National Exams May 2011

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 capacitance in Farads per meter per phase (neglecting ground effects) is 15×10^{-12}. Determine the value of the line inductance in H 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

a- 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]

b- 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 0.9 and 0.45 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	1.12	?
Condition B	1.55	?	?	45^o
Condition C	?	?	1.12	18^o

[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.

$R_1 = 2.7\ \Omega$ $R'_2 = 2.7\ \Omega$

$X_{l1} = 10.5\ \Omega$ $X'_{l2} = 10.5\ \Omega$

$X_m = 20{,}000\ \Omega$ $R_c = 37{,}500\ \Omega$

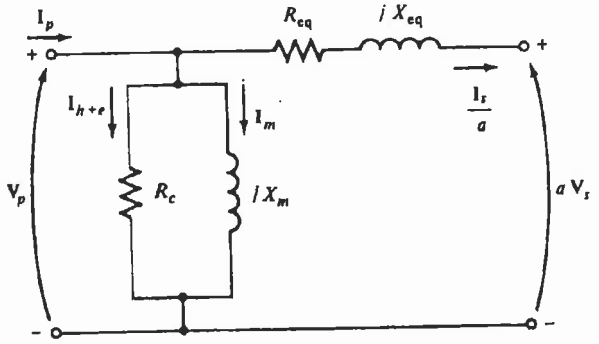

Figure (1) Equivalent Circuit of Transformer for Problem (3)

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]

Problem 4

a- The reactive power load (inductive) at a bus is increased by an increment ΔQ, explain how to determine the corresponding change in voltage $|\Delta V|$. [5 Points]

For the two bus system shown in Figure (2,) bus 1 is the reference (slack) bus with $|V_1| = 1.00$ and $\delta_1 = 0.0^o$. The load at bus 2 is 120 MW and 60 Mvar and the line impedance is $z_{12} = 0.12 + j0.16$ as shown in the figure. (Base MVA = 100)

b- Show that the expressions for active and reactive power at bus 2 are given by:

$$P_2 = -1.2 = 5\left[|V_2|\cos(126.87^O - \delta_2) + 0.6|V_2|^2\right]$$

$$Q_2 = -0.6 = 5\left[-|V_2|\sin(126.87^O - \delta_2) + 0.8|V_2|^2\right]$$

[5 points]

c- It is required to raise the magnitude of the voltage $|V_2|$ to 0.95 pu using a capacitor. Find the corresponding angle δ_2 and the MVAR rating of the required capacitor.

[5 Points]

d- Find the active and reactive powers at bus 1 and the active and reactive power loss in the line

[5 Points]

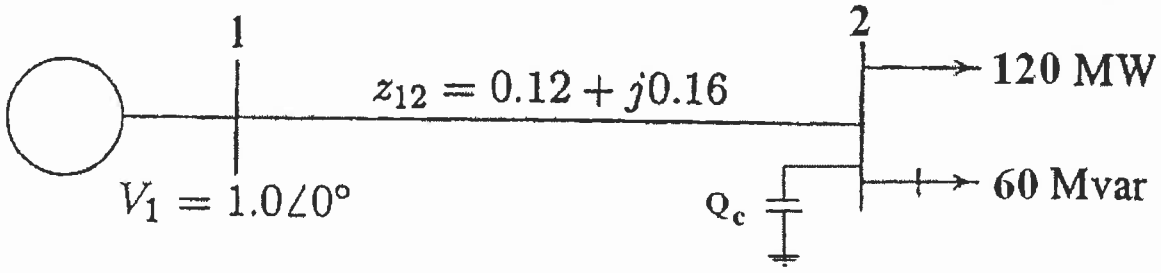

Figure (2) One-line Diagram for Problem 4

Problem 5

a- Explain how distance protection is applied 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 ohms referred to the high voltage side of the transformers. Assume that the voltages at buses 1 and 3 are in phase having equal magnitudes of 34.5 kV line-to-line. Find the current through the relays at B12 and B32 for balanced three phase faults at point y in the middle of line section 2-3. [5 Points]

c- Construct the positive sequence, negative sequence and zero sequence networks for a fault at point y. [5 points]

d- A line to line fault on phase a takes place at point y. Find the fault current through phase a [5 points]

