Power Engineering

EET 305

Lecture 10

- Overhead Transmission Lines I -

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Dr. Zaidoon AL-Shammari
Lecturer / Researcher
zaidoon.waleed@mustaqbal-college.edu.iq

Classification of Overhead Transmission Lines

- A transmission line has three constants R, L and C distributed uniformly along the whole length of the line.
- The resistance and inductance form the series impedance.
- The capacitance existing between conductors for 1-phase line or from a conductor to neutral for a 3-phase line forms a shunt path throughout the length of the line.
- Therefore, capacitance effects introduce complications in transmission line calculations.

Classification of Overhead Transmission Lines

Depending upon the manner in which capacitance is taken into account, the overhead transmission lines are classified as :

(i) Short transmission lines.

- When the length of an overhead transmission line is upto about 50 km and the line voltage is comparatively low (< 20 kV), it is usually considered as a short transmission line.

- Due to smaller length and lower voltage, the capacitance effects are small and hence can be neglected.
- Therefore, while studying the performance of a short transmission line, only resistance and inductance of the line are taken into account.

(ii) Medium transmission lines.

- When the length of an overhead transmission line is about 50-150 km and the line voltage is moderatly high (>20 kV < 100 kV), it is considered as a medium transmission line.

- Due to sufficient length and voltage of the line, the capacitance effects are taken into account.

- For purposes of calculations, the distributed capacitance of the line is divided and lumped in the form of condensers shunted across the line at one or more points.

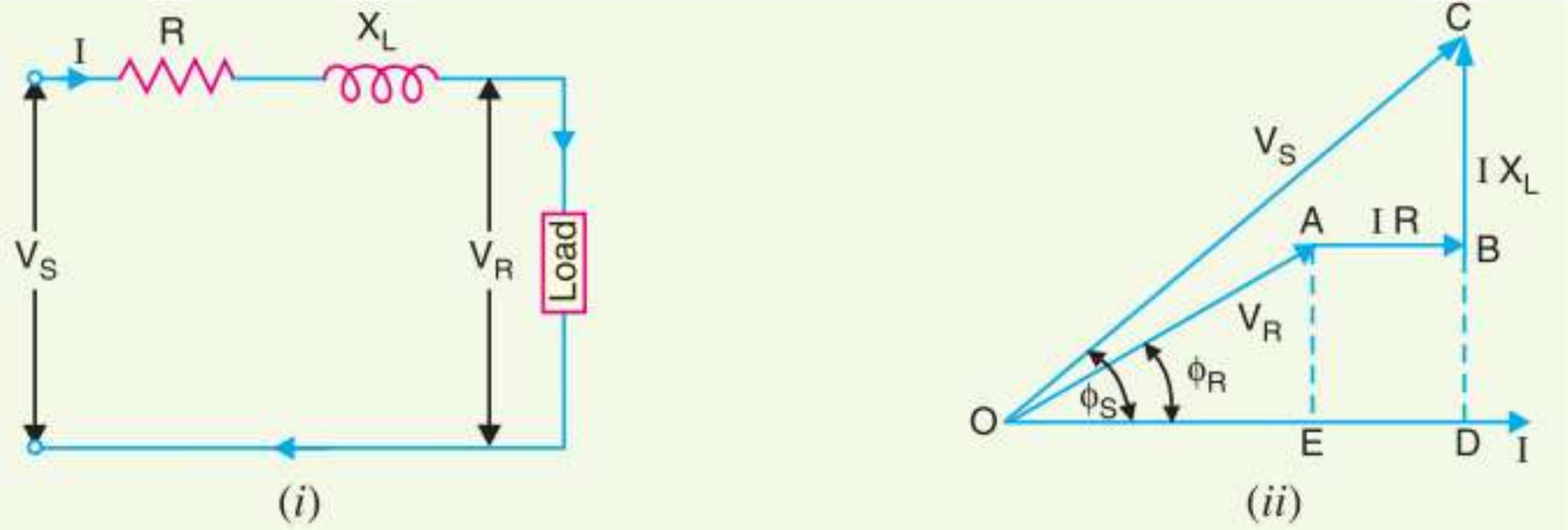
(iii) Long transmission lines.

- When the length of an overhead transmission line is more than 150km and line voltage is very high (> 100 kV), it is considered as a long transmission line.
- For the treatment of such a line, the line constants are considered uniformly distributed over the whole length of the line and rigorous methods are employed for solution.

