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UNIVERSITI TUN HUSSEIN ONN MALAYSIA

FINAL EXAMINATION
SEMESTER II
SESSION 2011/2012

COURSE NAME	:	POLYPHASE CIRCUIT ANALYSIS
COURSE CODE	:	BEF 23803
PROGRAMME	:	BEF
EXAMINATION DATE	:	JUNE 2012
DURATION	:	2 HOURS 30 MINUTES
INSTRUCTION	:	ANSWER **ALL** QUESTIONS

THIS PAPER CONSISTS OF **TWELVE (12)** PAGES

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Q1 (a) With the aid of suitable voltage and current waveforms, write the general expression of instantaneous voltage and current that appear across and flow through a resistor, capacitor and inductor, respectively.

(6 marks)

(b) Two different three-phase loads are connected in parallel from 1000V, 50 Hz three-phase power source in which the single-line diagram is given in Figure Q1(b). Load 1 and Load 2 are connected in wye and delta, respectively. Evaluate the system for

(i) the impedance value for each load,
(ii) the line current and phase current of Load 1 and Load 2,
(iii) the real and reactive power for each load,
(iv) the total real, reactive, and apparent power consumed by the two loads,
(v) the line current, I_L
(vi) the required capacitor to improve the system into unity power factor.

(19 marks)

Q2 (a) (i) Define the per-unit quantity used in solving electrical power network problems.
(ii) State three (3) advantages of using per-unit quantity in power system analysis.

(5 marks)

(b) A generator as shown in Figure Q2(b) is rated at 1000 VA and 230 V has impedance of j15% stamped on the nameplate. If the generator is short circuited at its terminals, find,
(i) Base current and base impedance of generator,
(ii) The actual impedance of generator,
(iii) The short circuit current if $E_{G(p.u.)} = 1.0$ p.u.
(iv) The short circuit apparent power (S) delivered by the generator,
(v) The actual value of short circuit current and apparent power.

(7 marks)

(c) Construct an impedance diagram for the one-line diagram of three-phase transmission system given in Figure Q2(c) and express all the quantities in p.u. Use common base of 50 MVA and 60 kV on the generator side. The generator has a synchronous reactance of 0.15 p.u. The line length is 90 km with the reactance of 0.35 Ω/km.

(13 marks)

Q3 (a) Proof that the constant ABCD parameters for nominal-T circuit of medium transmission line model as shown in Figure Q3(a) is given by,

$$A=\left(1+\frac{ZY}{2}\right) \qquad B=Z\left(1+\frac{YZ}{4}\right)$$

$$C=Y \qquad D=\left(1+\frac{ZY}{2}\right)$$

(10 marks)

(b) The impedance line of simple three-phase power system network is shown in Figure Q3(b). Construct Z_{bus} for the network, where the impedance labeled by 1 to 4 are shown in per unit. The branches are added in the order of their labels and numbered subscripts on Z_{bus}.

(15 marks)

Q4 (a) (i) In representation of three-phase symmetrical components, the positive-sequence, negative-sequence, and zero-sequence of phasor currents for each phase are given as follows,

$$I_a^1 = I_a^1\angle 0^\circ = I_a^1$$
$$I_b^1 = I_a^1\angle 240^\circ = a^2 I_a^1$$
$$I_c^1 = I_a^1\angle 120^\circ = aI_a^1$$

$$I_a^2 = I_a^2\angle 0^\circ = I_a^2$$
$$I_b^2 = I_a^2\angle 120^\circ = aI_a^2$$
$$I_c^2 = I_a^2\angle 240^\circ = a^2 I_a^2$$

$$I_a^0 = I_a^0\angle 0^\circ = I_a^0$$
$$I_b^0 = I_a^0\angle 0^\circ = I_a^0$$
$$I_c^0 = I_a^0\angle 0^\circ = I_a^0$$

Rewrite the unbalanced phasors current of phase 'a', phase 'b', and phase 'c' into symmetrical components by referring to phase 'a' components.

(ii) Obtain the unbalanced voltage phasor from the symmetrical components of a set of unbalanced three-phase voltage as follows,

$$V_a^{0} = 0.4\angle 90^\circ A \ , V_a^{1} = 1.0\angle 30^\circ A \, , V_a^{2} = 0.8\angle -20^\circ A$$

(9 marks)

(b) Sketch the zero sequence equivalent impedance diagram for the one-line diagram shown in Figure Q4(b). Then, find the total impedance for the circuit looking from point *F*. The zero sequence per-unit values for each component is depicted in Table Q4(b).

