National Exams May 2017

16-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

Consider the 1100-kV, bundle-conductor line shown in Figure (1.). Assume phase spacing D_1 = 16 m, bundle separation S = 50.00 cm, and conductor diameter is 3. 6 cm.

a- Calculate the inductance in henries per m per phase [5 points]
b- Calculate the capacitance in farads per meter per phase neglecting earth effects [5 points]
c- Calculate the capacitance in farads per m per phase including earth effects with h_1 = 21.00 m. [5 points]
d- Determine the A, B, C, and D parameters of the line assuming a long line model. [10 points]

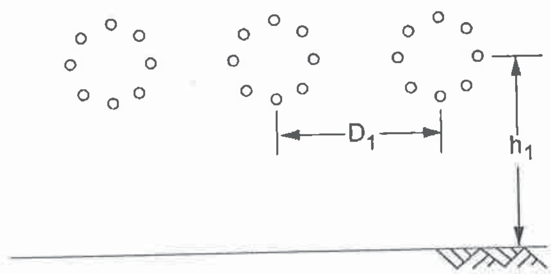

Figure (1) Line configuration for Problem (1)

Problem 2

a- Explain using your own word the meaning of armature reaction in a synchronous machine. [5 points]

b- Explain the conditions under which a synchronous machine appears as a source of reactive power to the electric network. [5 points]

c- A round rotor synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.00 pu. The synchronous reactance of the machine is 0.3 pu. The table given below relates to three operating conditions of the machine. (Q_2 is the reactive power at machine terminals) Complete the table neglecting armature reaction. [15 points]

	P	Q_2	E	δ
Condition A	?	0.0	1.12	?
Condition B	2.7	0.0	?	?
Condition C	?	?	1.1	37.5°

Problem 3

Consider a three-winding transformer, as shown in Figure (2,) with the following particulars:

Z_p= 0.025+j 0.08
V_1=410

Z_s= 0.025+j 0.07
$I_2=55\angle -30^\circ$

Z_t= 0.025+j 0.08
$I_3=45\angle -40^\circ$

Assume that V_1 is the reference, calculate:

(a) The primary current I_1. [5 points]
(b) The intermediate voltage V_0 [5 points]
(c) The secondary voltage V_2 and tertiary voltage V_3 referred to the primary side. [5 points]
(d) The apparent powers and power factors at the primary, secondary and tertiary terminals. [5 points]
(e) The transformer efficiency. [5 points]

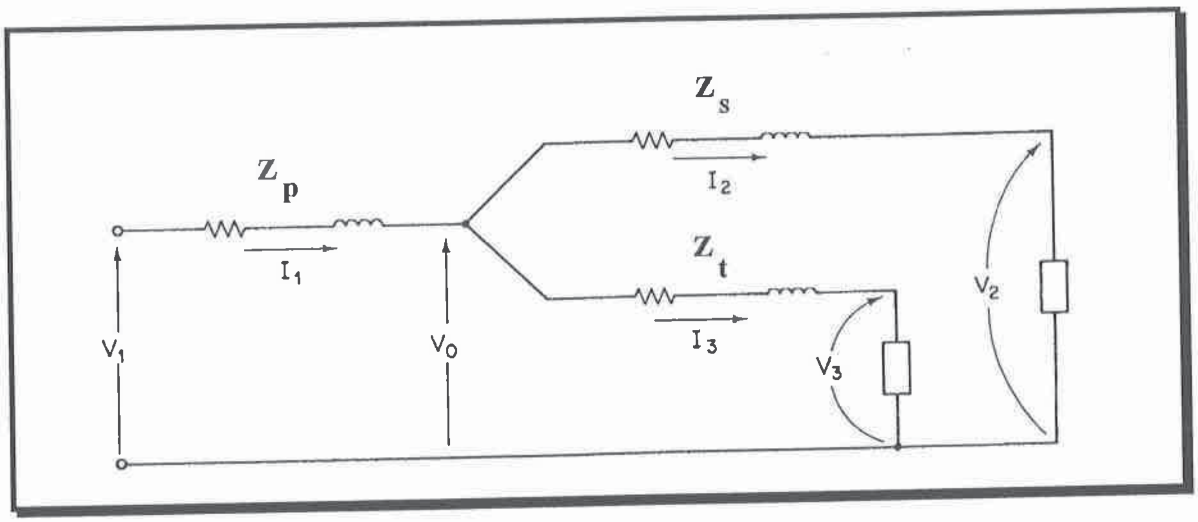

Figure (2) Three Winding Transformer Equivalent Circuit for Problem (3)

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 (3), 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 -12°. [5 points]

c- The active and reactive power generated at bus 1 [7.5 points]

d- The active and reactive power generated at bus 3 [7.5 points]