Single Phase Short Transmission Lines

- As stated earlier, the effects of line capacitance are neglected for a short transmission line.
- Therefore, while studying the performance of such a line, only resistance and inductance of the line are taken into account.
- The total line resistance and inductance are shown as concentrated or lumped instead of being distributed.

- The equivalent circuit of a single phase short transmission line is shown in Figure below.



Single Phase Short Transmission Lines

I = load current

R = loop resistance *i.e.*, resistance of both conductors

X_L = loop reactance

V_R = receiving end voltage

$\cos \phi_R$ = receiving end power factor (lagging)

V_S = sending end voltage

$\cos \phi_S$ = sending end power factor

Single Phase Short Transmission Lines

$$\text{Voltage regulation} = \frac{V_S - V_R}{V_R} \times 100$$

$$\text{Power delivered} = V_R I_R \cos \phi_R$$

$$\text{Line losses} = I^2 R$$

$$\text{Power sent out} = V_R I_R \cos \phi_R + I^2 R$$

$$\text{Transmission efficiency} = \frac{\text{Power delivered}}{\text{Power sent out}} \times 100$$

$$= \frac{V_R\, I_R \cos \phi_R}{V_R\, I_R \cos \phi_R + I^2 R} \times 100$$

$$V_S = V_R + I R \cos \phi_R + I X_L \sin \phi_R$$

Single Phase Short Transmission Lines

- Complex notation

$$* \ \overrightarrow{V_R} = V_R + j\,0$$

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

$$\vec{Z} = R + jX_L$$

$$\overrightarrow{V_S} = \overrightarrow{V_R} + \vec{I}\,\vec{Z}$$

$$= (V_R + j\,0) + I(\cos\phi_R - j\sin\phi_R)(R + j\,X_L)$$

- Approximate expression

$$V_S = V_R + I\,R\cos\phi_R + I\,X_L\sin\phi_R$$

Single Phase Short Transmission Lines

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

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

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

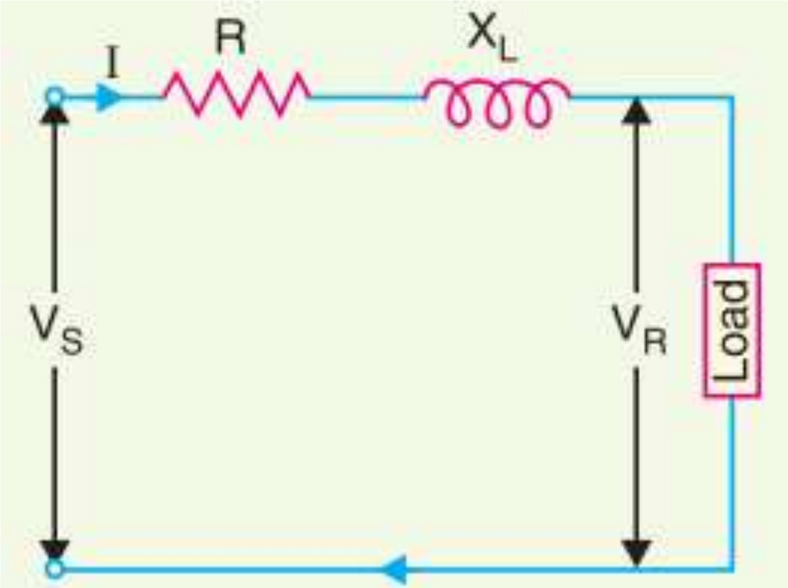
$$\therefore \quad I = \frac{P}{3 V_R \cos \phi_R}$$

Example

A single phase overhead transmission line delivers 1100 kW at 33 kV at 0·8 P.F. lagging. The total resistance and inductive reactance of the line are 10 Ω and 15 Ω respectively.

Determine : (i) sending end voltage (ii) transmission efficiency.

Sol:



Sol

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

Total line impedance, $\vec{Z} = R + j X_L = 10 + j\,15$

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

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

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

Sol

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

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

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

Sending end voltage, $\vec{V_S} = \vec{V_R} + \vec{I}\,\vec{Z}$

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

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

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

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

Sol

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

$$\text{Output delivered} = 1100 \text{ kW}$$

$$\text{Power sent} = 1100 + 17{\cdot}364 = 1117{\cdot}364 \text{ kW}$$

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

Or

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