UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: August 2015

Module Number: EE7240 **Module Name: Power System Analysis**

[Three Hours]

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

Q1 a) List the symmetrical and unsymmetrical fault types.

[1 Mark]

b) Starting from the first principles, develop sequence network connections for,

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

ii) open conductor fault in one conductor.

[4 Marks]

c) A single line diagram of a power system is shown in Figure Q1. The neutrals of the generator and the transformers are solidly grounded. The neutral of the motor is grounded through a reactance of $X_n = 0.05$ per unit on the motor base.

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

ii) Calculate the fault current in per unit for a single line to ground fault in phase '*a*' at the bus 2 in the power system shown in Figure Q1, by taking the pre-fault voltage (V_F) as $1.05 \angle 0^0$ per unit.

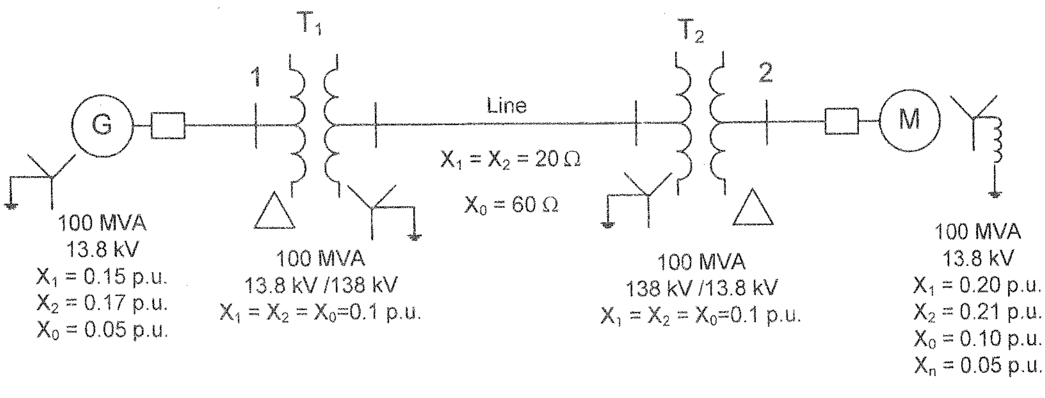

Figure Q1

[5 Marks]

Q2 a) What are the methods which can be used to improve the transient stability limit of a power system?

[1 Mark]

b) Explain the importance of swing curve in the context of power system stability.

[1 Mark]

c) A 2200 MVA, 24 kV and 60 Hz synchronous machine is connected to an infinite bus through a transformer and a double circuit line as shown in Figure Q2. The infinite bus voltage is 1.0 per unit. The direct axis transient reactance of the generator is 0.3 per unit. The transformer reactance is 0.2 per unit and the reactance of each transmission line is 0.3 per unit. Initially the machine is delivering 0.8 per unit real power and reactive power is 0. 074 per unit with a terminal voltage of 1.0 per unit. The inertia constant (H) is 5 MJ/MVA. All per unit quantities are calculated to a base of the rating of the synchronous machine.

i) A temporary three phase fault occurs at the sending end of one of the lines. When the fault is cleared, both lines are operating under normal conditions. Determine the critical clearing angle.

ii) If a three phase fault occurs at the middle of one of the lines and faulty line is isolated, determine the critical clearing angle.

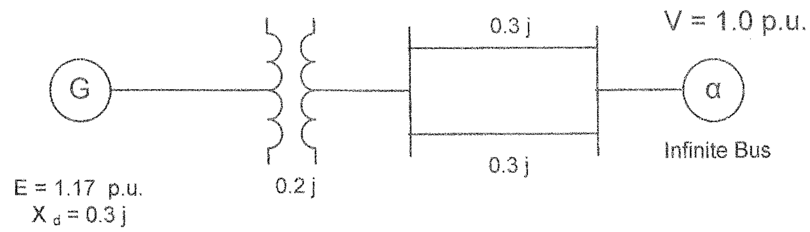

Figure Q2

[8 Marks]

Q3 a) List the assumptions made in the solution of the swing equation by point by point method

[2 Marks]

b) A 20 MVA, 50 Hz generator delivers 18 MW over a double circuit line to an infinite bus as shown in Figure Q3. The generator has kinetic energy of 2.52 MJ / MVA at rated speed and its transient reactance (X_d) is 0.35 per unit. Each transmission line has a reactance of 0.2 per unit on a 20 MVA base. Infinite bus voltage (V) is 1.0 per unit. A three phase fault occurs at the mid-point of one of the transmission lines. Obtain the swing curve over a period of 0.2 seconds for a sustained fault.