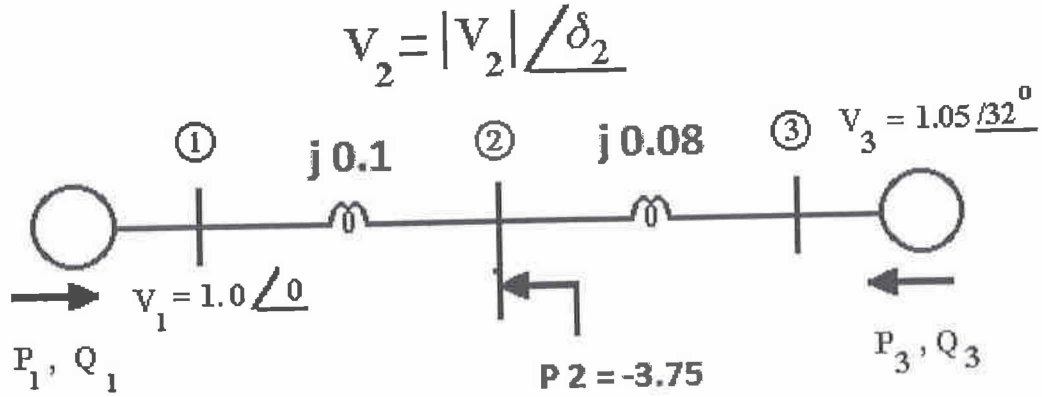

Figure (3) Circuit for Problem 4

PROBLEM 5

a Discuss the consequences of short circuit faults on electric power systems [5 Points]

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

c Find the fault current due to a bolted- three-phase short circuit in the middle of line B. [5 Points]

d Find the voltages at buses 4 and 5 under the fault conditions of part c above [10 Points]

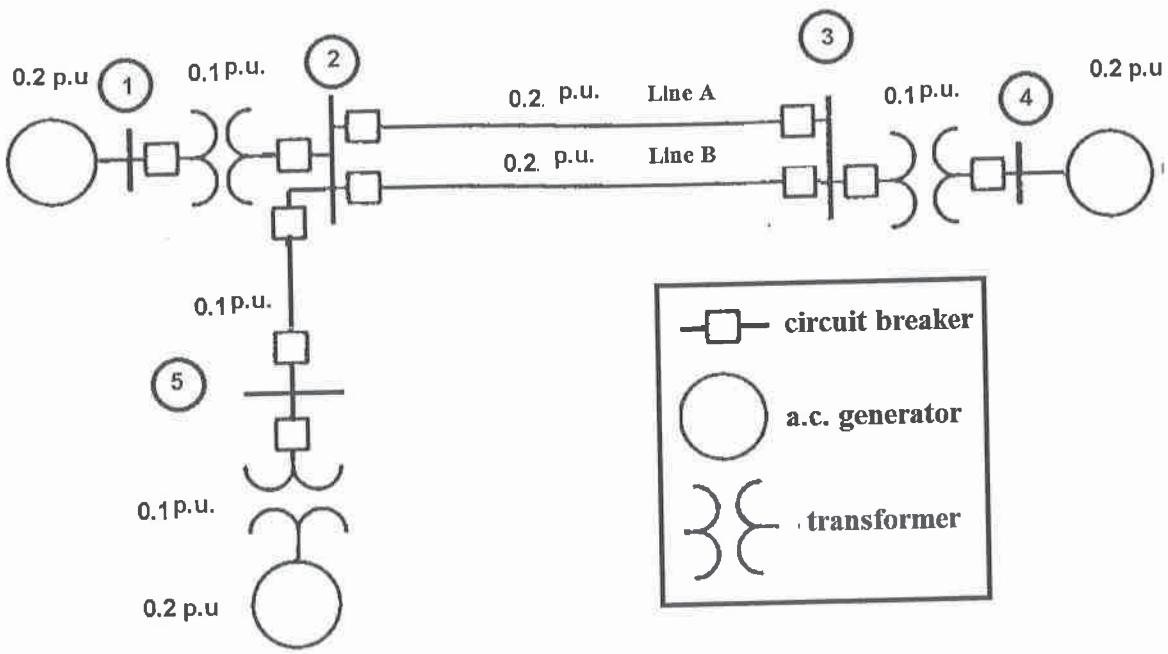

Figure (4) Single-line diagram for Problem (5)

PROBLEM 6

The positive, negative and zero sequence network representations of a simple electric power system are shown in Figure (5.) A single line to ground fault takes in the middle of the line between buses G and H. It is required to determine:

1- The current to the fault.[10 points]
2- The value of each phase voltage at buses G and H [15 points]

