National Exams December 2005

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 term "transmission line transposition" and its effects on the electrical performance of a high voltage electric transmission line. [5 Points]

Consider an experimental 2000 kV three phase bundle-conductor line with N-sub-conductors to each phase. Assume that the inductance in henries per meter per phase is 7.45×10^{-7}. It is also known that the capacitance in Farads per meter per phase (neglecting ground effects) is 14.98×10^{-12}.

b- Find the number of subconductors in the bundle (N). Note that you will need to round N up to the next even integer value. [5 points]

c- Assume that the line is 200 km long and neglect the series resistance of the line. Calculate the sending-end voltage, sending-end current, power, and power factor when the line is delivering 18,000 MVA at 0.85 PF lagging at rated voltage using the nominal π approximation. [10 points]

Problem 2

Consider the system shown in Figure 1, with a phase shifting transformer connecting buses 1 and 2.

This means that (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 $V_{m2} = \dfrac{V_1}{a}$. [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]

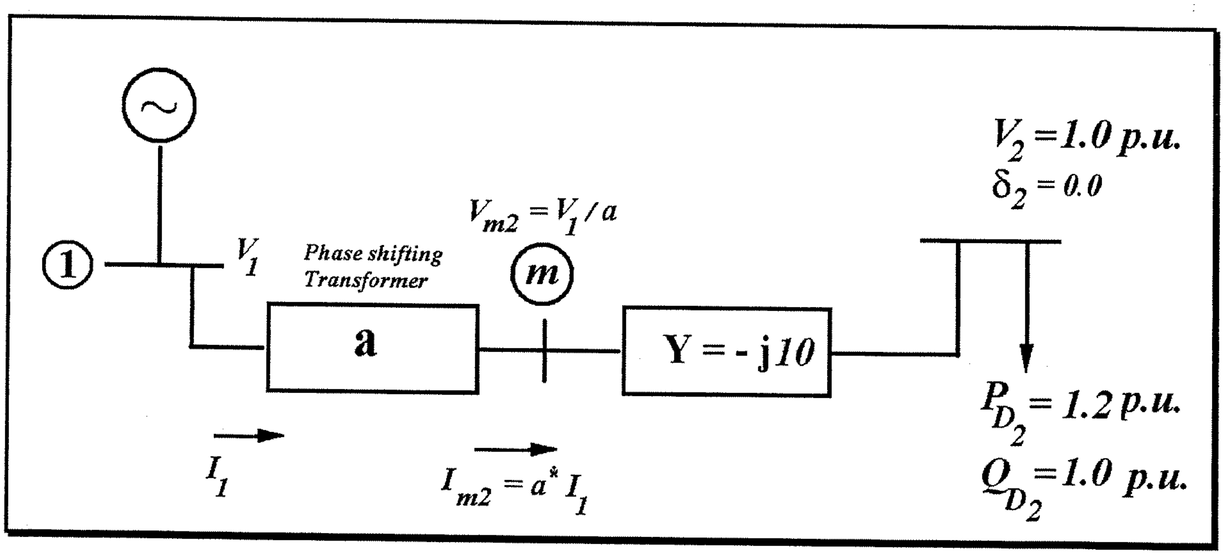

Figure (1) Circuit for Problem 2

Problem 3

The terminal voltage of a round rotor synchronous generator is kept constant at 1.00 pu. The synchronous reactance of the machine is 0.85 pu.

a- The load connected to the generator is P=0.9 pu and Q=0.75 pu (i.e. it is inductive.) Determine the torque angle δ and the magnitude of the required excitation voltage $|E|$. [5 points]

b- Assume that the upper limit on the excitation voltage magnitude is given by $|E| \leq 1.1$ Find the shunt compensation value required to provide the reactive load value Q=0.75 while maintaining the value of P=0.9. With reference to the reactive capability curve shown in Figure 1, is the machine operating in the safe zone for coolant pressure of 0.5 psig? [15 points]

