UNIVERSITY OF RUHUNA

Faculty of Engineering

End-Semester 7 Examination in Engineering: March 2022

Module Number: EE7215 **Module Name: Power System Protection (C-18)**

[Three Hours]

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

Q1 a) i) What is power system protection coordination and why is it important?

ii) Explain three types of protection coordination methods.

[2 Marks]

b) Figure Q1 shows an 11 kV power system. The feeder protection breaker CB1 is operated by a numerical relay with Standard Inverse (SI) overcurrent protection and an Instantaneous over current protection. The fault level at the location of CB1 is 6000 A. Strong faults (above 3000 A) will be cleared by the instantaneous overcurrent element of R1. Weaker faults towards the end of the feeder (equal to and less than 3000 A) will be cleared by the SI element of R1.
The pickup current for R1 SI element must be set at 45 MVA (150% of the maximum load of 30 MVA). Rate CT1 for 45 MVA continuous load. Relay R2 is the backup to R1. It has SI element only. R2 SI element must be set at 60 MVA. Rate CT2 for 60 MVA continuous load.
In addition, the following information is given for the system.

Relays:

SI pickup range: 1-12 A, Step = 0.5 A
TMS range: 0.1-1, Step = 0.05
Instantaneous pickup range: 6-144 A, Step = 1 A

CT's:

Accuracy: 10P20
Secondary: 5A
Burden = 1 Ω
Ratios given to select: 100/5,250/5,400/5,600/5,800/5

SI time characteristic formula

$$t_d = \frac{TMS \times 0.14}{(\frac{I}{I_{pickup}})^{0.02} - 1}$$

where,

t_d - Operation time delay (SI)
TMS - Time Multiplier Setting
I - Actual fault current
I_{pickup} - Pick up current

i) Calculate Current Transformer (CT) ratios for CT1 and CT2.

ii) Calculate the pickup current of the instantaneous overcurrent element of R1 and the SI element of R1.

iii) Calculate the pickup current of the SI element of R2.

iv) If the TMS of R1 is set to 0.1 s, determine the TMS for R2 to have a minimum discrimination time of 0.3 s for 1500 A fault current at point A. Given that CB2 to CB1 line impedance is negligible.

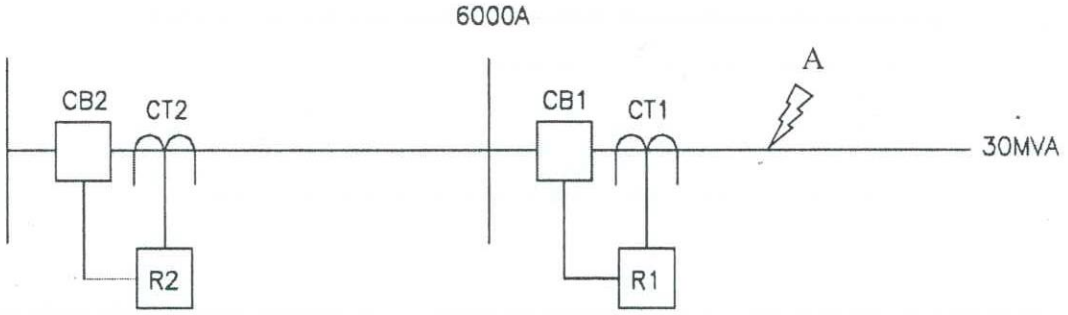

Figure Q1

[8 Marks]

Q2 a) i) What is differential protection relay? Explain applications of differential protection in power system protection.

ii) Explain working principle of percentage differential protection relay.

[4 Marks]

b) Figure Q2 shows a 132/33 kV transformer having continuous rating of 60 MVA, 140% short-time overload capacity and differential protection. High Voltage (HV) side CT is 300/5 and Low Voltage (LV) side CT is 1500/5. To ensure the stability for the differential protection scheme for load current and external through faults, the CT currents from the 132 kV high voltage and 33 kV medium voltage (MV) sides of the transformer must be balanced at the differential protection elements.

i) Calculate the HV and LV side CT secondary current at full load condition.

ii) What is the ideal ratio for the auxiliary transformer windings?

iii) Show that the differential protection scheme is stable in 140% load condition with selected auxiliary transformer ratio.

