UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION MAY 2013

TITLE OF PAPER: **Power Systems**

COURSE CODE: **EE 452**

TIME ALLOWED: **THREE** HOURS

Student Name:	
Student Number:	

INSTRUCTIONS:

6. Answer all questions.
7. 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.
8. 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)
9. Marks for different questions are indicated on the beginning of the question.
10. Rough work maybe done in the examination answer book and crossed through.

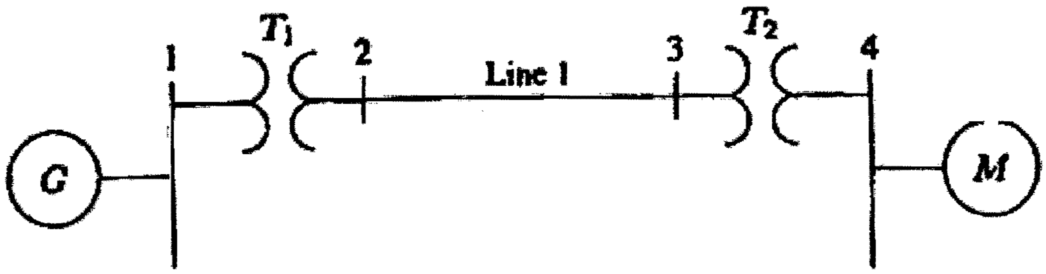
DO NOT OPEN THIS PAPER UNTIL PERMISSION HAS BEEN GRANTED BY THE INVIGILATOR

This paper starts at page 1 and ends at page 18.

Question 1: Solve the following questions (16 marks)

The one-line diagram of the three-phase power system is shown in the following figure. The data in ohm for each device as follows:
Generator: Y connected, 80MVA, 11 kV, Z=j1 Ω.
Transformer T1: Y-Δ connected, 50MVA, 11 kV / 345 kV (line-to-line), Z=j1.4 Ω (referred to primary).
Transformer T2: Δ-Y connected, 50 MVA, 345 kV / 11 kV (line-to-line), Z=j0.2 Ω (referred to secondary).
Motor M: 60 MVA, 11 kV (line-to-line), Z=0.3 Ω.

Line 1 has an impedances of j40 Ω.



a) **Select a common base of 100 MVA and 11 kV (line to line) on the generator side. Find the base voltage and base impedance at each section of the system.**

b) Draw the equivalent diagram of the network with all impedances in per unit.

c) Calculate the internal generator emf in per unit assuming the motor operates at full load, 0.707 pf leading at 11 kV.

d) Calculate the generator line-to-line emf in Volts and motor current in Amps.

Question 2: Solve the following questions (15 marks)

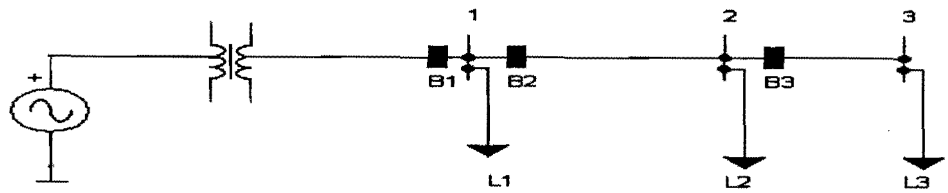
The objective is to select the tap settings (TS) and time dial settings to protect the system shown below from the fault. Assume that CO8 is used for each breaker, one for each phase with 0.5 sec coordination time intervals. The relay for each breaker is connected so that all of the three phases of breaker open when the fault is detected on one phase. A 33 kV line-to-line voltage is assumed at all buses during normal operation.

Note: Use the CO-8 time delay over current relay characteristic curves shown below to solve the question.

