Universiti Tun Hussein Onn Malaysia

UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
(TAKE HOME)
SEMESTER I
SESSION 2020/2021

COURSE NAME	:	POWER SYSTEM FUNDAMENTAL
COURSE CODE	:	BNE 22203
PROGRAMME CODE	:	BNE
EXAMINATION DATE	:	JANUARY/FEBRUARY 2021
DURATION	:	3 HOURS
INSTRUCTION	:	ANSWER **ALL** QUESTIONS. **OPEN BOOK EXAMINATION**

TERBUKA

THIS QUESTION PAPER CONSISTS OF **NINE (9)** PAGES

Q1 (a) Power-system quantities such as voltage, current, power, and impedance are often expressed in per-unit or percent of specified base values. State **TWO (2)** advantages of per unit system in power system.

(2 marks)

(b) One-line diagrams are widely used in three-phase power systems studies. Simplify the one-line diagram as shown in **Figure Q1 (b)** into a reactance diagram.

(2 marks)

(c) **Figure Q1 (c)** shows a single-line diagram of an 8-bus system. Line-1 and Line-2 have reactance 10 Ω and 15 Ω, respectively. The manufacturer's data of generator, transformers, and motor are given in **Table Q1 (c)**. The three phase Load-1 at bus-4 absorbs 35MVA, 0.7 lagging at 11kV, while the three-phase Load-2 at bus-8 absorbs 15MVA, 0.8 lagging at 11kV. Draw an impedance diagram with all impedances including the load impedance marked in per-unit. Select a common base of 100 MVA and 200kV on the Line-1.

(16 marks)

Q2 (a) A three-phase fault occurs in a simple three-bus power system as shown in **Figure Q2 (a)**. Determine the total actual fault current.

(14 marks)

(b) The present trend is towards AC for generation and distribution and DC for transmission. Discuss the reasons for it and explain HVDC in details.

(6 marks)

Q3 (a) Selection of types of insulator is important in developing a new transmission line. As a project manager, recommend a suitable type of insulator for a tower which need a change in the direction of line and explain why this selection is suitable.

(4 marks)

(b) A three-phase, 50 Hz, completely transposed 200 km line has two 795,000-cmil 26/2 ACSR conductors per bundle and the line constants are given as:

Resistance/phase/km = 0.1 Ω
Reactance/phase/km = 0.5 Ω
Susceptance/phase/km = j10^{-5} S

The full load condition at the receiving end of the line is 20 MW at 0.8 p.f lagging and at 66 kV. Assuming the nominal π line model,

(i) Determine the sending end voltage and voltage regulation of the line. Given the calculated ABCD parameters of the nominal π line model as:

$$A = D = 1 + \frac{ZY}{2} = 0.9002\angle 1.27^0$$

$$B = Z = 101.98\angle 78.69^0\ \Omega$$

$$C = Y\left(1 + \frac{ZY}{4}\right) = 1.9001\times 10^{-3}\angle 90.60^0$$

(10 marks)

(ii) If the transmission line in **Q3 (b)** delivers 20 MVA at unity power factor to the load, compare and discuss the new voltage regulation of the transmission line with the one obtained in **Q3 (b)(i)**.

(6 marks)

Q4 (a) A power system network is shown in **Figure Q4 (a)**. The values marked are impedances in per unit on a base of 100 MVA. The current entering buses 1 and 2 are $I_1 = 1.4 - j2.5$ pu and $I_2 = 0.7 - j1.5$ pu, respectively. Determine the bus voltages in per unit.

(8 marks)

(b) In the one line diagram shown in **Figure Q4 (b)**, bus 1 is a slack bus with $V_1 = 1.0\angle 0°$ pu. A load of 280 MW and 60 Mvar is taken from bus 2. The line impedance is $Z_{12} = 0.02 + j0.04$ pu on a base of 100 MVA. Determine $V_2^{(2)}$ using Newton Raphson method. Given $\delta_2^{(1)} = -0.1$ rad and $|V_2^{(1)}| = 0.92$ pu.

(12 marks)

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Q5 (a) A single-phase auto transformer has a voltage ratio of 320 V : 250 V as shown in **Figure Q5 (a)**. If I_3 is equal to 17.5A, find the kVA rating of the load.

