National Exams December 2019

16-Elec-B7, Power Systems Engineering

Open Book Examination

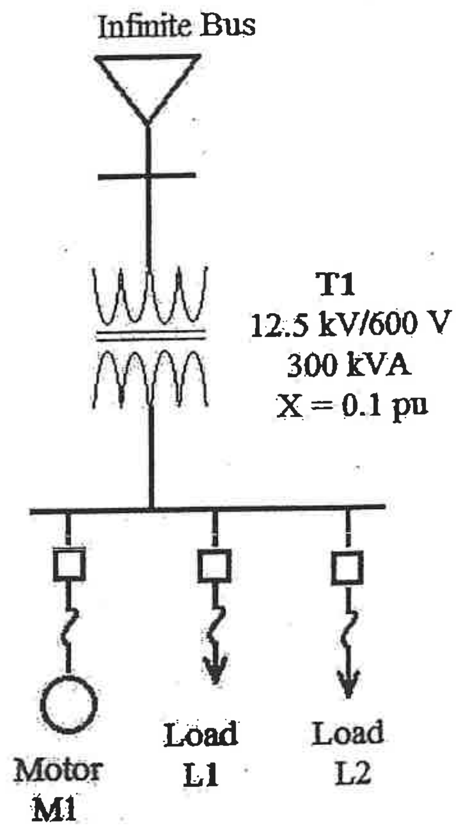
3 Hours Duration

Notes

1) If doubt exists as to the interpretation of any question, the candidate is urged to submit, with the answer paper, a statement of any assumptions made.
2) Any non-communicating calculator is permitted. This is an Open Book examination. You must indicate the type of calculator use in the writing of this exam. **Please write the name and model designation of the calculator used 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 the answer book will be graded.
4) All questions are of equal value

Question 1: [20 Marks]

A single line diagram for the three-phase distribution system of a small manufacturing company is shown. Load, L1 is presently unused and disconnected, Load L2 is a heating load of 150 kW and motor M1 is a 125 hp motor (1 hp = 746 W) which operates at 85.4% efficiency and 0.8 lagging power factor. The 600 V bus operates at rated voltage. Choose a base power of 500 kVA and a base voltage of 600 V for the low voltage side of the transformer and perform the following calculations:



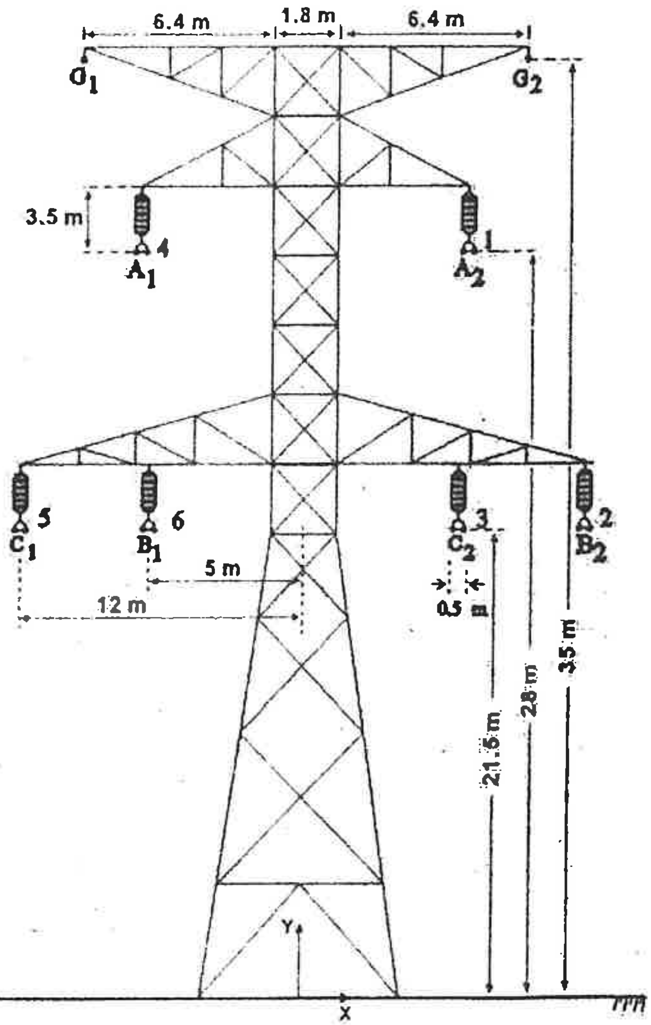
a) Determine the per-unit current and impedance base values for the high voltage side of the transformer. (5 Marks)

b) Determine the per-unit impedance value for the transformer T1 and the motor load M2 using the base values specified. (5 Marks)

c) Ignoring load L1, determine the primary (high voltage) transformer current in amps if the load bus is operating at 600 V. (5 Marks)

d) Determine the maximum unity power factor load that can be supplied from the L1 feeder without overloading the transformer. (5 Marks)

