UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

SUPPLEMENTARY EXAMINATION JULY 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.

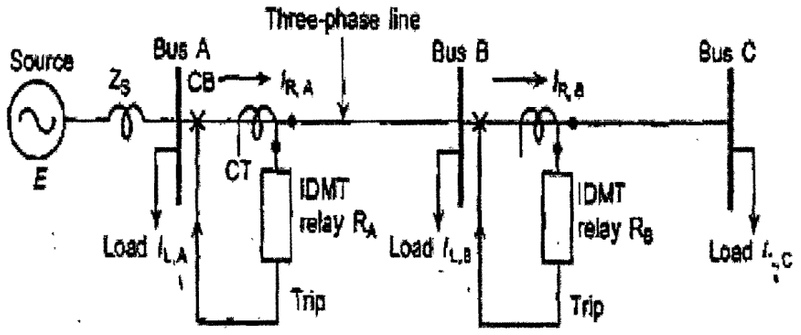
DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

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} = 200 A	I_{LB} = 150 A	I_{LC} = 130 A
$I_{f\max}$ =2500 A	$I_{f\max}$ = 2000 A	$I_{f\max}$ = 1000

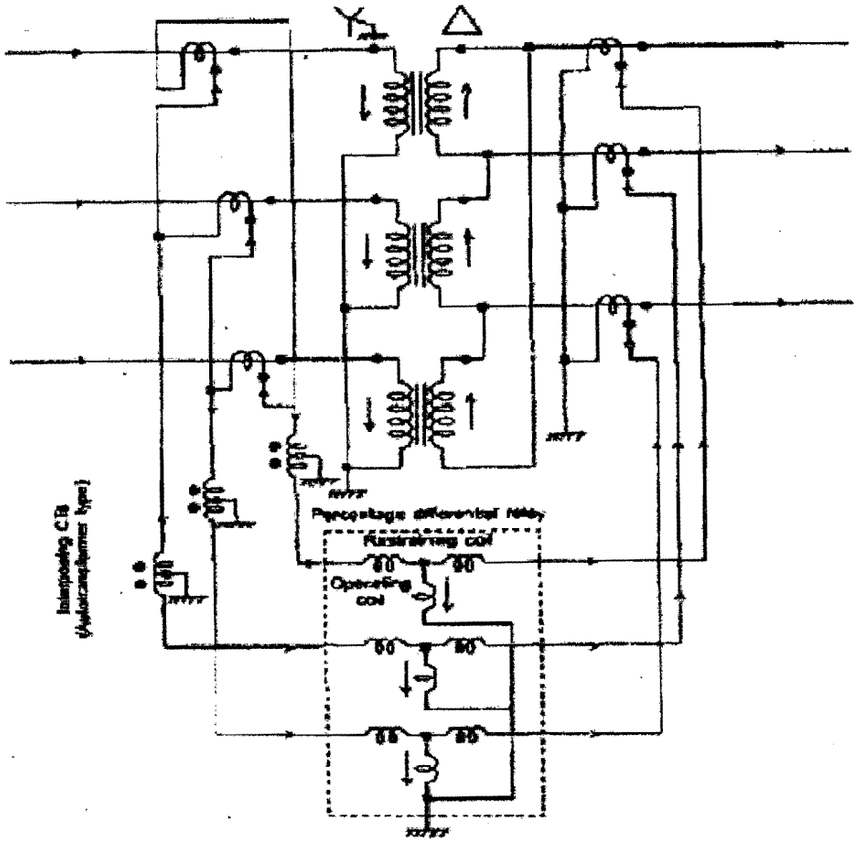


a) **Determine the CT ratios and the plug settings for the relays at bus A and bus B. Assume 20% overload when calculating the maximum load, 2 A relay rating is used and the plug settings to be done at 100%.**
Note: Assume the available CT ratings are: 100 A, 200 A, 300 A, 400 A, 500 A, 600 A .....,etc

b) **Determine the time dial setting for the relay at bus A. Assume the time dial setting for the relay at bus B is 0.3 sec ($T_{DS,B} = 0.3\text{sec}$), each circuit breaker operating time is 0.4 sec ($T_{CB} = 0.4\text{sec}$) and each relay overshoot time is calculated to be 25% of the summation of relay operating time and circuit breaker operating time of the previous coordinated relay ($T_{os} = 0.25 * (T_{CB} + T_R)$).**

Question 2: Solve the following questions (10 marks)

For a 60 MVA, 25 kV / 85 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 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) 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 rated 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.

