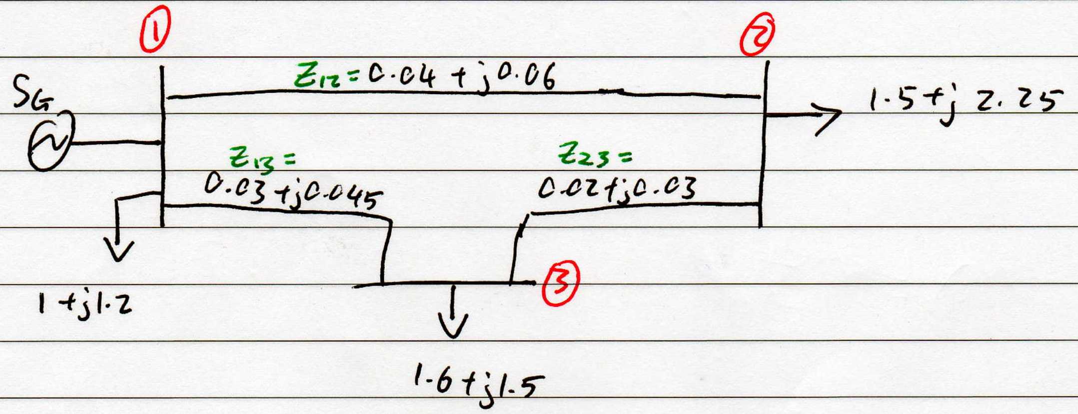
PYP EE4530 NOV/DEC 14 Megarine Tee

1)




a) $Y_{11} = \frac{1}{Z_{12}} + \frac{1}{Z_{13}} = 32.36 \angle -56.3^\circ$

$Y_{12} = Y_{21} = -\frac{1}{Z_{12}} = 13.87 \angle 123.69^\circ$

$Y_{13} = Y_{31} = -\frac{1}{Z_{13}} = 18.49 \angle 123.69^\circ$

$Y_{22} = \frac{1}{Z_{12}} + \frac{1}{Z_{23}} = 41.6 \angle -56.3^\circ$

$Y_{23} = Y_{32} = -\frac{1}{Z_{23}} = 27.74 \angle 123.69^\circ$

$Y_{33} = \frac{1}{Z_{13}} + \frac{1}{Z_{23}} = 46.23 \angle -56.3^\circ$

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

$$Y_{bus} = \begin{bmatrix} 32.36 \angle -56.3^\circ & 13.87 \angle 123.69^\circ & 18.49 \angle 123.69^\circ \\ 13.87 \angle 123.69^\circ & 41.6 \angle -56.3^\circ & 27.74 \angle 123.69^\circ \\ 18.49 \angle 123.69^\circ & 27.74 \angle 123.69^\circ & 46.23 \angle -56.3^\circ \end{bmatrix}$$ #

b) $V_1 = 1 \angle 0^\circ$, assume $V_2^0 = V_3^0 = 1 \angle 0^\circ$,

$$V_2^1 = \frac{1}{41.6 \angle -56.3^\circ} \left[ \frac{(-1.5 - j2.25)^*}{1 \angle 0^\circ} - 13.87 \angle 123.69^\circ \times 1 \angle 0^\circ - 27.74 \angle 123.69^\circ \times 1 \angle 0^\circ \right]$$

$= 0.9352 \angle -0.01^\circ$ #

$$V_3^1 = \frac{1}{46.23 \angle -56.3^\circ} \left[ \frac{(-1.6 - j1.5)^*}{1 \angle 0^\circ} - 18.49 \angle 123.69^\circ \times 1 \angle 0^\circ - 27.74 \angle 123.69^\circ \times 0.9352 \angle -0.01^\circ \right]$$

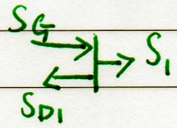
$= 0.915 \angle -0.69^\circ$ #

c) $V_2 = 0.8026\angle -0.8^\circ$, $V_3 = 0.8255\angle -1.29^\circ$

$S_1 = V_1 I_1^*$, $I_1 = V_1 Y_{11} + V_2 Y_{12} + V_3 Y_{13}$

$S_1 = 1\angle 0^\circ \times \left[1\angle 0^\circ \times 32.36\angle -56.3^\circ + 0.8026\angle -0.8 \times 13.87\angle 123.69^\circ + 0.8255\angle -1.29^\circ \times 18.49\angle 123.69^\circ\right]^*$

