National Exams December 2016

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 "bundle conductor transmission line" and discuss the effects of its use on the electrical performance of a high voltage electric transmission line. [5 Points]

b- Consider an N sub-conductors bundle conductor line. Show that the ratio of the capacitive geometric mean radius (CGMR) to the geometric mean radius (GMR) is given by:

$$\frac{CGMR}{GMR} = e^{0.25/N}$$

[5 points]

c- Consider an experimental 2000 kV three phase bundle-conductor line with 16-sub-conductors to each phase. Assume that the line inductance in H per meter per phase (neglecting ground effects) is 0.744×10^{-6}. Determine the value of the capacitance in Farads per meter. Determine the value of the line characteristic impedance. [5 points]

d- Assume that the line length is 250 km and neglect the series resistance of the line. Calculate the parameters A and B of the line. [5 points]

Problem 2

Explain the meaning of the terms over-excited and under-excited with respect to synchronous machines, and explain how a synchronous machine can be operated to appear as a source of reactive power. [5 points]

A salient pole synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.00 pu. The reactances x_d and x_q are 0.95 and 0.4 respectively. The table given below relates to three operating conditions of the machine. (Q_2 is the reactive power at machine terminals) Complete Table (1,) neglecting armature reaction.

Table (1) Loading Conditions for Problem 2

	P	**Q_2**	**E**	δ
Condition A	?	0.0	1.07	?
Condition B	1.42	?	?	47°
Condition C	?	?	1.27	40.00°

[15 Points]

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.

$R_1 = 2.45\ \Omega$	$R'_2 = 2.45\ \Omega$
$X_{l1} = 9.85\ \Omega$	$X'_{l2} = 9.85\ \Omega$
$X_m = 24{,}800\ \Omega$	$R_c = 38{,}750\ \Omega$

Use the equivalent Cantilever model circuit of the transformer shown in Figure (1).

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]

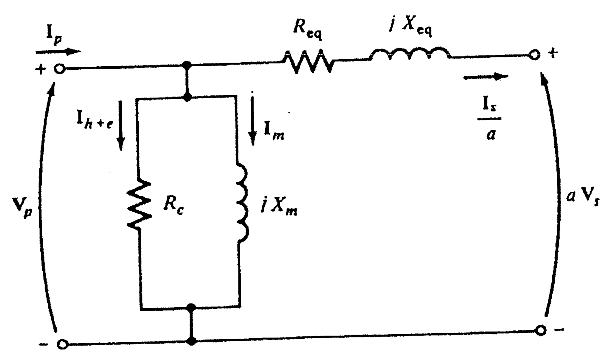

Figure (1) Equivalent Circuit of Transformer for Problem (3)

Problem 4

Consider the two-bus system shown in Figure (2,) where bus 1 is the reference (slack) bus with $|V_1| = 1.00$ and $\theta_1 = 0.0°$. The active power load at bus 2 in per unit is 1.0 and the reactive power load in per unit is j 0.125. Assume that the line impedance is $z_{12} = j0.125$ as shown in the figure.

a. Recall the general form of the power flow equations given below:

$$P_i(|V|,\theta) = |V_i|\sum |V_j||Y_{ij}|\cos(\theta_i - \theta_j - \psi_{ij})$$

$$Q_i(|V|,\theta) = |V_i|\sum |V_j||Y_{ij}|\sin(\theta_i - \theta_j - \psi_{ij})$$

Show that the active and reactive power injections (into the system) at bus 2 are given by:

$$P_2(|V|,\theta) = -1.0 = a|V_2|\sin\theta_2$$

$$Q_2(|V|,\theta) = -0.125 = a|V_2|\left[|V_2| - \cos\theta_2\right]$$ [4 Points]

b. Verify the result of part (a) from first principles, and find the value of the parameter a. [4 points]

c. Show that the value of $|V_2|$ for this situation satisfies the following equation:

$$b|V_2|^4 - c|V_2|^2 + d = 0$$

Determine the values of b, c, d, $|V_2|$, and θ_2. [4 Points]

d. Determine the values of $|V_2|$ and θ_2. [4 points]

