National Exams December 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 benefits of using high voltage alternating current in electric power transmission systems. [4 points]

A 200 km, completely transposed 60 Hz, three phase line has flat horizontal phase spacing of 10 m between adjacent phases, as shown in Figure (1). Each phase consists of a three-sub-conductor bundle conductor, with sub-conductor outside radius of 0.014 m, a sub-conductor GMR of 0.0115 m, and a bundle spacing S= 0.4 m.

b- Calculate the inductive reactance of the line. [4 points]

c- Calculate the shunt capacitive susceptance of the line. [4 points]

d- Assume that the line has an X/R ratio of 8 and negligible shunt conductance. Find the exact value of the parameter C of the line (use hyperbolic function definitions.) [4 points]

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

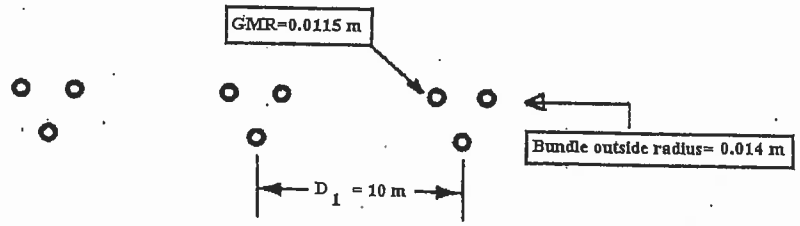


Figure (1) Transmission Line Configuration for Problem (1)

Problem 2

a- Sketch the reactive capability curve of a synchronous machine, and explain the underlying principles for its various segments. [5 points]

b- A round rotor synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.00 pu. The synchronous reactance of the machine is 0.325 p.u. 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.

	P	Q_2	E	δ
Condition A [5 points]	?	0.0	1.08	?
Condition B [5 points]	2.15	0.0	?	?
Condition C [5 points]	?	?	1.12	38°

Problem 3

a- Explain the effects of frequency on different types of losses in an electric transformer. [5 points]

A 25-kVA, 2200/220 V, 60-Hz, single-phase transformer has the following equivalent-circuit parameters referred to the high-voltage side.

$R_1 = 2.5\ \Omega$ $\quad R'_2 = 2.5\ \Omega$

$X_{l1} = 10\ \Omega$ $\quad X'_{l2} = 10\ \Omega$

$X_m = 25{,}000\ \Omega$ $\quad R_c = 40{,}000\ \Omega$

Use the equivalent Cantilever model circuit of the transformer shown in Figure (2).

b- A short circuit test is conducted on the transformer with 22 volts applied to the secondary side with the primary short circuited. Determine the readings of the ammeter and wattmeter connected to the secondary side for this test. [5 points]

c- An open circuit test is conducted on the transformer with 2,200 volts applied to the primary side with the secondary side left open. Determine the readings of the ammeter and wattmeter connected to the primary for this open circuit test. [5 points]

d- The transformer is supplying 15 kVA at 220-V and a lagging power factor of 0.85. Determine the primary voltage. [5 points]

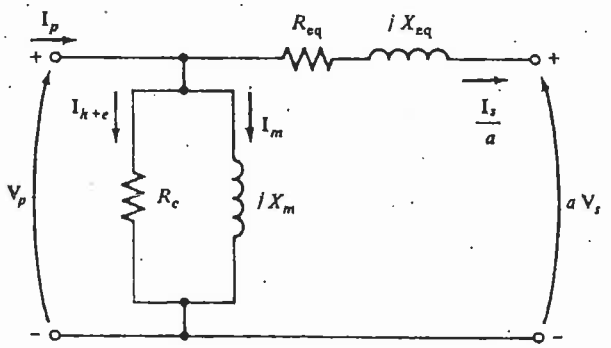


Figure (2) Equivalent Circuit of Transformer for Problem (3)

Problem 4

For the two bus system shown in Figure (3,) bus 1 is the reference (slack) bus with $|V_1| = 1.00$ and $\delta_1 = 0.0°$. At bus 2, the active load is 4.0 p.u. and the reactive load is -0.6 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 to maintain the voltage at bus 2 within the required limits. [10 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]

