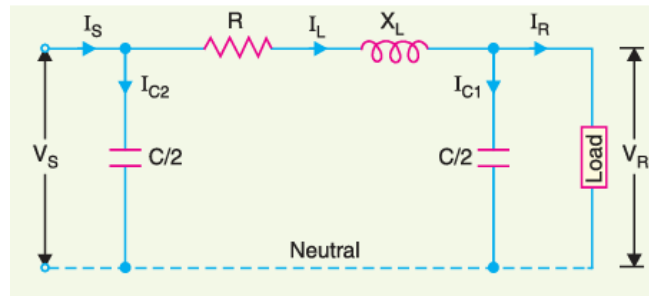




3. Nominal π Method

In this method, capacitance of each conductor (i.e., line to neutral) is divided into two halves; one half being lumped at the sending end and the other half at the receiving end as shown in Fig. 10.16. It is obvious that capacitance at the sending end has no effect on the line drop. However, its charging current must be added to line current in order to obtain the total sending end current.



- Let
- I_R = load current per phase
 - R = resistance per phase
 - X_L = inductive reactance per phase
 - C = capacitance per phase
 - $\cos \phi_R$ = receiving end power factor (*lagging*)
 - V_S = sending end voltage per phase

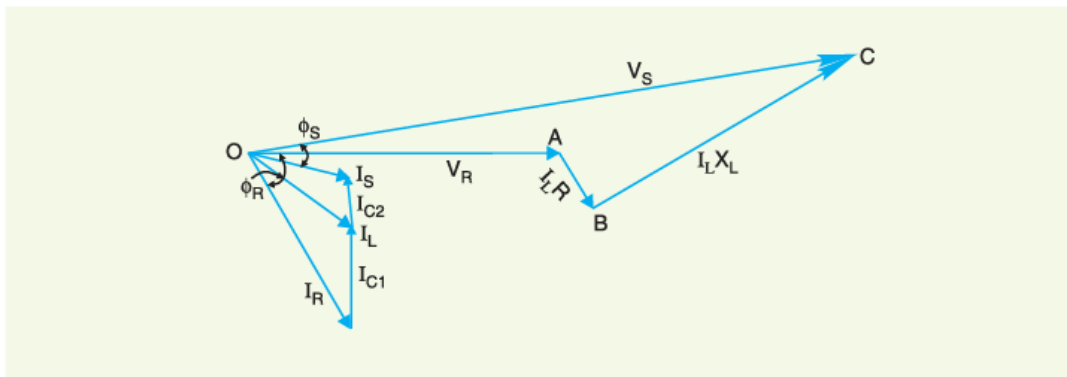
The *phasor diagram for the circuit is shown in Fig. 10.17. Taking the receiving end voltage as the reference phasor, we have,

$$\vec{V}_R = V_R + j0$$

Load current,
$$\vec{I}_R = I_R (\cos \phi_R - j \sin \phi_R)$$

Charging current at load end is

$$\vec{I}_{C1} = j \omega (C/2) \vec{V}_R = j \pi f C \vec{V}_R$$





Line current, $\vec{I}_L = \vec{I}_R + \vec{I}_{C1}$
 Sending end voltage, $\vec{V}_S = \vec{V}_R + \vec{I}_L \vec{Z} = \vec{V}_R + \vec{I}_L (R + jX_L)$
 Charging current at the sending end is

$$\vec{I}_{C2} = j\omega (C/2) \vec{V}_S = j\pi f C \vec{V}_S$$

∴ Sending end current, $\vec{I}_S = \vec{I}_L + \vec{I}_{C2}$

Example 10.13 A 3-phase, 50Hz, 150 km line has a resistance, inductive reactance and capacitive shunt admittance of 0.1 Ω, 0.5 Ω and 3×10^{-6} S per km per phase. If the line delivers 50 MW at 110 kV and 0.8 p.f. lagging, determine the sending end voltage and current. Assume a nominal π circuit for the line.

Solution. Fig. 10.18 shows the circuit diagram for the line.