(4 marks)

(b) Assuming a constant power is developed at a fixed terminal voltage for a synchronous generator model shown in **Figure Q5 (b)**. From the figure, proved the following equation:

$$P_{3\phi} = 3V_t I_a \cos\phi = \frac{3V_t E \sin\delta}{X_s}$$

(5 marks)

(c) A 40 MVA, 25 kV, 1000 r/min, 3-phase generator has a synchronous reactance (Xs) of 5 Ω per phase and is connected to an infinite busbar. If the exciting voltage is 14.3 kV (line to neutral), the system voltage is 24 kV (line to line) and using standard frequency in Malaysia, calculate the torque angle when the generator delivers 60 MW.

(5 marks)

(d) A 36 MVA, 21 kV, 1800 r/min, 3-phase generator connected to a power grid has a synchronous reactance, (X_s) of 9 Ω per phase. If the exiting voltage is 12 kV (line-to-neutral), and the system voltage is 17.31 kV (line-line), calculate the following:

(i) The active power which the machine delivers when the torque angle, δ is 45° (electrical)

(4 marks)

(ii) The peak power that the generator can deliver before it falls out of step (loses synchronism).

(2 marks)

- **END OF QUESTIONS** -

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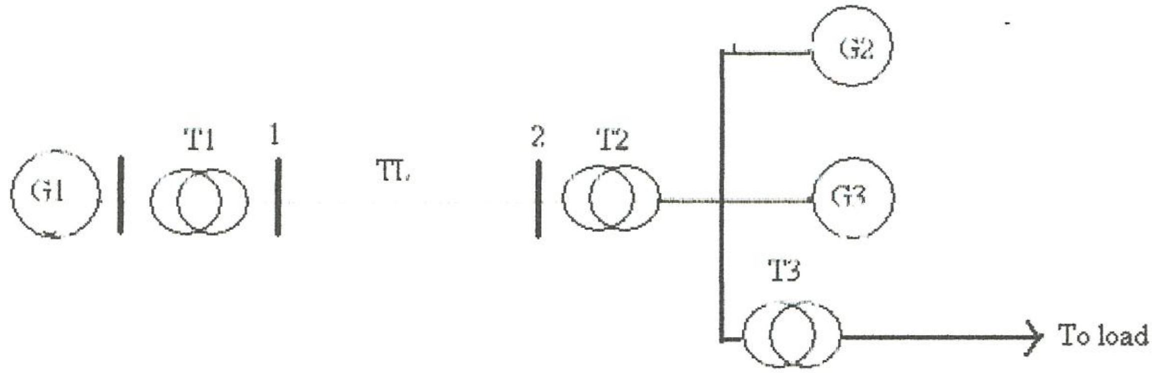

Figure Q1 (b)

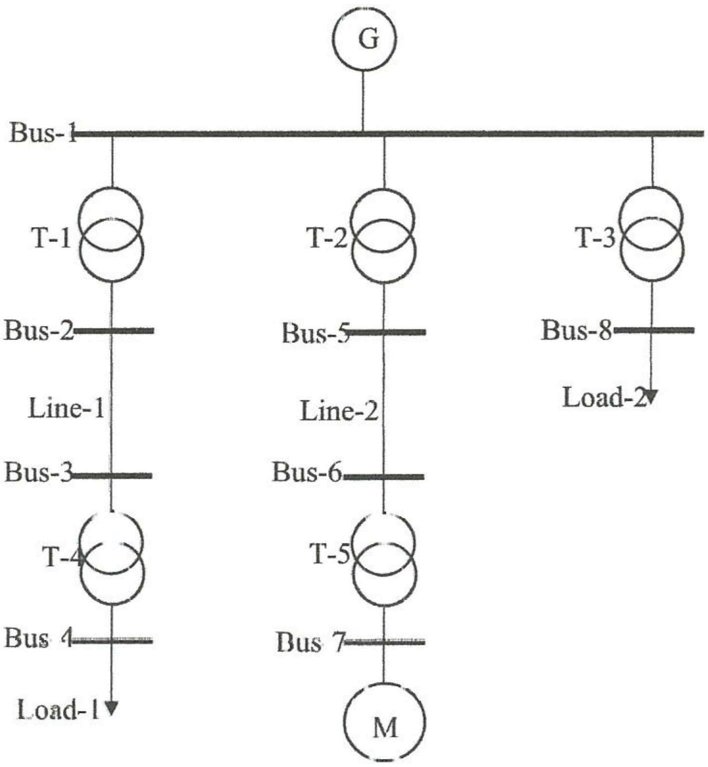

Figure Q1 (c)