(16 marks)

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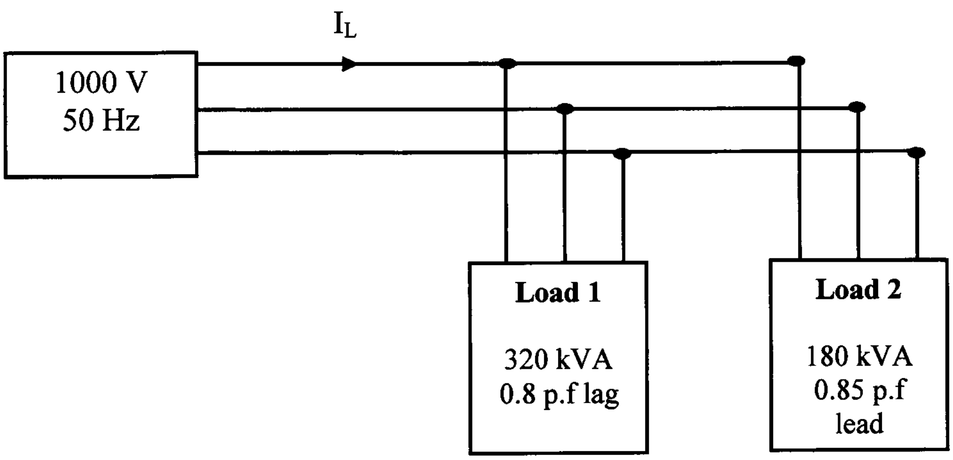

FIGURE Q1(b)

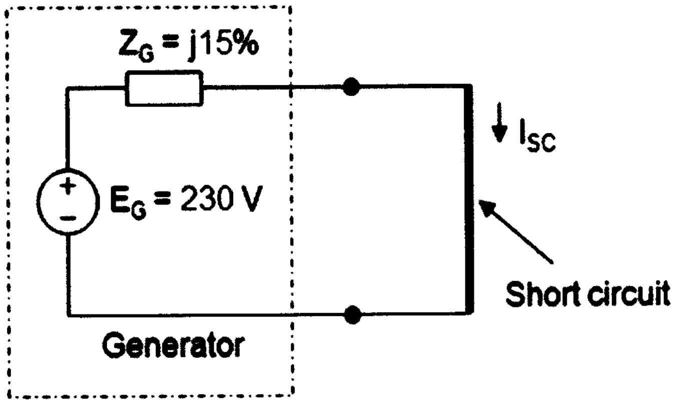

FIGURE Q2(b)

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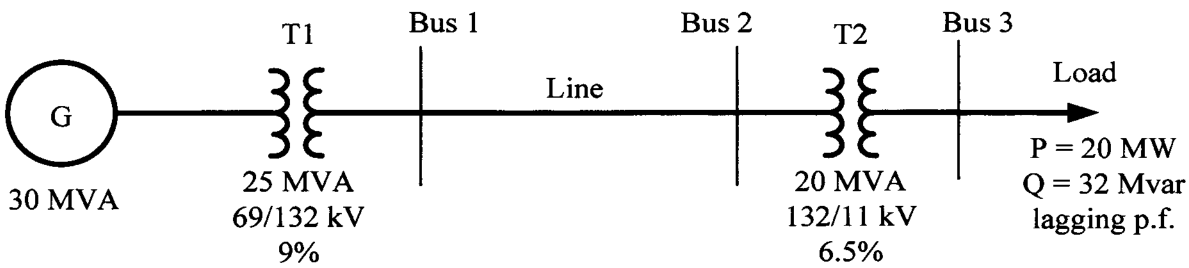

FIGURE Q2(c)

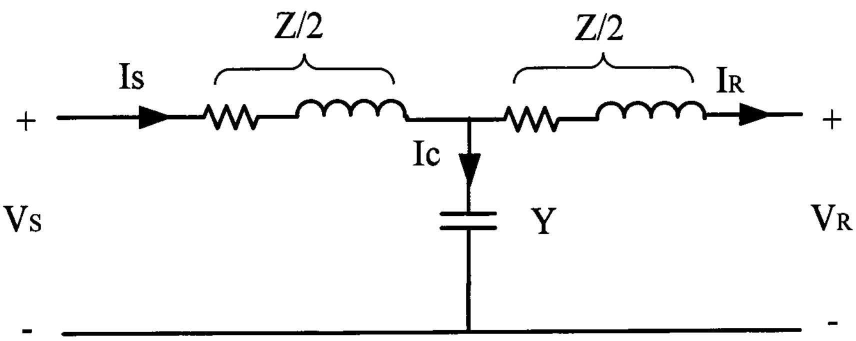

FIGURE Q3(a)