$= 3.731 + j4.687$ # $\Rightarrow P_1 = 373.1\,MW$, $Q_1 = 468.7\,MVar$




$S_G = S_1 + S_{D1}$

$= (3.731 + j4.687) + (1 + j1.2)$

$= 4.731 + j5.887$ # $\Rightarrow P_G = 473.1\,MW$, $Q_G = 588.7\,MVar$

$I_{L12} = (V_1 - V_2)/Z_{12} = (1\angle 0^\circ - 0.8026\angle -0.8^\circ)/(0.04 + j0.06)$

$= 2.743\angle -53.1^\circ$

$S_{L12} = |I_{L12}|^2 \times Z_{12} = |2.743|^2 \times (0.04 + j0.06)$

$= 0.3 + j0.4514$ # $\Rightarrow$

$P_{L12} = 30\,MW$, $Q_{L12} = 45.14\,MVar$

2) $S_B = 1000\,MVA$

$f_B = 50\,Hz$

$$\beta_{new} = \beta_{old}\left[\frac{S_{B\,old}}{S_{B\,new}}\right], \quad D_{new} = D_{old}\left[\frac{S_{B\,old}}{S_{B\,new}}\right]$$

$$\beta_A = 40\times\left[\frac{1000}{1000}\right] = 40 \qquad D_A = 0\times\left[\frac{1000}{1000}\right] = 0$$

$$\beta_B = 60\times\left[\frac{500}{1000}\right] = 30 \qquad D_B = 2\times\left[\frac{500}{1000}\right] = 1$$

$$\beta_C = 25\times\left[\frac{800}{1000}\right] = 20 \qquad D_C = 2.5\times\left[\frac{800}{1000}\right] = 2$$

$\Delta P_{LB} = 93/1000 = 0.093$ , $f_{o\,sys} = 50\,Hz$

a i) $$\Delta f = \frac{-\Delta P_L}{\beta_A+\beta_B+\beta_C+D_A+D_B+D_C} = \frac{-0.093}{40+30+20+0+1+2} = -0.001$$

$\Rightarrow \Delta f_{act} = -0.05\,Hz$

$\therefore f_{n\,sys} = \Delta f_{act} + f_{o\,sys} = 49.95\,Hz$ #

ii) $\Delta P_{tie\,i} = \Delta P_i - \Delta P_{Li} - D_i\Delta f$, where $\Delta P_{tie\,i}$ is power flowing out of Area $i$

