National Exams December 2018

16-Elec-B7, Power Systems Engineering

<u>3 hours duration</u>

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 "Ferranti effect in transmission lines" and why is it important in power system operations. [5 Points]

Consider a 400 km, 765-kV three phase line with the following parameters:

$$A = 0.95\angle 2^o \qquad B = 195\angle 87.5^o$$

b- Determine the parameter C of the line. [5 Points]

c- Assume that the line delivers 1000 MW at 720 kV at 0.85 power factor lagging, determine the sending end voltage and current, power factor, and the transmission efficiency. [15 Points]

Problem 2

A salient pole synchronous machine is connected to an infinite bus whose voltage is kept constant at 1.00 pu. The direct axis reactance is 0.95 pu.

a- To produce an active power of P = 1.15, the excitation voltage is E = 1.15 and the torque angle is given by δ = 32°. Determine the value of the quadrature axis reactance of the machine. [5 points]

b- Assume that X_q=0.6. Complete Table (1) relating to four operating conditions of the machine (Q_2 is the reactive power at machine terminals.) Neglect armature reaction.

Table (1) Loading Conditions for Problem (2)

	P	Q_2	E	δ
Condition A [5 points]	?	0.0	1.10	?
Condition B [5 points]	?	?	1.15	38°
Condition C [5 points]	1.9	?	?	42°
Condition D [5 points]	1.2	?	1.18	?

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.

$R_{eq} = 5.4\ \Omega$ $X_{eq} = 21\ \Omega$

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

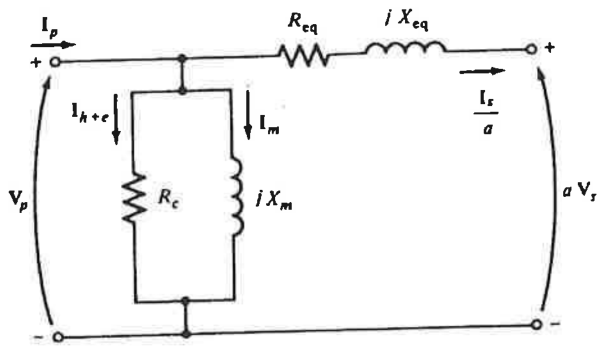

Figure (1) Equivalent Circuit of Transformer for Problem (3)

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

Consider the system shown in the single-line diagram of Figure (2).

a- Assume that $S_{D2} = 2.0 + j1.2$ and that Q_{G2} is initially set at zero, find the magnitude of bus 2 voltage $|V_2|$ and its angle exactly. [8 points]

b- The voltage magnitude at bus 2 is required to be within the range $0.95 \leq |V_2| \leq 1.05$. Based on the result of part a, determine the required value of the reactive power generation at bus 2. [5 points]

c- Assume that the load at bus 2 is capacitive at $S_{D2} = 0.5 - j0.7$, find the magnitude of bus 2 voltage $|V_2|$ and its angle exactly. [8 points]

d- The voltage magnitude at bus 2 is required to be within the range $0.95 \leq |V_2| \leq 1.05$, determine the type and amount of reactive power generation needed at bus 2. [4 points]

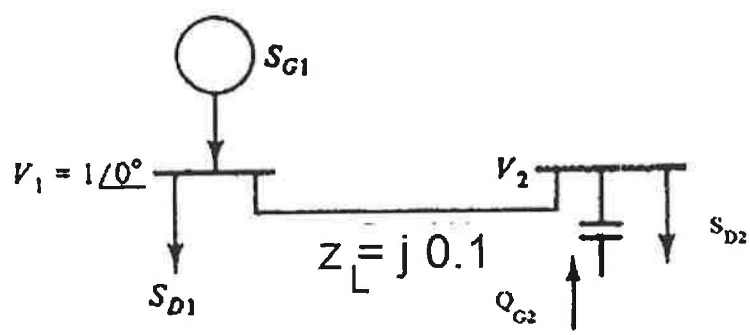

Figure (2) Single-line diagram for Problem (4)

Problem 5

a- Name three protection schemes employed for High Voltage Transmission lines in an electric power system. [5 points]