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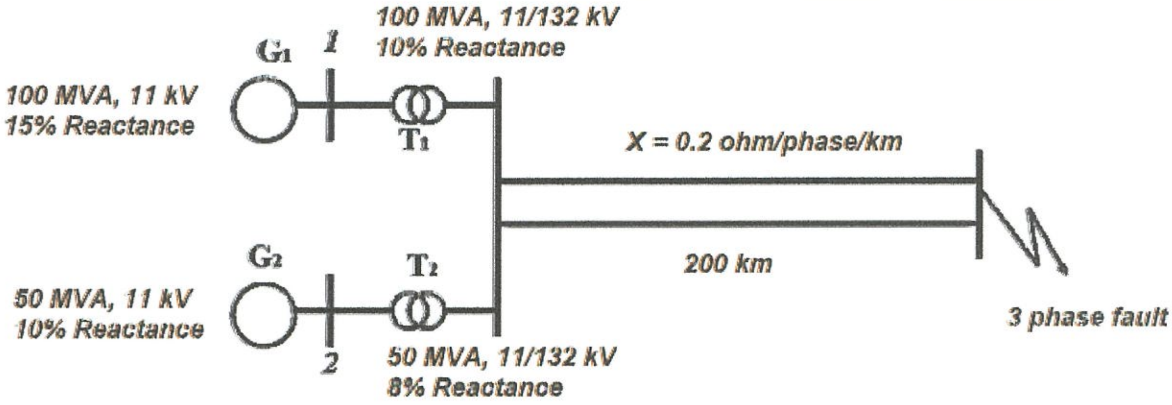

Figure Q2 (a)

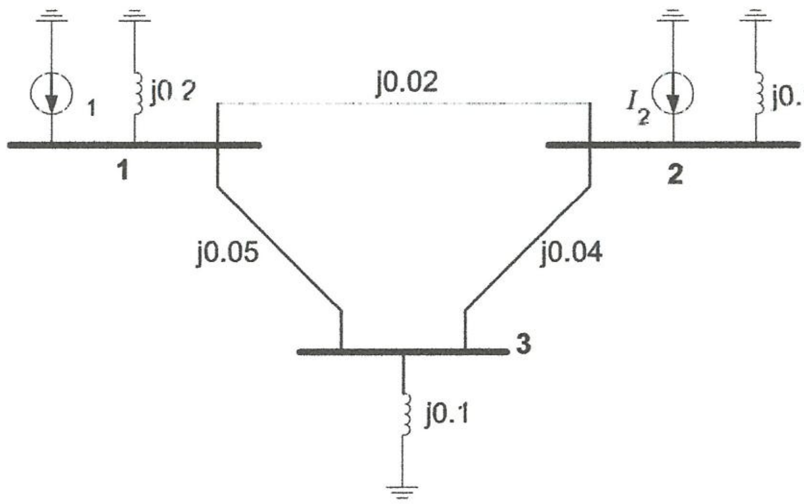

Figure Q4 (a)

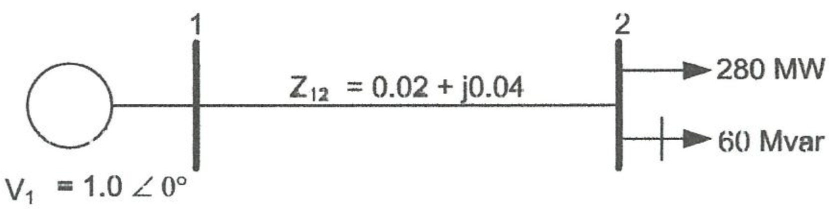

Figure Q4 (b)

