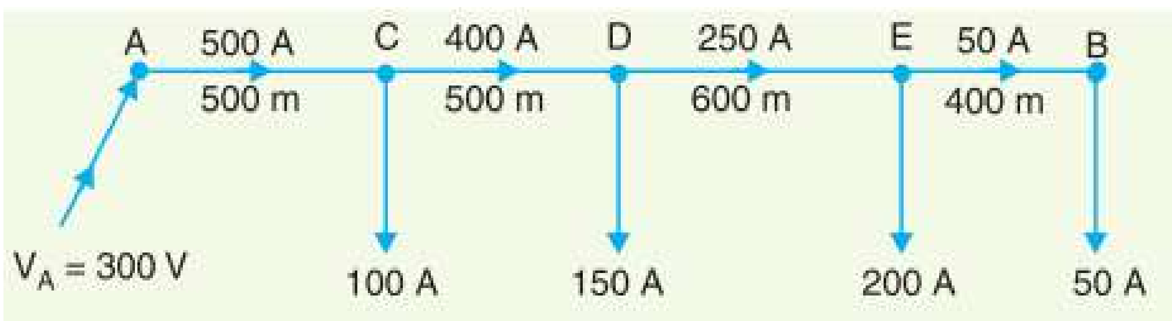


- Current in section AC = I1 + I2 + I3 + I4
- Current in section CD = I2 + I3 + I4
- Current in section DE = I3 + I4
- Current in section EF = I4
- Voltage drop in section AC = r1 (I1 + I2 + I3 + I4)
- Voltage drop in section CD = r2 (I2 + I3 + I4)
- Voltage drop in section DE = r3 (I3 + I4)
- Voltage drop in section EF = r4 I4
- Total voltage drop in the distributor= r1 (I1 + I2 + I3 + I4) + r2 (I2 + I3 + I4) + r3 (I3 + I4) + r4 I4
- **The minimum potential will occur at point F which is farthest from the feeding point A.**

D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

Example: 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.

Solution: Step 1: Draw the single line diagram of the distributor with its tapped currents.



D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

Contd…

- Step 2: Calculate the Resistances/ Currents in various sections and P.D at various load points.
  - Resistance per 1000 m of distributor = 2 × 0·01 = 0·02Ω
  - There are four sections of a distributor AB are AC, CD, DE and EB are shown in figure
  - The loads are taken from the distributor at C, D, E, and B are shown in figure
  - The minimum potential is occurred at point B

S.NO	RESISTANCE in Ω	CURRENTS in A	POTENTIAL DIFFERENCE in V
1	R_{AC} = 0.02X500/1000= 0.01	I_{AC} = 500	$V_C = V_A - I_{AC} R_{AC}$ = 300 - 500X0.01 = 295
2	R_{CD} = 0.02X500/1000= 0.01	I_{CD} = 400	$V_D = V_C - I_{CD} R_{CD}$ = 295 - 400X0.01 = 291
3	R_{DE} = 0.02X600/1000= 0.012	I_{DE} = 250	$V_E = V_D - I_{DE} R_{DE}$ = 291- 250X0.012 = 288
4	R_{EB} = 0.02X400/1000= 0.008	I_{EB} = 50	$V_B = V_E - I_{EB} R_{EB}$ = 288- 50X0.008 = 287.6

D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

Example: A 2-wire d.c. distributor, 500 m long is fed at one of its ends. The cross-sectional area of each conductor is 3·4 cm^2 and the resistivity of copper is 1·7 μΩcm. The distributor supplies 200 A at a distance of 300m from the feeding point and 100 A at the terminus. Calculate the voltage at the feeding end if the voltage at the terminus is to be 230 V.

Solution:?

D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

Example: What should be the minimum cross-sectional area of each conductor in a two-core cable 100 m long to limit the total voltage drop to 4% of the declared voltage of 250V when the conductors carry 60A ? The resistivity of the conductor is $2 \cdot 845\ \mu\Omega$ cm.

- Solution:?

D.C DISTRIBUTION FED AT ONE END- CONCENTRATED LOADING

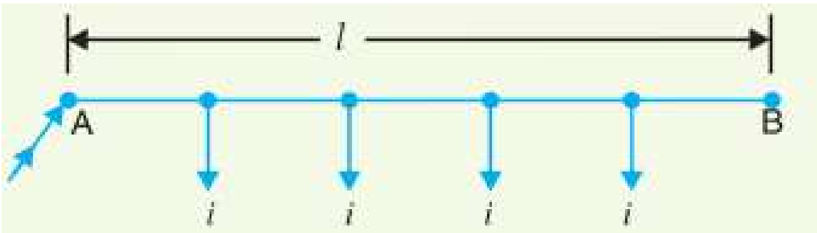
Example: A 2-wire d.c. distributor AB is 300 metres long. It is fed at point A. The various loads and their positions are given below :

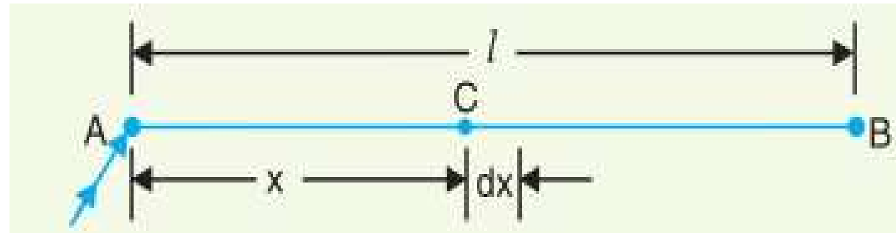
At Point	Distance from A in metres	Concentrated load in amperes
C	40	30
D	100	40
E	150	100
F	250	50

If the maximum permissible voltage drop is not to exceed 10 V, find the cross-sectional area of the distributor. Take $\rho = 1{\cdot}78 \times 10^{-8}\ \Omega m$.

Solution:?

D.C DISTRIBUTION FED AT ONE END- UNIFORM LOADING





- Single line diagram of a 2-wire d.c distributor A B fed at one end A and
- It is loaded uniformly with **i amperes per metre** length.
- Let l metres be the length of the distributor and r ohm be the resistance per metre run.
- Consider a point C on the distributor at a distance x metres from the feeding point A.
- Then current at point C is $= i\,l - i\,x$ amperes $= i\,(l - x)$ amperes
- Consider a small length dx near point C.
- Its resistance is r dx and the voltage drop over length dx is $dv = i\,(l - x)\,r\,dx = i\,r\,(l - x)\,dx$.

D.C DISTRIBUTION FED AT ONE END- UNIFORM LOADING Contd…

- Total voltage drop in the distributor up to point C is v = $\int_0^x$ i r(l−x) dx= i r (l x- $\frac{x^2}{2}$)
- The voltage drop over the distributor AB can be obtained by putting $x = l$ in the above expression.
- Voltage drop over the distributor AB = i r (l . l -$\frac{l^2}{2}$) = $\frac{1}{2}$irl^2 = $\frac{1}{2}$(i l)(r l) = $\frac{1}{2}$ IR.
- Where, i l = I, the total current entering at point A , and r l = R, the total resistance of the distributor.
- The total voltage drop is equal to that produced by the whole of the load assumed to be concentrated at the middle point.
- Power loss in length dx (P) = $[\text{i}\ (l - x)]^2 \times$ r dx
- Power loss for entire length is P = $\int_0^l [\text{i}\ (l - x)]^2 \times$ r dx $= \frac{i^2 r l^3}{3}$

D.C DISTRIBUTION FED AT ONE END- UNIFORM LOADING Contd…

Example: A 2-wire d.c. distributor 200 metres long is uniformly loaded with 2A/metre. Resistance of single wire is 0·3 Ω/km. If the distributor is fed at one end, calculate :

(i) The voltage drop upto a distance of 150 m from the feeding point

(ii) The maximum voltage drop

Solution:

- Current loading, $i = 2A/m$
- Resistance of distributor per metre run, $r = 2x0.3/1000 = 0.0006\Omega/m$
- Length of distributor, $l = 200m$

D.C DISTRIBUTION FED AT ONE END- UNIFORM LOADING Contd…

Solution:

- Voltage drop upto a distance *x* metres from feeding point $\mathbf{V_x = ir(lx - x^2/2)}$

i. In this example the value of *x* is 150m, then drop is $V_{150} = 2*0.0006(200*150-150^2/2) = 22.5$ V

- Total current entering the distributor is $I = il = 2*200 = 400\ A$

- Total resistance of the distributor is $R = rl = 0.0006*200 = 0.12\ \Omega$

ii. Total drop over the distributor is $\mathbf{V_{AB} = IR/2} = 0.12*400/2 = 24$ V

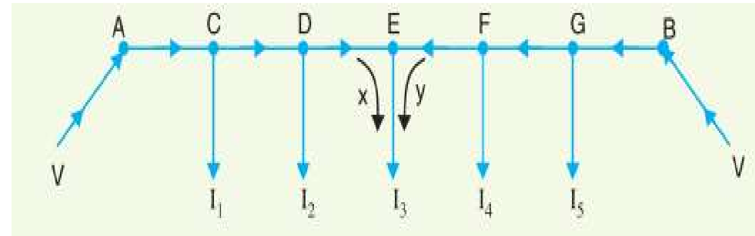
D.C DISTRIBUTION FED AT ONE END- UNIFORM LOADING

Example: A uniform 2-wire d.c. distributor 500 metres long is loaded with 0.4 ampere/metre 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 $\rho = 1{\cdot}7 \times 10^{-6}\ \Omega$ cm.