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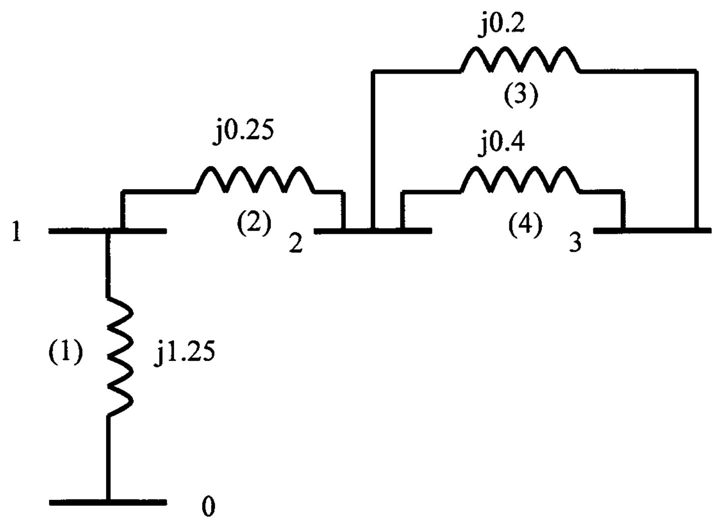

FIGURE Q3(b)

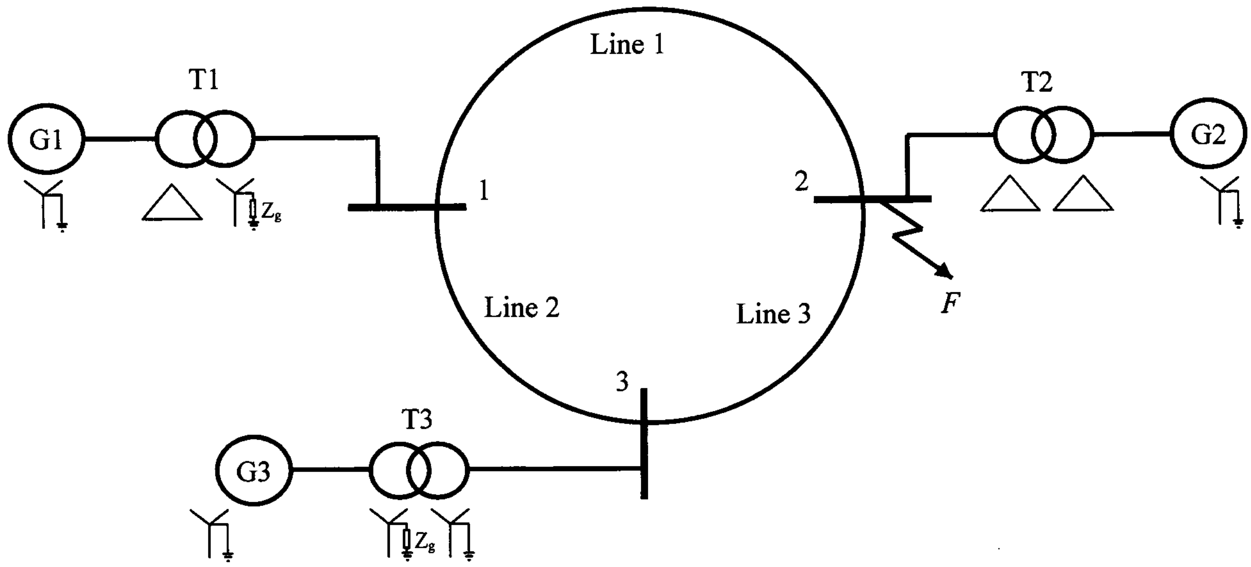

FIGURE Q4(b)

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TABLE Q4(b)

Components	**X^0 (pu)**
G_1	0.07
G_2	0.10
G_3	0.05
T_1	0.10
T_2	0.10
T_3	0.12
Line 1	0.50
Line 2 = Line 3	0.80

