INTI
International College Penang

FINAL
Examination Paper

(COVER PAGE)

Session	:	**April 2018**
Programme	:	Diploma in Electrical and Electronic Engineering (DEEI)
Course	:	**EEE2113: Electric Power Systems and Machines**
Date of Examination	:	2 August 2018 (Thursday)
Time	:	8:00am – 10:00am Reading Time : Nil
Duration	:	2 Hours

Special Instructions :

This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks.

Materials permitted :

Non-Programmable Scientific Calculator

Materials provided :

Nil

Examiner(s)	:	**Ken Kong Seng Kuok**
Moderator	:	Dr. Ooi Beng Lee

This paper consists of 9 printed pages, including the cover page

INTI INTERNATIONAL COLLEGE PENANG

DIPLOMA IN ELECTRICAL AND ELECTRONIC ENGINEERING PROGRAMME (DEEI)
EEE2113: ELECTRIC POWER SYSTEMS AND MACHINES
FINAL EXAMINATIONS: APRIL 2018 SESSION

Instructions: This paper consists of **SIX (6)** questions. Answer any **FOUR (4)** questions in the answer booklet provided. All questions carry equal marks.

Question 1

(a) Data obtained from short-circuit and open-circuit tests of a 75 kVA, 4600/230 V, 50 Hz transformer are:

Open-circuit Test	**Short-circuit Test**
(Low-voltage side Data)	(High-voltage side Data)
$V_{OC} = 230$ V	$V_{SC} = 160.8$ V
$I_{OC} = 13.04$ A	$I_{SC} = 16.3$ A
$P_{OC} = 521$ W	$P_{SC} = 1200$ W

(i) **Solve** for the core-loss resistance ($R_{fe,LS}$) from open-circuit test data. (5 marks)

(ii) **Solve** for the magnetizing reactance ($X_{M,LS}$) from open-circuit test data. (5 marks)

(iii) **Determine** the transformer windings resistance ($R_{eq,HS}$) from short-circuit test data. (3 marks)

(iv) **Determine** the transformer windings reactance ($X_{eq,HS}$) from short-circuit data. (5 marks)

(b)

(i) **Convert** the transformer winding resistance ($R_{eq,HS}$) and reactance ($X_{eq,HS}$) into their respective per unit value using the transformer high side rating as base. (4 marks)

(ii) **Determine** the voltage regulation of the transformer operating at rated load and 0.75 power factor lagging using the per unit value of the transformer winding impedance established in part (i). (3 marks)

continue...

Question 2

(a)

(i) **Explain** the working principle of photovoltaic solar system to generate electricity in terms of energy input, material and potential barrier. (8 marks)

(ii) An off-grid residency plans to install photovoltaic solar system to be self-sustaining on the electricity demand. Listed below are some acquired data:
Estimated monthly demand: 200 kWh
Solar panel yield, r: 20.6%
Annual average solar radiation on tilted panel, H: 2000 $kWh/m^2.y$
Coefficient for losses, PR: 0.75
Calculate the solar panel area to accommodate the need of the residency. (5 marks)
Note: $E = A \cdot r \cdot H \cdot PR$
E: annual energy production
A: total solar panel area
(Please refer other parameters from the question.)

(b)

(i) **Describe** the conditions an alternator must match before it can be synchronized to the grid. (8 marks)

(ii) **Explain** the consequences of synchronizing the alternator with different line voltage at the terminal to the grid. Appraise the situation from both perspective of lower or higher line voltages. (4 marks)

continue...

Question 3

(a) The yearly load duration curve of certain plant is considered as a straight line from 40,000 kW to 8,000 kW. To meet this load, three turbo-generators; 2 rated at 20,000 kW each and 1 at 10,000 kW, are installed.

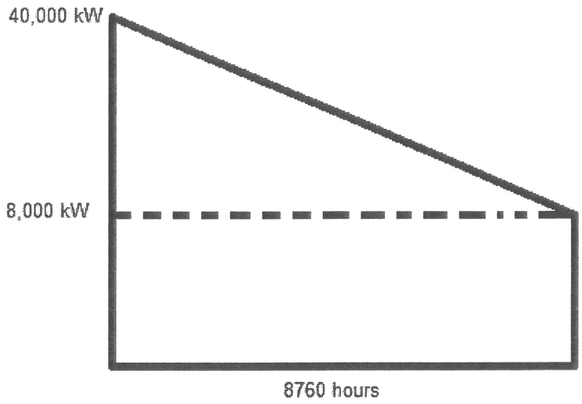

Figure Q3a: Yearly load duration curve of certain plant

(i) **Determine** the installed capacity. (5 marks)

(ii) **Calculate** the plant factor. (5 marks)

(iii) **Identify** the maximum demand. (5 marks)

(iv) **Solve** for the load factor. (5 marks)

(v) **Calculate** the utilization factor. (5 marks)

continue...

