First Course on Power Systems

Module 4: Power Flow in Power System Networks

By
Ned Mohan
Professor of ECE
University of Minnesota

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

Module 4: Power Flow in Power System Networks

Need for Calculating Power Flow

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

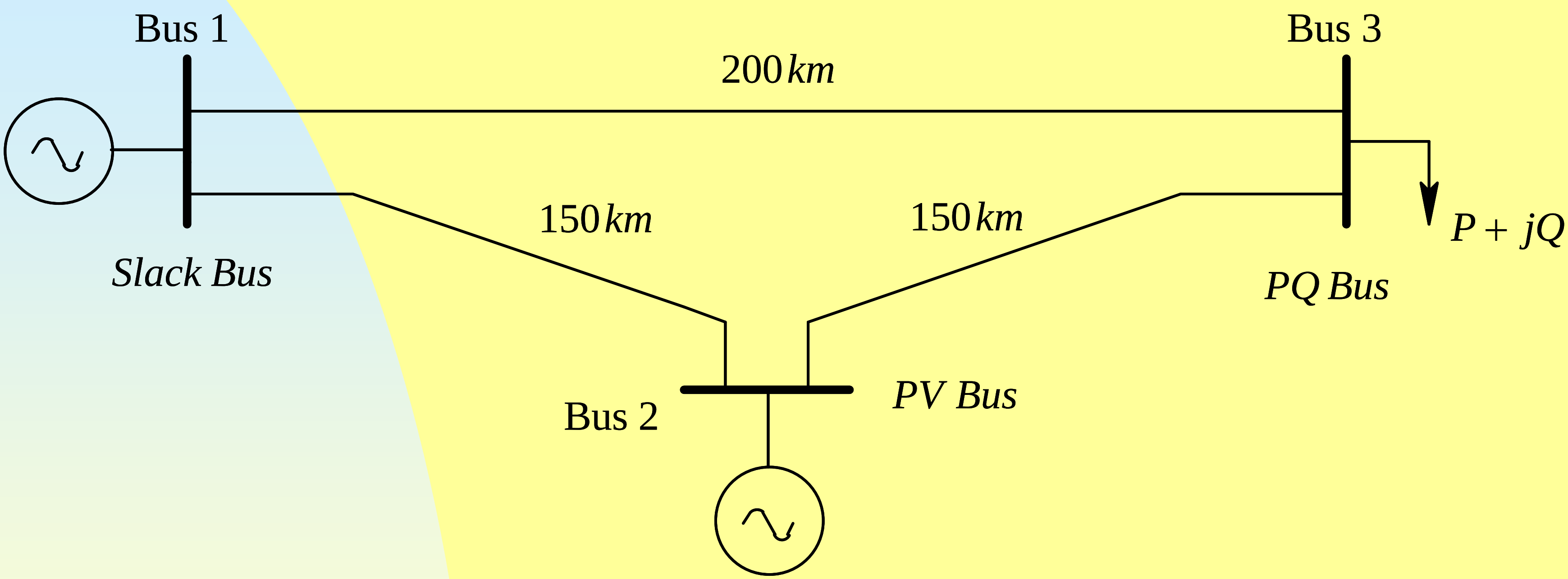
System Representation for Power Flow Solution

- 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

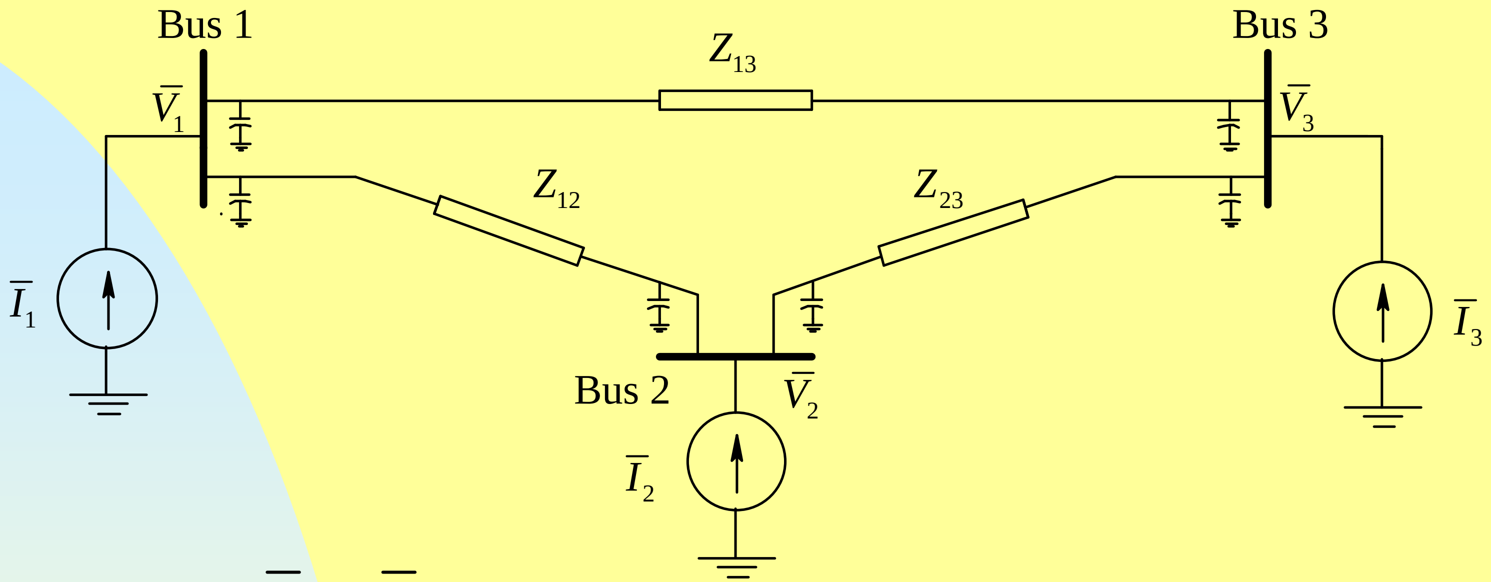
From Table 4-1:
series reactance = 0.376 Ω / km,
series resistance = 0.037 Ω / km,
shunt susceptance $B(=\omega C)$ = $4.5 \mu\mho / km$

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

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

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

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

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