Total resistance/phase, $R = 0.1 \times 150 = 15 \Omega$
 Total reactance/phase, $X_L = 0.5 \times 150 = 75 \Omega$
 Capacitive admittance/phase, $Y = 3 \times 10^{-6} \times 150 = 45 \times 10^{-5}$ S
 Receiving end voltage/phase, $V_R = 110 \times 10^3 / \sqrt{3} = 63,508$ V
 Load current, $I_R = \frac{50 \times 10^6}{\sqrt{3} \times 110 \times 10^3 \times 0.8} = 328$ A
 $\cos \phi_R = 0.8$; $\sin \phi_R = 0.6$

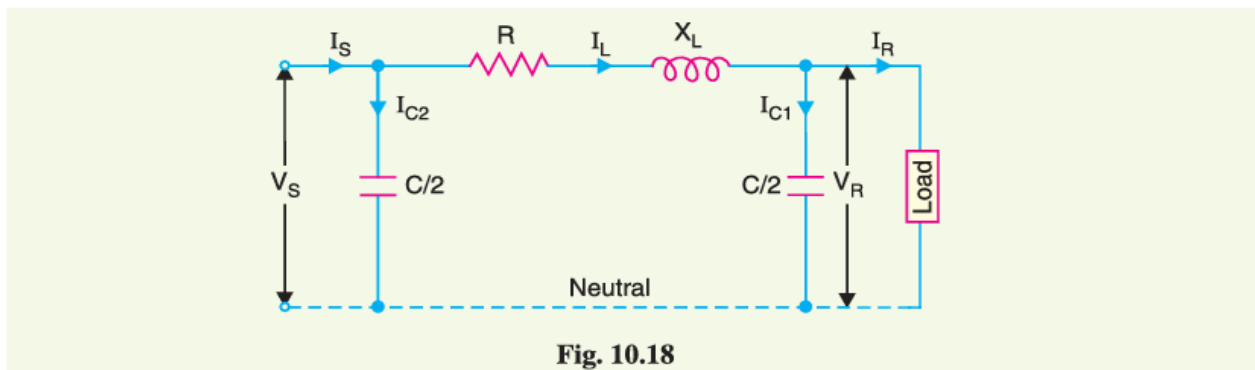


Fig. 10.18

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

$$\vec{V}_R = V_R + j0 = 63,508 \text{ V}$$

Load current, $\vec{I}_R = I_R (\cos \phi_R - j \sin \phi_R) = 328 (0.8 - j0.6) = 262.4 - j196.8$

Charging current at the load end is

$$\vec{I}_{C1} = \vec{V}_R j \frac{Y}{2} = 63,508 \times j \frac{45 \times 10^{-5}}{2} = j 14.3$$

Line current, $\vec{I}_L = \vec{I}_R + \vec{I}_{C1} = (262.4 - j 196.8) + j 14.3 = 262.4 - j 182.5$



Sending end voltage,

$$\begin{aligned}\vec{V}_S &= \vec{V}_R + \vec{I}_L \vec{Z} = \vec{V}_R + \vec{I}_L (R + j X_L) \\ &= 63,508 + (262.4 - j 182.5) (15 + j 75) \\ &= 63,508 + 3936 + j 19,680 - j 2737.5 + 13,687 \\ &= 81,131 + j 16,942.5 = 82,881 \angle 11^\circ 47' V\end{aligned}$$

\therefore Line to line sending end voltage = $82,881 \times \sqrt{3} = 1,43,550 \text{ V} = \mathbf{143.55 \text{ kV}}$

Charging current at the sending end is

$$\begin{aligned}I_{C2} &= j \vec{V}_S Y / 2 = (81,131 + j 16,942.5) j \frac{45 \times 10^{-5}}{2} \\ &= -3.81 + j 18.25\end{aligned}$$

Sending end current,

$$\begin{aligned}\vec{I}_S &= \vec{I}_L + \vec{I}_{C2} = (262.4 - j 182.5) + (-3.81 + j 18.25) \\ &= 258.6 - j 164.25 = 306.4 \angle -32.4^\circ \text{ A}\end{aligned}$$

\therefore Sending end current = **306.4 A**

Example 10.14. A 100-km long, 3-phase, 50-Hz transmission line has following line constants:

Resistance/phase/km = 0.1Ω

Reactance/phase/km = 0.5Ω

Susceptance/phase/km = $10 \times 10^{-6} \text{ S}$

If the line supplies load of 20 MW at 0.9 p.f. lagging at 66 kV at the receiving end, calculate by nominal π method :

- (i) sending end power factor (ii) regulation
(iii) transmission efficiency

Solution. Fig. 10.19 shows the circuit diagram for the line.

