UNIVERSITI TEKNOLOGI PETRONAS

FINAL EXAMINATION
JANUARY 2025 SEMESTER

COURSE	**:**	**EEB3013/EFB3013 - POWER SYSTEMS**
DATE	**:**	**15 APRIL 2025 (TUESDAY)**
TIME	**:**	**2.30 PM - 5.30 PM (3 HOURS)**

INSTRUCTIONS TO CANDIDATES

1. Answer **ALL** questions in the Answer Booklet.
2. Begin **EACH** answer on a new page in the Answer Booklet.
3. Indicate clearly answers that are cancelled, if any.
4. Where applicable, show clearly steps taken in arriving at the solutions and indicate **ALL** assumptions, if any.
5. **DO NOT** open this Question Booklet until instructed.

Note :

i. There are **SEVEN (7)** pages in this Question Booklet including the cover page and appendix.

ii. **DOUBLE-SIDED** Question Booklet.

1. You work as a consulting engineer at Mint Consult Sdn. Bhd. A consumer has requested you to design a standalone solar PV system for his small house that equipped with AC appliances as shown in **TABLE Q1a**. The consumer also has provided you with the solar PV system equipment specifications and other related information to complete your design as shown in **TABLE Q1b**.

[20 marks]

TABLE Q1a

Appliance	Operating hours/day	Power (W)	Quantity
Lighting	8	50	5
Television	8	100	1
Refrigerator	24	300	1

TABLE Q1b

PV module	Rated power (Wp)	200
	Open circuit voltage - Voc (V)	37.50
	Short circuit current - Isc (A)	8.50
	Max. power voltage - Vmp (V)	31.50
	Max. power current - Imp (A)	7.50
Wiring, connection & losses in the battery (%)		30
Panel Generation Factor (PGF)		4.5
Days of autonomy		4
Safety margin for inverter (%)		20
Safety margin for solar charge controller		1.2
Battery (Vdc)		12
Battery loss		0.8
Battery depth of discharge factor		0.6

2. As a new engineer at a consulting firm in Perak, you have been assigned to design a 132-kV, 150-MVA, 50-Hz three-phase, 100-km long transmission line that has the following parameters:

$r = 0.03\ \Omega/\text{km}$; $x = 0.15\ \Omega/\text{km}$; $y = 1.50 \times 10^{-6}$ S/km;

The transmission line is supplying an apparent power of 100 MVA, 0.85 power factor lagging and at 132 kV. Solve for the sending end line-to-line voltage (up to four decimal places).

[20 marks]

3. As a planning engineer you need to carry out power flow studies to ensure the power system can operate within the stipulated voltage level. The bus data and reactance of the lines calculated on common 100 MVA base for a three-bus power system are listed in **TABLE Q3a** and **TABLE Q3b** respectively.

TABLE Q3a

Bus No.	Type	P_{LOAD} p.u.	Q_{LOAD} p.u.	V p.u.
1	Slack	0	0	$1.00\angle 0^0$
2	P - Q	1.0	0.5	V_2
3	P - Q	2.0	1.0	V_3

TABLE Q3b

From Bus	To Bus	X p.u.
1	2	0.01
2	3	0.01
1	3	0.02

Assume the per unit initial voltage $V_2 = 1.00\angle 0^0$ and $V_3 = 1.00\angle 0^0$. Use Gauss-Seidel method by performing three iterations to solve for the per unit voltages V_2, V_3 and actual slack bus apparent power (up to four decimal places).

[20 marks]

4. After a recent breakdown, you need to perform short circuit studies on a small power system network as shown in **FIGURE Q4** where the percentage reactance for the generators, transformers and line are calculated on common 100 MVA base as tabulated in **TABLE Q4**.

