



MACHAKOS UNIVERSITY

University Examinations for 2018/2019

SCHOOL OF ENGINEERING AND TECHNOLOGY

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

FIFTH YEAR SPECIAL/SUPPLEMENTARY EXAMINATION FOR BACHELOR OF SCIENCE (ELECTRICAL AND ELECTRONICS ENGINEERING)

EEE 505: SWITCHGEAR AND PROTECTION

DATE:

TIME:

INSTRUCTIONS

- *This paper consists of Five Questions*
- *Question One is Compulsory*
- *Attempt Any other Two Questions*
- *Make your answers Exact and Concise*

QUESTION ONE (COMPULSORY) (30 MARKS)

For the system shown in Figure Q 1a), and starting from the data that are given there, carry out the following:

- Calculate the nominal currents and three-phase short-circuit levels at each breaker.
- Select the transformation ratios of the CTs.

- Determine the values of the pick-up setting, time dial and instantaneous settings of all phase relays to ensure a coordinated protection arrangement.
- Find the percentage of the line BC protected by the instantaneous unit of the overcurrent relay associated with breaker 2.
- Draw the time/current characteristics of the relays on the system.

Take into account that the discrimination margin is 0.4 s and all relays have inverse time characteristics, as shown in Figure Q 1b). Further, the relays have pick-up setting of 1 to 12 A in steps of 1 A and Instantaneous currents of 6 to 144 A in steps of 1 A.

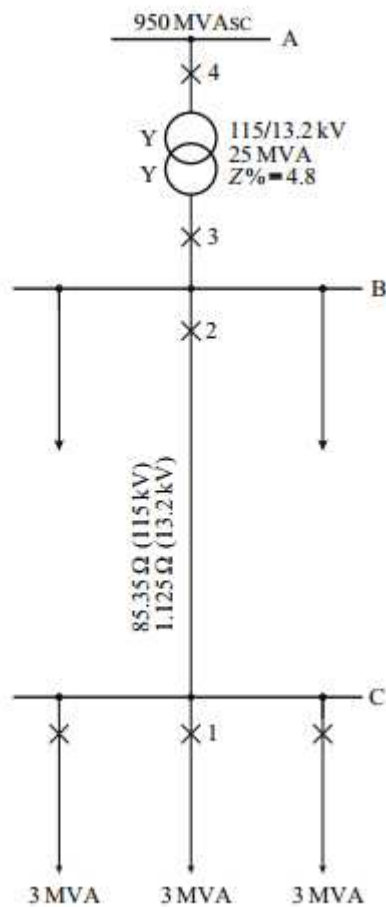


Figure Q 1a)

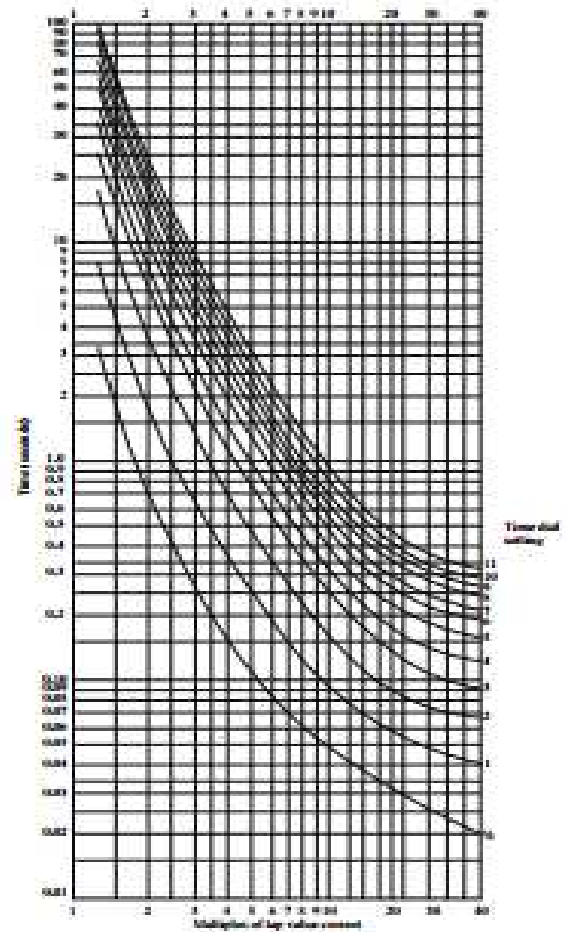


Figure Q 1b)

QUESTION TWO (20 MARKS)

- a) Using a well labelled diagram and equations, explain the operation of Percentage Differential Relaying (PDR) [5marks]
- b) Using Diagrams explain the following aspects of Transmission Line Protection
 - (i) Pilot Relaying [4marks]
 - (ii) Power Line Carrier System[5marks]
- c) Discuss the Differential Protection of the following
 - (i) Transformer [3marks]
 - (ii) Generator [3marks]

QUESTION THREE (20MARKS)