Solution:

- Current entering the distributor, I= $i \times l = 0.4 \times 500 = 200$A
- Maximum permissible voltage drop=10V
- Let r ohm be the resistance per metre length of the distributor (both wires).
- Max. voltage drop = $\frac{1}{2}$ I R [$R = r\,l$]
- Area of cross-section of the distributor conductor is, $a = \frac{\rho l}{r/2}$

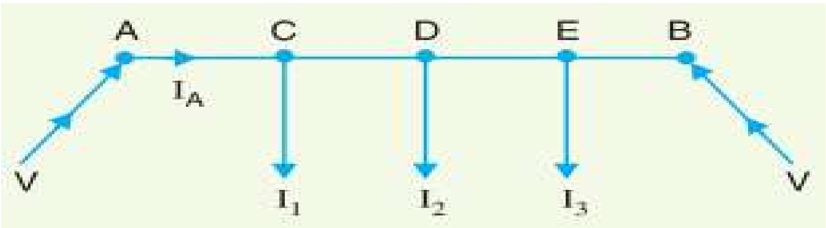
D.C DISTRIBUTION FED AT BOTH ENDS- CONCENTRATED LOADING

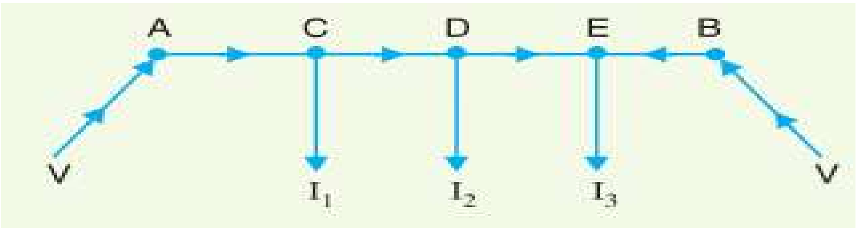


❖Two ends fed with equal or unequal voltages:

- Consider a distributor A B fed at both ends with equal voltages V volts
- The loads I_1, I_2, I_3, I_4 and I_5 tapped off at points C, D, E, F and G.
- 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 as we reach the other feeding point B.
- All the currents tapped off between points A and E will be supplied from the feeding point A while those tapped off between B and E will be supplied from 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, the point of minimum potential on the distributor is more important.

D.C DISTRIBUTION FED AT BOTH ENDS- CONCENTRATED LOADING Contd..





❖ **POINT OF MINIMUM POTENTIAL FOR BOTH EQUAL AND UNEQUAL VOLTAGES:**

- The concentrated loads I_1, I_2 and I_3 tapped off at points C, D and E.
- Suppose the current supplied by feeding end A is I_A
- Then current in various sections of the distributor are $I_{AC} = I_A$; $I_{CD} = I_A - I_1$; $I_{DE} = I_A - I_1 - I_2$; $I_{EB} = I_A - I_1 - I_2 - I_3$
- Voltage drop between A and B = Voltage drop over AB

$$V_A - V_B = I_A R_{AC} + (I_A - I_1)\, R_{CD} + (I_A - I_1 - I_2)\, R_{DE} + (I_A - I_1 - I_2 - I_3)\, R_{EB}$$

- From the above equation the unknown current I_A can be calculated.
- **The load point where the currents are coming from both sides of the distributor is the point of minimum potential**
- In this case the minimum potential point is at point E, which is shown in above figure.

D.C DISTRIBUTION FED AT BOTH ENDS- CONCENTRATED LOADING

Contd…

Example: A 2-wire d.c. distributor cable AB is 600m long and is fed from both ends at 220V. Loads of 20A, 40A, 50A and 30A are tapped at distances of 100 m, 250 m, 400 m and 500 m from the feeding point A respectively. If the area of X-section of distributor conductor is 1cm^2 find the minimum consumer voltage. Take $\rho = 1.7 \times 10^{-6}$ Ωcm.

Solution: Step 1: Let I_A amperes be the current supplied from the feeding end A and draw the single line diagram of the distributor with its tapped currents as shown in Fig.1.

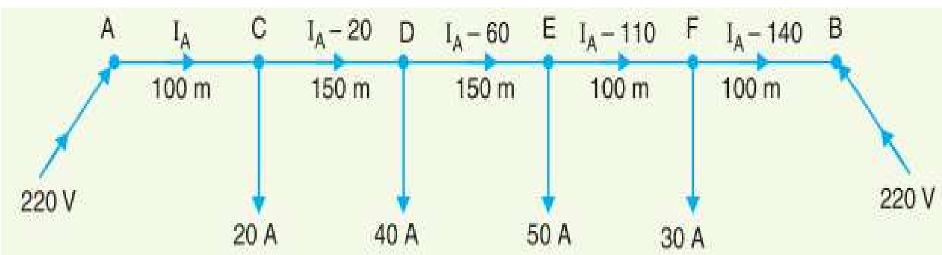


Fig.1

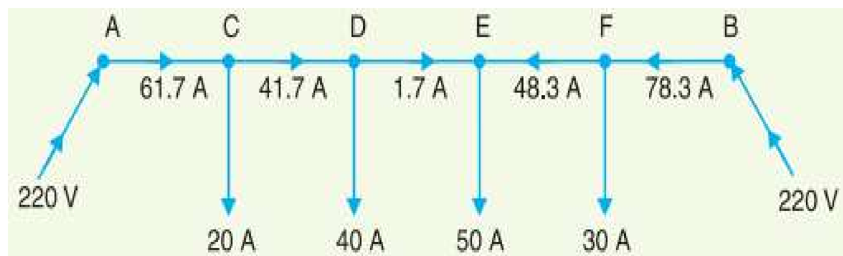


Fig.2

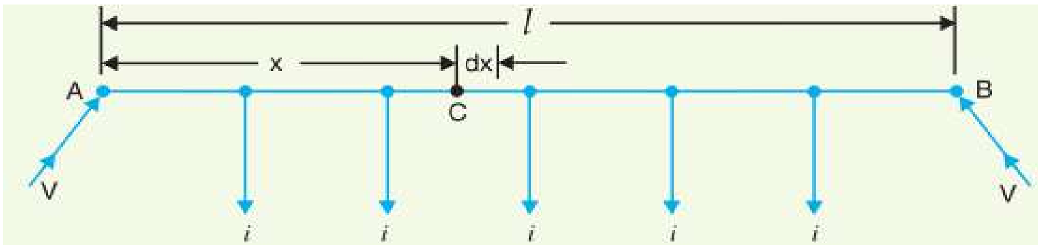
D.C DISTRIBUTION FED AT BOTH ENDS- CONCENTRATED LOADING

Contd…

- Step 2: Calculate the Resistances/ Currents in various sections and minimum consumer voltage.
  - Resistance of 1m(100cm) length of distributor = 2 $\rho l/a$= $2 \times 1.7 \times 10^{-6} \times 100/1 = 3.4 \times 10^{-4}\ \Omega$
  - By using known equation calculate the unknown current i.e., I_A= 61.7A
  - The actual distribution of currents in the various sections of the distributor is shown in Fig.2.
  - Minimum potential point is at E and its potential value is $V_E = V_A - [I_{AC} R_{AC} + I_{CD} R_{CD} + I_{DE} R_{DE}] = 215.69V$

S.NO	RESISTANCE in Ω	Temporary currents in A	Actual currents in A
1	$R_{AC} = 3.4x10^{-4}\times100 =0.034$	$I_{AC} = I_A$	$I_{AC} = 61.7$
2	$R_{CD} = 3.4x10^{-4}\times150= 0.015$	$I_{CD} = I_A-20$	$I_{CD} = 41.7$
3	$R_{DE} = 3.4x10^{-4}\times150= 0.015$	$I_{DE} = I_A-60$	$I_{DE} = 1.7$
4	$R_{EF} = 3.4x10^{-4}\times100 = 0.034$	$I_{EF} = I_A-110$	$I_{EF} = -48.3$
5	$R_{FB} = 3.4x10^{-4}\times100 =0.034$	$I_{FB}= I_A-140$	$I_{FB}= -78.3$

D.C DISTRIBUTION FED AT BOTH ENDS- UNIFORM LOADING



❖**Distributor fed at both ends with equal voltages:**

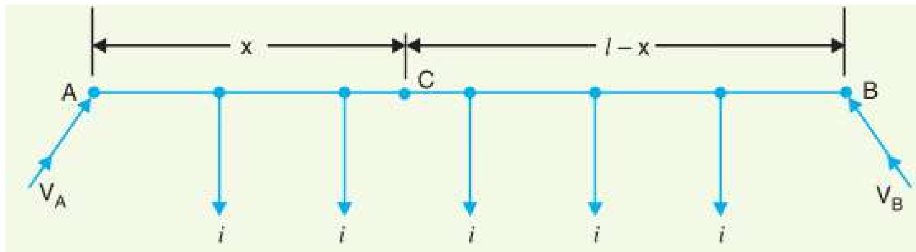
- Consider a distributor AB of length l metres, having resistance r ohms per metre run and with uniform loading of i amperes per metre run.
- Let the distributor be fed at the feeding points A and B at equal voltages, say V volts.
- The total current supplied to the distributor is il and current supplied from each feeding point is il/2.
- Consider a point C on the distributor at a distance x metres from the feeding point A.
- Then current at point C is = (i $l/2 - $ i x) amperes = i ($l/2 - x$) amperes

D.C DISTRIBUTION FED AT BOTH ENDS- UNIFORM LOADING Contd…

- Consider a small length dx near point C.
- Its resistance is r dx and the voltage drop over length dx is $dv = i\,(l/2 - x)\, r\, dx = i\, r\,(l/2 - x)\, dx$.
- Total voltage drop up to point C is $v = \int_0^x i\, r(\frac{l}{2} - x)\, dx = \frac{ir}{2}(lx - x^2)$
- The maximum voltage drop will occur at mid-point i.e. $x = l/2$.
- The maximum voltage drop $= \frac{ir}{2}(l \cdot \frac{l}{2} - \frac{l^2}{4}) = \frac{1}{8} i r l^2 = \frac{1}{8}(i\, l)(r\, l) = \frac{1}{8}$ IR.
- Minimum voltage = $(V - \frac{1}{8}$ IR) volts.
- Power loss in length dx (P) $= [i\,(l/2 - x)]^2 \times r\, dx$
- $P = \int_0^l [i\,(l/2 - x)]^2 \times r\, dx = \frac{i^2 r l^3}{12}$

- Where,
  - $i\, l$ = I, the total current entering at point A, and
  - $r\, l$ = R, the total resistance of the distributor.

D.C DISTRIBUTION FED AT BOTH ENDS- UNIFORM LOADING



❖ **Distributor fed at both ends with unequal voltages:**

➢ Consider a distributor A B of length *l* meters, having resistance r ohms per meter run and with uniform loading of i amperes per meter run.

➢ Let the distributor be fed at the feeding points A and B at voltages V_A and V_B respectively.

➢ Let the point of minimum potential C is situated at a distance x meters from the feeding point A.

➢ The current supplied by the feeding point A is i*x*.

➢ Voltage drop in section AC = $\frac{1}{2}irx^2$ volts.

