UNIVERSITY OF SWAZILAND

MAIN EXAMINATION, SECOND SEMESTER

MAY 2018

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.

THIS PAPER SHOULD NOT BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

THIS PAPER CONTAINS SIX (6) PAGES INCLUDING THIS PAGE

QUESTION ONE *(25 marks)*

(a) For the circuit shown below, Assume the fault occurs very close to the switchgear. This means that the cable impedance between the switchgear and the fault may be ignored, ignore any arc resistance and cable impedance between the transformer secondary and the switchgear.

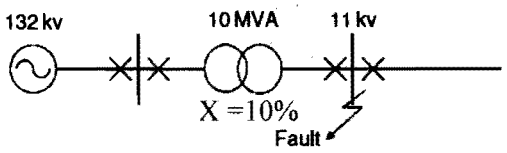

Fig. Q 1

i. Calculate the short-circuit MVA on the LV side of the transformer to determine the breaking capacity of the switchgear to be installed. [3]

ii. Calculate the fault current downstream after a particular distance from the transformer with the impedance of the line/cable being 1.5 Ω. [4]

(b) Give the methods of neutral grounding commonly used in three phase systems and state the factors affecting the choice of grounding method. [7]

(c) 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]

(d) Draw the block diagram of a microprocessor based overcurrent protection scheme. [5]

QUESTION TWO *(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]

Question Three (25 Marks)

Solve the following questions

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

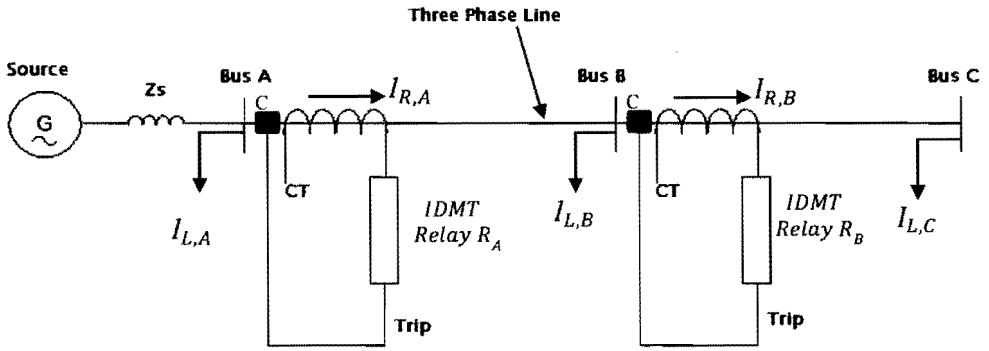

Fig. Q 2

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. [4]

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 $T_{OS} = 0.1(T_{CB} + T_R)$ [8]

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

c) 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. Q 3.

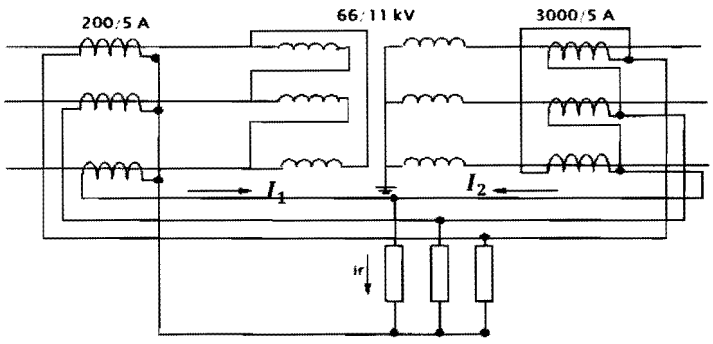

Fig. Q 3

(i) Calculate the relay current at normal load. [9]
(ii) The relay current at 130% of the rated current. [2]

QUESTION FOUR *(25 marks)*

Solve the following questions

(a) 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) Draw the schematic diagram of the protection scheme in (a) [3]
(iii) Calculate the percentage of each stator windings that is unprotected against faults when the machine is operating at normal voltage. [4]
(iv) Find the minimum resistance to provide protection for 90% of the rotor winding. [2]

(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 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

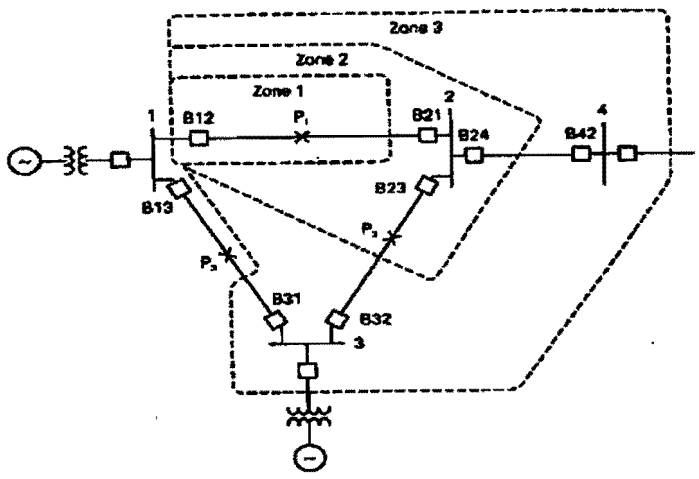

Fig. Q 4(b)

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. [5]

