First Course on Power Systems

Module 9: Voltage Regulation and Voltage Stability

By
Ned Mohan
Professor of ECE
University of Minnesota

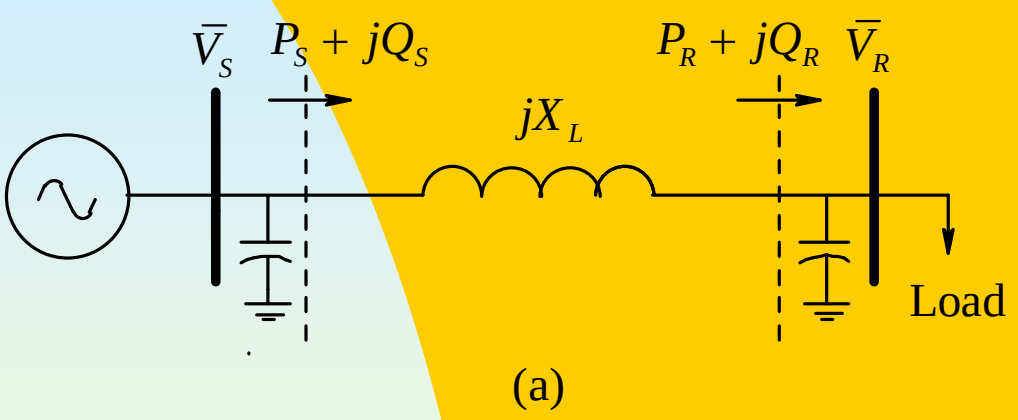
Reference Textbook:
First Course on Power Systems by Ned Mohan, www.mnpere.com

Module 9: Voltage Regulation and Voltage Stability

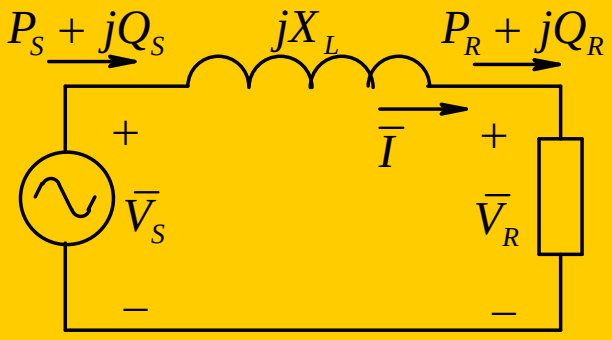
Importance:

- Increased Loading of Transmission Lines
- Several Blackouts can be attributed to this

A Radial System



(a)



(b)

Fig. 10-1 A radial system.

$$P_R = \frac{V_S V_R}{X_L} \sin\delta$$

$$\frac{V_R}{V_S} = \cos\delta \left(\frac{1}{1 + \frac{Q_R}{V_R^2 / X_L}} \right)$$

Reactive Power Need at Higher Loading:

$$P_R = \frac{V_S V_R}{X_L} \sin\delta \qquad \frac{V_R}{V_S} = \cos\delta \left(\frac{1}{1 + \frac{Q_R}{V_R^2 / X_L}} \right)$$

- Both voltages close to 1 per unit
- Large power transfer means larger angle
- Q_R must be negative

Voltages and Current Phasors with Both-Side Voltages at 1 PU

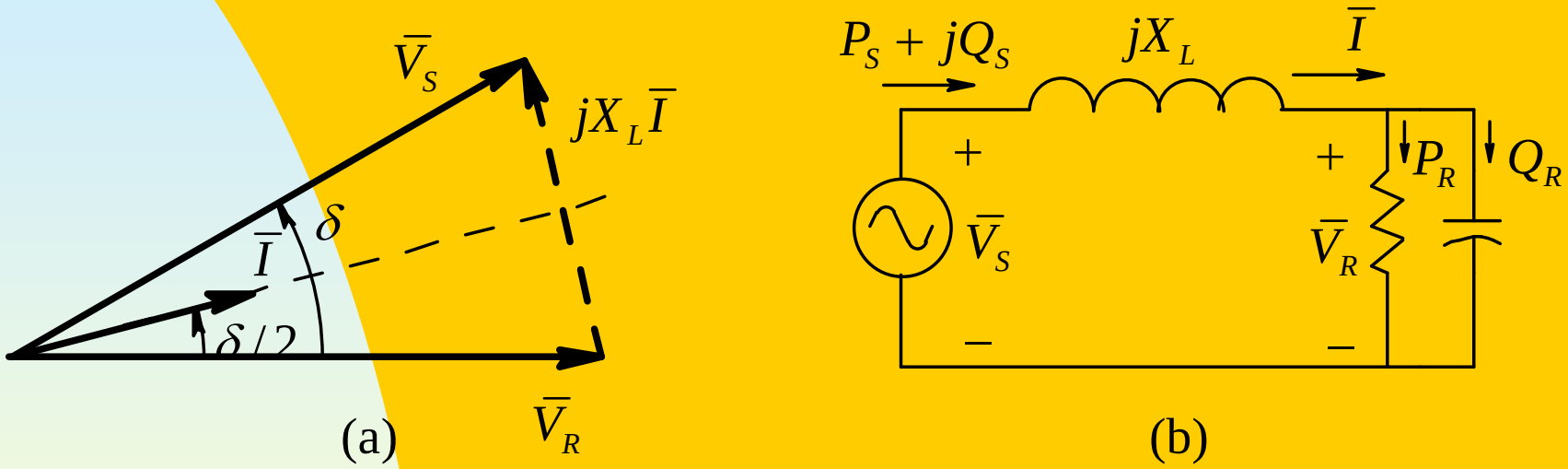


Fig. 10-2 Phasor diagram and the equivalent circuit with $V_S = V_R = 1\text{pu}$.

