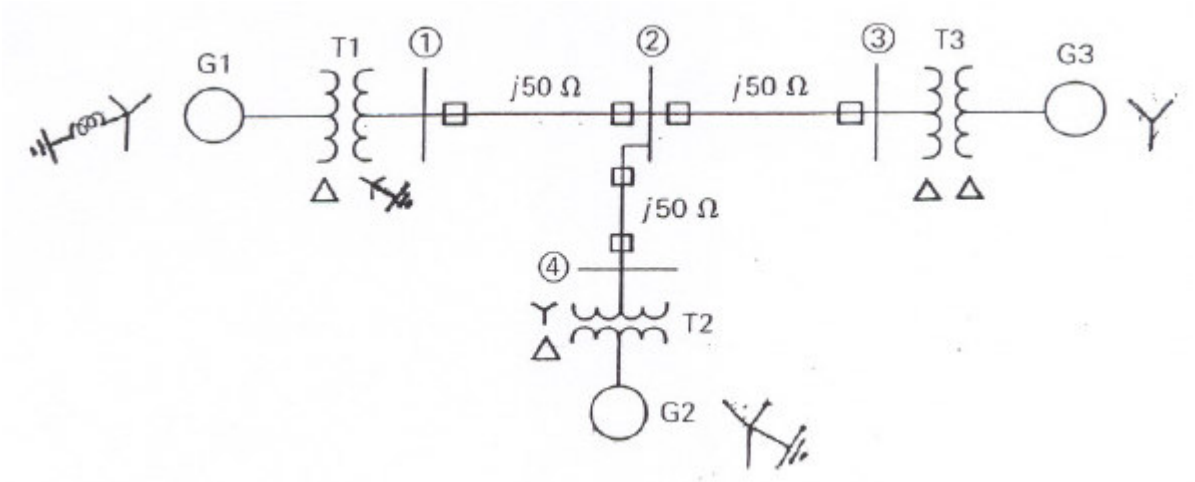
ECE470 POWER SYSTEMS I

Homework Set 9

1. The single-line diagram of a 3ϕ power system is shown below. Each line has 50 Ω reactance in the positive and negative sequences, and 150 Ω zero sequence reactance. The remaining system data, on equipment rating bases are:

G1	13.8 kV	500 MVA,	X_1= 0.2,	X_2= 0.1	X_o= 0.05,	X_n= 0.1
G2	18 kV	750 MVA,	X_1= 0.5,	X_2= 0.3	X_o= 0.1	
G3	20 kV	1000 MVA,	X_1= 0.3,	X_2= 0.2	X_o= 0.08	
T1	15/500 kV	500 MVA,	X = 12%			
T2	20/500 kV	750 MVA,	X = 10%			
T3	22/500 kV	1000 MVA,	X = 10%			



a) Draw the positive-, negative-, and zero-sequence impedance diagrams using 1000 MVA, 500 kV base in the zone of each line.

b) All machines in part (a) have 1.2 pu excitation. For faults at bus 3, and based on your answer to part (a) determine the Thevenin equivalents of the positive, negative and zero sequence networks.

c) Evaluate the phase voltages and phase currents (pu) for the following faults:
i) 3ϕ-G ii) 1ϕ-G iii) 2ϕ iv) 2ϕ-G

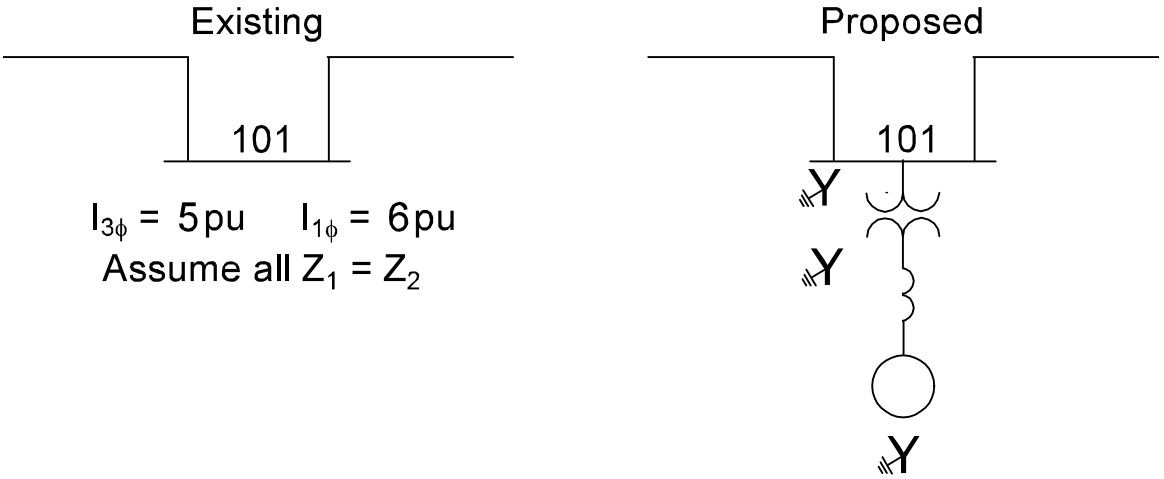
d) Re-calculate the fault currents in part (a) if all generator neutrals are opened.

2. The existing 3ϕ and 1ϕ-G fault levels at bus 101 are: 5 pu and 6 pu respectively. The system planning department are considering installing additional generation at bus 101 via a transformer with $X_1 = X_2 = X_0 = 0.08$ pu; the generator sub-transient reactances are $X_1 = X_2 = 0.25$ pu, $X_0 = 0.06$ pu. Assume all excitation voltages are 1.0 pu.

a) Determine the positive, negative and zero sequence Thevenin equivalents at bus 101 prior to the addition.

b) What will be the 3ϕ and 1ϕ-G fault levels at bus 101 after the generator and transformer have been installed?

c) Which transformer configurations would make the fault levels better?



3.

a) A building is grounded by a single earth electrode which has a diameter of 2 cm and is 3 m long. The resistivity of the surrounding earth is 25 Ω.m. There is no surface material ($C_S = 1.0$) and the highest ground fault is 200 A, which will take 0.2 sec to clear. Based on 50 kg body weight, compare the allowable and actual touch potentials and determine if the grounding system is adequate.

b) Repeat if a second ground rod is driven and bonded to the first. Assume that the expression for the resistance of 2 ground rods is:

$$R_g = \frac{\rho}{4\pi L}\left[\ln\left(\frac{8L}{d}\right) - 0.377\right]$$

c) The foregoing system is to be improved by placing a surface covering of insulating material in the vicinity of both ground electrodes. The surface material is 15 cm thick and has a resistivity of 5000 Ω.m. Calculate the new allowable touch potential and determine if the grounding system is adequate.