

National Exams December 2015
07-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 “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 series impedance $z=0.02 +j 0.54 \Omega/\text{km}$ and shunt admittance $y=j7.8 \times 10^{-6} \text{ mho}/\text{km}$.

- b- Find the characteristic impedance Z_c , the propagation constant γ , the attenuation constant α , and the phase constant β . [10 Points]
- c- Assume that the line delivers 100 MW at 750 kV at 0.955 power factor lagging.. Use the long line model to determine the sending end voltage and current, power factor, and transmission efficiency. [10 Points]

Problem 2

- a- 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]

The reactances X_d and X_q of a salient-pole synchronous generator are 1 and 0.6 per unit respectively.

- b- Neglecting armature resistance, find the generated voltage in per unit when the generator delivers its rated kVA at 0.8 lagging power factor and rated terminal voltage. [10 Points]
- c- Repeat Part b for 0.8 power factor leading [10 Points]

Problem 3

- a- Explain the effects of frequency on different types of losses in an electric transformer. [5 Points]

A 230-V: 6.6 kV, **50 Hz**, 45 kVA, transformer has a magnetizing reactance (measured from the 230-V) terminals of 46.00Ω . The 230-V winding has a leakage reactance of $28.00 \text{ m}\Omega$ and the 6.6 kV winding has a leakage reactance of 25.00Ω . The transformer is to be used on a **60 Hz** system.

- b- Calculate the magnetizing reactance referred to the low voltage winding and the leakage reactance of each winding. [5 Points]
- c- With 240 V applied to the low voltage (primary) winding and with the secondary winding open circuited, calculate the primary winding current and the secondary winding voltage. [10 Points]
- d- With 24 V applied to the low voltage (primary) winding and with the secondary winding short circuited, calculate the primary winding current. [5 Points]

Problem 4

- a- List the advantages and disadvantages of using shunt capacitors on electric power transmission lines. [5 Points]

Consider the two bus system of Figure (1.) Bus 1 is designated as the reference (slack) bus with $|V_1| = 1.00$ and $\delta_1 = 0.0^\circ$. The line admittance is $y = -j10$ as shown in the figure. The voltage at bus 2 is to be maintained between 0.95 and 1.05 p.u.

At bus 2, the net apparent power load is $S_D = 3 + j0.75$.

- b- Determine the value of voltage $|V_2|$ and if the capacitor bank should be switched on or off to maintain the voltage at bus 2 within the required limits. [10 Points]
- c- Assume now that the voltage $|V_2|$ is set to the appropriate limit, under the conditions established in part (b.) Determine the value of the required reactive power produced by the capacitor (or limiting reactor). [5 Points]
- d- Find the angle δ_2 corresponding to the condition of part (c.) [5 Points]

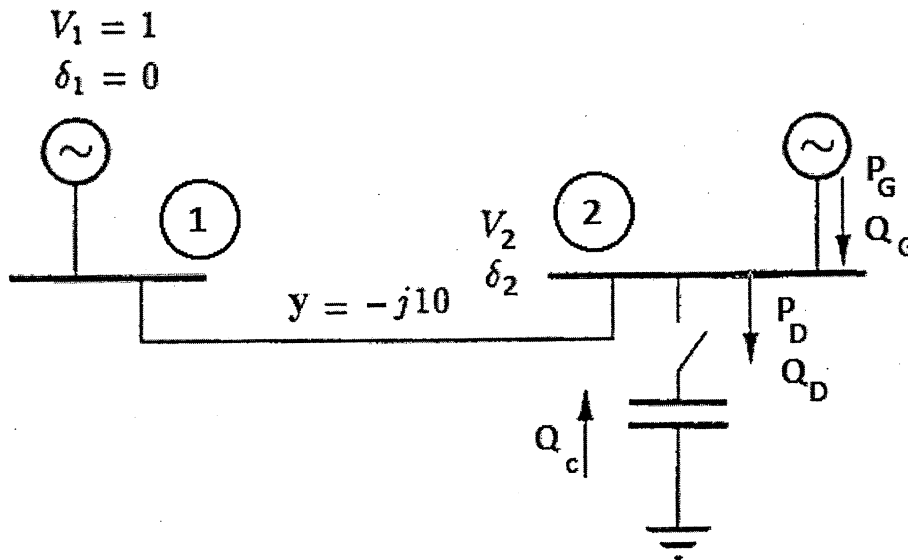


Figure (1) One-line Diagram for Problem (4)

Problem 5

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

Consider the system shown in the single-line diagram of Figure (2). All reactances are shown in per unit to the same base. Assume that the voltage at both sources is 1 p.u.

