UNIVERSITY OF SWAZILAND

FACULTY OF SCIENCE
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

MAIN EXAMINATION MAY 2014

TITLE OF PAPER: **Power Systems**

COURSE CODE: **EE 452**

TIME ALLOWED: **THREE** HOURS

Student Name:	
Student Number:	

INSTRUCTIONS:

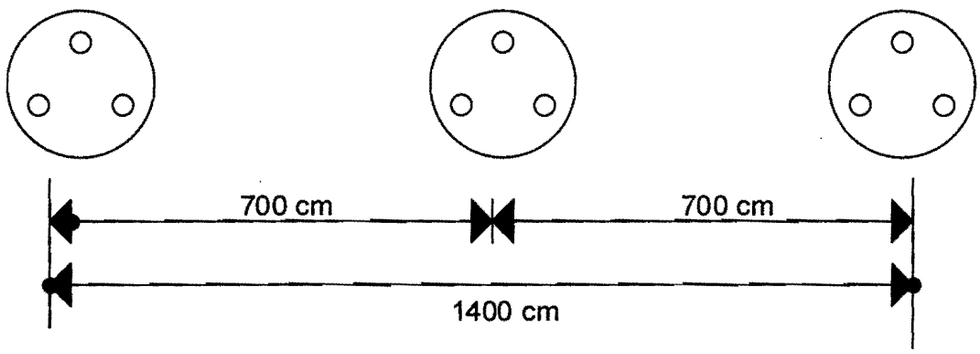
1. Answer all questions.
2. Give your answers on the question paper, and if more space is required, complete your answer on the back of the paper or in your answer book and mention about the place of your answer completion.
3. Put the question sheet inside the answer book upon submission of your exam 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 (8 marks)

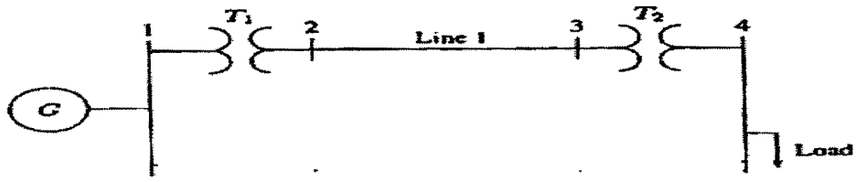
A 460 KV three phase transposed line composed of three ACSR conductors per phase with horizontal conductor configuration shown in the figure below. The conductors have diameter of 2.5 cm. The line spacing measured from center of bundle is shown in the figure. Bundle spacing is 35 cm. Find the inductance and capacitance per phase per Km of the line.
Note: Show how GMR_L is obtained for the bundle.



Question 2: Solve the following questions (19 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, 80 MVA, 15 kV, Z=j1.2 Ω.
Transformer T1: Y-Δ connected, 50MVA, 15 kV / 400 kV (line-to-line), Z=j1.6 Ω (referred to primary).
Transformer T2: Δ-Y connected, 50 MVA, 400 kV / 11 kV (line-to-line), Z=j0.3 Ω (referred to secondary).
The three-phase load at bus 4 absorbs 30 MVA ($|S_{load}(3\varphi)| = 30MVA$), 0.707 power factor lagging at 10.5 kV.

Line 1 has impedance of j35Ω.



a) Select a common base of 100 MVA and 15 kV (line to line) on the generator side. Calculate the base line-to-line voltage and base impedance at each section of the system.

b) Calculate the ohmic value of load impedance assuming the load at bus 4 absorbs 30 MVA ($|S_{load}(3\varphi)| = 30MVA$), 0.707 power factor lagging at 10.5 kV.

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

d) Calculate the internal generator emf in per unit assuming the load at bus 4 absorbs 30 MVA ($|S_{load}(3\varphi)| = 30MVA$), 0.707 power factor lagging at 10.5 kV.

e) Calculate the internal generator line to line voltage in Volts and the line current in Amps.

Question 3: Solve the following questions (18 marks)

A three phase 50 Hz, 300 kV three phase transmission line is 320 Km. The series impedance per Km of the line is $z = 1.2\angle 75°\Omega$. The shunt admittance per Km of the line is $y = 5*10^{-6}\angle 90° Si$.

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

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

Not: Use long line model.

b) If the transmission line is assumed to be lossless transmission line with an inductance per phase of 3.69 mH/Km and shunt capacitance of 0.016 μF/Km. Calculate the line phase constant β and the surge impedance Z_C.

c) In b, if the line-to-line voltage at the sending end of the transmission line was $V_S = 300$ 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 $V_S = V_R$.

Note: Show how the final equation for X_{Lsh} is obtained.

Question 4: Solve the following questions (15 marks)

Given the following network with

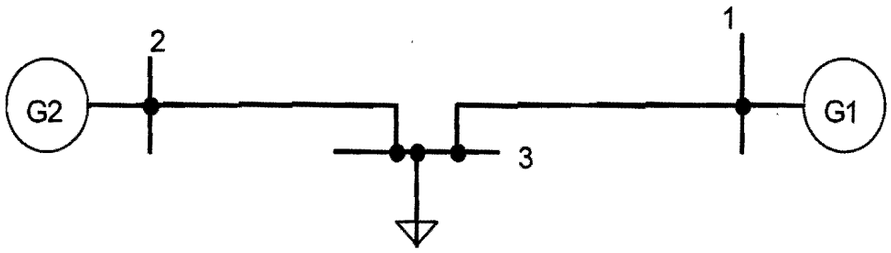
$V_1 = 1\angle 0\ pu$ *Slackbus*

$P_2 = 1.5\ pu$ $|V_2| = 1.1\ pu$ *PVbus*

$P_3 = -1.8\ pu$ $Q_3 = -1.2\ pu$ *PQbus*

$Y_{L23} = -j4$

$Y_{L13} = -j5$



a) Write the Ybus admittance matrix 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 of the load flow problem was $V_1 = 1pu$, $V_2 = 1.1\angle 19.7681° pu$, $V_3 = 0.8432\angle -4.0807° pu$, calculate the active and reactive power flow in the line 3-2 (P_{32}, Q_{32}). What is the direction of the active and reactive power flow? From bus 3 to bus 2 or from bus 2 to bus 3.