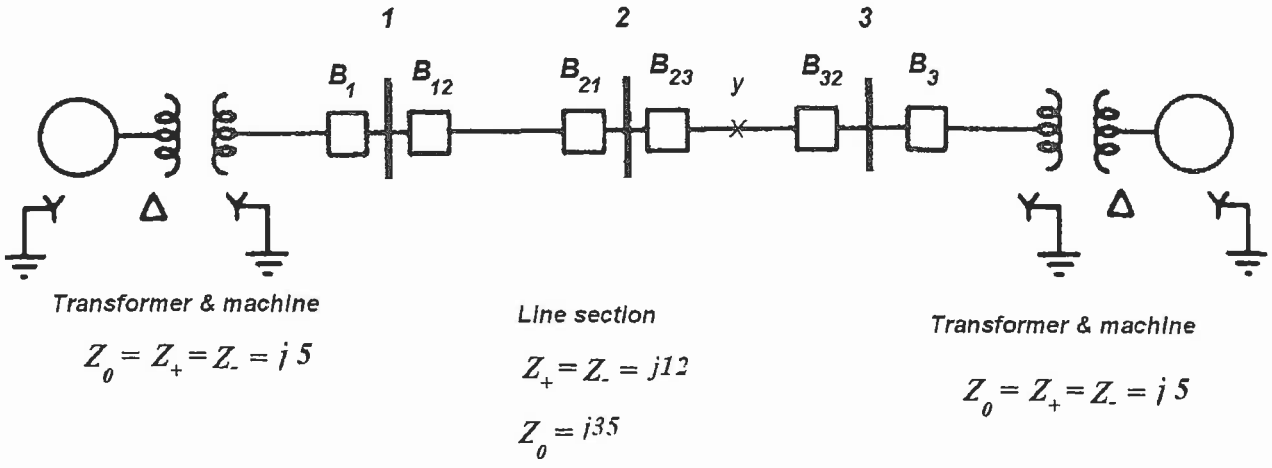

Figure (3) Single-line diagram for Problem 5

Problem 6

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 (4). 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 fault current and voltage at bus 1 due to a bolted- three-phase short circuit on line 1-3 at F1 as indicated in Figure (4). [15 points]

