COLLEGE OF ENGINEERING AND TECHNOLOGIES
ALMUSTAQBAL UNIVERSITY

Power Engineering

EET 305

Lecture 11

- Three-Phase Short Transmission Lines -

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Three-Phase Short Transmission Lines

- For reasons associated with economy, transmission of electric power is done by 3-phase system.
- This system may be regarded as consisting of three single phase units, each wire transmitting one-third of the total power.
- As a matter of convenience, we generally analyse 3-phase system by considering one phase only.

- Therefore, expression for regulation, efficiency etc. derived for a single phase line can also be applied to a 3-phase system.
- Since only one phase is considered, phase values of 3-phase system should be taken.
- Thus, VS and VR are the phase voltages, whereas R and XL are the resistance and inductive reactance per phase respectively.

Three-Phase Short Transmission Lines

Figure below

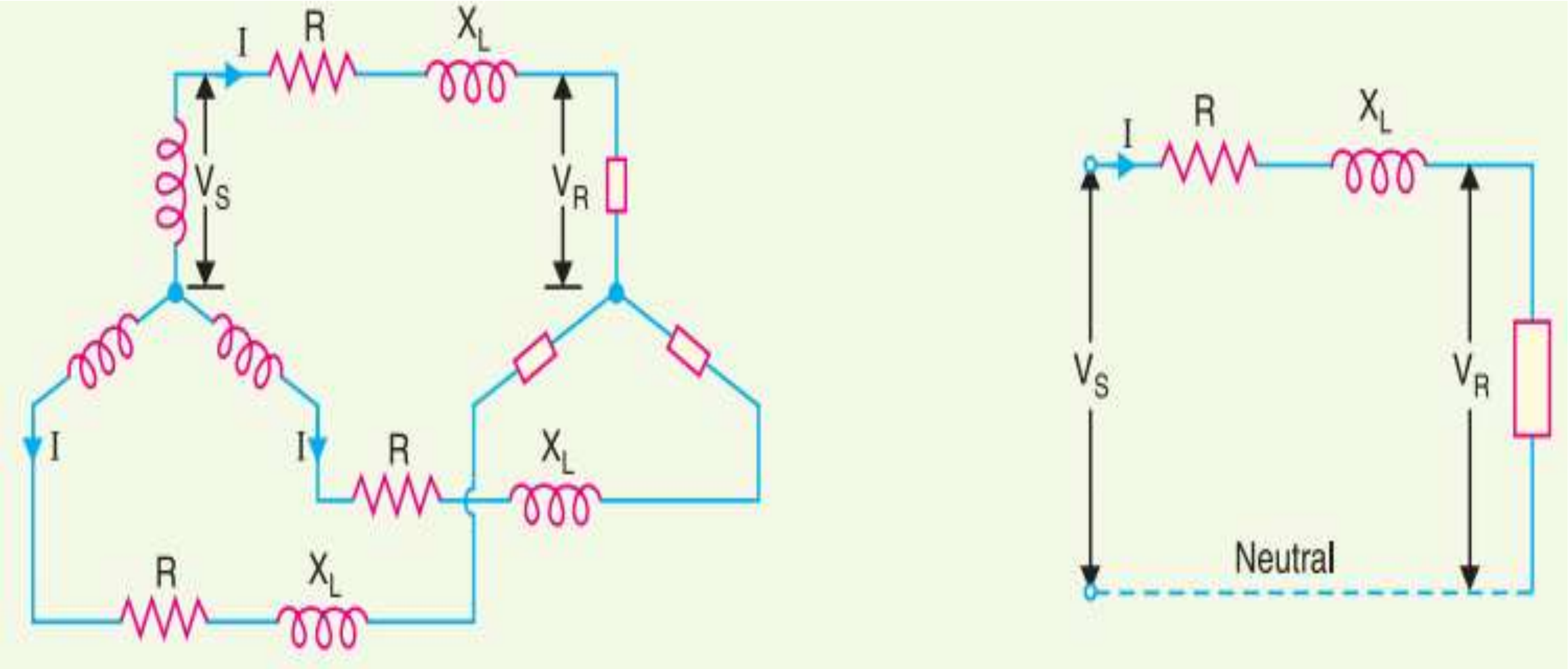
(i) shows a Y-connected generator supplying a balanced Y-connected load through a transmission line.

