

National Exams December 2014
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 “line transposition” and why is it needed. [5 Points]

Consider a 150 km, 138-kV three phase line with series impedance $z=0.17 +j 0.79 \Omega/\text{km}$ and shunt admittance $y=j5.4 \times 10^{-6} \text{ mho}/\text{km}$.

- b- Find the characteristic impedance Z_0 , the propagation constant γ , the attenuation constant α , and the phase constant β . [10 Points]

- c- Assume that the line delivers 15 MW at 132 kV at unity power factor. 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 differences between salient-pole and cylindrical rotor synchronous machines in terms of reactance and maximum power transfer values. [5 Points]

A 125 MVA 11 kV three phase 50 Hz synchronous generator has a synchronous reactance of 1.33 p.u. The generator achieves rated open circuit voltage at a field current of 325 A. The generator is connected to a network with an equivalent line-line voltage of 11 kV and an equivalent impedance of 0.17 pu on the generator base. The generator is loaded to a real power of 110 MW.

- b- Find the generated voltage E_{af} in p.u. such that the network is operating at unity power factor at the external network equivalent voltage. Find the corresponding field current, the generator terminal voltage and power factor. [10 Points]

- c- Assume that the generator is operating at its rated terminal voltage. Find the generated voltage E_{af} in p.u., the corresponding field current, the generator terminal current and power factor. [10 Points]

Problem 3

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

A feeder whose impedance is $(0.17 +j 2.2) \Omega$ supplies the high voltage side of a 400-MVA, 22 5kV: 24kV, 50-Hz, three-phase Y- Δ transformer whose single phase equivalent series reactance is 6.08Ω referred to its high voltage terminals. The transformer supplies a load of 375 MVA at 0.89 power factor leading at a voltage of 24 kV (line to line) on its low voltage side.

- b- Find the line to line voltage at the high voltage terminals of the transformer. [10 Points]

- c- Find the line to line voltage at the sending end of the feeder. [10 Points]

Problem 4

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

Consider the network shown in Figure (1.) It is known that the static load-flow equations are given by:

$$\frac{P_i - jQ_i}{V_i^*} = \sum_{j=1}^n (Y_{ij}V_j) \quad (i = 1, 2, 3)$$

Each equation is complex, and therefore we have $2n$ real equations. Use the following approximation:

$$e^{j\theta_{ik}} = 1 + j\theta_{ik}$$

Of course the angles are in radians. Assume that for all lines $z_L = j0.5$, $P_{G2} = 0.2$, $S_{D3} = 0.3 + j0.1$

- b- Use the imaginary parts of the load flow equation for bus 3 to determine $|V_3|$. [10 Points]
(Use the larger of the solutions.)
- c- Use the real parts of the load flow equation for buses 2 and 3 to determine the angles θ_2 and θ_3 [10 Points]

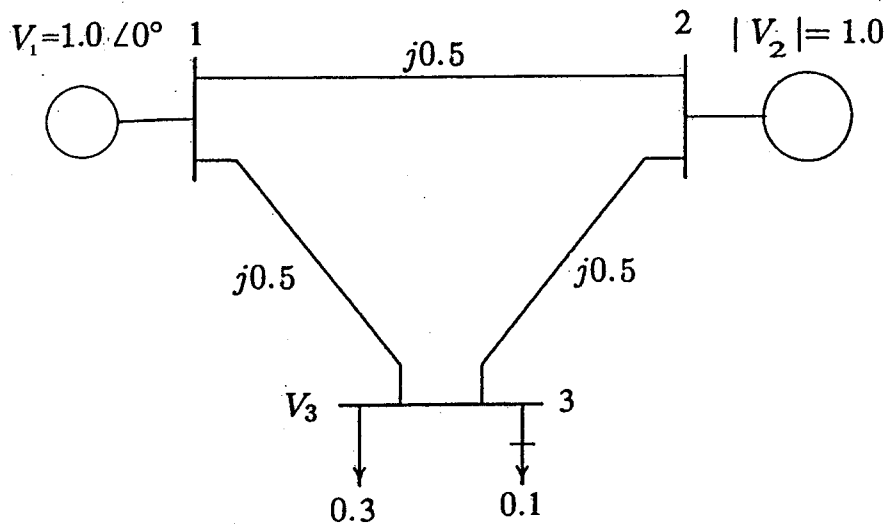


Figure (1) Network for Problem (4)