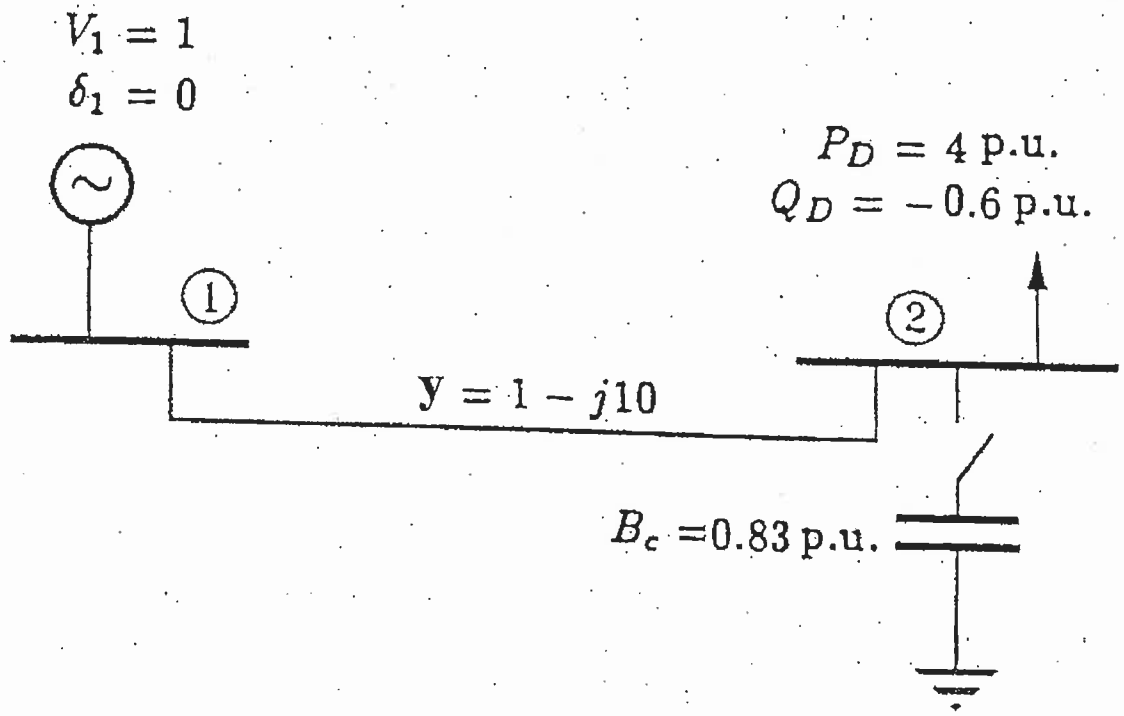


Figure (3) One-line Diagram for Problem (4)

Problem 5

a- Discuss the consequences of short circuit faults on an electric power systems [5 points]

b- Protective schemes are routinely used for electric power transformers. Name at least three different types of transformer protective schemes (by function) and explain briefly their principles of operation. [5 points]

Consider the system shown in the single-line diagram of Figure (4.) All reactances are shown in per unit to the same base. Assume that the voltage at both sources is 1 p.u.

c- Find the fault current due to a bolted- three-phase short circuit at bus 5. [5 points]

d- Find the voltages at buses 1 and 2 under the fault conditions of part (c) above [5 points]

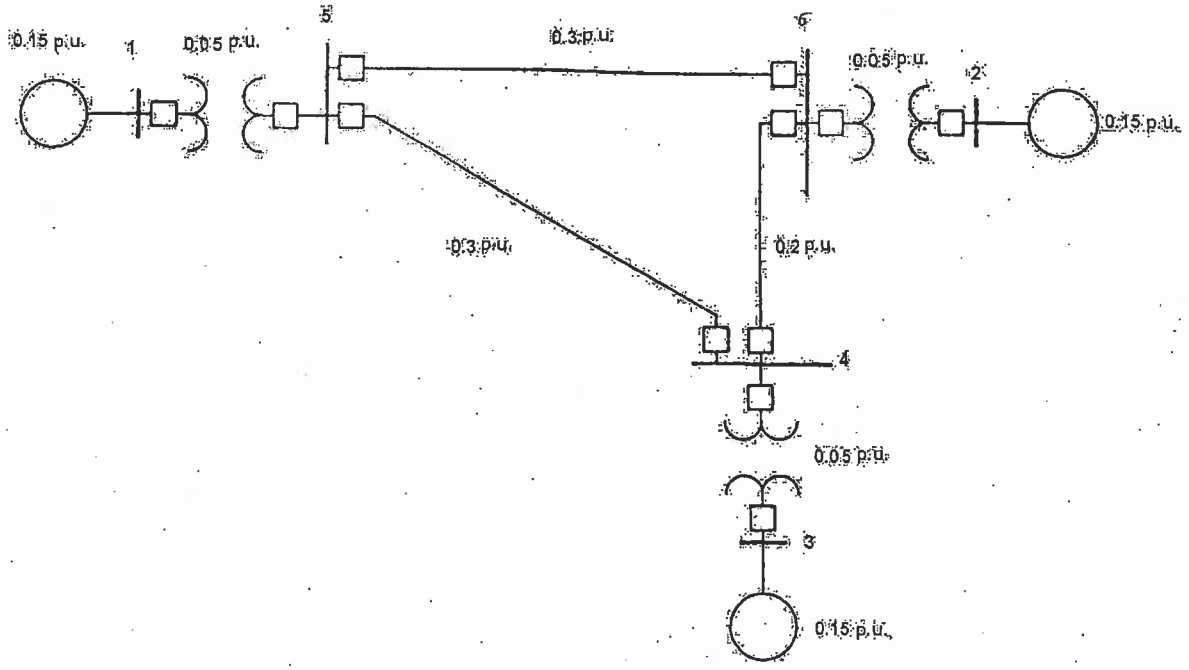


Figure (4) Single-line diagram for Problem (5)

