

**07-Elec-B7, Power Systems Engineering**

**National Exams December 2013  
07-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 Explain the meaning of the term "transposed line" and why is it needed. [5 Points]

A 500-km, 765-kV, 60 Hz three phase transmission line has a series impedance  $z=0.015 + j 0.3 \Omega/\text{km}$  and a shunt admittance  $y = j 5 \times 10^{-6} \text{ S/km}$ . The full load at the receiving end is 2300 MVA at a lagging power factor of 0.85 and at 97.5 % of rated voltage. Determine:

b The ABCD parameters of the line using the exact long line hyperbolic expressions. [7.5 Points]

c The sending end voltage, current, power factor and transmission efficiency. [7.5 Points]

**Problem 2**

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]

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 0.95 and 0.4 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	$\delta$
<b>Condition A</b>	?	0.0	1.08	?
<b>Condition B</b>	1.45	?	?	45°
<b>Condition C</b>	?	?	1.3	37.5°

[15 Points]

**Problem 3**

a- List five different transformer types used in the electric power system. [5 points]

Consider a three-winding transformer, as shown in Figure 1, with the following

particulars:

$$Z_p = 0.01 + j 0.08$$

$$Z_s = 0.01 + j 0.08$$

$$Z_t = 0.01 + j 0.08$$

$$V_2 = 440$$

$$I_2 = 100 \angle -25^\circ$$

$$I_3 = 80 \angle -35^\circ$$

Assume that  $V_2$  is the reference phasor, calculate:

- The intermediate voltage  $V_0$  (3 points)
- The primary current  $I_1$  and the primary voltage  $V_1$ . (3 points)
- The tertiary voltage  $V_3$  referred to the primary side. (3 points)
- The apparent powers and power factors at the primary, secondary and tertiary terminals. (3 points)
- The transformer efficiency. (3 points)

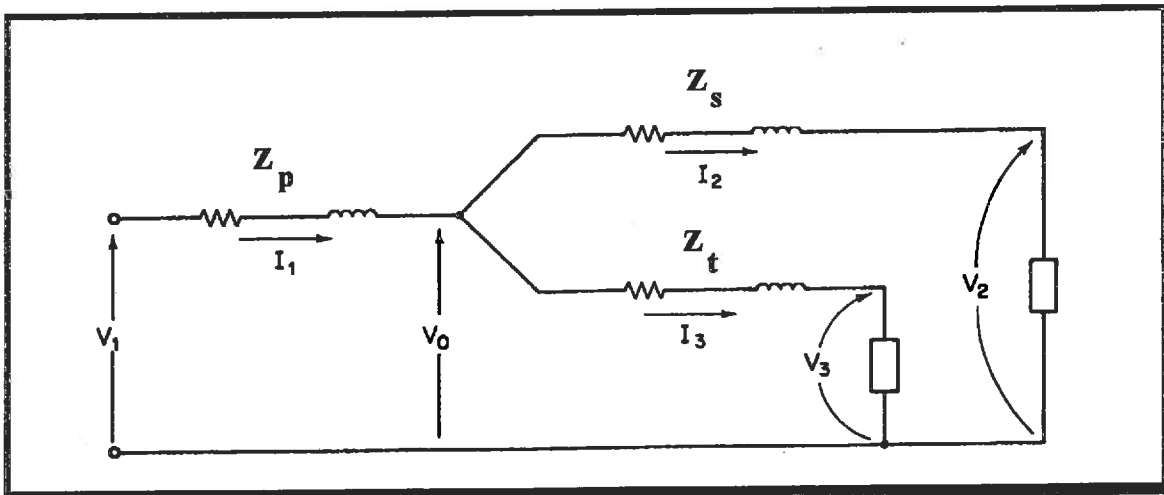


Figure (1) Three Winding Transformer Equivalent Circuit for Problem 3

**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 (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  $-7^\circ$ . [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]

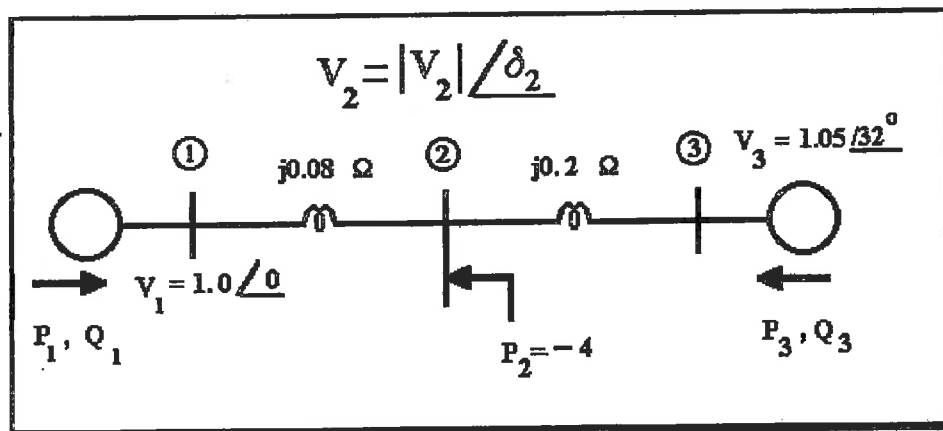


Figure (2) Circuit for Problem 4

**Problem 5**

- a- Discuss the consequences of short circuit faults on an 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 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 in the middle of line 1-3. [5 points]
- d- Find the voltages at buses 1 and 2 under the fault conditions of part c above [5 points]

