UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: July 2017

Module Number: EE7203 **Module Name: Power System Analysis**

[Three Hours]

[Answer **all questions**, each question carries **10 marks**]

Q1 a) Starting from the first principles, develop the sequence network diagrams for,

i) line to line to ground (L-L-G) fault.

ii) open conductor fault in a one phase.

[4 Marks]

b) A single line diagram of a power system is shown in Figure Q1. The neutrals of the generator and the transformer T_1 are solidly grounded.

i) Draw the per unit sequence network diagrams for the single line diagram shown in Figure Q1.

ii) Calculate the fault current, for a line to line to ground(L-L-G) fault from phase '*b*' to phase '*c*' to ground at the point F in the power system shown in Figure Q1. Assume that the pre-fault voltage at the generator is $1.2\angle 0^0$ per unit.

[6 Marks]

Q2 a) A four pole, 50 Hz, 100 MVA turbo-generator has an inertia constant of 8.0 MJ/MVA.

i) Calculate the stored energy in the rotor at synchronous speed.

ii) If the mechanical input is suddenly increased to 80 MW for an electrical load of 50 MW, calculate the rotor acceleration neglecting mechanical and electrical losses.

iii) If the acceleration calculated in ii), is maintained for 10 cycles, calculate the change in torque angle and rotor speed in revolutions per minute at the end of 10 cycles.

[3 Marks]

b) In the power system shown in Figure Q2 (b), initially the circuit breaker A is closed while the circuit breaker B is open. A three phase fault occurs at point P close to the bus and it is cleared by the circuit breaker A, after a short period of time. Prove that the critical clearing time is given by the equation,

$$t_{cr} = \sqrt{\frac{4H}{\omega_s P_m}(\delta_{cr} - \delta_0)}$$

where,

t_{cr}	=	critical clearing time
δ_{cr}	=	critical clearing angle
P_m	=	mechanical input power in p.u.
δ_0	=	Initial operating angle for mechanical input power P_m
H	=	inertia constant
ω_s	=	synchronous speed of the machine

[2 Marks]

c) The single line diagram of Figure Q2 (c) shows a generator connected through two parallel transmission lines to a large metropolitan area which can be considered as an infinite bus. A short transmission line is connected to the bus 1 as indicated in Figure Q2 (c). The generator which is operating at 50 Hz is delivering 1.0 p.u. power to the system and the inertia constant of the machine is 5 MJ/MVA. Both the terminal voltage and the infinite bus voltage are 1.0 p.u. At point F, close to the bus 1, a three phase fault occurs and it is cleared by the circuit breaker CB_5, after a short period of time. Determine,

i) the critical clearing angle.

ii) the critical clearing time.

[5 Marks]

Q3 a) i) State the importance of numerical solution of swing equation in power system stability studies.

ii) List the assumptions made in the numerical solution of swing equation using point by point method.

[3 Marks]

b) A 400 MVA, 50 Hz generator delivers 380 MW over a double circuit line to an infinite bus. The generator has a kinetic energy of 8 MJ/MVA at rated speed. A three phase short circuit occurs at the mid point of a line and it is cleared after 0.25 seconds. The pre-fault, during the fault and the post fault power angle characteristics are given by $P_{e1} = 1.69 \sin\delta$, $P_{e2} = 0.495 \sin\delta$ and $P_{e3} = 1.2 \sin\delta$ respectively. Obtain the torque against time curve for the system up to 0.3 seconds by taking the time interval of 0.05 seconds.

[7 Marks]

Q4 a) i) What is the function of an excitation system in a power plant?

ii) List the types of excitation systems available.

iii) Describe the operation of a dc excitation system with necessary diagrams.

iv) Draw the block diagram of the Automatic Voltage Regulation (AVR) loop.

v) Explain the role of Automatic Load Frequency Control (ALFC) system in a power system.

[6 Marks]

b) The following data are given for a control area of a power system.

Rated capacity	=	500 MW
Operating load	=	250 MW
Inertia Constant	=	5 seconds
Speed regulation of the governor	=	2.4 Hz/ p.u. MW
Operating frequency	=	50 Hz

i) Determine the primary ALFC parameters for the control area assuming a linear load frequency variation.

ii) Calculate the static frequency drop, if the load is suddenly increased by 50 MW without changing the speed changer setting.

iii) Calculated the increase in generator output due to the frequency drop calculated in ii).

[4 Marks]

Q5 a) i) List the main components in a protective system and explain their functions.

ii) Current Transformers (CTs) are used for the metering purposes as well as for the protection purposes. State the differences between a metering CT and a protection CT.

iii) List the types of overcurrent protection relays and draw the time-current characteristic curves for each overcurrent relay.

iv) Explain why a differential protection is considered as a unit protection.

v) Explain what is meant by time based discrimination and current based discrimination in a protective system.

