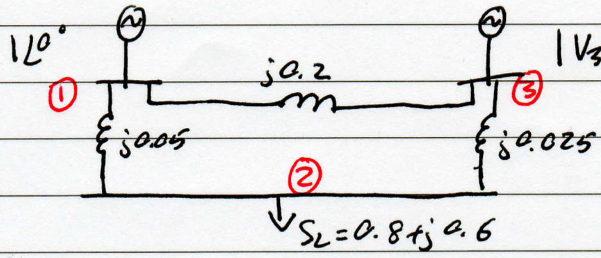
PYP EE4530 NOV/DEC 13 Megarine Tee

1)



$|V_3| = 1$, $P_3 = 0.6$, $-0.5 \leq Q \leq 0.5$

$$\begin{bmatrix} Y_{11} & Y_{12} & Y_{13} \\ Y_{21} & Y_{22} & Y_{23} \\ Y_{31} & Y_{32} & Y_{33} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ V_3 \end{bmatrix} = \begin{bmatrix} I_1 \\ I_2 \\ I_3 \end{bmatrix}$$

a) $\cancel{Y_{11}}$,

$$Y_{bus} = \begin{bmatrix} -j25 & j20 & j5 \\ j20 & j60 & j40 \\ j5 & j40 & j45 \end{bmatrix}$$

$$S = VI^* = P + jQ$$

$$V_2 = \left[\left(\frac{S_2}{V_2}\right)^* - V_1 Y_{21} - V_3 Y_{23}\right]\frac{1}{Y_{22}}$$

$$V_3 = \left[\left(\frac{S_3}{V_3}\right)^* - V_1 Y_{31} - V_2 Y_{32}\right]\frac{1}{Y_{33}}$$

$$Q_3 = V_3 V_1 Y_{31} \sin(\delta_3 - \delta_1 - \gamma_{31}) + V_3 V_2 Y_{32} \sin(\delta_3 - \delta_2 - \gamma_{32}) + V_3 V_3 Y_{33} \sin(\delta_3 - \delta_3 - \gamma_{33})$$

Using G-S process: $V_2^0 = 1\angle 0°$, $\delta_3^0 = 0°$, $Q_3^0 = 0$

$$V_2^{k+1} = \left[\left(\frac{S_2}{V_2^k}\right)^* - V_1 Y_{21} - V_3^k Y_{23}\right]\frac{1}{Y_{22}}$$

$$Q_3^{k+1} = V_3^k V_1 Y_{31} \sin(\delta_3^k - \delta_1 - \gamma_{31}) + V_3^k V_2^{k+1} Y_{32} \sin(\delta_3^k - \delta_2^{k+1} - \gamma_{32}) + V_3^k V_3^k Y_{33} \sin(\delta_3^k - \delta_3^k - \gamma_{33})$$

$$V_3^{k+1} = \left[\left(\frac{P + jQ^{k+1}}{V_3^k}\right)^* - V_1 Y_{31} - V_2^{k+1} Y_{32}\right]\frac{1}{Y_{33}}$$

$$V_2^1 = \left[\left(\frac{-0.8 - j0.6}{1\angle 0}\right)^* - 1\angle 0 \times j20 - 1\angle 0 \times j40\right]\frac{1}{j60} = 0.99\angle -0.772° \ \#$$

$$Q_3^1 = 1 \times 1 \times 5 \sin(0 - 0 - 90°) + 1 \times 0.99 \times 40 \sin(0 - (-0.772) - 90°) + 1 \times 1 \times 45 \sin(0 - 0 + 90°)$$

$= 0.40359$ (in range)

$$V_3^1 = \left[\left(\frac{0.6 + j0.40359}{1\angle 0}\right)^* - 1\angle 0 \times j5 - 0.99\angle 0.772 \times j40\right]\frac{1}{j45} = 1\angle 0.0846° \ \#$$

b) $I_{13} = [V_1 - V_3]/j0.2 = 0.007383 \angle 180°$

$I_{12} = [V_1 - V_2]/j0.05 = 0.3345 \angle 37.1°$

$S_{13} = V_1 I_{13}^* = 0.007383 \angle 180°$ #

$S_{12} = V_1 I_{12}^* = 0.3345 \angle 37.1°$ #

c) Since the network is pure inductive, sum of all real power supplied by the 2 generator must be equal to load real power.