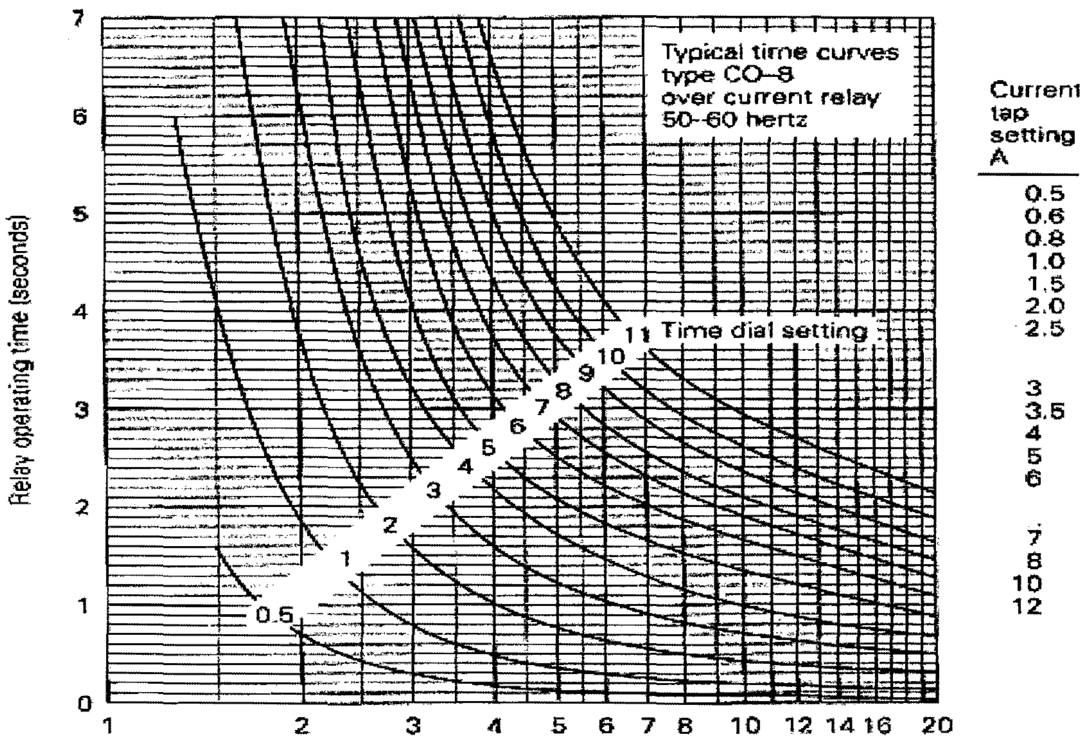
Bus	S	Lagging pf	CT
1	15 MVA	0.95	B1 relay: 400/5
2	10 MVA	0.95	B2 relay: 300/5
3	8 MVA	0.95	B3 relay: 200/5

Fault data

Bus	Max fault current
1	3000
2	2000
3	1000



CO-8 time delay over current relay characteristic.



a) Calculate the plug setting (tap setting) for the relay at breaker B3.

b) Calculate the plug setting (tap setting) for the relay at breaker B2.

c) Calculate the plug setting (tap setting) for the relay at breaker B1.

d) What is the time dial setting for the relay at breaker B3.

e) Calculate the time dial setting for the relay at breaker B2. Assume the breaker B3 operating time $T_{breaker}$ =0.1 sec and the coordination time $T_{coordination} = 0.5\,\text{sec}$.

Question 3: Solve the following questions (17 marks)

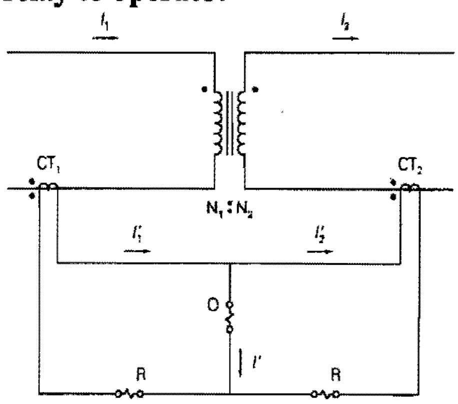
a) A CO8 over current relay with current tap setting TS=6 A and time dial setting TDS= 3 sec is used with current transformer CT. Use the CO-8 time delay over current relay characteristic curves given in Question 2 to determine the operating time in case the current I' that flows in the CT has the following magnitudes:

I'=5A:

I'=12 A:

I'=24 A:

b) In a differential protection of a transformer, the current through the differential relay is i', the current through the CT in primary winding i'_1 and the current through the CT in secondary winding i'_2. Distinguish between the normal condition and the fault condition that causes the differential relay to operate?



c) Is changing the voltage magnitude between two ends of the transmission line will affect the real or reactive power flow through the line? What is the direction of that type of power flow: from the higher voltage side towards the lower voltage side or from lower voltage side towards the higher voltage side.

d) Is changing the phase shift between two ends of the transmission line will affect the real or reactive power flow through the line? What is the direction of that type of power flow: from the lagging voltage side towards the leading voltage side or from leading voltage side towards the lagging voltage side.

e) If a voltage at the sending end of transmission line is $V_S = 30kV\angle 15°$ and the voltage at the receiving end of transmission line is $V_R = 25kV\angle 40°$. What is the direction of the active power flow and reactive power flow: from sending end towards the receiving end or from receiving end towards the sending end.

- **Direction of active power flow:**
- **Direction of reactive power flow:**

f) In a differential protection of a three phase Δ-Y connected transformer, how the CTs in the Δ side and the CTs in the Y side of the transformer should be connected, in Y-Δ or Δ-Y?

