National Exams May 2009

07-Elec-B7, Power Systems Engineering

Open Book examination

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 meaning of the term "transposed line" and why is it needed. [5 Points]

b- Consider a three-phase transmission line modeled using the ABCD parameters as follows:

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

Assume that:

$$C = 0.2\angle 85^\circ$$

Suppose that the apparent power load at the receiving end of the line is 1.2 pu, at 0.8 power factor lagging while the receiving end voltage is 1 pu. The sending end current is found to be $I_s = 1.08\angle -27^\circ$. Find the values of the line parameters A, and B. [5 Points]

c- Find the sending end voltage, power factor, and efficiency of transmission under the operating conditions of part (b). [10 Points]

Problem 2

a- Explain why it is important to provide sufficient reactive power throughout an electric power system. List the major sources of reactive power in the system. [5 points]

b- A salient pole synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.00 pu. The direct and quadrature axis reactances of the machine are 0.6 and 0.3 pu respectively. Table (1) relates to three operating conditions of the machine. (Q_2 is the reactive power at machine terminals) Complete the table neglecting armature reaction. [15 points]

Table (1) Operating Conditions of Problem (2)

	P	Q_2	E	δ
Condition A	?	0.0	1.10	?
Condition B	?	?	1.15	37.5°
Condition C	1.8	?	?	37°

Problem 3

Consider the system shown in Figure (1,) where a phase shifting transformer connects buses 1 and 2.

The transformer parameter a is a complex variable expressed as $a = e^{j\theta}$, where θ is the phase-shift angle. Assume that $\theta = -\pi/18$

(a) Explain the basis for the transformer relations: $I_{m2} = a^* I_1$ and $V_{m2} = \frac{V_1}{a}$. [5 points]

(b) Find the voltage, current and power factor at the generator bus 1. [5 points]
(c) Find the active and reactive powers generated at bus 1. [5 points]
(d) Find the efficiency of transmission between buses 1 and 2. Explain your answer. [5 points]

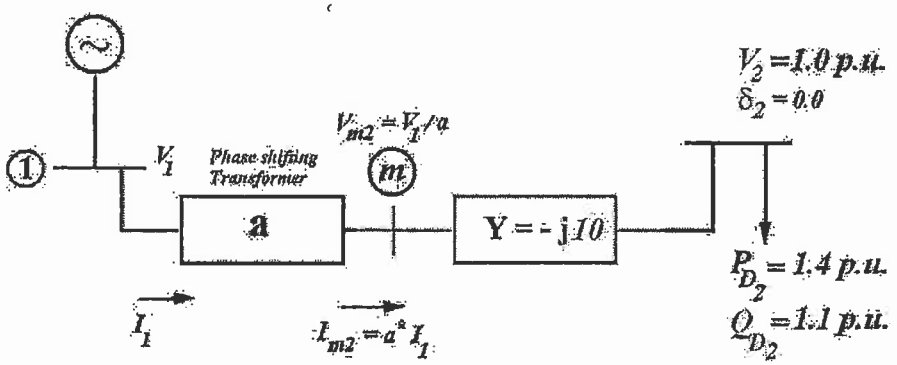

Figure (1) Circuit for Problem 3

Problem 4

a- List the types of buses in a conventional power flow problem formulation. For each type, identify the known and unknown variables. [5 Points]

In the simple electric power system shown in Figure (2), it is required to find the following:

b- The voltage magnitude and the reactive power injection at bus 2 assuming that the voltage angle is -8°. [5 Points]
c- The active and reactive power generated at bus 1. [5 Points]
d- The active and reactive power generated at bus 3. [5 Points]

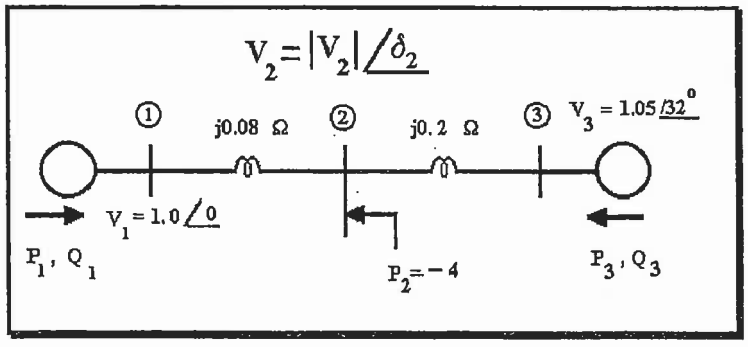

Figure (2) Circuit for Problem 4

Problem 5

a- Discuss the main causes for short circuit faults on Canadian electric power systems. [5 points]

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.

b- Find the voltage at bus 1 due to a bolted- three-phase short circuit on line 1-3 at F1 as indicated in Figure (3). [10 points]

c- Determine the fault current contributions from bus 3 and bus 1 and hence find the total fault current and the voltage at bus 4 under fault conditions. [5 points]