$P_{g1} = 0.007383 \cos 180° + 0.3345 \cos 37.1°$

$= 0.2594$

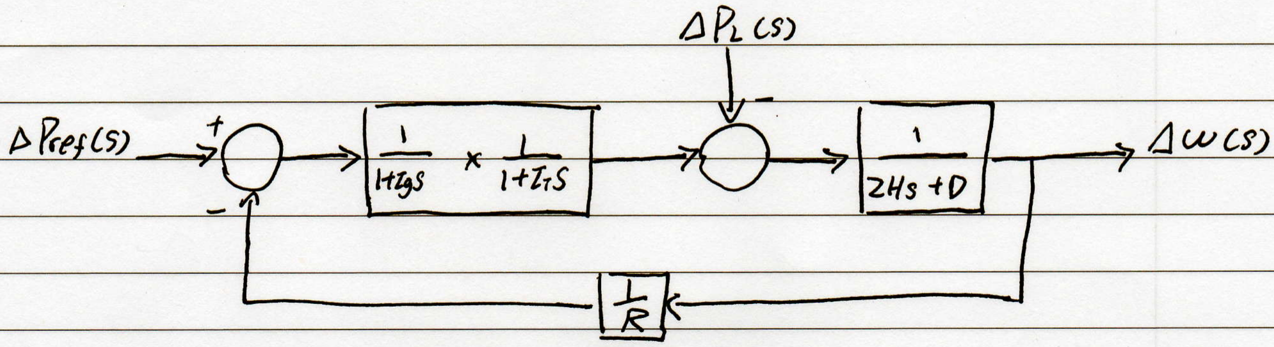
$P_{g3} = 0.6$

$P_L = 0.8$

$P_{g1} + P_{g3} = 0.8594 \neq P_L = 0.8$

$\therefore$ We can conclude that the first iteration has yet to reach the correct load flow solution. #

2)



a i) $$\frac{\Delta \omega(s)}{\Delta P_L(s)} = \frac{-\frac{1}{2Hs+D}}{1 + \frac{1}{2Hs+D} \times \frac{1}{1+\tau_g s} \times \frac{1}{1+\tau_T s} \times \frac{1}{R}} = \frac{-(1+\tau_g s)(1+\tau_T s)}{(2Hs+D)(1+\tau_g s)(1+\tau_T s) + 1/R}$$

Characteristic Equation: Let $1/R = k$

$$(2Hs + D)(1+\tau_g s)(1+\tau_T s) + 1/R$$
$$\Rightarrow (10s+1)(1+0.2s)(1+0.8s) + k$$
$$\Rightarrow (10s + 2s^2 + 1 + 0.2s)(1+0.8s) + k$$
$$\Rightarrow 10s + 8s^2 + 2s^2 + 1.6s^3 + 1 + 0.8s + 0.2s + 0.16s^2 + k$$
$$\Rightarrow [1.6]s^3 + [10.16]s^2 + [11]s + [1+k]$$

Using Routh Array,

s^3	1.6	11
s^2	10.16	$1+k$
s^1	$\frac{(1.6)(1+k)-(11\times 10.16)}{-10.16}$	0
s^0	$1+k$	

$$\Rightarrow \frac{(-1.6 - 1.6k + 111.76)}{+10.16}$$

For stability, $(-1.6 - 1.6k + 111.76)$ must not be greater than 0

$\therefore -1.6 - 1.6k + 111.76 > 0$

$\Rightarrow 68.85 > k$

Since $k = \frac{1}{R}$ $\therefore$ $R > \frac{1}{68.85} = 0.01452$ ##

ii) if $\Delta P_L(s) = \frac{0.1}{s}$, $\Delta \omega_{ss} < |0.01|$ $\Rightarrow$ magnitude of drop.