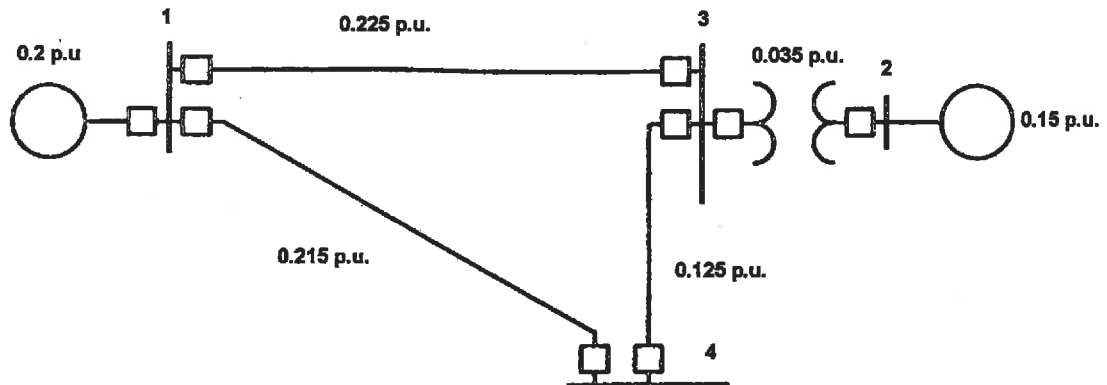


Figure (3) Single-line diagram for Problem 5

**Problem 6**

Consider the system of Figure (4.) The reactances of all components in p.u. are indicated in Table (2)

- a. Sketch and label carefully the positive, and negative, equivalent networks for this system. [4 Points]
- b. Sketch and label carefully the zero sequence equivalent network for this system including the switch S. Note that the switch is normally closed when the high voltage side of the transformer is grounded. An open switch means a broken ground connection. [4 Points]
- c. Assume that a single line to ground fault takes place at bus 2, while switch S is closed. Find the fault current through phase A. [4 Points]
- d. Repeat part (c) with the switch open (ungrounded transformer T1.) What is the effect of transformer grounding on the fault current? [4 Points]
- e. Assume that a three phase ground fault takes place at bus 2. Find the fault current. [4 Points]

Table (2) Component reactances for Problem 5 in per unit

	Generators $G_1$ & $G_2$	Transformers $T_1$ & $T_2$	Lines $L_1$ & $L_2$
Positive sequence reactance $X_+$	0.2	0.275	0.225
Negative sequence reactance $X_-$	0.15	0.275	0.225
Zero sequence reactance $X_0$	0.05	0.275	0.225

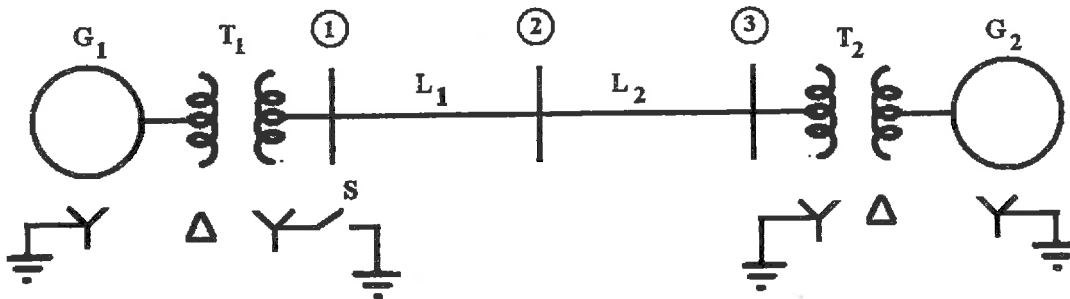


Figure (4) One-line diagram for Problem (6)

**Problem 7**

Consider the circuit shown in Figure (5.) Assume that  $E = 1.2$  p.u. and  $V = 1.00$  p.u.

- Find the initial power angle  $\delta$  when the active component of the load on the circuit is 3 p.u. [5 points]
- 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]
- Determine the maximum angle of oscillation under a sustained fault. [5 points]

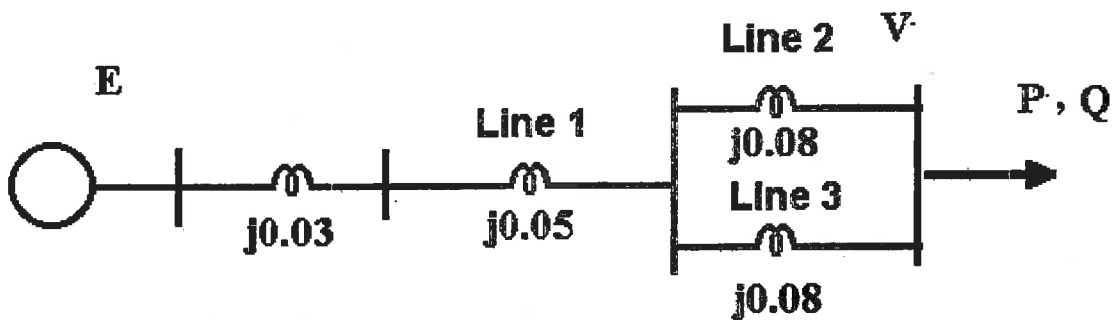


Figure (5) Circuit for Problem (7)