Each conductor has a resistance of R Ω and inductive reactance of X L Ω.

(ii) shows one phase separately.

The calculations can now be made in the same way as for a single phase line

Three-Phase Short Transmission Lines



Effect on transmission efficiency

$$P = V_R * I \cos \phi_R \quad \text{(For 1-phase line)}$$

$$I = \frac{P}{V_R \cos \phi_R}$$

$$P = 3\, V_R I \cos \phi_R \quad \text{(For 3-phase line)}$$

$$I = \frac{P}{3V_R \cos \phi_R}$$

Example

An overhead 3-phase transmission line delivers 5000 kW at 22 kV at 0·8 p.f. lagging. The resistance and reactance of each conductor is 4 Ω and 6 Ω respectively. Determine :

(i) sending end voltage

(ii) percentage regulation

(iii) transmission efficiency.

Solution

Load power factor, $\cos\phi_R = 0{\cdot}8$ lagging

Receiving end voltage/phase, * $V_R = 22{,}000/\sqrt{3} = 12{,}700$ V

Impedance/phase, $\vec{Z} = 4 + j\,6$

Line current, $I = \dfrac{5000 \times 10^3}{3 \times 12700 \times 0{\cdot}8} = 164$

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

Solution

$$\vec{V_R} = V_R + j\,0 = 12700 \text{ V}$$

$$\vec{I} = I(\cos\phi_R - j\sin\phi_R) = 164\,(0\cdot8 - j\,0\cdot6) = 131\cdot2 - j\,98\cdot4$$

(*i*) Sending end voltage per phase is

$$\vec{V_S} = \vec{V_R} + \vec{I}\,\vec{Z} = 12700 + (131\cdot2 - j\,98\cdot4)\,(4 + j\,6)$$

$$= 12700 + 524\cdot8 + j\,787\cdot2 - j\,393\cdot6 + 590\cdot4$$

$$= 13815\cdot2 + j\,393\cdot6$$

$$\text{Magnitude of } V_S = \sqrt{(13815\cdot2)^2 + (393\cdot6)^2} = 13820\cdot8 \text{ V}$$

Solution

$$\text{Line value of } V_S = \sqrt{3} \times 13820{\cdot}8 = 23938 \text{ V} = \mathbf{23{\cdot}938 \text{ kV}}$$

(ii) $$\% \text{ age Regulation} = \frac{V_S - V_R}{V_R} \times 100 = \frac{13820{\cdot}8 - 12700}{12700} \times 100 = \mathbf{8{\cdot}825\%}$$

(iii) $$\text{Line losses} = 3I^2R = 3 \times (164)^2 \times 4 = 3{,}22{,}752 \text{ W} = 322{\cdot}752 \text{ kW}$$

$$\therefore \quad \text{Transmission efficiency} = \frac{5000}{5000 + 322{\cdot}752} \times 100 = \mathbf{93{\cdot}94\%}$$

Example

A short 3-φ transmission line with an impedance of (6 + j 8) Ω per phase has sending and receiving end voltages of 120 kV and 110 kV respectively for some receiving end load at a p.f. of 0·9 lagging. Determine the power output

Solution

Resistance of each conductor, $R = 6\ \Omega$

Reactance of each conductor, $X_L = 8\ \Omega$

Load power factor, $\cos\phi_R = 0{\cdot}9$ lagging

Receiving end voltage/phase, $V_R = 110 \times 10^3/\sqrt{3} = 63508\ \text{V}$

Sending end voltage/phase, $V_S = 120 \times 10^3/\sqrt{3} = 69282\ \text{V}$

Solution

Let I be the load current. Using approximate expression for V_S, we get,

$$V_S = V_R + IR\cos\phi_R + IX_L\sin\phi_R$$

$$69282 = 63508 + I \times 6 \times 0{\cdot}9 + I \times 8 \times 0{\cdot}435$$

$$8{\cdot}88\,I = 5774$$

$$I = 5774/8{\cdot}88 = 650{\cdot}2\ \text{A}$$

$$\text{Power output} = \frac{3\,V_R\,I\cos\phi_R}{1000}\ \text{kW} = \frac{3 \times 63508 \times 650{\cdot}2 \times 0{\cdot}9}{1000}$$

$$= \mathbf{1{,}11{,}490\ kW}$$