CMR INSTITUTE OF TECHNOLOGY	USN	

Internal Assessment Test II

Sub:	TRANSMISSION AND DISTRIBUTION						Code:	21EE51
Date:	30/01/2024	Duration:	90 Min	Max Marks:	50	Sem: 5	Section:	A & B

Note: Answer any FIVE FULL Questions

		Marks	OBE CO	OBE RBT
1	Derive an expression for sending end voltage and current for long transmission line using rigorous method. Expression for Vs= 5 marks Expression for Is=4marks Circuit diagram-1 mark	[10]	CO4	L2
2	Explain the classification of distribution systems and scheme of distributor system Classifications Current Scheme- brief explanation -3 each mark	[10]	CO5	L2
3	A single phase overhead transmission line delivers of length 40Km,1100KW at 33Kv at 0.8p.f lagging. The load resistance and inductive reactance of the line are 10Ω and 15Ω respectively. Determine i)sending end voltage ii) sending end power factor iii) transmission efficiency Vs=5mark Is=2mark Losses=2 marks Efficiency=1marks	[10]	CO5	L3
4(a)	A 2 wire D.C distributor AB is fed from both ends .At feeding point A the voltage is 230V. The total length of distributor is 2000m and loads connected are, 250A at 500m from A, 10A at 750m from A, 30A at 1000m from A, 60A at 2000m from A. the resistance of one conductor is 0.3Ω/km, calculate (i) currents in various sections (ii) voltage drops at various sections. Currents in various section=4 marks voltage drops at various section=4 marks Single line diagram-2 marks	[6]	CO5	L3
4(b)	Derive an expression for sending end voltage and sending end current of a single phase short transmission line by approximate method with the help of vector diagram. Vector diagram=1 Circuit =1 Expression for vs and Is=2 marks	[4]	CO4	L2
5	Derive an expression for the generalized A, B, C, D constants for equipment for T & pi representation and show that AD-BC=1. T method- 4 marksfor proving abcd constant as AD-BC=1 Pi method- 4 marksfor proving abcd constant as AD-BC=1	[10]	CO4	L2
6	A 110kV,50 hz,3 phase transmission line delivers load of 40MW at 0.85 lagging pf at the receiving end .the generalized constants of the transmission line are A=D=0.95 <1.4^0,B=96	[10]	CO4	L3

	< 78 ^{0} ,C=0.0015<90 ^{0} mho. Find the regulation of the line and charging current .Use nominal T method. Regulation= 8marks Ic= 2 marks			
7	Explain how a two-wire D.C. distributor with concentrated loads fed at one end can be represented by a single-line diagram. Single line diagram=3 marks Voltage drops=5 marks Current= 2marks	[10]	CO5	L3
8	Discuss the nominal T-model of medium transmission line with appropriate it circuit diagram and phasor diagram and hence obtain the expressions for regulation and ABCD constants for the same. Phasor diagram- 2 marks Circuit diagram-2marks Expression for voltage and current =3 Obtaining ABCD=3marks	[10]	CO4	L2

Solutions

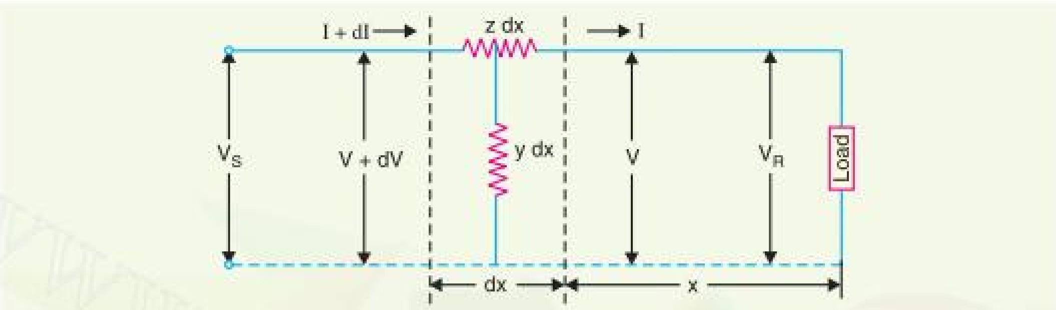


Fig. 10.22

Consider a small element in the line of length dx situated at a distance x from the receiving end.