Question 2 [20 Marks]



A 60 Hz, 345 kV, double circuit transmission line is shown with appropriate dimensions (ignore the A_2, B_2, and C_2 conductors). Each phase is a bundled conductor consisting of two ACSR conductors with a diameter of 12.75 mm (code name Pigeon) and which are separated by 0.5 m as shown. (Note: $\mu_o = 4\pi \times 10^{-7}$ H/m and $\varepsilon_o = 8.85 \times 10^{-12}$ F/m)

a) Determine the per-phase inductance of this transmission line (the A_1 phase is directly above the B_1 phase). (8 Marks)

b) If each conductor of the bundle has a resistance of 0.15 Ohms per km and the capacitance is calculated to be 0.038 µF/km, determine, and draw the appropriate per phase model for a 50 km length of this transmission line. (4 Marks)

c) The A, B, C, D parameters of a similar voltage and capacity transmission line are given below. Determine the sending end voltage and current for a rated receiving end voltage and loading of 200 MVA at unity power factor. (8 Marks)

$A = D = 0.95\angle 0°$

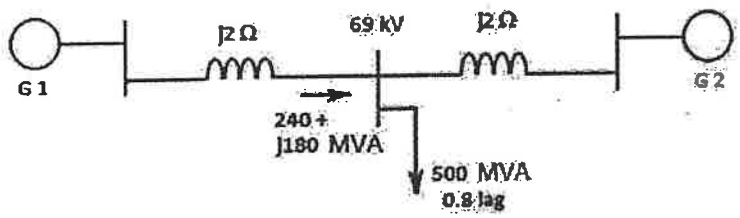
$B = 33.2\angle 75°$

$C = 0.00027\angle 89°$

Question 3 [20 Marks]

A) A three phase 500 MVA load at 0.8 power factor lagging is supplied by two generators as shown in the diagram through two transmission lines. The load voltage is 69 kV. Generator 1 delivers 240 MW and 180 MVAR to the load through the transmission line. Determine:

I. The current in transmission line 1 (from G1 to load bus). (4 Marks)



II. The terminal voltage at the output of generator 1. (4 Marks)

III. The reactive power that is supplied by generator G2 at its terminals. (5 Marks)

B) What is the difference between a "swing (or slack)" bus and a "generator" bus in terms of the unknown variables for the load flow set up? (4 Marks)

C) When the load flow solutions are returned to the user, what should you be looking for in order to ensure the power system is functioning properly? Address at least three items. (3 Marks)

Question 4 [20 Marks]

A 100 MVA, 20 kV, cylindrical rotor, synchronous generator has a saturated synchronous reactance of 1.5 pu.

a. What internal excitation (in V_{l-l}) is required to deliver ½ rated load at 0.8 pf lagging at rated terminal voltage? (3 Marks)

b. What is the generator torque angle for the load of part a)? (2 Marks)

c. At the value of excitation set for part a) what is the maximum power (in Watts) the generator can deliver? (3 Marks)

d. If the excitation voltage is increased by 10 %, from that determined in part a), but the load power is held constant, what quantities will change as a result? Draw a phasor diagram to demonstrate your reasoning. (4 Marks)

