National Exams May 2003

98-Elec-B7, Power Systems Engineering

3 hours duration

NOTES

1. If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a clear statement of any assumptions made.
2. Any non-communicating calculator is permitted. This is an Open Book examination. Note to the candidates: you must indicate the type of calculator being used, i.e. write the name and model designation of the calculator on the first inside left hand sheet of the exam work book.
3. Any five questions constitute a complete paper. Only the first five questions as they appear in your answer book will be marked.
4. All questions are of equal value.

Problem 1

a- Explain the function of shunt capacitors in electric power systems. [4 Marks]

A 300 km, completely transposed 60 Hz, three phase line has flat horizontal phase spacing with 10 m between adjacent phases, as shown in Fig. (1). Each phase consists of a three-bundle conductor, with outside radius of 0.014 m, a GMR, D_s = 0.0115 m, and a bundle spacing of 0.4 m.

b- Calculate the positive-sequence inductive reactance of the line. [4 Marks]

c- Calculate the positive-sequence shunt capacitive susceptance of the line. [4 Marks]

d- Assume that the line has an X/R ratio of 5 and negligible shunt conductance. Find the exact value of the parameter A of the line. [4 Marks]

e- If the no load receiving end voltage of the line is 348 kV (line to line), find the value of the sending end voltage. [4 Marks]

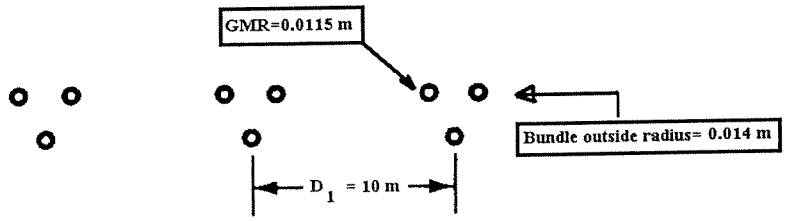

Figure 1 Transmission Line Configuration for Problem 1

Problem 2

a- Explain the differences between the round rotor and salient-pole synchronous machine designs. [5 Marks]

b- Prove the following relation for a salient-pole synchronous machine [5 Marks]

$$\tan\delta = \frac{PX_q}{V^2 + QX_q}$$

A salient-pole synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.05 pu. The direct axis reactance of the machine is 0.95 pu and the quadrature axis reactance is 0.4 pu respectively. Neglect armature reaction.

c- The table given below relates to two operating conditions of the machine. Complete the table. [10 Marks]

	P	Q	E	δ
Condition A	?	?	1.3	40°
Condition B	2.0	0	?	?

Problem 3

a- What are the differences between an auto-transformer and a regulating transformer? [5 Marks]

A 4600/460 V, 200-kVA, 60-Hz, step-down, single-phase transformer has the following equivalent-circuit parameters referred to the high-voltage side.

$R_{eq} = 1.35\ \Omega$ $X_{eq} = 6.2\ \Omega$

The admittance of the shunt branch representing the core loss and magnetizing reactance referred to the primary side is given by:

$$Y_c = [0.2 - j1.1] \times 10^{-3} S$$

The transformer supplies a load of 180 kVA at a lagging power factor of 0.8 at 460 V and. Use the equivalent circuit of the transformer shown in Figure (2) to determine:

b- The magnitude of the required primary voltage. [7.5 Marks]

c- The power factor of the primary side, the input MVA, and the efficiency of the transformer. [7.5 Marks]

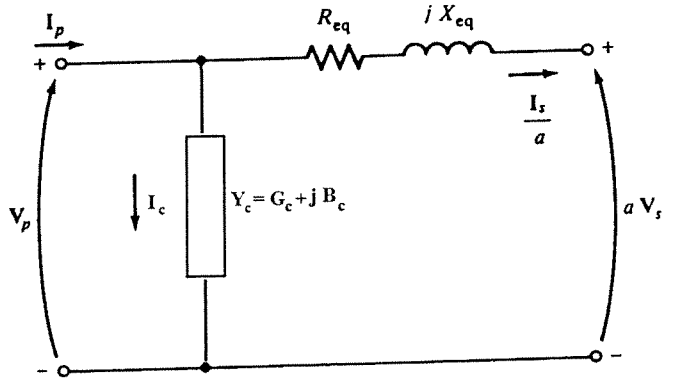

Figure 2 Equivalent Circuit of Transformer for Problem 3

Problem 4

a- Explain the consequences of short circuit faults in an electric power system. [4 Marks]

b- Construct the Z_{BUS} matrix of the system shown in Figure (3) using the following steps

Step 1:

Connect buses 1 and 2 to the reference bus. [4 Marks]

Step 2:

Connect buses 1 and 2 by the j 0.8 impedance. [4 Marks]

Step 3:

Connect bus 3 to bus 1 by the j 0.3 impedance. [4 Marks]

Step 4:

Connect buses 3 and 2 by the j 0.35 impedance. [4 Marks]

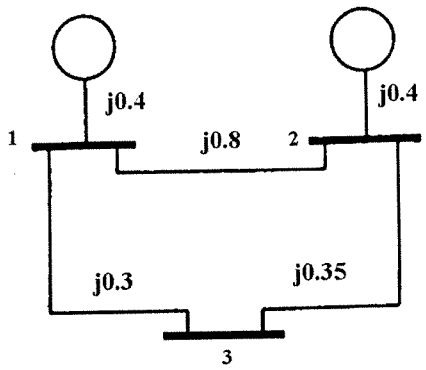

Figure 3 Single-line diagram for Problem 4

Problem 5

Consider the system shown in the single-line diagram of Figure 4. All reactances are shown in per unit to the same base. It is required to find the following:

a- The active and reactive power generated at bus 1. [5 Marks]

b- The voltage magnitude and its phase angle at bus 3. [5 Marks]

c- The active and reactive power of the load at bus 3. [5 Marks]

d- The active and reactive power generation at bus 4. [5 Marks]

