UNIVERSITY OF SWAZILAND

SUPPLEMENTARY EXAMINATION, SECOND SEMESTER

MAY 2017

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Switchgear and Protection

COURSE CODE : EE551

TIME ALLOWED: THREE HOURS

INSTRUCTIONS:

1. **There are five questions in this paper. Answer any four questions. Each question carries 25 marks.**
2. **If you think not enough data has been given in any question you may assume any reasonable values.**

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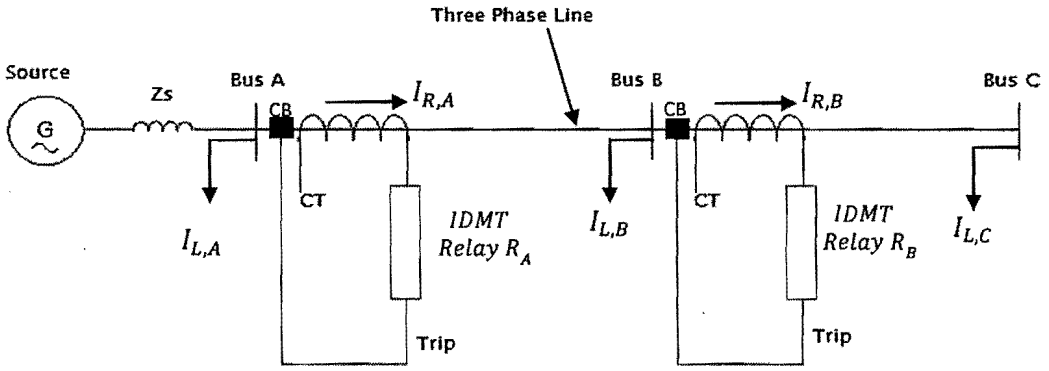
THIS PAPER CONTAINS EIGHT (8) PAGES INCLUDING THIS PAGE

QUESTION ONE *(25 marks)* Solve the following questions

Consider a radial feeder with three buses A, B and C where IDMT OC relays used. The load current at each bus and fault currents when having a fault at each bus are given below



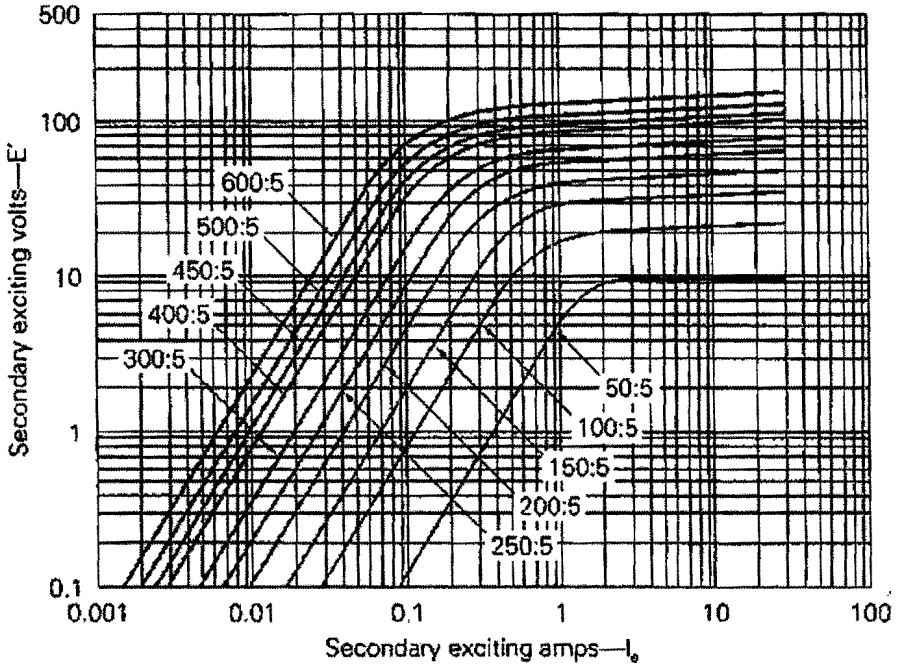
Bus A	Bus B	Bus C
$I_{L,A}$ = 200 A	$I_{L,B}$ = 115 A	$I_{L,C}$ = 125 A
$I_{FA,\,max}$ = 2500 A	$I_{FB,\,max}$ = 2000 A	$I_{FC,\,max}$ = 1500 A

a) Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 20% overload when calculating the maximum load, 5 A relay rating is used and the plug settings to be done at 130%. [4]

Note: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A ..., etc.

b) Determine the time dial setting for the relay at bus A. Assume the time dial setting for the relay at bus B is 0.1 sec ($T_{DS,B}$ =0.1 sec), each circuit breaker operating time is 0.3 sec (T_{CB} = 0.3 sec) and each relay overshoot time is calculated to be 15% of the summation of relay operating time and circuit breaker operating time of the previous coordinated relay $T_{OS} = 0.15(T_{CB} + T_R)$ [7]

c) The figure below shows excitation curves for a multi-ratio bushing CT with a C100 ANSI accuracy classification.