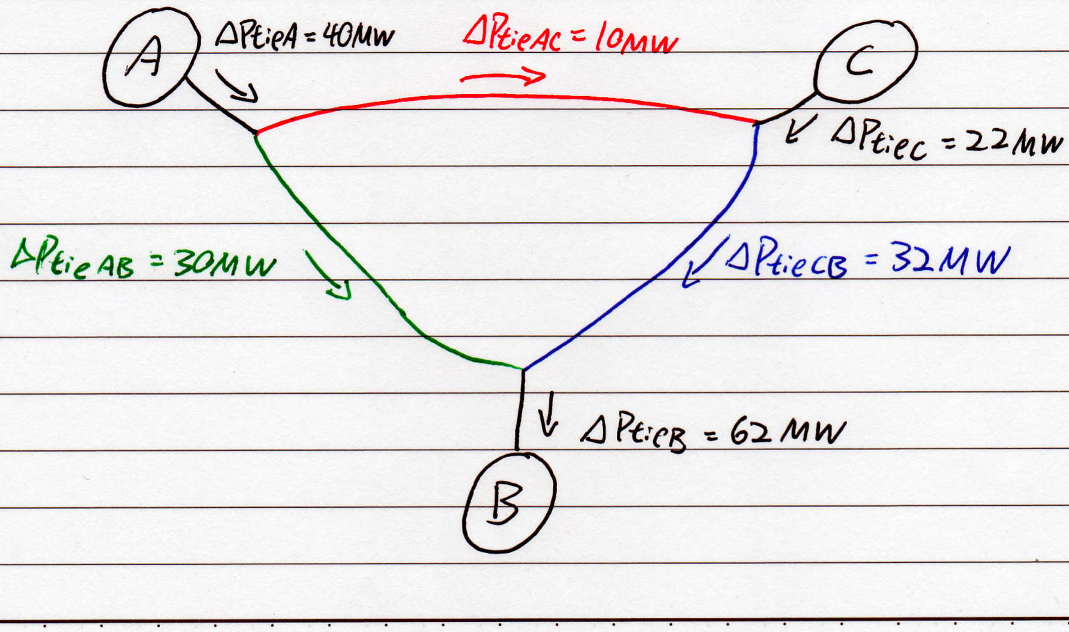
In Per Unit,

$\Delta P_{tie\,A} = (-\beta_A\Delta f) - 0 - (D_A\Delta f) = 0.04 \Rightarrow \Delta P_{tie\,A} = 40\,MW$

$\Delta P_{tie\,B} = (-\beta_B\Delta f) - 0.093 - (D_B\Delta f) = -0.062 \Rightarrow \Delta P_{tie\,B} = -62\,MW$

$\Delta P_{tie\,C} = (-\beta_C\Delta f) - 0 - (D_C\Delta f) = 0.022 \Rightarrow \Delta P_{tie\,C} = 22\,MW$

Power balance $\Rightarrow$ Total $\Delta P_{tie} = 0$ $\therefore \Delta P_{tie\,A} + \Delta P_{tie\,B} + \Delta P_{tie\,C} = 0$



b) Lossless, $\lambda = ICR = \frac{dCR}{dP}$, $P_D = 220MW$

$ICR_1 = 12 + 0.05P_1$ — (1) $\quad 10 \le P_1 \le 120MW$

$ICR_2 = 17 + 0.03P_2$ — (2) $\quad 10 \le P_2 \le 60MW$

$ICR_3 = 15 + 0.02P_3$ — (3) $\quad 10 \le P_3 \le 80MW$

$P_1 + P_2 + P_3 = 220MW$

From (1), $P_1 = (\lambda - 12)/0.05$

From (2), $P_2 = (\lambda - 17)/0.03$

From (3), $P_3 = (\lambda - 15)/0.02$

$\therefore [(\lambda-12)/0.05] + [(\lambda-17)/0.03] + [(\lambda-15)/0.02] = 220$

$[20\lambda - 240] + [33.33\lambda - 566.67] + [50\lambda - 750] = 220$

$103.33\lambda = 1776.67$

$\therefore \lambda = 17.194$

$\Rightarrow P_1 = 103.88MW$, $P_2 = 6.47MW$, $P_3 = 109.71MW$

Since $P_3 > P_{3max}$, $\therefore$ Set $P_3 = 80MW$

$P_1 + P_2 + 80 = 220 \quad \Rightarrow P_2 = 140 - P_1$ — (4)

$12 + 0.05P_1 = 17 + 0.03P_2$ — (5)

