National Exams December 2002

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 phase shifting transformers in electric power systems. [5 points]

b- Consider a 500-kV, 60 Hz three-phase transmission line modeled using the ABCD parameters as follows:

$$V_s = AV_r + BI_r$$
$$I_s = CV_r + AI_r$$
$$A^2 - BC = 1$$

An open circuit test is conducted at the receiving end of the line, ($I_r = 0$), with the receiving end voltage maintained at 500 kV (line-to-line value). The sending end voltage is found to be 450 kV (line-to-line value) and leads the receiving end voltage by 1.3°. The sending end active power input to the line is 5.18 MW at 0.021-power factor leading. Find the line parameters A, B, and C. [10 Points]

c- Suppose that the load at the receiving end of the line of part b is 500 MVA at nominal voltage, and lagging power factor of 0.8 at rated voltage. Determine the sending end voltage, current, active and reactive power and power factor. [5 points]

Problem 2

a- Sketch and explain the synchronous machine reactive capability curve. [5 points]

b- A round rotor synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.05 pu. The synchronous reactance of the machine is 0.4. The table given below relates to two operating conditions of the machine. Complete the table neglecting armature reaction. [15 points]

	P	Q	E	δ
Condition A	?	?	1.3	40°
Condition B	2.0	0	?	?
Condition C	?	0	1.2	?

Problem 3

a- List the different types of losses in a transformer and explain possible ways of reducing them. [5 points]

A single-phase power transformer has an equivalent circuit as shown in Figure (1.) The admittance of the shunt branch representing the core loss and magnetizing reactance referred to the primary side is given by:

$$Y_c = 1.1x10^{-3} S$$

When the primary voltage is 14.26 kV, the active power supply is 4.1 MW at 0.81 power factor leading. Under these conditions, the power factor at the secondary side is 0.85 lagging and the efficiency of the transformer is 97%.

b- Find the value of the current at the secondary side referred to the primary side. [5 points]

c- Find the elements of the equivalent circuit of the transformer in ohms referred to the primary side. [5 points]

d- Find the voltage on the secondary side referred to the primary side. [5 points]

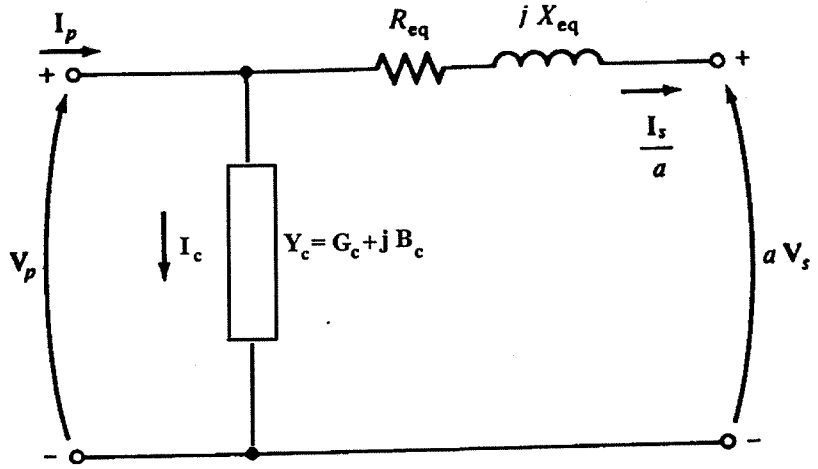

Figure 1 Equivalent Circuit of Transformer for Problem 3

Problem 4

For the power system shown in Figure 2:

a- Assume that the reactive shunt compensation is $Q_{G2} = 0.0$ Show that it is not possible to serve the load S_{D2} under this condition [7 points]

b- Find the voltage V_2 exactly when we set $jQ_{G2} = j2.0$. [7 points]

c- Find the value of Q_{G2} to obtain $|V_2| = 0.975$. [6 points]

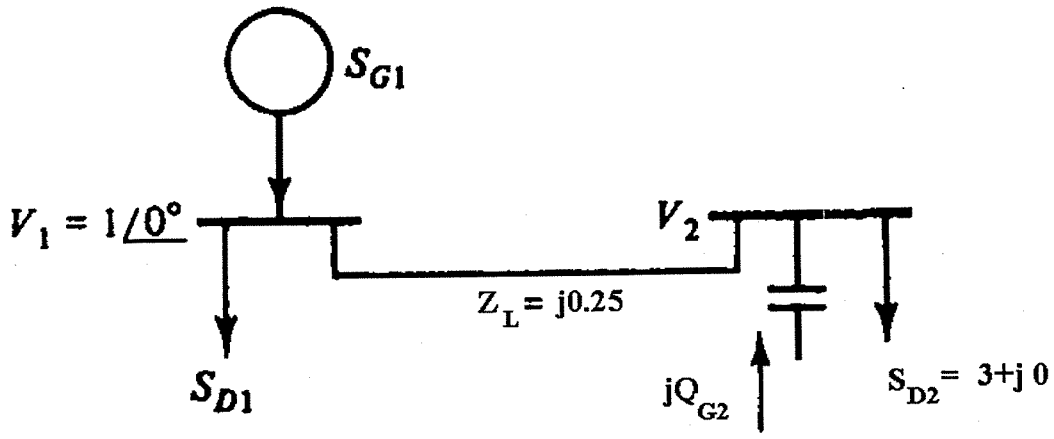

Figure 2 Single-line diagram for Problem 4

Problem 5

Consider the system shown in the single-line diagram of Figure 3. All reactances are shown in per unit to the same base. Assume that the voltage at both sources is 1 p.u.