Let z = series impedance of the line per unit length

y = shunt admittance of the line per unit length

V = voltage at the end of element towards receiving end

$V + dV$ = voltage at the end of element towards sending end

$I + dI$ = current entering the element dx

I = current leaving the element dx

Then for the small element dx,

$z\,dx$ = series impedance

$y\,dx$ = shunt admittance

Obviously, $dV = I\,z\,dx$

or $$\frac{dV}{dx} = I\,z \qquad \text{...(i)}$$

Now, the current entering the element is $I + dI$ whereas the current leaving the element is I. The difference in the currents flows through shunt admittance of the element *i.e.*,

1. dI = Current through shunt admittance of element $= V\,y\,dx$

Then for the small element dx,

$$z\,dx = \text{series impedance}$$

$$y\,dx = \text{shunt admittance}$$

Obviously, $dV = I\,z\,dx$

or $$\frac{dV}{dx} = I\,z \qquad ...(i)$$

Now, the current entering the element is $I + dI$ whereas the current leaving the element is I. The difference in the currents flows through shunt admittance of the element *i.e.*,

$$dI = \text{Current through shunt admittance of element} = V\,y\,dx$$

or $$\frac{dI}{dx} = V\,y \qquad ...(ii)$$

Differentiating eq. (*i*) w.r.t. x, we get,

$$\frac{d^2V}{dx^2} = z\,\frac{dI}{dx} = z\,(V\,y) \qquad \left[\because \frac{dI}{dx} = V\,y \textit{ from } \text{exp.}\,(ii)\right]$$

or $$\frac{d^2V}{dx^2} = y\,z\,V \qquad ...(iii)$$

The solution of this differential equation is

$$V = k_1 \cosh\left(x\sqrt{y\,z}\right) + k_2 \sinh\left(x\sqrt{y\,z}\right) \qquad ...(iv)$$

Differentiating exp. (*iv*) *w.r.t.* x, we have,

$$\frac{dV}{dx} = k_1\sqrt{y\,z}\,\sinh(x\sqrt{y\,z}) + k_2\sqrt{y\,z}\,\cosh(x\sqrt{y\,z})$$

But $$\frac{dV}{dx} = I\,z \qquad \text{[from exp. } (i)]$$

$\therefore$ $$I\,z = k_1\sqrt{y\,z}\,\sinh(x\sqrt{y\,z}) + k_2\sqrt{z\,y}\,\cosh(x\sqrt{y\,z})$$

or $$I = \sqrt{\frac{y}{z}}\left[k_1 \sinh\,(x\sqrt{y\,z}) + k_2 \cosh\left(x\sqrt{y\,z}\right)\right] \qquad ...(v)$$

Equations (*iv*) and (*v*) give the expressions for V and I in the form of unknown constants k_1 and k_2. The values of k_1 and k_2 can be found by applying end conditions as under :

At $x = 0$, $V = V_R$ and $I = I_R$

Putting these values in eq. (*iv*), we have,

$$V_R = k_1 \cosh 0 + k_2 \sinh 0 = k_1 + 0$$

$\therefore$ $$V_R = k_1$$

Similarly, putting $x = 0$, $V = V_R$ and $I = I_R$ in eq. (*v*), we have,

$$I_R = \sqrt{\frac{y}{z}}\left[k_1 \sinh 0 + k_2 \cosh 0\right] = \sqrt{\frac{y}{z}}\left[0 + k_2\right]$$

$\therefore$ $$k_2 = \sqrt{\frac{z}{y}}\,I_R$$

Substituting the values of k_1 and k_2 in eqs. (*iv*) and (*v*), we get,

$$V = V_R \cosh(x\sqrt{y\,z}) + \sqrt{\frac{z}{y}}\,I_R \sinh(x\sqrt{y\,z})$$

and $$I = \sqrt{\frac{y}{z}}\,V_R \sinh(x\sqrt{y\,z}) + I_R \cosh(x\sqrt{y\,z})$$

The sending end voltage (V_S) and sending end current (I_S) are obtained by putting $x = l$ in the above equations *i.e.*,

$$V_S = V_R \cosh(l\sqrt{y\,z}) + \sqrt{\frac{z}{y}}\,I_R \sinh(l\sqrt{y\,z})$$

$$I_S = \sqrt{\frac{y}{z}}\,V_R \sinh(l\sqrt{y\,z}) + I_R \cosh(l\sqrt{y\,z})$$

Now, $$l\sqrt{y\,z} = \sqrt{l\,y \cdot l\,z} = \sqrt{Y\,Z}$$

and $$\sqrt{\frac{y}{z}} = \sqrt{\frac{y\,l}{z\,l}} = \sqrt{\frac{Y}{Z}}$$

where Y = total shunt admittance of the line

Z = total series impedance of the line

Therefore, expressions for V_S and I_S become :