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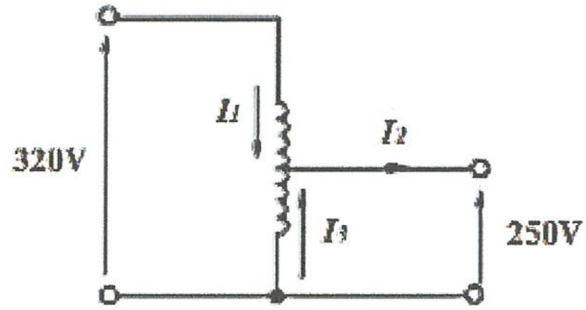

Figure Q5 (a)

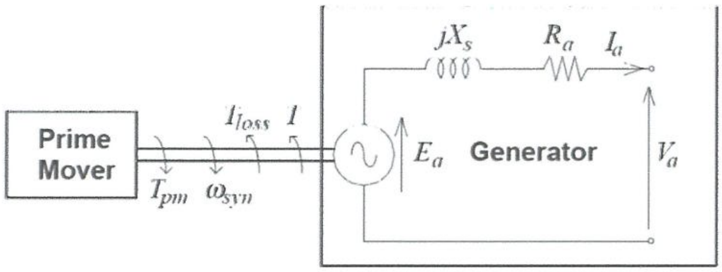

Figure Q5 (b)

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Table Q1 (c) : Parameters of generator, transformers, and motor

	S(MVA)	V(kV)	X(%)
Generator, G	100	22	15
Transformer 1 (T-1)	50	22/220	6
Transformer 2 (T-2)	50	22/110	5
Transformer 3 (T-3)	20	22/11	10
Transformer 4 (T-4)	40	200/11	7
Transformer 5 (T-5)	40	110/11	8
Motor, M	30	10.45	18

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Appendix

NEWTON RAPHSON	$P_i = \sum_{j=1}^{n} \lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \cos(\theta_{ij} - \delta_i + \delta_j)$
	$Q_i = -\sum_{j=1}^{n} \lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \sin(\theta_{ij} - \delta_i + \delta_j)$
	$\begin{bmatrix} \Delta P \\ \Delta Q \end{bmatrix} = \begin{bmatrix} J_1 & J_2 \\ J_3 & J_4 \end{bmatrix} \begin{bmatrix} \Delta \delta \\ \Delta \lvert V \rvert \end{bmatrix}$
Daigonal J_1	$\frac{\partial P_i}{\partial \delta_i} = \sum_{j \neq i} \lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \sin(\theta_{ij} - \delta_i + \delta_j)$
Off-Daigonal J_1	$\frac{\partial P_i}{\partial \delta_j} = -\lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i$
Daigonal J_2	$\frac{\partial P_i}{\partial \lvert V_i \rvert} = 2\lvert V_i \rvert \lvert Y_{ii} \rvert \cos\theta_{ii} + \sum_{j \neq i} \lvert V_j \rvert \lvert Y_{ij} \rvert \cos(\theta_{ij} - \delta_i + \delta_j)$
Off-Daigonal J_2	$\frac{\partial P_i}{\partial \lvert V_j \rvert} = \lvert V_i \rvert \lvert Y_{ij} \rvert \cos(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i$
Daigonal J_3	$\frac{\partial Q_i}{\partial \delta_i} = \sum_{j \neq i} \lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \cos(\theta_{ij} - \delta_i + \delta_j)$
Off-Daigonal J_3	$\frac{\partial Q_i}{\partial \delta_j} = -\lvert V_i \rvert \lvert V_j \rvert \lvert Y_{ij} \rvert \cos(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i$
Daigonal J_4	$\frac{\partial Q_i}{\partial \lvert V_i \rvert} = -2\lvert V_i \rvert \lvert Y_{ii} \rvert \sin\theta_{ii} - \sum_{j \neq i} \lvert V_j \rvert \lvert Y_{ij} \rvert \sin(\theta_{ij} - \delta_i + \delta_j)$
Off-Daigonal J_4	$\frac{\partial Q_i}{\partial \lvert V_j \rvert} = -\lvert V_i \rvert \lvert Y_{ij} \rvert \sin(\theta_{ij} - \delta_i + \delta_j) \quad j \neq i$