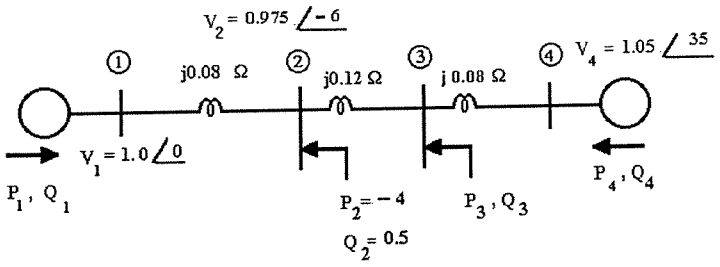

Figure 4 Single-line diagram for Problem 5

Problem 6

Consider the system shown in the single-line diagram of Figure 5. The required sequence reactances in per unit to the same base are as follows:

G_1	$X_1 = X_2 = 0.15$	$X_o = 0.06$	
G2	$X_1 = X_2 = 0.25$	$X_o = 0.10$	
G3	$X_1 = X_2 = 0.4$	$X_o = 0.10$	$X_n = 0.1$
G4	$X_1 = X_2 = 0.4$	$X_o = 0.12$	
Transformers	$X_{T1} = X_{T2} = 0.1$	$X_{T3} = 0.24$	$X_{T4} = 0.15$

Lines: Positive and Negative Sequence $X_{13}=X_{12}=X_{23} = 0.15$

Lines: Zero Sequence $X_{12} = 0.6$ $X_{13} =X_{23} = 0.40$

a- Draw the zero-, positive-, and negative- sequence reactance diagrams. [7.5 Marks]

b- Determine the The'venin's equivalent of each sequence network as viewed from the fault bus 3. [7.5 Marks]

c- Determine the fault current in per unit for a double line to ground fault at bus 3. [5 Marks]

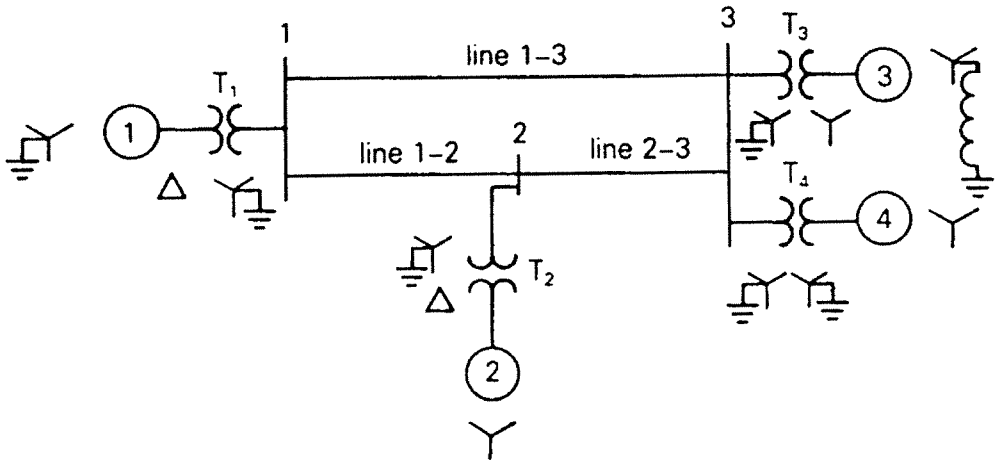

Figure 5 Single line diagram for Problem 6

Problem 7

Consider the circuit shown in Figure (6). Assume that E = 1.2 p.u., and V = 1.05 p.u. The load on the circuit is 5 p.u., when a three phase short circuit takes place in the middle of transmission line 3. Find if the system will remain stable under a sustained fault. [20 Marks]

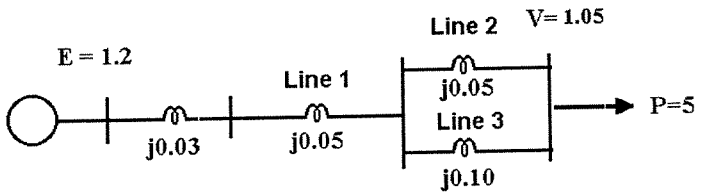

Figure 6 Circuit for Problem 7

Marking Scheme

PROBLEM 1

(a) 4 Marks (b) 4 Marks (c) 4 Marks
(d) 4 Marks (d) 4 Marks

PROBLEM 2

(a) 5 Marks (b) 5 Marks (c) 10 Marks

PROBLEM 3

(a) 5 Marks (b) 7.5 Marks (c) 7,5 Marks

PROBLEM 4

(a) 4 Marks (b) 4 Marks (c) 4 Marks (d) 4 Marks (d) 4 Marks

PROBLEM 5

(a) 5 Marks (b) 5 Marks (c) 5 Marks (d) 5 Marks

PROBLEM 6

(a) 7.5 Marks (b) 7.5 Marks (c) 5 Marks

PROBLEM 7

(20 Marks)