$$\mathbf{V_S = V_R \cosh\sqrt{YZ} + I_R\sqrt{\frac{Z}{Y}}\sinh\sqrt{YZ}}$$

$$\mathbf{I_S = V_R\sqrt{\frac{Y}{Z}}\sinh\sqrt{YZ} + I_R \cosh\sqrt{YZ}}$$

Distribution system Classification

classified on the basis of current

- A C Distribution System
- D C Distribution System

classified on the basis of Construction

- Overhead System
- Underground System

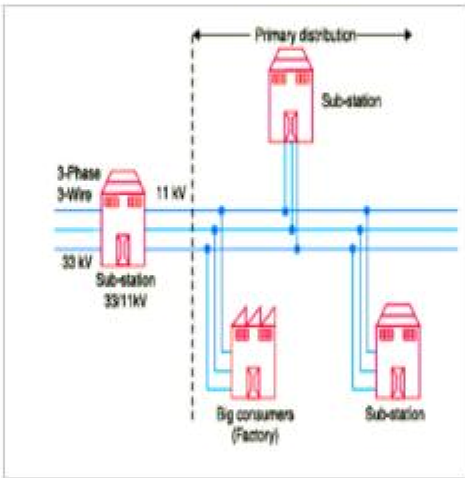
classified on the basis scheme of Connection

- Radial System
- Ring main system
- Interconnected System

2.

Primary Distribution System

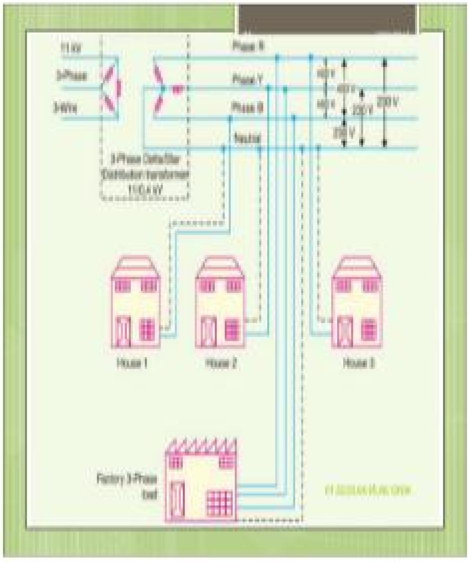
- Operates at voltage greater than the general utilization
- Handles large block if electrical energy.
- Voltage used depends upon the amt of power to be conveyed & distance required to fed.
- Primary Distribution is carried out by 3 phase 4 wire system.



3.

Secondary Distribution System

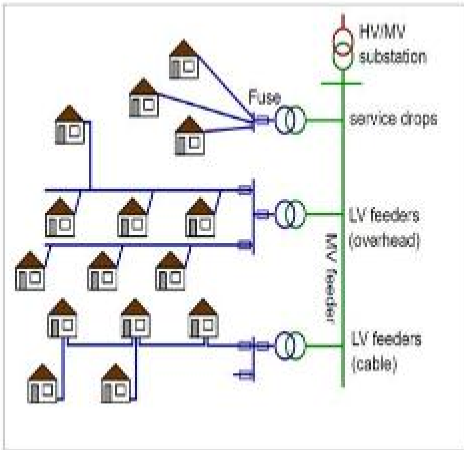
- Voltage b/n any two phases will be 400V.
- The single phase domestic loads are connected between any one phase and neutral.
- The three phase loads are connected across three phase lines.



4.

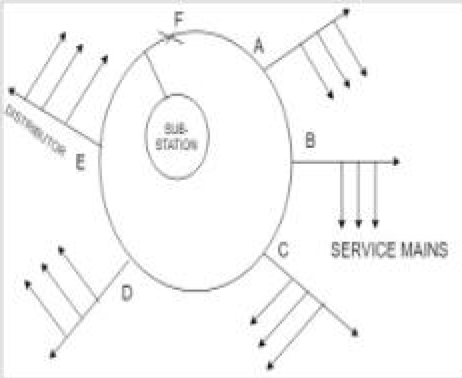
Radial Distribution System

- This system is used only when substation or generating station is located at the center of the consumers.
- In this system, different feeders radiate from a substation or a generating station and feed the distributors at one end.
- The main **characteristic of a radial distribution system** is that the power flow is in only one direction.
- It is the simplest system and has the lowest initial cost.



