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.

Correction to Q4.
(made c. 10.30 am)

Corrected Copy

Q2.
(11.30am)

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]

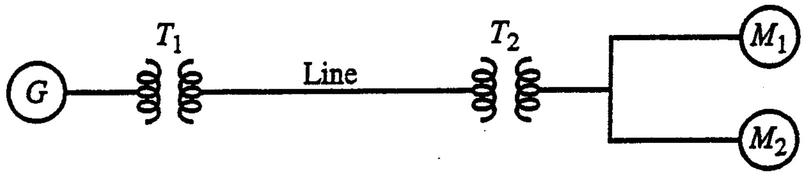

Figure 2.1

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]

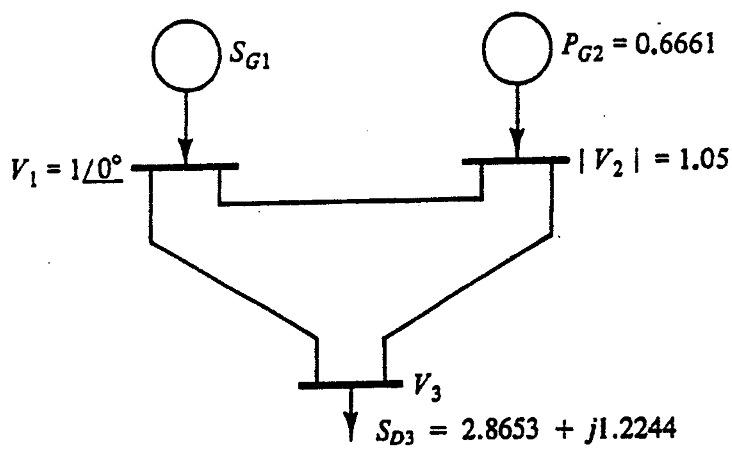

Figure 3.1

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

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

$$C_2 = 8P_{\cancel{1}\,2} + 0.009P_{\cancel{1}\,2}^2 \quad \$/hr \qquad 400 \le P_{\cancel{1}\,2} \le 1000 \qquad (4.2)$$

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]

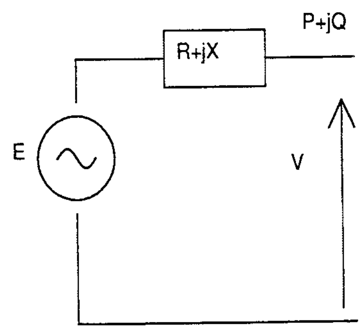

Figure 5.1: A simple power system

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]