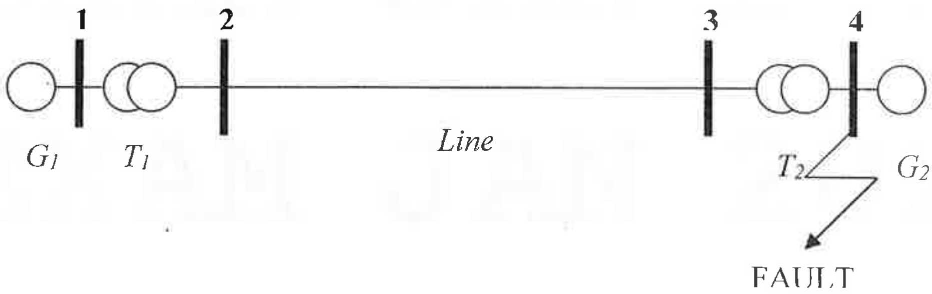

FIGURE Q4

TABLE Q4

Component	Voltage rating	Reactance
G_1	11 kV	10 %
T_1	11/132 kV	15 %
Line	132 kV	20 %
T_2	132/11 kV	15 %
G_2	11 kV	10 %

During the breakdown, a bolted three-phase fault had occurred at bus 4. If the pre-fault voltage was 1.00 per unit, solve for the actual fault current, fault MVA and per unit voltage at bus 1 and bus 4 (up to four decimal places).

[20 marks]

5. A short transmission system consists of 2 substations and interconnected to the grid by 132 kV overhead lines with parameters as shown in **TABLE Q5**. A lightning strike has caused a 1000 kV surge enters substation A. Evaluate the surge propagation voltages at Substation A and B until the second transmitted and reflected wave at Substation A using Bewley Lattice diagram (up to three decimal places).

[20 marks]

TABLE Q5

From Bus	To Bus	L (μH/km)	C (μF/km)	Attenuation Factor
Grid	Substation A	1100	0.002	1
Substation A	Substation B	400	0.0055	0.9

-END OF PAPER-

APPENDIX

$$V_i^{(k+1)} = \frac{\frac{P_i - jQ_i}{V_i^{*(k)}} + \sum_{j=1}^{n} y_{ij} V_j^{(k)}}{\sum_{j=0}^{n} y_{ij}} \quad j \neq i$$

$$P_i^{(k+1)} = \mathcal{R}\left\{V_i^{*(k)}\left[V_i^{(k)}\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j^{(k)}\right]\right\} \quad j \neq i$$

$$Q_i^{(k+1)} = -\,\mathfrak{I}\left\{V_i^{*(k)}\left[V_i^{(k)}\sum_{j=0}^{n} y_{ij} - \sum_{j=1}^{n} y_{ij}V_j^{(k)}\right]\right\} j \neq i$$

$$Z_0 = \sqrt{\frac{L}{C}}$$

$$E_T = \alpha E$$

$$E_R = \beta E$$

$$A = 1 + \frac{YZ}{2}$$

$$B = Z$$

$$C = \left(1 + \frac{YZ}{4}\right) Y$$

$$D = 1 + \frac{YZ}{2}$$

$$Battery\ capacity = \frac{Wh\ x\ days\ of\ autonomy}{battery\ loss\ x\ depth\ of\ charge\ x\ battery\ voltage}$$

$$I = \frac{S_{3ph}}{\sqrt{3} x V_L}$$

$$Z_{AB} = \frac{Z_A Z_B + Z_B Z_C + Z_C Z_A}{Z_C}$$

$$Z_{BC} = \frac{Z_A Z_B + Z_B Z_C + Z_C Z_A}{Z_A}$$

$$Z_{CA} = \frac{Z_A Z_B + Z_B Z_C + Z_C Z_A}{Z_B}$$

$$Z_A = \frac{Z_{AB} Z_{CA}}{Z_{AB} + Z_{BC} + Z_{CA}}$$

$$Z_B = \frac{Z_{AB} Z_{BC}}{Z_{AB} + Z_{BC} + Z_{CA}}$$

$$Z_C = \frac{Z_{BC} Z_{CA}}{Z_{AB} + Z_{BC} + Z_{CA}}$$

$$\begin{bmatrix} V_S \\ I_S \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} V_R \\ I_R \end{bmatrix}$$

$$Percentage\ VR = \frac{\frac{V_S}{A} - V_R}{V_R}$$

$$\eta = \frac{P_{R(3\emptyset)}}{P_{S(3\emptyset)}}$$

$$Z_b = \frac{kV_b^2}{MVA_b}$$

$$\alpha = \frac{2Z_2}{Z_2 + Z_1}$$

$$\beta = \frac{Z_2 - Z_1}{Z_2 + Z_1}$$