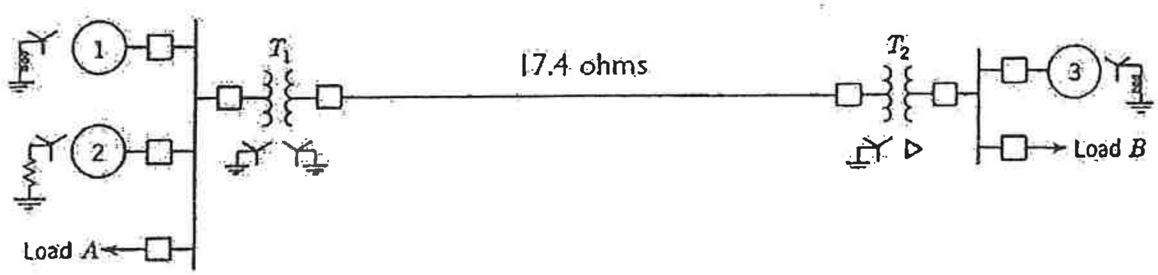
e. If a sudden three-phase short circuit is applied to the terminals of the generator, sketch the short circuit current as a function of time, identifying at least four features of the current waveform over time? (4 Marks)

f. Draw a sketch of the rotor of a four-pole salient pole synchronous generator and identify the following: Direct axis, Quadrature axis, Field winding, Amortisseur winding. (4 Marks)

Question 5 [20 Marks]

A) The single line diagram for a power system is shown with appropriate impedance values below (in pu were not otherwise stated). Use a 100 MVA base and draw the zero sequence network for this system in preparation for a stability study (10 – 15 cycles). Provide impedance values on your diagram where possible. (10 Marks)

All generators: 100 MVA; 20 kV; $X_s = 1.8$; $X_s' = 0.6$; $X_s'' = 0.2$; $X_o = 0.3$; $X_g = 0.1$
All Transformers: 100 MVA; 20/138kV (or 138/20 kV); $X_l = 0.15$ $X_g = 0$
Transmission line as shown in Ohms
Load A: 50 MW, Delta connected
Load B: 75 MW, Wye connected



B) At a given bus (**NOT** the system shown in part A), a power system has a positive sequence reactance of j0.23 pu, a negative sequence reactance of j0.23 pu and a total zero sequence reactance of j0.45 pu. Determine the following for rated pre-fault current:

i. The magnitude of a solid three phase fault in pu at the location specified. (3 Marks)
ii. The magnitude of a single line to ground fault in pu at the same location. (3 Marks)
iii. Explain how you block zero sequence current from flowing in a generator. (2 Marks)
iv. Explain why it is important to minimize the zero and negative sequence current in a generator. (2 Marks)

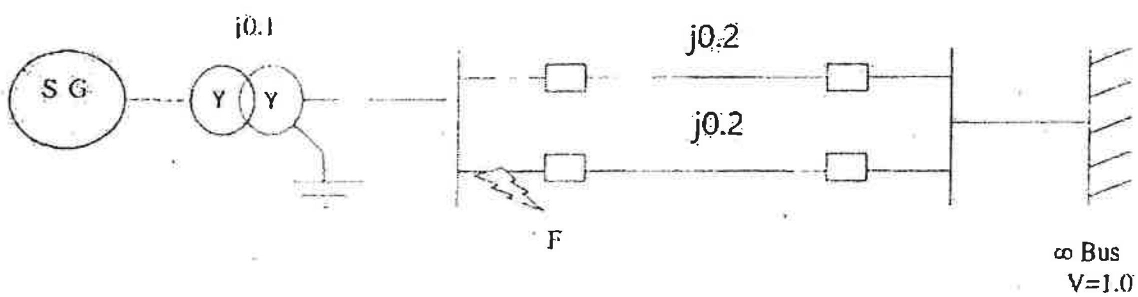
Question 6: [20 Marks]

A generator, with a transient reactance of j0.5 pu, delivers 0.6 pu real power to an infinite bus through a transformer and two transmission lines in parallel as shown below. A solid three phase fault occurs at position near "F" which is cleared by opening both ends of the transmission leaving only one line in service.

If the generator internal voltage is 1.5 pu, determine the initial power angle. (2 Marks)

Draw the relationship between the real power flow from the generator to the infinite bus as a function of the relative angle δ before the fault, during the fault and after the fault is cleared. Indicate the mechanical power, the initial operating angle, the maximum angle and the final angle after the fault is cleared. (5 Marks)

Use the diagram drawn to show how stability can be assessed by the equal area method. (3 Marks)



Explain what is meant by the phrase "critical clearing time" and why is it important? (3 Marks)

How is the load flow solution connected to a stability study? (3 Marks)

Why does an arc form when a circuit breaker opens and give two methods used to extinguish the "arc" that results when a circuit breaker is opened under load. (4 Marks)