Ring Main Distribution system

- Feeder covers the whole area of supply in the ring fashion and finally terminates at the substation from where it is started.
- Closed loop form and looks like a ring.



Interconnected distribution system

- When a ring main feeder is energized by two or more substations or generating stations.

Advantages

- reliability
- 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.

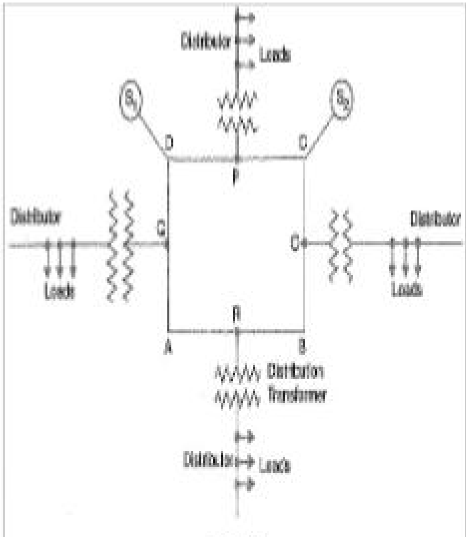


Fig. 12.30

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

Fig. 13.5 shows the single line diagram of a 2-wire d.c. distributor *A B* 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.

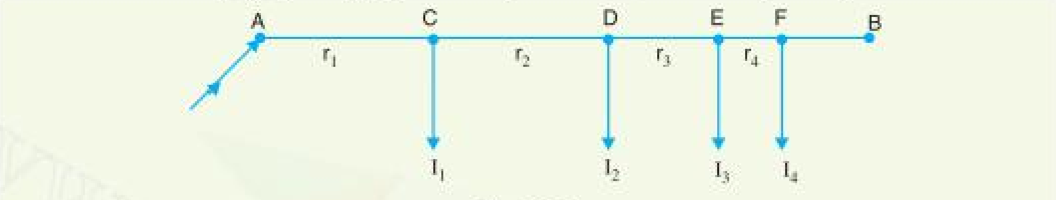


Fig. 13.5

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* $= r_4 I_4$

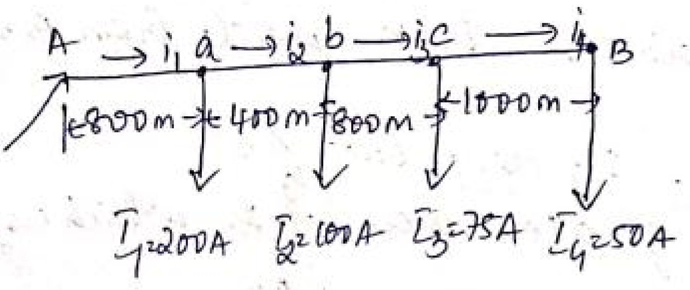
∴ Total voltage drop in the distributor

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

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

7.

4a



$$R_{Aa} = \frac{0.004 \times 80}{100} = 0.032\,\Omega$$

$$R_{ab} = \frac{0.004 \times 400}{100} = 0.016\,\Omega$$

$$R_{bc} = \frac{0.004 \times 800}{100} = 0.032\,\Omega$$

$$R_{cB} = \frac{0.004 \times 10}{100} = 0.04\,\Omega$$

$i_1 = I_1 + I_2 + I_3 + I_4 = 200 + 100 + 75 + 50 = 425A$

$i_2 = 425 - 200 = 225A$

$i_3 = 225 - 100 = 125A$

$i_4 = 125 - 75 = 50A$

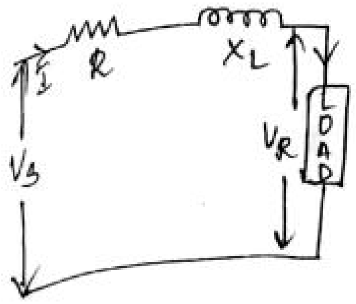
$V_a = V_A - i_1 R_{Aa} = 250 - 425 \times 0.032 = 236.4V$

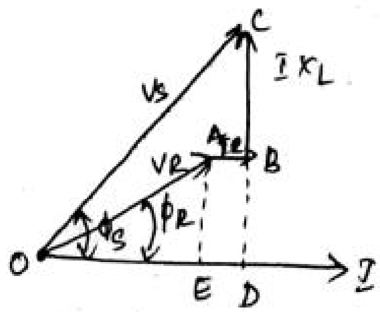
$V_b = V_a - i_2 R_{ab} = 236.4 - 225 \times 0.016 = 232.8V$