$$\lim_{s \to 0} s\Delta\omega(s) = \lim_{s \to 0} \frac{-\cancel{\Delta P}\, 0.1[1+T_g s][1+T_T s]\, s}{([2Hs+D][1+T_g s][1+T_T s]+k)\, s}$$

$$\Rightarrow \frac{0.1}{1+k} < 0.01 \Rightarrow \frac{0.1}{0.01} < 1+k \Rightarrow 9 < k \Rightarrow 9 < \frac{1}{R} \Rightarrow R < 0.111$$

$\therefore$ the highest value of R is 0.111 #

b) Loss, $ICR = \frac{dCR}{dP}$, $P_1 + P_2 + P_3 = P_D + P_{loss}$, $P_D = 500MW$

$ICR_1 = 5.3 + 0.008P_1$	$200 \leq P_1 \leq 450$
$ICR_2 = 5.5 + 0.012P_2$	$120 \leq P_2 \leq 350$
$ICR_3 = 5.8 + 0.018P_3$	$90 \leq P_3 \leq 225$

$P_{loss} = 0.000228P_2^2$

$$5.3 + 0.008P_1 = \lambda$$
$$5.5 + 0.012P_2 = \lambda\left(1 - \frac{\partial P_{loss}}{P_2}\right) = \lambda(1 - 0.000456P_2)$$
$$5.8 + 0.018P_3 = \lambda$$

Method 1: Assume $\lambda = 7.52$

$5.3 + 0.008P_1 = 7.52$ $\Rightarrow P_1 = 277.5\,MW$

$5.5 + 0.012P_2 = 7.52(1 - 0.000456P_2)$ $\Rightarrow P_2 = 130.9\,MW$

$5.8 + 0.018P_3 = 7.52$ $\Rightarrow P_3 = 95.6\,MW$

$P_1 + P_2 + P_3 = P_D + P_{loss}$

$504\,MW = 503.9\,MW$

Since $P_1 + P_2 + P_3 \approx P_D + P_{loss}$

$\therefore \lambda \approx \$7.52/MWh$ (shown) #

Method 2: Iteration

$$5.3 + 0.008 P_1^{k+1} = \cancel{7.52}\ \lambda^k \quad -(1)$$
$$5.5 + 0.012 P_2^{k+1} = \cancel{\lambda}\ \lambda^k (1 - 0.000456 P_2^k) \quad -(2)$$
$$5.8 + 0.018 P_3^{k+1} = \lambda^k \quad -(3)$$

$$P_1^{k+1} + P_2^{k+1} + P_3^{k+1} = P_D + P_{loss}^k \quad -(4)$$

From (1), $P_1^{k+1} = [\lambda^k - 5.3]/[0.008]$

From (2), $P_2^{k+1} = [\lambda^k - 0.000456\lambda^k P_2^k - 5.5]/[0.012]$

From (3), $P_3^{k+1} = [\lambda^k - 5.8]/[0.018]$

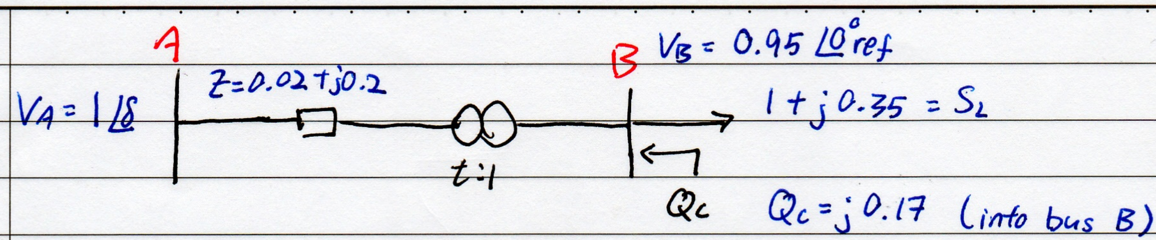
$\therefore$ From (4), $[\lambda^k - 5.3]/[0.008] + [\lambda^k - 0.000456\lambda^k P_2^k - 5.5]/[0.012] + [\lambda^k - 5.8]/[0.018] = P_D + P_{loss}^k$

Once λ^k is known, sub λ^k into eq. (1),(2),(3) to find P_1^{k+1}, P_2^{k+1}, P_3^{k+1}.