Total resistance/phase, $R = 0.1 \times 100 = 10 \Omega$

Total reactance/phase, $X_L = 0.5 \times 100 = 50 \Omega$

Susceptance/phase, $Y = 10 \times 10^{-6} \times 100 = 10 \times 10^{-4} \text{ S}$

Receiving end voltage/phase, $V_R = 66 \times 10^3 / \sqrt{3} = 38105 \text{ V}$

Load current, $I_R = \frac{20 \times 10^6}{\sqrt{3} \times 66 \times 10^3 \times 0.9} = 195 \text{ A}$

$\cos \phi_R = 0.9$; $\sin \phi_R = 0.435$



Al-Mustaqbal University / College of Technical Engineering
Department of Electrical Engineering Technique
Third Class
Subject: Advanced Power Engineer
Lecturer: Dr Hasan Muwafaq Gheni
2nd term – Lecture3 : Medium Transmission Line

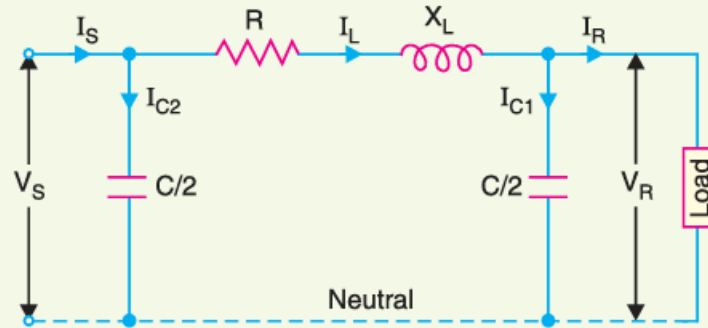


Fig. 10.19

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

$$\vec{V}_R = V_R + j0 = 38105 \text{ V}$$

Load current,
$$\vec{I}_R = I_R (\cos \phi_R - j \sin \phi_R) = 195 (0.9 - j0.435) = 176 - j85$$

Charging current at the receiving end is

$$\vec{I}_{C1} = \vec{V}_R j \frac{Y}{2} = 38105 \times j \frac{10 \times 10^{-4}}{2} = j19$$

Line current,
$$\vec{I}_L = \vec{I}_R + \vec{I}_{C1} = (176 - j85) + j19 = 176 - j66$$

Sending end voltage ,
$$\begin{aligned} \vec{V}_S &= \vec{V}_R + \vec{I}_L \vec{Z} = \vec{V}_R + \vec{I}_L (R + jX_L) \\ &= 38,105 + (176 - j66) (10 + j50) \\ &= 38,105 + (5060 + j8140) \\ &= 43,165 + j8140 = 43,925 \angle 10.65^\circ \text{ V} \end{aligned}$$

Sending end line to line voltage = $43,925 \times \sqrt{3} = 76 \times 10^3 \text{ V} = 76 \text{ kV}$

Charging current at the sending end is

$$\begin{aligned} \vec{I}_{C2} &= \vec{V}_S jY/2 = (43,165 + j8140) j \frac{10 \times 10^{-4}}{2} \\ &= -4.0 + j21.6 \end{aligned}$$

\therefore Sending end current,
$$\begin{aligned} \vec{I}_S &= \vec{I}_L + \vec{I}_{C2} = (176 - j66) + (-4.0 + j21.6) \\ &= 172 - j44.4 = 177.6 \angle -14.5^\circ \text{ A} \end{aligned}$$

(i) Referring to phasor diagram in Fig. 10-20,

$$\theta_1 = \text{angle between } \vec{V}_R \text{ and } \vec{V}_S = 10.65^\circ$$

$$\theta_2 = \text{angle between } \vec{V}_R \text{ and } \vec{I}_S = -14.5^\circ$$



Al-Mustaqbal University / College of Technical Engineering
Department of Electrical Engineering Technique
Third Class
Subject: Advanced Power Engineer
Lecturer: Dr Hasan Muwafaq Gheni
2nd term – Lecture3 : Medium Transmission Line

$$\begin{aligned}\therefore \phi_S &= \text{angle between } \vec{V}_S \text{ and } \vec{I}_S = \theta_2 + \theta_1 \\ &= 14.5^\circ + 10.65^\circ = 25.15^\circ\end{aligned}$$

$$\therefore \text{Sending end p.f., } \cos \phi_S = \cos 25.15^\circ = \mathbf{0.905 \text{ lag}}$$

$$(ii) \text{ \% Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100 = \frac{43925 - 38105}{38105} \times 100 = \mathbf{15.27 \%}$$

$$(iii) \text{ Sending end power} = 3 V_S I_S \cos \phi_S = 3 \times 43925 \times 177.6 \times 0.905 \\ = 21.18 \times 10^6 \text{ W} = 21.18 \text{ MW}$$

$$\text{Transmission efficiency} = (20/21.18) \times 100 = \mathbf{94 \%}$$