[7 Marks]

b) i) Describe the operating principle of a distance protection relay with appropriate diagrams.

ii) List the types of distance protection relays.

[3 Marks]

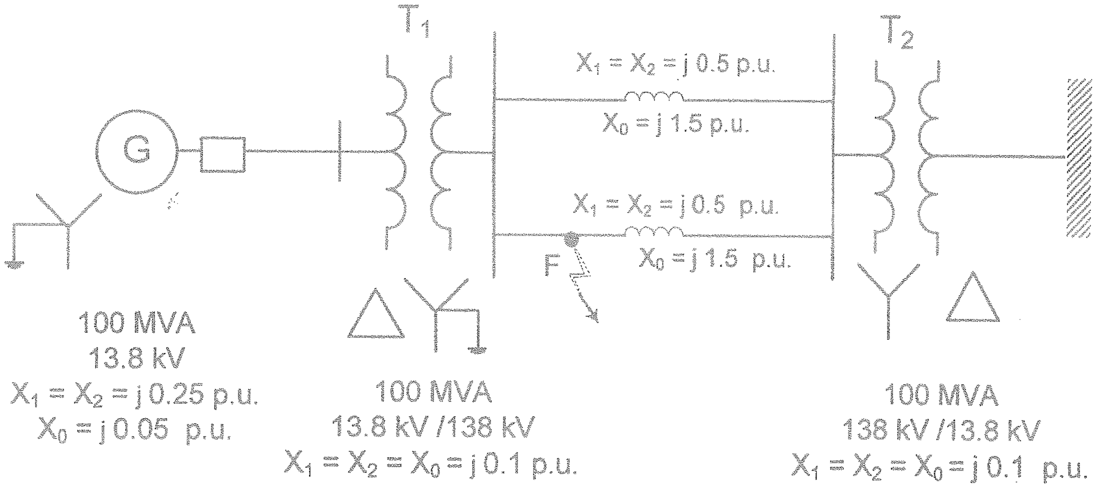

Figure Q1

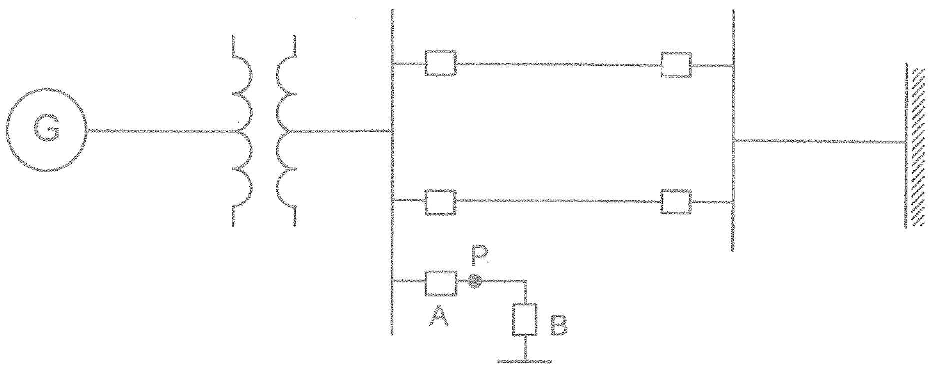

Figure Q2 (b)

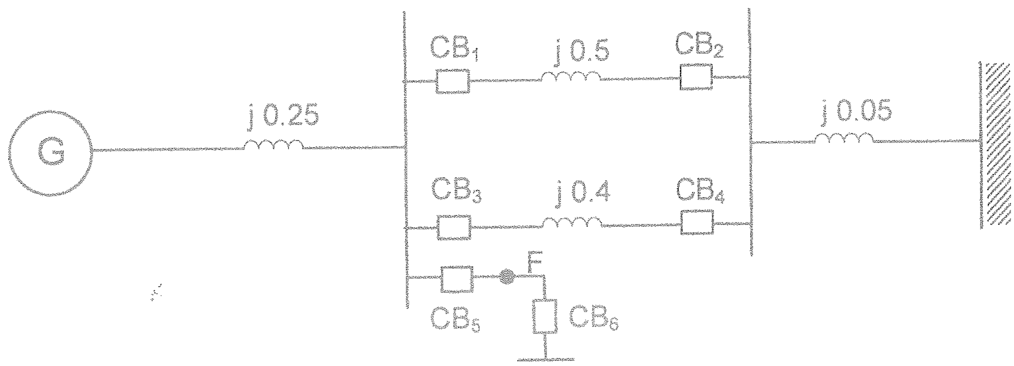

Figure Q2 (c)