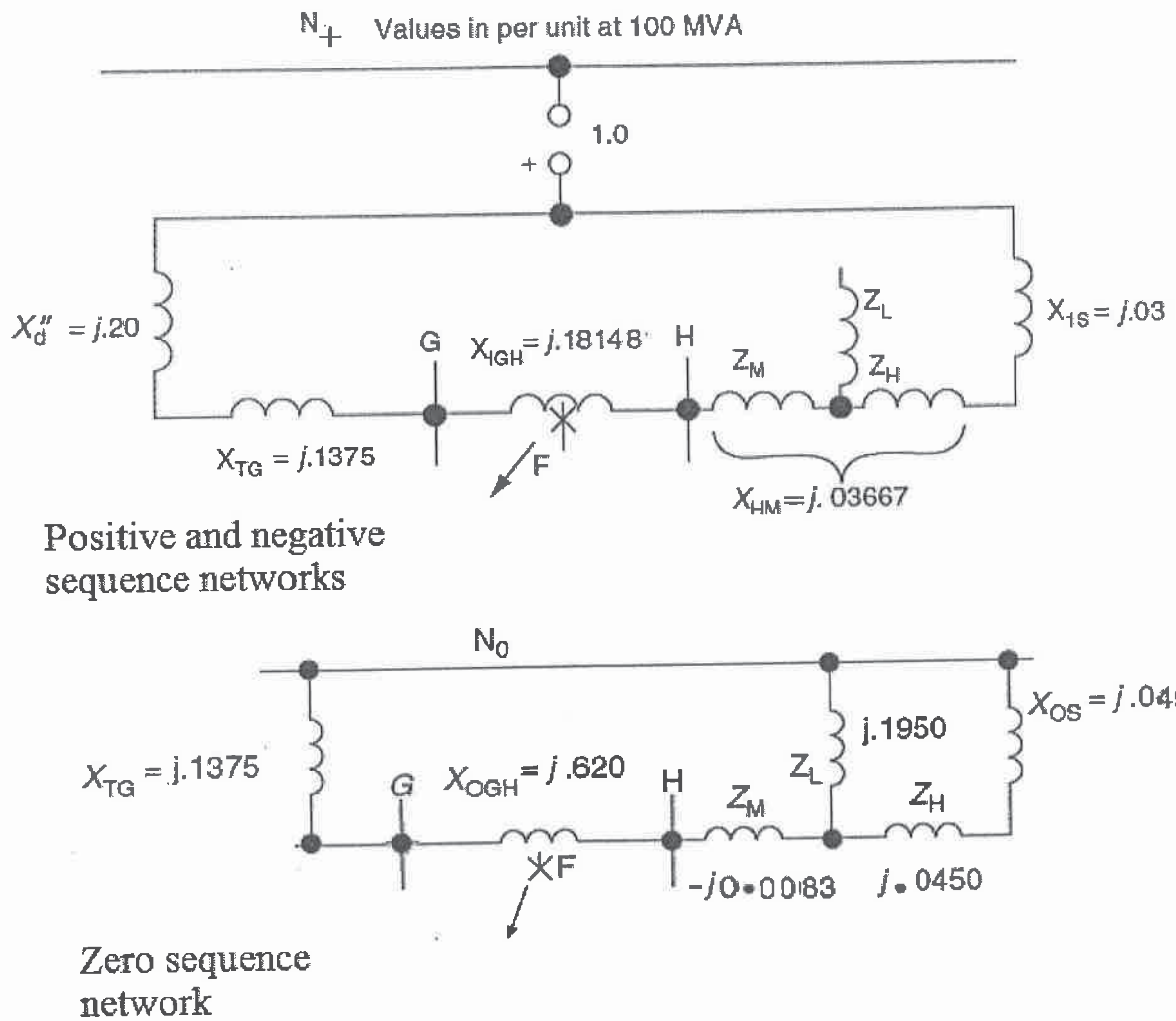

Figure (5) Sequence Network Representation for Problem (6)

Problem 7

Consider the circuit shown in Figure (6) Assume that E = 1.25 p.u., and V = 1.00 p.u. The active component of the load on the circuit is 3 p.u., when a three phase short circuit takes place in the middle of transmission line 3.

a) It is known that the system will remain stable when this fault is sustained. Determine the maximum angle of oscillations $\delta_{\max}$.[5 points]

b) Assume now that the active component of the load on the circuit is 3.2 p.u., when the fault takes place. Verify that the system will be unstable under sustained fault conditions.[5 points]

c) Assume that for the conditions of part (b,) the fault is cleared at $\delta_c = 85^o$ by opening the circuit breakers at both ends of line 3. Carry out the necessary calculations to show that the system will remain stable under these conditions. [5 points]

d) Determine the maximum angle of oscillations $\delta_{\max}$ under the assumptions of part (c.) [10 points]

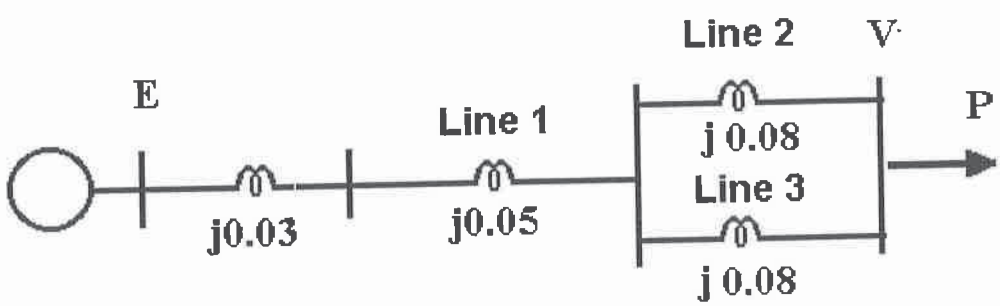

Figure (6) Circuit for Problem (7)