National Exams May 2006

98-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 "transposition of a line," and describe how it is done. [5 Points]

b- A salient-pole synchronous machine with negligible armature resistance has the following parameters all expressed in the per unit system:

$$X_d = 1.1 \qquad X_q = 0.9$$

The machine is connected to a transmission line represented by:

$$A = 0.98\angle 0.2^o \qquad B = 0.2\angle 85^o$$

The load at the end of the line draws a current of 1 pu at a voltage of 1 pu. The load power factor is unity. Calculate the apparent power output of the machine. [10 Points]

c- Calculate the required excitation voltage and torque angle. [5 Points]

Problem 2

a- Explain the physical meaning of the term reactive power under pure sinusoidal operating conditions. How does a capacitor differ from an inductor in terms of reactive power in an electric system? [5 points]

A 200 km, completely transposed 60 Hz, three phase transmission line has flat horizontal phase spacing with 10 m between adjacent phases. Each phase consists of a three-bundle conductor, with outside radius of 0.014 m, a GMR, Ds= 0.0115 m, and a bundle spacing of 0.4 m.

b- Calculate the positive-sequence inductive reactance and shunt capacitive susceptance of the line. [5 Points]

c- Assume that the line has an X/R ratio of 5 and negligible shunt conductance. Find the exact A and B parameters of the line. [5 Points]

d- If the sending end voltage of the line is 345 kV (line to line), find the value of the receiving end voltage at no load at the receiving end. [5 Points]

Problem 3

a- A 500 KVA, 2300/230 V single phase transformer delivers full rated KVA at 0.8 p.f. lagging to a load at rated secondary voltage. The primary voltage magnitude is 2400 V under these conditions and the efficiency is 0.97. Find the equivalent circuit parameters of this transformer neglecting the no load circuit. [10 Points]

b- Consider a 2300/230 V single phase transformer whose equivalent series impedance referred to the high voltage side is Z=0.262 + j 0.415 Assume that the load on the secondary of the transformer is 400 kVA at 0.85 p.f. lagging with the receiving end voltage maintained at 230 V. Find the active power input at the primary side. [10 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 (1), 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]

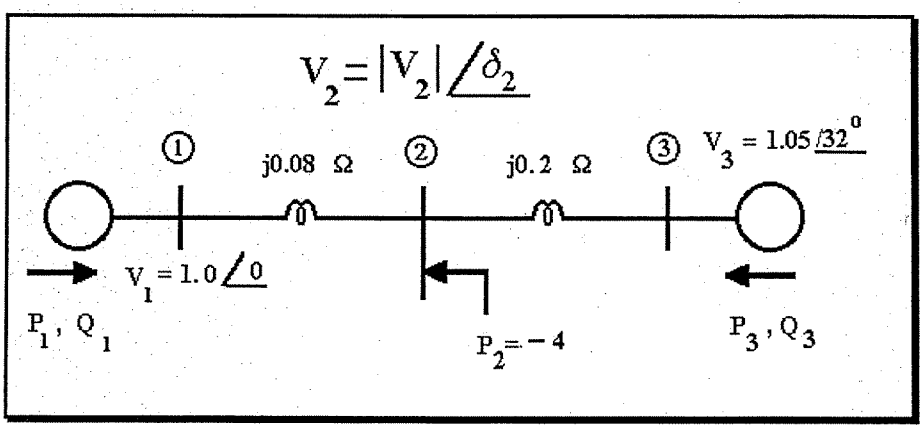

Figure (1) Circuit for Problem 4

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 (2.) 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 points x and y in the middle of line sections 1-2 and 2-3 respectively. [5 Points]