Problem 6

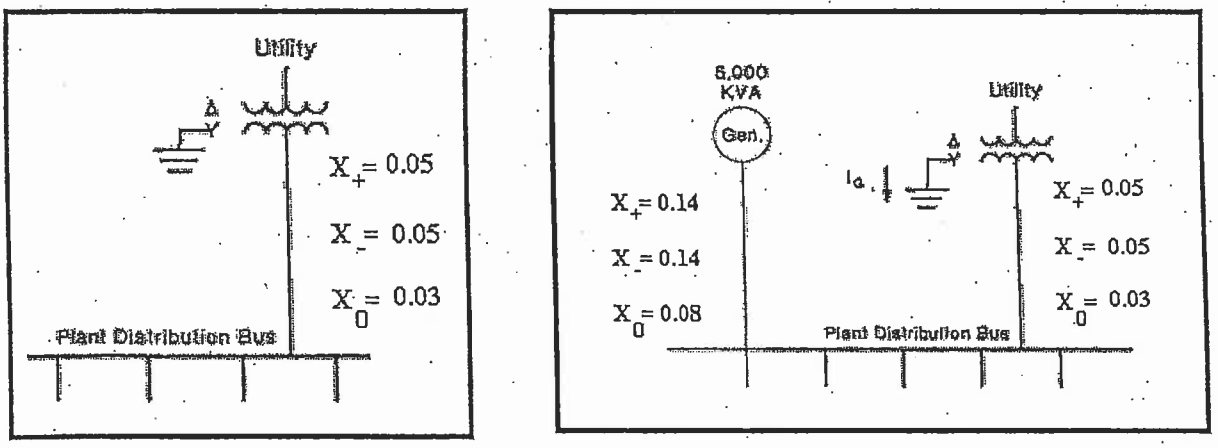
a- Explain the reasons for applying system grounding in electric power systems. [5 points]

Consider the industrial plant distribution bus which is supplied by a utility source with per-unit sequence reactances of $X_+ = X_- = 0.05$ and $X_0 = 0.03$ as shown in Figure (5-a). Assume that all reactances are given on a 5,000 kVA base, and that the plant's bus voltage is 4,160-V.

b- A double line to ground fault takes place on phases B and C of the bus. Determine the fault current through phase B of the bus. [4 points]

Assume now that an ungrounded 5,000 kVA generator with per-unit sequence reactances of $X_+ = X_- = 0.14$ and $X_0 = 0.08$ is added at the distribution bus as shown in Figure (5-b).

c- A double line to ground fault takes place on phases B and C of the bus. Determine the fault current through phase B of the bus. [8 points]



(a) (b)

Figure (5) Single-line diagrams for Problem (6)

Problem 7

Consider the circuit shown in Figure (6.) Assume that E = 1.44 p.u. and V = 1.00 p.u.

a Find the initial power angle δ when the active component of the load on the circuit is 3 p.u. [5 points]

b A three phase short circuit takes place in the middle of transmission line 3. Determine whether the system will remain stable or not when the fault is sustained. [10 points]

c Determine the maximum angle of oscillation under a sustained fault. [5 points]

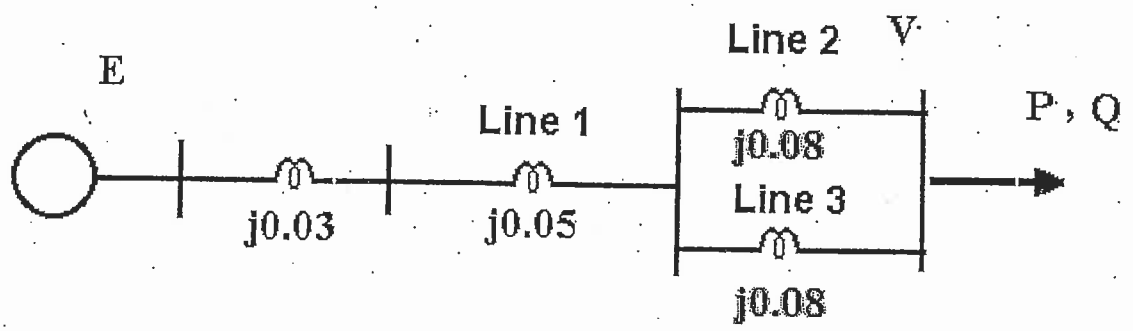


Figure (6) Circuit for Problem (7)