UNIVERSITY OF SWAZILAND
MAIN EXAMINATION, MAY 2017

FACULTY OF SCIENCE AND ENGINEERING

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

TITLE OF PAPER:	**POWER SYSTEMS**
COURSE NUMBER:	**EE452**
TIME ALLOWED:	**THREE HOURS**

INSTRUCTIONS:

1. There are five questions in this paper. **Answer any FOUR questions.**
2. Questions carry equal marks.
3. Marks for different sections of a question are shown on the right hand margin.
4. If you think not enough data has been given in any question you may assume any reasonable values, and state these summed values.
5. **A page containing useful formulae, some of which you may need, is attached at the end**

THIS PAPER IS NOT TO BE OPENED UNTIL PERMISSION HAS BEEN GIVEN BY THE INVIGILATOR

THIS PAPER HAS SEVEN (7) PAGES INCLUDING THIS PAGE

QUESTION 1 ***(25 marks)***

(a) A three-phase 400-kV line consists of two bundled same-phase conductors each of radius 0.8 cm spaced as shown in Fig.Q1. Each same-phase conductors are 20 cm apart.

(i) Calculate the inductance per phase per km of the line. *(8 marks)*

(ii) Calculate its capacitance between line and neutral per phase per km. *(4 marks)*

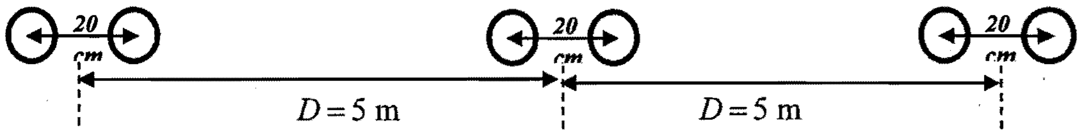

Fig.Q1

(b) A 3-phase 50-Hz overhead short transmission line has an impedance of $2.5 + j6.5\ \Omega$ per phase. A load of 9 MW with lagging power factor of 0.85 is connected at the receiving end where the line-to-line voltage is 22 kV.

(i) Determine the magnitude and phase of the line-to-neutral and line-to-line voltages at the sending end. Use the receiving end voltage as reference phase. *(10 marks)*

(ii) Draw a labeled phasor diagram of all voltages and currents. *(3 marks)*

QUESTION 2 *(25 marks)*

(a) Given the π-model of a medium length transmission line, derive its *ABCD* constants. *(5 marks)*

(b) A 3-phasse, 132 kV medium transmission line is connected to a 50-MW load at a lagging power factor of 0.9. The line series and shunt line constants are $Z = 91\angle 72°\ \Omega$ and $Y = 0.002\angle 90°$ S respectively. Calculate the following:

(i) The *ABCD* constants of the line assuming the π-model is used. *(6 marks)*

(ii) The sending end line-to-line voltage. *(7 marks)*

(iii) The sending end current. *(2 marks)*

(iv) The sending end power factor. *(2 marks)*

(v) The efficiency of transmission *(3 marks)*

QUESTION 3 *(25 marks)*

(a) Consider a simple power system composed of a generator, a 400kV overhead transmission line and a load, as shown in Fig. Q.2a

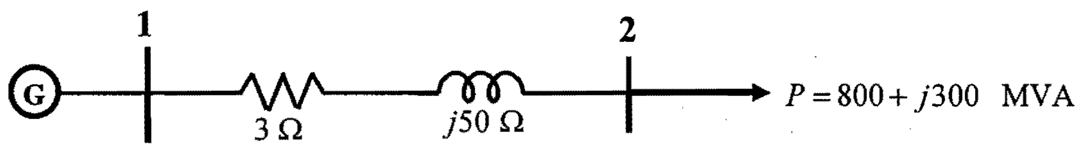

Fig. Q.2a

If the desired voltage at the consumer busbar (2) is 400 kV, calculate:

(i) The active and reactive losses in the line. *(7 marks)*

(ii) The voltage magnitude and phase angle at the generator busbar (1). *(4 marks)*

(iii) The active and reactive power generated. *(4 marks)*

(b) Briefly explain, giving advantages and disadvantages, each of the following power distribution systems:

(i) Radial systems *(3 marks)*

(ii) Loop (Ring) systems *(4 marks)*

(iii) Interconnected systems *(3 marks)*

QUESTION 4 *(25 marks)*

(a) A three-phase overhead transmission line has resistance 5 Ω per phase and inductive reactance of 18 Ω per phase. The line feeds a three-phase load of 24 MW, power factor 0.8 lagging, at a line-to-line voltage of 33 kV. A synchronous condenser is situated at the receiving end which maintains the voltages at both ends of the line at 33 kV. Calculate the MVAr of the condenser.