Once λ, P_1, P_2, P_3 & P_{loss} converge, their final value can be known.

k	P1	P2	P3	Ploss	λ
0	100.0	100.0	300.0	2.280	7.480
1	272.4	136.5	93.3	4.250	7.527
2	278.4	129.9	96.0	3.846	7.518
3	277.3	131.1	95.5	3.918	7.520
4	277.5	130.9	95.6	3.905	7.520
5	277.5	130.9	95.5	3.907	7.520
6	277.5	130.9	95.5	3.907	7.520

3)



$S_B = 1000 MVA$
$V_{B1} = 400 kV$ } Base
$Z_{B1} = 160 \Omega$

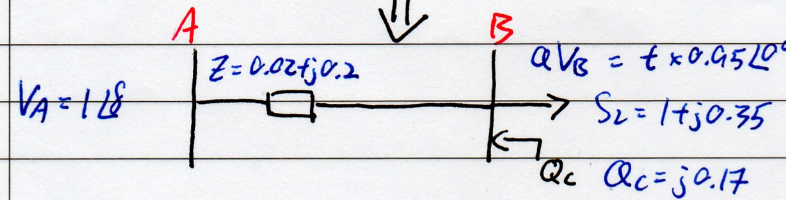
$|V_B| = 95\%$ of $|V_A|$ when Q_c injected.

$V_{pri} = a V_{sec}$, where a is $\frac{Pri}{sec}$ turn ratio.

$Z_{pri} = a^2 Z_{sec}$

$\Downarrow$

a)



$a = t/1$

$Q = Q_L - Q_c$

$$\Delta V = |V_A| - |aV_B| = \frac{PR + QX}{|aV_B|} \Rightarrow 1 - t0.95 = \frac{(1 \times 0.02) + [(0.35 - 0.17)(0.2)]}{t\,0.95}$$

$$\Rightarrow t0.95 - t^2 0.9025 - 0.056 = 0$$

$$\Rightarrow t = \underset{\text{(reject)}}{0.0626}, \; 0.9899_{\#}$$ (With Q_c injected)

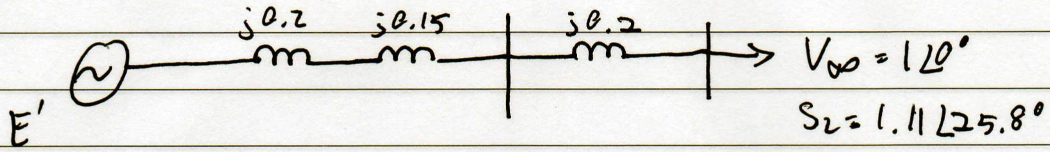
b) $|V_A| = 1$, $|V_B| = 1$, $t = 0.95$

$$\Delta V = |V_A| - |tV_B| = \frac{PR + X(Q_L - Q_C)}{|tV_B|}$$

$$\Rightarrow 1 - 0.95 = \frac{0.02 + 0.2(0.35 - Q_C)}{0.95}$$

$$\Rightarrow Q_C = 0.2125 \ \#$$

4)



