Form No. T611

Philadelphia University
Faculty of Engineering

Student Name:
Student Number:

Dept. of Electrical Engineering
Second Exam, First Semester: 2017/2018

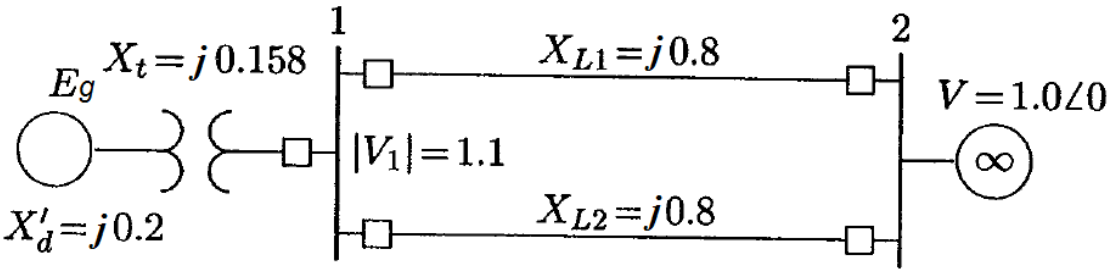
Course Title: Power Systems 2	**Date: 27/12/2017**
Course No: (610412)	**Time Allowed: 50 Minutes**
Lecturer: Dr. Mohammad Abu-Naser	**No. of Pages: 1**

Question 1: ***(10Mark)***

Objectives: This question is related to stability analysis of power systems

A 60 Hz synchronous generator has a transient reactance of *j*0.2 pu and inertia constant H=5.66 MJ/MVA. The generator is connected to an infinite bus through a transformer and a double circuit transmission line as shown in the figure. The generator is delivering a real power of 0.77 pu to bus bar 1. Voltage magnitude at bus 1 is 1.1 pu. The infinite bus voltage $V=1\angle 0°$.

a) Determine internal generator voltage (E_g)
b) Write the swing equation that describes the rotor angle during disturbance.
c) A three-phase fault occurs at the middle of one of the lines, the fault is cleared, and the faulted line is isolated. Determine the critical clearing angle using the equal-area criterion.

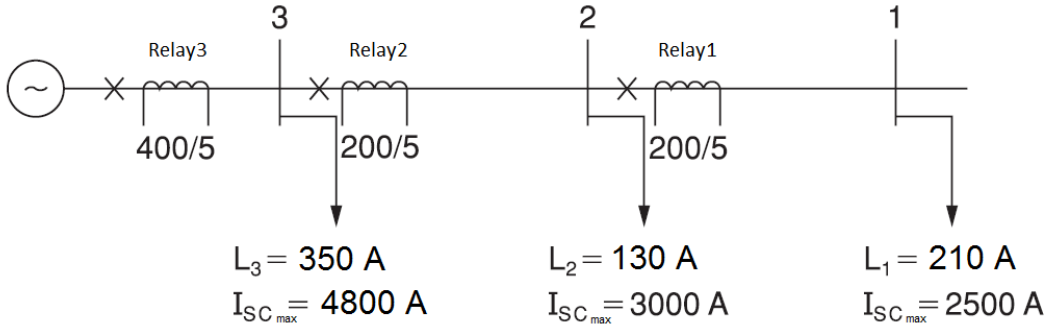


Question 2: ***(10Mark)***

Objectives: This question is related to protection of power systems

For the radial system shown below:

a) Select relay settings (CTS and TDS) to protect the system with 0.4 second coordination time interval. Assume CO-7 relay characteristics.
b) Determine the operating time of circuit breakers 1 and 2 for a fault of 1600A.



Good luck

Power Systems 2
Second Exam
First semester, 2017/2018
Model Answers

Question 1

a) $P = \frac{V_1 V_2}{X} \sin\delta$

$0.77 = \frac{1.1 \times 1}{.8 \| 1.8} \sin\delta \Rightarrow 0.77 = \frac{1.1}{0.4} \sin\delta \Rightarrow \delta = 0.28 \text{ rad} = 16^\circ$

$V_1 = 1.1 \angle 16^\circ$ pu

$I = \frac{V_1 - V_2}{j.4} = \frac{1.1\angle 16^\circ - 1\angle 0^\circ}{j.4} = .773 \angle -10.65^\circ$ pu

$E_g = V_1 + I(j.2 + j.158)$

$= 1.1\angle 16^\circ + .773\angle -10.65^\circ (j.358) = 1.25 \angle 27.5^\circ$

$\delta_0 = 0.48 \text{ rad} = 27.5^\circ$

b) $P_{e_1} = \frac{E_g V_t}{X} \sin\delta$

$= \frac{1.25 \times 1}{.8 \| 1.8 + .2 + .158} \sin\delta = 1.648 \sin\delta$

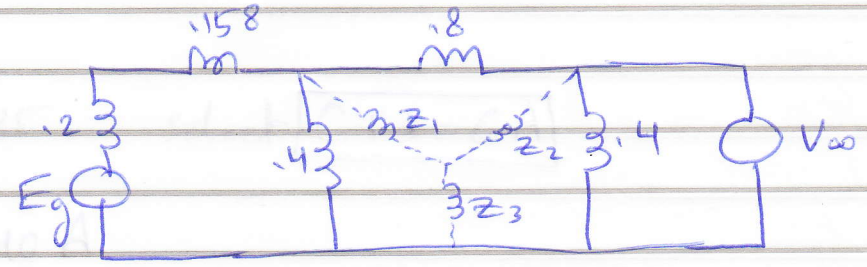
$\frac{H}{\pi f} \frac{d^2\delta}{dt^2} = P_m - P_e$