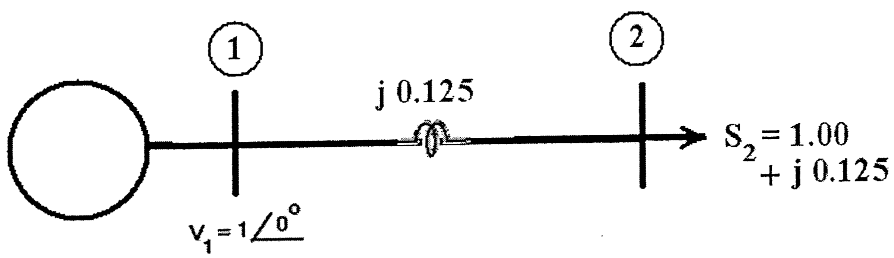

Figure (2) One-line Diagram for Problem 4

Problem 5

Consider the system shown in the single-line diagram of Figure (3). The required reactances in per unit to the same base are as follows:

G_1	$X_1 = 0.25$
G2	$X_1 = 0.2$
Transformers	$X_{T1}= 0.04$
	$X_{T2}= 0.05$
Lines	$X_{12}= 0.10$
	$X_{13}= 0.12$

Consider the case of a balanced three phase fault at bus 3. Determine the current through line 1-2 in per unit. [20 Points]

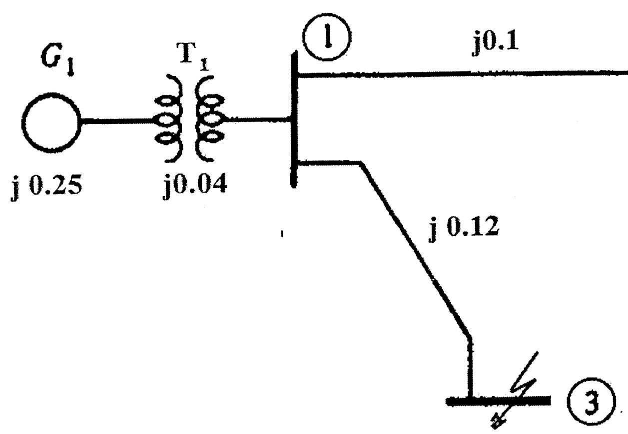

Figure (3) Single line diagram for Problem 5

Problem 6

a- Explain the reasons for applying system grounding in electric power systems. [4 points]

Consider the industrial plant distribution bus which is supplied by a utility source with per-unit sequence reactances of $X_+ = X_- = 0.06$ and $X_0 = 0.04$ as shown in Figure (4-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- Determine the fault current for a single line to ground fault on phase A of the bus.

Assume now that an ungrounded 5,000 kVA generator with per-unit sequence reactances of $X_+ = X_- = 0.15$ and $X_0 = 0.1$ is added at the distribution bus as shown in Figure (4-b). [4 points]

c-

d- Determine the fault current for a single line to ground fault on phase A of the bus. [4 points]

Assume now that the utility transformer is grounded through a 6 Ω grounding resistor as shown in Figure (4-c.)

e- Determine the value of the grounding resistor in per unit. [4 points]

f- Determine the fault current for a single line to ground fault on phase A of the bus. [4 points]