Sub (4) into (5),

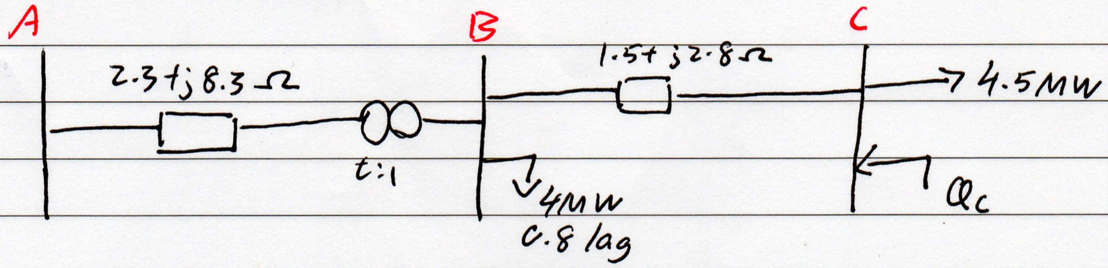
$12 + 0.05P_1 = 17 + 0.03[140 - P_1]$

$\Rightarrow P_1 = 115MW$ #

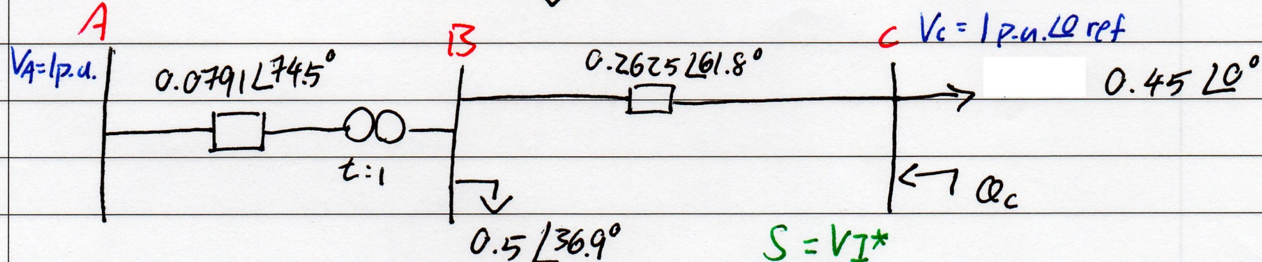
$\Rightarrow P_2 = 25MW$ #

& $P_3 = 80MW$ #

3) Under nominal transformer turn ratio:




⇓ to per unit




$S = VI^*$

$S_B = 10MVA$
$V_{B1} = 33kV$    $V_{B2} = 11kV$ } Base value
$Z_{B1} = 108.9\Omega$    $Z_{B2} = 12.1\Omega$

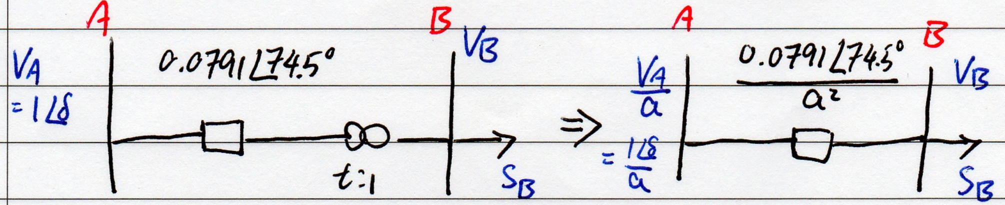
$V_{pri} = a\,V_{sec}$
$Z_{pri} = a^2 Z_{sec}$
$I_{pri} = \frac{1}{a} I_{sec}$
} where $a$ is $\frac{pri}{sec}$ turn ratio

a) $I_c = \left(\frac{S_c}{V_c}\right)^* = 0.45\angle 0°$

$V_B = V_c + I_c(0.2625\angle 61.8°) = 1.061\angle 5.63°$

$S_B = 0.5\angle 36.9° + 0.45\angle 0° + |I_c|^2(0.2625\angle 61.8°)$
$= 0.9413\angle 21.6°$

refer to sec., $a = t/1$




$\underbrace{V_S - V_R = \frac{PR+QX}{V_R}}_{\text{parameter in magnitu}}$

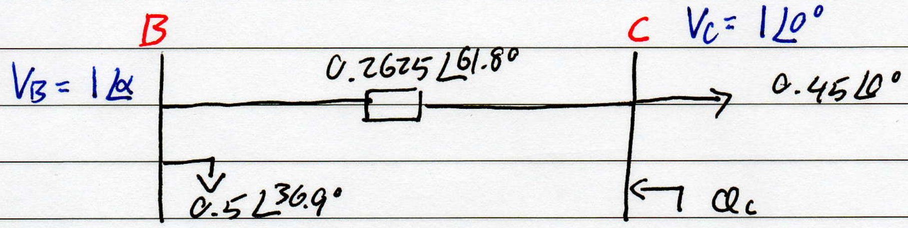
$\Delta V = \frac{V_A}{t} - V_B = \frac{PR+QX}{t^2 V_B} \Rightarrow t V_A V_B - t^2 V_B^2 = PR + QX$