a- Find the fault current due to a bolted- three-phase short circuit at bus 3. [10 points]

b- Find the fault current supplied by each generator and the voltage at each of the buses 1 and 2 under fault conditions. [10 points]

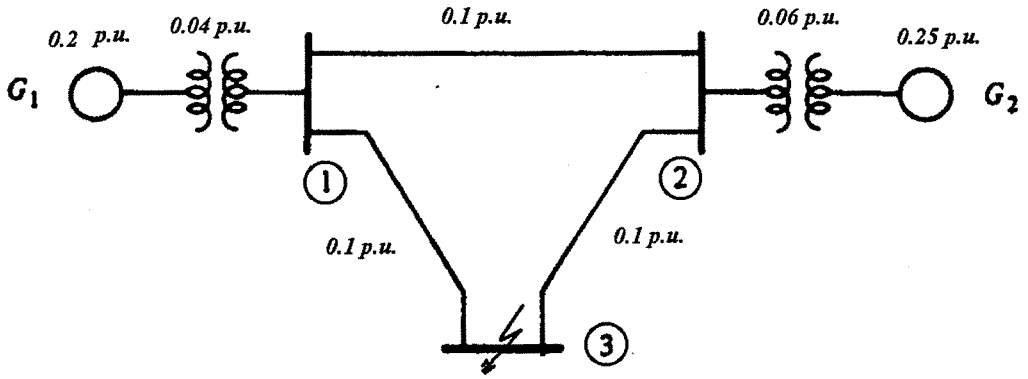

Figure 3 Single-line diagram for Problem 5

Problem 6

a- Discuss the advantages and disadvantages of grounding the neutral of Y connected generator and transformer windings. [5 points]

The following are the line currents at the terminals of a Y connected three phase source operating under unbalanced conditions.

$$I_A = 1 \qquad I_B = 1e^{-j30} \qquad I_C = 1e^{j30}$$

The sequence values of the line to neutral voltages are given by:

$$V_+ = 1 \qquad V_- = 0.5e^{j60} \qquad V_o = 0.5e^{-j60}$$

b- Determine the positive, negative and zero sequence currents. Is the neutral of the source grounded? Why? [5 points]

c- Determine the phase coordinate values of the line to neutral voltages [5 points]

d- Find the total apparent power delivered by the source using both phase and sequence values obtained in parts (c) and (d). [5 points]

Problem 7

Consider the system shown in the single-line diagram of Figure 5. Here, a 60-Hz synchronous generator having a transient reactance of 0.30 p.u. is connected to an infinite bus through a transformer whose reactance is 0.10 p.u. and two parallel transmission lines. The reactance of line 1-2 is 0.2 p.u., while that of section 1-3 is 0.10 p.u., and that of section 3-2 is 0.20 p.u. as indicated in the figure. The generator delivers an apparent power of 2.5 p.u. at 0.8 pf lagging to the infinite bus. The magnitude of the voltage at bus 2 is 1.0 p.u.

a- Determine the excitation voltage of the generator under these conditions. [7 points]

b- Determine the equation of the electrical power delivered by the generator versus its power angle. [3 points]

c- Suppose that the synchronous generator is initially operating in the steady state condition given earlier. A three phase-to-ground bolted short circuit occurs at point F on transmission line 1-3, close to breaker B13. Due to relay malfunctioning, all circuit breakers remain closed. Calculate the critical clearing angle. [10 points]

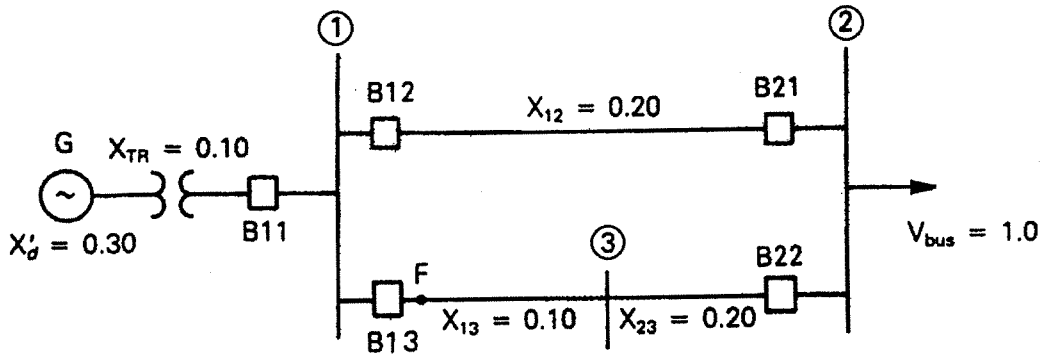

Figure 4 Circuit for Problem 7