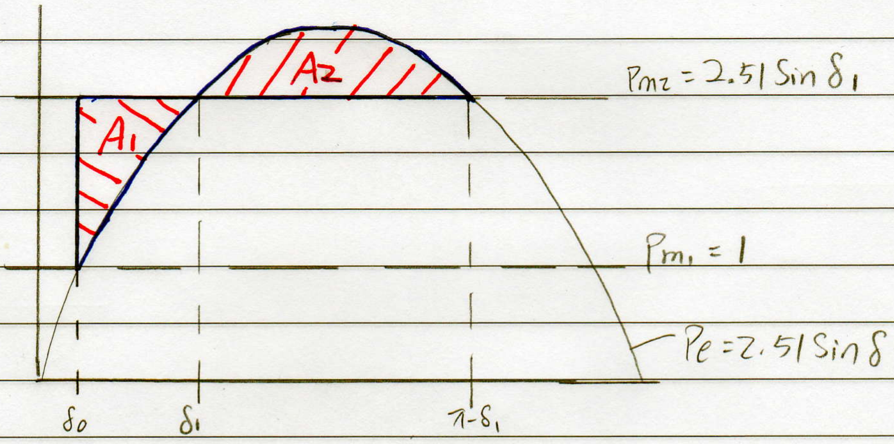
a) $I_L = (S_2/V_\infty)^* = 1.11\angle -25.8°$

$Z_T = j0.2 + j0.15 + j0.20 = j0.55$

$E\angle\delta = V_\infty + I_L Z_T = 1.38\angle 23.5°$ #

$P_e = \frac{1.38\times 1}{0.55}\sin\delta = 2.51\sin\delta$ #

b)



$\delta_0 = 23.5° = 0.4417\,\text{rad}$, $A_1 = A_2$

$$A_1 = \int_{\delta_0}^{\delta_1} (P_{m2} - P_e)\,d\delta = \int_{\delta_0}^{\delta_1} (2.51\sin\delta_1 - 2.51\sin\delta)\,d\delta$$

$$= \left[\delta\, 2.51\sin\delta_1 + 2.51\cos\delta\right]_{\delta_0}^{\delta_1} = \left[2.51\delta_1\sin\delta_1 + 2.51\cos\delta_1 - 2.51\delta_0\sin\delta_1 - 2.51\cos\delta_0\right]$$

$$= 2.51\delta_1\sin\delta_1 + 2.51\cos\delta_1 - 1.109\sin\delta_1 - 2.269$$

$$A_2 = \int_{\delta_1}^{\pi-\delta_1} (P_e - P_{m2})\,d\delta = \int_{\delta_1}^{\pi-\delta_1} (2.51\sin\delta - 2.51\sin\delta_1)\,d\delta$$

$$= \left[-2.51\cos\delta - \delta\, 2.51\sin\delta_1\right]_{\delta_1}^{\pi-\delta_1}$$

$$= \left[-2.51\cos(\pi-\delta_1) - (\pi-\delta_1)\times 2.51\sin\delta_1 + 2.51\cos\delta_1 + \delta_1 2.51\sin\delta_1\right]$$

$$= 2.51\cos\delta_1 - 7.885\sin\delta_1 + 2.51\delta_1\sin\delta_1 + 2.51\cos\delta_1 + 2.51\delta_1\sin\delta_1$$

$\Rightarrow A_1 = A_2$

$$-1.109 \sin\delta_1 - 2.269 = -7.885 \sin\delta_1 + 2.51\delta_1 \sin\delta_1 + 2.51\cos\delta_1$$

$$\Rightarrow \quad 2.51\cos\delta_1 = -2.269 + 6.776\sin\delta_1 - 2.51\delta_1\sin\delta_1$$

$$\delta_1 = \cos^{-1}\left[\frac{6.776\sin\delta_1 - 2.51\delta_1\sin\delta_1 - 2.269}{2.51}\right]$$

Using iteration, $\delta_1^0 = 45° = 0.7854$ rad (initial assumption)
(calculation in Radian)

k	δ_1^k
0)	$45°$
1)	$63.3°$
2)	$58.6°$
3)	$58.2°$
4)	$58.2°$

$\therefore \delta_1 = 58.2°$

$P_{m2} = 2.51 \sin\delta_1 = 2.133$

$\Delta P = P_{m2} - P_{m1} = 1.133$

$\therefore$ The maximum permissible sudden increase of the generator power output for maintaining the system stability is 1.133 p.u. #