THE OPEN UNIVERSITY OF SRI LANKA
BACHELOR OF TECHNOLOGY
ECX5332 – Power systems II
Final Examination 2006/2007

034

Duration Three Hours

Date: 10th April 2007 Time: 0930-1230

This paper consists of six questions. Answer ANY ***FOUR*** *questions. All questions carry equal marks.*

Graph papers and log-log papers will be available on your request

Question(1)

Certain generator G delivers apparent power of 2.5 pu at 0.8 power factor lagging to a system via transformer T and parallel transmission lines as shown in figure Q1. The voltage at the system busbar is maintained at 1.0 pu. Reactance of transmission lines, transformer and transient reactance of generator are indicated in the figure Q1.

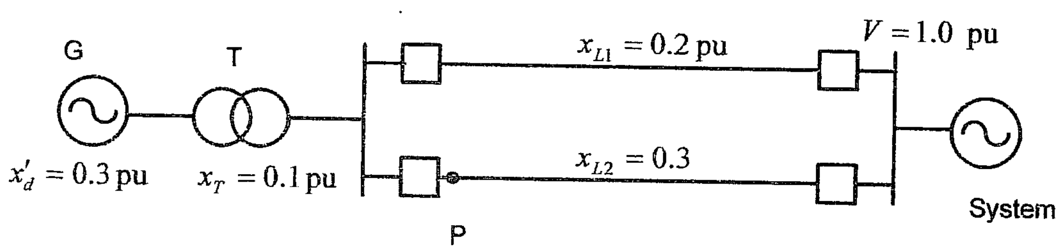

Figure Q1

a. Determine the excitation voltage of the generator G. [7 marks]

b. Write power angle equation. [3 marks]

c. A three-phase to ground fault occurs at point P. The fault is isolated by opening the circuit breakers at the end of effected line. Calculate the critical clearing angle. [8 marks]

d. If H=5 MJ/MVA determine the initial rotor acceleration just after the fault. [2 marks]

e. Without any calculation sketch the variation of power angle (after the fault) with time for each of following situations:
   i. Circuit breakers are opened before critical clearing angle (with/without damper windings).
   ii. Circuit breakers are opened after the critical clearing angle (with/without damper windings).

[5 marks]

Question (2)

a. What are the important features in a differential relay used in power transformer protection? If transformer is connected in Delta/Star draw the sketch of differential relay protection. [5 marks]

b. Briefly explain the zone settings of distance relay. [3 marks]

c. A 132 kV transmission line is protected by a Mho relay of $10\angle 25^0$ Ohm which is installed at the one end of the line. Current and potential transformation ratios that are installed at the relay location are 600:5 and 132 kV: 120 V respectively. The impedance of the transmission line is 35+j138 Ohm.

i. Sketch the characteristic of the relay on the R-X plane. [5 marks]

ii. Determine the part of the transmission line protected by the relay as a percentage of its total length. [9 marks]

iii. Suppose a fault occurs at 30% from the relay location. Show in R-X diagram the maximum fault resistance that relay allow (no need to calculate) [3 marks]

Question (3)

(a) Briefly explain term "discriminating margin". [5 marks]

(b)A certain radial distribution line is protected by an over-current relay installed at circuit breaker A. The relay has plug settings at 2.5, 3.75, 5.0, 6.25, 7.5, 8.75 and 10.0 A and the time leaver setting is continuously adjustable from 0.1 to 1.0. The relay at A has plug setting of 2.5 A and time leaver setting of 0.1.

The operating time-current characteristic of the relay is given bellow:

Operating time (s)	1.5	0.45	0.39	0.265	0.2
Fault current (A)	375	1000	1250	2500	5000

A remote back-up protection to the relay A is provided by an identical relay installed at circuit breaker B.

Maximum fault current through A and B	4500 A
Minimum load current through B	160 A
Current transformation ratio at A and B	500:5

i. What is the range of minimum fault current and maximum load current through relay at A. [8 marks]

ii. Select suitable pick-up setting and time leaver setting for relay B (Assume that minimum fault current through system is greater than value obtained in part (a)). [12 marks]

