UNIVERSITY OF ESWATINI

SIT/RESIT EXAMINATION, FIRST SEMESTER

APRIL/MAY 2021

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER: Switchgear and Protection

COURSE CODE : EEE552

TIME ALLOWED: Three Hours

INSTRUCTIONS:

1. There are five questions in this paper. Choose 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 NINE (9) PAGES INCLUDING THIS PAGE

Question 1 (25 Marks)

Consider a radial feeder with three buses A, B and C where IEC standard inverse (IDMT OC) relays used as shown in Fig. Q1(a). The load current at each bus and fault currents when having a fault at each bus are given

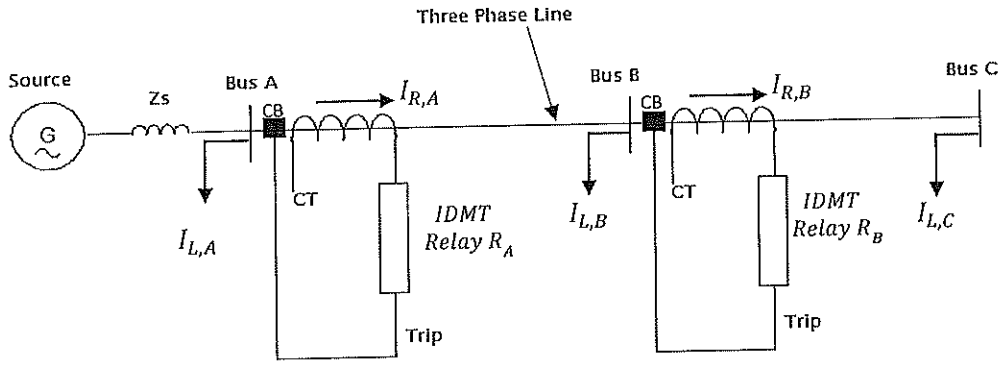


Fig. Q1(a)

Table 1

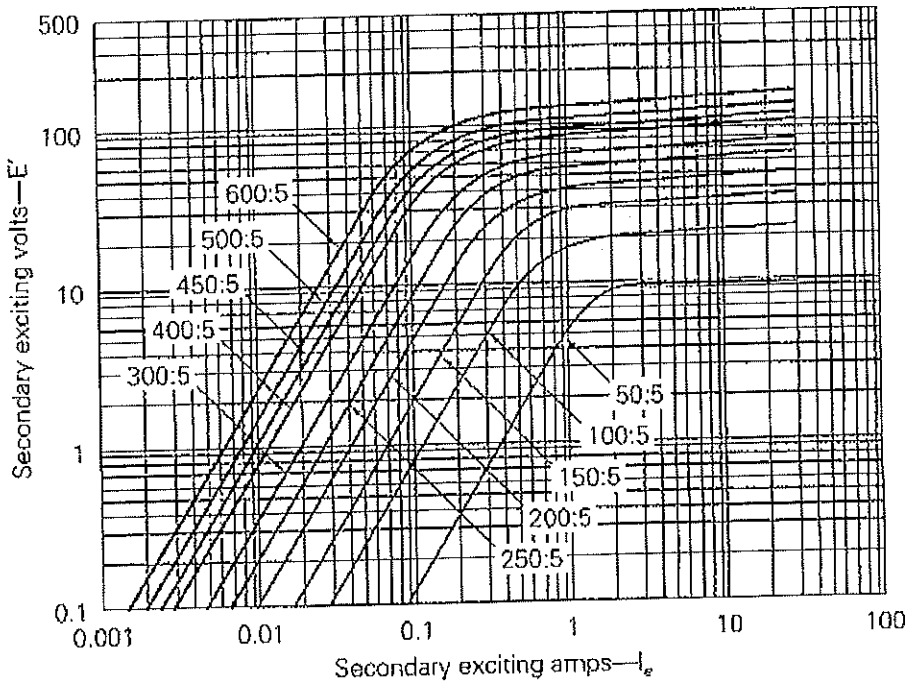
Bus A	Bus B	Bus C
$I_{L,A}$ = 200 A	$I_{L,B}$ = 115 A	$I_{L,C}$ = 125 A
$I_{FA,\,max}$ = 2500 A	$I_{FB,\,max}$ = 2000 A	$I_{FC,\,max}$ = 1500 A

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) Fig. Q1(c) 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

Fig. Q1(c)

(i) Evaluate the performance of the multi-ratio Current Transformer with 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 (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 (25 marks)

(a) A 50MVA, 66 kV, 3-phase star connected alternator is protected by Merz-Price circulating current system as shown in Fig. Q3(a). If the ratio of the current transformer is 2000/5, the minimum operating current for the relay is 0.85 A.

