UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION MAY 2013

TITLE OF PAPER: **Switchgear and Protection**
COURSE CODE: **EE 551**

TIME ALLOWED: **THREE** HOURS

Student Name:	
Student Number:	

INSTRUCTIONS:

1. Answer all questions.
2. Give your answers on the question paper, and if more space is required, complete your answer on the back of the paper or in your answer book and mention about the place of your answer completion.
3. Put the question sheet inside the answer book upon submission of your exam paper.
   (DON'T FORGET TO SUBMIT BOTH OF THE ANSWER BOOK AND QUESTION PAPER)
4. Marks for different questions are indicated on the beginning of the question.
5. Rough work maybe done in the examination answer book and crossed through.

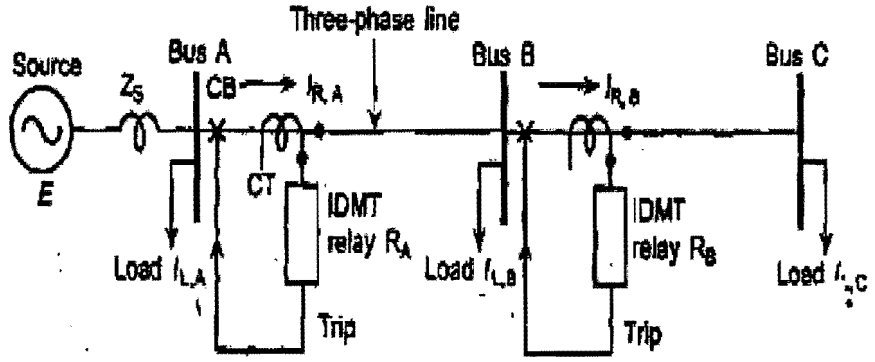
DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

This paper starts at page 1 and ends at page 16

Question 1: Solve the following questions (13 marks)

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:

Bus A	Bus B	Bus C
$I_{LA} = 200$ A	$I_{LB} = 115$ A	$I_{LC} = 125$ A
$I_{f\max}$ =2500 A	$I_{f\max} = 2000$ A	$I_{f\max} = 1500$