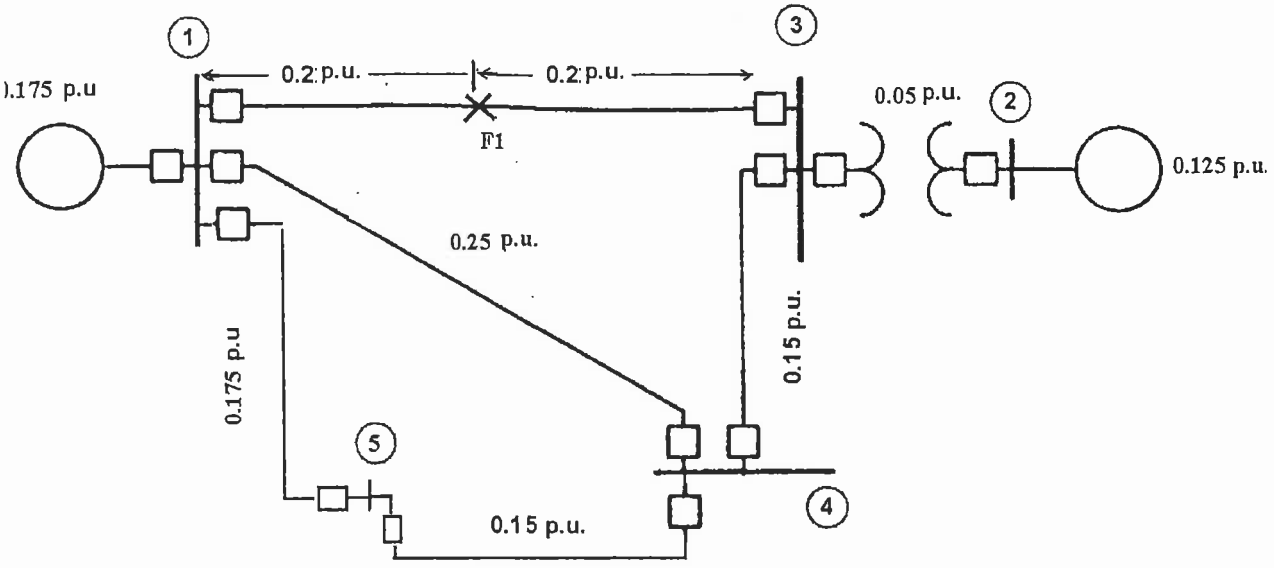

Figure (4) Single-line diagram for fault 1 in Problem 6

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 0.30 p.u. is connected to an infinite bus through a transformer whose reactance is 0.10 p.u. and two parallel transmission lines. The reactance of line 1-2 is 0.3 p.u., while that of section 1-3 is 0.10 p.u., and that of section 3-2 is 0.10 p.u. as indicated in the figure. The generator delivers an apparent power of 1.3 p.u. at 0.85 pf lagging to the infinite bus. The magnitude of the voltage at bus 2 is 1.0 p.u.

a- Determine the excitation voltage of the generator under these conditions. [7 points]

b- Determine the equation of the electrical power delivered by the generator versus its power angle. [3 points]

c- Suppose that the synchronous generator is initially operating in the steady state condition given earlier. A three phase-to-ground bolted short circuit occurs at bus 3, close to breaker B13. Due to relay malfunctioning, all circuit breakers remain closed. Calculate the critical clearing angle. [10 points]

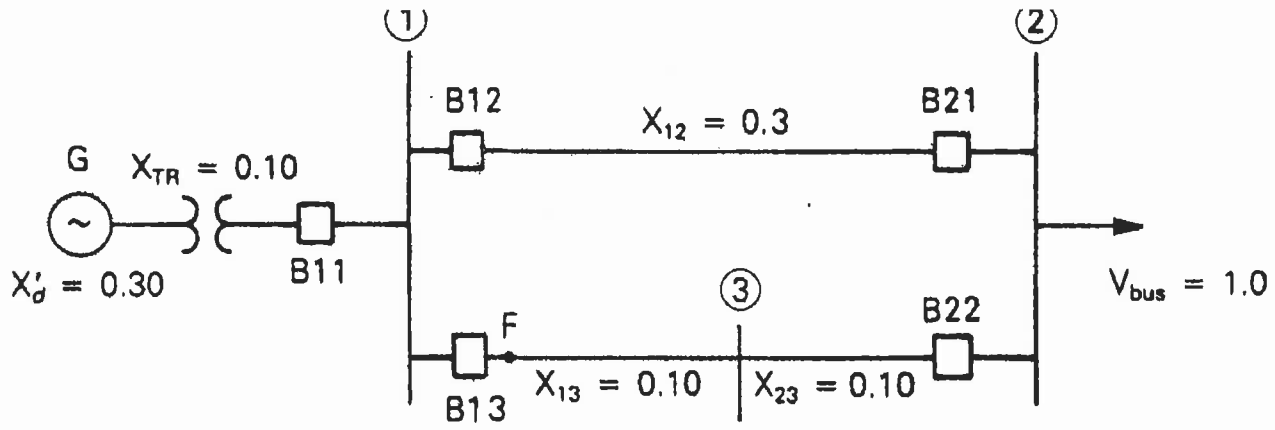

Figure 4 Circuit for Problem 7