UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION MAY 2014

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.

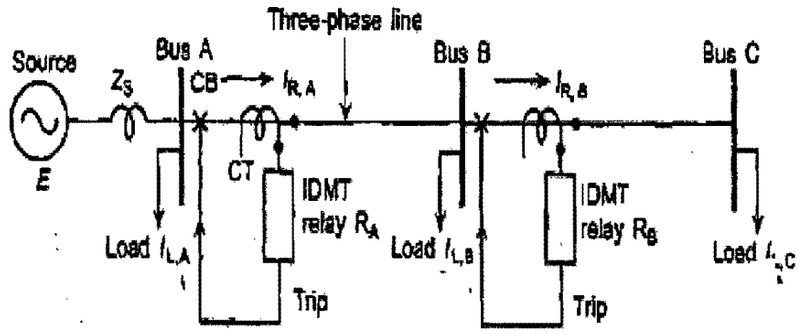
DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

This paper starts at page 1 and ends at page 18

Question 1: Solve the following questions (11 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} = 160 A	I_{LB} = 150 A	I_{LC} = 130 A
$I_{f\max}$ =2000 A	$I_{f\max}$ = 1500 A	$I_{f\max}$ = 1000 A

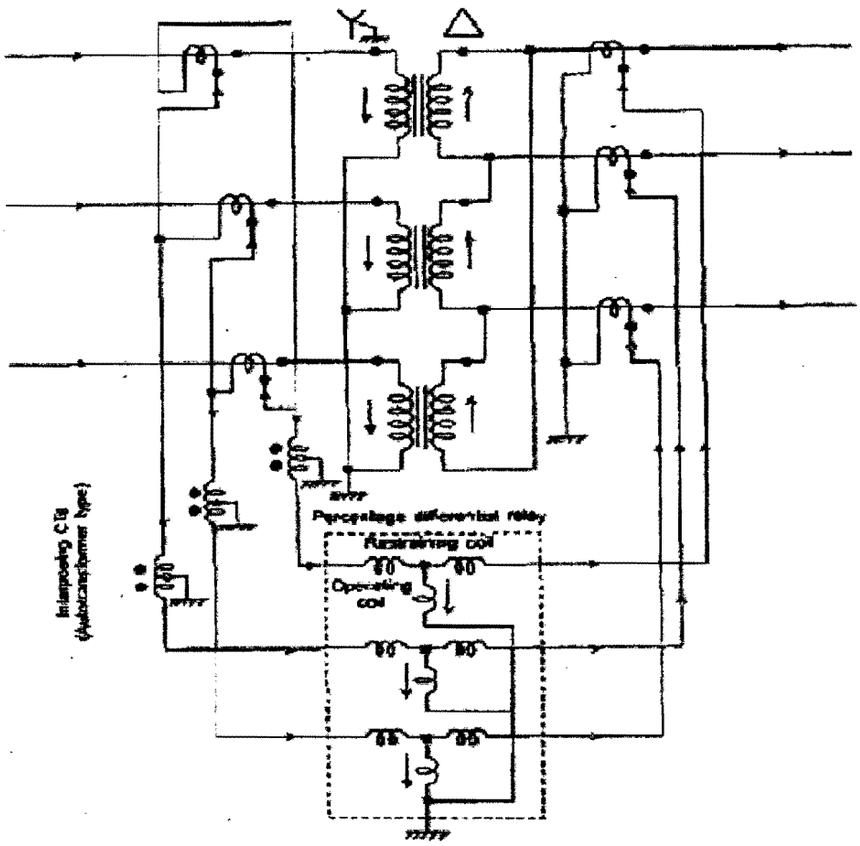


a) **Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 30% overload when calculating the maximum load, 2 A relay rating is used and the plug settings to be done at 100%.**
Not: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A .....,etc

b) **Determine the time dial setting for the relay at bus A. Assume the time dial setting for the relay at bus B is 0.2 sec ($T_{DS,B} = 0.2\,\text{sec}$), each circuit breaker operating time is 0.3 sec ($T_{CB} = 0.3\,\text{sec}$) and each relay overshoot time is calculated to be 20% of the summation of relay operating time and circuit breaker operating time of the previous coordinated relay ($T_{os} = 0.2 * (T_{CB} + T_R)$).**

Question 2: Solve the following questions (10 marks)

For a 60 MVA, 11 kV / 220 kV (line to line), 50 Hz star-delta transformer. The objective is to design a percentage differential scheme.



a) **Calculate the maximum full load current in the primary and the secondary sides lines. Assume 25% overload when calculating the maximum load.**
(Calculate: $I_{lp,\max}$, $I_{ls,\max}$ **)**

b) **Calculate the CT ratio of the CT in the primary side and the CT in the secondary winding assuming 5 A relay rating.**
(Calculate: CT_p, CT_s**)**

Not: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A .....,etc

c) **Calculate the CT pilot currents in the primary and the secondary sides of the transformer assuming maximum current is flowing in the primary and the secondary sides lines.**
(Calculate: $I_{pi,p}, I_{pi,s}$**)**

