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National Exams May 2002

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- List some advantages and disadvantages of using series capacitors in electric power systems.[5 points]

b- Consider a 500-kV, 60 Hz three-phase transmission line modeled using the ABCD parameters as follows:

$$V_s = AV_r + BI_r$$
$$I_s = CV_r + AI_r$$
$$A^2 - BC = 1$$

Results of tests conducted at the receiving end the line involving open circuit ($I_r = 0$) and short circuit ($V_r = 0$) are given by:

$$Z_{oc} = \left.\frac{V_s}{I_s}\right|_{I_r=0} = 820\angle\underline{-88.8^o}$$

$$Z_{sc} = \left.\frac{V_s}{I_s}\right|_{V_r=0} = 200\angle\underline{78^o}$$

Find the line parameters A, B, and C. [10 Points]

c- Suppose that the load at the receiving end of the line of part b is 750 MVA at nominal voltage, and lagging power factor of 0.83 at rated voltage. Determine the sending end voltage, current, active and reactive power and power factor. [5 points]

Problem 2

a- Explain the differences in features and uses between round rotor and salient pole synchronous machines. [5 points]

A 25-MVA 13.8-kV 0.85-PF-lagging Y-connected round-rotor synchronous generator has a negligible armature resistance and a synchronous reactance of $5\,\Omega$. The generator is connected to a 13.8-kV infinite bus.

b- Find the armature current, the torque angle and the internal generated voltage under rated conditions. [5 points]

c- Assume that the internal generated voltage is decreased by 10 percent, while the active power output is maintained at rated value; find the corresponding torque angle, armature current, and power factor. [10 points]

Problem 3

a- List the different types of losses in a transformer and explain possible ways of reducing them. [5 points]

A 5000-kVA 115/13.8-kV single-phase power transformer has a per unit resistance of 1 percent and a per unit reactance of 5 percent. The following data pertain to an open-circuit test performed on the low-voltage side of the transformer:

V_{OC} = 13.8 kV I_{OC} = 15.3 A P_{OC} = 43.5 kW

b- Find the elements of the equivalent circuit of the transformer in ohms referred to the low-voltage side. Use the equivalent circuit shown in Figure 1. [5 points]

c- If the voltage on the secondary side is 13.8 kV and the power supplied is 4000 kW at 0.85 PF lagging, find the primary voltage, current, power factor, and efficiency of the transformer under these conditions. [10 points]

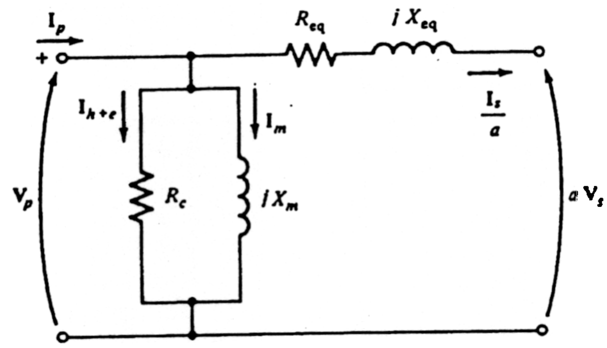

Figure 1 Equivalent Circuit of Transformer for Problem 3

Problem 4

a- List the reasons for using regulating transformers on electric power transmission lines. [5 points]

Consider the system shown in the single-line diagram of Figure 2. It is required to:

b- Find the voltage V_2 exactly. [10 points]

c- Find the value of $S_1 = S_{G1} - S_{D1} = S_{12}$. [5 points]

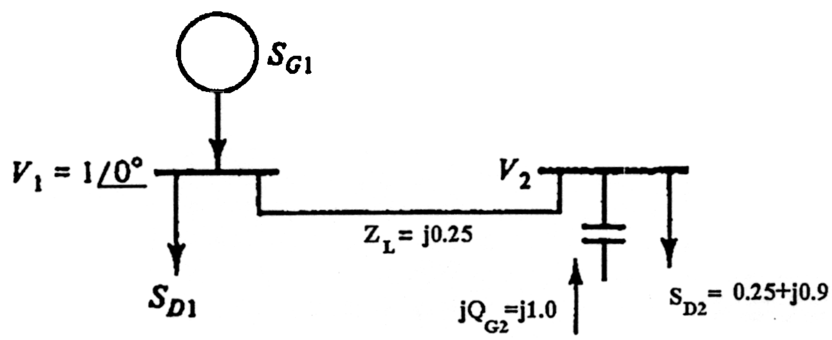

Figure 2 Single-line diagram for Problem 4

Problem 5

a- Discuss the main causes for short circuit faults on Canadian electric power systems. [5 points]

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

c- Find the fault current due to a bolted- three-phase short circuit at bus 5. [10 points]