$V_c = V_b - i_3 R_{bc} = 232.8 - 125 \times 0.032 = 228.8V$

$V_B = V_c - i_4 R_{cB} = 228.8 - 50 \times 0.04 = 226.8V.$

4b





The phasor diagram for the lagging load p.f is as shown in figure.

consider the Δ^{le} ODC,

$$(OC)^2 = (OD)^2 + (DC)^2$$

$$V_S^2 = (OE + ED)^2 + (DB + BC)^2$$

$$= (V_R \cos\phi_R + IR)^2 + (V_R \sin\phi_R + IX_L)^2$$

$$\cos\phi_R = \frac{OE}{V_R}$$

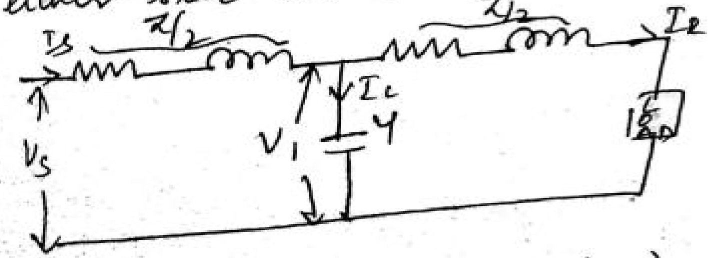
$$\sin\phi_R = \frac{AE}{V_R}.$$

Is= Ir

5

② Medium lines:-

In this Method, the whole line to Neutral capacitance is assumed to be concentrated at the middle point of the line & half the line resistance & reactance are lumped on either side as shown in figure.



$$\vec{V_s} = \vec{V_1} + \vec{I_s}\,\vec{Z}/2$$

$$\vec{V_1} = \vec{V_R} + \vec{I_R}\cdot\frac{\vec{Z}}{2}$$

$$\vec{I_s} = \vec{I_c} + \vec{I_R}$$

$$\vec{I_c} = \vec{I_s} - \vec{I_R}$$

$$I_c = \vec{V_1}\cdot\vec{Y}$$
$$= \vec{Y}\left(\vec{V_R} + \vec{I_R}\cdot\frac{\vec{Z}}{2}\right)$$

$$\vec{I_s} = \vec{Y}\left(\vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2}\right) + \vec{I_R}\cdot\frac{\vec{Z}}{2}$$
$$= \vec{Y}\cdot\vec{V_R} + \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)$$

5.

$$\vec{V_s} = \vec{V_R} + \frac{\vec{I_R}\vec{Z}}{2} + \frac{\vec{I_s}\vec{Z}}{2}$$

Substituting the value of I_s

$$= \vec{V_R} + \vec{I_R}\frac{\vec{Z}}{2} + \left[\vec{Y}\vec{V_R} + \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\right]$$

$$\vec{V_s} = \vec{V_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \left(\vec{Z} + \frac{\vec{Y}\vec{Z}^2}{4}\right)I_R.$$

$$\vec{I_s} = \vec{Y}\vec{V_R} + \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)$$

$$\vec{A} = \vec{D} = \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) \quad \vec{B} = \vec{Z}\left(1 + \frac{YZ}{4}\right) \quad C = \vec{Y}$$

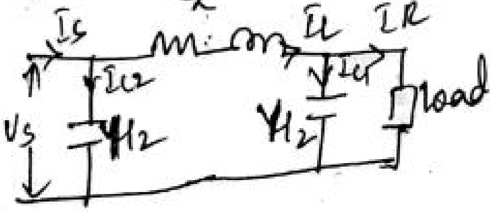
$$\vec{A}\vec{D} - \vec{B}\vec{C} = \left(1 + \frac{YZ}{2}\right)^2 - \vec{Z}\left(1 + \frac{\vec{Y}\vec{Z}}{4}\right)\vec{Y}$$

$$= 1 + \frac{Y^2Z^2}{4} + 2\cdot\frac{YZ}{2} - \vec{Z}\vec{Y} - \frac{\vec{Y}^2\vec{Z}^2}{4}$$

$$\vec{A}\vec{D} - \vec{B}\vec{C} = 1$$

iii) Medium lines – Nominal π method:-

In this method, line to neutral capacitance is divided into two halves, one half being concentrated at the load end & another half at the sending end.



