Power System Analysis II *** Midterm I *** March 22, 2011
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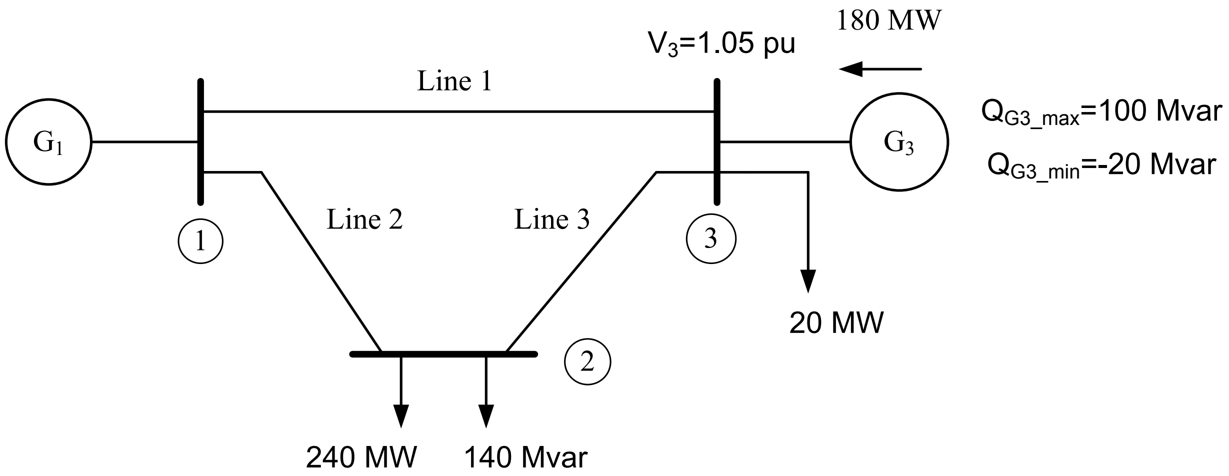
P1 (45): The figure below shows a single-line diagram of a 3-bus power system. Assume that the system base power is 100 MVA and the system base voltage is 230 kV. The transmission line data is given in the Table below. The magnitude of the voltage at bus 3 is maintained constant at 1.05 per-unit.

Bus-to-bus	$\bar{Z}'$ [Ω]	$\bar{Y}'$ [S]
1-3	$j84.64$	$j3.7807\text{x}10^{-5}$
1-2	$j52.90$	$j1.5123\text{x}10^{-4}$
2-3	$j42.32$	0



a) Determine the input data for the power flow program.
b) Calculate the elements of $\bar{Y}_{bus}$.
c) Calculate $V_2(1)$, $\delta_2(1)$ using Gauss-Seidel method. Take $\bar{V}_2(0) = 1\angle 0°$ and $\delta_3(0) = 0$ as the initial guess.

ANSWERs

$$\bar{Y}_{bus} = \begin{bmatrix} -j16.2 & j10 & j6.25 \\ j10 & -j22.46 & j12.5 \\ j6.25 & j12.5 & -j18.74 \end{bmatrix}$$

$\bar{V}_2(1) = 0.973\angle -6.3°$

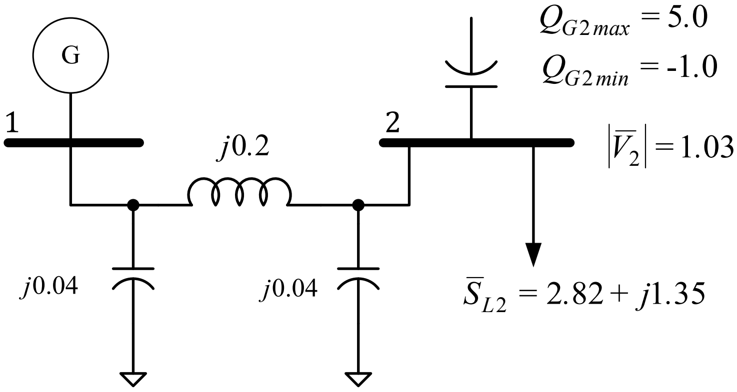
P2 (10): **a)** Explain the 3 methods used to control the power flow in an electric power system. **b)** Explain in detail how the power control is achieved in a synchronous generator.

P3 (45): For the power system shown below,

a) Taking $\delta_2(0) = 0°$ as the initial guess, calculate $\bar{V}_2(1)$ using Newton-Raphson method. Assume that the magnitude of the voltage at bus 2 is maintained constant at 1.03 per-unit.

b) Find $Q_{G2}(1)$, and check if its value is within the limits.

c) Find $\bar{S}_2(1)$



ANSWERs

$$\bar{V}_2(1) = 1.03 \underline{/ -31.3736°} \quad pu$$

$$Q_{G2}(1) = Q_2(1) + Q_{L2} = 0.865 + 1.35 = 2.215 \quad pu$$

2.215 pu is less than 5 pu limit, so bus 2 can maintain its voltage at 1.03.

$$\bar{S}_2(1) = -2.6812 + j0.865$$

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The Gauss-Seidel method is given by

$$\bar{V}_k(i+1) = \frac{1}{\bar{Y}_{kk}}\left[\frac{P_k - jQ_k}{\bar{V}_k^*(i)} - \sum_{n=1}^{k-1} \bar{Y}_{kn}\bar{V}_n(i+1) - \sum_{n=k+1}^{N} \bar{Y}_{kn}\bar{V}_n(i)\right]$$

Newton-Raphson method is based on the following equations:

$$P_k[x(i)] = V_k(i)\sum_{n=1}^{N} Y_{kn}V_n(i)\cos(\delta_k(i) - \delta_n(i) - \theta_{kn})$$

$$Q_k[x(i)] = V_k(i)\sum_{n=1}^{N} Y_{kn}V_n(i)\sin(\delta_k(i) - \delta_n(i) - \theta_{kn})$$

Step 1

$$\begin{bmatrix} \Delta P(i) \\ \Delta Q(i) \end{bmatrix} = \begin{bmatrix} P - P[x(i)] \\ Q - Q[x(i)] \end{bmatrix}$$

Step 2 Calculate the Jacobian matrix

Step 3

$$\begin{bmatrix} J1(i) & J2(i) \\ J3(i) & J4(i) \end{bmatrix} \begin{bmatrix} \Delta\delta(i) \\ \Delta V(i) \end{bmatrix} = \begin{bmatrix} \Delta P(i) \\ \Delta Q(i) \end{bmatrix}$$

Step 4

$$\begin{bmatrix} \delta(i+1) \\ V(i+1) \end{bmatrix} = \begin{bmatrix} \delta(i) \\ V(i) \end{bmatrix} + \begin{bmatrix} \Delta\delta(i) \\ \Delta V(i) \end{bmatrix}$$

Exam duration is 75 minutes