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Formula

Single Phase per-unit system

$$\text{Base current, A} = \frac{\text{base kVA}_{1\phi}}{\text{base voltage, kV}_{LN}}$$

$$\text{Base impedance} = \frac{\text{base voltage, V}_{LN}}{\text{base current, A}}$$

$$\text{Base impedance} = \frac{(\text{base voltage, kV}_{LN})^2}{\text{base MVA}_{1\phi}}$$

$$\text{Base power, kW}_{1\phi} = \text{base kVA}_{1\phi}$$

$$\text{Base power, MW}_{1\phi} = \text{base MVA}_{1\phi}$$

Three Phase per-unit system

$$\text{Base current, A} = \frac{\text{base kVA}_{3\phi}}{\sqrt{3}\ \text{X base voltage, kV}_{LL}}$$

$$\text{Base impedance} = \frac{(\text{base voltage, kV}_{LL})^2}{\text{base MVA}_{3\phi}}$$

$$\text{Base power, kW}_{3\phi} = \text{base kVA}_{3\phi}$$

$$\text{Base power, MW}_{3\phi} = \text{base MVA}_{3\phi}$$

$$\text{Per-unit Z}_{new} = \text{per-unit Z}_{old}\left(\frac{\text{base kV}_{old}}{\text{base kV}_{new}}\right)^2\left(\frac{\text{base MVA}_{new}}{\text{base MVA}_{old}}\right)$$

Transmission Line

$$V_s = AV_R + BI_R$$
$$I_s = CV_R + DI_R$$

$$S_{3\phi} = 3V_\phi I_\phi^* = \sqrt{3}V_L I_L^*$$

$$P_{3\phi} = 3V_\phi I_\phi \cos\theta = \sqrt{3}V_L I_L \cos\theta$$

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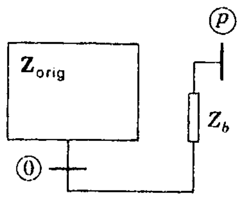
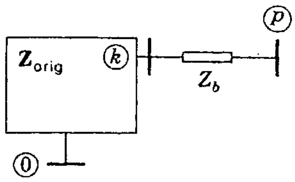
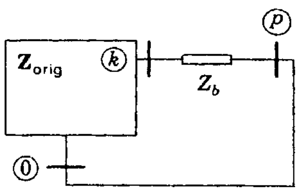
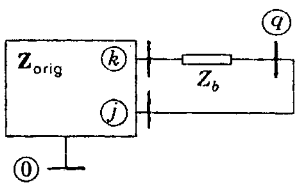
Modification of existing $\mathbf{Z}_{bus}$

Case	Add branch Z_b from	$\mathbf{Z}_{bus(new)}$
1	Reference node to new bus (p) 	$\begin{matrix} & & (p) \\ & \mathbf{Z}_{orig} & \begin{matrix}0\\ \vdots \\ 0\end{matrix} \\ (p) & 0 \cdots 0 & Z_b \end{matrix}$
2	Existing bus (k) to new bus (p) 	$\begin{matrix} & (k) & (p) \\ (k) & \mathbf{Z}_{orig} & \text{col. } k \\ (p) & \text{row } k & Z_{kk} + Z_b \end{matrix}$
3	Existing bus (k) to reference node  (Node (p) is temporary.)	• Repeat Case 2 and • Remove row p and column p by Kron reduction
4	Existing bus (j) to existing bus (k)  (Node (q) is temporary.)	• Form the matrix $\begin{matrix} & & (q) \\ & \mathbf{Z}_{orig} & \text{col. } j - \text{col. } k \\ (q) & \text{row } j - \text{row } k & Z_{th,jk} + Z_b \end{matrix}$ where $Z_{th,jk} = Z_{jj} + Z_{kk} - 2Z_{jk}$ and • Remove row q and column q by Kron reduction