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 in the middle of line 1-3. [10 Points]
- c- Find the voltages at buses 1 and 2 under the fault conditions of part b above. [10 Points]

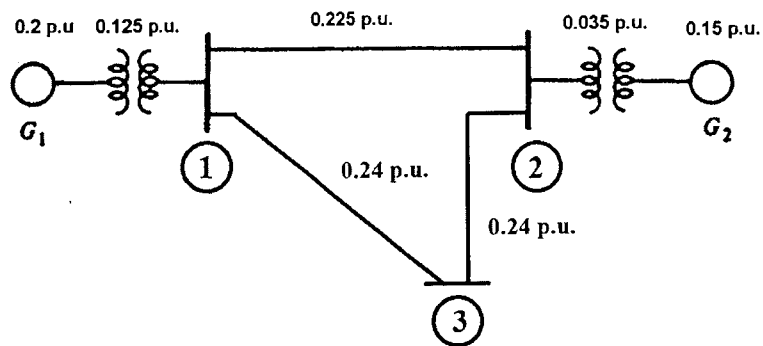


Figure (2) Single-line diagram for Problem 5

PROBLEM 6

Consider the system shown in the single-line diagram of Figure (3.) The required sequence reactances in per unit to the same base are as follows:

$$G_1 \text{ and } G_2 \quad X_1 = X_2 = 0.20 \quad X_0 = 0.05$$

$$\text{Transformers} \quad X_{T1} = X_{T2} = 0.05$$

$$\text{Lines: Positive and Negative Sequence} \quad X_{12} = 0.10$$

$$\text{Lines: Zero Sequence} \quad X_{12} = 0.30$$

- a- Determine the Thevenin's equivalent of each sequence network as viewed from the fault at the middle of the lower line 1-2. [15 Points]
- b- Determine the fault current in per unit for a single line to ground fault at the middle of the lower line 1-2. [10 Points]

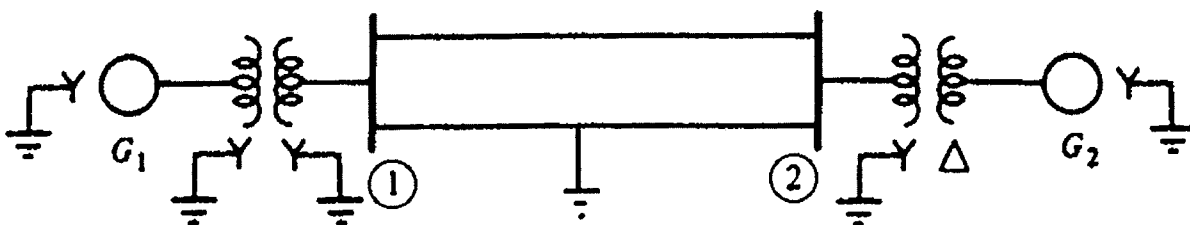


Figure (3) Single line diagram for Problem 6

Problem 7

Consider the circuit shown in Figure (4.) Assume that $E = 1.44$ p.u. and $V = 1.00$ p.u.

- Find the initial power angle δ 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]

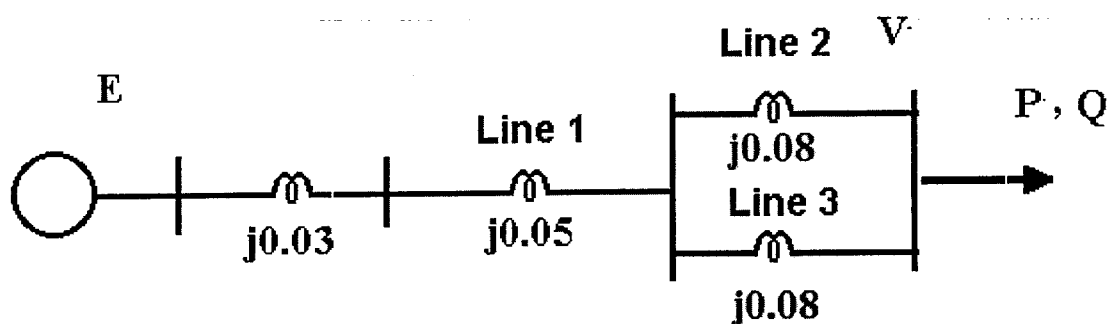


Figure (4) Circuit for Problem (7)