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

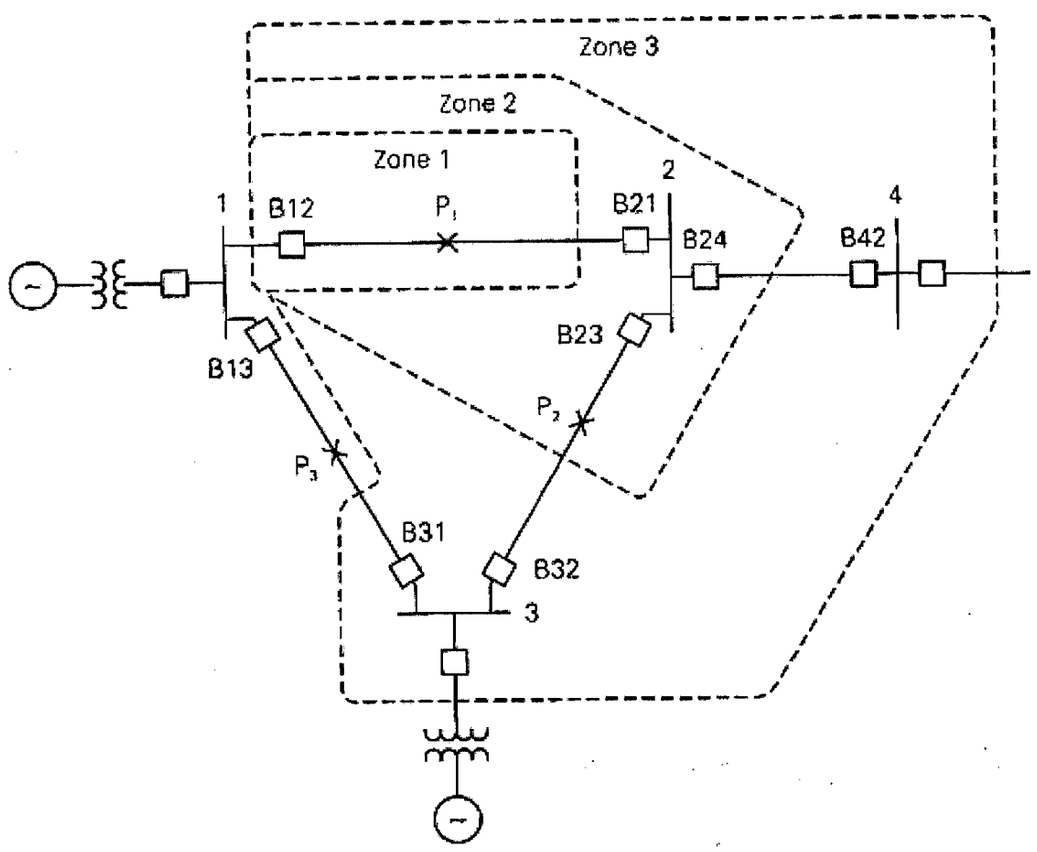
e) **Calculate the spill current required for tripping assuming the percentage differential relay of 25% slope.**

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	15+j70
2-3	8+j40
2-4	10+j50
1-3	4+j45

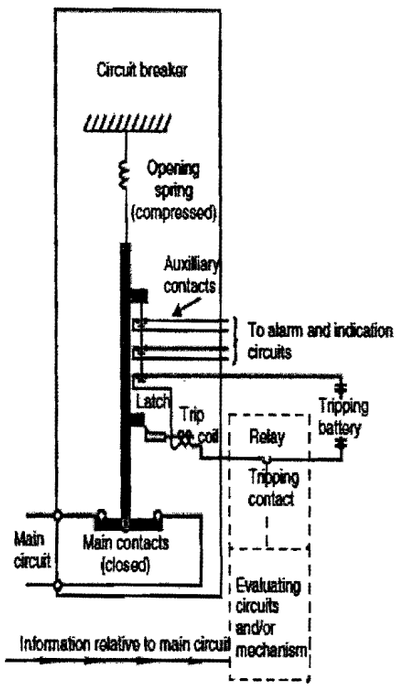
Breaker	CT ratio	VT Ratio
B12	3000:5	5000:1



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

Question 4: Solve the following questions (19 marks)

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



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

- **Small oil circuit breaker:**

- **Vacuum circuit breaker:**

- **Puffer type SF6 circuit breaker:**

c) **Explain briefly about the two tripping mechanisms in the miniature circuit breaker. Draw the characteristics of the miniature circuit breaker.**

Question 5: Solve the following questions (21 marks)

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

a) Loss of excitation:

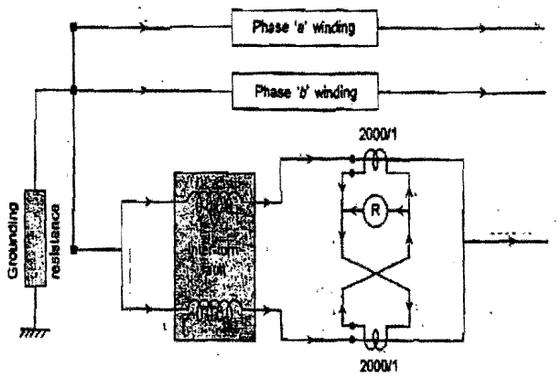
b) Over speeding:

c) Unbalanced loading.