The direction of active power flow:

The direction of reactive power flow:

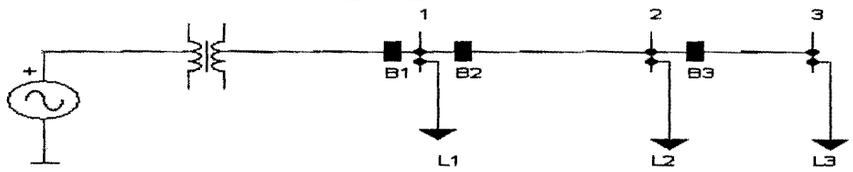
Question 5: Solve the following questions (13 marks)

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 over current relay is used for each breaker, one for each phase with 0.4 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.

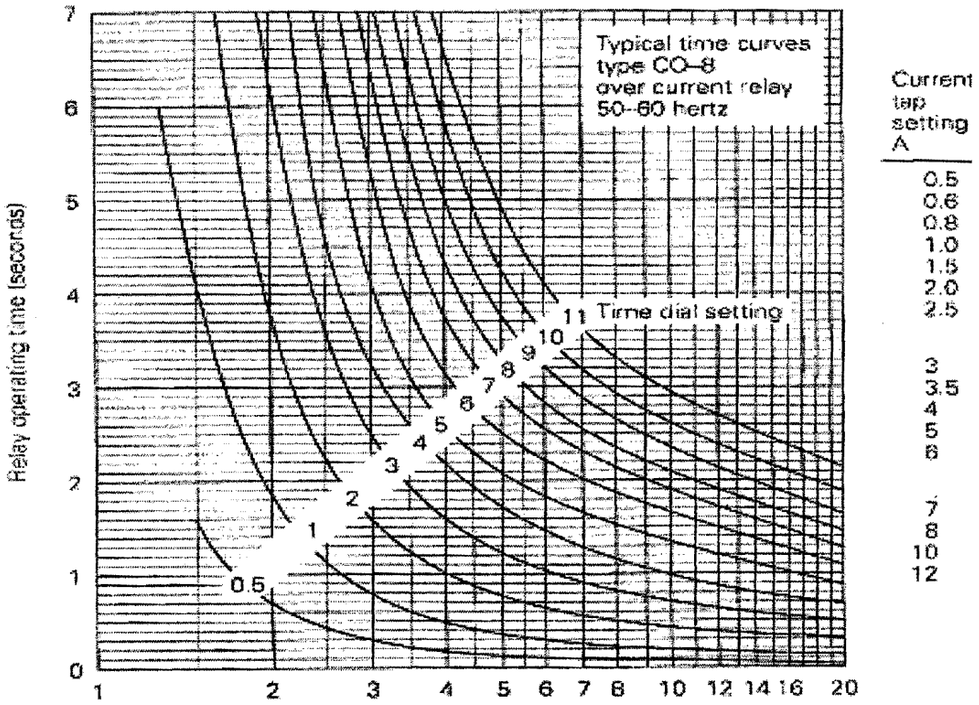
Bus	S	Lagging pf	CT
1	13 MVA	0.95	B1 relay: 400/5
2	11 MVA	0.95	B2 relay: 300/5
3	7 MVA	0.95	B3 relay: 200/5

Fault data

Bus	Max fault current
1	3000
2	2000
3	1000



CO-8 over current relay time delay 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 $T_{coordination} = 0.4\,\text{sec}$.

Question 6: Solve the following questions (18 marks)

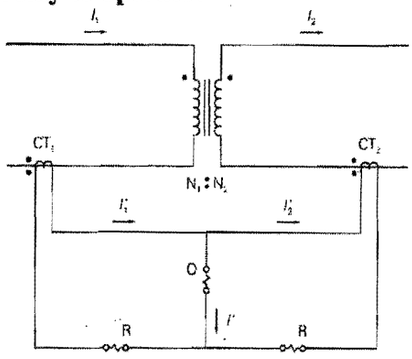
a) A CO8 over current relay with current tap setting TS=2 A and time dial setting TDS= 4 sec is used with current transformer CT. Use the CO-8 over current relay time delay characteristic curves given in Question 5 to determine the operating time in case the current I' that flows in the CT has the following magnitudes:

I'=2 A:

I'=10 A:

I'=20 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) **If a voltage at the sending end of transmission line is $V_S = 20kV\angle 30°$ and the voltage at the receiving end of transmission line is $V_R = 25kV\angle 10°$**
Note: You don't need to do calculations

- **Will the active power flow from the sending end to receiving end or form the receiving end to sending end. Indicate the reason.**

- **Will the reactive power flow from the sending end to receiving end or form the receiving end to sending end. Indicate the reason.**

d) **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?**

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

f) **Draw the 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)

g) **A transmission line has an impedance $Z_{AB} = 6 + j20\Omega$ is protected with impedance relay having CT ratio 3000/5 A and VT ratio 2000/1 V. Calculate the impedance relay setting. What is the condition at which the impedance relay will trip the circuit breaker?**

Question 7: Solve the following questions (9 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 capacitance to neutral per phase.
(Note: Derive equation for C_n)