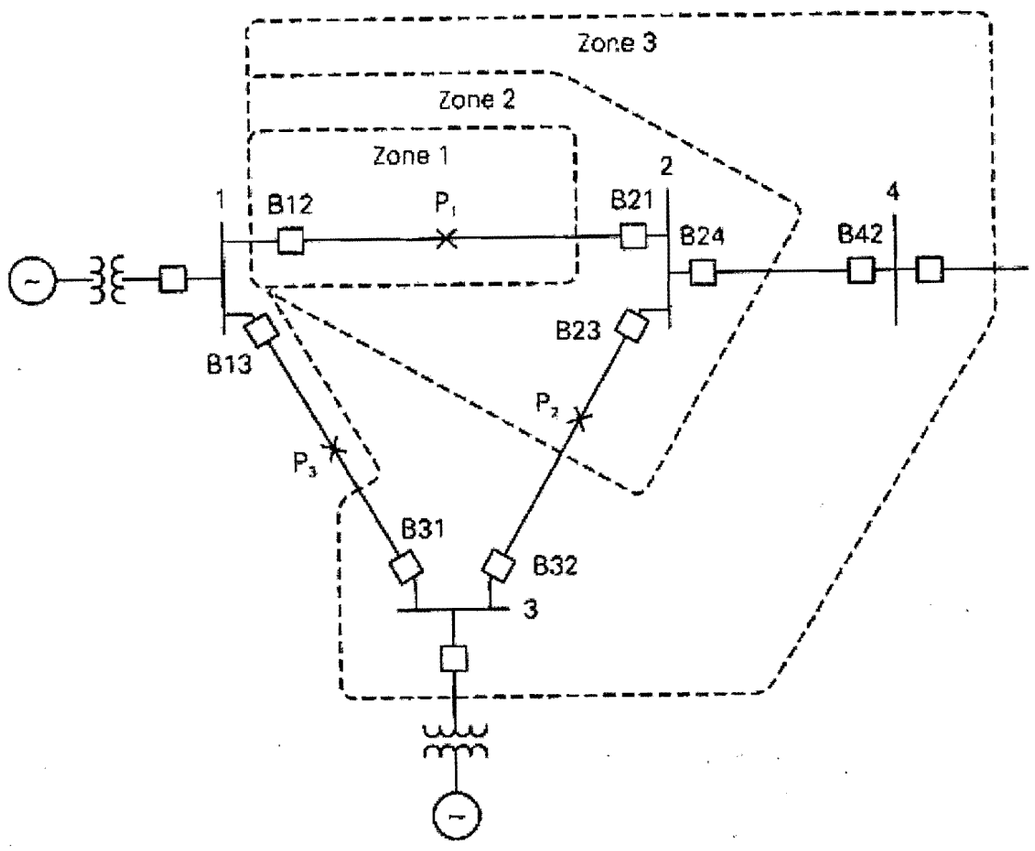
e) Calculate the spill current required for tripping assuming the percentage differential relay of 30% slope.

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	5+j30
2-3	8+j66
2-4	9+j38
1-3	11+j60

Breaker	CT ratio	VT Ratio
B12	4000:5	3200:1



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 (19 marks)

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

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

- **Puffer type SF6 circuit breaker:**

- **Minimum oil circuit breaker:**

c) **Explain briefly about the two tripping mechanisms in the miniature circuit breaker. Draw the characteristics of the miniature circuit breaker. What is been used to interrupt the arc in the miniature circuit breaker?**

Question 5: Solve the following questions (22 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 prime mover:

c) Loss of excitation.

