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15/ENG04/040

ASSIGNMENT 3

Question 1

a) Contingency planning involves the itemisation of actions to be taken to bring into balance supply-demand equation.

b i) Excitation control
ii) Regulating transformers
iii) Line Reactance compensators
iv) Reactive power sinks or sources

c) Steady state stability limit is the maximum power that can be transmitted to the receiving end without loss of synchronism.

d i) Increase in system voltage
ii) Reduction in transfer Reactance

e i) - Pre-fault condition

$$X_I = j\left[0.28 + \frac{0.16 + 0.24 + 0.16}{2} + 0.16\right] = 0.72\,pu$$

$$P_{eI} = \frac{|E| \cdot V}{X_I} \sin\delta = \frac{1.25 \times 1}{0.72} \sin\delta = 1.736 \sin\delta$$

$$1 = 1.736 \sin\delta_0$$

$$\delta_0 = \sin^{-1}\left(\frac{1}{1.736}\right)$$

$$\delta_0 = 35.2^\circ \simeq 0.62\,rad$$

- During fault
Since fault occurs at one end of the line,
$P_{eII} = 0$

- Post-fault

$X_{III} = 0.28 + 0.16 + 0.24 + 0.16 + 0.16 = 1.0\ pu$

$P_{eIII} = \frac{1.25 \times 1}{1} \sin\delta = \underline{\underline{1.25 \sin\delta}}$

$1 = 1.25 \sin\delta_0$

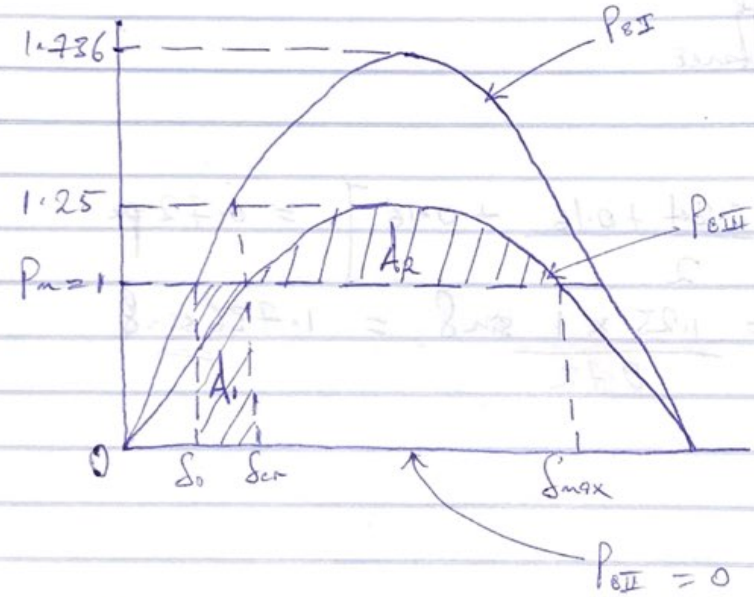
$\delta_0 = \sin^{-1}\left(\frac{1}{1.25}\right)$

$\delta_0 = 0.927\ rad$

$P_{eI} = 1.736 \sin\delta$

$P_{eII} = 0$

$P_{eIII} = 1.25 \sin\delta$



Maximum δ_{max} for $A_1 = A_2$ is given by

$\delta_{max} = \pi - \delta_0$

For A_1

$\delta_{max} = \pi - \delta_0$

$= \pi - 0.62$

$= 2.52$

For A_2

$\delta_{max} = \pi - \delta_0$

$= \pi - 0.927$

$= 2.21$

$P_m = P_{max} \sin \delta_0$

$A_1 = P_m (\delta_{cr} - \delta_0)$

$= 1(\delta_{cr} - 0.62)$

$= \delta_{cr} - 0.62$

$A_2 = \int_{\delta_{cr}}^{\delta_{max}} (P_{out} - P_m) \, d\delta$

$= \int_{\delta_{cr}}^{\delta_{max}} (1.25 \sin\delta - 1) \, d\delta$

$\cancel{= -1.25 \cos\delta - \delta \Big|_{\delta_{cr}}^{\delta_{max}} 2.21}$

$\cancel{= -1.25 \cos\left(2.21 \times \frac{180}{\pi}\right) + 1.25 \cos \delta_{cr} - 2.21 + \delta_{cr}}$

$= \int_{\delta_{cr}}^{\delta_{max}} 1.25 \sin\delta \, d\delta - \int_{\delta_{cr}}^{\delta_{max}} 1 \, d\delta$

$= 1.25 \left[-\cos\delta\right]_{\delta_{cr}}^{\delta_{max}} - \left[\delta\right]_{\delta_{cr}}^{\delta_{max}}$

$= -1.25 \cos(\delta_{max} - \delta_{cr}) - (\delta_{max} - \delta_{cr})$

[Recall for A_2, $\delta_{max} = 2.21$]

So

$A_2 = -1.25 \cos(2.21) + 1.25 \cos \delta_{cr} - 2.21 + \delta_{cr}$

$= 0.7457 + 1.25 \cos \delta_{cr} - 2.21 + \delta_{cr}$

$= 1.25 \cos \delta_{cr} + \delta_{cr} - 1.464$

for $A_1 = A_2$:

$\cancel{\delta_{cr}} - 0.62 = 1.25 \cos \delta_{cr} + \cancel{\delta_{cr}} - 1.464$

$\cos \delta_{cr} = \dfrac{1.464 - 0.62}{1.25} = \dfrac{0.844}{1.25} = 0.6752$

$\therefore \delta_{cr} = \cos^{-1}(0.6752) = 47.53° \;\; \Omega \;\; 0.8296 \text{ rad}$

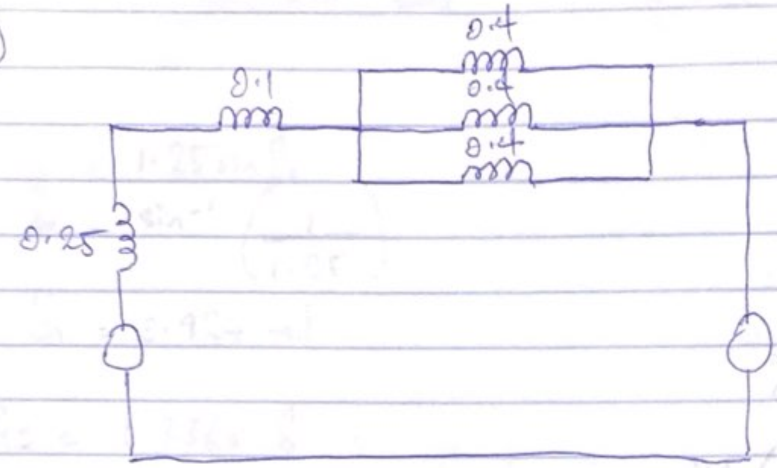
Question 2

a i) Steady state

ii) Dynamic

iii) Transient

b)



i) $V_t = |V_t| \angle \alpha = 1 \angle \alpha$

$$P_e = \frac{|V_t||V|}{X} \sin\alpha$$

$$\therefore 1 = \frac{1 \times 1}{(0.25 + 0.1)} \sin\alpha$$

$\sin\alpha = 0.35$

$\alpha = \sin^{-1}(0.35) = 20.5^\circ$

Current into infinite bus

$$I = \frac{|V_t| \angle \alpha - |V| \angle 0}{X}$$

$$= \frac{1 \angle 20.5 - 1 \angle 0}{j0.35}$$

Recall $A \angle \theta = A(\cos\theta + j\sin\theta)$

$$I = \frac{1[\cos 20.5 + j\sin 20.5] - 1}{j0.35}$$

$= 1.016 \angle 10.21^\circ$

$\triangleq 1 + j0.18$

Emf behind transient X

$E' = |V|\angle 0 + IX$

$$\left[X = 0.25 + 0.1 + \frac{0.4}{3} = j0.483\right]$$

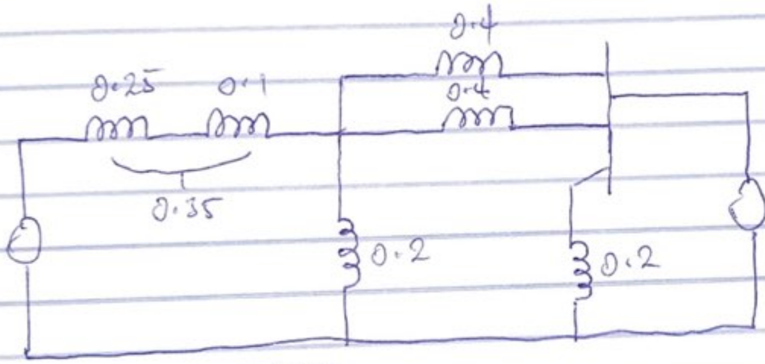
$E' = 1\angle 0 + j0.483\,(1 + j0.18)$

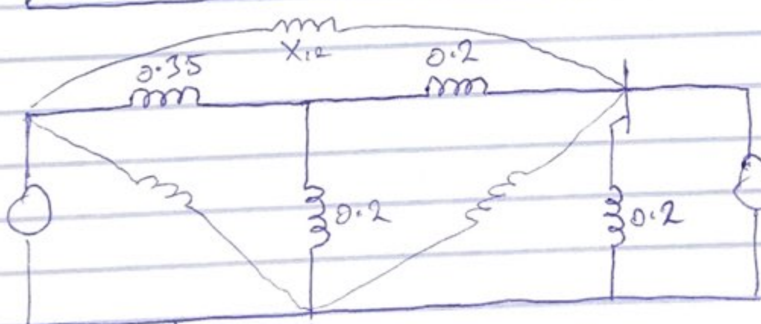
$= 1 - 0.08694 + j0.483$

$= 0.9131 + j0.483$

$= 1.033\angle 27.88°$

ii) When one line is shorted





Using Star-Delta Conversion

$$X_{12} = \frac{0.35(0.2) + 0.35(0.2) + 0.2(0.2)}{0.2}$$

$= 0.9$

$$P_e = \frac{|E|\cdot V}{X}\sin\delta = \frac{1.033\times 1}{0.9}\sin\delta = 1.148\sin\delta$$

$P_{max} = 1.148\ pu$