- a) Explain the principle of operation of a Digital Relay, giving the Relay Architecture and its merits over the other types of protective relays [5 marks]
- b) An electromagnetic relay of attracted armature type is as shown in Figure Q 3b). All the symbols carry their usual meaning. It has constants $k_1 = 0.6$ and $k_2 = 10$. Determine from First Principles
 - (i) Whether the relay will operate when a current of 4A and 5A flowing through the relay winding [4 marks]
 - (ii) The minimum current required to operate the relay [1 mark]
- c) Figure Q 3c) shows the elements used in a single-phase time lag overcurrent relay. An RC circuit is used to produce time delay for a solid – state relay. For a step input voltage $v_i(t) = 6u(t)$, the output voltage $v_o(t) = 3V$ and $C = 10 \mu F$.
 - (i) Determine from First Principles, the time delay for the following cases $R = 10 \text{ k } \Omega$ and $R = 1 \text{ M } \Omega$ [3marks]

- (ii) Sketch the output $v_o(t)$ versus time for the case in Q 3ci) above [1mark]
- d) Figure Q 3d) shows a biased percentage differential relay applied for the protection of synchronous generator windings. The relay has 0.1A minimum pick up current and a 10 % bias slope.
- A fault has occurred near the grounded neutral end of the generator when the generator is on load. As a result, the currents flowing at each end are as shown in the figure. Explain whether the relay will operate or not [3 marks]
 - Would the relay operate at the given value of fault current in Q 3d (i) above if the generator was carrying no load ? [2 marks]
 - On the same diagram, show the relay operating characteristics and the points that represent the operating and restraining currents in the relay for the two conditions in Q3d(i) and Q3d(ii) above [1 mark]

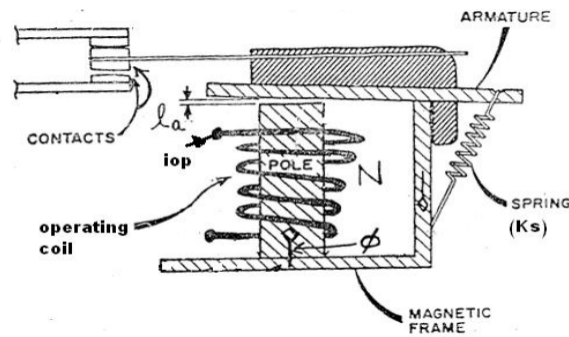


Figure Q 3b)

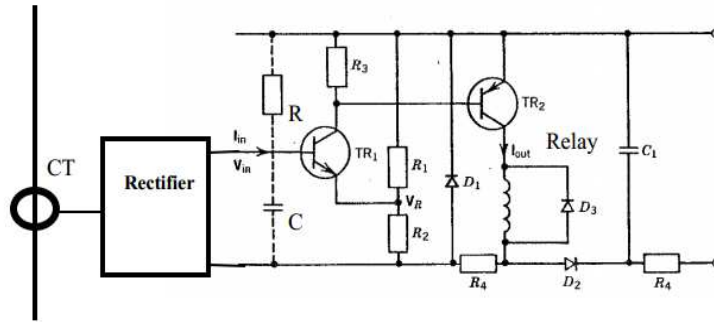


Figure Q 3 c)

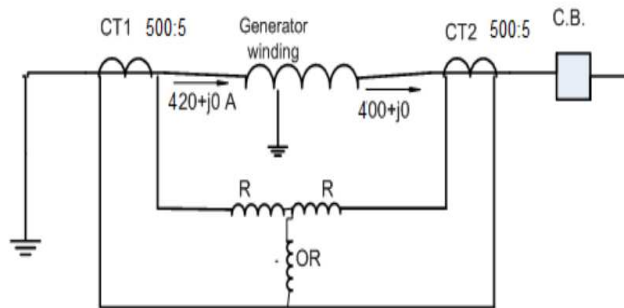


Figure Q 3d)

QUESTION FOUR (20 MARKS)

- Explain the Five Digital Relay Characteristics [2.5 marks]
- Explain the classification of Circuit Breakers in terms of the rated current, type of operation and the nature of trip currents [3 marks]
- Beginning from a well labelled diagram, explain the adaptation of low voltage ACB to its function [5 marks]
- A 100HP 480V 0.85pf 80% efficiency motor has starting upto 5.9 rated current upto 85 with voltage dip of 80% during starting. Design a suitable Circuit Breaker for the motor (Take 1HP=746W) [4 marks]

e) An overcurrent relay set to operate at 8A is connected to a multi ratio current transformer whose excitation curve is given in Figure Q 4e) with CT ratio of 100:5, $Z_S = 0.082 \Omega$ and $Z_B = 0.8 \Omega$. The core area is $2.8 \times 10^{-3} m^2$ and $f = 50 Hz$.