Question 4

(a) The following Figure Q4a shows a single line diagram indicating a network connecting 4 generators and 2 reactors. The machine rating and percentage reactance are listed below the figure. A symmetrical fault developed along the feeder labelled G.

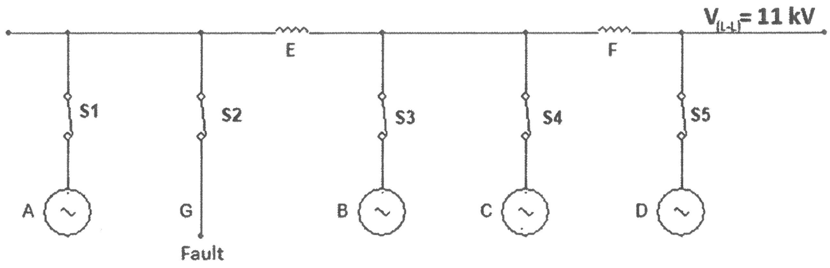

Figure Q4a: Single line diagram with fault point G.

A: 10,000 kVA, 10%
B: 20,000 kVA, 15%
C: 20,000 kVA, 15%
D: 12,500 kVA, 12.5%
E: 8,000 kVA, 5%
F: 10,000 kVA, 5%

(i) **Produce** the per unit reactance on a power base of 25,000 kVA. (12 marks)

(ii) **Sketch** the reactance diagram of the system at fault. (3 marks)

(b)

(i) **Assess** the rupturing capacity of the breaker on feeder G (7 marks)

(ii) **Estimate** the fault current. (3 marks)

continue...

Question 5

(a) A circuit of a single-phase transmission line is composed of three solid 0.25 cm radius wires. The return circuit is composed of two 0.5 cm radius wires. The arrangement of conductors is shown in the Figure Q5a.

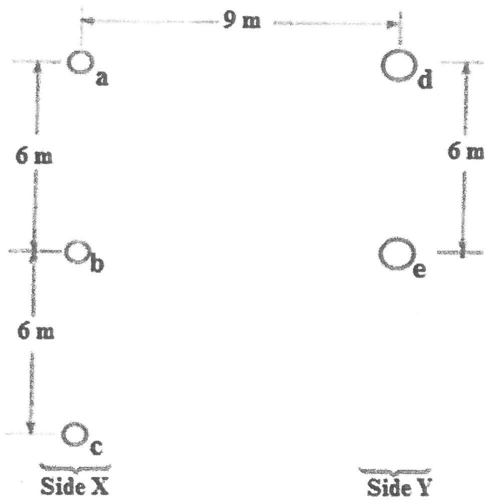

Figure Q5a: Composite conductors single phase transmission scheme

(i) **Estimate** the Geometric Mean Distance (G.M.D.) in between both sides of the transmission lines. (5 marks)

(ii) **Identify** for the Geometric Mean Radius (G.M.R.) of both sides. (10 marks)

(iii) **Determine** the inductance of the transmission line in Henrys per meter (H/m) (5 marks)

(b) **Explain** the need for transpose line and **outline** the transpose line configuration. (5 marks)

continue...

Question 6

(a) A 3-phase overhead line has resistance and reactance per phase of 5 Ω and 20 Ω respectively. The load at the receiving end is rated 25 MW at 33 kV line voltage with a power factor of 0.8 lagging. A synchronous condenser is connected at the receiving end to maintain the line voltage at both sending end and receiving end to be 33 kV.

