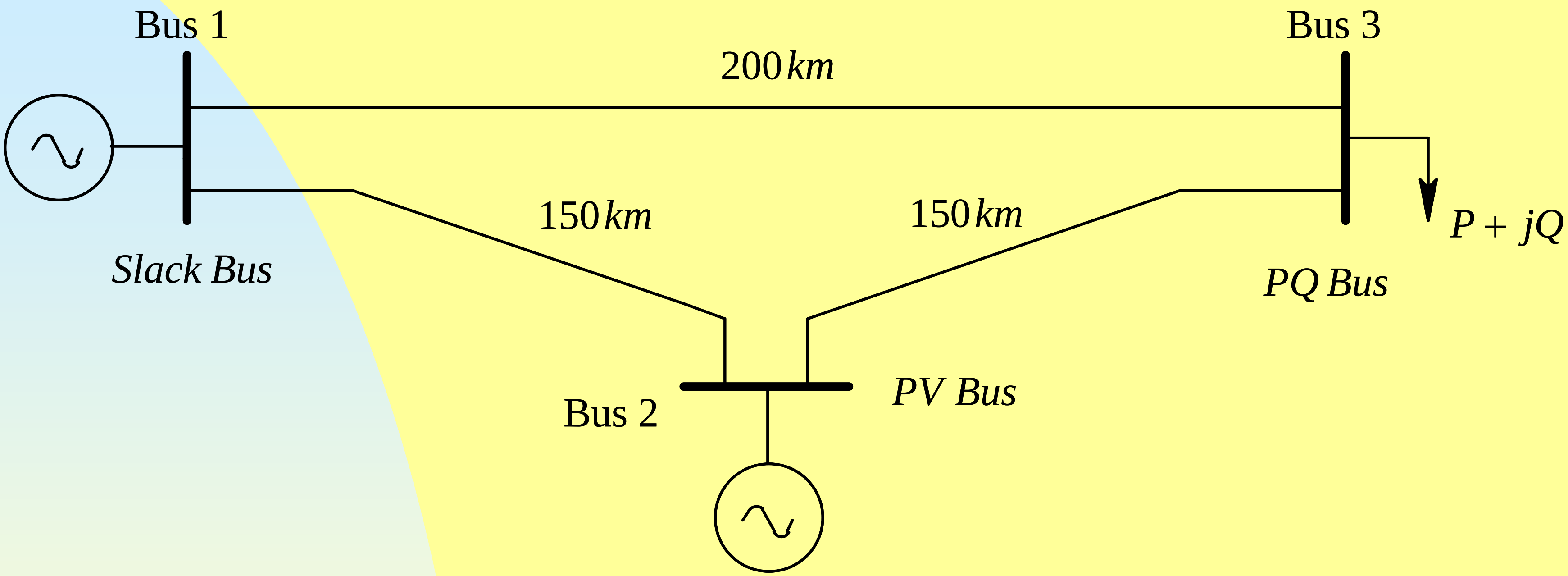
N-R Applied to 3-Bus Example:



Example 5-4 In the example system of Fig. 5-1, ignore all the shunt susceptances. Bus-1 is a slack bus with $V_1 = 1.0\,pu$ and $\theta_1 = 0$. Bus-2 is a PV bus with $V_2 = 1.05\,pu$ and $P_2^{sp} = 2.0\,pu$. Bus-3 is a PQ bus with injections of $P_3^{sp} = -5.0\,pu$ and $Q_3^{sp} = -1.0\,pu$. Using the N-R procedure, calculate the power flow on all three lines in this example power system.