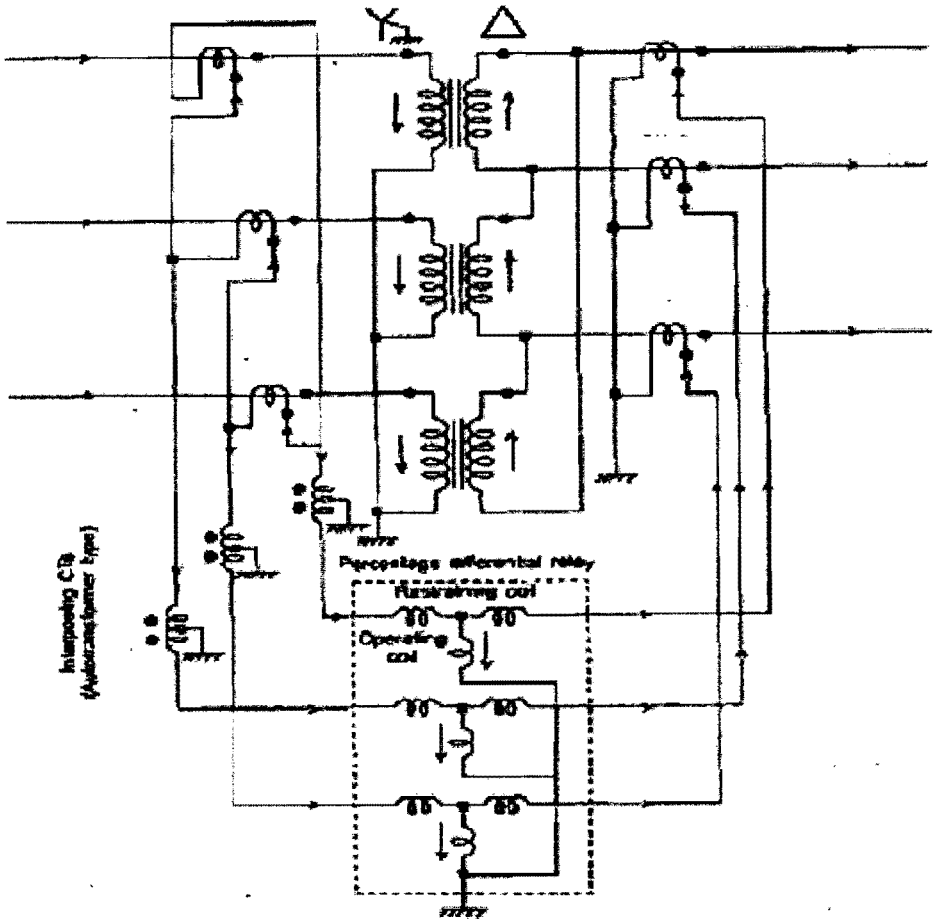


a) Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 20% overload when calculating the maximum load, 2 A relay rating is used and the plug settings to be done at 100%.

b) Determine the time dial setting for the relay at bus A. Assume the time dial setting for the relay at bus B is 0.2 sec ($T_{DS,B} = 0.2\text{sec}$), each circuit breaker operating time T_{CB} is 0.4 sec and each relay overshoot time is calculated to be 15% of the summation of relay operating time and circuit breaker operating time $T_{os} = 0.15 * (T_{CB} + T_R)$ of the previous coordinated relay.

Question 2: Solve the following questions (10 marks)

For a 50 MVA, 15V / 75 kV (line to line), 50 Hz star-delta transformer. The CT ratio at the primary side is 2500:5 A and CT ratio at the secondary side is 500:5 A. The objective is to design a percentage differential scheme.



a) **Calculate the maximum full load current in each winding of the primary and the secondary sides. Assume 20% overload when calculating the maximum load (Calculate: $I_{l,p\max}$, $I_{l,s\max}$)**

b) **Assume the CT ratio at the primary side is 2500:5 A and the CT ratio at the secondary side is 500:5 A and a rated current was flowing in the primary and secondary sides of transformer. Calculate the CT pilot currents in the primary and the secondary sides of the transformer.**
(Calculate: $I_{pi,p}, I_{pi,s}$ **)**

c) **Calculate the current ratio of the interposing CT in the primary.**

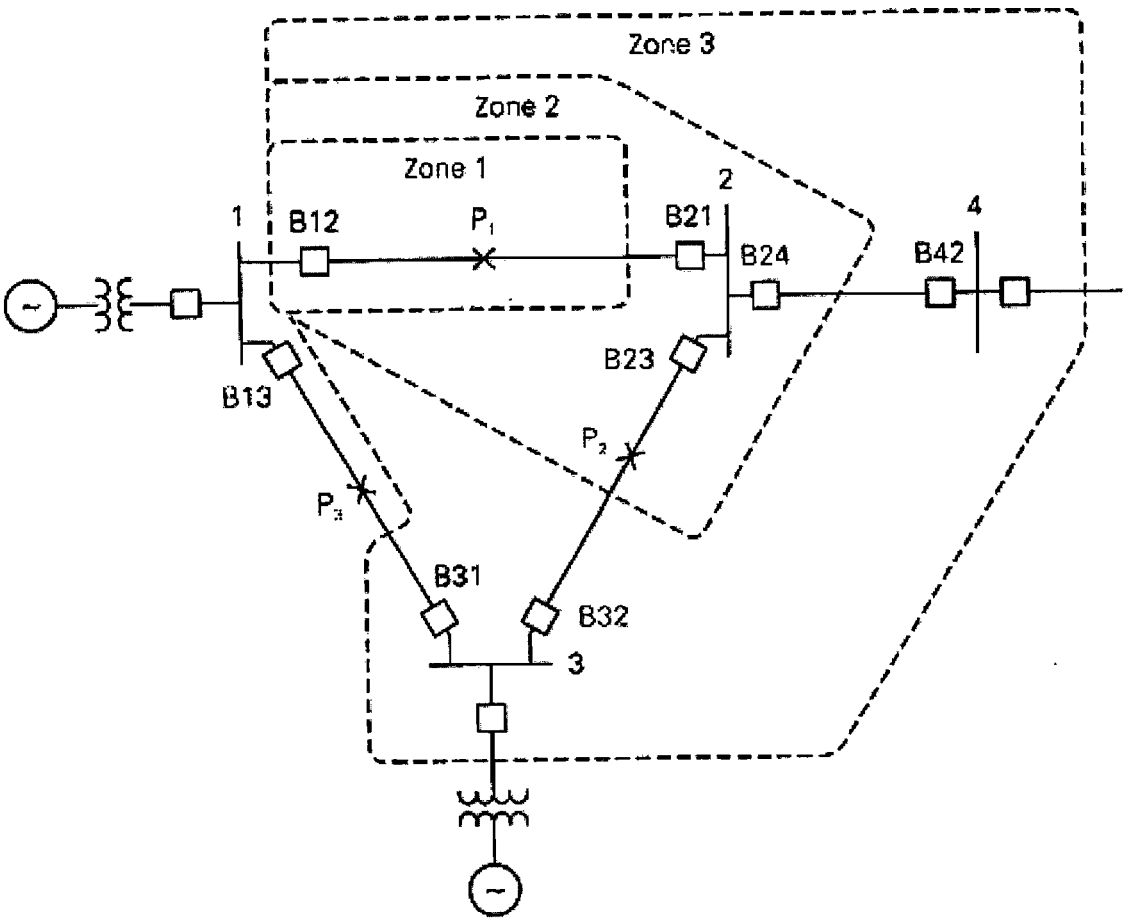
d) **Calculate the spill current required for tripping assuming the percentage differential relay of 30% slope.**