$$\vec{Z} = \vec{R} + j\vec{X_L}$$

$$\vec{Y} = j\omega C$$

$$\vec{I_s} = \vec{I_{c2}} + \vec{I_L}$$

$$I_{c2} = V_s \cdot \frac{Y}{2} \qquad \vec{I_L} = \vec{I_{c1}} + \vec{I_R}$$

$$I_{c1} = V_R \cdot \frac{Y}{2} \qquad I_L = \vec{V_R} \cdot \frac{\vec{Y}}{2} + \vec{I_R}$$

$$\vec{V_s} = \vec{V_R} + \vec{I_L}\vec{Z}$$

$$= \vec{V_R} + \vec{V_R} \cdot \frac{\vec{Y}\vec{Z}}{2} + \vec{I_R}\vec{Z}$$

$$\boxed{\vec{V_s} = \vec{V_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{I_R}\vec{Z}}$$

$$\vec{I_s} = \vec{I_{c2}} + \vec{I_L}$$

$$\vec{I_s} = \vec{V_s} \cdot \frac{\vec{Y}}{2} + \vec{V_R}\frac{\vec{Y}}{2} + \vec{I_R}$$

$$= \left\{\vec{V_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{I_R}\vec{Z}\right\}\frac{\vec{Y}}{2} + \vec{V_R}\frac{\vec{Y}}{2} + \vec{I_R}$$

$$= \vec{I_R} \cdot \frac{\vec{Y}\vec{Z}}{2} + \vec{I_R} + \vec{V_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\frac{\vec{Y}}{2} + V_R \cdot \frac{\vec{Y}}{2}$$

$$= \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{V_R}\frac{\vec{Y}}{2} + V_R\frac{\vec{Y}}{2} + \frac{Y^2 Z}{4} V_R$$

$$= \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{V_R} Y + \frac{Y^2 Z}{4} V_R$$

$$\boxed{\vec{I_s} = \vec{I_R}\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) + \vec{V_R}\left(1 + \frac{YZ}{4}\right)\vec{Y}}$$

$$A = 1 + \frac{\vec{Y}\vec{Z}}{2} = D \qquad B = \vec{Z} \qquad \vec{C} = \left(1 + \frac{\vec{Y}\vec{Z}}{4}\right)\vec{Y}$$

$$\vec{A}\vec{D} - \vec{B}\vec{C} = \left(1 + \frac{\vec{Y}\vec{Z}}{2}\right)\left(1 + \frac{\vec{Y}\vec{Z}}{2}\right) - \vec{Z}\vec{Y}\left(1 + \frac{\vec{Y}\vec{Z}}{4}\right)$$

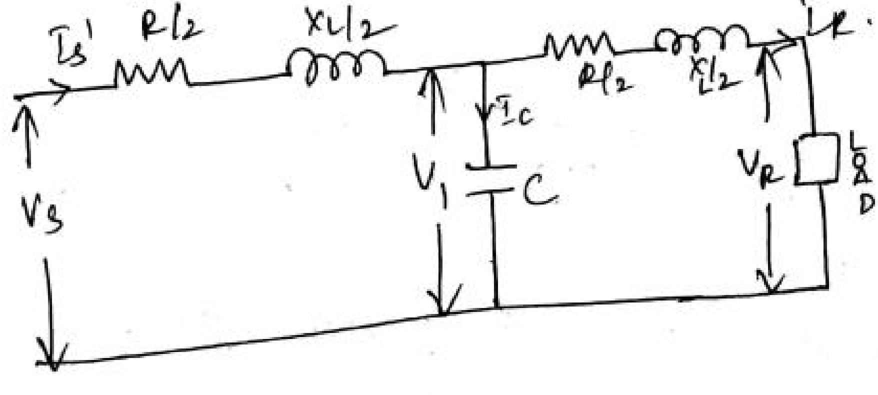
$$= 1 + \frac{\vec{Y}\vec{Z}}{2} + \frac{\vec{Y}\vec{Z}}{2} + \frac{\vec{Y}^2\vec{Z}^2}{4} - \vec{Z}\vec{Y} - \frac{\vec{Z}^2\vec{Y}^2}{4}$$