Since $V_A = 1$, $V_B = 1.061$, $P = 0.8752$, $Q = 0.3465$, $R = 0.02114$, $X = 0.07622$

$\Rightarrow$ $(1.061)^2 t^2 - (1.061)t + 0.04491 = 0$    $\therefore t = 0.898$ *, $0.0444$ (rejected)

* t range typically ±10% of nominal value.

b)




$\Delta V = V_B - V_c = \dfrac{PR + QX}{V_c}$ } in Per Unit magnitude

$V_B = 1$, $V_c = 1$, $P = 0.45$, $Q = -Q_c$, $R = 0.124$, $X = 0.2313$,

$\Rightarrow PR + QX = 0 \Rightarrow (0.45)(0.124) = Q_c(0.2313)$

$\Rightarrow Q_c = 0.2412 \Rightarrow Q_{c\,act} = 2.412\,\text{MVar}$ into bus C. #

b) Method 2: with angle

$$I_c = \frac{V_B\angle\alpha - V_c\angle 0}{Z\angle\beta}, \quad S_c = V_c I_c^* = V_c\angle 0^\circ\left[\frac{V_B\angle -\alpha - V_c\angle 0}{Z\angle -\beta}\right]$$

$$S_c = \frac{V_c V_B}{Z}\angle -\alpha+\beta - \frac{V_c^2}{Z}\angle\beta$$

$$= \underbrace{\left[\frac{V_c V_B}{Z}\cos(-\alpha+\beta) - \frac{V_c^2}{Z}\cos(\beta)\right]}_{P_R} + j\underbrace{\left[\frac{V_c V_B}{Z}\sin(-\alpha+\beta) - \frac{V_c^2}{Z}\sin(\beta)\right]}_{Q_R}$$

Since $P_R, V_c, V_B, Z, \beta$ are known, $\therefore$ find $\alpha$. ~~where~~

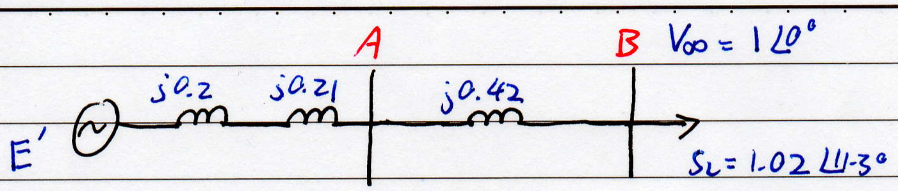
$\Rightarrow \alpha = 8^\circ$

Since $\alpha$ is known, use $Q_R$ equation to find $Q_R$

$\Rightarrow Q_R = -0.2832$ $\therefore$ capacitative compensator.

$Q_c = 0.2832 \Rightarrow Q_{c\,act} = 2.832\,\text{MVar}$ into bus C. #

4)




a) $I_L = \left(\frac{S_L}{V_\infty}\right)^* = 1.02\angle -11.3°$

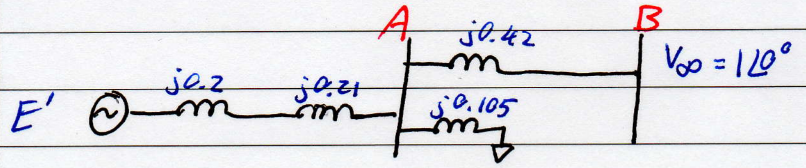
$Z_{T_1} = j0.2 + j0.21 + j0.42 = j0.83$

$E'\angle\delta = V_\infty + Z_{T_1} I_L = 1.4313\angle 35.45°$ # E' is constant.