Question 3: Solve the following questions (9 marks)

The following table gives the positive sequence line impedances as well as the CT and VT ratios of the distance relay at B12 for 345 kV (line to line) system.

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

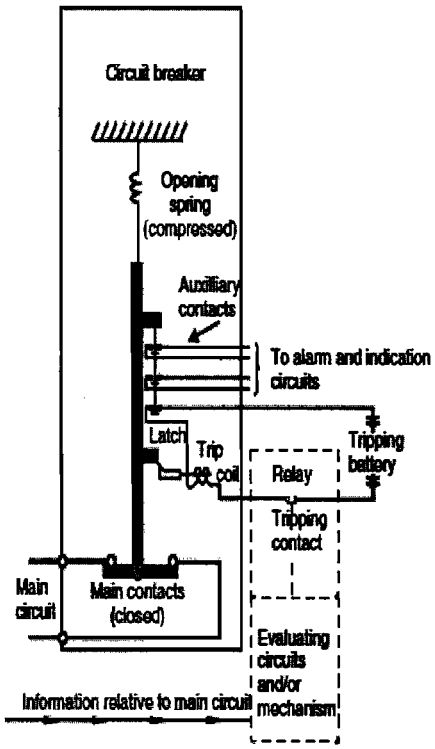
Breaker	CT ratio	VT Ratio
B12	2500:5	400:1



a) Determine the three impedance relay zones settings at breaker B12 Z_{r1}, Z_{r2}, Z_{r3}, and time delay for the relay to trip in each zone.

Question 4: Solve the following questions (17 marks)

a) Explain the principle of operation of the circuit breaker.



b) Give brief definition of the arc problem in circuit breaker and the proposed solutions for it.

c) List the main types of circuit breakers.

d) Explain briefly about the two tripping mechanisms in miniature circuit breaker:

Question 5: Solve the following questions (20 marks)

Give simple definition of the following types of generator faults and provide brief explanation how that type of fault will affect the operation of generator and what is the proposed protection against each type of fault.

a) Rotor ground fault:

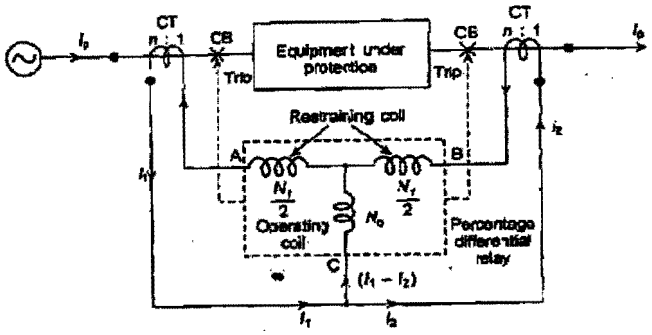
b) Loss of excitation:

c) Loss of prime mover.

d) Unbalanced loading.

