National Exams May 2005

98-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 "transmission capacity of a line," and describe at least one method to increase its value at the system design stage and another during operation of the line. [5 Points]

b- Consider a three-phase, 240-mile, 760-kV, 1500 MVA, bundle-conductor 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:

$$B = 125.9\angle\underline{87.5^{\circ}}$$

Suppose that the apparent power load at the receiving end of the line is 1500 MVA, at 0.95 power factor lagging while the receiving end voltage is 700 kV. The sending end voltage is found to be $V_s = 760.5\angle\underline{19.66^{\circ}}$ kV. Find the line parameters A, and C. [5 Points]

c- Find the sending end current, power factor, and efficiency of transmission under the conditions cited in 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. The table given below 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]

	P	Q_2	E	δ
Condition A	?	0.0	1.12	?
Condition B	?	?	1.25	37.5°
Condition C	2.0	?	?	40°

Problem 3

a- List five different transformer types used in the electric power system. [5 points]

Consider a three-winding transformer, as shown in Figure 1, with the following particulars:

Z_p= 0.02+j 0.08	Z_s= 0.02+j 0.08	Z_t= 0.02+j 0.08
V_2=400	$I_2=60\angle{-30^\circ}$	$I_3=50\angle{-40^\circ}$

Assume that V_2 is the reference phasor, calculate:

(a) The intermediate voltage V_0 (3 points)
(b) The primary current I_1 and the primary voltage V_1. (3 points)
(c) The tertiary voltage V_3 referred to the primary side. (3 points)
(d) The apparent powers and power factors at the primary, secondary and tertiary terminals. (3 points)
(e) The transformer efficiency. (3 points)

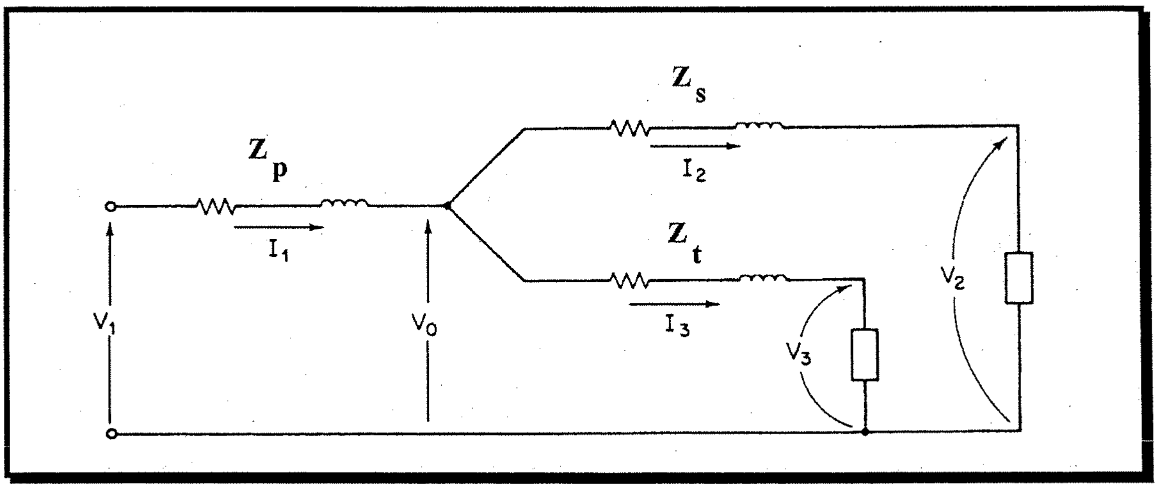

Figure (1) Three Winding Transformer Equivalent Circuit for Problem 3

Problem 4

In the two bus system shown in Figure (2,) bus 1 is the reference (slack) bus with $|V_1| = 1.00$ and $\delta_1 = 0.0^o$. At bus 2, the active load is 4.2 p.u. and the reactive load is -0.8 p.u. and the line admittance is $y_{12} = 0.8 - j10$ as shown in the figure. The voltage at bus 2 is to be maintained between 0.95 and 1.05 p.u.

a- Determine if the capacitor bank C1 should be switched on. [7 points]

b- Find the voltage $|V_2|$ under the appropriate conditions established in part (a.) The rating of the capacitor C1 is 0.1 p.u. [7 points]

c- Find the angle δ_2 corresponding to the conditions of part (b.) [6 points]