- (i) Will the relay detect a 200A fault current on the primary side? **[2.5marks]**
- (ii) Determine whether or not the CT will saturate. The lower limit for saturation of steel is 1.2T **[2marks]**
- (iii) Compute the percentage CT error **[1 mark]**

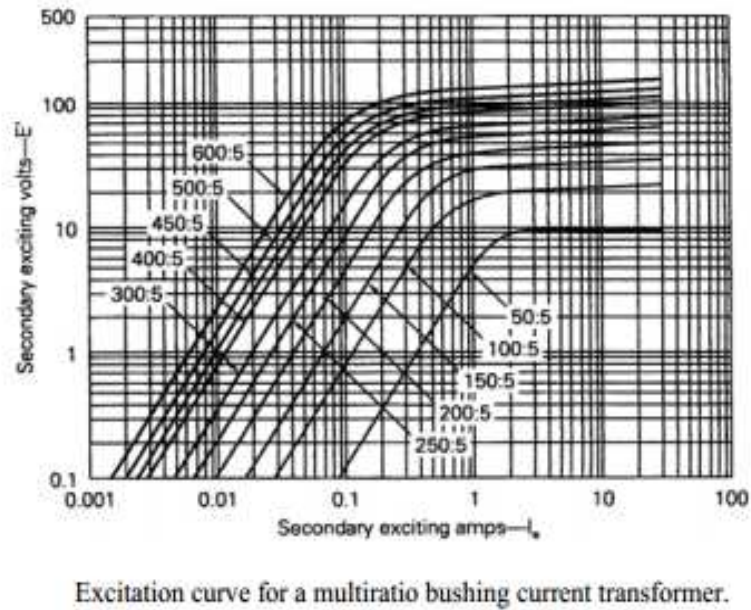


Figure Q 4e)

QUESTION FIVE (20 MARKS)

- a) Consider the system shown in Figure Q 5a). Assume that the three lines are identical with positive sequence impedance $Z_1 = j 0.1 p.u.$ Assume that the six line breakers are controlled by zone distance and directional only three-phase faults:

- (i) Determine Zone 1, Zone 2 and Zone 3 settings relays. Consider for all distance relays in per-unit (3 marks)
- (ii) If the CTs are rated 400:5 A , and the VTs 133kV:115 V, convert the settings in 5a i) above into ohms (3marks)
- (iii) Discuss relay operations for a fault at point X, assuming X is 10% down the line L_{31} from bus 3 (3marks)

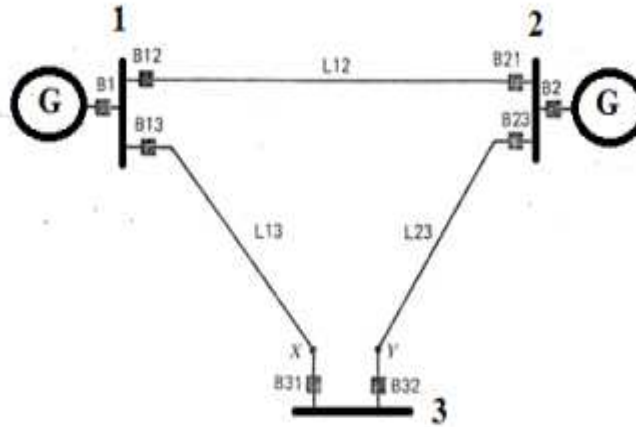


Figure Q 5a)

b) Figure Q 5b) shows a 345kV transmission loop (ring system). Table Q 5b) gives positive – sequence line impedances as well as CT and VT ratios at B_{12} for the system shown.

- (i) Design a three-zone impedance relay for the B_{12} breaker in vector form. Consider only a solid, three-phase fault (5.5marks)
 - (ii) Describe the Zones in 5b i) above (2.5marks)
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- (i) The maximum current for line 1-2 during emergency loading conditions is 1500 A at a power factor of 0.95 lagging. Verify that B_{12} does not trip during normal and emergency loadings (3marks)

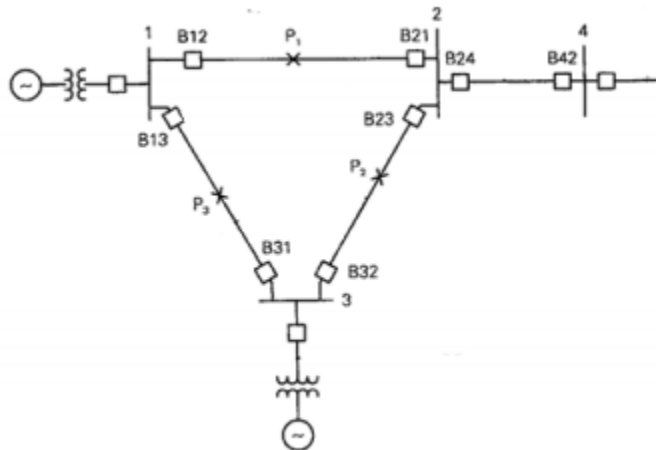


Figure Q 5b)

Table Q 5b)

Line	Positive-Sequence Impedance Ω	
1-2	$8 + j50$	
2-3	$8 + j50$	
2-4	$5.3 + j33$	
1-3	$4.3 + j27$	
Breaker	CT Ratio	VT Ratio
B12	1500:5	3000:1