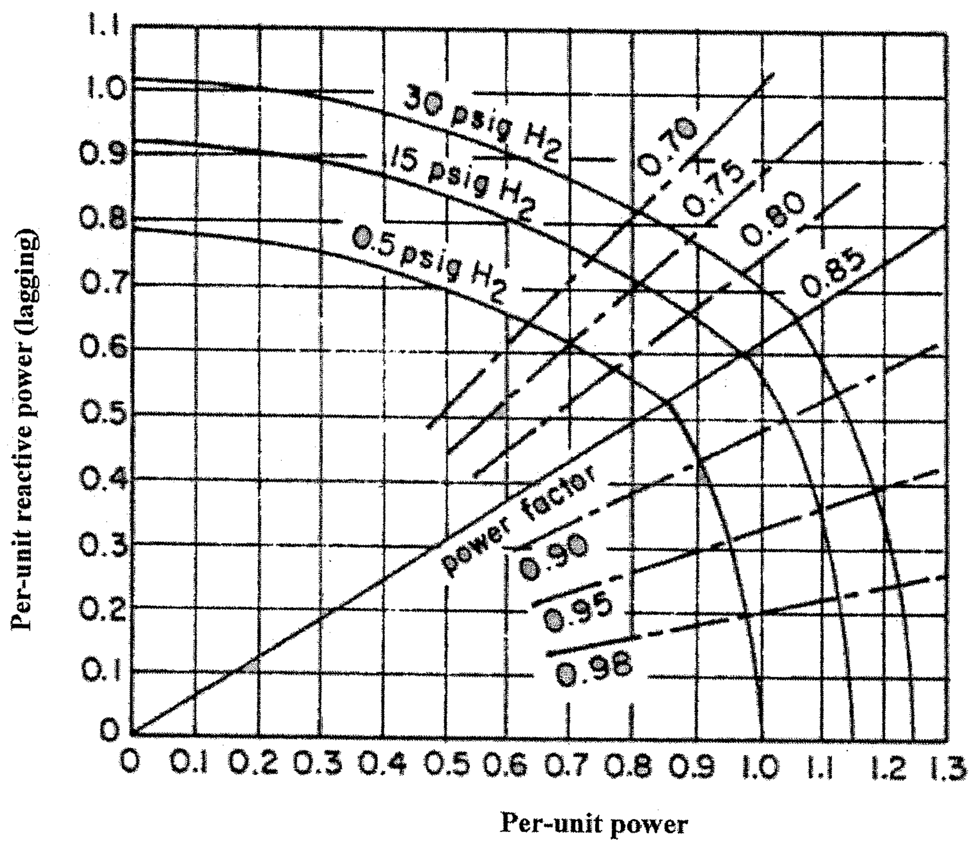

Figure (2) Reactive capability curve for Problem 3

Problem 4

For the two bus system shown in Figure (3,) bus 1 is the reference (slack) bus with $|V_1| = 1.00$ and $\delta_1 = 0.0^\circ$. At bus 2, the active load is 4.3 p.u. and the reactive load is -0.636 p.u. and the line admittance is $y_{12} = 1 - j10$ 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 should be switched on or off. [5 points]

b- Find the voltage $|V_2|$ under the appropriate conditions established in part (a.) The susceptance of the capacitor is 0.83 p.u. [5 points]

c- Find the angle δ_2 corresponding to the conditions of part (b.) [5 points]

d- Find the active and reactive power generation and power factor at bus 1 corresponding to the conditions of part (b.) [5 points]

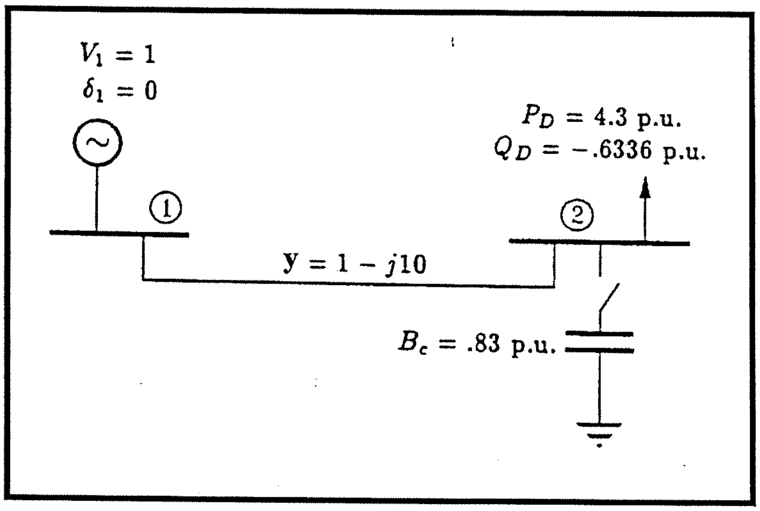

Figure (3) One-line Diagram for Problem 4

Problem 5

a- Name three protection schemes employed for distribution networks in an electric power system. [5 points]

b- In the single-line diagram of Figure (4,) all line and generator reactances are shown in per unit to the same base. Assume that the excitation voltage for both generators is 1 p.u. Find the voltage at bus 3 due to a bolted- three-phase short circuit in the middle of line 2-4 at F as indicated in Figure (4). [15 points]