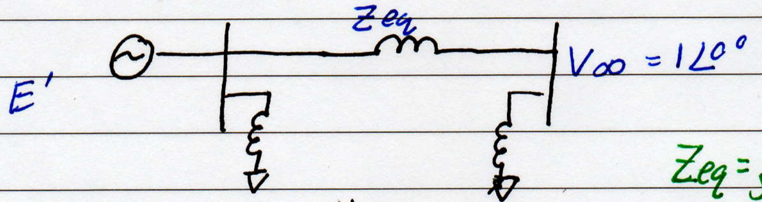
$P_{e_1} = \left|\frac{E' V_\infty}{Z_{T_1}}\right| \sin\delta = 1.7245 \sin\delta$ # (Pre)

~~b)~~

b)

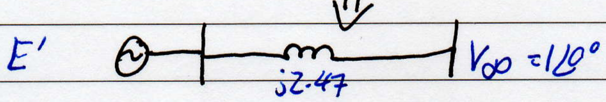



$\Downarrow$ Y-Δ transformation




$Z_{eq} = j0.2 + j0.21 + j0.42 + \frac{(j0.2+j0.21)(j0.42)}{j0.105}$
$= j2.47$

$\Downarrow$

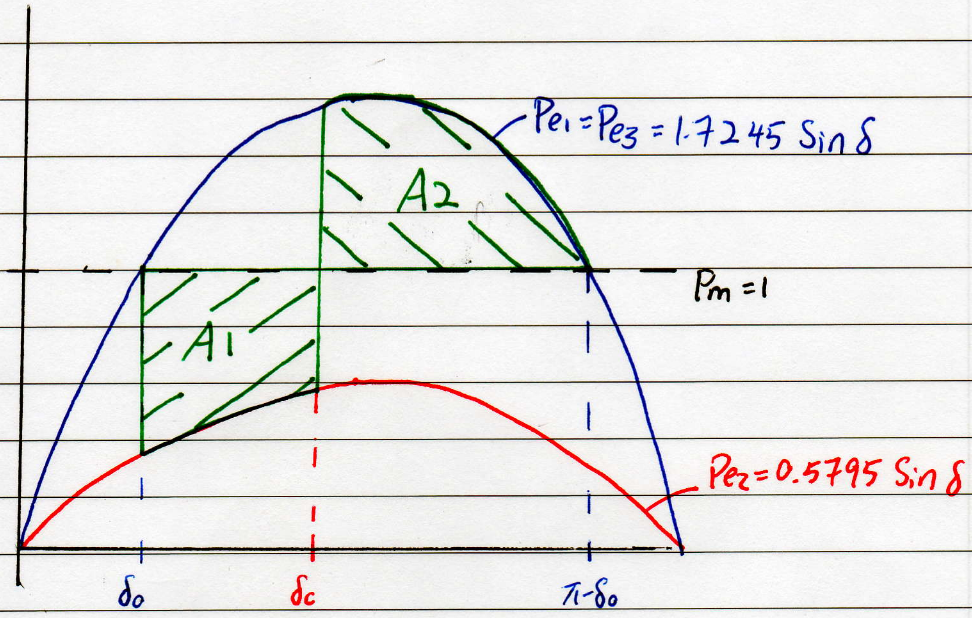



$P_{e_2} = \left|\frac{E' V_\infty}{Z_{eq}}\right| \sin\delta = 0.5795 \sin\delta$ (During)

$P_{e_3} = P_{e_1} = 1.7245 \sin\delta$ (Post)

$\delta_0 = 35.45° = 0.6187$ rad

$\delta_c = 82° = 1.4312$ rad




$$A_1 = \int_{\delta_0}^{\delta_c} (P_m - P_{e2})\,d\delta = \int_{\delta_0}^{\delta_c} (1 - 0.5795 \sin\delta)\,d\delta = \left[\delta + 0.5795\cos\delta\right]_{\delta_0}^{\delta_c}$$

$$= \left[\delta_c + 0.5795\cos\delta_c - \delta_0 - 0.5795\cos\delta_0\right] = 0.4211$$

$$A_2 = \int_{\delta_c}^{\pi-\delta_0} (P_{e3} - P_m)\,d\delta = \int_{\delta_c}^{\pi-\delta_0} (1.7245\sin\delta - 1)\,d\delta = \left[-1.7245\cos\delta - \delta\right]_{\delta_c}^{\pi-\delta_0}$$

$$= \left[-1.7245\cos(\pi-\delta_0) - \pi + \delta_0 + 1.7245\cos\delta_c + \delta_c\right] = 0.5531$$

Since $A_2 > A_1$ $\therefore$ Stable system #