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:

a) Calculate the nominal currents and three-phase short-circuit levels at each breaker.

b) Select the transformation ratios of the CTs.

c) Determine the values of the pick-up setting, time dial and instantaneous settings of all phase relays to ensure a coordinated protection arrangement.

d) Find the percentage of the line BC protected by the instantaneous unit of the overcurrent relay associated with breaker 2.

e) 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.

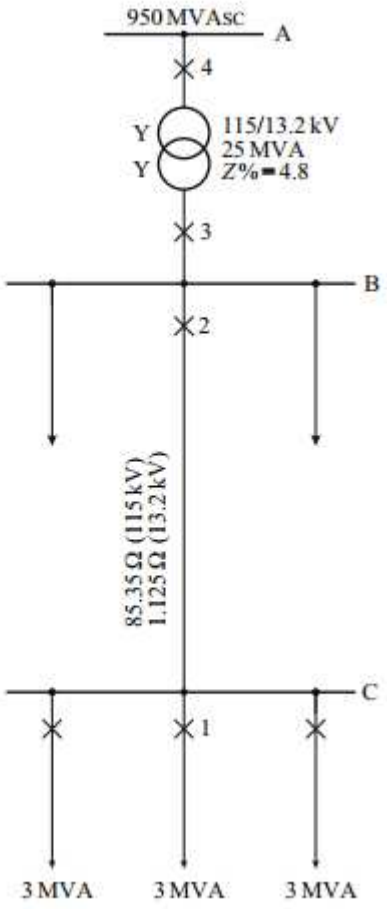


Figure Q 1a)

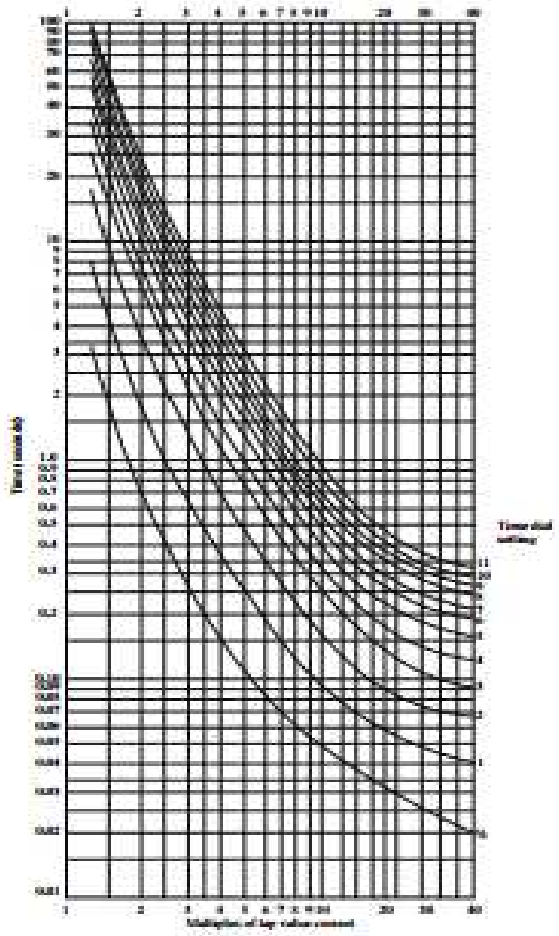


Figure Q 1b)

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 $v_0(t) = 3V$ and $C = 10\ \mu F$.

(i) Determine from First Principles, the time delay for the following cases R = 10 k Ω and R = 1 M Ω [3marks]

(ii) Sketch the output $vo(t)$ 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.

(i) 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]

(ii) 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]

(iii) 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]

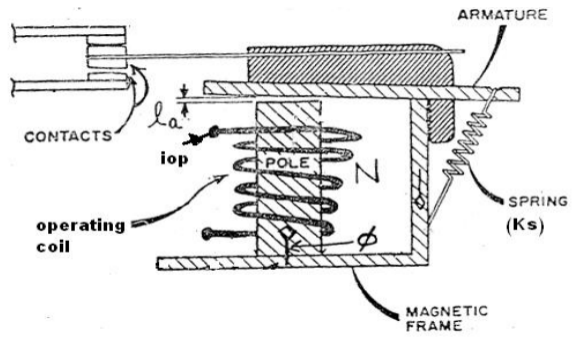


Figure Q 3b)

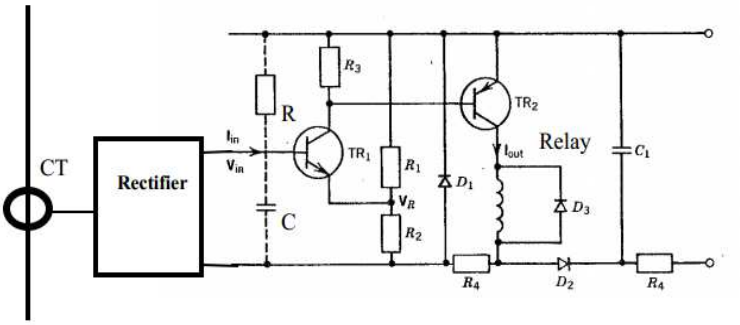


Figure Q 3 c)

