



MACHAKOS UNIVERSITY

University Examinations 2022/2023 Academic Year

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF BUILDING AND CIVIL ENGINEERING

FIFTH YEAR SECOND SEMESTER EXAMINATION FOR

BACHELOR OF SCIENCE IN ELECTRICAL AND ELECTRONIC ENGINEERING

EEE516: SWITCHGEAR AND PROTECTION

DATE: _____

TIME: _____

INSTRUCTIONS

1. This paper consists of **FIVE** questions.
2. Answer **QUESTION ONE** and any other **TWO** questions.
3. All workings must be clearly shown.

QUESTION ONE COMPULSORY (30 MARKS)

- a) What is a circuit breaker and how is it important in electrical power systems? [2 marks]
- b) Define and explain the following terms as applied to circuit breakers: [4 marks]
- i. Arc voltage
 - ii. Recovery voltage
- c) A 50 Hz, 11 kV, 3-phase alternator with earthed neutral has a reactance of 5 ohms per phase and is connected to a bus-bar through a circuit breaker. The distributed capacitance up to circuit breaker between phase and neutral is $0.01 \mu F$. Determine [6 marks]
- i. peak re-striking voltage across the contacts of the breaker
 - ii. frequency of oscillations
 - iii. the average rate of rise of re-striking voltage up to the first peak
- d) Define and explain the following terms as applied to protective relaying: [4 marks]
- i. Pick-up value
 - ii. Current setting
 - iii. Plug-setting multiplier
 - iv. Time-setting multiplier

- e) Fig. Q1e) shows a curve between time of operation and plug setting multiplier of a typical relay.

Determine the time of operation of a 5-ampere, 3-second overcurrent relay having a current setting of 125% and a time setting multiplier of 0.6 connected to supply circuit through a 400/5 current transformer when the circuit carries a fault current of 4000 A. Use the curve shown in Fig. Q1e.

[4 marks]

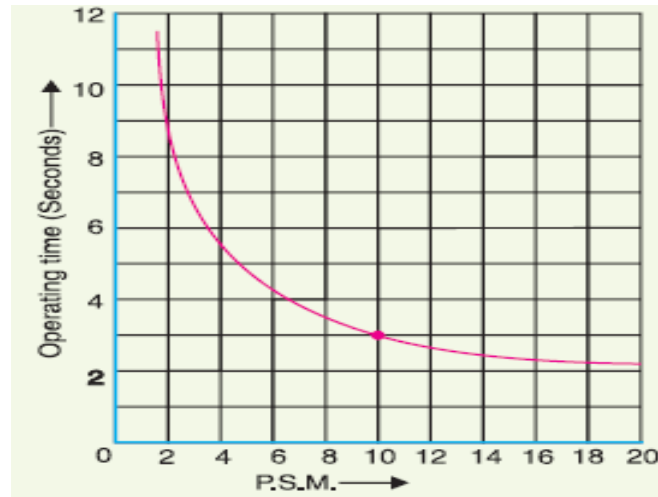


Fig. Q1e)

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 6Ω , Sketch the circuit diagram and hence, calculate:

[6 marks]

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

g) A 3-phase transformer of 220/11,000 line volts is connected in star/delta. The protective transformers on 220 V side have a current ratio of 600/5. What should be the CT ratio on 11,000 V side?

[4

marks]

QUESTION TWO (20 MARKS)

- a) Discuss the following motor protection strategies and how they can be applied to protect an AC motor. [6 marks]

- i. Motor short-circuit protection
- ii. Under-voltage protection
- iii. Loss-of-load protection

- b) Table Q2b) shows relevant parameters of a HV induction motor that needs to be protected. Presented motor is protected using MiCOM P241 relay.

Table Q2b. HV motor characteristics

Parameter	Value
Rated output (kW) – CMR	1000
Rated frequency (Hz)	50
Rated voltage (kV)	3.3
System earthing	Solid
Rated power factor/efficiency	0.9/0.92
Control device	Circuit breaker
Stall withstand time cold/hot (sec)	20/7
Starting current (%)	550 DOL
Permitted starts cold/hot	3/2
CT ratio	250/1
Start time at 100% voltage (sec)	4
Start time at 80% voltage (sec)	5.5
Heating/cooling time constant (min)	25/75

With design explanations, calculate, the following important protection settings:

- (i) Motor thermal protection [2 marks]
 - (ii) Short circuit motor protection [2 marks]
 - (iii) Ground-fault motor protection [2 marks]
 - (iv) Locked rotor/excessive start time motor protection [2 marks]
 - (v) Stall motor protection [2 marks]
 - (vi) Negative phase sequence protection [2 marks]
- c) An air-blast circuit breaker is designed to interrupt a transformer magnetizing current of 11 A (r.m.s.) chops the current at an instantaneous value of 7 A. If the values of L and C in the circuit are 35.2 H and 0.0023 μF , find the value of voltage that appears across the contacts of the breaker. Assume that all the inductive energy is transferred to the capacitance. [2 marks]

QUESTION THREE (20 MARKS)

- a) Why are circuit breakers designed to have a short-time rating? [2 marks]

- b) In a short circuit test on a circuit breaker, the following readings were obtained on single frequency transient: [4 marks]

- (i) time to reach the peak re-striking voltage, 50 μ sec
- (ii) the peak re-striking voltage, 100 kV

Determine the average RRRV and frequency of oscillations.

- c) Describe the construction and principle of operation of an induction type directional overcurrent relay. [8 marks]
- d) A star-connected, 3-phase, 10 – MVA , 6.6 kV alternator has a per phase reactance of 10%. It is protected by Merz-Price circulating-current principle which is set to operate for fault currents not less than 175 A . Calculate the value of earthing resistance to be provided in order to ensure that only 10% of the alternator winding remains unprotected. [6 marks]

QUESTION FOUR (20 MARKS)

- a) Define a protective relay and outline three fundamental requirements of protective relaying. [4 marks]
- b) With the aid of a diagram explain the key concepts behind the Merz-Price voltage balance system for protection of 3-phase feeders. [6marks]
- c) A 3-phase transformer having line-voltage ratio of 0.4 kV/11kV is connected in star-delta and protective transformers on the 400 V side have a current ratio of 500/5. [6marks]
- i. Sketch the circuit connections.
 - ii. What must be the ratio of the protective transformers on the 11 kV side?
- d) A star-connected, 3-phase, 10 MVA, 6.6 kV alternator is protected by circulating current protection, the star point being earthed via a resistance r . Estimate the value of earthing resistor if 85% of the stator winding is protected against earth faults. Assume an earth fault setting of 20%. Neglect the impedance of the alternator winding. [4 marks]

QUESTION FIVE (20 MARKS)

- a) With the aid of a diagram, describe briefly the action of an oil circuit breaker. How does oil help in arc extinction? [6marks]
- b) Briefly outline FOUR essential features of Switchgear. [4marks]
- c) A circuit breaker is rated as 1500 A, 1000 MVA, 33 kV, 3-second, 3-phase oil circuit breaker. Find [6marks]
- i. rated normal current
 - ii. breaking capacity

- iii. rated symmetrical breaking current
 - iv. rated making current
 - v. short-time rating
 - vi. rated service voltage.
- d) A star-connected, 3-phase, 10 MVA, 6.6 kV 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 7.5Ω . If the minimum operating current for the relay is 0.5 A, calculate the percentage of each phase of the stator winding which is unprotected against earth-faults when the machine is operating at normal voltage.

[4marks]