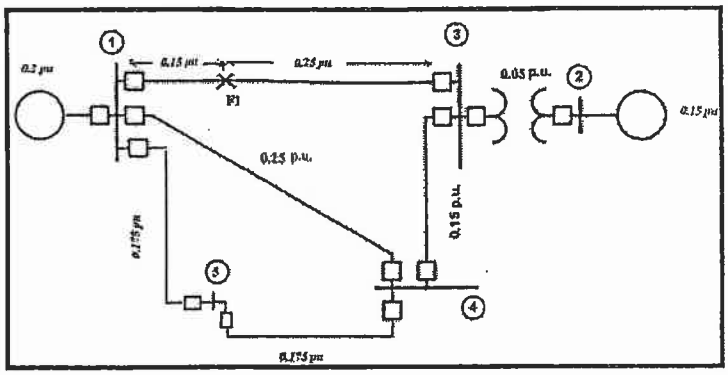

Figure (3) Single-line diagram for fault in Problem 5

Problem 6

Consider the system of Figure (4.) The reactances of all components in p.u. are indicated in Table (2.)

a- Sketch and label carefully the positive, negative, and zero sequence equivalent networks for this system including the switch S. Note that the switch is normally closed when the high voltage side of the transformer is grounded. An open switch means a broken ground connection. [5 Points]

b- Assume that a single line to ground fault takes place on phase A at bus 2, while switch S is closed. Find the current through phase A of lines L1 and L2 . [5 Points]

c- Repeat part (b) with the switch open (ungrounded transformer T1.) What is the effect of grounding the transformer on the fault current? [5 Points]

d- Assume that a three phase ground fault takes place at bus 2. Find the fault current. [5 Points]

Table (2) Component reactances in per unit for Problem 6

	Generators G_1 & G_2	Transformers T_1 & T_2	Lines L_1 & L_2
Positive sequence reactance X_+	0.2	0.25	0.20
Negative sequence reactance X_-	0.15	0.25	0.20
Zero sequence reactance X_o	0.1	0.25	0.30

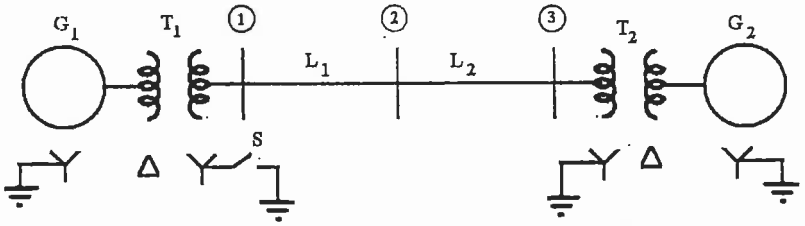

Figure (4) One-line diagram for Problem (6)

Problem 7

Consider the system shown in the single-line diagram of Figure (5.) Here, a 60-Hz synchronous generator whose transient reactance is 0.30 p.u. is connected to bus 1 through a transformer whose reactance is 0.10 p.u. Bus 1 is connected to the infinite bus labeled 2 through two parallel paths. The first path is transmission line (1-2) whose reactance is 0.2 p.u. The second path connects buses 1 and 2 via bus 3. Section 1-3 consists of two parallel lines whose reactances are 0.10 p.u. As indicated in the figure, the reactance of section 3-2 is 0.10 p.u. The generator delivers an active power of 1.8 p.u. to a 0.8 pf lagging load connected to the infinite bus (2.) The magnitude of the voltage at bus 2 i s 1.0 p.u.

a- Determine the value of the excitation voltage of the generator under these conditions. [5 points]

b- Determine the equation of the electrical power delivered by the generator versus its power angle under the conditions of part (a). [3 points]

c- Suppose that the magnitude of the voltage at bus 2 is 1.0 p.u and the generator's excitation voltage is set at E= 1.2. Suppose that the synchronous generator is initially operating in the steady state delivering an active power of 2.0 p.u., and that a three phase-to-ground bolted short circuit occurs at point F between breakers Be and Bg in one line of section 1-3. The fault is cleared by opening breakers B_e and B_g for $\delta = 80^o$. Determine whether the system is stable or not under these conditions. [12 points]

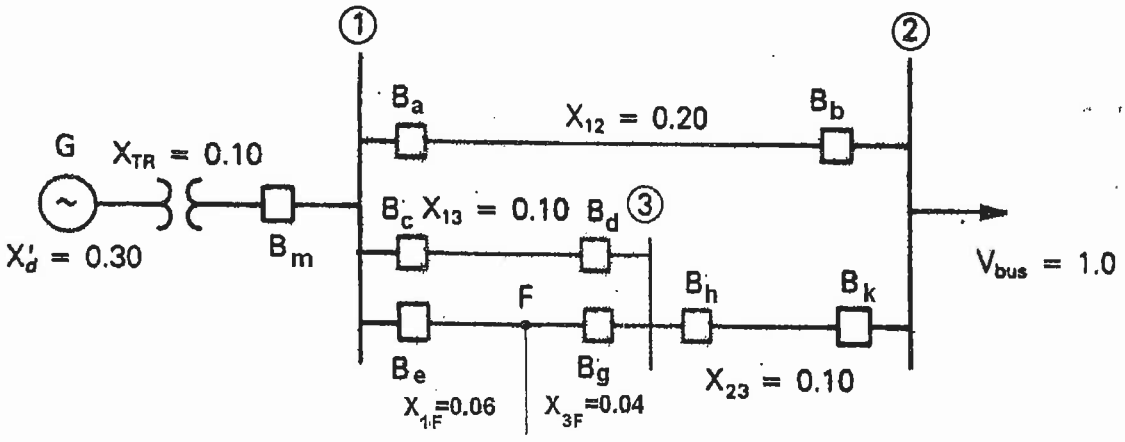

Figure (5) Circuit for Problem 7