Consider the system shown in the single-line diagram of Figure (3-a). All reactances are shown in per unit to the same base. Assume that the voltage at all sources is 1 p.u,

b- Eliminate buses 5, and 6 to obtain the diagram of Figure (3-b). Determine X_a [5 points]

c- Eliminate bus 4 to obtain the diagram of Figure (3-c). Determine X_b [5 points]

d- A three-phase bolted fault takes place at bus 3 as indicated in Figure (3-c). Find the short circuit current flowing into the fault at bus. [5 points]

e- Find the voltage at bus 1 as indicated in Figure (3-c). [5 points]

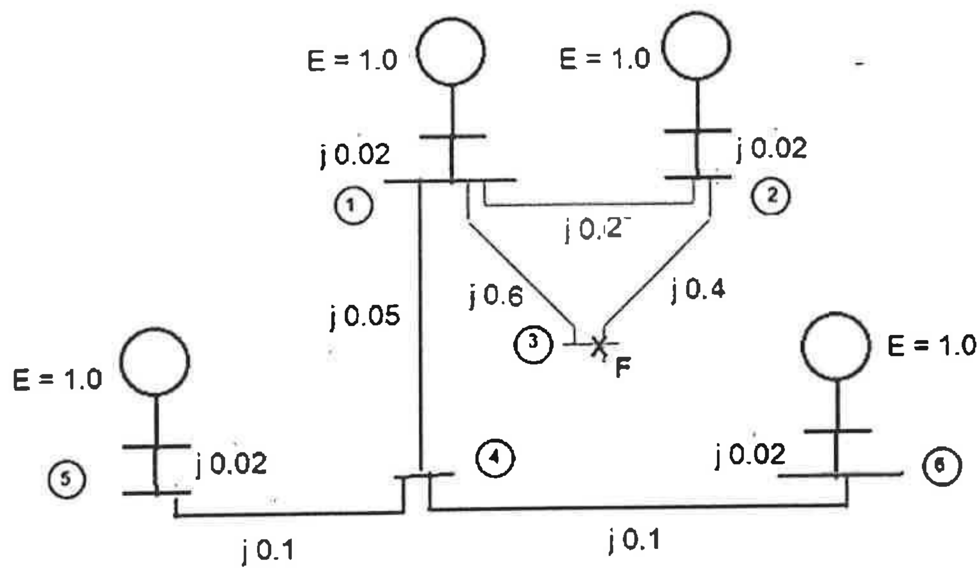

Figure 3 (a)

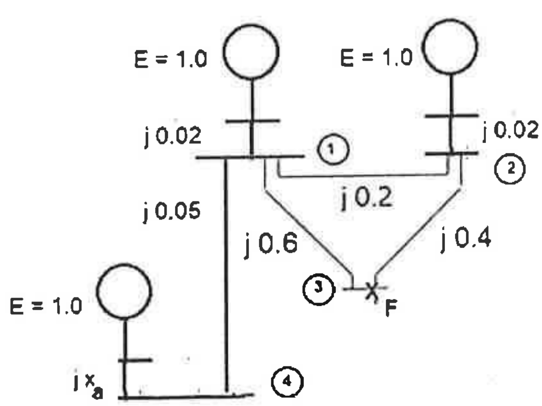

Figure 3 (b)

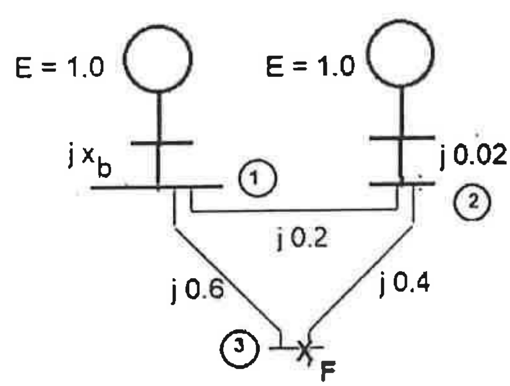

Figure 3 (c)