D.C DISTRIBUTION FED AT BOTH ENDS- UNIFORM LOADING Contd…

- The current supplied by the feeding point B is i(*l*-*x*).
- Voltage drop in section BC = $\frac{1}{2}$ir$(l-x)^2$ volts.
- Voltage at point C, $V_C = V_A -$ Drop over AC = V_A- $\frac{\mathrm{ir}x^2}{2}$
- Also, the Voltage at point C, $V_C = V_B -$ Drop over BC = V_B- $\frac{\mathrm{ir}(l-x)^2}{2}$
- Therefore, V_A- $\frac{\mathrm{ir}x^2}{2} = V_B$- $\frac{\mathrm{ir}(l-x)^2}{2}$
- By solving the above equation we get minimum potential point, x = $\frac{V_A - V_B}{irl} + \frac{l}{2}$
- Therefore, the point on the distributor where minimum potential occurs can be calculated i.e. x meters.

D.C DISTRIBUTION FED AT BOTH ENDS

Example: A 2-wire d.c. distributor AB 500 metres long is fed from both ends and is loaded uniformly at the rate of 1·0 A/metre. At feeding point A, the voltage is maintained at 255 V and at B at 250 V. If the resistance of each conductor is 0·1 Ω per kilometre, determine :

(i) the minimum voltage and the point where it occurs

(ii) the currents supplied from feeding points A and B

Solution:

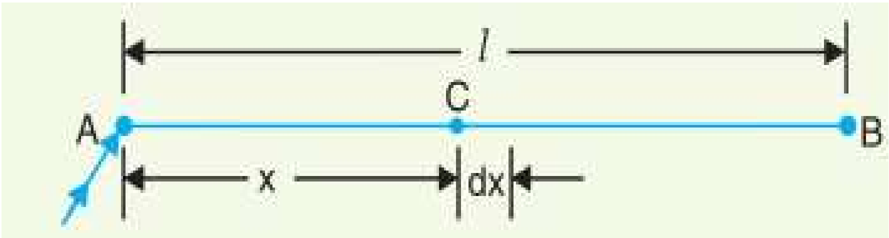
(i) Let the minimum potential occur at a point C distant x metres from the feeding point A.

- $x = \frac{V_A - V_B}{irl} + \frac{l}{2} = \frac{255-250}{1 \times 0.0002 \times 500} + \frac{500}{2} = 300\text{m}$
- Minimum voltage, $V_C = V_A -$ Drop over AC $= V_A - \frac{\text{ir}x^2}{2} = 255\text{-}9\text{=}246\text{V}$

(ii) Current supplied from A = i x = 1 × 300 = 300 A

- Current supplied from B = i (l − x) = 1 (500 − 300) = 200 A

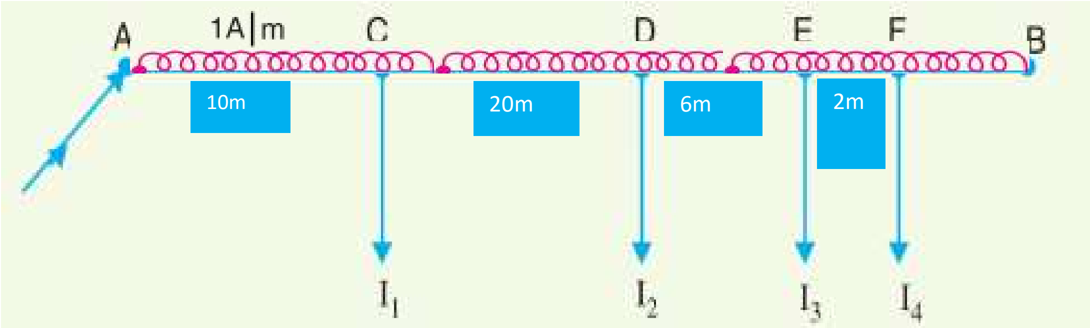
DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING



❖Distributor fed at one end:

- Single line diagram of a 2-wire d.c distributor A B fed at one end A.
- The concentrated loads I_1, I_2, I_3 and I_4 tapped off at points C, D, E and F respectively.
- The distributor is also loaded uniformly at the rate of i A/m.
- Let the resistance of the distributor per metre (go and return) is r Ω.
- The total drop over any section of the distributor is equal to the sum of drops due to concentrated and uniform loading in that section.

DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING



Drop due to concentrated loads:

- Drop in section $AC = I_{AC}R_{AC}$
- Drop in section $CD = I_{CD}R_{CD}$
- Drop in section $DE = I_{DE}R_{DE}$
- Drop in section $EF = I_{EF}R_{EF}$
- Where, $I_{AC}= I_1 + I_2 + I_3 + I_4$; $I_{CD}= I_2 + I_3 + I_4$;

  $I_{DE}= I_3 + I_4$ and $I_{EF}= I_4$.
- R_{AC}= r×10m; R_{CD}=r×20m; R_{DE}=r×6m; R_{EF}=r×2m.
- Drop over AB is V_{AB}=$V_{AC} + V_{CD} + V_{DE} + V_{EF}$

Drop due to uniform loading:

- Voltage drop over the distributor AB = $\frac{1}{2}$irl^2
- Voltage drop over AD = i r ($l\,x$- $\frac{x^2}{2}$)

Calculation of potential at a given point:

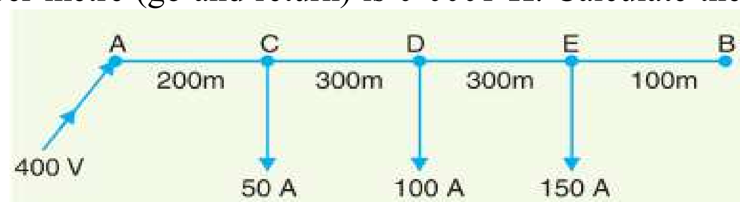
- Voltage at point B = V_A − Drop over AB due to concentrated − Drop due to uniform load.

  = V_A −[V_{AB} (concentrated)+V_{AB} (uniform)]
- Voltage at point D = V_A − [V_{AD} (concentrated)+V_{AD} (uniform)]

  = $V_A - [(V_{AC} + V_{CD})$ + i r (l x- $\frac{x^2}{2}$)].

DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING

Example: A 2-wire d.c. distributor cable AB is 900m long is fed at A at 400V and supplies loads of 50A, 100A and 150A are tapped off from C, D and E which are at a distance 200 m, 500 m and 800 m from the feeding point A respectively. The distributor is also loaded uniformly at the rate of 0.5A/m. If the resistance of distributor per metre (go and return) is 0·0001 Ω. Calculate the voltage at point B and at point D.



Solution: Step 1: drop due to concentrated loads.

- Drop over AB is $V_{AB}=I_{AC} R_{AC}+I_{CD}R_{CD}+I_{DE}R_{DE}=300 \times (200\times0.0001)+7.5+4.5=18V$

- Step 2: drop due to uniform loading.

- Drop over AB, $V_{AB} = irl^2/2= 0.5 \times 0.0001\times 900^2/2 = 20.25V$

- Drop over AD is $V_{AD} = i\ r\ (l\ x- x^2/2\ ) = 0.5 \times 0.0001(900 \times 500-500^2/2)=16.25V$

- Step 3: Calculation of voltage at point B and at point D:

- Voltage at point B is $V_B = V_A$- [V_{AB} (concentrated loading) + V_{AB} (uniform loading)]= 400-[18+20.205]=361.75V

- Voltage at point D is $V_D = V_A$- [V_{AD} (concentrated loading) + V_{AD} (uniform loading)]= 400-[6+7.5+16.25]=370.25V

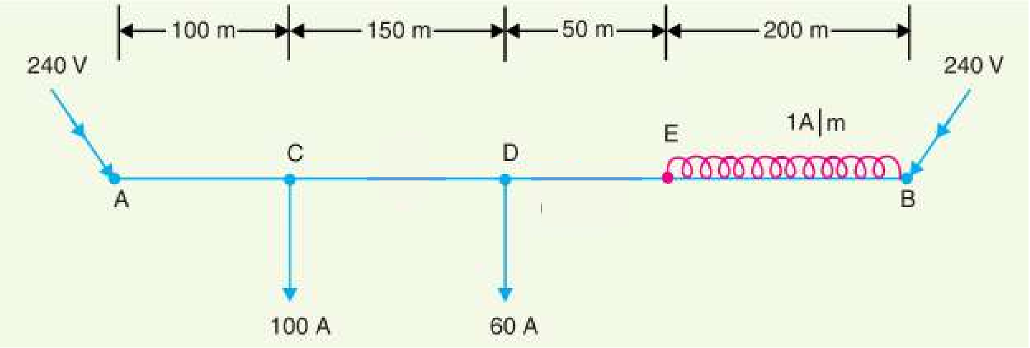
DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING

Example 13.20: Two conductors of a d.c. distributor cable AB 1000 m long have a total resistance of 0·1 Ω. The ends A and B are fed at 240 V. The cable is uniformly loaded at 0·5 A per metre length and has concentrated loads of 120 A, 60 A, 100 A and 40 A at points distant 200 m, 400 m, 700 m and 900 m respectively from the end A. Calculate (i) the point of minimum potential (ii) currents supplied from ends A and B (iii) the value of minimum potential.

Solution:

DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING

Example 13.21: A d.c. 2-wire distributor AB is 500m long and is fed at both ends at 240 V. The distributor is loaded as shown in below figure. The resistance of the distributor (go and return) is $0{\cdot}001\Omega$ per metre. Calculate (i) the point of minimum voltage and (ii) the value of this voltage.

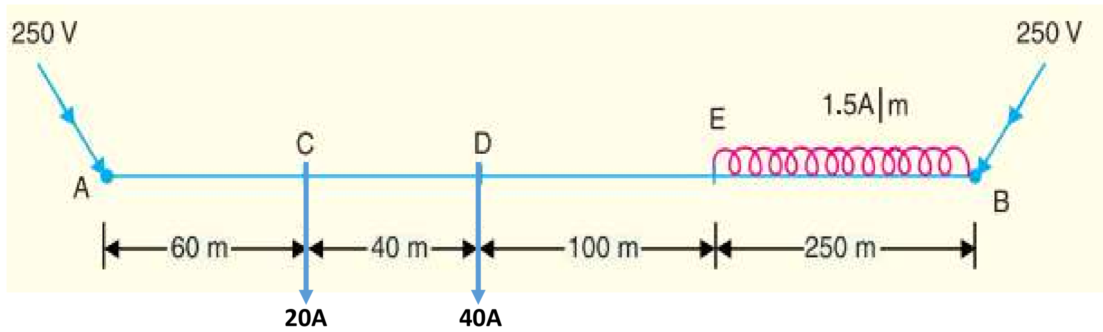


Solution:

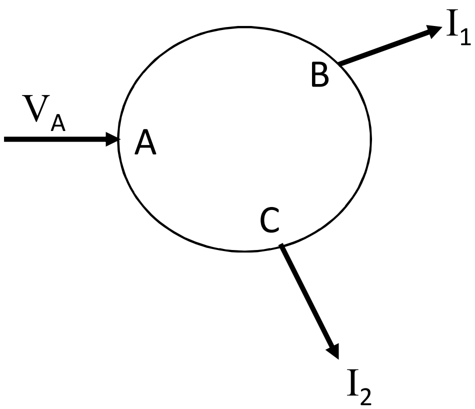
DISTRIBUTOR WITH BOTH CONCENTRATED AND UNIFORM LOADING

Example TP3: A d.c. 2-wire distributor AB is 450m long and is fed at both ends at 250 V. The distributor is loaded as shown in below figure. The resistance of each conductor is 0·05Ω per km. Find the point of minimum potential and its potential.

