UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2021

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

[Three Hours]

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

Q1. a) Derive swing equation for a single machine connected to an infinite bus.

[2.0 Marks]

b) A generator operating at 50 Hz delivers 1 pu power to an infinite busbar through a network in which resistance can be neglected. A fault occurs in the network reducing the maximum power transferable to 0.2 pu. Before the fault, maximum power transferable is 1.8 pu and after clearing the fault it is 1.5 pu.

i) Draw power (pu) vs load angle (radians) curves for pre-fault, post-fault and during the fault situations in the same graph.

[2.0 Marks]

ii) Using the equal area criterion, determine the critical clearing angle.

[4.0 Marks]

iii) Suggest a method to improve the stability of this system.

[2.0 Marks]

Q2. a) Draw the block diagram of the Automatic Voltage Regulator (AVR) of a synchronous generator by indicating all transfer functions inside each model.

[2.0 Marks]

b) Briefly explain the function of a governor in a steam power plant.

[1.0 Mark]

c) Two generators G1 and G2 with ratings of 350 MW and 250 MW with generator droops of 4% and 3% respectively deliver a common load of 450 MW in parallel at 50 Hz with 60% share coming from G1. Assume free governor action.

i) Determine no load and full load frequencies of each generator.

[4.0 Marks]

ii) Determine the maximum load that the pair of generators can deliver without overloading either of them and the corresponding operating frequency of the generators.

[3.0 Marks]

Q3. a) List three types of over current relays.

[1.0 Mark]

b) Consider the power system shown in Figure Q3b1. Assume BC is a transmission line and there are three distribution lines starting from C. Use the following data for your calculations.

Breaker number	Current Transformer (CT) ratio
1	300/5
2	1200/5
3	2200/5
4	300/5

- All relays have inverse time characteristics.
- Over Load Factor (OLF) for pick-up setting is 1.5
- Relay data:
  - Pick-up setting: 1 to 12 A in steps of 1 A
  - Time dial setting as shown in Figure Q3b2
  - Instantaneous setting: 6 to 144 A in steps of 1A

i) Calculate the nominal currents and three phase short circuit currents at each breaker.

[3.0 Marks]

ii) Determine the pick-up setting, time dial setting and instantaneous setting of Relay 1 and Relay 2 to ensure a coordinated protection arrangement.

[3.0 Marks]

iii) Draw the Time vs Plug Multiplier Setting (PMS) curves of Relay 1 and Relay 2 in the same graph.

[3.0 Marks]

Q4. a) Explain <u>one</u> of the following protection types.

- Distance protection
- Generator protection
- Transformer protection

[5.0 Marks]

b) Draw the schematic diagram of a single phase transformer differential protection scheme by indicating the salient parameters.

[2.0 Marks]

c) Explain the limitations of numerical relays compared to those in electromechanical relays.

[3.0 Marks]

Q5. a) Briefly explain what a per unit (pu) system is.

[2.0 Marks]

b) Prove that for a line to ground (L-G) fault on a generator, the sequence networks should be connected in series during the network analysis.

[3.0 Marks]

c) A single line to ground fault occurs on phase A of a 30 MVA, 11 kV, star connected three phase generator. The generator is running on no load at the rated terminal voltage. It has positive, negative and zero sequence reactances of 0.6 pu, 0.4 pu and 0.08 pu respectively. Assume that the generator neutral is grounded through a reactance of 6 Ω. Using the proof in Q5. b), calculate the fault current.

[5.0 Marks]

