National Exams May 2014

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 "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, four-conductor 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:

$$B = 125.9\angle 87.5^o$$

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 $V_s = 760.5\angle 19.66^o$ kV. Find the line parameters A, and C. [5 Points]

c- Find the sending end voltage, current, and power factor for an apparent power load at the receiving end of the line of 1400 MVA, at 0.85 power factor lagging while the receiving end voltage is 700 kV. [10 Points]

Problem 2

a- Explain the differences between salient-pole and cylindrical rotor synchronous machines in terms of reactance and maximum power transfer values. [5 points]

b- A three phase salient pole synchronous generator is connected to an infinite bus bar. The quadrature axis and direct axis reactance are X_d = 12 Ω and X_q=9Ω. The line-to-line voltage of the infinite bus is 34.5 kV, and the line-to-neutral excitation voltage E is 30 kV. Determine the value of power angle δ corresponding to maximum active power delivered to the bus. Compute the value of maximum active power [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.

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

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

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

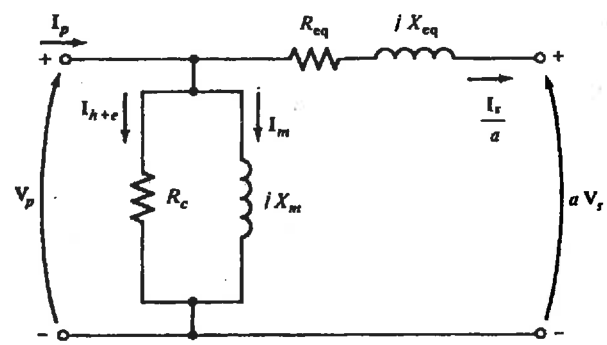


Figure (1) Equivalent Circuit of Transformer for Problem (3)

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

b- A short circuit test is conducted on the transformer with 20 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 2,250 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 0.8. Determine the primary voltage. [5 points]

Problem 4

a- List the types of buses in a conventional power flow problem formulation. For each type, identify the known and unknown variables.
[5 Points]

In the simple electric power system shown in Figure (2), it is required to find the following:

b- The voltage magnitude and the reactive power injection at bus 2 assuming that the voltage angle is -5°.
[5 Points]

c- The active and reactive power generated at bus 1. [5 Points]

d- The active and reactive power generated at bus 3. [5 Points]

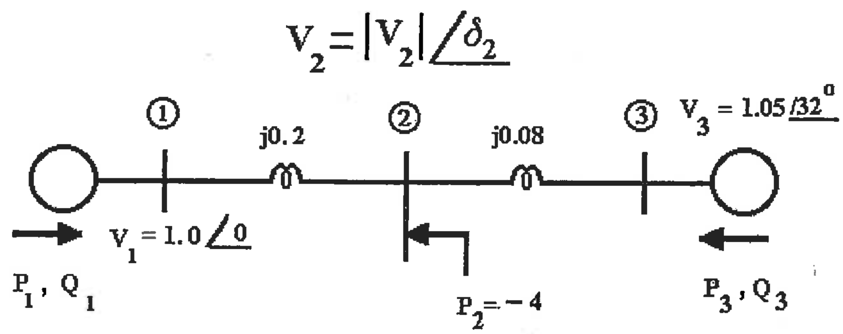


Figure (2) Circuit for Problem 4

Problem 5

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 3. 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 voltage at bus 1 due to a bolted- three-phase short circuit on line 1-3 at F1 as indicated in Figure (3-a). [7.5 points]

c- Assume that line 1-3 is opened as a result of the fault condition F1. Subsequently a bolted- three-phase short circuit takes place on line 1-4 at F2 as indicated in Figure (3-b). Find the voltage at bus 1 under fault conditions. [7.5 points]