Solution:



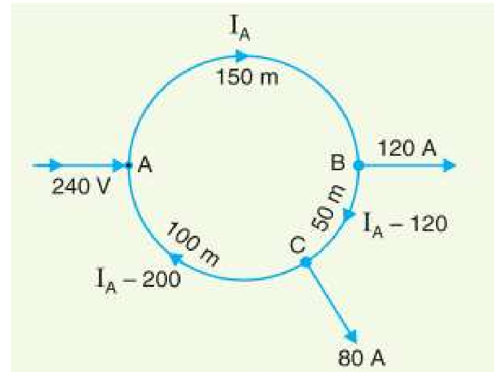
RING DISTRIBUTOR



- 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.
- The most simple case of a ring distributor is the one having only one feeding point as shown in figure
- In this case point A is the feeding point and tapping's are taken from points B and C.
- It is equivalent to a straight distributor fed at both ends with equal voltages.

RING DISTRIBUTOR

Example 13.22: 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 : (i) current in each section of distributor, (ii) voltage at points B and C



(i)

Solution:

- Resistance per 100 m of distributor = 2 × 0·03 = 0·06Ω
- Resistance of section AB, R_{AB} = 0·06 × 150/100 = 0·09 Ω
- Resistance of section BC, R_{BC} = 0·06 × 50/100 = 0·03 Ω
- Resistance of section CA, R_{CA} = 0·06 × 100/100 = 0·06 Ω

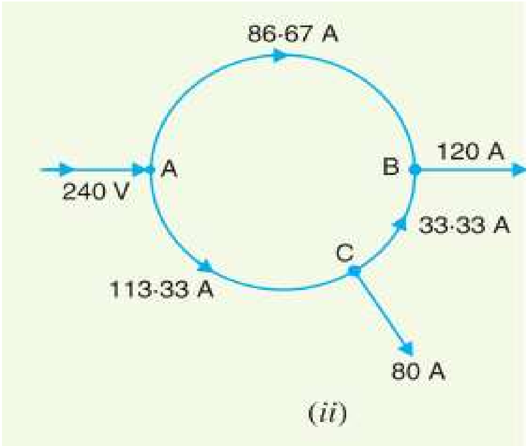
Step 1: Let us suppose that a current I_A flows in section AB of the distributor.

- Then currents in sections BC and CA will be (I_A − 120) and (I_A − 200) respectively as shown in Fig. (i).
- According to Kirchhoff's voltage law, the voltage drop in the closed loop ABCA is zero i.e.
- $I_{AB} R_{AB} + I_{BC} R_{BC} + I_{CA} R_{CA} = 0$

  or $0{\cdot}09\ I_A + 0{\cdot}03\ (I_A - 120) + 0{\cdot}06\ (I_A - 200) = 0$
- Therefore the current in section AB is $I_A = 15{\cdot}6/0{\cdot}18 = 86{\cdot}67$ A

RING DISTRIBUTOR Contd…

- Step 2: Calculate the actual currents in various sections:



- Current in section AB, $I_{AB} = I_A = 86 \cdot 67$ A from A to B
- Current in section BC, $I_{BC} = I_A - 120 = 86 \cdot 67 - 120 = -33 \cdot 33$ A= 33.33 A from C to B
- Current in section CA, $I_{CA} = I_A - 200 = 86 \cdot 67 - 200 = -113 \cdot 33$ A=113 ·33 A from A to C
- The actual distribution of currents is as shown in Fig. (ii)
- From Fig. (ii) it is clear that the minimum potential point is at B

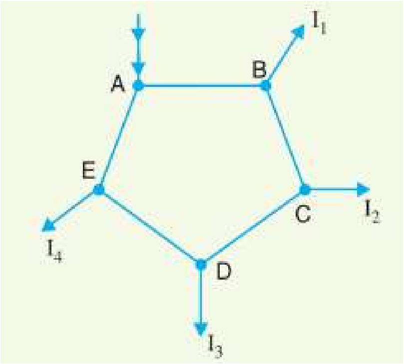
- Voltage at point B, $V_B = V_A - I_{AB} R_{AB} = 240 - 86 \cdot 67 \times 0 \cdot 09 = 232 \cdot 2$ V
- Voltage at point C, $V_C = V_B + I_{BC} R_{BC} = 232 \cdot 2 + 33 \cdot 33 \times 0 \cdot 03 = 233 \cdot 2$ V

RING DISTRIBUTOR

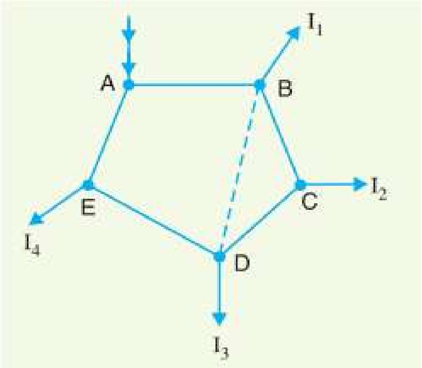
Example 13.23: A 2-wire d.c. distributor ABCDEA is fed at point A at 220 V and is loaded as 10A at B ; 20A at C ; 30A at D and 10 A at E. The resistances of various sections (go and return) are : AB = 0·1 Ω ; BC = 0·05 Ω ; CD = 0·01Ω ; DE = 0·025 Ω and EA = 0·075 Ω. Determine :(i) the point of minimum potential, (ii) current in each section of distributor

Solution:

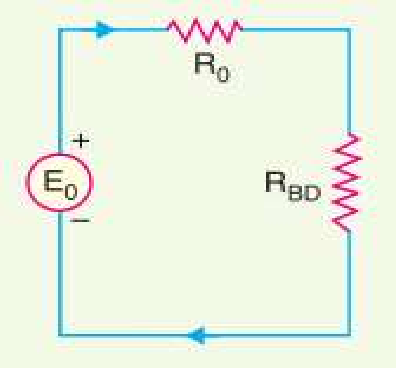
RING MAIN DISTRIBUTOR WITH INTERCONNECTOR



(i)



(ii)



(iii)

- Sometimes a ring distributor has to serve a large area, in such a case, voltage drops in the various sections of the distributor may become excessive.
- In order to reduce voltage drops in various sections, distant points of the distributor are joined through a conductor called interconnector.
- The first figure shows the ring distributor ABCDEA.
- The points B and D of the ring distributor are joined through an interconnector BD as shown in second figure.
- There are several methods for solving such a network.
- However, the solution of such a network can be readily obtained by applying the Thevenin's theorem.

RING MAIN DISTRIBUTOR WITH INTERCONNECTOR Contd…

❑ Procedure to obtain Thevenins equivalent circuit:

- Consider an interconnector BD to be disconnected and find the Thevenin's equivalent circuit voltage E_0 between B and D.
- Calculate the Thevenin's equivalent resistance R_0 resistance viewed from points B and D of the network composed of distribution lines only.
- R_{BD} is the resistance of the interconnector BD and Thevenin's equivalent circuit is shown in Fig (iii).
- Calculate the current in an interconnector, $I_{BD} = \frac{E_0}{R_0 + R_{BD}}$

❑ Main steps to analyze the ring main distributor with interconnector:

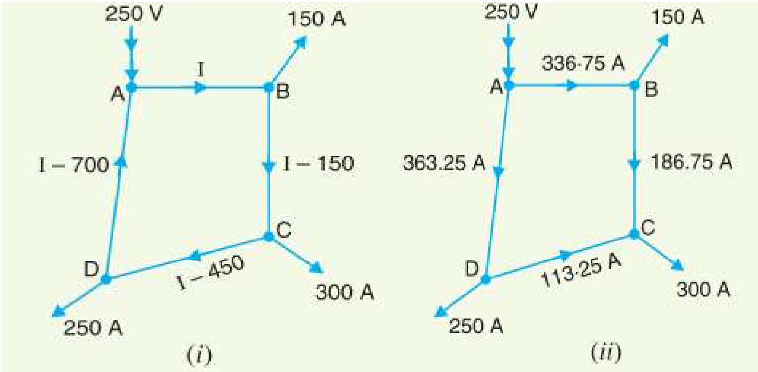
- **In case (i)- without interconnector:** calculate the potentials on various load points.
- **In case (ii)-with interconnector:** calculate the new potentials on various load points, after applying Thevenins theorem to obtain interconnector current.

❖ **Therefore, the advantage with the use of interconnector is the voltage drops in the various sections of the distributor are reduced.**

RING MAIN DISTRIBUTOR WITH INTERCONNECTOR

Example13.24: A d.c. ring main ABCDA is fed from point A from a 250 V supply and the resistances (including both lead and return) of various sections are as follows : AB = 0·02 Ω ; BC = 0·018 Ω ; CD = 0·025 Ω and DA = 0·02 Ω. The main supplies loads of 150 A at B ; 300 A at C and 250 A at D. Determine the voltage at each load point. If the points A and C are linked through an interconnector of resistance 0·02 Ω, determine the new voltage at each load point.