(15 marks)

(b) The system load power demand for a given day can be approximated by the expression

$$P = 280 - 38e^{-0.01t}\cos(0.5417t - 1)\ \text{MW}$$

where t is the time of the day in hours. Calculate:

(i) Determine the times of the day when peak demands occur. Use differentiation or otherwise. *(6 marks)*

(ii) The peak demands in MW *(4 marks)*

QUESTION 5 *(25 marks)*

(a) Explain why it is important to correct power factor in industrial installations which have poor power factors? *(5 marks)*

(b) A portion of an industrial facility has a power factor of 0.7 lagging. The facility has the following power consumption parameters:

Load is 180 kW, 400 V 3-phase

The installation is run for an average of 624 hours per month

The Utility Monthly Tarrif (charging) schedule is as follows:

Energy Consumption Charge = E0.923 per kWh

kVA Demand Charge = E127.11 per kVA

(i) Calculate the total monthly energy consumption. *(3 marks)*

(ii) Calculate the kVA demand of the installation. *(2 marks)*

(iii) Determine the average monthly bill given by the utility for this facility. *(3 marks)*

(iv) If it is decided that capacitors be used to improve the power factor to 0.95, determine the kVAR of the required capacitors and new kVA demand. *(5 marks)*

(v) What would be the new monthly bill after power factor improvement? *(4 marks)*

(vi) The savings in utility bills per month are used to cover the cost of power factor improvement. If the capacitors cost E4000.00 per 5 kVAR, how long will take to recover this cost? *(3 marks)*

USEFUL FORMULAE SOME OF WHICH YOU MAT NEED

SUMMARY OF TRANSMISSION LINE *ABCD* CONSTANTS

Parameter	$A = D$	B	C
Units	p.u.	Ω	S
Short Line $G=C=0$	1	Z	0
Medium Line $G=0$ (π-model)	$1+\frac{YZ}{2}$	Z	$Y\left(1+\frac{YZ}{4}\right)$
Long Line (length l, equivalent π-model)	$\cosh(\gamma l)=1+\frac{Y'Z'}{2}$	$Z_c\sinh(\gamma l)=Z'$	$\frac{1}{Z_c}\sinh(\gamma l)=Y'\left(1+\frac{Y'Z'}{4}\right)$
Lossless Line (length l, $R=G=0$)	$\cos(\beta l)$	$jZ_c\sin(\beta l)=jX'$	$\frac{j\sin(\beta l)}{Z_c}$

Equivalent π-model of long line:

$$Z' = Z_C \sinh\gamma\ell = Z\frac{\sinh\gamma\ell}{\gamma\ell}, \qquad \frac{Y'}{2}=\frac{1}{Z_C}\tanh\frac{\gamma\ell}{2}=\frac{Y}{2}\frac{\tanh\gamma\ell/2}{\gamma\ell/2}$$

Equivalent π-model of lossless line: $Z' = jX' = jZ_C\sin\beta\ell$, $\quad \frac{Y'}{2}=j\frac{\sin\beta\ell}{Z_C}$

For lossless line:

$Z_C=\sqrt{L/C}$ Ω, $\beta=\omega\sqrt{LC}$ rad/m, $v=1/\sqrt{LC}$, Note here L is inductance/unit length

Injection of VARs into a Short Transmission Line results in:

$$V_S^2=\left[V_R+I_pR-(I_c-I_q)X\right]^2+\left[I_pX+(I_c-I_q)R\right]^2$$

where $I_R = I_p - jI_q$

$$L=\frac{\mu_o}{2\pi}\ln\frac{GMD}{GMR_L} \text{ per conductor}, \qquad C_{an}=\frac{2\pi\varepsilon_o}{\ln\frac{GMD}{GMR_C}}$$

$\mu_o = 4\pi\times10^{-7}$ H/m $\qquad \varepsilon_o = 8.854\times10^{-12}$ F/m