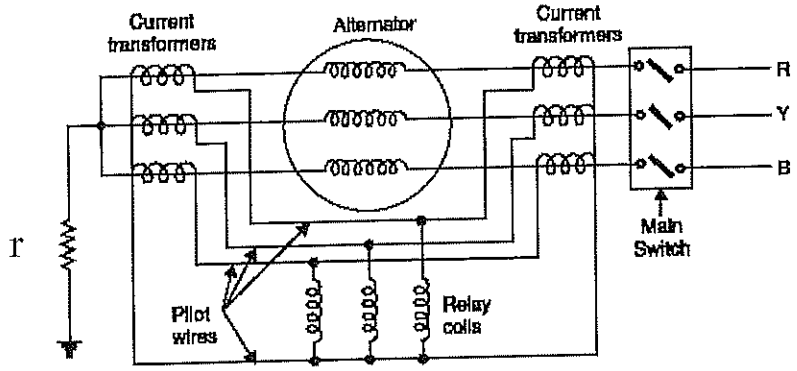


Fig. Q3(a)

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,

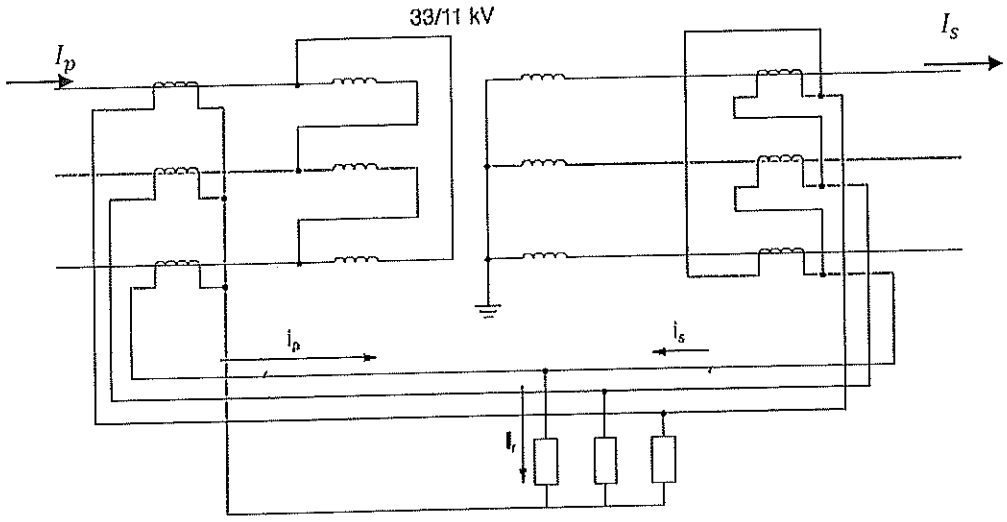


Fig. Q3(b)

(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 (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 Fig. Q4 [6]

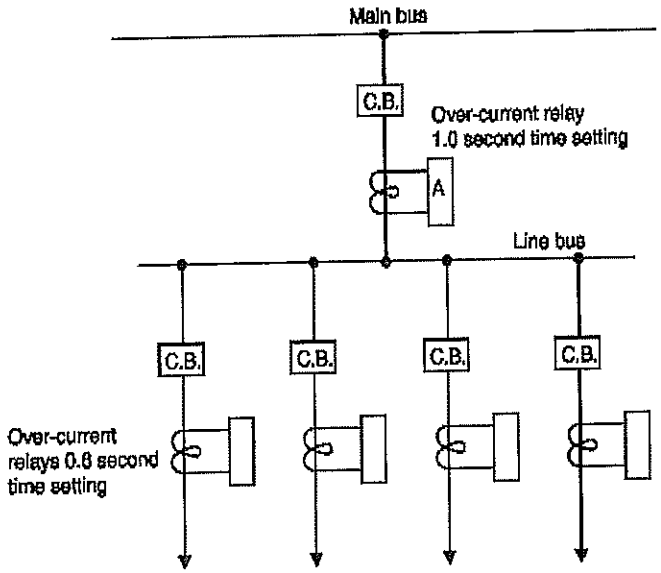


Fig.Q4

Question 5 (25 Marks)