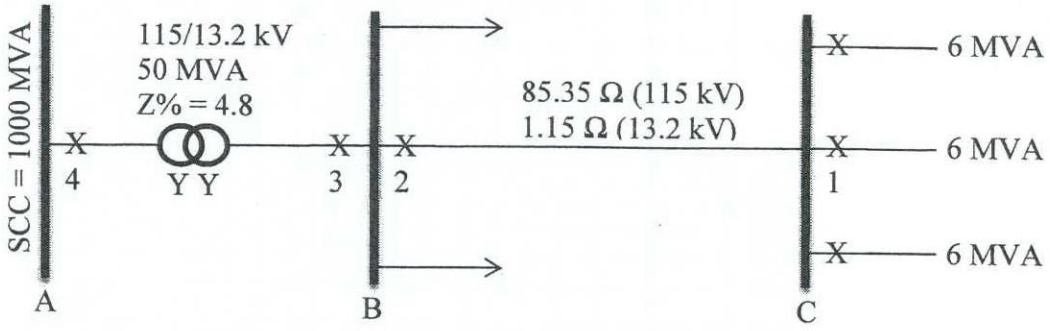

Figure Q3b1

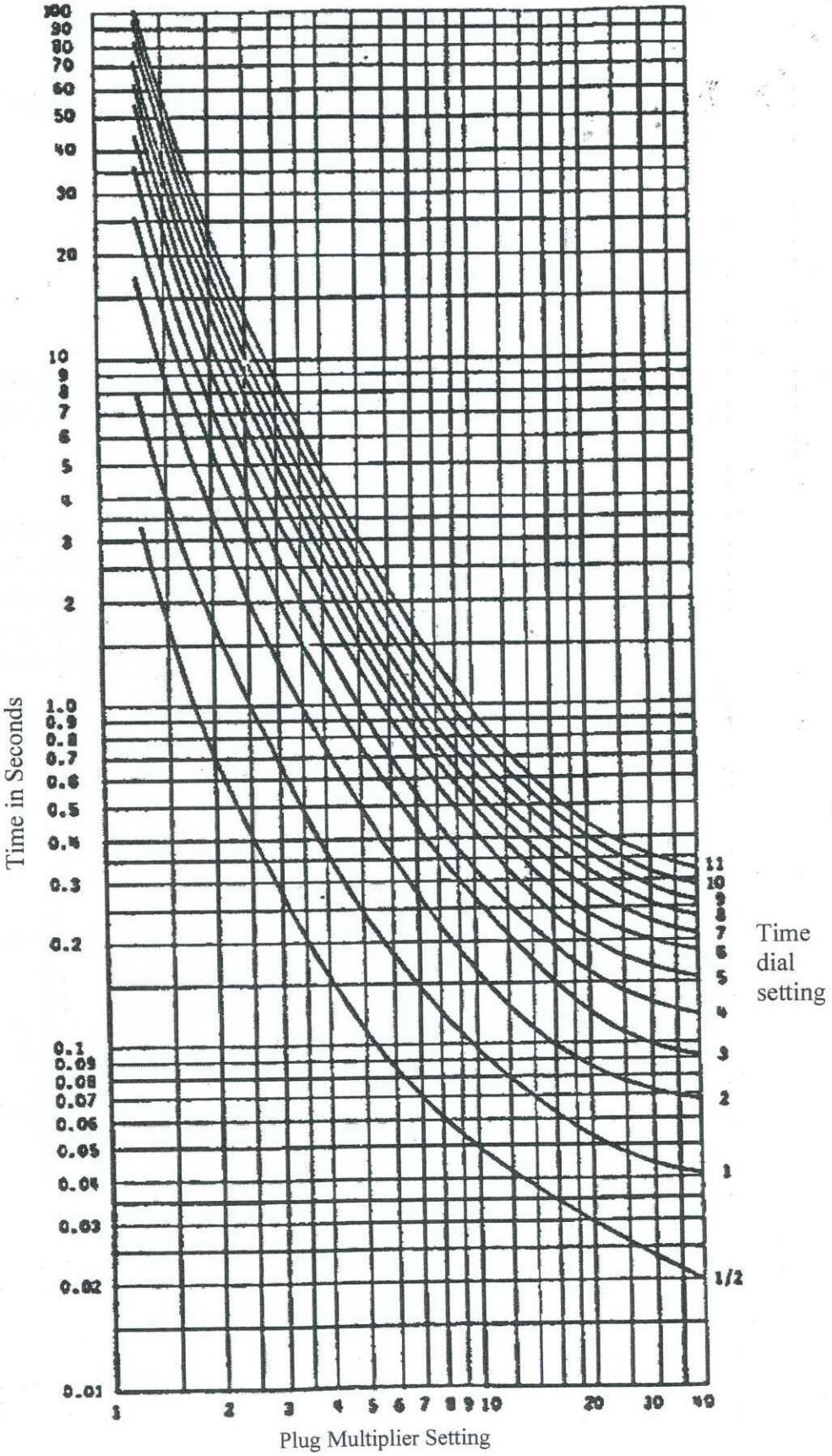
Time in Seconds
100
90
80
70
60
50
40
30
20
10
9
8
7
6
5
4
3
2
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
1
2
3
4
5
6
7
8
9
10
20
30
40
Plug Multiplier Setting
11
10
9
8
7
6
5
4
3
2
1
1/2
Time dial setting

Figure Q3b2