(i) **Determine** the load current at the receiving end and its corresponding quadrature components. (10 marks)

(ii) **Calculate** for the capacity of the synchronous condenser.
Note: The following formula is provided for reference for solving this problem.
$V_S^2 = \{V_R + I_P R - (I_M - I_Q)X\}^2 + \{I_P X + (I_M - I_Q)R\}^2$ (10 marks)

(b) **Contrast** the following methods of voltage control in terms of reactive power injection and flexibility:
- Synchronous condenser
- Static capacitor
- Tap-changing transformer

(5 marks)

~The End~

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Summary of Equations:

Transformers

P = V·I

V = I·R

$|Z| = \sqrt{R^2 + X^2}$

Voltage Regulation$_{(p.u.)}$ = $\sqrt{\left(R_{eq(p.u.)} + \cos\theta\right)^2 + \left(X_{eq(p.u.)} + \sin\theta\right)^2} - 1$

$a = \frac{N_{HS}}{N_{LS}} \approx \frac{V_{HS}}{V_{LS}}$ turns ratio

$I_{HS} = \frac{1}{a} I_{LS}$ (high side-low side current relationship)

$Z_{eq,HS} = R_{HS} + a^2R_{LS} + j(X_{HS} + a^2X_{LS})$ impedance referred to high side

$Z_{eq,LS} = \frac{1}{a^2} R_{HS} + R_{LS} + j(\frac{1}{a^2} X_{HS} + X_{LS})$ impedance referred to low side

$Z_{in,HS} = Z_{eq,HS} + a^2Z_{load}$ input impedance (referred to high side)

Load Study

$average\ demand(W) = \frac{total\ energy\ demand\ (W \cdot hr)}{total\ time\ (hr)}$

$load\ factor = \frac{average\ demand(W)}{maximum\ demand(W)}$

$demand\ factor = \frac{maximum\ demand(W)}{total\ connected\ load(W)}$

$diversity\ factor = \frac{sum\ of\ individual\ maximum\ demand(W)}{maximum\ demand\ on\ power\ station\ (W)}$

$plant\ capacity\ factor(plant\ factor) = \frac{average\ demand\ on\ the\ plant(W)}{total\ plant\ capacity(W)}$

$plant\ use\ factor(utilization\ factor) = \frac{actual\ energy\ produced(W \cdot hr)}{plant\ capacity(W) \times total\ time(hr)}$

Per Unit System

$Z_{(p.u.)} = Z_{(actual)} \cdot \left(\frac{S_{(base)}}{V^2_{(base)}}\right)$

$Z_{pu(new)} = Z_{pu(old)} \times \left(\frac{V_{b(old)}}{V_{b(new)}}\right)^2 \times \frac{VA_{base(new)}}{VA_{base(old)}}$ (changing per unit value from one base reference to another base reference)

Cable Parameters

$G.M.D. = \sqrt[mn]{(D_{aA}D_{aB} \ldots D_{am}) \ldots (D_{nA}D_{nB} \ldots D_{nm})}$

$G.M.R._L = \sqrt[n^2]{r'^n (d_{12}d_{13}d_{14} \cdots d_{1n}) \cdot (d_{21}d_{23} \cdots d_{2n}) \cdots (d_{n1}d_{n2} \cdots d_{nn-1})}$

$G.M.R._C = \sqrt[n^2]{r^n (d_{12}d_{13}d_{14} \cdots d_{1n}) \cdot (d_{21}d_{23} \cdots d_{2n}) \cdots (d_{n1}d_{n2} \cdots d_{nn-1})}$

$L = 2 \times 10^{-7} \ln\left(\frac{G.M.D.}{G.M.R._L}\right)$ (H/m) (general per unit length inductance)

$C = \frac{2\pi\varepsilon}{\ln\left(\frac{G.M.D.}{G.M.R._C}\right)}$ (F/m) (general per unit length capacitance)

Cable Grading

$g = \frac{V12}{x \ln\left(\frac{D2}{D1}\right)}$ (dielectric stress)

$V_n = g_{max}\, r_{n-1}\, ln\left(\frac{r_n}{r_{n-1}}\right)$; n = 1, 2, 3… (voltage distribution)

Optimal Dispatch

$\lambda = \frac{P_D + \sum_{i=1}^{n} \frac{\beta_i}{2\gamma_i}}{\sum_{i=1}^{n} \frac{1}{2\gamma_i}}$ (incremental cost)

$P_i = \frac{\lambda - \beta_i}{2\gamma_i}$ (power output)

Voltage Control Method

$t_s = \sqrt{\frac{\frac{|V_1|}{|V_2|}}{1 - \frac{R\ \ P\ \ + X\ \ Q}{|V_1||V_2|}}}$ (tap-changing transformer adjustment ratio)