Solution: case (i): **without interconnector:**



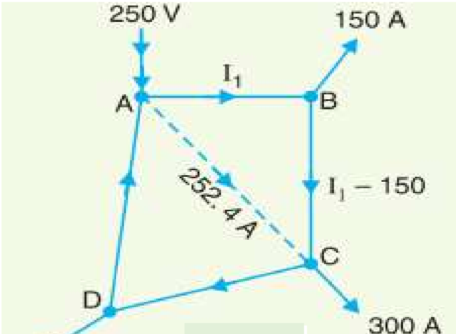
- Let us suppose that a current 'I' flows in section AB of the distributor.
- Then currents in various sections of the distributor are shown in Fig.(i)
- According to KVL, the voltage drop in the closed loop ABCDA is zero
- That is, $I_{AB} R_{AB} + I_{BC} R_{BC} + I_{CD} R_{CD} + I_{DA} R_{DA} = 0$

  or $0{\cdot}02I + 0{\cdot}018\,(I - 150) + 0{\cdot}025\,(I - 450) + 0{\cdot}02\,(I - 700) = 0 = 0$
- Therefore the current in section AB is I = 27.95/0·083 = 336·75 A
- The actual distribution of currents is as shown in Fig. (ii), then calculate the voltage drops in various sections
- Voltage drops in sections AB, BC, CD and DA are: $\mathbf{V_{AB} = 6.735V; V_{BC} = 3.361V; V_{CD} = 2.831V; V_{DA} = 7.265V}$
- **Voltage at load points B, C and D are: V_B = 250-6.735=243.265V; similarly, V_C = 239.904V and V_D = 242.735V**

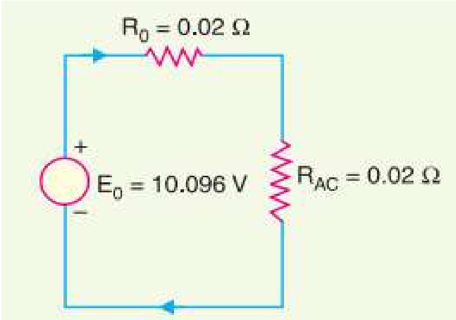
RING MAIN DISTRIBUTOR WITH INTERCONNECTOR Contd…

❖ case (ii): **with interconnector.**

- Fig. (iii) shows the ring distributor with interconnector AC.
- The current in the interconnector can be found by applying Thevenin's theorem.
- E_0 = Voltage between points A and C= 250 − 239·904 = 10·096 V
- R_0 = Resistance viewed from points A and C $= \frac{(0.02+0.018)(0.02+0.025)}{(0.02+0.018)+(0.02+0.025)} = 0.02\Omega$
- R_{AC} = Resistance of interconnector = 0·02 Ω
- Thevenin's equivalent circuit is shown in Fig. (iv).
- Current in interconnector AC $= \frac{E_0}{R_{AC}+E_0} = \frac{10.096}{0.02+0.02} = 252.4$ A from A to C
- Let us suppose that current in section AB is I_1.
- Then current in section BC will be $I_1 - 150$.
- As the voltage drop round the closed mesh ABCA is zero,
- Therefore $0{\cdot}02\ I_1 + 0{\cdot}018\ (I_1 - 150) - 0{\cdot}02 \times 252{\cdot}4 = 0$ and $I_1 = 203.15$ A



(iii)

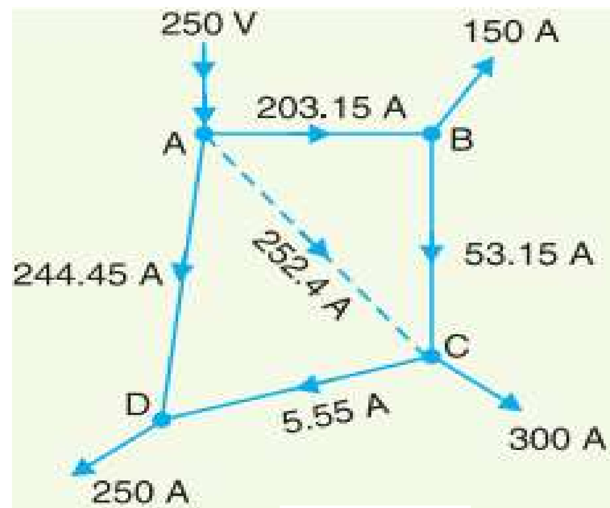


(iv)

RING MAIN DISTRIBUTOR WITH INTERCONNECTOR Contd…

- The actual distribution of currents in the ring distributor with interconnector is shown in Fig. (v).

- Now calculate new voltage drops in various sections of the ring distributor with interconnector
- Voltage drop in section AB is $V_{AB} = 203{\cdot}15 \times 0{\cdot}02 = 4{\cdot}063$ V
- Voltage drop in section BC is $V_{BC} = 53{\cdot}15 \times 0{\cdot}018 = 0{\cdot}960$ V
- Voltage drop in section CD is $V_{CD} = 5{\cdot}55 \times 0{\cdot}025 = 0{\cdot}139$ V
- Voltage drop in section AD is $V_{AD} = 244{\cdot}45 \times 0{\cdot}02 = 4{\cdot}9$ V
- Potential of B is $V_{B'} = 250 - 4{\cdot}063 = 245{\cdot}93$ V
- Potential of C is $V_{C'} = 245{\cdot}93 - 0{\cdot}96 = 244{\cdot}97$ V
- Potential of D is $V_{D'} = 250 - 4{\cdot}9 = 245{\cdot}1$ V



(v)

RING MAIN DISTRIBUTOR WITH INTERCONNECTOR

Example 13.24: A d.c. ring main ABCDA is fed from point A from a 250 V supply and the resistances (including both lead and return) of various sections are as follows : AB = 0·02 Ω ; BC = 0·018 Ω ; CD = 0·025 Ω and DA = 0·02 Ω. The main supplies loads of 150 A at B ; 300 A at C and 250 A at D. Determine the voltage at each load point. If the points A and C are linked through an interconnector of resistance 0·02 Ω, determine the new voltage at each load point.

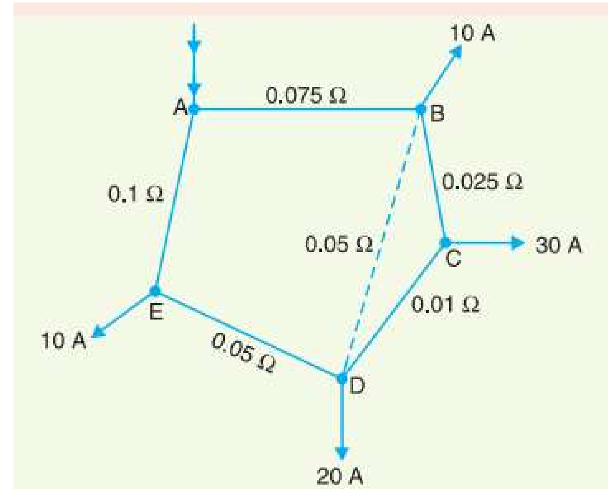
- Comparison table:

S.No	Voltage drops without interconnector	Voltage drops with interconnector	Voltages without interconnector	Voltages with interconnector
1	$V_{AB} = 6.735V$	$V_{AB} = 4.063V$	$V_A = 250V$	$V_A = 250V$
2	$V_{BC} = 3.361V$	$V_{BC} = 0.960V$	$V_B = 243.265V$	$V_B = 245.93V$
3	$V_{CD} = 2.831V$	$V_{CD} = 0.139V$	$V_C = 239.904V$	$V_C = 244.97V$
4	$V_{DA} = 7.265V$	$V_{DA} = 4.9V$	$V_D = 242.735V$	$V_D = 245.1V$

- **Observations:**
  - **It may be seen that with the use of interconnector, the voltage drops in the various sections of the distributor are reduced.**

RING MAIN DISTRIBUTOR WITH INTERCONNECTOR

Example 13.25: The below figure shows a ring distributor with interconnector BD. The supply is given at point A. The resistances of go and return conductors of various sections are indicated in the figure. Calculate the current in the interconnector and its voltage drop.



Solution:

THREE WIRE D.C DISTRIBUTION SYSTEM

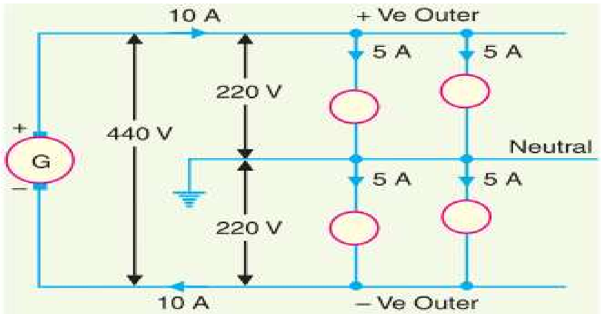


Fig.1.

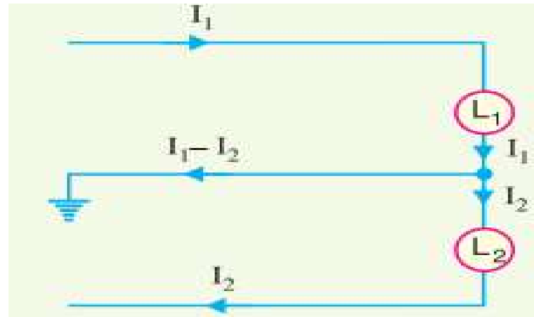


Fig.2.

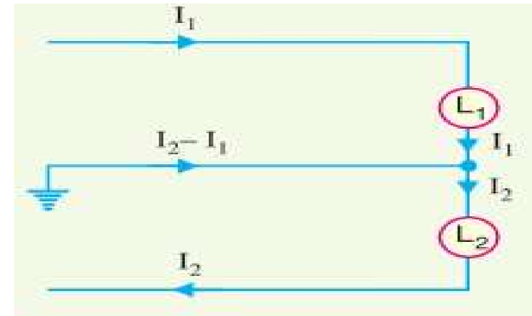


Fig.3.

❖ **The current in the neutral wire will depend upon the loads applied to the two sides:**

1. If the loads applied on both sides of the neutral are equal then, the current in the neutral wire will be zero as shown in Fig.1. So, the potential of the neutral will be exactly half-way between the outers.
2. If the load on the positive outer (I_1) is greater than on the negative outer (I_2), then out of balance current $I_1 - I_2$ will flow in the neutral wire from load end to supply end as shown in Fig.2.

   ➢Under this condition, the potential of neutral wire will no longer be midway between the potentials of the outers.
3. If the load on the negative outer (I_2) is greater than on the positive outer (I_1), then out of balance current $I_2 - I_1$ will flow in the neutral wire from supply end to load end as shown in Fig.3.

   ➢Under this condition, the potential of neutral wire will no longer be midway between the potentials of the outers.
4. The area of X-section of neutral is taken half as compared to either of the outers.