- b- Find the fault current due to a bolted- three-phase short circuit at bus 4. [10 Points]
- c- Find the voltages at buses 1 and 2 under the fault conditions of part b above. [10 Points]

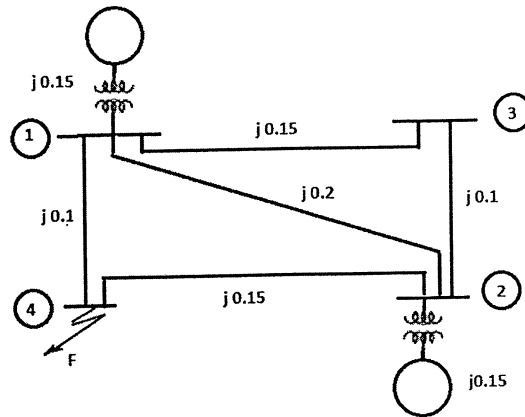


Figure (2) Single-line diagram for Problem 5

Problem 6

A 25 MVVA, 11kV, three phase generator has a subtransient reactance of 20%. The generator supplies two motors over a transmission line with transformers at both ends as shown in the one line diagram of Fig. (3-a) The rated inputs of the motors are 15 and 7.5 MVA at 10 kV with 25% subtransient reactance. The three phase transformers are both rated at 30 MVA, 10.8/121 kV, delta/Y with leakage reactance of 10% each. The series reactance of the line is 100Ω . Assume zero sequence reactances for the generator and motors of 0.06 per unit. Current limiting reactors of 2.5Ω each are connected in the neutral of the generator and motor no. 2. The zero sequence reactance of the transmission line is 300Ω

- a- Using a base of 25MVA, 11 kV on the generator side, verify that the sequence networks of the system are as shown in Fig. (3-b) and (3-c) [10 points]
- b- A line to line fault occurs on phases B and C, at point F (midway between e and f) , determine the fault current at point F. [15 points]