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

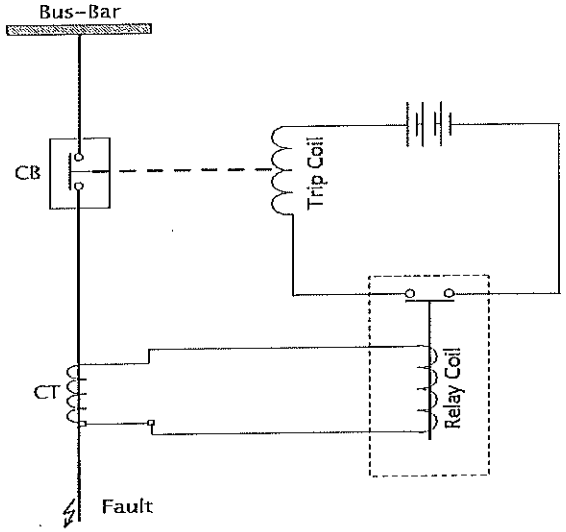


Fig. Q5(a)

(b) Table 2 and Table 3 gives the positive sequence line impedances as well as the CT and VT ratios for the distance relay at B12 for a 132 kV (line to line) system respectively.

Table 2 Line data

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

Table 3 Instrument Transformer ratios

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

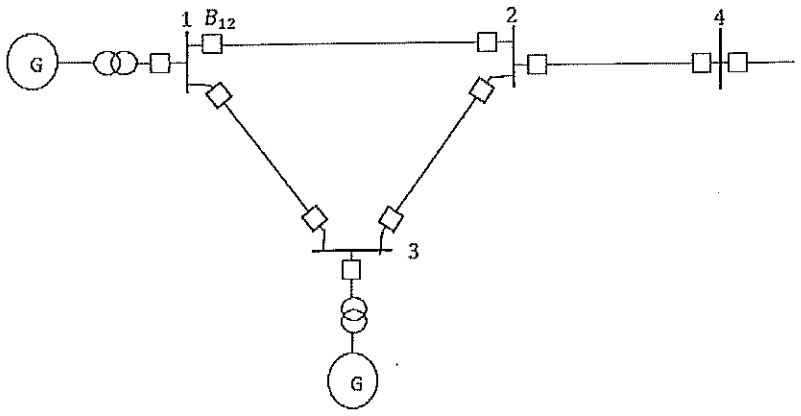


Fig. Q5(b)

i. Determine the three impedance relay zones settings Zr_1, Zr_2, Zr_3 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)

(i) 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]