CT ratio	Secondary resistance Ω
50:5	0.061
100:5	0.082
150:5	0.104
200:5	0.125
250:5	0.146
300:5	0.168
400:5	0.211
450:5	0.230
500:5	0.242
600:5	0.296

(i) Evaluate the performance of the multi-ratio Current Transformer with a 200 : 5 CT ratio, for the following secondary output currents $I' = 5A$ and burden $Z_B = 0.5\ \Omega$ [5]

(ii) Explain why it is not advisable to open circuit current transformers. [4]

(iii) Describe the knee point voltage of Current Transformer [5]

Question 2: Solve the following questions (25 marks):

(a) Give the classification of circuit breakers based on the medium used for arc extinction? [6]

(b) Give the three advantages of SF6 Circuit Breaker. [3]

(c) Discuss the theories which explain the phenomenon of arc extinction. [4]

(d) Define the term *pilot* with reference to power line protection. [2]

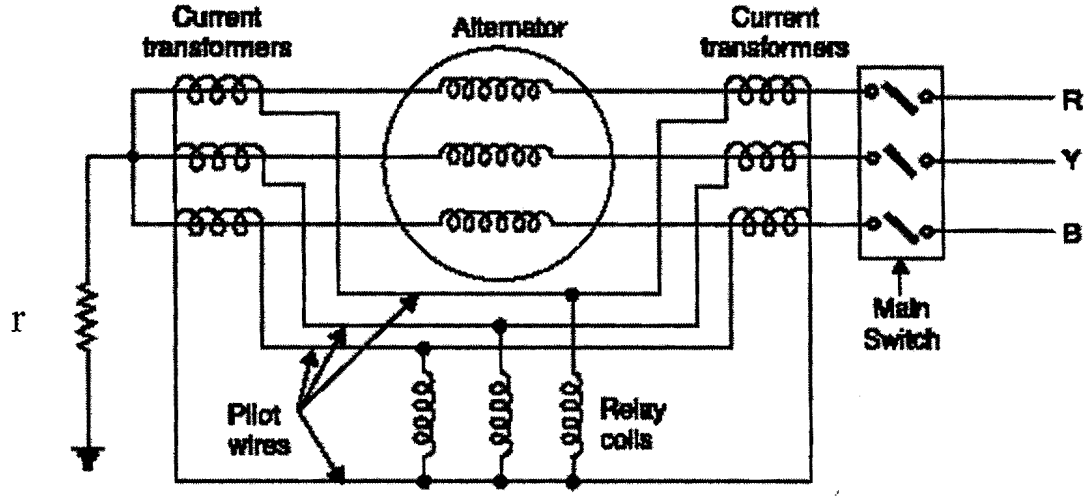
(e) A current transformer has turns ratio 1:188 and is rated 1000/5A. The core loss component is 2.5A and the magnetizing component is 8 A under full load conditions. Find the phase and ratio errors under full load conditions if the secondary circuit power factor is 0.75 lagging.

i. The Ratio error [6]

ii. The Phase Angle error [4]

Question 3: Solve the following questions (25 marks)

(a) A 50MVA, 66 kV, 3-phase star connected alternator is protected by Merz-Price circulating current system. If the ratio of the current transformer is 2000/5, the minimum operating current for the relay is 0.85 A.