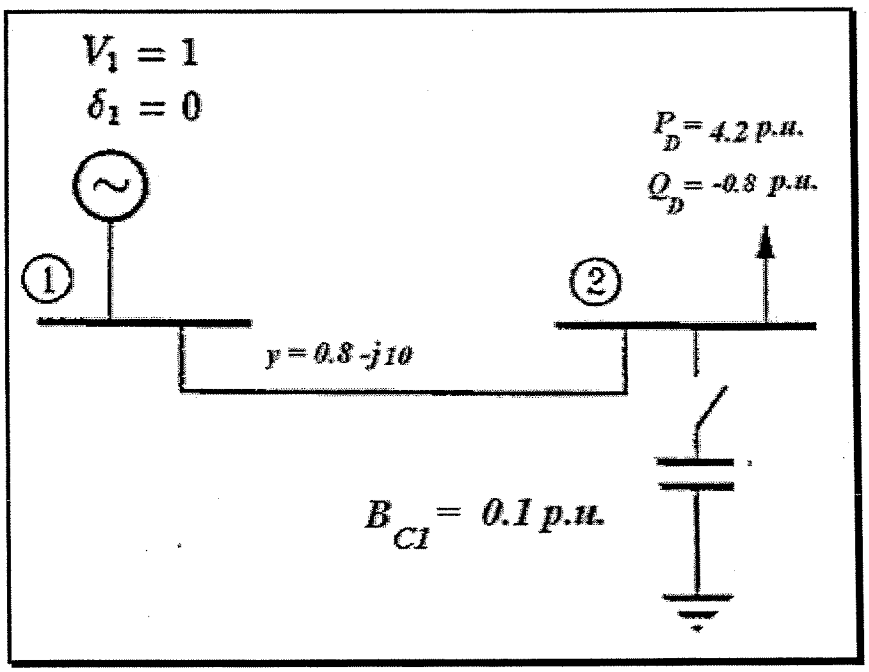

Figure (2) One-line Diagram for Problem 4

Problem 5

a- Name three protection schemes employed for High Voltage Transmission lines in an electric power system. [5 points]

b- 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, find the voltage at bus 3 due to a bolted- three-phase short circuit in the middle of line 1-5 at F1 as indicated in Figure (3). [15 points]

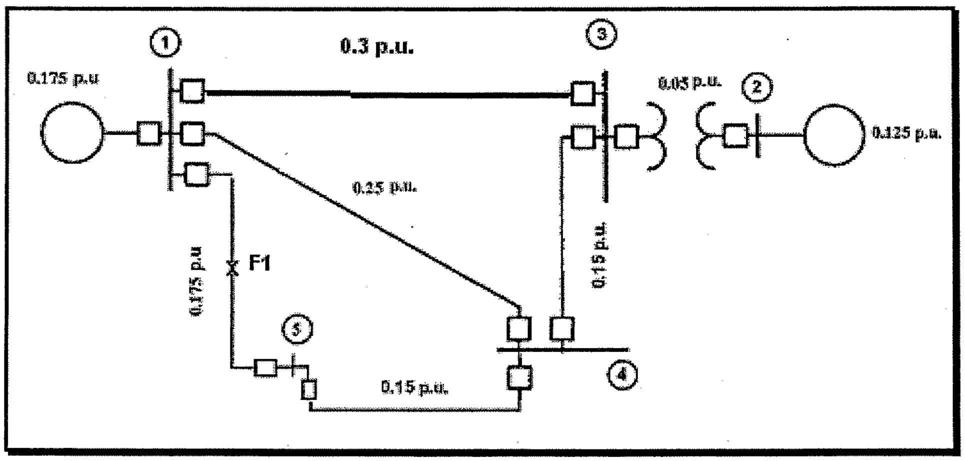

Figure 3 Single-line diagram for fault 1 in Problem 5

Problem 6

Consider fault currents seen at breaker B3 that take place at bus 4, in the system shown in the single-line diagram of Figure 4. The source voltage is 34.5 kV, line-to-line. Determine the fault currents for the following unbalanced faults:

a- Symmetrical three phase fault. [3 points]

b- Single line to ground fault. [5 points]

c- Double line to ground fault [5 points]

d- Line to line fault. [5 points]

e- Which fault involves the smallest fault current? [2 points]