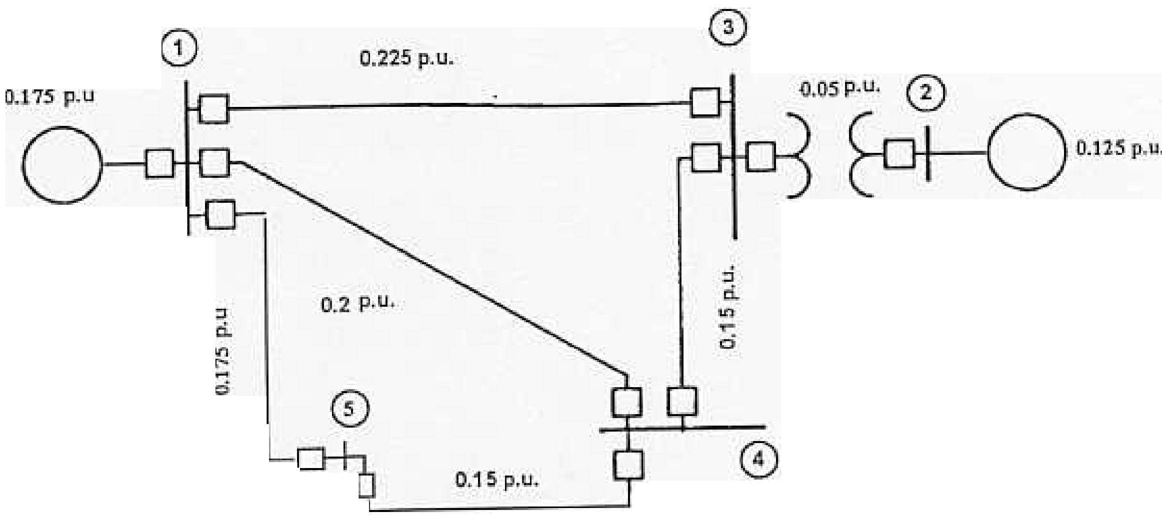

Figure 3 Single-line diagram for Problem 5

Problem 6

Consider the system shown in the single-line diagram of Figure 4. The required sequence reactances in per unit to the same base are as follows:

G_1	$X_1 = X_2 = 0.20$	$X_o = 0.05$
G2	$X_1 = X_2 = 0.25$	$X_o = 0.075$
Transformers	$X_{T1} = 0.04$	
	$X_{T2} = 0.06$	
Lines: Positive and Negative Sequence	$X_{12} = 0.10$	
	$X_{13} = X_{23} = 0.15$	
Lines: Zero Sequence	$X_{12} = 0.25$	
	$X_{13} = X_{23} = 0.30$	

a- Draw the zero-, positive-, and negative- sequence reactance diagrams. [7.5 points]

b- Determine the Thevenin's equivalent of each sequence network as viewed from the fault bus 3. [7.5 points]

c- Determine the fault current in per unit for a double line to ground fault at bus 3. [5 points]

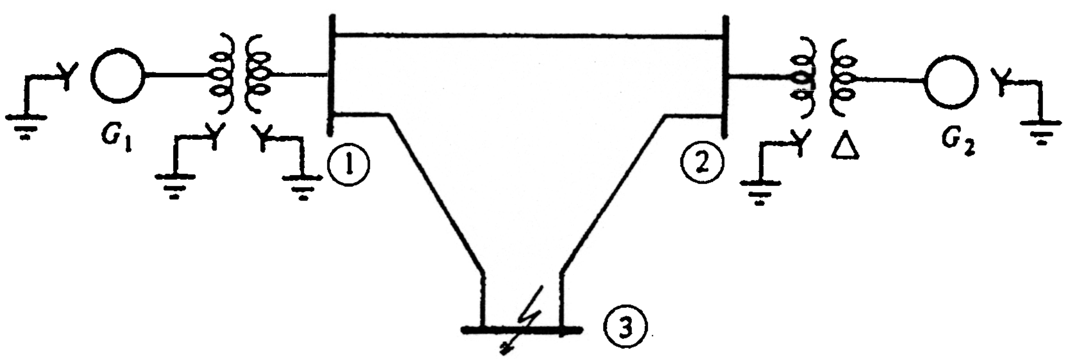

Figure 4 Single line diagram for Problem 6

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 0.30 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 0.2 p.u., while that of section 1-3 is 0.10 p.u., and that of section 3-2 is 0.20 p.u. as indicated in the figure. The generator delivers a real power of 1.5 p.u. at 0.9 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 the middle of transmission line 1-2. Due to relay malfunctioning, all circuit breakers remain closed. Calculate the critical clearing angle. [10 points]

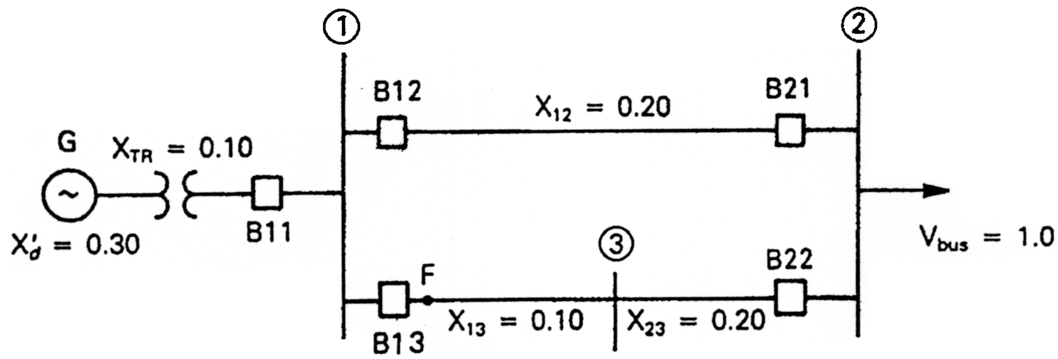

Figure 5 Circuit for Problem 7