Question 6: Solve the following questions (18 marks)

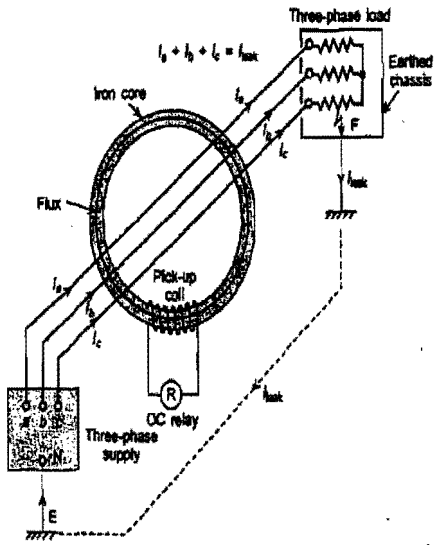
a) **Draw the characteristic of the percentage differential relay showing the trip and restrain regions. Give general equation with explanation for the condition at which the relay will trip.**
(Note: Define each variable in the equation.You don't need to do derivation for the equation)



b) **Draw the characteristic of the mho relay showing the trip and restrain regions. Give general equation with explanation for the condition at which the relay will trip.**
(Note: Define each variable in the equation.You don't need to do derivation for the equation)

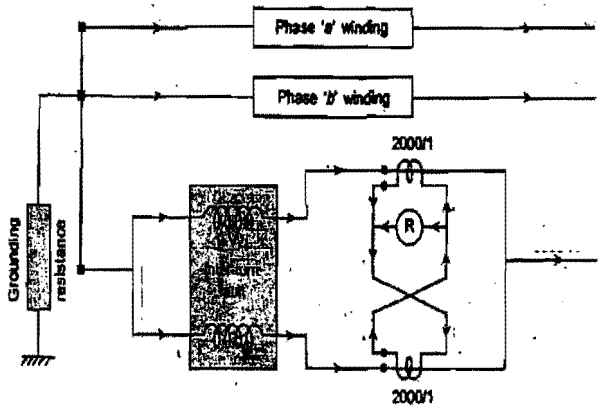
c) **Distinguish between the normal condition and the fault condition that will cause the relay to energize in the following earth leakage relay.**
Note: Start from the net mmf acting on the toroidal core.

Normal condition:



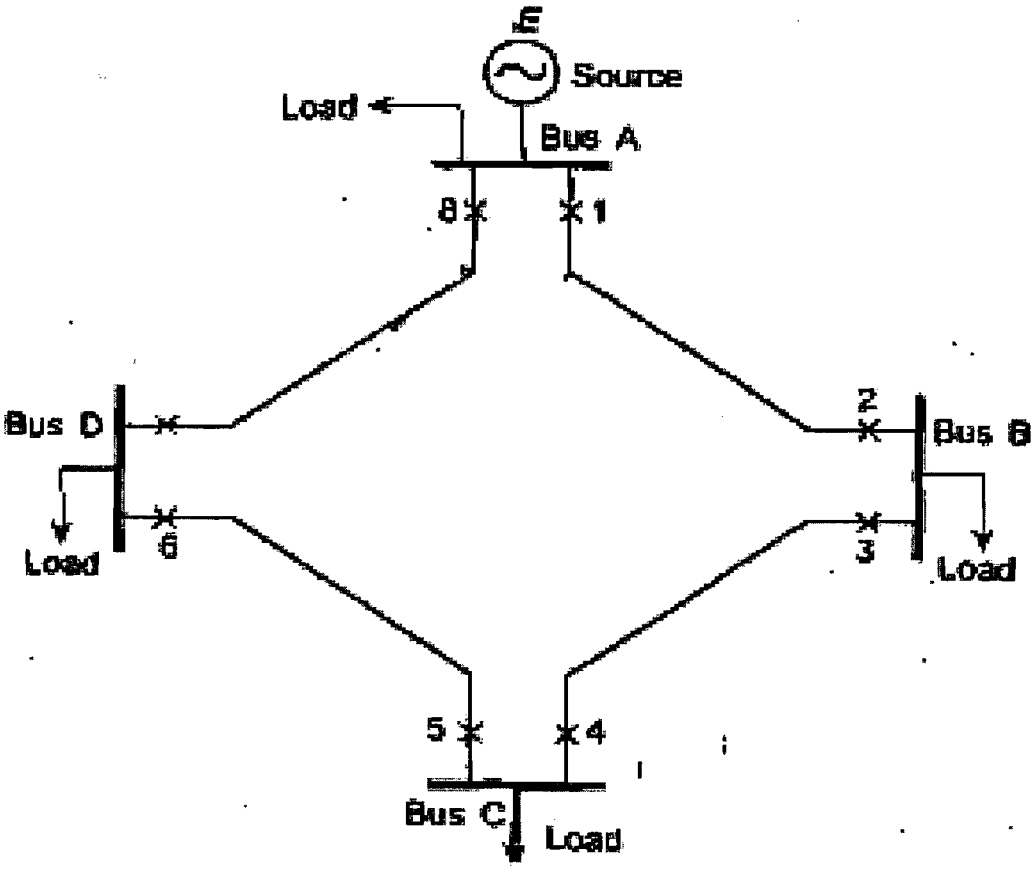
Fault condition:

d) **Determine the spill current in the following transverse differential protection if half of the winding in which there is an inter-turn fault carries 2000 A wherease the healthy half carries 4000 A . The CT ratio is 2000/1 A.**



e) **A busbar, having two incoming feeders and one outgoing feeder, being protected by a high impedance busbar differential protection scheme with supervisory relay. The currents in the two incoming feeders are 150 A and 350 A respectively. Calculate the CT ratio of all CTs and the voltage setting assuming maximum external current 13 kA and the impedance $Z_s = (R_S + R_L) = 4\Omega$. Assume the secondary of all CTs has 1A relay rating.**

f) **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.**



Question 7: Solve the following multiple choices (13 marks)

1) Over speeding problem in turbo-generator occurs because of
   a) Sudden reduction of active power supplied by generator.
   b) Sudden increase of active power supplied by generator.
   c) Sudden reduction of reactive power supplied by generator.

2) Generator will work as induction generator under the following type of fault
   a) Loss of excitation.
   b) Loss of prime mover.
   c) Unbalanced loading.

3) Generator will work as synchronous motor under the following type of fault
   a) Loss of excitation.
   b) Loss of prime mover.
   c) Unbalanced loading.

4) Generator rotor core over heating will result in the following type of fault
   a) Loss of excitation.
   b) Loss of prime mover.
   c) Unbalanced loading.

5) Protection against turbo-generator loss of prime mover is done using
   a) Mho relay.
   b) Directional over current relay.
   c) Negative sequence filter and over current relay

6) Protection against turbo-generator loss of excitation is done using
   a) Mho relay.
   b) Directional over current relay.
   c) Stopping steam supply from turbine.

7) Protection against turbo-generator overspeeding is done using
   a) Mho relay.
   b) Directional over current relay.
   c) Stopping steam supply from turbine.

8) Protection against generator unbalanced loading is done using
   a) Mho relay.
   b) Directional over current relay.
   c) Negative sequence filter and over current relay

9) Protection against generator three phase stator windings phase and ground faults is done using
   a) Longitudinal percentage differential protection.
   b) Transverse differential protection.
   c) Negative sequence filter and over current relay

10) Protection against generator three phase stator windings inter-turn fault is done with

a) longitudinal percentage differential protection.
b) Transerve differential protection.
c) Bucholz relay.

11) Protection against transformer inter-turn fault is done using

a) longitudinal percentage differential protection.
b) Transerve differential protection.
c) Bucholz relay.

12) Transformer inrush current causes

a) Heating in transformer winding.
b) Heating in transformer core.
c) Large magnetizing current when energizing transformer.

13) Protection against transformer inrush current problem is done using

a) Bucholz relay.
b) Restricted earth leakage protection .
c) Harmonic restraint percentage differential relay.

14) Protection against transformer ground fault is done using

a) Bucholz relay.
b) Restricted earth leakage protection.
c) Over current realy.

15) The earth fault relay is energized when when the residual voltage U_{en} has

a) Low value.
b) Value equal to the unfaulted phase.voltage
c) High value.

16) The reactance relay trips when

a) $X_{seen} < X_n$
b) $X_{seen} > X_n$
c) $Z_{seen} < Z_{set}$.

17) Which relay will have a directional capability?

a) Reactance relay
b) Mho relay
c) Impedance relay