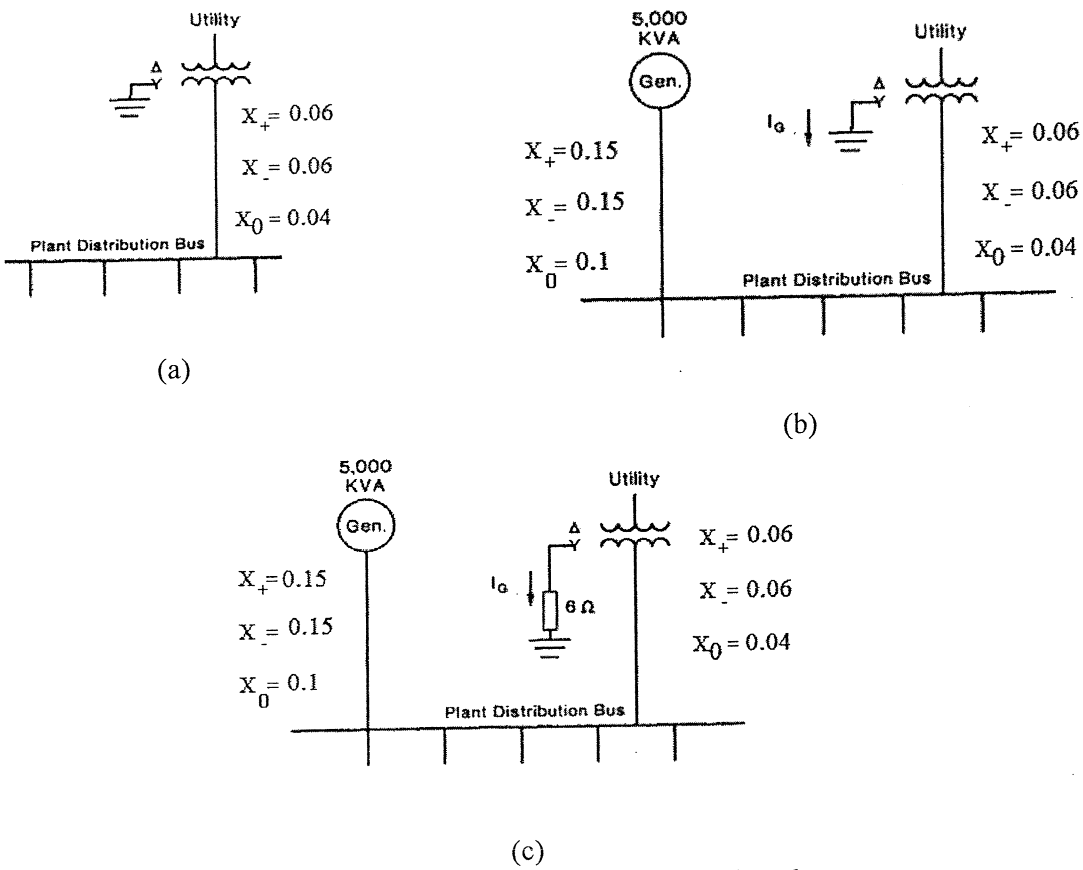

Figure (4) Single-line diagrams for Problem 6

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 0.15 pu. is connected to an infinite bus through a transformer whose reactance is 0.1 p. u. and a double circuit transmission line with circuits having a reactance of 0.6 p.u. each as indicated in the figure. The generator delivers a real power of 0.9 pu. to bus 1. The magnitude of the voltage at bus 1 is 1.05 pu. The infinite bus voltage is 1.0 pu with an angle zero.

a- Determine the excitation voltage of the generator under these conditions. [10 points]

b- A three phase fault occurs at the middle of one transmission circuit as shown. Assume that the generator excitation voltage remains constant at E'= 1.14 pu. Let the parameter (a) be 0.25 (i.e. the fault is close to bus 1). Will the system remain stable under sustained fault conditions? [10 points]

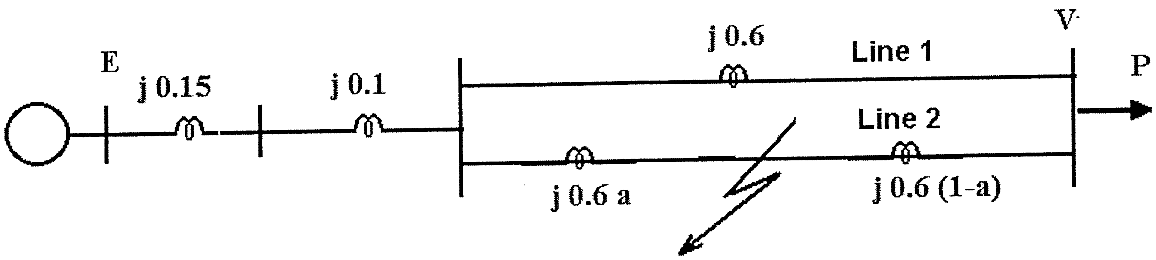

Figure (5) Circuit for Problem 7