$\frac{5.66}{\pi \times 60} \frac{d^2\delta}{dt^2} = .77 - 1.648 \sin\delta$

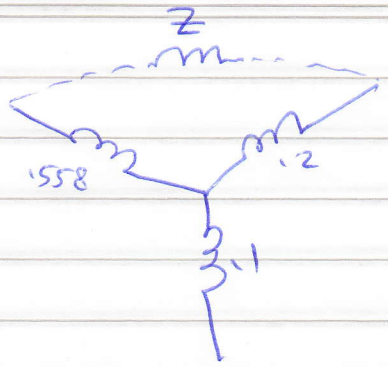
$\frac{d^2\delta}{dt^2} = 25.64 - 54.88 \sin\delta$

c) $Z_1 = Z_2 = \frac{.8 \times .4}{.8 + .4 + .4} = .2$

$Z_3 = \frac{.4 \times .4}{.8 + .4 + .4} = .1$



$Z_1 + .2 + .158 = .558$



$$Z = .2 + .558 + \frac{.2 \times .558}{.1}$$

$$= 1.874$$

$$P_{e2} = \frac{E_g V_2}{Z} \sin\delta$$

$$= \frac{1.25 \times 1}{1.874} \sin\delta = 0.667 \sin\delta$$

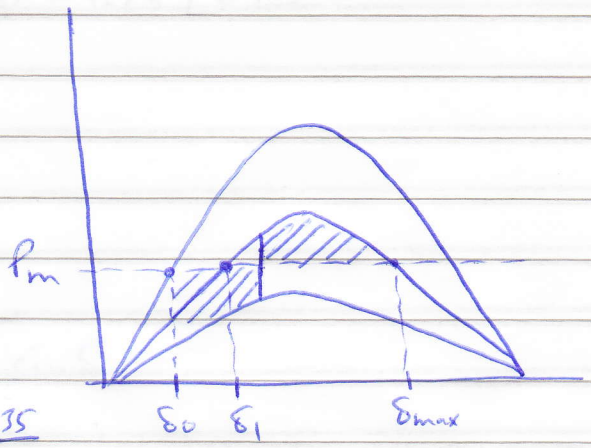
$$P_{e3} = \frac{E_g V_2}{.2 + .158 + .8} \sin\delta = 1.079 \sin\delta$$

$$\delta_1 = \sin^{-1}\left(\frac{.77}{1.079}\right) = .795 \text{ rad}$$

$$= 45.53^\circ$$

$$\delta_{max} = \pi - .795$$

$$= 2.35 \text{ rad} = 134.5^\circ$$



$$\cos\delta_{cr} = \frac{P_m(\delta_{max} - \delta_0) - P_{max2}\cos\delta_0 + P_{max3}\cos\delta_{max}}{P_{max3} - P_{max2}}$$

$$= \frac{.77(2.35 - .48) - .667\cos.48 + 1.079\cos 2.35}{1.079 - .667}$$

$$= .22$$

$$\delta_{cr} = \cos^{-1} .22 = 1.35 \text{ rad} = 77.2^\circ .$$

Question 2

a) Relay 1

$$PSM = \frac{210}{200/5} = 5.25 \quad \text{select } \boxed{CTS = 6A}$$

Relay 2

$$I_{L2} = 210 + 130 = 340 \text{ A}$$

$PSM = \frac{340}{200/5} = 8.5$ select $\boxed{CTS = 10}$ A

Relay 3

$I_{L3} = 210 + 130 + 350 = 690$ A

$PSM = \frac{690}{400/5} = 8.625$ select $\boxed{CTS = 10}$ A

Now TDS

Relay 1

$PSM = \frac{3000/200/5}{6} = 12.5$

$\boxed{TDS = \frac{1}{2}}$, From curve $T_1 = 0.1$ s.

Relay 2

backup $PSM = \frac{3000/(200/5)}{10} = 7.5$

$T_2 = .4 + .1 = .5$ s $\Rightarrow \boxed{TDS = 2}$.

Relay 3

relay 2 primary $PSM = \frac{4800/200/5}{10} = 12$, from curve $T_2 = .4$ s

relay 3 backup $PSM = \frac{4800/400/5}{10} = 6$

$T_3 = .4 + .4 = .8$ s $\Rightarrow \boxed{TDS = 3}$

b) Relay 1

$PSM = \frac{1600/200/5}{6} = 6.67$

From curve $TDS = \frac{1}{2} \Rightarrow T = 0.1$ s

Relay 2

$PSM = \frac{1600/200/5}{10} = 4$

From curve $TDS = 2 \Rightarrow T = 0.7$ s