THREE WIRE D.C DISTRIBUTION SYSTEM

Example 13.26: A load supplied on 3-wire d.c. system takes a current of 50 A on the +ve side and 40 A on the negative side. The resistance of each outer wire is 0·1 Ω and the cross-section of middle wire is one-half of that of outer. If the system is supplied at 500/250 V, find the voltage at the load end between each outer and middle wire.

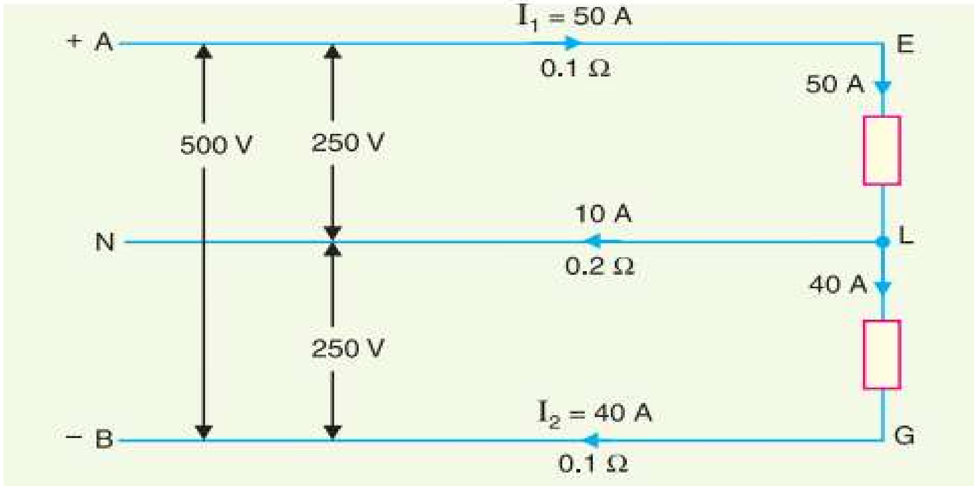
Solution:

Voltage at the load end on the +ve side,

$$V_{EL} = 250 - I_1 R_{AE} - (I_1 - I_2) R_{NL}$$
$$= 250 - 50 \times 0{\cdot}1 - (10) \times 0{\cdot}2 = \mathbf{243\ V}$$

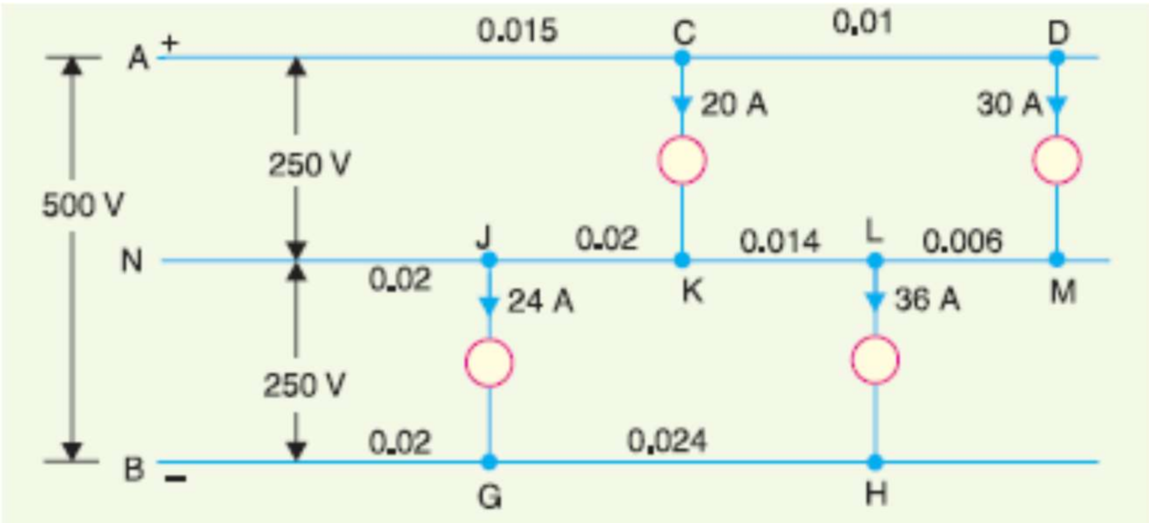
Voltage at the load end on the −ve side,

$$V_{LG} = 250 + (I_1 - I_2) R_{NL} - I_2 R_{BG}$$
$$= 250 + 10 \times 0{\cdot}2 - 40 \times 0{\cdot}1 = \mathbf{248\ V}$$



THREE WIRE D.C DISTRIBUTION SYSTEM

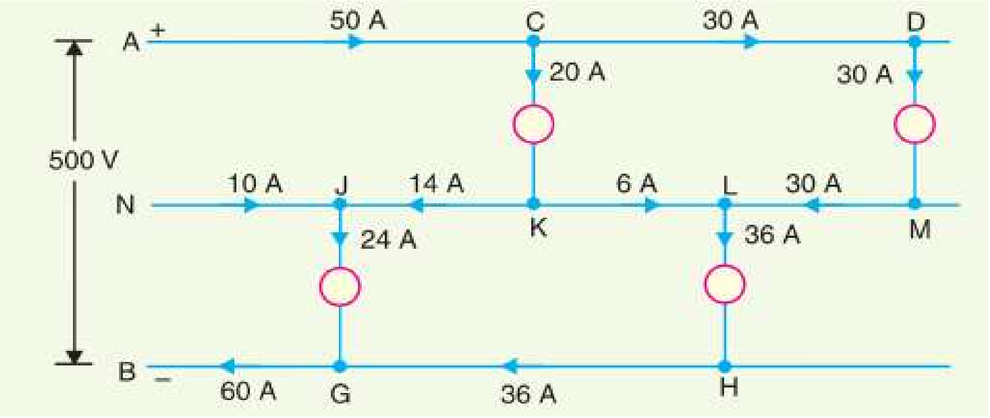
Example 13.29: A 3-wire, 500/250 V distributor is loaded as shown in below figure. The resistance of each section is given in ohm. Find the voltage across each load point.



THREE WIRE D.C DISTRIBUTION SYSTEM

Solution: The voltage drops in the various sections are

Section	*Resistance* (Ω)	*Current* (*A*)	*Drop* (*V*)
AC	0·015	50	0·75
CD	0·01	30	0·3
ML	0·006	30	0·18
KL	0·014	6	0·084
KJ	0·02	14	0·28
NJ	0·02	10	0·2
HG	0·024	36	0·864
GB	0·02	60	1·2



Voltage across load *CK* = 250 – Drop in *AC* – Drop in *KJ* + Drop in *NJ*
= 250 – 0·75 – 0·28 + 0·2 = **249·17 V**

Voltage across load *DM* = 249·17 – Drop in *CD* – Drop in *ML* + Drop in *KL*
= 249·17 – 0·3 – 0·18 + 0·084 = **248·774 V**

Voltage across load *JG* = 250 – Drop in *NJ* – Drop in *GB*
= 250 – 0·2 – 1·2 = **248·6 V**

Voltage across load *LH* = 248·6 + Drop in *KJ* – Drop in *KL* – Drop in *HG*
= 248·6 + 0·28 – 0·084 – 0·864 = **247·932 V**

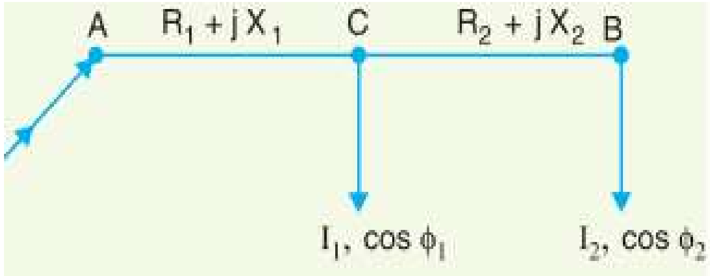
CALCULATION OF VOLTAGE DROPS IN A.C DISTRIBUTION

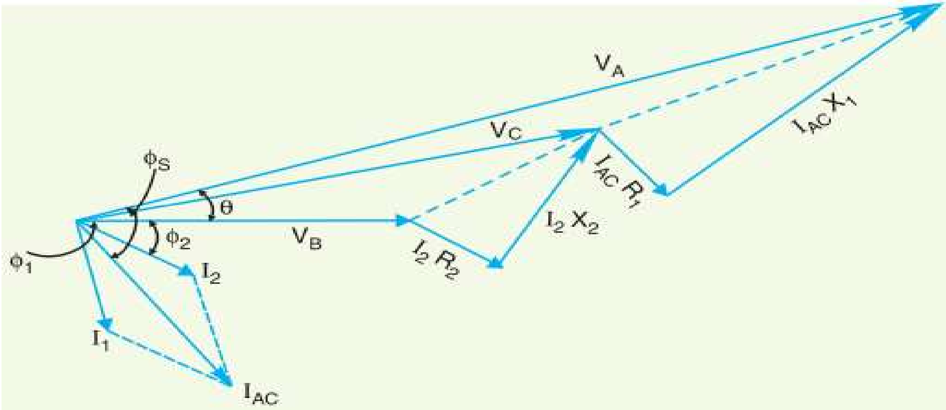
➢ **A.C. distribution calculations differ from those of D.C. distribution in the following respects :**

S.NO	D.C distribution	A.C distribution
1.	The voltage drop is due to resistance alone.	Voltage drops are due to the combined effects of resistance, inductance and capacitance.
2.	Additions and subtractions of currents or voltages are done arithmetically	Additions and subtractions of currents or voltages are done vectorially.
3.	Loads are tapped off form the distributor are generally at various points without power factor.	Loads are tapped off form the distributor are generally at different power factors. ❑ There are two ways of referring power factor: (i) It may be w.r.t. receiving or sending end Voltage. (ii) It may be w.r.t. to load voltage itself.

