UNIVERSITY OF ESWATINI

MAIN EXAMINATION, SECOND SEMESTER

MAY 2019

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 SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE (25 Marks)

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

b) Discuss Primary protection and Backup protection with reference to Fig. Q.1(b) [4]

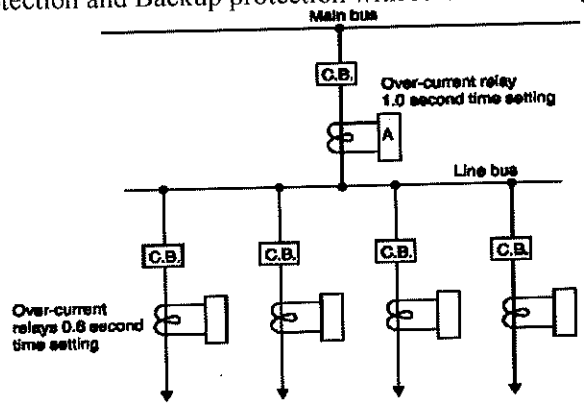


Fig. Q 1 (b)

c) Consider a radial feeder with two buses A and B where inverse CO8 relays used. The load current at each bus and fault currents when having a fault at each bus are given below.

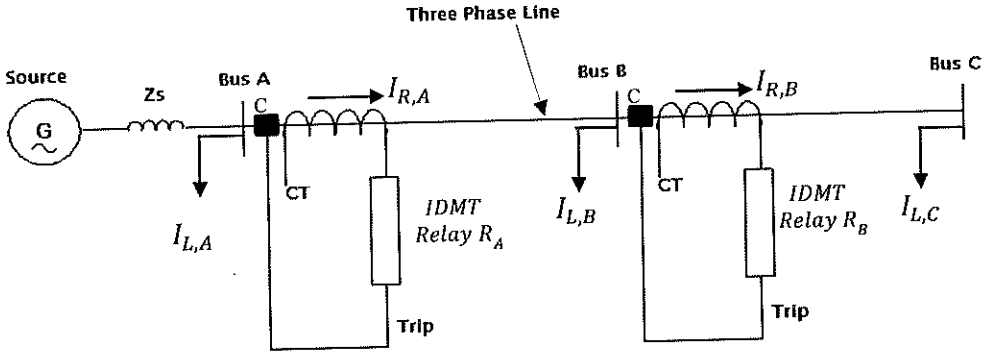


Fig. Q.1(c)

Bus A	Bus B	Bus C
$I_{L,A}$ = 330 A	$I_{L,B}$ = 240 A	$I_{L,C}$ = 160 A
$I_{FA,\,max}$ = 500 A	$I_{FB,\,max}$ = 3000 A	$I_{FC,\,max}$ = 240 A

i. Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 15% overload when calculating the maximum load, 5 A relay rating is used and the plug settings to be done at 120%. Note: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A …, etc. [6]

ii. 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 0.2 sec (T_{CB} = 0.2 sec) and each relay overshoot time is calculated to be 10% of the summation of relay operating time and circuit breaker operating time of the previous coordinated relay $T_{OS} = 0.1(T_{CB} + T_R)$ [13]

QUESTION TWO (25 Marks)

(a) A three phase Delta-Wye connected 50 MVA; 66/11kv transformer is protected by a differential relay. The ratios on the primary and secondary side are 200: 5 and 3000: 5 respectively as shown in Fig. Q2.

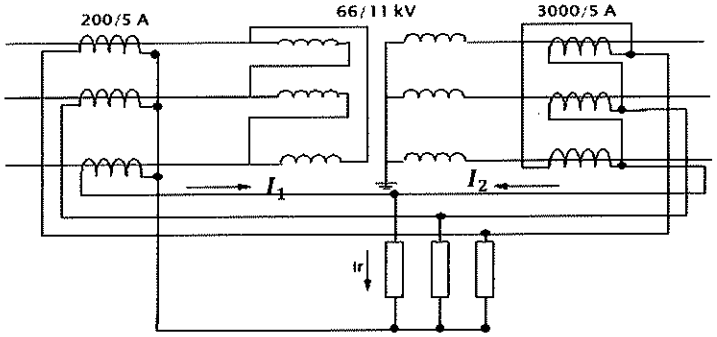


Fig. Q.2

(i) Calculate the relay current at normal load. [10]
(ii) The relay current at 130% of the rated current. [2]

(b) A 10MVA, 6.6 kV, 3-phase star connected alternator is protected by Merz-Price circulating current system. If the ratio of the current transformer is 1000/5, the minimum operating current for the relay is 0.75 A and the neutral point earthing resistance is 6 Ω.