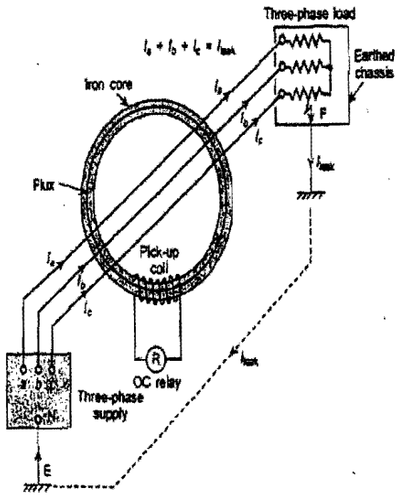
d) Unbalanced loading.

Question 6: Solve the following questions (21 marks)

a) **Starting from the universal torque equation, derive an equation with proper explanation for the condition at which the impedance relay will energize. Draw the characteristic of the impedance relay showing the trip and restrain regions. Indicate whether the distance relay exhibit directional property.**

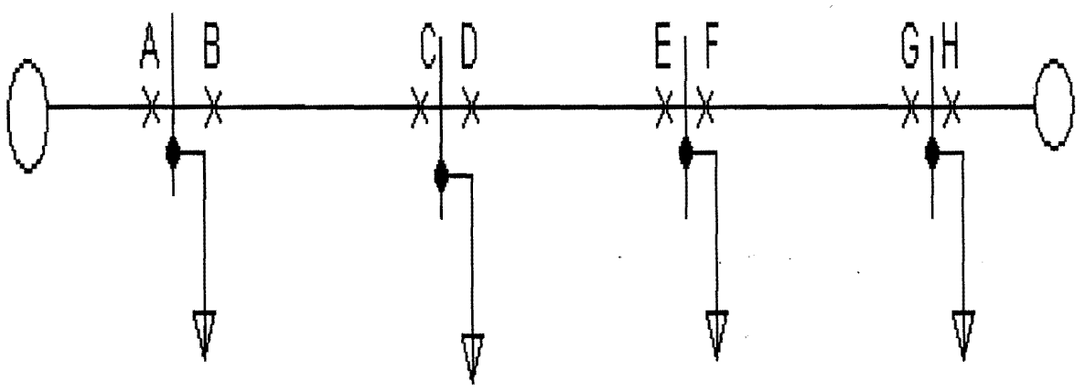
b) **Distinguish between the normal condition and the fault condition that will cause the relay to energize in the following earth leakage relay.**
Note: Start from the net mmf acting on the toroidal core.

Normal condition:



Fault condition:

c) **Coordinate the direction of supervision and the time delay between the directional OC relays in the following feeder fed from two sources 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 FG, which relays are going to energize and what will be their operating time acceding to your coordination?

d) 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 200 A and 350 A respectively. Calculate the CT ratio of all CTs, the voltage setting assuming maximum external fault current 25 kA, the pickup current setting for minimum internal fault current 1000 A and the stabilizing resistance value. Assume the secondary of all CTs has 1A relay rating, the impedance $Z_s = (R_S + R_L) = 4\Omega$, the over current relay impedance $R_{oc} = 1\Omega$ and the CT magnetizing current $I_0 = 0.03A$.

e) Draw the trip and restrain region of directional over current relay has maximum torque angle RCA=50. What is the decision criteria for forward fault?

f) 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= _____

g) Complete the following statement:

The Mho relay will energize when the following condition is satisfied:

Main equation of the condition: _____

Where Z_{seen} **is** _____

$\tau =$ _____

θ_{PC} **is** _____

θ **is** _____

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

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

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

4) Protection against transformer ground fault is done using
   a) Bucholz relay.
   b) Restricted earth leakage protection.
   c) Over current realy.

5) 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.

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

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

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

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

10) Protection against generator unbalanced loading is done using

a) Mho relay.
b) Directional over current relay.
c) Negative sequence filter and over current relay

11) 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

12) 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.

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

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

14) Protection against transformer inrush current problem is done using

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

15) Which relay will have a directional capability?

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