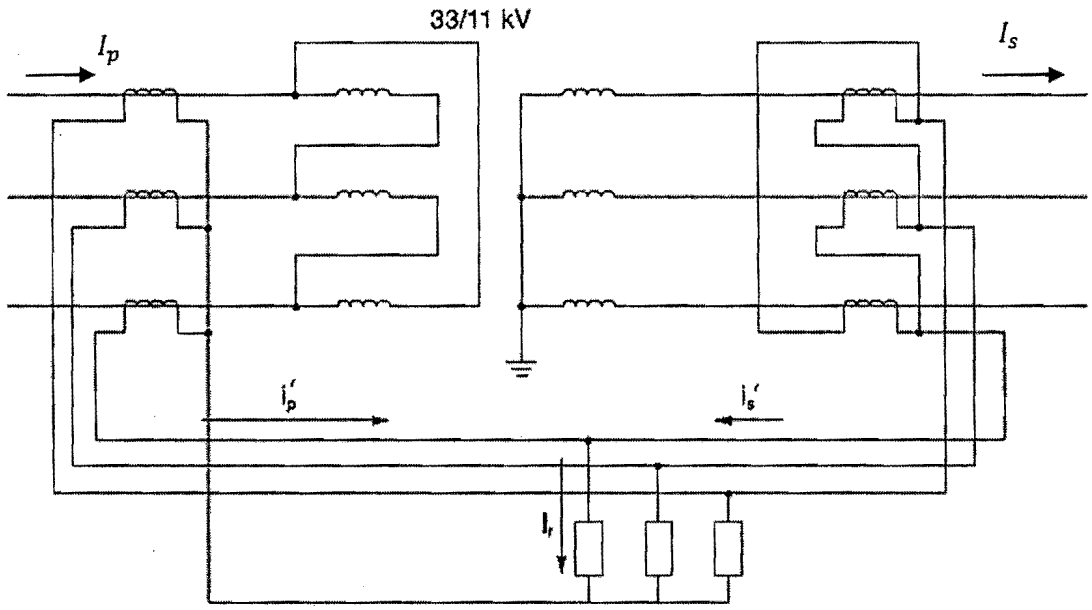


Calculate:

i) The minimum resistance to provide protection for 95% of the rotor winding. [10]

ii) Give the limitations of Merz Price protection. [3]

(b) Consider the three-phase Δ –Y connected, 30-MVA, 33:11 kV transformers with differential relay protection as shown in the figure below,



(i) Determine the CT ratios for differential protection of the three-phase, Δ–Y connected transformer, such that the circulating current in the transformer does not exceed 5 A. [10]

(ii) Compute the relay current setting for faults drawing up to 150 % of rated transformer current. [2]

Question 4: Solve the following questions (**25 marks**):

a) Derive and draw the characteristics of an impedance relay. [5]

b) Explain with sketches the R-X diagrams for the following distance relays.
   (i) Mho relay [3]

   (ii) Reactance relay [3]

   (iii) Directional Relay [3]

c) What is the need of relay coordination? [2]

d) Name the different kinds of over current relays. [3]

e) Discuss Primary protection and Backup protection with reference to the Figure Q4 below [6]

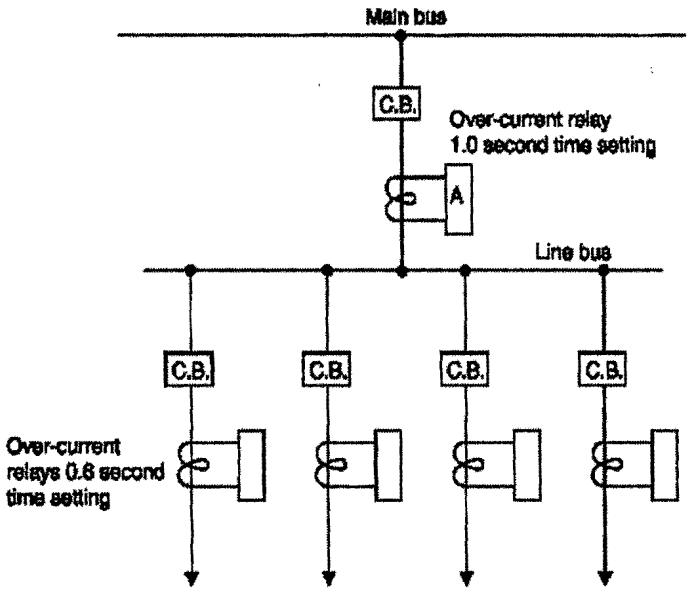


Figure Q4

Question 5

(a) Explain the principle of operation of the circuit breaker. [4]

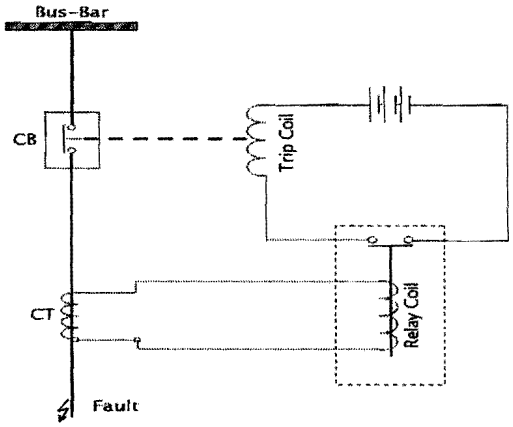


Figure Q5a

(b) The following table gives the positive sequence line impedances as well as the CT and VT ratios of the distance relay at B12 for a 132 kV (line to line) systems.