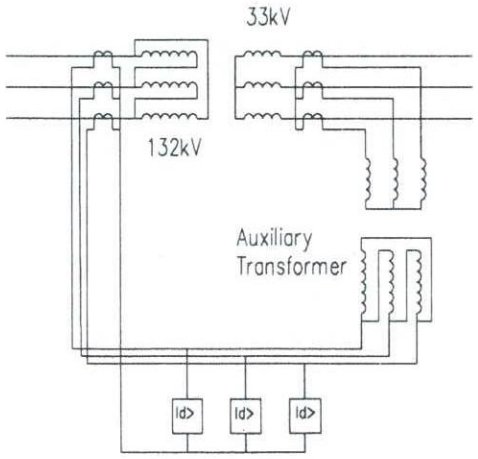

Figure Q2

[6 Marks]

Q3 a) i) What is the difference between protection relay commissioning test and periodic maintenance test?

ii) Explain the importance of protection relay periodic maintenance test.

[4 Marks]

b) In a 33 kV electrical system metering circuit, 4 meters are connected to a CT as shown in Figure Q3. The distance from CT to the meter panel is 28 m. The CT and the meters are connected using a 2 Core, 4 mm^2 Cu cable. Cable resistance per meter is 4.61 mΩ/m. The CT ratio is 200/5 A. The available burden ratings of CT are 2.5, 5, 10, 15, 20 and 30 VA.

i) Select most suitable CT burden rating for the given circuit from the available CT burden ratings.

ii) If the CT is ring type, propose a method to use it as 100/5 A CT for a feeder with rated ampere rate of 100 A.

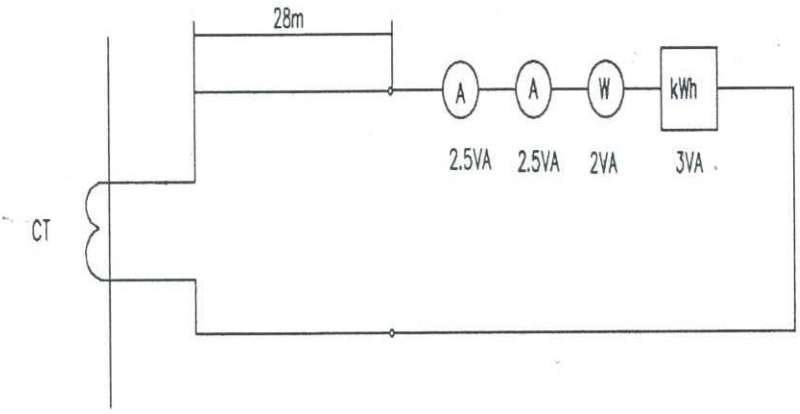

Figure Q3

[6 Marks]

Q4 a) i) Explain advantages of distance protection relay in transmission line protection with compared to line overcurrent protection and line differential protection relay.

ii) With a neat sketch, explain the working principle, the torque equation and the operational characteristics for admittance relay.
Universal torque equation is given as

$$T = K_1 I^2 + K_2 V^2 + K_3 VI \cos(\theta - \tau) + K_4$$

Where, all the notations have usual meanings.

[6 Marks]

b) It is given that the pick-up value for reverse power stage P< 32R is 4 % of the rated active power of a generator. Generator apparent power is 2500 kVA, rated power factor is 0.8 and rated voltage is 11 kV.

i) Calculate the reverse power pick-up current setting.

ii) Propose a time characteristic for the reverse power protection function.

[4 Marks]

Q5 a) i) Explain the importance of reverse power protection in generator protection?

ii) What is the difference between the overcurrent protection relay and the thermal overload relay?

[3 Marks]

b) Table Q5 gives the data sheet of a motor.

i) Calculate the Hot/Cold ratio.

ii) Calculate the motor full load current.

iii) If the motor service factor is 1.1, calculate the thermal overload relay pick up current.

iv) Calculate the Time Multiplier Setting of the relay if tripping time at lock rotor should be 80% of the lock rotor withstand time at minimum starting voltage (Cold Condition). The thermal overload relay operating characteristics formula is given by

$$t_d = \frac{TMS \times 0.14}{(\frac{I}{I_{pickup}})^{0.02} - 1}$$

where, all the symbols have their usual meaning.

v) Show that with the selected thermal overload protection characteristics, the motor starting operation is safe.

Table Q5

Rated output (kW)	650 kW
Rated voltage (V)	6600 V
No. of phases and frequency	3 Ph. 50 Hz
Power factor	0.85
CT Ratio	100 A / 1 A
Locked rotor current in % of Full Load Current (FLC)	500%
Starting current in % of FLC	600%
Starting time	22 s
Locked rotor withstand time (Hot Condition)	23 s
Locked rotor withstand time (Cold Condition)	33 s
Maximum permissible starting time	39 s
No load current	30 A
Locked rotor withstand time at minimum starting voltage	32 s (Hot) 45 s (Cold)
Maximum Permissible running time at full load and at 75% rated voltage	5 min

[7 Marks]