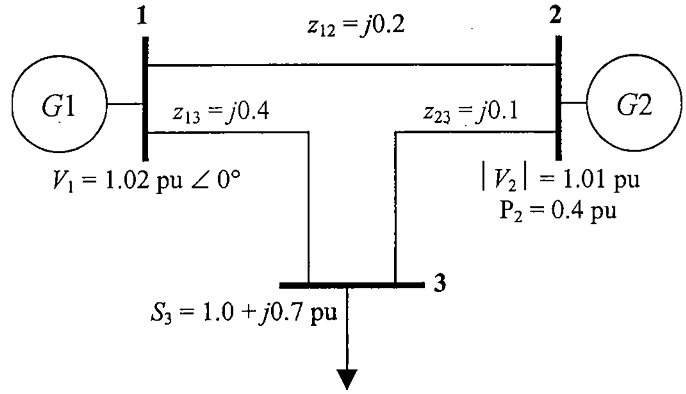
EEL 4213 Power System I
Test # 1

1. From the one-line diagram of a three-bus system shown above, find the bus admittance matrix. (20 pts)



$$y_{12} = -j\,5.0$$
$$y_{13} = -j2.5$$
$$y_{32} = -j10.0$$

$$Y_{BUS} = j\begin{bmatrix} -7.5 & 5 & 2.5 \\ 5 & -15 & 10 \\ 2.5 & 10 & -12.5 \end{bmatrix}$$

$$y_{LOAD} = \left(\frac{S}{V}\right)^* = \frac{1.0 - j\,0.7}{1.0}$$

$$Y'_{BUS} = \begin{bmatrix} -j7.5 & j5.0 & j2.5 \\ j5.0 & -j15 & j10.0 \\ j2.5 & j10.0 & 1-j13.2 \end{bmatrix}$$

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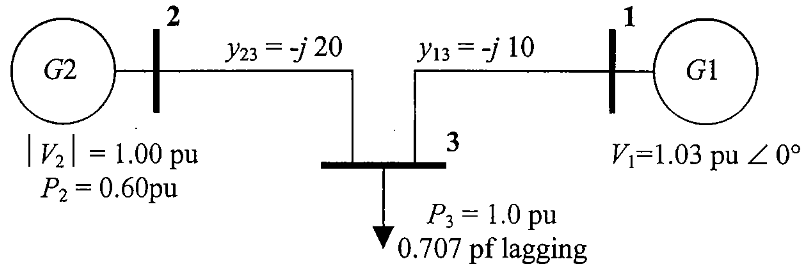
2. For the network shown above, find new voltage angles and magnitudes of buses #2 and #3 after ~~two~~ (2) iteration [k = ~~1~~ 2] using the <u>Fast Decoupled</u> power flow method (assume flat starting conditions, $1\angle 0$). (40 pts)



INITIAL COND.

$$\begin{bmatrix}\delta_2^0\\ \delta_3^0\end{bmatrix} = \begin{bmatrix}0\\0\end{bmatrix}$$

$$\begin{bmatrix}V_3^0\end{bmatrix} = \begin{bmatrix}1.0\end{bmatrix}$$

$$Y_{BUS} = j\begin{bmatrix}-10 & 0 & 10\\ 0 & -20 & 20\\ 10 & 20 & -30\end{bmatrix}; \quad -B' = \begin{bmatrix}20 & -20\\ -20 & 30\end{bmatrix}; \quad -B'' = \begin{bmatrix}30\end{bmatrix}$$

$$\begin{bmatrix}-B'\end{bmatrix}^{-1} = \begin{bmatrix}0.15 & 0.1\\ 0.1 & 0.1\end{bmatrix}; \begin{bmatrix}-B''\end{bmatrix}^{-1} = \begin{bmatrix}\frac{1}{30.}\end{bmatrix}$$

$$P_2 = (1.0)(1.0)(20)\cos(-90+0-0) + (1.0)(1.0)(20)\cos(90+0-0) = 0$$

$$P_3 = (1.0)(1.0)(30)\cos(-90+0-0) + (1.0)(1.0)(20)\cos(90+0-0) + (1.03)(1.0)(10)\cos(90+0-0)$$

$$= 0$$

$$-Q_3 = (1.0)(1.0)(30)\sin(-90) + (1.0)(1.0)(20)\sin(90+0-0) + (1.03)(1.0)(10)\sin(90+0-0)$$