Line	Positive sequence impedance Ω
1-2	11+j60
2-3	9+j35
2-4	8+j55
1-3	5+j30

Circuit Breaker	CT ratio	VT ratio
B12	2500:5	400:1

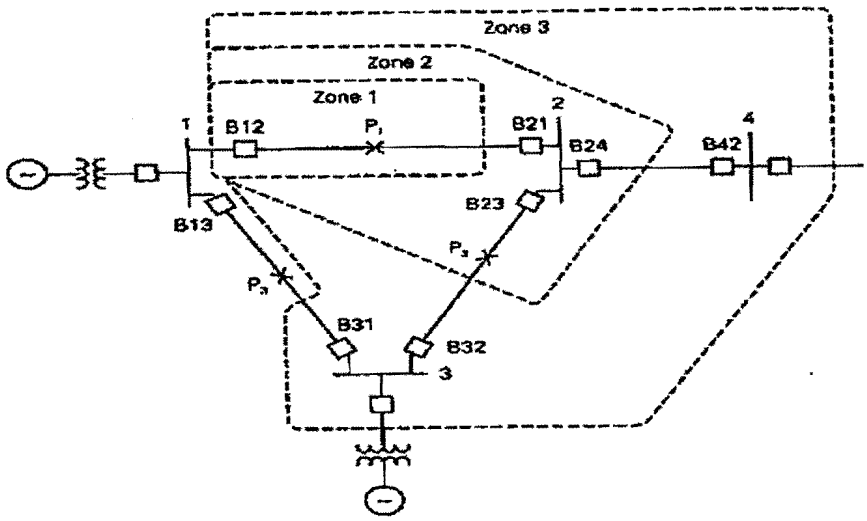


Figure Q5b

(i) Determine the three impedance relay zones settings Z_{r1}, Z_{r2}, Z_{r3} for the breaker B12, [9]

(ii) Maximum current for line 1-2 during emergency loading conditions is 180 A at a power factor 0.7 lagging. Verify that B12 does not trip during normal and emergency loadings. [8]

(c) Coordinate the direction of supervision and the time delay between the directional OC relays in the following ring network so that a fault in any section causes only the CBs associated with that section to trip. [6]

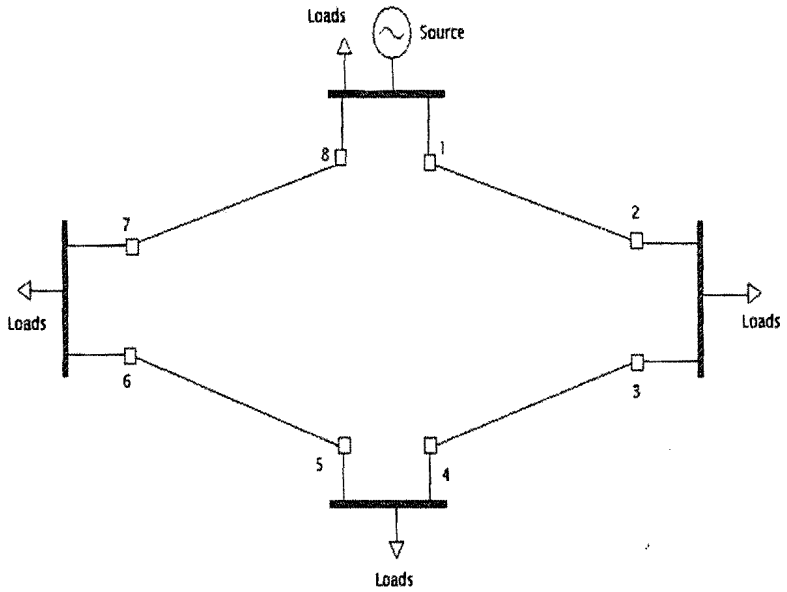


Figure Q5c

(d) If there is a fault in the middle of the line 5-6, which relays are going to energize and what will be their operating time acceding to your coordination? [2]