METHODS OF SOLVING A.C. DISTRIBUTION PROBLEMS

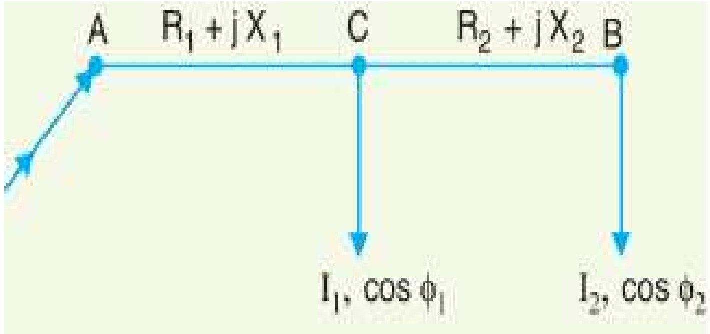
- **Power factors referred to receiving end voltage (V_B):**
- Let distributor AB with concentrated loads of I_1 and I_2 tapped off at points C and B.
- Let lagging power factors at C and B be $\cos\varphi_1$ and $\cos\varphi_2$ with respect to V_B.
- Let R_1, X_1 & R_2, X_2 be the resistance and reactance of sections AC & CB.
- Impedance of section AC, $\vec{Z}_{AC} = R_1 + j X_1$
- Impedance of section CB, $\vec{Z}_{CB} = R_2 + j X_2$
- Load current at point C, $\vec{I}_1 = I_1(\cos\varphi_1 - j \sin\varphi_1)$
- Load current at point B, $\vec{I}_2 = I_2(\cos\varphi_2 - j \sin\varphi_2)$
- Current in section CB, $\vec{I}_{CB} = \vec{I}_2 = I_2(\cos\varphi_2 - j \sin\varphi_2)$
- Current in section CB, $\vec{I}_{AC} = \vec{I}_1 + \vec{I}_2$
- Voltage drop in section CB, $\vec{V}_{CB} = \vec{I}_{CB}\ \vec{Z}_{CB}$
- Voltage drop in section AC, $\vec{V}_{AC} = \vec{I}_{AC}\ \vec{Z}_{AC}$
- Sending end voltage, $\vec{V}_A = \vec{V}_B + \vec{V}_{CB} + \vec{V}_{AC}$
- Sending end current, $\vec{I}_A = \vec{I}_1 + \vec{I}_2$



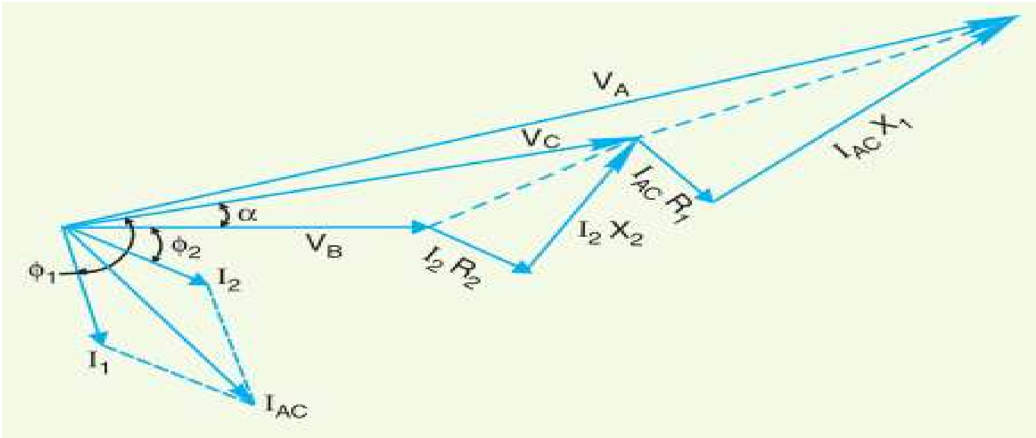


METHODS OF SOLVING A.C. DISTRIBUTION PROBLEMS Contd…

- **Power factors referred to respective load voltages (V_C & V_B):**



- Let distributor AB with concentrated loads of I_1 and I_2 tapped off at points C and B.
- Then φ_1 is the angle between V_C and I_1 and φ_2 is the angle between V_B and I_2.
- Let R_1, X_1 & R_2, X_2 be the resistance and reactance of sections AC & CB.
- Impedance of section AC, $\vec{Z}_{AC}$= R_1+ j X_1
- Impedance of section CB, $\vec{Z}_{CB}$= R_2+ j X_2
- Load current at point C, $\vec{I}_1$= I_1(cosφ_1-j sinφ_1)
- Load current at point B, $\vec{I}_2$= I_2(cosφ_2-j sinφ_2)
- Current in section CB, $\vec{I}_{CB}$= $\vec{I}_2$= I_2(cosφ_2-j sinφ_2)
- Current in section CB, $\vec{I}_{AC}$= $\vec{I}_1$ + $\vec{I}_2$
- Voltage drop in section CB, $\vec{V}_{CB}$= $\vec{I}_{CB}$ $\vec{Z}_{CB}$
- Voltage at point C, $\vec{V}_C$= $\vec{V}_B$+ $\vec{V}_{CB}$ = $V_C\angle\alpha$
- Now, $\vec{I}_1$= $I_1\angle-\phi_1$ w.r.t voltage V_C
- Therefore, $\vec{I}_1$= $I_1\angle-(\phi_1-\alpha)$ w.r.t V_B
- Voltage at point A, $\vec{V}_A$= $\vec{V}_B$+ $\vec{V}_{CB}$+$\vec{V}_{AC}$



Example 14.1: A single phase a.c. distributor AB 300 metres long is fed from end A and is loaded as under
(i) 100 A at 0·707 p.f. lagging 200 m from point A

(ii) 200 A at 0·8 p.f. lagging 300 m from point A

The load resistance and reactance of the distributor is 0·2 Ω and 0·1 Ω per kilometre. Calculate the total voltage drop in the distributor. The load power factors refer to the voltage at the far end.

THREE WIRE D.C DISTRIBUTION SYSTEM

Solution:

Solution. Fig. 14.4 shows the single line diagram of the distributor.

Impedance of distributor/km $= (0{\cdot}2 + j\,0{\cdot}1)\ \Omega$

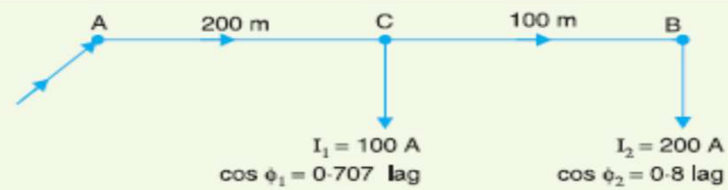


Fig. 14.4

Impedance of section AC, $\overrightarrow{Z_{AC}} = (0{\cdot}2 + j\,0{\cdot}1) \times 200/1000 = (0{\cdot}04 + j\,0{\cdot}02)\ \Omega$

Impedance of section CB, $\overrightarrow{Z_{CB}} = (0{\cdot}2 + j\,0{\cdot}1) \times 100/1000 = (0{\cdot}02 + j\,0{\cdot}01)\ \Omega$

Taking voltage at the far end B as the reference vector, we have,

Load current at point B, $\overrightarrow{I_2} = I_2(\cos\phi_2 - j\sin\phi_2) = 200\,(0{\cdot}8 - j\,0{\cdot}6)$
$= (160 - j\,120)$ A

Load current at point C, $\overrightarrow{I_1} = I_1(\cos\phi_1 - j\sin\phi_1) = 100\,(0{\cdot}707 - j\,0{\cdot}707)$
$= (70{\cdot}7 - j\,70{\cdot}7)$ A

Current in section CB, $\overrightarrow{I_{CB}} = \overrightarrow{I_2} = (160 - j\,120)$ A

Current in section AC, $\overrightarrow{I_{AC}} = \overrightarrow{I_1} + \overrightarrow{I_2} = (70{\cdot}7 - j\,70{\cdot}7) + (160 - j\,120)$
$= (230{\cdot}7 - j\,190{\cdot}7)$ A

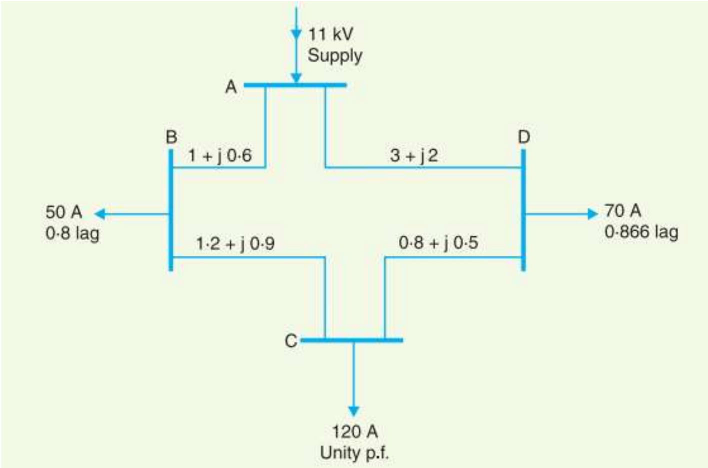
Voltage drop in section CB, $\overrightarrow{V_{CB}} = \overrightarrow{I_{CB}}\,\overrightarrow{Z_{CB}} = (160 - j\,120)\,(0{\cdot}02 + j\,0{\cdot}01)$
$= (4{\cdot}4 - j\,0{\cdot}8)$ volts

Voltage drop in section AC, $\overrightarrow{V_{AC}} = \overrightarrow{I_{AC}}\,\overrightarrow{Z_{AC}} = (230{\cdot}7 - j\,190{\cdot}7)\,(0{\cdot}04 + j\,0{\cdot}02)$
$= (13{\cdot}04 - j\,3{\cdot}01)$ volts

Voltage drop in the distributor $= \overrightarrow{V_{AC}} + \overrightarrow{V_{CB}} = (13{\cdot}04 - j\,3{\cdot}01) + (4{\cdot}4 - j\,0{\cdot}8)$
$= (17{\cdot}44 - j\,3{\cdot}81)$ volts

Magnitude of drop $= \sqrt{(17{\cdot}44)^2 + (3{\cdot}81)^2} = $ **17·85 V**

Example 14.6: A 3-phase ring main ABCD fed at A at 11 kV supplies balanced loads of 50 A at 0.8 p.f. lagging at B, 120 A at unity p.f. at C and 70 A at 0·866 lagging at D, the load currents being referred to the supply voltage at A. The impedances of the various sections are :Section AB = (1 + j 0·6) Ω ; Section BC = (1·2 + j 0·9) Ω; Section CD = (0·8 + j 0·5) Ω ; Section DA = (3 + j 2) Ω. Calculate the currents in various sections and station bus-bar voltages at B, C and D.



Example 14.6: A 3-phase ring main ABCD fed at A at 11 kV supplies balanced loads of 50 A at 0.8 p.f. lagging at B, 120 A at unity p.f. at C and 70 A at 0·866 lagging at D, the load currents being referred to the supply voltage at A. The impedances of the various sections are :Section AB = (1 + j 0·6) Ω ; Section BC = (1·2 + j 0·9) Ω; Section CD = (0·8 + j 0·5) Ω ; Section DA = (3 + j 2) Ω. Calculate the currents in various sections and station bus-bar voltages at B, C and D.