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

Answer the following questions

(a) Discuss Primary protection and Backup protection with reference to Fig. Q 5(a) [4]

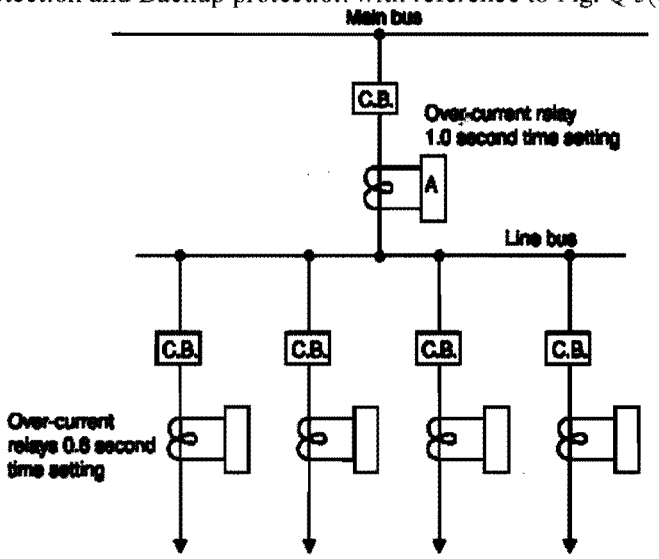

Fig. Q 5(a)

(b) Explain the principle of operation of the circuit breaker in Fig. Q 5(b) [3]

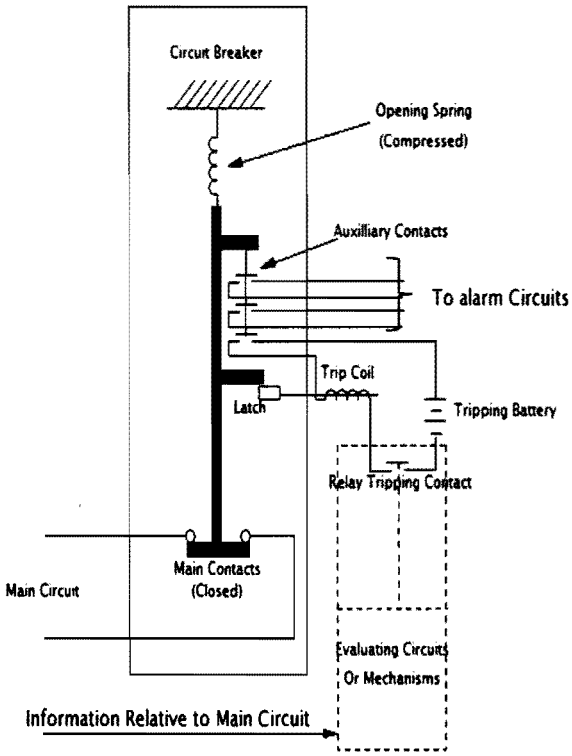

Fig. Q 5(b)

(c) 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]

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

(e)

i. Draw the one line diagram and indicate the protective zones for the power system shown in Fig. Q . [3]

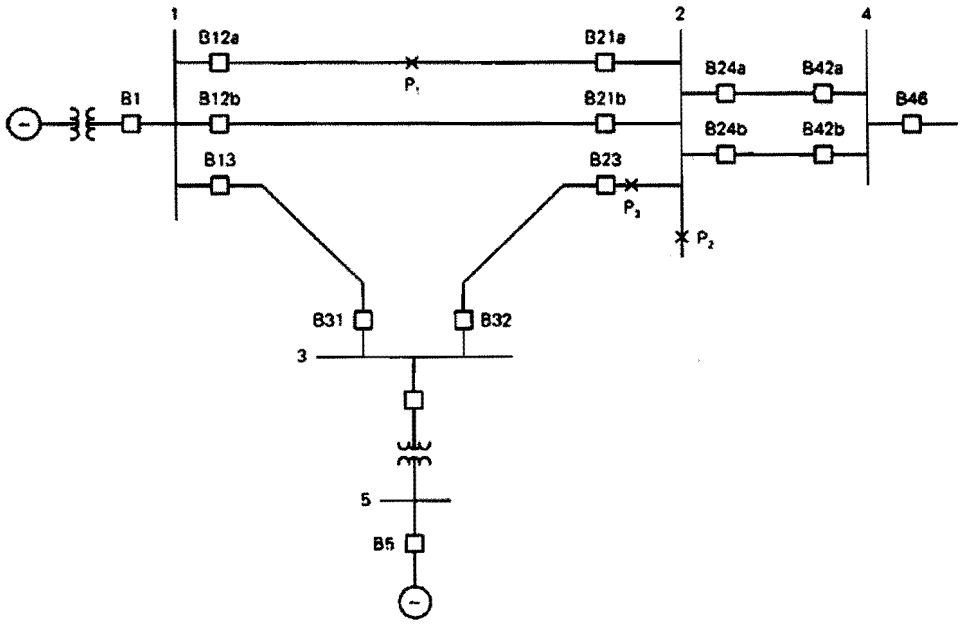

Fig. Q 5(e)

ii. Which circuit breakers should open in the circuit in Fig Q5(e) for a fault at :
a. P1 [1]
b. P2 [1]

iii. Briefly explain the importance of overlapping protection zones [1]