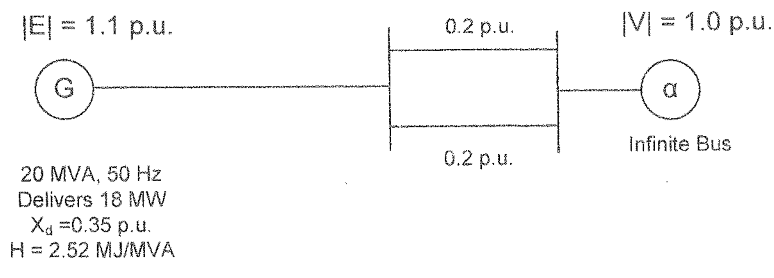

Figure Q3

[8 Marks]

Q4 a) What is the basic role of Automatic Load Frequency Control (ALFC)?

[1 Mark]

b) Draw the complete block diagram of uncontrolled single area ALFC loop.

[2 Marks]

c) Consider the speed governing system of 50 Hz, 100 MW generator having 6% speed regulation. Find the increase in frequency, if the turbine power is decreased by 4 MW with the speed changer setting unchanged.

[2 Marks]

d) Develop an expression for static frequency drop corresponding to step load increase assuming that the speed changer remains unchanged.

[2 Marks]

e) The data pertaining to an uncontrolled single area power system are as follows.

Total rated capacity	= 2500 MW
Nominal operating load	= 1500 MW
Nominal Frequency	= 50 Hz
Inertia constant	= 4 sec.
Speed Regulation	= 2 Hz/MW per unit

Assume that the load frequency characteristic of the system is linear. For a decrease of 20 MW load, determine,

i) steady state frequency deviation.

ii) transfer function of the power system.

[3 Marks]

Q5 a) What is meant by a fault in a power system?

[0.5 Marks]

b) Discuss the effects of faults in a power system.

[1.5 Mark]

c) Briefly explain the operating principle of following relays.

i) Current differential relay

ii) Voltage differential relay

[2 Marks]

d) Consider the radial system of feeders shown in Figure Q5. There are four substations (B, C, D and E) fed from station A, making four feeder zones. The calculated fault currents at each of the substations are shown in Table Q5. The maximum load current at each bus is 100 A. The operating time of the breakers is 0.5 s and overshoot is 10%. Design a overcurrent protection scheme for this system using Inverse Definite Minimum Time (IDMT) relays by calculating the,

i) CT ratios,

ii) Plug Setting Multiplier (PSM) and

iii) Time Setting Multiplier (TSM) for each of the IDMT relays placed at A, B, C and D substations.

Make the necessary assumptions and state them all.

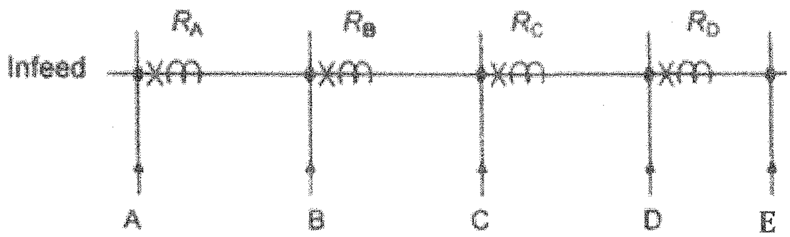

Figure Q5

Table Q5: Fault currents at each of the substations

Substation	A	B	C	D
Fault Current (A)	6000	5000	3000	2000

[6 Marks]