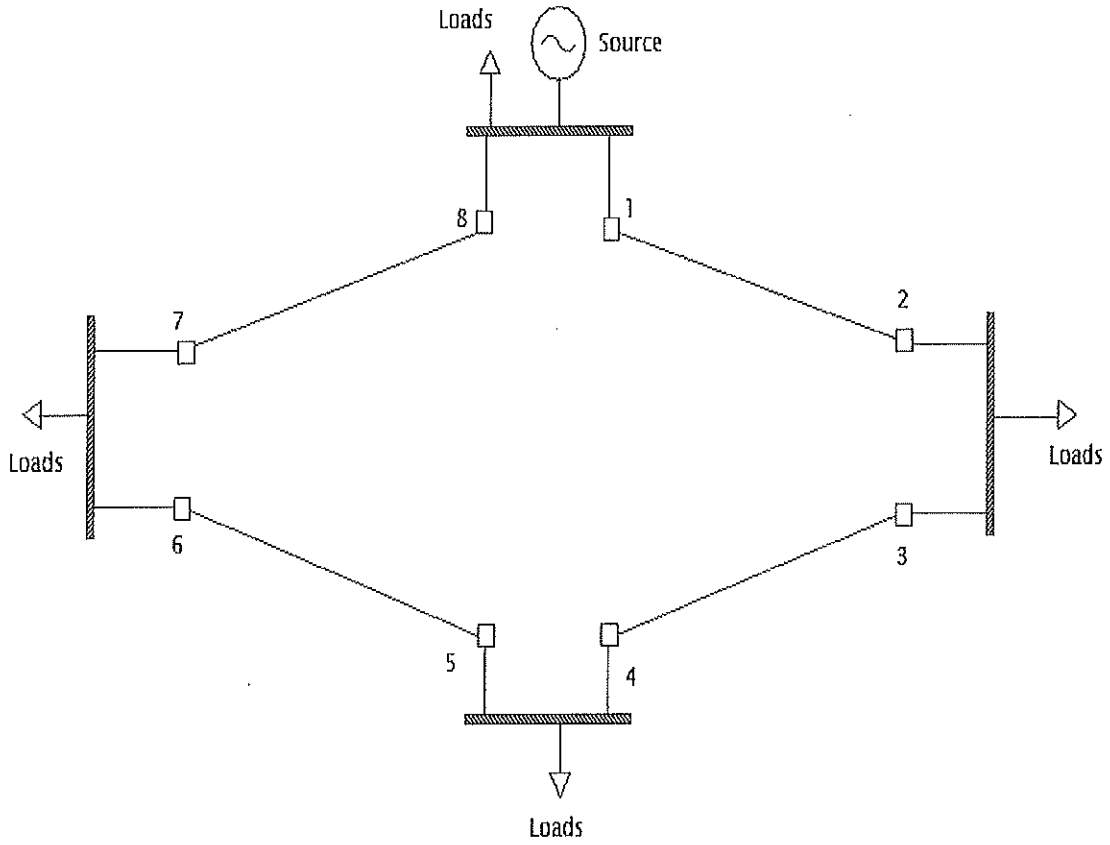


Fig. Q5(c)

(iii) 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]

Some Useful Information

Table 4

Electrical Properties						
	Current Ratings					
Cable size (mm^2)	Ground (A)	Ducts (A)	Air (A)	Impedance (Ω/km)	Voltage drop (mV/A/m)	1s short circuit rating (kA)
1.5	23	18	18	14.48	25.080	0.17
2.5	30	24	24	8.87	15.363	0.28
4.0	38	31	32	5.52	9.561	0.46
6.0	48	39	40	3.69	6.391	0.69
10.0	64	52	54	2.19	3.793	1.15
16.0	82	67	72	1.38	2.390	1.84
25.0	126	101	113	0.8749	1.515	2.87
35.0	147	120	136	0.6335	1.097	4.02
50.0	176	144	167	0.4718	0.817	5.75
70.0	215	175	207	0.3325	1.097	4.02
95.0	257	210	253	0.2460	0.427	10.92
120.0	292	239	293	0.2012	0.348	13.80
150.0	328	269	336	0.1698	0.294	17.25
185.0	369	303	384	0.1445	0.250	21.27
240.0	422	348	447	0.1220	0.211	27.60
300.0	472	397	509	0.1090	0.189	34.50

K = 115 for PVC/copper cables of 1000 V rating
K = 143 for XLPE/copper cables of 1000 V rating
K = 76 for PVC/aluminum (solid or stranded) cables of 1000 V rating
K = 92 for XLPE/aluminum (solid or stranded) cables of 1000 V rating.

Table 5

Curve Description	*Standard*	α	β	L
Moderately Inverse	IEEE	0.02	0.0515	0.114
Very Inverse	IEEE	2.0	19.61	0.491
Extremely Inverse	IEEE	2.0	28.2	0.1217
Inverse	CO8	2.0	5.95	0.18
Short Time Inverse	CO2	0.02	0.0239	0.0169
Standard Inverse	IEC	0.02	0.14	0
Very Inverse	IEC	1.0	13.5	0
Extremely Inverse	IEC	2.0	80.0	0
Long Time Inverse	UK	1.0	120	0