VARIOUS SYSTEMS OF TRANSMISSION

- Different possible systems of Transmission
  - D.C. system
    - D.C. two-wire
    - D.C. two-wire with mid-point earthed
    - D.C. three-wire
  - Single-phase A.C. system
    - Single-phase two-wire
    - Single-phase two-wire with mid-point earthed
    - Single-phase three-wire
  - Two-phase A.C. system
    - Two-phase three-wire
    - Two-phase four-wire
  - Three-phase A.C. system
    - Three-phase three-wire
    - Three-phase four-wire

VARIOUS SYSTEMS OF TRANSMISSION

- From the possible systems of power transmission, it is difficult to say which is the best system unless and until some method of comparison is adopted.
- The cost of conductor material is one of the most important charges in a system.
- The best system for transmission of power is that for which the volume of conductor material required is minimum.
- Therefore, the volume of conductor material required forms the basis of comparison between different systems.
- While comparing the amount of conductor material required in various systems, the proper comparison shall be on the basis of equal maximum stress on the dielectric.

❖ There are two cases :
  - Overhead system
  - Underground system

VARIOUS SYSTEMS OF TRANSMISSION

- When transmission is by overhead system:
  - In the overhead system, the maximum disruptive stress exists between the conductor and the earth.
  - Therefore, the comparison of the system in this case has to be made on the basis of maximum voltage between conductor and earth.
- When transmission is by underground system:
  - In the underground system, the chief stress on the insulation is between conductors.
  - Therefore, the comparison of the systems in this case should be made on the basis of maximum potential difference between conductors.
- Comparison of Conductor Material in Overhead System:
  - In comparing the relative amounts of conductor material necessary for different systems of transmission, similar conditions will be assumed in each case as:
    - Same power (P watts) transmitted by each system.
    - The distance (*l* metres) over which power is transmitted remains the same.
    - The line losses (W watts) are the same in each case.
    - The maximum voltage between any conductor and earth (V_m) is the same in each case for overhead system/ The maximum voltage between conductors (V_m) is the same in each case for underground system.

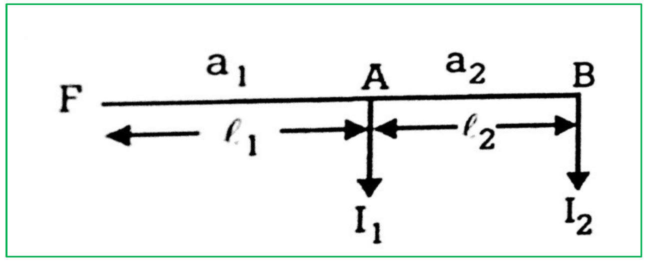
COMPARISON OF VARIOUS SYSTEMS OF TRANSMISSION

❖ The ratio of conductor material in any system compared with that in the corresponding 2-wire d.c. system.

System	Same maximum voltage to earth	Same maximum voltage between conductors
1. D.C. system		
(i) Two-wire	1	1
(ii) Two-wire mid-point earthed	0·25	1
(iii) 3-wire	0·3125	1·25
2. Single phase system		
(i) 2 wire	$2/\cos^2\phi$	$2/\cos^2\phi$
(ii) 2-wire with mid-point earthed	$\frac{0\cdot 5}{\cos^2\phi}$	$\frac{2}{\cos^2\phi}$
(iii) 3-wire	$\frac{0\cdot 625}{\cos^2\phi}$	$\frac{2\cdot 5}{\cos^2\phi}$
3. Two-phase system		
(i) 2-phase, 4-wire	$\frac{0\cdot 5}{\cos^2\phi}$	$\frac{2}{\cos^2\phi}$
(ii) 2-phase, 3-wire	$\frac{1\cdot 457}{\cos^2\phi}$	$\frac{2\cdot 914}{\cos^2\phi}$
4. Three-phase system		
(i) 3-phase, 3-wire	$\frac{0\cdot 5}{\cos^2\phi}$	$\frac{1\cdot 5}{\cos^2\phi}$
(ii) 3-phase, 4-wire	$\frac{0\cdot 583}{\cos^2\phi}$	$\frac{1\cdot 75}{\cos^2\phi}$

STEPPED AND TAPERED MAINS

This method is practically not feasible because more joints are involved which is technically undesirable.



- A distributor whose cross sectional area at different parts is selected such that the total volume of copper utilized for a given constant voltage drop is called stepped distributor.
- Consider a distributor feeding two loads I_1, I_2 tapped off at points A and B.
- Let a_1, l_1 and a_2, l_2 be the area of cross section and lengths of sections FA and AB respectively and ρ be the resistivity of distributor.
- Then the Resistance for section FA (both go and return) = $\frac{2\rho l_1}{a_1}$
- And the Resistance for section AB (both go and return) = $\frac{2\rho l_2}{a_2}$

STEPPED AND TAPERED MAINS

- Voltage drop in section FA = $\frac{2\rho l_1}{a_1}(I_1 + I_2)$= v(let), then $a_1 = \frac{2\rho l_1}{v}(I_1 + I_2)$
- Voltage drop in section AB = $\frac{2\rho l_2}{a_2} I_2$= v_t- v , then a_2 = $\frac{2\rho l_2}{v_t - v} I_2$
- Where, v_t is the total voltage drop in the distributor which is constant.
- Total voltage drop in the distributor (v_t)= $\frac{2\rho l_1}{a_1}(I_1 + I_2)$+ $\frac{2\rho l_2}{a_2} I_2$
- Total volume of the copper = $2a_1 l_1 + 2a_2 l_2$= $\frac{4\rho l_1^2}{v}(I_1 + I_2)$+ $\frac{4\rho l_2^2}{v_t - v} I_2$
- Minimum volume of copper, $\frac{d(volume)}{dv}$= 0 = - $\frac{4\rho l_1^2}{v^2}(I_1 + I_2)$ + $\frac{4\rho l_2^2}{(v_t - v)^2} I_2$
- Simplifying the above equation, we get, $\frac{a_1}{a_2} = \sqrt{\frac{I_1 + I_2}{I_2}}$ at the current density is not same in the section.
- Therefore, for minimum volume of copper, the area of cross section of the distributor be proportional to the square root of the current carried by that part of the distributor.
- For the same current density, we get, $\frac{a_1}{a_2} = \frac{I_1 + I_2}{I_2}$

COMPARISON OF D.C. AND A.C. DISTRIBUTION

D.C distribution	A.C distribution
Required less number of conductors. So less cost	Required more number of conductors. So more cost
No L & C effect. So no phase displacement then construction of line is easy	Construction of line is difficult
Less voltage drop. So better voltage regulation	More voltage drop. So poor voltage regulation.
No skin effect & No corona loss.	Skin effect & Corona loss exists.
Electric power cannot be generated at high d.c. voltage due to commutation problems.	The power can be generated at high voltages.
No charging capacitance. So no power loss due to charging capacitor	Power loss due to charging capacitor exists.
Maintenance is difficult and cost is high.	Easy and cheap maintenance is possible
No stability problems & No dielectric losses.	Stability & dielectric losses exists.
Less insulation stress. So line requires less insulation	More insulation stress. So line requires more insulation
No step up / step down of voltage is possible with transformers	Step up / step down of voltage is possible with transformers
DC switches and Circuit breakers are complex equipment and have less efficiency.	They are less complex in a.c distribution system.
Construction of d.c. distrubution line is less complicated	Construction of a.c. distrubution line is more complicated

MULTIPLE CHOICE QUESTIONS

1. Which type of distribution is preferred in residential areas?

a) Single phase, 2-wire b) 3-phase, 3-wire c) 3-phase, 4-wire d) 2-phase, 4-wire

2. Which distribution system is energised by two or more generating stations or substations?

a) Radial systems b) Interconnected systems c) Ring main systems d) All of these

3. Distributors fed at both ends has an advantage of

a) continuous supply b) fault isolation c) being economical d) all of these

4. The main consideration in the design of a feeder is the

a) current carrying capacity b) voltage drop c) power flow d) all of these

5. The underground system has ……… initial cost than the overhead system

a) less b) more c) equal d) none of the above

6. In a 3-wire system, the area of cross section of neutral wire is generally…… of either outer.

a) half b) double c) same d) none of these

MULTIPLE CHOICE QUESTIONS

7. The d.c. interconnector is used .... the voltage drops in the various sections of the distributor.

a) to reduce b) to increase c) both (a) or (b) d) none of these

8. Out of the following systems of distribution, which system offers the best economy?

a) Direct current system b) AC single phase system c) AC 3 phase 3 wire system d) AC 3 phase 4 wire

9. Name the cable which connects the distributor to the consumer terminals.

a) Distributors b) Service mains c) Feeders d) All of these

10. The point of minimum potential for a uniform distributor, fed at one end is at

a) the middle b) the far end c) a point between the far end and the middle

d) a point between the feeding end and the middle

11. In a.c. system, additions and subtractions of currents are done

a) vectorially b) arithmetically c) both (a) and (b) d) None

12. A line which connects a distributor to the substation is called.

a) Distributor b) Service main c) Feeder d) line

OLD QUESTIONS

2\. a) Explain about the Different types of Boilers in details with neat sketch. (8M)
   b) Explain about the classifications of pulverizing mills. (8M)

3\. a) Write short notes on Reflectors and Coolants in nuclear reactors. (8M)
   b) Explain the structure of an atom. What is the difference between atomic number and mass number and also mention their relevance in nuclear reaction. (8M)

4\. a) Find the power loss equation for DC distributor fed at one end-uniformly loading system. (8M)
   b) Explain about the comparisons between comparison of DC and AC distribution. (8M)

5\. a) Explain about main and transfer bus bar system with relevant diagrams. (8M)
   b) List the advantages and disadvantages of Gas-insulated substation. (8M)

6\. a) Explain about the Grading of cables in detail. (8M)
   b) Find the most economical diameter of a single core cable to be used on a 132 kV, 3-phase system. Find also the overall diameter of the insulation if the peak permissible stress is not to exceed 60 kV per cm. (8M)

7\. a) A consumer has a maximum demand of 200KW, maintain 1 load factor of 40%.The tariff rates are Rs 100 per KW of maximum demand plus 10 paisa per Kwh, Find (i) total energy consumed per annum (ii) The annual electricity bill. (8M)
   b) Define the following terms (i) Flat rate tariff, (ii) Maximum demand, (iii) Average load and (iv) Simple tariff. (8M)

Thank you