d) Rotor ground fault:

Question 6: Solve the following questions (22 marks)

a) **Determine the spill current in the following transverse differential protection if half of the winding in which there is an inter-turn fault carries 1500 A whereas the healthy half carries 3500 A . The CT ratio is 2000/1 A.**

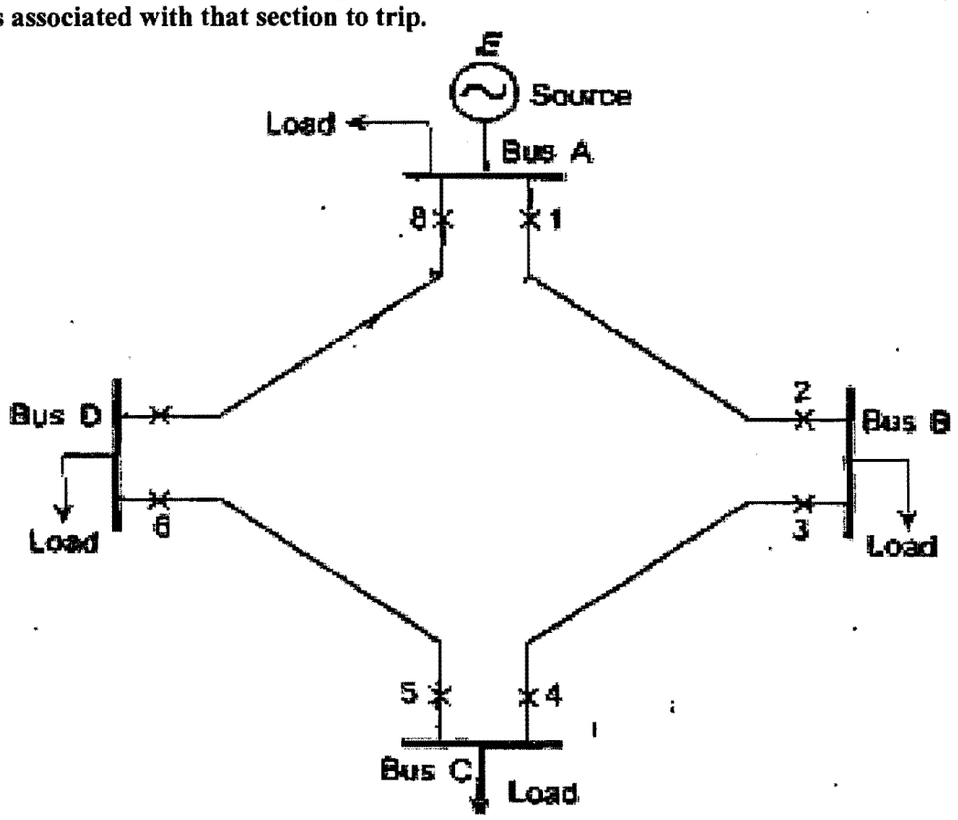


b) Draw the characteristic of the Mho relay showing the trip and restrain regions. Give general equation with explanation for the condition at which the relay will trip. Note: Define each variable in the equation. You don't need to do derivation for the condition.

c) 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 300 A and 400 A respectively. Calculate the CT ratio of all CTs, the voltage setting assuming maximum external fault current 20 kA, the pickup current setting for minimum internal fault current 800 A and the stabilizing resistance value. Assume the secondary of all CTs has 1A relay rating, the impedance $Z_s = (R_S + R_L) = 5\Omega$, the over current relay impedance $R_{oc} = 1\Omega$ and the CT magnetizing current $I_0 = 0.02A$.

d) Draw the trip and restrain region of directional over current relay has maximum torque angle RCA=60. What is the decision criteria for forward fault? Mention the condition at which the relay will operate.

e) 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.



If there is a fault in the middle of the line BC, which relays are going to energize and what will be their operating time acceding to your coordination?

f) HRC fuse with current rating of 150 A and it is of class R having a fusing factor 2. Calculate the minimum fusing current at which the fuse will melt.

g) Complete the following statement:

The percentage differential relay will energize when the following condition is satisfied:

The condition: _____

Main equation of the condition: _____

Where k= _____

Question 7: Solve the following multiple choices (8 marks)

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

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

3) Protection against transformer inter-turn fault is done using
a) Transerve differential protection.
b) Longitudinal percentage differential protection.
c) Bucholz relay.

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

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

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

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

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

8) Protection against generator three phase stator windings inter-turn fault is done with
a) Longitudinal percentage differential protection.
b) Bucholz relay.
c) Transerve differential protection.

9) Transformer inrush current causes

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

10) Protection against transformer inrush current problem is done using

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

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

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

12) Which relay will have a directional capability?

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