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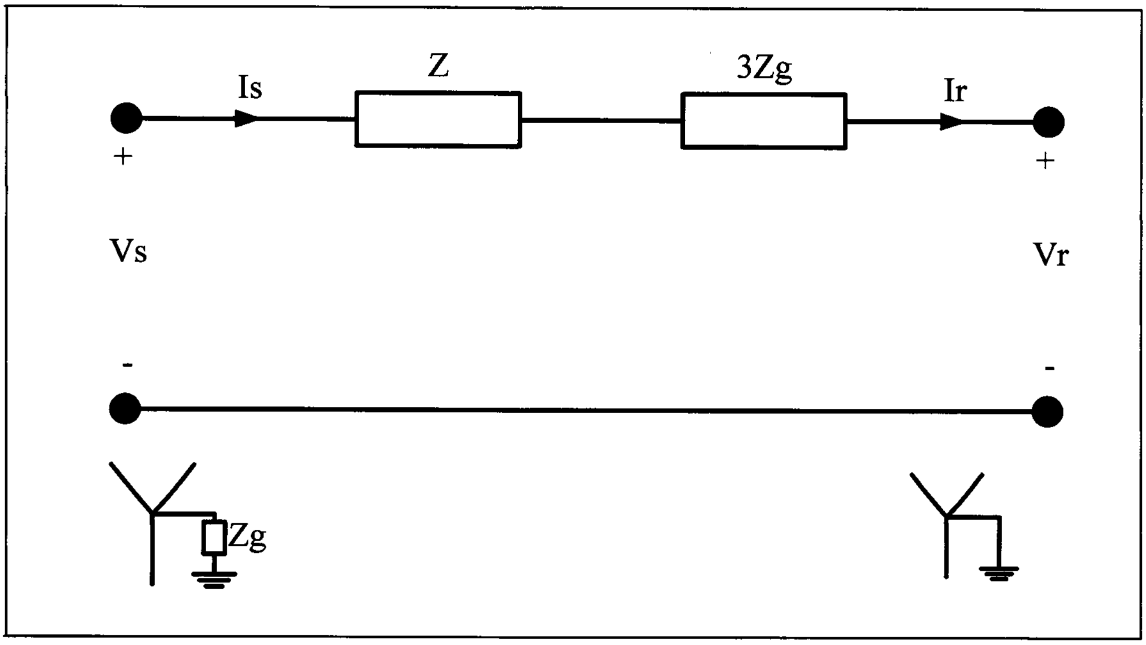
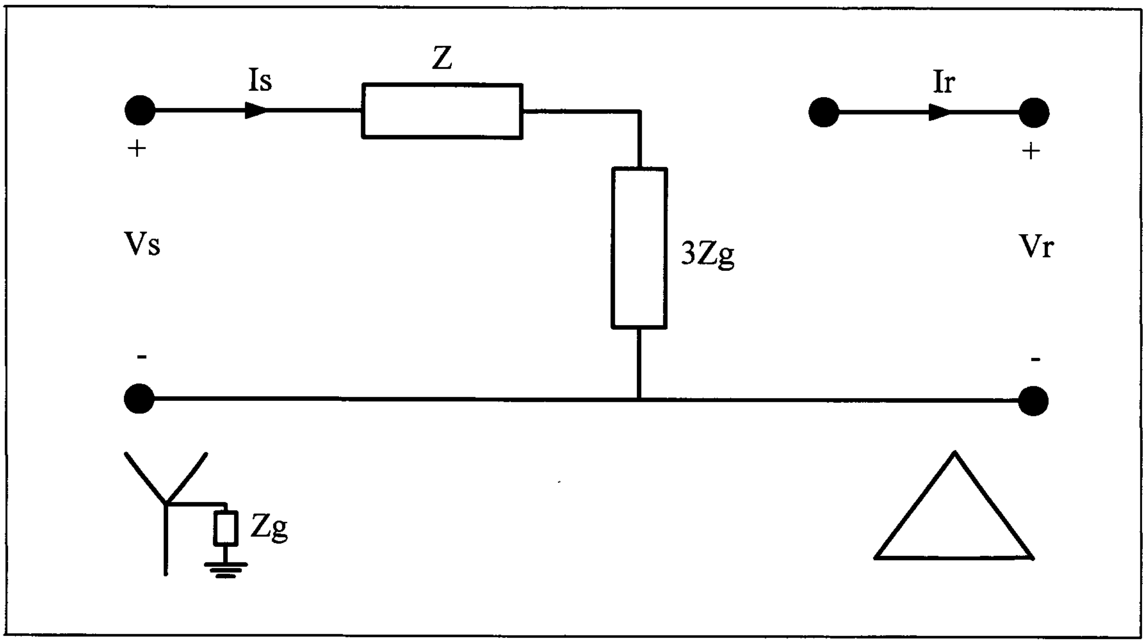
Zero sequence equivalent circuit of Transformer





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