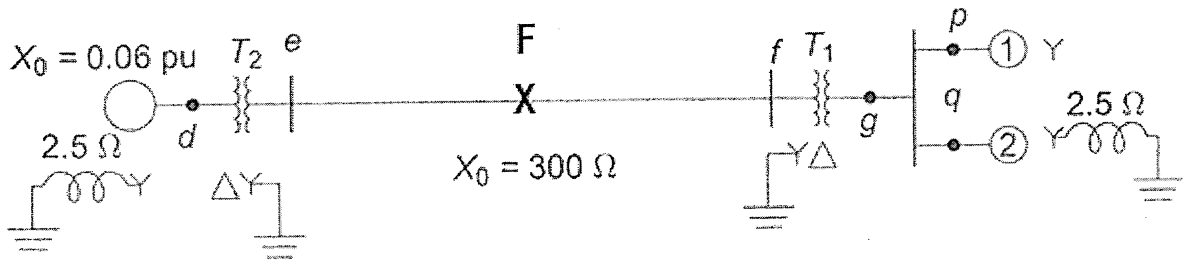


Figure (3-a) Single line diagram for Problem 6

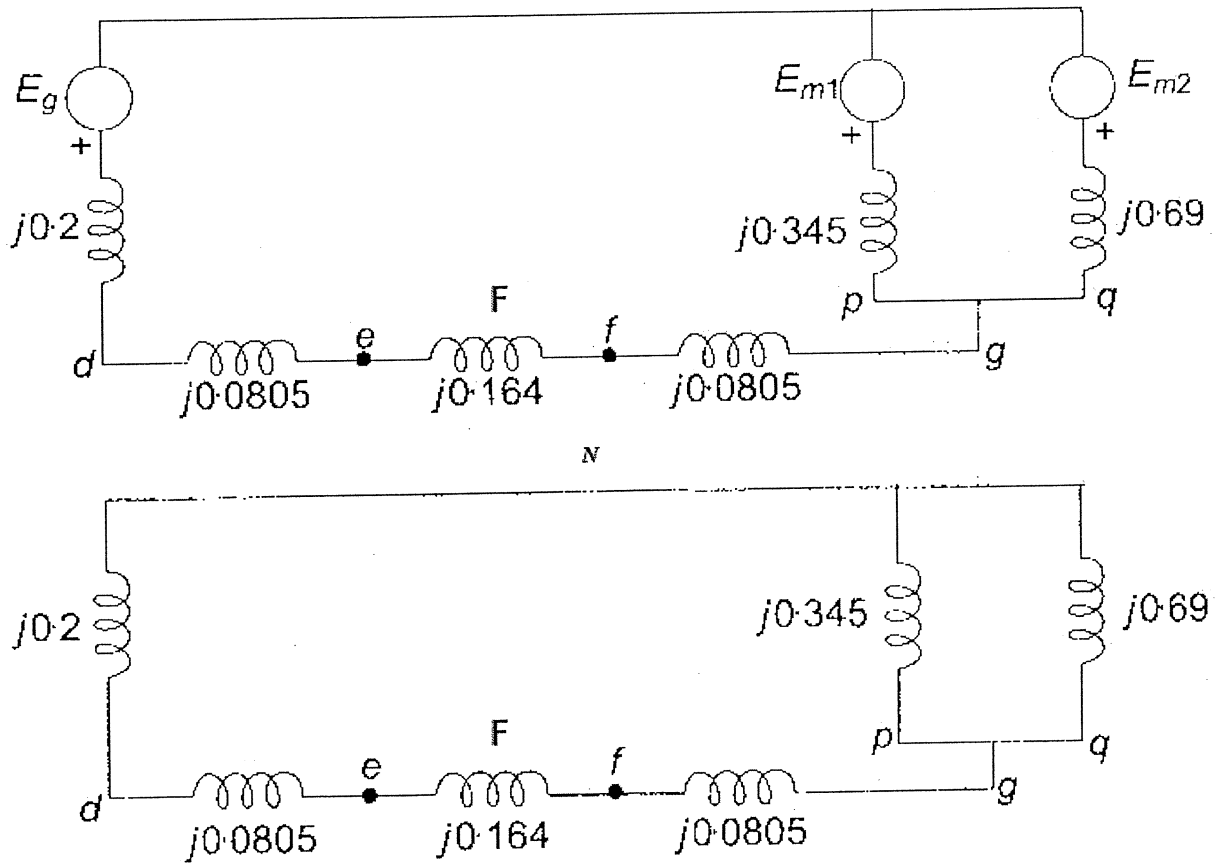


Figure (3-b) Positive and negative sequence equivalent circuits for system of problem 6

Problem 7

Consider the circuit of Figure (4,) with $X = 0.4$ and $\alpha=0.2$. A three-phase fault takes place at the point F. The fault is cleared by opening the faulted line.

- Find the initial power angle δ when the active component of the load on the circuit is 1 p.u. [5 points]
- Find the power angle curve, during the fault. [5 points]
- Find the post fault power angle curve. [5 points]
- Determine the critical clearing angle [10 points]

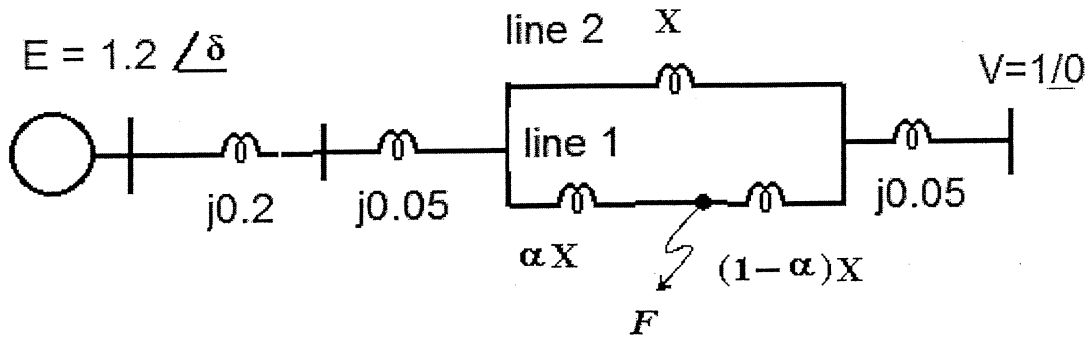


Figure (4) Circuit for Problem (7)