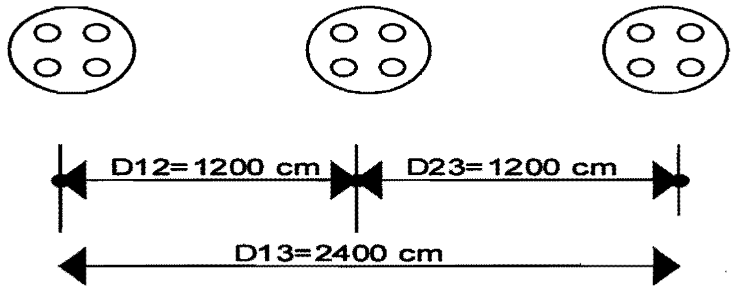
g) List the compensation methods used to increase the voltage level in power system when under voltage is detected in the system.

h) Draw the R-X characteristic of the distance relay showing the trip and restrain regions. Give an equation with proper explanation for the condition at which the relay will trip.
(Note: Define each variable in the equation)

i) A transmission line has an impedance $Z_{AB} = 5 + j40\Omega$ is protected with impedance relay having CT ratio 1000/5 A and VT ratio 4000/1 V. Calculate the impedance relay setting. What is the condition at which the impedance relay will trip the circuit breaker?

Question 4: Solve the following questions (9 marks)

A 400 KV three phase transposed line composed of four ACSR conductors per phase with conductors configuration shown below. The conductors have diameter of 3 cm. The line spacing measured from center of bundle is shown in the figure. Bundle spacing is 40 cm. Find the inductance and capacitance per phase per Km of the line.



Question 5: Solve the following questions (18 marls)

A three phase 50 Hz transmission line is 340 Km long. The series impedance per Km of the line is $z = 0.8\angle 74°\Omega$. The shunt admittance per Km of the line is $y = 6 * 10^{-6}\angle 90° Si$.

a) **Calculate the transmission line constants A, B, C, D and write the long transmission line model in the following form:**

$$\begin{bmatrix} V_s \\ I_s \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

Note: Use long line model.

b) If the line to neutral voltage at the sending end of the transmission line was $V_s = 192.5\angle 22.9454°$ kV, determine the receiving end line to neutral voltage at no load.

c) If the transmission line is assumed to be lossless transmission line with an inductance per phase of 2.45 mH/Km and shunt capacitance of 0.019 μF/Km. Calculate the line phase constant β and the surge impedance Z_C.

d) In c, if the line to line voltage at the sending end of the transmission line was $V_s = 220$ kV. What is the required inductor reactance to be connected at the receiving end of transmission line so that the sending end voltage will be equal to receiving end voltage $V_S = V_R$.

Question 6: Solve the following questions (15 marks)

Given the following network with

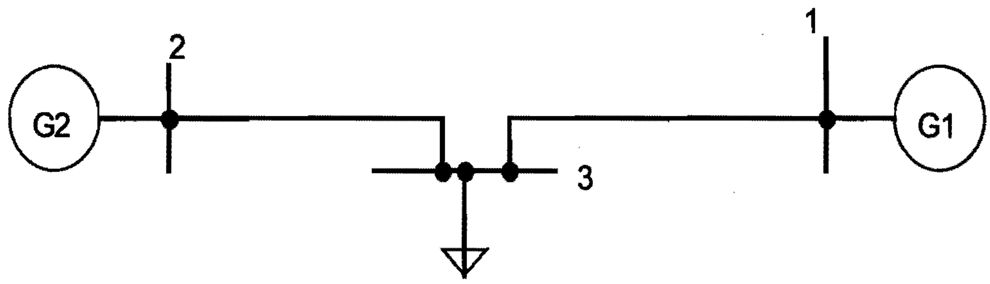
$V_1 = 1\angle 0\ pu$ *Slackbus*

$P_2 = 1.8\ pu$ $|V_2| = 1.05\ pu$ *PVbus*

$P_3 = -2\ pu$ $Q_3 = -1.2\ pu$ *PQbus*

$Y_{L23} = -j8$

$Y_{L13} = -j5$



a) **Write the admittance matrix Ybus of the system.**
Note: No need to make derivation of the Ybus matrix.

b) Solve for the first iteration of V_2 using Gauss Seidel method.

c) If the solution to the load flow problem was $V_1 = 1pu$, $V_2 = 1.05\angle 11.0889° pu$, $V_3 = 0.9109\angle -2.5167° pu$, calculate the active and reactive power flow in line 3-1 (P_{31}, Q_{31}).

Question 7: Solve the following questions (10 marks)

Consider one meter length of three phase transposed transmission line with three long conductors of radius r as shown in the figure below. Derive an equation for the inductance per phase L.