Power Flow Results in the Example Power System

$$\begin{bmatrix} P_2^{sp} - P_2 \\ P_3^{sp} - P_3 \\ Q_3^{sp} - Q_3 \end{bmatrix} = \underbrace{\begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial \theta_3} & \frac{\partial P_2}{\partial V_3} \\ \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial \theta_3} & \frac{\partial P_3}{\partial V_3} \\ \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial \theta_3} & \frac{\partial Q_3}{\partial V_3} \end{bmatrix}}_{J} \begin{bmatrix} \Delta\theta_2 \\ \Delta\theta_3 \\ \Delta V_3 \end{bmatrix}$$

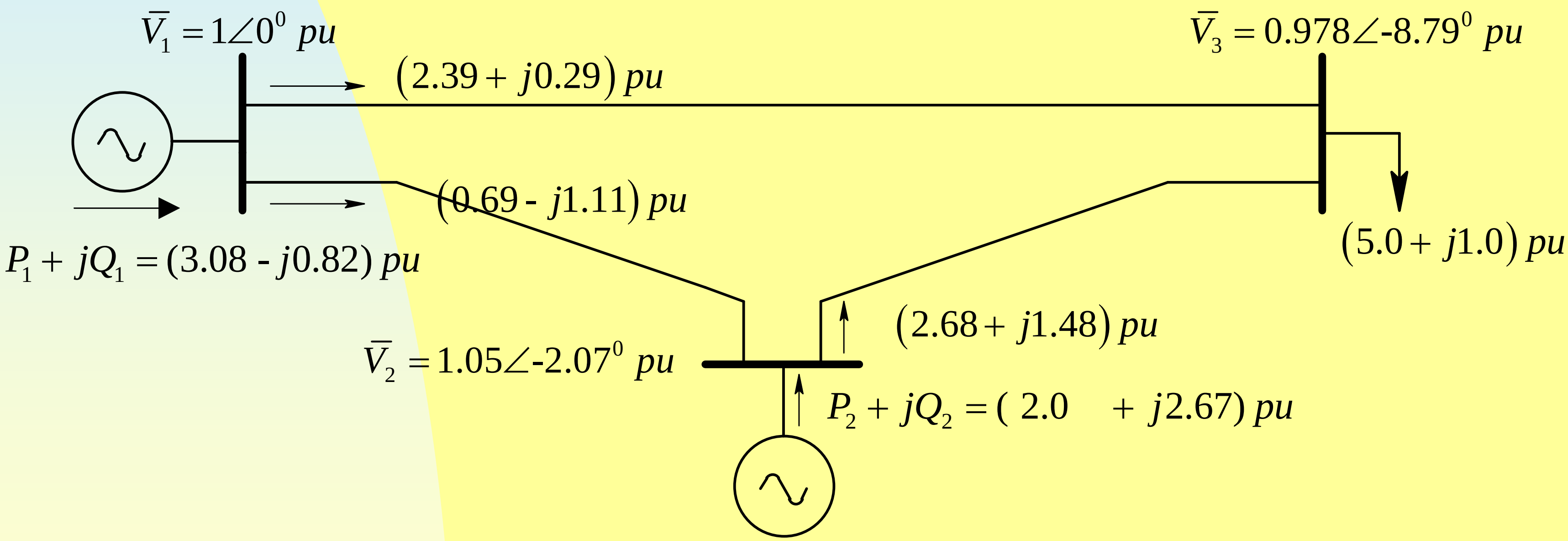
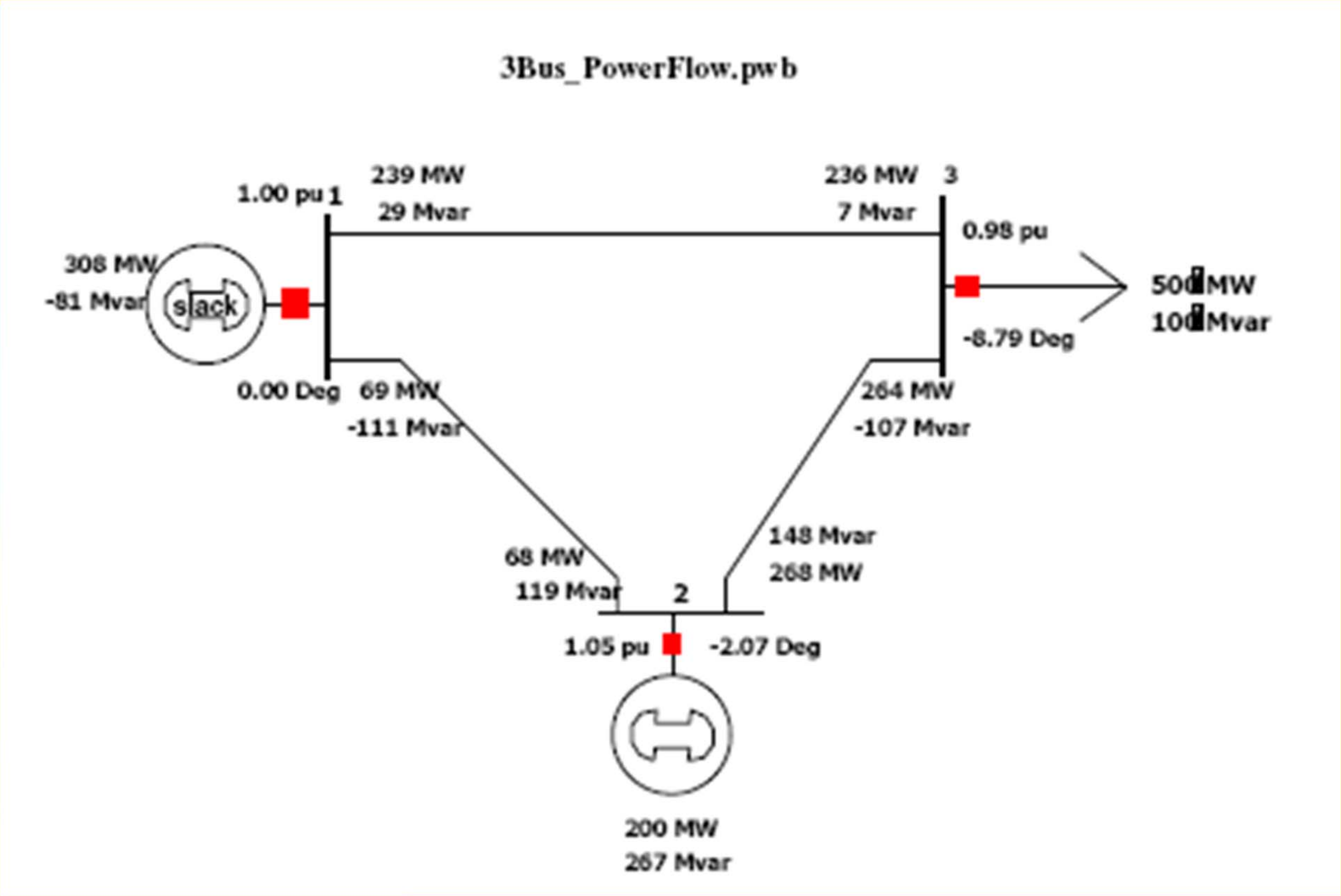