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, negative, and zero sequence equivalent networks 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. [5 Points]

b- Assume that a double line to ground fault takes place on phases B and C at bus 2, while switch S is closed. Find the current through phase B of line L1. [10 Points]

c- Repeat part (b) with the switch open (ungrounded transformer T1.) What is the effect of grounding the transformer on the fault current? [10 Points]

Table (2) Component reactances in per unit for Problem 6

	Generators G_1 & G_2	**Transformers T_1 & T_2**	**Lines L_1 & L_2**
Positive sequence reactance X_+	**0.2**	**0.25**	**0.30**
Negative sequence reactance X_-	**0.15**	**0.25**	**0320**
Zero sequence reactance X_o	**0.1**	**0.25**	**0.30**

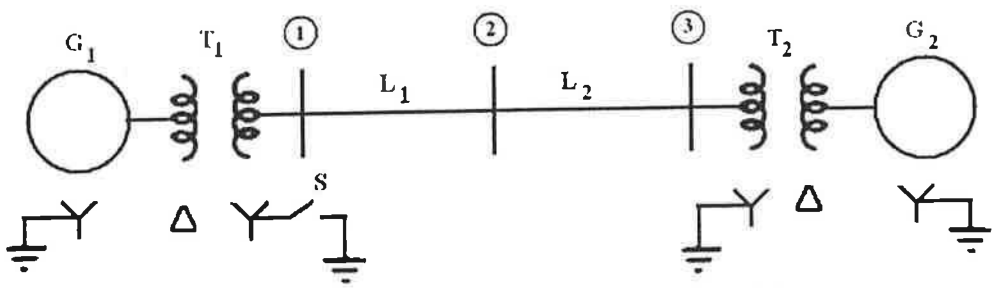

Figure (4) One-line diagram for Problem (6)

Problem 7

Consider the circuit shown in Fig. (5) Assume that E = 1.25 p.u., and V = 1.00 p.u.

a- Assume that the active component of the load on the circuit is 0.5 p.u. Find the initial power angle δ.
b- With the value of the load set at 0.5 p.u., a three-phase short circuit takes place in the middle of transmission line 1. Will the system be stable under a sustained fault?
c- Assume that the active component of the load on the circuit is 0.3 p.u. Find the initial power angle δ.
d- With the value of the load set at 0.3 p.u., a three-phase short circuit takes place in the middle of transmission line 1. Will the system be stable under a sustained fault?

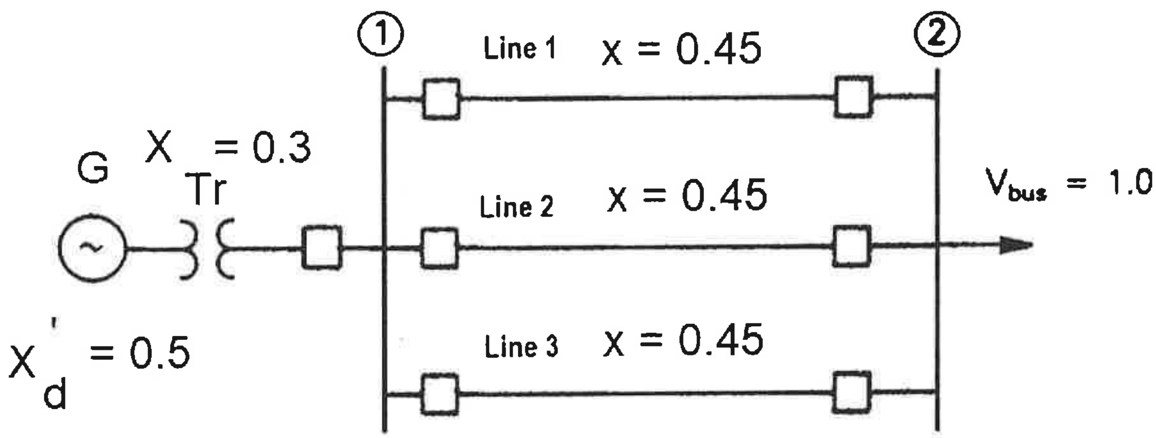

Figure (5) Circuit for Problem (7)