$$\vec{A}\vec{D} - \vec{B}\vec{C} = 1$$

8

1. Nominal T Method :-

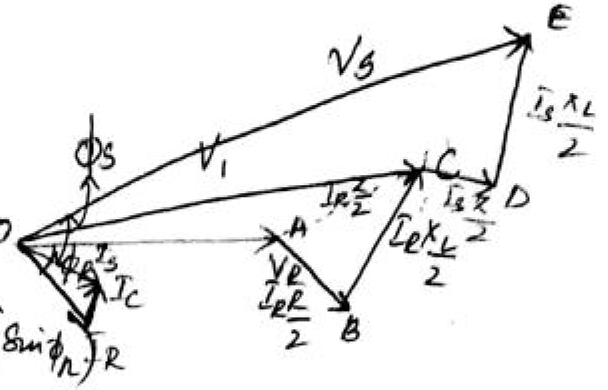
In this method, the whole line capacitance is assumed to be concentrated at the middle pt of the line & half the line resistance & reactance are lumped on its either side as shown. Therefore in this arrangement, full charging current flows over half the line.



phasor diagram:
Taking V_R as refrence phasor we've.

$\vec{V_R} = V_R + j0$

$\vec{I_R} = I_R(\cos\phi_R - j\sin\phi_R)$



v/g a/c C, $\vec{V_1} = \vec{V_R} + \vec{I_R}\, Z/2$

$= \vec{V_R} + I_R(\cos\phi_R - j\sin\phi_R)\left(\frac{R}{2} + j\frac{X_L}{2}\right)$

Capacitive current $\vec{I_C} = j\omega C\vec{V_1} = j\,2\pi f C\vec{V_1}$

sending end current $\vec{I_S} = \vec{I_R} + \vec{I_C}$

Sending end v/g $\vec{V_S} = \vec{V_1} + \vec{I_S}\frac{Z}{2} = \vec{V_1} + \vec{I_S}\left(\frac{R}{2} + j\frac{X_L}{2}\right)$

Receiving end voltage/phase, $V_R = 132 \times 10^3/\sqrt{3} = 76210$ V

Receiving end current, $I_R = \dfrac{50 \times 10^6}{\sqrt{3} \times 132 \times 10^3 \times 0.8} = 273$ A

$\cos\phi_R = 0.8; \quad \sin\phi_R = 0.6$

Taking receiving end voltage as the reference phasor, we have,

$$\vec{V_R} = V_R + j\,0 = 76210\,\angle 0°$$

$$\vec{I_R} = I_R\,\angle -\phi_R = 273\,\angle -36.9°$$

Sending end voltage per phase is

$$\vec{V_S} = \vec{A}\,\vec{V_R} + \vec{B}\,\vec{I_R}$$
$$= 0.95\,\angle 1.4° \times 76210\,\angle 0° + 96\,\angle 78° \times 273\,\angle -36.9°$$
$$= 72400\,\angle 1.4° + 26208\,\angle 41.1°$$
$$= 72400\,(\cos 1.4° + j\sin 1.4°) + 26208\,(\cos 41.1° + j\sin 41.1°)$$
$$= 72400\,(0.9997 + j\,0.0244) + 26208\,(0.7536 + j\,0.6574)$$
$$= (72378 + j\,1767) + (19750 + j\,17229)$$
$$= 92128 + j\,18996 = 94066\,\angle 11.65°\text{ V}$$

6.

Sending end current, $\vec{I_S} = \vec{C}\ \vec{V_R} + \vec{D}\ \vec{I_R}$

$= 0{\cdot}0015 \angle 90° \times 76210 \angle 0° + 0{\cdot}95 \angle 1{\cdot}4° \times 273 \angle -36{\cdot}9°$

$= 114 \angle 90° + 260 \angle -35{\cdot}5°$

$= 114 (\cos 90° + j \sin 90°) + 260 (\cos 35{\cdot}5° - j \sin 35{\cdot}5°)$

$= 114 (0 + j) + 260 (0{\cdot}814 - j\ 0{\cdot}58)$

$= j\ 114 + 211 - j\ 150 = 211 - j\ 36$

Charging current, $\vec{I_C} = \vec{I_S} - \vec{I_R} = (211 - j36) - 273 \angle -36{\cdot}9°$

$= (211 - j\ 36) - (218 - j\ 164) = -7 + j\ 128 =$ **$128{\cdot}2 \angle 93{\cdot}1°$ A**

$$\% \text{ Regulation} = \frac{(V_S/A) - V_R}{V_R} \times 100 = \frac{94066/0{\cdot}95 - 76210}{76210} \times 100 = \mathbf{30\%}$$