Fig. 5-4 Power-Flow results of Example 5-4.

Power World:


3Bus_PowerFlow.pwb
1.00 pu
1
239 MW
29 Mvar
236 MW
3
7 Mvar
0.98 pu
308 MW
-81 Mvar
slack
500 MW
100 Mvar
-8.79 Deg
0.00 Deg
69 MW
-111 Mvar
264 MW
-107 Mvar
148 Mvar
268 MW
68 MW
119 Mvar
2
1.05 pu
-2.07 Deg
200 MW
267 Mvar

Fast-Decoupled N-R Method

$$\underbrace{\begin{bmatrix} P^{sp}-P \\ Q^{sp}-Q \end{bmatrix}}_{(2n_{PQ}+n_{PV})\times 1} = \underbrace{\begin{bmatrix} \dfrac{\partial P}{\partial \theta} & \dfrac{\partial P}{\partial V} \\ \dfrac{\partial Q}{\partial \theta} & \dfrac{\partial Q}{\partial V} \end{bmatrix}}_{\underbrace{[J]}_{(2n_{PQ}+n_{PV})\times(2n_{PQ}+n_{PV})}} \underbrace{\begin{bmatrix} \Delta\theta \\ \Delta V \end{bmatrix}}_{(2n_{PQ}+n_{PV})\times 1}$$

$$\left[P^{sp}-P\right] = \left[\frac{\partial P}{\partial \theta}\right]\left[\Delta\theta\right]$$

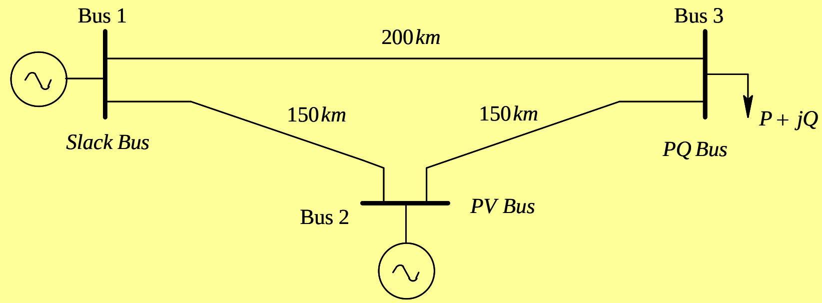
$$\left[Q^{sp}-Q\right] = \left[\frac{\partial Q}{\partial V}\right]\left[\Delta V\right]$$

Sensitivity Analysis:

$$\left[\Delta Q\right] = \left[\frac{\partial Q}{\partial V}\right]\left[\Delta V\right]$$

$$\left[\Delta V\right] = \left[\frac{\partial Q}{\partial V}\right]^{-1}\left[\Delta Q\right]$$

Reaching the Bus VAR Limit:



$$\begin{bmatrix} P_2^{sp} - P_2 \\ P_3^{sp} - P_3 \\ Q_3^{sp} - Q_3 \\ \boldsymbol{Q_2^{lim} - Q_2} \end{bmatrix} = \underbrace{\begin{bmatrix} \frac{\partial P_2}{\partial \theta_2} & \frac{\partial P_2}{\partial \theta_3} & \frac{\partial P_2}{\partial V_3} & \frac{\partial \boldsymbol{P_2}}{\partial \boldsymbol{V_2}} \\ \frac{\partial P_3}{\partial \theta_2} & \frac{\partial P_3}{\partial \theta_3} & \frac{\partial P_3}{\partial V_3} & \frac{\partial \boldsymbol{P_3}}{\partial \boldsymbol{V_2}} \\ \frac{\partial Q_3}{\partial \theta_2} & \frac{\partial Q_3}{\partial \theta_3} & \frac{\partial Q_3}{\partial V_3} & \frac{\partial \boldsymbol{Q_3}}{\partial \boldsymbol{V_2}} \\ \frac{\partial \boldsymbol{Q_2}}{\partial \boldsymbol{\theta_2}} & \frac{\partial \boldsymbol{Q_2}}{\partial \boldsymbol{\theta_3}} & \frac{\partial \boldsymbol{Q_2}}{\partial \boldsymbol{V_3}} & \frac{\partial \boldsymbol{Q_2}}{\partial \boldsymbol{V_2}} \end{bmatrix}}_{J} \begin{bmatrix} \Delta\theta_2 \\ \Delta\theta_3 \\ \Delta V_3 \\ \boldsymbol{\Delta V_2} \end{bmatrix}$$

Summary

- Need for Power Flow
- System Representation
- Basic Power Flow Equations
- N-R Solution Procedure
- Fast-Decoupled N-R
- Sensitivity Analysis
- Reaching the Bus VAR Limit