Question (4)

a. Write hyperbolic equations for voltage and current at any point of a long length transmission line. [2 marks]

b. Use equations above to prove

$$\underline{V}_x = \underline{V}_2\left[\left(Cosh\underline{\gamma} l_x + \frac{P_2}{P_{Surge}} Sinh\underline{\gamma} l_x\right) - j\frac{Q_2}{P_{surge}} Sinh\underline{\gamma} l_x\right]$$

where P_{surge} surge impedance loading

[5 marks]

c. A three phase 500 kV, 300 km transmission line has a series reactance of 0.34 Ω/km and shunt admittance of $j4.5\text{x}10^{-6}$ S/km.
   i. Calculate surge impedance, propagation constant and wave length. [3 marks]
   ii. Calculate the surge impedance loading when the voltages at both ends are maintained at 510 kV. [2 marks]
   iii. Power delivered through the line in the situation above is 1.2 times of the surge impedance loading. Calculate the reactive power at the both ends of the line. [8 marks]
   iv. Without any calculation sketch the variation of voltage, current and reactive power through the line when power delivered through the line P is
   (a). greater than P_{surge} (b). less than P_{surge}
   (consider voltage at both ends are equal) [5 marks]

Question (5)

Certain power system is shown in figure Q5. Reactances of the lines, power at generators and loads (on common base) are given in the figureQ5.

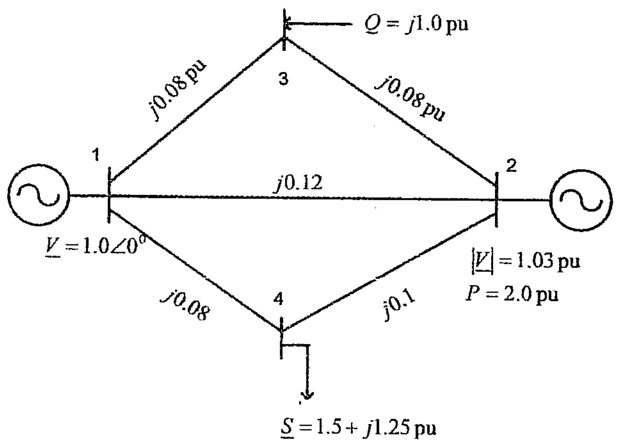

Figure Q5

i. Calculate the elements of nodal admittance matrix. [10 marks]
ii. Considering the node 1 as slack bus calculate the voltages at nodes using Gauss-Zeidel method. One iteration is sufficient. [15 marks]

Question (6)

a. Explain why Newton-Raphson method (or its modifications) is more adequate for load flow calculations of bulk power systems. [3 marks]
b. What do you understand by "flat start" with related to the load flow calculations? [2 marks]

c. Certain power system consists of 800 nodes and 12 nodes out of these are PV buses. What is the order of Jakobian matrix? Determine the orders of sub-matrices: [3 marks]

$$\frac{\partial P}{\partial V}, \frac{\partial P}{\partial \delta}, \frac{\partial Q}{\partial V}, \frac{\partial Q}{\partial \delta}$$

d. Power flow calculation of the system shown in figure Q6 is performed by using Newton-Raphson method. Voltage at nodes after 3rd iteration and Admittance of the lines (on common base) are given bellow:

$\underline{V}_1 = 1.1\angle 0^0$ pu	$\underline{Y}_{12} = -1.96 + j7.84$
$\underline{V}_2 = 1.05\angle 3.27$ pu	$\underline{Y}_{13} = -2.56 + j12.82$
$\underline{V}_3 = 1.01\angle -1.80^0$ pu	$\underline{Y}_{23} = -1.96 + j7.84$

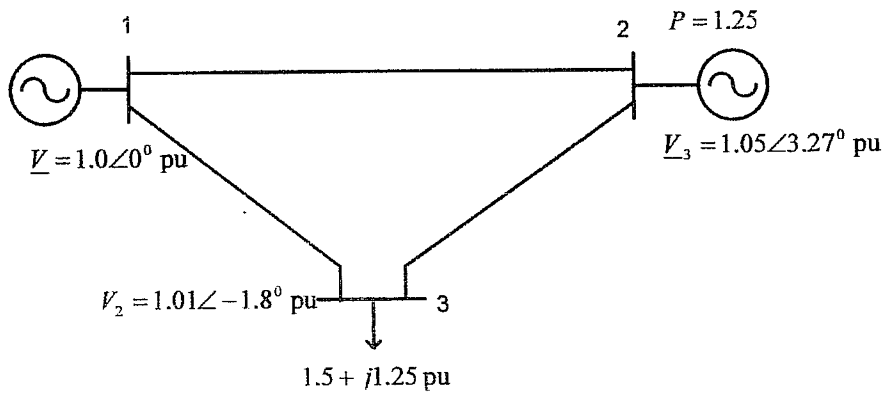

Figure Q6

i. Calculate the maximum power mismatch [10 marks]

ii. Find the reactive power of generator G2. [4 marks]

iii. Suppose the reactive power obtained above exceed the reactive power limit of the generator G2. What is the change at the next step of load flow calculation? [3 marks]