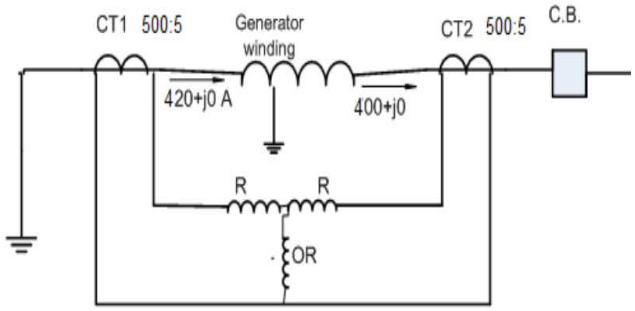


Figure Q 3d)

QUESTION FOUR (20 MARKS)

a) Explain the Five Digital Relay Characteristics [2.5 marks]

b) Explain the classification of Circuit Breakers in terms of the rated current, type of operation and the nature of trip currents [3 marks]

c) Beginning from a well labelled diagram, explain the adaptation of low voltage ACB to its function [5 marks]

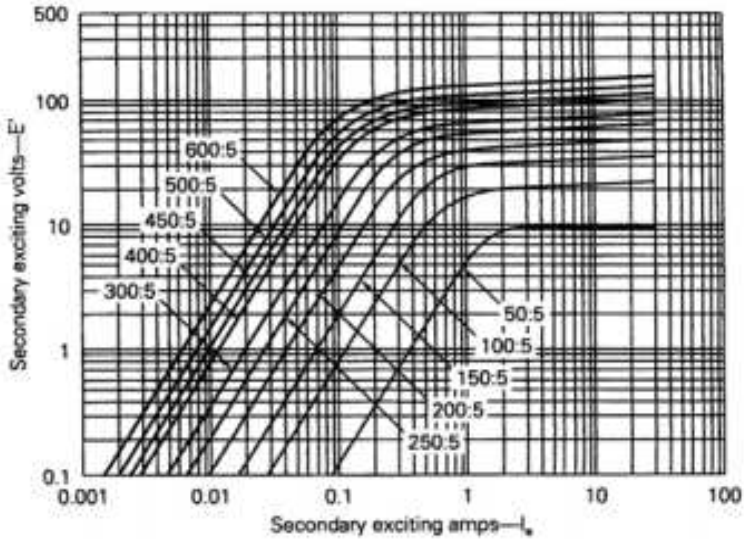
d) A 100HP 480V 0.85pf 80% efficiency motor has starting upto 5.9 rated current upto 85 with voltage dip of 80% during starting. Design a suitable Circuit Breaker for the motor (Take 1HP=746W) [4 marks]

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 $2.8x10^{-3}m^2$ 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]**



Excitation curve for a multiratio bushing current transformer.

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)

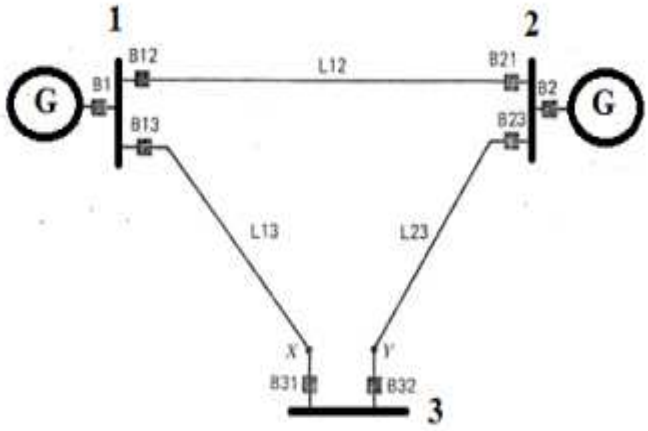


Figure Q 5a)

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)

(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)

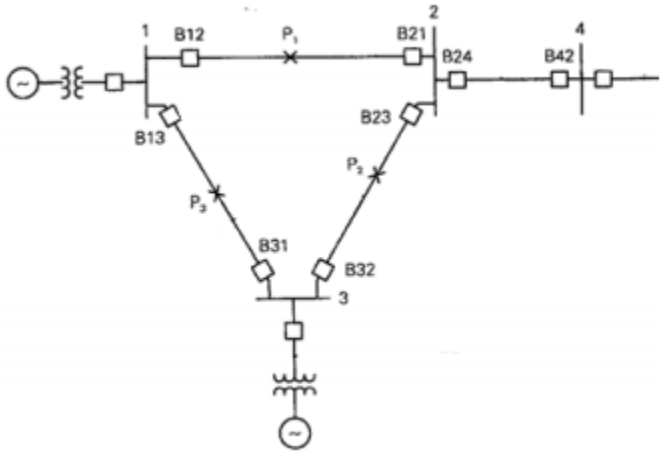


Figure Q 5b)

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