



# MACHAKOS UNIVERSITY

University Examinations for 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONIC ENGINEERING)

EEE 505: SWITCHGEAR AND PROTECTION

DATE:

TIME:

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**INSTRUCTIONS:** This examination paper contains five questions. Answer **Question ONE** and any other **TWO Questions**. Question ONE carries 30 Marks and ALL the other questions carry 20 Marks each.

## QUESTION ONE (COMPULSORY) (30 MARKS)

- a) Give four classifications of circuit breakers. (2 marks)
- b) List four important components found in a switchgear. (2 marks)
- c) Give six advantages of a fuse (3 marks)
- d) A fuse wire of a circular cross section has a radius of 0.8mm. The wire blows off at a current of 8A. Calculate the radius of the wire that will blow off at a current of 1A. (4 marks)
- e) Using well labelled diagrams explain the following bus-bar architecture (4 marks)
  - i. Single bus bar system
  - ii. Single bus-bar system with sectionalisation
- f) A star connected 3 phase, 10MVA, 6.6kV alternator is protected by Merz-price circulating current principle using 1000/5 amperes current transformers. The star point of the alternator is earthed through a resistance of 7.5  $\Omega$ . If the minimum operating current for the relay is

0.5A, calculate the percentage of each phase of the stator winding which is unprotected against earth faults when the machine is operating at normal voltage (8 marks)

g) An alternator rated 10kV is protected by balance circuiting current system has its neutral grounded through a resistance of  $10\Omega$ . The protective relay is set to operate when there is an out of balance of 1.8A in the pilot wires which are connected to the secondary of current transformer with ratio 1000/5. Determine: (7 marks)

- i) The percentage winding which remains unprotected
- ii) The minimum value of the earthing resistance required to protect 80% of the winding

### QUESTION TWO (20 MARKS)

a) Explain the arc phenomenon of a circuit breaker. (2 marks)

b) What are some of the methods which are used to increase the resistance of the arc. (2 marks)

c) Briefly discuss the following terms as used in power system protection. (6 marks)

- i. Arc voltage
- ii. Re-striking voltage
- iii. Recovery voltage

d) A 3-phase transformer of 220/11000 line volts is connected in star/delta. The protective transformers on 220V side have current ratio of 600/5. What should be the CT ratio on 11000V side? (4 marks)

e) The overcurrent relay has a current setting of 150% and a time multiplier of 06. The primary of relay is connected to secondary CT having ratio of 400/5. Calculate the time of operation if the circuit carries a fault current of 5000A. The time current characteristics of the relay as shown in the figure Q2 (e) below. (6 marks)

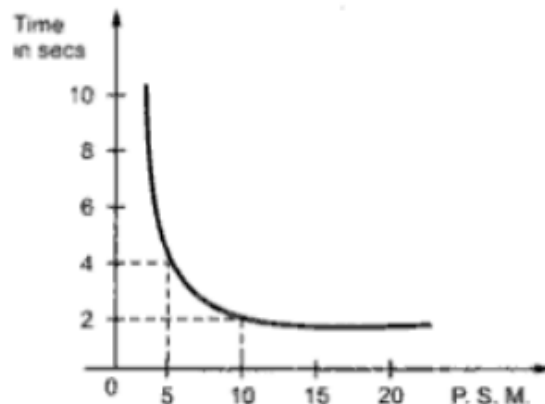


Figure Q2(e)

### QUESTION THREE (20 MARKS)

- a) Explain the following types of circuit breakers (4 marks)
- i. Bulk oil circuit breaker
  - ii. Low oil circuit breaker
- b) A circuit breaker is rated as 1500A, 1000MVA, 33kV and 3 seconds 3-phase oil circuit breaker. Find: (6 marks)
- i. Rated normal current
  - ii. Breaking capacity
  - iii. Rated symmetrical breaking current
  - iv. Rated making current
  - v. Short time rating
  - vi. Rated service voltage
- c) A 6.6kV, star connected alternator has a transient reactance of  $2\Omega$  per phase and negligible winding resistance. It is protected by circulating current Merz-Prince protection. The alternator neutral is earthed through the resistance of  $7.5\ \Omega$ . The relays are set to operate when there out of balance current of 1A in secondary of 500/5A a current transformer. How much % of winding is protected against earth fault? (10 marks)

### QUESTION FOUR (20 MARKS)

- a) Show that the current carrying capacity of a fuse element is directly proportional to its diameter (2 marks)
- b) A fuse wire of circular cross section has a radius of 0.8mm. The wire blows off at a current of 8A. Calculate the radius of the wire that will blow off at a current of 1A. (3 marks)
- c) A three phase transformer having line voltage ratio of 0.4kV/11kV is connected in star-delta and protective transformers on the 400V side have a current ratio of 500/5. What must be the ratio of the protective transformer on the 11kV side? (6 marks)
- d) A 10 MVA, 6.6 kV, 3-phase star-connected alternator is protected by Merz-Price circulating current system. If the ratio of the current transformers is 1000/5, the minimum operating current for the relay is 0.75 A and the neutral point earthing resistance is  $6\Omega$ , calculate :

- i) The percentage of each of the stator windings which is unprotected against earth faults when the machine is operating at normal voltage. (5 marks)
- ii) The minimum resistance to provide protection for 90% of the stator winding. (4 marks)

**QUESTION FIVE [20 MARKS]**

- a) Explain the principle of operation of the following types of relays (6 marks)
  - i. Attracted armature type relay
  - ii. Solenoid type relay
  - iii. Balanced beam type relay
- b) A 50MVA, 3-phase, 33kV synchronous generator is protected by the Merz-Price protection using 1000/5 ratio CTs. It's provided with restricted earth fault protection with the earthing resistance of  $7.5\Omega$ . Calculate the percentage of winding unprotected in each phase against earth faults if the minimum operating current of relay is 0.5A.

**(6 marks)**

- c) A synchronous generator rated at 20kV protected by circulating current system having neutral grounded through a resistance of  $15\Omega$ . The differential protective relay is set to operate when there is an out of balance of 3A. the CTs have a ratio of 1000/5A. Determine:  
**[8Marks]**
  - i) The % of winding remains unprotected
  - ii) The value of earth resistant to achieve 75% protection of winding