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

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

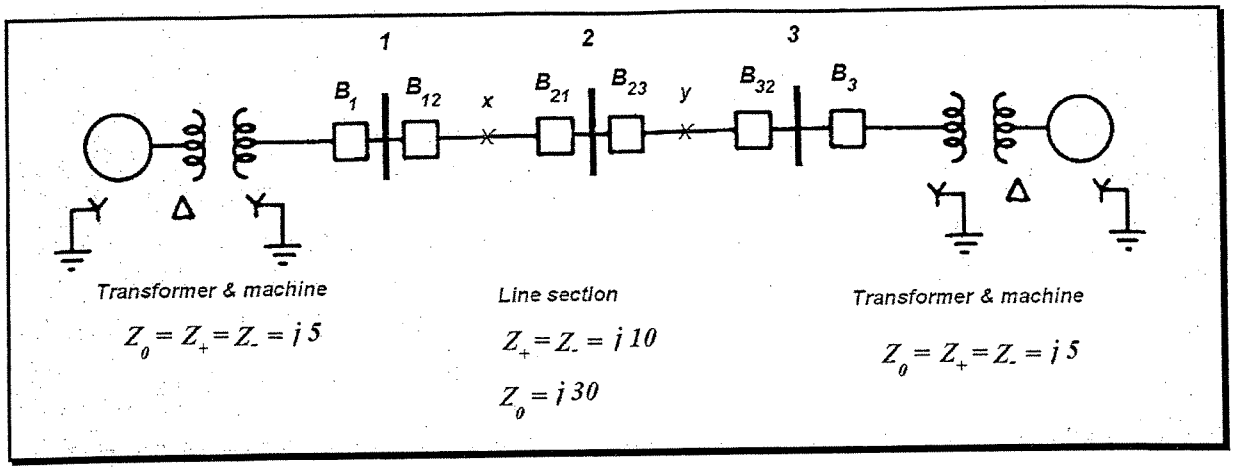

Figure (2) Single-line diagram for Problem 5

Problem 6

Consider the system shown in the single-line diagram of Figure (3.) 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 2-3 is 0.20 p.u. as indicated in the figure. The generator delivers an apparent power of 2 p.u. at 0.8 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. [5 points]

b- Determine the equation of the electrical power delivered by the generator versus its power angle. [5 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 point F on transmission line 1-3, close to breaker B13. Due to relay malfunctioning, all circuit breakers remain closed. Calculate the critical clearing angle. [10 points]

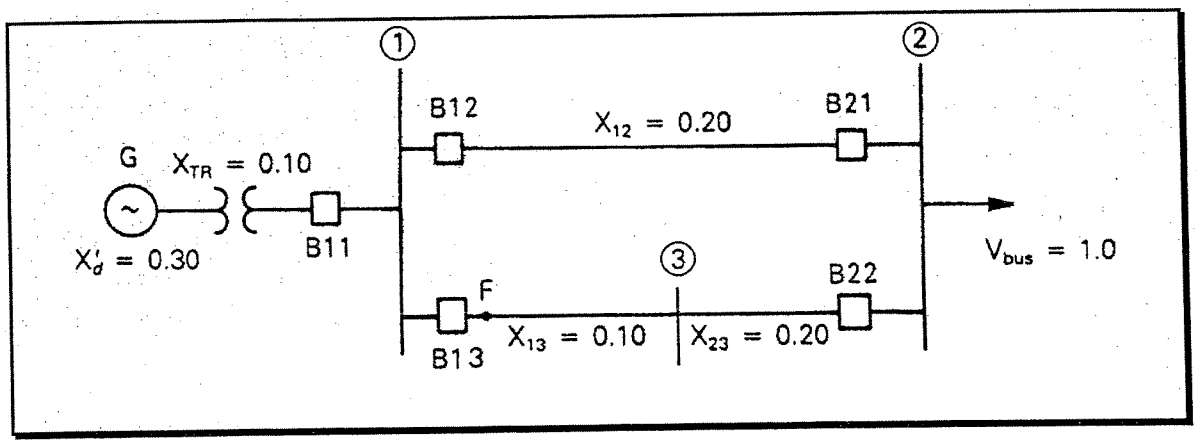

Figure (3) System for Problem 6