IMPERIAL COLLEGE LONDON

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
EXAMINATIONS 2003

EEE PART III/IV: M.Eng., B.Eng. and ACGI

ELECTRICAL ENERGY SYSTEMS

Wednesday, 7 May 10:00 am

Time allowed: 3:00 hours

There are SIX questions on this paper.

Answer FOUR questions.

Correcting to Q4.
(made c. 10:30 am)

Q2.
(11:30 am)

Corrected Copy

Any special instructions for invigilators and information for candidates are on page 1.

Examiners responsible	First Marker(s) :	B.C. Pal, D. Popovic
	Second Marker(s) :	D. Popovic, B.C. Pal

1. Suppose that a radial line of length l which connects buses 1 and 2 is terminated in its characteristic impedance Z_c at bus 2. The propagation constant $\gamma = \alpha + j\beta$.

   (a) Find the impedance V_1/I_1, the voltage gain $|V_2|/|V_1|$, the current gain $|I_2|/|I_1|$, the complex gain $-S_{21}/S_{12}$ where $-S_{21} = V_2 I_2^*$ and $S_{12} = V_1 I_1^*$, and the real power efficiency $-P_{21}/P_{12}$. [12]

   (b) Repeat part (a) for the case of a lossless line. [8]

2. Draw a per-unit diagram for the system whose one-line diagram is shown in Figure 2.1 The three phase and line-line ratings are as follows:

Generator G: 15 MVA, 13.8 kV, $X = 0.15$ p.u.
Motor M1: 5 MVA, 13.2 kV, $X = 0.15$ p.u.
Motor M2: 5 MVA, 14.4 kV, $X = 0.15$ p.u.
Transformer T1: 25 MVA, 13.2/161 kV, $X = 0.1$ p.u.
Transformer T2: 15 MVA, 13.8/161 kV, $X = 0.1$ p.u.
Line: $j100\,\Omega$ (actual)

Select a base of 100 MVA and 161 kV in the transmission line. [20]

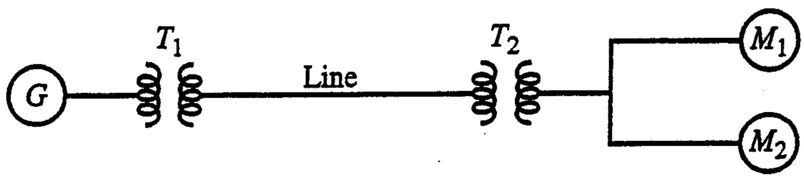

Figure 2.1

3. Figure 3.1 shows a single-line diagram of a three-bus power system. All data are in per-unit. The elements of the symmetric bus admittance matrix Y_{BUS} are as follows:

$Y_{11} = Y_{22} = Y_{33} = -j19.98$
$Y_{12} = Y_{13} = Y_{23} = j10$

(a) Write the power-flow equations to be solved by the Newton-Raphson method. Identify the unknown variables to be solved. [8]

(b) Use Newton-Raphson method to compute θ_2, $|V_3|$, θ_3, S_{G1} and Q_{G2} after two iterations. Use zero initial phase angles and 1.0 per-unit initial bus voltage magnitudes. [12]

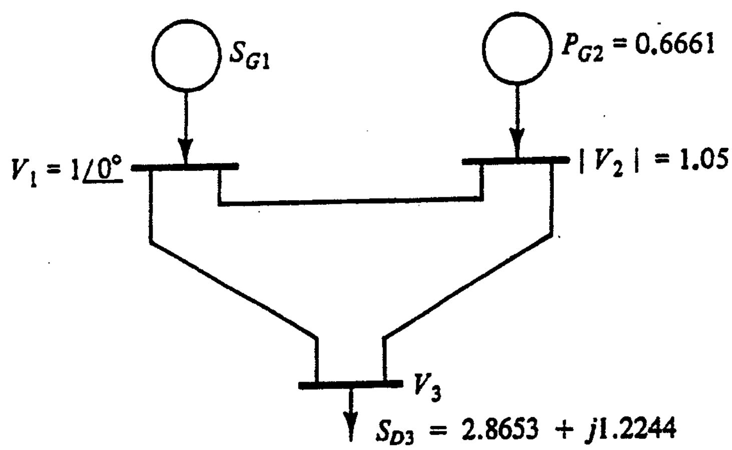

Figure 3.1

4. (a) Why do fuel cost characteristics in fossil-fuel units have minimum limits? [4]

(b) An area of an interconnected power system has two fossil-fuel units operating on economic dispatch. The variable operating costs of these units are given by

$$C_1 = 10P_1 + 0.008P_1^2 \quad \$/hr \qquad 100 \leq P_1 \leq 600 \qquad (4.1)$$

$$C_2 = 8P_2 + 0.009P_2^2 \quad \$/hr \qquad 400 \leq P_2 \leq 1000 \qquad (4.2)$$

where P_1 and P_2 are in MW. Determine the power output of each unit, the incremental operating cost(s) and the total operating cost, C_T, that minimises cost of operation (C_T) for load demand of 1000 and 1400 MW respectively. Transmission losses are neglected. [16]

5. (a) Why is it so important to have constant frequency in system operation? [5]

(b) Figure 5.1 shows a simple power system supplying power of $P + jQ$ to a load at voltage V and at a lagging power factor.The line connecting the sending and the receiving end has an impedance $R + jX$. δ is the angle between the vectors E and V. Show that

$$\Delta V_p = \frac{RP}{V} + \frac{XQ}{V} \quad \text{and} \quad \Delta V_q = \frac{XP}{V} - \frac{RQ}{V}$$

when $E^2 = (V + \Delta V_p)^2 + \Delta V_q^2$. When $X >> R$ and δ is expressed in radian, also show that $Q \propto \Delta V_p$ and $P \propto \delta$ in the range $0 < \delta < \frac{\pi}{4}$. [15]

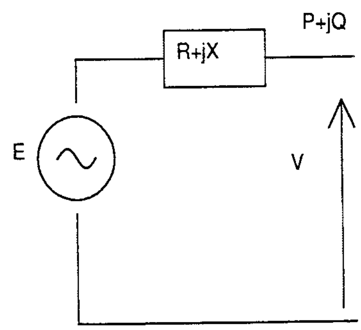

Figure 5.1: A simple power system

6. (a) What is the method of symmetrical components? Discuss its advantages over phase systems? [5]

(b) Given the line-to-ground voltages $V_{ag} = 280\angle 0^0, V_{bg} = 250\angle - 110^0$ and $V_{cg} = 290\angle 130^0$ volts,

calculate in volts

(i) line-to-line voltages V_{ab}, V_{bc} and V_{ca} [3]

(ii) the sequence components of the line-to-ground voltages V_{Lg1}, V_{Lg2} and V_{Lg0} [5]

(iii) the sequence components of the line-to-line voltage, V_{LL1}, V_{LL2} and V_{LL0}. Also, verify that $V_{LL1} = \sqrt{3}V_{Lg1}\angle + 30^0$ and $V_{LL2} = \sqrt{3}V_{Lg2}\angle - 30^0$. [7]