3

Receiving end voltage, $V_R = 33$ kV $= 33{,}000$ V

$$\therefore \quad \text{Line current, } I = \frac{kW \times 10^3}{V_R \cos\phi_R} = \frac{1100 \times 10^3}{33{,}000 \times 0{\cdot}8} = 41{\cdot}67 \text{ A}$$

As $\cos\phi_R = 0{\cdot}8 \quad \therefore \quad \sin\phi_R = 0{\cdot}6$

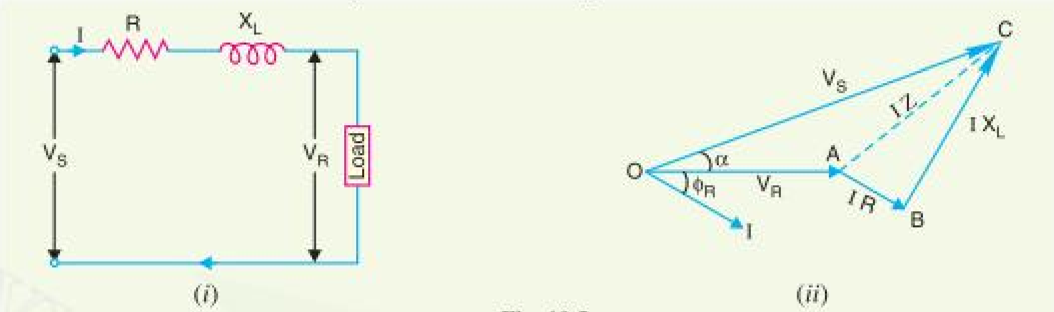


Fig. 10.5

The equivalent circuit and phasor diagram of the line are shown in Figs. 10.5 (*i*) and 10.5 (*ii*) respectively. Taking receiving end voltage $\vec{V_R}$ as the reference phasor,

$\vec{V_R} = V_R + j\,0 = 33000$ V

$\vec{I} = I (\cos\phi_R - j \sin\phi_R)$

$= 41{\cdot}67 (0{\cdot}8 - j\,0{\cdot}6) = 33{\cdot}33 - j\,25$

(*i*) Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I}\ \vec{Z}$

$= 33{,}000 + (33{\cdot}33 - j\,25{\cdot}0)(10 + j\,15)$

$= 33{,}000 + 333{\cdot}3 - j250 + j500 + 375$

$= 33{,}708{\cdot}3 + j\,250$

$\therefore$ Magnitude of $V_S = \sqrt{(33{,}708{\cdot}3)^2 + (250)^2} =$ **33,709 V**

$\therefore$ Magnitude of V_S = $\sqrt{(33{,}708\cdot 3)^2 + (250)^2}$ = [illegible]

(ii) Angle between $\overrightarrow{V_S}$ and $\overrightarrow{V_R}$ is

$$\alpha = \tan^{-1}\frac{250}{33{,}708\cdot 3} = \tan^{-1} 0\cdot 0074 = 0\cdot 42^\circ$$

$\therefore$ Sending end power factor angle is

$$\phi_S = \phi_R + \alpha = 36\cdot 87^\circ + 0\cdot 42^\circ = 37\cdot 29^\circ$$

$\therefore$ Sending end p.f., $\cos\phi_S = \cos 37\cdot 29^\circ =$ **0·7956 lagging**

(iii) Line losses $= I^2R = (41\cdot 67)^2 \times 10 = 17{,}364 \text{ W} = 17\cdot 364 \text{ kW}$

Output delivered = 1100 kW

Power sent = 1100 + 17·364 = 1117·364 kW

$\therefore$ Transmission efficiency $= \dfrac{\text{Power delivered}}{\text{Power sent}} \times 100 = \dfrac{1100}{1117\cdot 364} \times 100 =$ **98·44%**

Note. V_S and ϕ_S can also be calculated as follows :

$$V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R \text{ (approximately)}$$
$$= 33{,}000 + 41\cdot 67 \times 10 \times 0\cdot 8 + 41\cdot 67 \times 15 \times 0\cdot 6$$
$$= 33{,}000 + 333\cdot 36 + 375\cdot 03$$
$$= 33708\cdot 39 \text{ V which is approximately the same as above}$$

$$\cos\phi_S = \frac{V_R\cos\phi_R + IR}{V_S} = \frac{33{,}000 \times 0\cdot 8 + 41\cdot 67 \times 10}{33{,}708\cdot 39} = \frac{26{,}816\cdot 7}{33{,}708\cdot 39}$$
$$= 0\cdot 7958$$