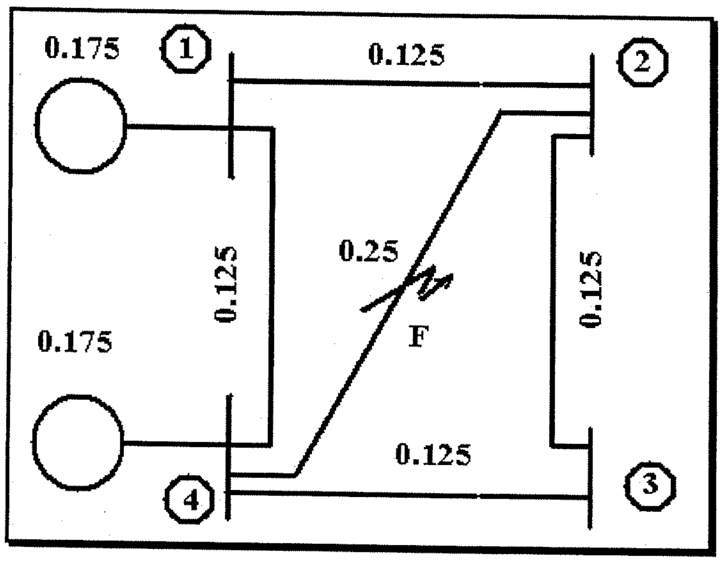

Figure 4 Single-line diagram for fault 1 in Problem 5

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 Points]

b- Determine the The'venin's equivalent of each sequence network as viewed from a fault location in the middle of line 1-3. [7.5 Marks]

c- Determine the fault current in per unit for a single line to ground fault at the middle of line 1-3 [5 Points]

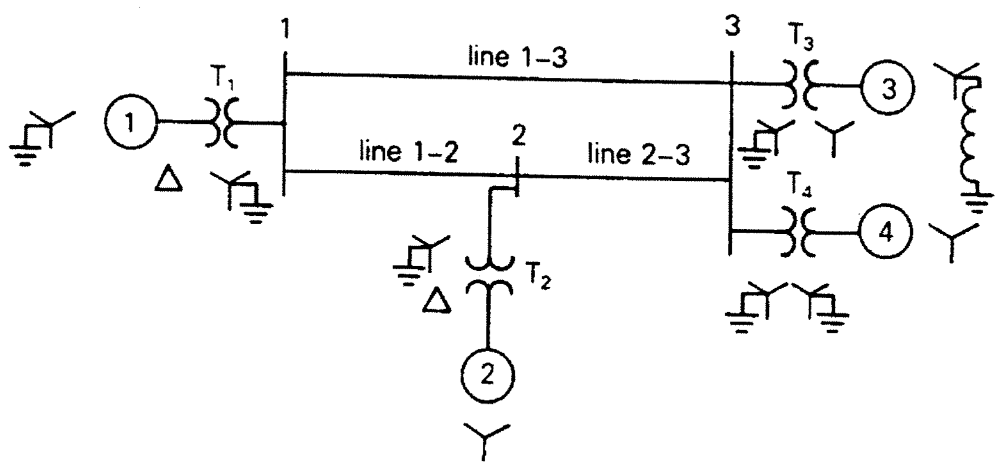

Figure 5 Single line diagram for Problem 6

Problem 7

Consider the circuit shown in Figure (6). Assume that E = 1.1 p.u., and V = 0.95 p.u. The load on the circuit is 6 p.u., when a three phase short circuit takes place in the middle of transmission line 3. Find if the system will remain stable if the fault is cleared by removing line 3 (i.e. open) at $\delta = 55^o$. [20 points]

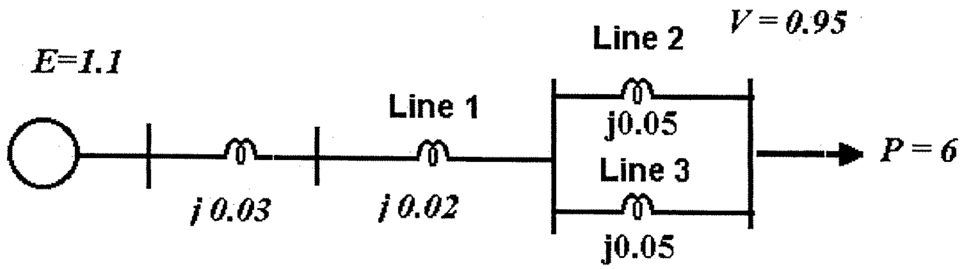

Figure 6 Circuit for Problem 7