(i) What are the main types of stator winding faults? [3]
(ii) Calculate the percentage of each stator windings that is unprotected against faults when the machine is operating at normal voltage. [8]
(iii) Find the minimum resistance to provide protection for 90% of the rotor winding. [2]

QUESTION THREE (25 Marks)

(a) Explain the principle of operation of the circuit breaker in Fig. Q.3(a) [3]

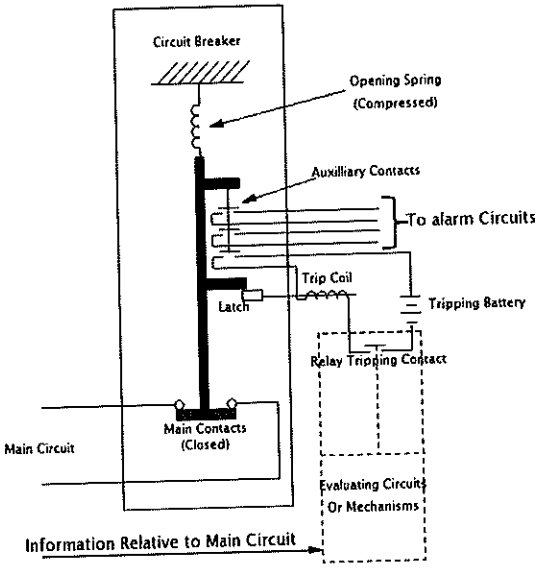
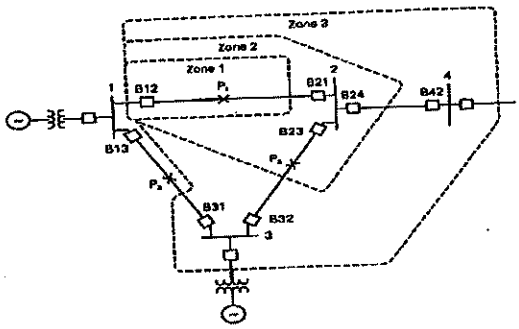


Fig. Q.3 (a)

(b) Explain briefly how the arc is interrupted in the following types of breakers:

i. Vacuum circuit breaker [3]
ii. Puffer type SF6 circuit breaker [3]
iii. Minimum oil circuit breaker [2]

(c) The following table gives the positive sequence line impedances as well as the CT and VT ratios of the distance relay at B12 for 400 kV (line to line) systems.



Line	Positive sequence impedance Ω
1-2	7+j30
2-3	12+j20
2-4	15+j35
1-3	5+j21

Circuit Breaker	CT ratio	VT ratio
B12	2000:5	3000:1

Fig. Q.3(c)

i. Determine the three impedance relay zones settings Z_{r1}, Z_{r2}, Z_{r3} for the breaker B12. [8]

ii. Maximum current for line 1-2 during emergency loading conditions is 1500 A at a power factor 0.75 lagging. Verify that B12 does not trip during normal and emergency loadings, discuss your answer. [6]

QUESTION FOUR ***(25 marks)***

(a) Give the two methods of arc interruption and explain each [4]

(b) Numerical relays are technically superior to the conventional types of relays, discuss the general characteristics of numerical relays. [10]

(c) In ANSI/IEEE (IEEE Standard C37.2-2008) protective relays are generally referred to by standard device numbers. Letters are sometimes added to specify the application. Describe the devices denoted by the following device numbers. [5]

(i) 21
(ii) 32
(iii)51
(iv)67
(v) 87

(d) A 400 kV, 3-phase, 50 Hz, 500 km transmission line has a capacitance to earth of 0.02 μF/km per phase. Calculate the inductance and kVA rating of the Peterson coil used for earthing the above system. [6]

QUESTION FIVE ***(25 marks)***

a) Define the following terms as used in Circuit breakers
(i) Re-striking voltage [2]
(ii) Recovery voltage [2]
(iii) RRRV [2]

b) A 50Hz, 3-phase alternator has the line voltage of 11 kV. The generator is connected to a circuit breaker; the inductive reactance up to the circuit breaker is 7.5 **Ω**/phase. The distributed capacitance up to the circuit breaker between phase and neutral is 0.01μF.

(i) Determine the peak re-striking voltage across the contacts of circuit breaker. [4]
(ii) Frequency of re-striking voltage transients [3]
(iii) Maximum RRRV [3]
(iv) Average rate of re-striking voltage up to peak re-striking voltage. [4]

c) Discuss the Buchholz relay with reference to:

(i) Principle of operation [2]

(ii) The limitations [3]

END OF EXAMINATION

Useful Information

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