$$= -30 + 20 + 10.3 = 0.3$$

$$\begin{bmatrix}\Delta\delta_2\\ \Delta\delta_3\end{bmatrix} = \begin{bmatrix}0.15 & 0.1\\ 0.1 & 0.1\end{bmatrix}\begin{bmatrix}\frac{0.6-0.0}{1.0}\\ \frac{-1.0-0.0}{1.0}\end{bmatrix} = \begin{bmatrix}-0.01\\ -0.04\end{bmatrix} \qquad \delta_2^{[1]} = -0.01 \quad \delta_3^{[1]} = -0.04$$

$$\begin{bmatrix}\Delta V_3\end{bmatrix} = \begin{bmatrix}\frac{1}{30}\end{bmatrix}\begin{bmatrix}\frac{-1.0 - -0.3}{1.0}\end{bmatrix} = \begin{bmatrix}-0.0233\end{bmatrix} \qquad V_3^{[1]} = 0.977$$

$$P_2 = (1.0)^2(20)\cos(-90) + (1.0)(0.977)(20)(\cos(+90 - -0.01 + -0.04)) = 0.586$$

$$P_3 = (.977)^2(30)\cos(-90) + (1.0)(0.977)(20)\cos(+90 - -0.04 + -0.01) + (0.977)(1.03)(10)\cos(90+0 - -0.0$$

$$= 0 - 0.586 - 0.402 = -0.988$$

$$-Q_3 = (0.977)^2(30)\sin(-90) + (0.977)(1.0)(20)\sin(90 - -0.04 + -0.01) + (0.977)(1.03)(10)\sin(90 - -0.04 + 0)$$

$$= -28.64 + 19.53 + 10.05 \approx 0.94 \qquad \delta_2^{[2]} = -0.00913$$

$$\begin{bmatrix}\Delta\delta_2\\ \Delta\delta_3\end{bmatrix} = \begin{bmatrix}0.15 & 0.1\\ 0.1 & 0.1\end{bmatrix}\begin{bmatrix}\frac{0.6-0.586}{1.0}\\ \frac{-1.0 - -0.988}{0.977}\end{bmatrix} = \begin{bmatrix}0.00087\\ 0.00017\end{bmatrix} \qquad \delta_3^{[2]} = -0.0398$$

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$$\begin{bmatrix}\Delta V_3\end{bmatrix} = \begin{bmatrix}\frac{1}{30}\end{bmatrix}\begin{bmatrix}\frac{-1.0 - -0.94}{0.977}\end{bmatrix} = \begin{bmatrix}-0.002\end{bmatrix} \qquad V_3^{[2]} \approx 0.975$$

3. The generator cost functions of three generators are given by

$$C_1 = 290 + 5.0P_1 + 0.008P_1^2 \quad (\$/h/MW) \qquad 100 \le P_1 \le 300$$
$$C_2 = 270 + 5.5P_2 + 0.009P_2^2 \quad (\$/h/MW) \qquad 200 \le P_2 \le 350$$
$$C_3 = 300 + 4.5P_3 + 0.007P_3^2 \quad (\$/h/MW) \qquad 175 \le P_3 \le 400$$

where the powers are given in MW. The total load demand is 550 MW.

a) Find the optimal dispatch of the three generators without any limits (20 pts)
b) What is the new dispatch if generator limits are enforced (20 pts)

If you use the method of iterations, you may start with an initial value of 6

a) $\beta_1 = 5.0 \quad \gamma_1 = 0.008 \qquad P_{LOAD} = 550\ MW$

$\beta_2 = 5.5 \quad \gamma_2 = 0.009$

$\beta_3 = 4.5 \quad \gamma_3 = 0.007$

$$\lambda_{(a)} = \frac{550 + \frac{5}{0.016} + \frac{5.5}{0.018} + \frac{4.5}{0.014}}{\frac{1}{0.016} + \frac{1}{0.018} + \frac{1}{0.014}} = 7.861$$

$$P_1 = \frac{7.861 - 5.0}{0.016} = 178.8$$

$$P_2 = \frac{7.861 - 5.5}{0.018} = 131.1$$

$$P_3 = \frac{7.861 - 4.5}{0.014} = 240.1$$

b) $P_2 = 200$ MEET LOWER LIMIT

$$\lambda_{(B)} = \frac{350 + \frac{5}{0.016} + \frac{4.5}{0.014}}{\frac{1}{0.016} + \frac{1}{0.014}} = 7.347$$

$$P_1 = \frac{7.347 - 5.0}{0.016} = 146.7$$

$$P_3 = \frac{7.347 - 4.5}{.014} = 203.3$$

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