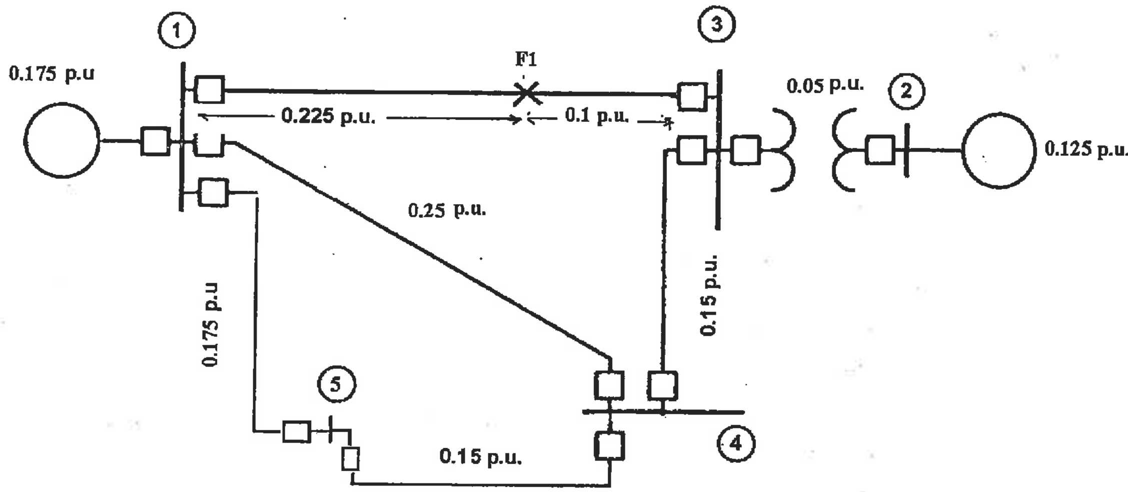


Figure 3-a Single-line diagram for fault 1 in Problem 5

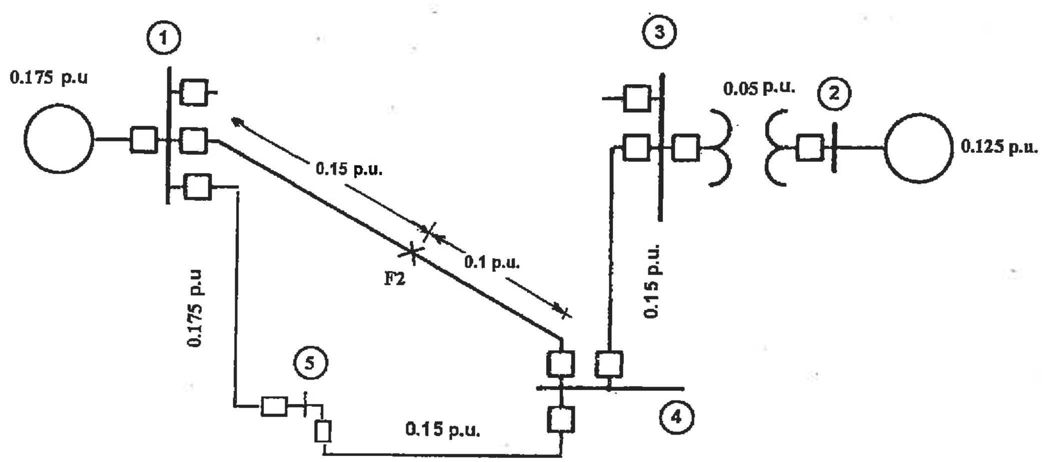


Figure 3-b Single-line diagram for fault 2 in Problem 5

PROBLEM 6

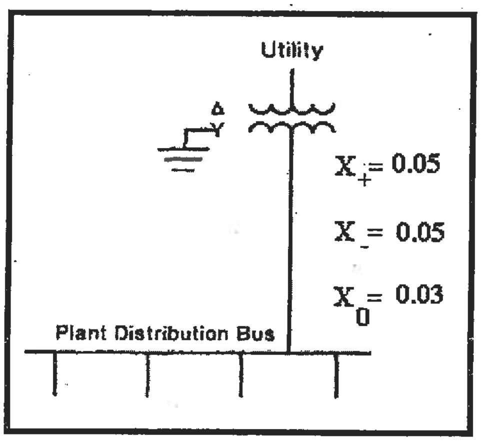
a- Explain the reasons for applying system grounding in electric power systems. [5 points]

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 (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.

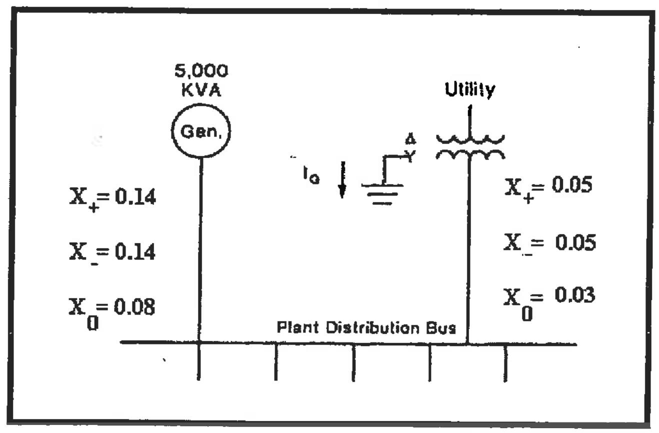
b- A single line to ground fault takes place on phases B and C of the bus. Determine the fault current through phase B of the bus. [4 points]

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 (4-b).

c- A single 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 (4) Single-line diagrams for Problem (6)

Problem 7

Consider the circuit shown in Figure (5.) Assume that E = 1.42 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 2.24.1 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]

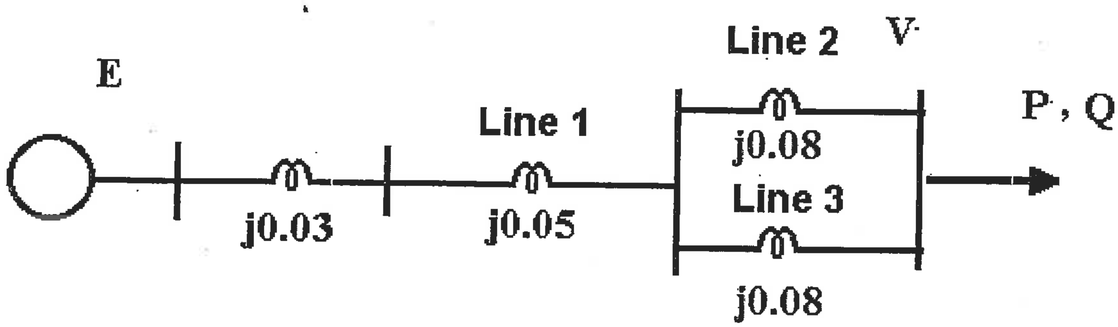


Figure (5) Circuit for Problem (7)