

# First Course on Power Systems

## Module 4: Power Flow in Power System Networks

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**Reference Textbook:**  
**First Course on Power Systems by Ned Mohan,**  
**[www.mnpere.com](http://www.mnpere.com)**

# Module 4: Power Flow in Power System Networks

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# Need for Calculating Power Flow

- For Planning and Operation Purposes
- Contingency Analysis
- In Short-Circuit and Transient Stability Analysis

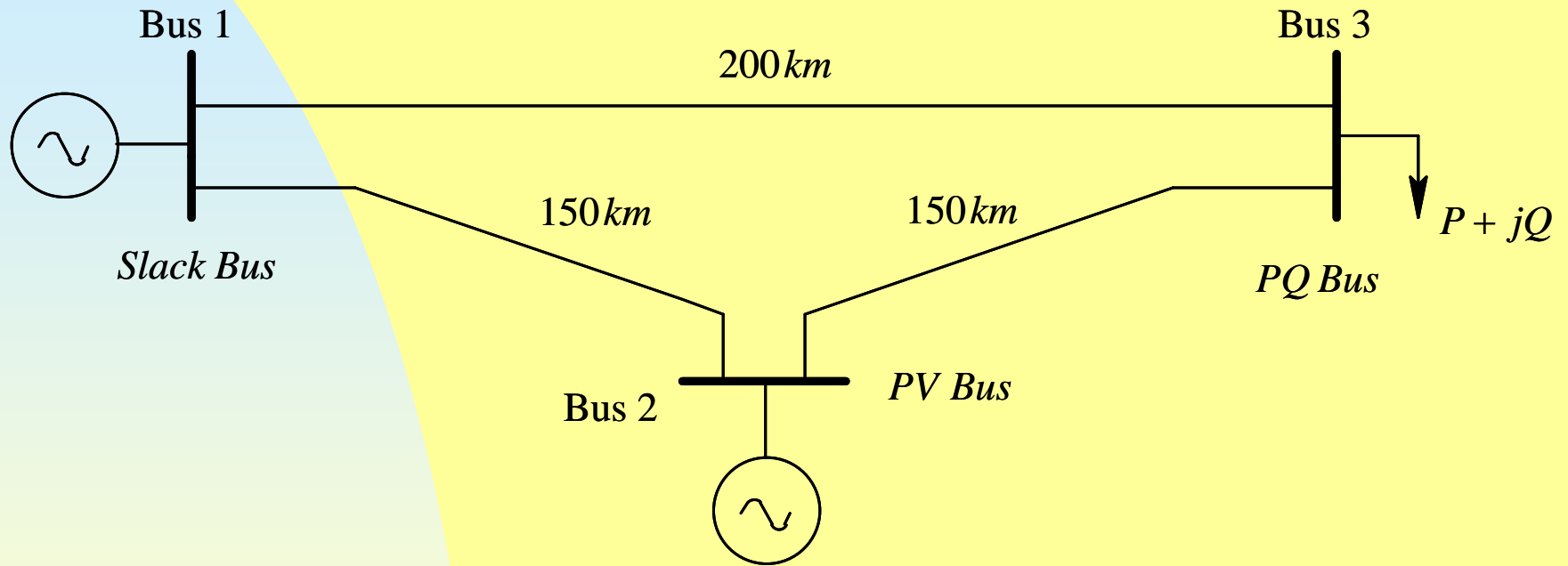
# System Representation for Power Flow Solution

- On the Bulk Power System
- Balanced Three-Phase System
- Transmission Line Representation
- Transformer Representation
- Load Representation

# Description of the Power System

- Load Buses called PQ Buses
- Generator Buses called PV Buses
- One Slack (Infinite) Bus
- PQ Bus with  $P=0$  and  $Q=0$

# 345-kV Three-Bus Example Power System



# Transmission Lines in Example System

From Table 4-1:

series reactance =  $0.376 \Omega/km$ ,

series resistance =  $0.037 \Omega/km$ ,

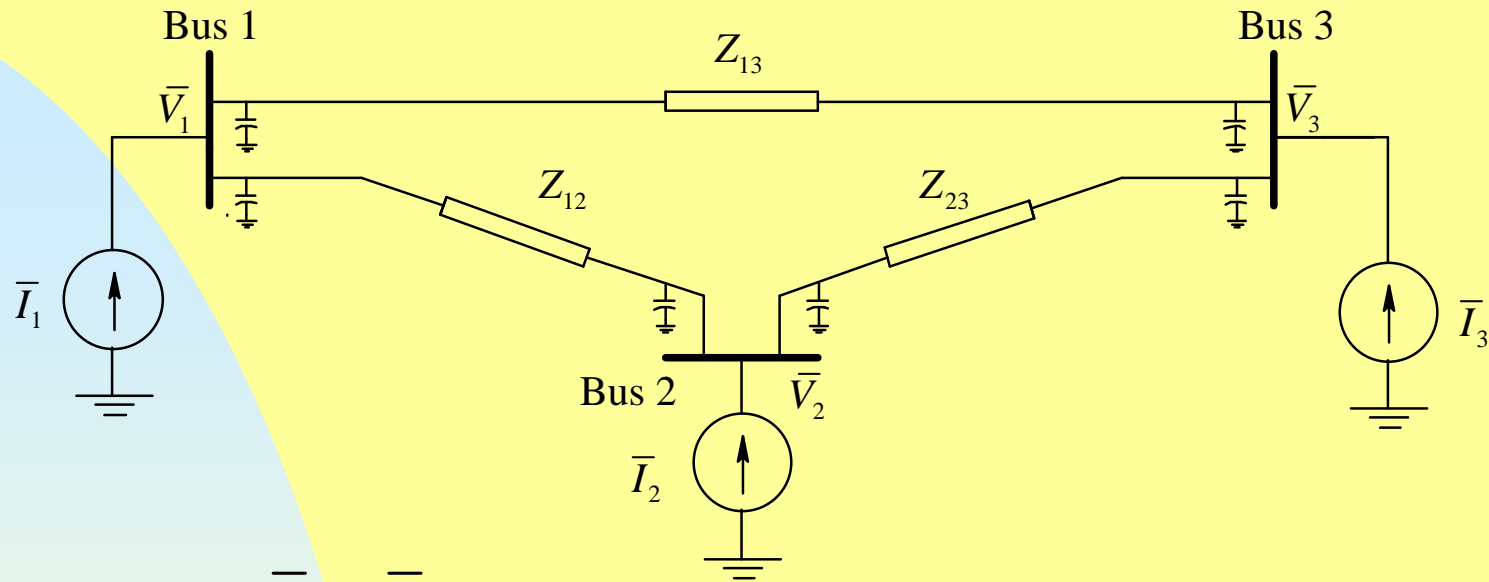
shunt susceptance  $B(= \omega C) = 4.5 \mu\text{S}/km$

$$Z_{base} = \frac{kV_{base}^2 (phase)}{MVA_{base} (1-\phi)} = \frac{kV_{base}^2 (L-L)}{MVA_{base} (3-\phi)} = 1190.25 \Omega \quad Y_{base} = 1/Z_{base}$$

Table 5-1 Per-Unit Values in the Example System

Line	Series Impedance $Z$ in $\Omega$ (pu)	Total Susceptance $B$ in $\mu\text{S}$ (pu)
1-2	$Z_{12} = (5.55 + j56.4)\Omega = (0.0047 + j0.0474)$ pu	$B_{Total} = 675 \mu\text{S} = (0.8034)$ pu
1-3	$Z_{13} = (7.40 + j75.2)\Omega = (0.0062 + j0.0632)$ pu	$B_{Total} = 900 \mu\text{S} = (1.0712)$ pu
2-3	$Z_{23} = (5.55 + j56.4)\Omega = (0.0047 + j0.0474)$ pu	$B_{Total} = 675 \mu\text{S} = (0.8034)$ pu

# Building the Admittance Matrix



$$\bar{I}_k = \bar{V}_k Y_{kG} + \sum_{\substack{m \\ m \neq k}} \frac{\bar{V}_k - \bar{V}_m}{Z_{km}}$$

$$Y_{kk} = Y_{kG} + \sum_{\substack{m \\ m \neq k}} \frac{1}{Z_{km}}$$

$$\bar{I}_k = \bar{V}_k \left( Y_{kG} + \sum_{\substack{m \\ m \neq k}} \frac{1}{Z_{km}} \right) - \sum_{\substack{m \\ m \neq k}} \frac{\bar{V}_m}{Z_{km}}$$

$$Y_{km} = -\frac{1}{Z_{km}}$$



# Admittance Matrix

$$Y_{kk} = Y_{kG} + \sum_{\substack{m \\ m \neq k}} \frac{1}{Z_{km}}$$

$$Y_{km} = -\frac{1}{Z_{km}}$$

$$\begin{bmatrix} \bar{I}_1 \\ \bar{I}_2 \\ \dots \\ \bar{I}_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \dots & \dots & \dots & Y_{1n} \\ Y_{21} & Y_{22} & \dots & \dots & \dots & Y_{2n} \\ \dots & \dots & \dots & \dots & \dots & \dots \\ \dots & \dots & \dots & \dots & \dots & \dots \\ Y_{n1} & Y_{n2} & \dots & \dots & \dots & Y_{nn} \end{bmatrix} \begin{bmatrix} \bar{V}_1 \\ \bar{V}_2 \\ \dots \\ \bar{V}_n \end{bmatrix}$$