$$\bar{V}_S = \bar{V}_R + jX_L\bar{I} \qquad Q_{Line} = I^2 X_L$$

$$Q_s = -Q_R \qquad Q_S = Q_R + \underbrace{I^2 X_L}_{Q_{Line}} \qquad I^2 X_L = Q_{Line} = 2|Q_R|$$

Voltage Profile for Three Values of SIL

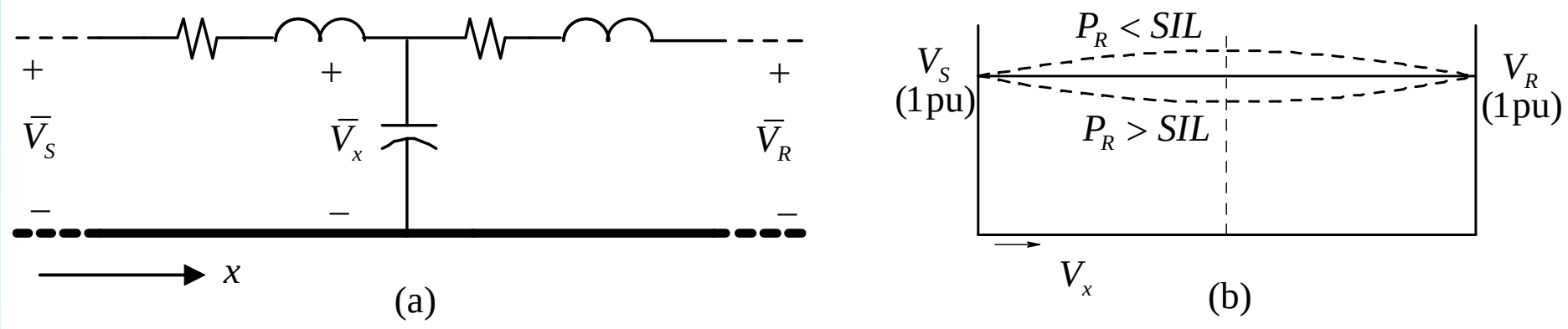
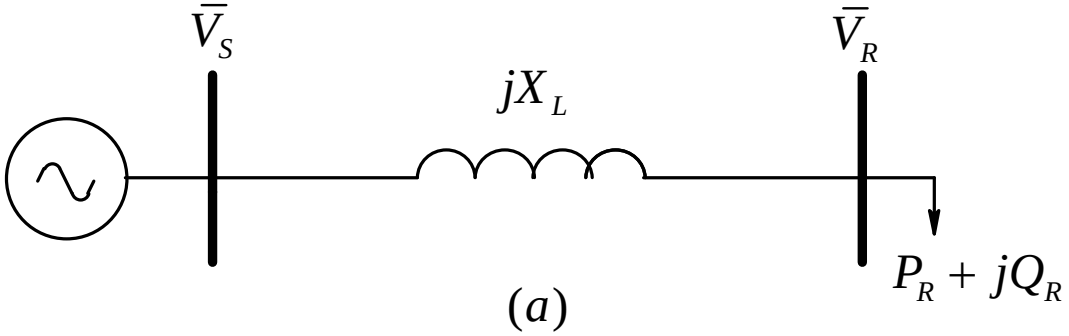


Fig. 10-3 Voltage profile along the transmission line.

"Nose" Curves at Three Power Factors as a function of Loading



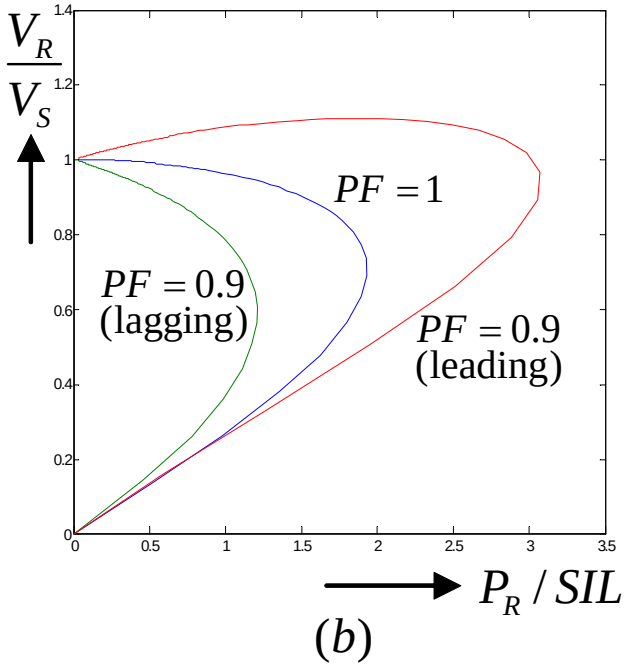


Fig. 10-4 Voltage collapse in a radial system (example of 345-kV line, 200 km long).