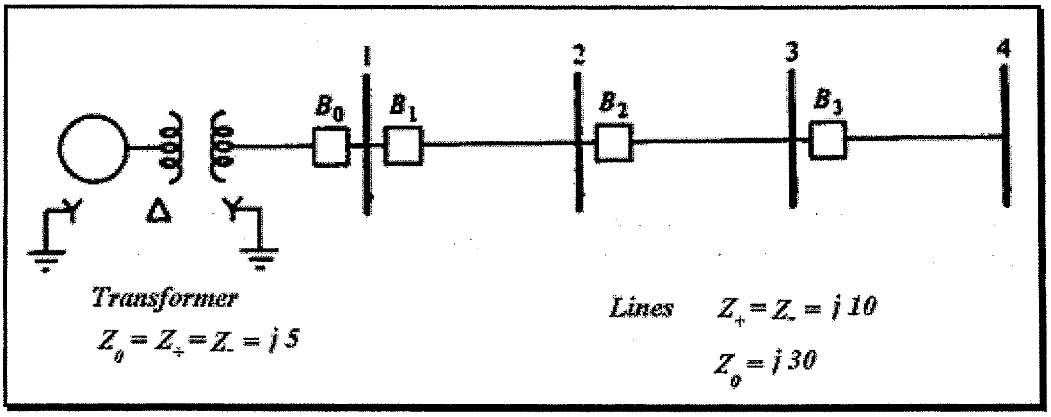

Figure 4 Single line diagram for Problem 6

Problem 7

Consider a round-rotor generator operating at a normal frequency of 60 Hz, while delivering a steady state power $P_G = 0.8$ to an infinite bus through a transformer bank and a double circuit transmission line as shown in Figure 5. Assume that $E_a = 1.35$, and that the infinite bus voltage is maintained at 1 pu, H=5 MJ/MVA. Use the approximate expression relating the angle to time differences:

$$\Delta t = \sqrt{\frac{2H\Delta\delta}{\pi f_o P_m}}$$

a- At t_o a three phase fault takes place in the middle of line A. Find the critical fault clearing angle, and the critical clearing time in cycles. [5 points]

b- Six cycles following fault inception, the circuit breakers at both ends of line A open to isolate the fault. Determine whether the system is stable under these conditions. [5 points]

c- Assume that the fault condition is cleared 6 cycles following the action taken in part (b,) and that line A is restored to service by closing its circuit breakers. Determine the maximum angle of swing associated with the situation. [10 points]

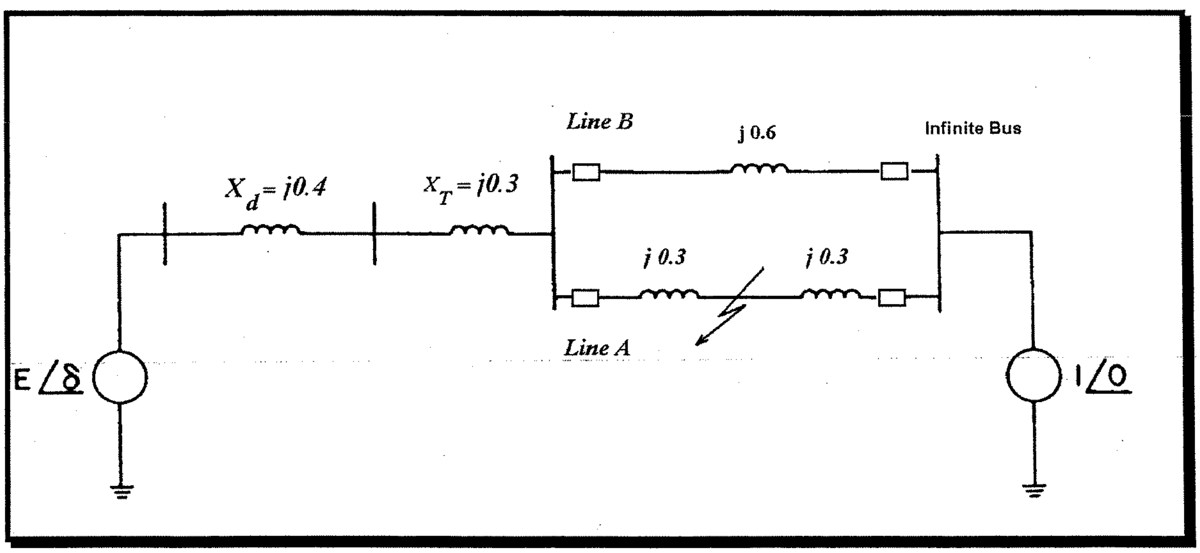

Figure 5 Circuit for Problem 7