TUTORIAL 7: THREE PHASE POWER SYSTEMS

7.1: Three (30 + j30) Ω identical impedances are connected in Delta and supplied by a 173V 3-phase system through three lines each having impedance of (0.8 + j0.6) Ω. Find:

1) the current magnitude in each of the delta-connected impedances, and
2) the voltage cross each of Delta impedance.

7.2: A 415V, 50 HZ, 4-wire three-phase balanced power supply with sequence RYB is connected to the following loads:

A single resistance of 12 Ω between R phase and neutral;

An inductive impedance of (2 + j8) Ω between B phase and neutral;

A capacitor of 120μF between R and Y phase;

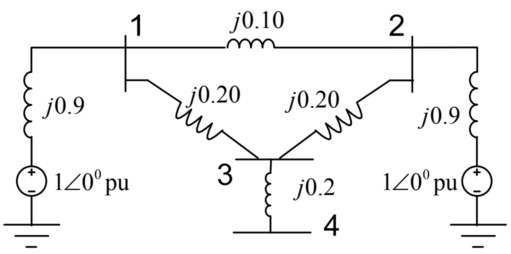
A three-phase, delta connected induction motor operating at 10kW and 0.75 p.f. lagging.

Calculate:

1) the magnitude and phase angle of the current in the four lines of the supply, and
2) the total power from the supply.

7.3: The figure below shows the per-phase per-unit network of a 4-bus power system. Develop Thevenin equivalent circuits as viewed

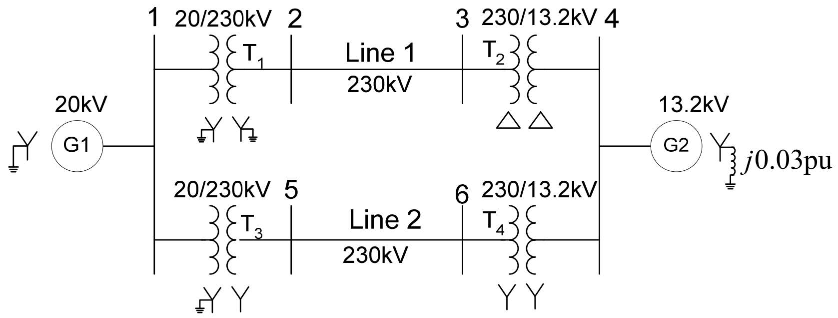
1) from bus 4 and ground, and
2) from bus 2 and ground.



Tutorial 8: Sequence Components and Sequence Networks

8.1: The phase voltages at a bus of an unbalanced power system are $V_a = 1\angle 0^0, V_b = 1\angle -90^0, V_c = 2\angle 135^0$. Find the sequence voltages of three unbalanced voltages and prove that: $V_a = V_a^{(0)} + V_a^{(1)} + V_a^{(2)}$.

8.2: The component parameters of the following system are given in Table. The power rating for each apparatus is 200MVA. Sketch the sequence networks and find the Thevenin equivalent reactance of each sequence network seen from bus 4. Assume that pre-fault voltage at bus 4 is $1\angle 0^0$pu. (Exercise: the same question for Bus 5)



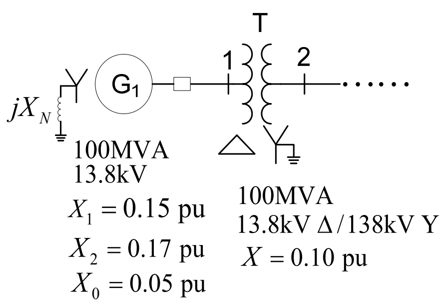
Component	kV Rating	X_1(pu)	X_2(pu)	X_0(pu)
G_1	20	0.20	0.14	0.05
G_2	13.2	0.20	0.14	0.05
T_1	20/230	0.20	0.20	0.20
T_2	230/13.2	0.30	0.30	0.30
T_3	20/230	0.25	0.25	0.25
T_4	230/13.2	0.35	0.35	0.35
Line 1	230	0.15	0.15	0.35
Line 2	230	0.22	0.22	0.55

8.3: Part of a power system is shown in the figure. $V_f = 1\angle 0^0$pu. X_N=5%. For a bolted double line-to-ground fault occurs on phase b and c at bus 1, the three-phase currents out of G_1:

$I_a = 0.4008\angle 90^0$ pu，$I_b = 6.1817\angle 152.86^0$ pu，$I_c = 6.1817\angle 27.14^0$ pu

Currents I_{fb} and I_{fc} from bus 1 to ground: $I_{fb} = 7.8104\angle 157.25^0$ pu and $I_{fc} = 7.8104\angle 22.75^0$ pu.

a) Calculate per-unit sequence currents of phase *a* flowing from delta side of transformer T_1 to bus 1.
b) Calculate per-unit three-phase currents flowing from bus 2 to Y side of T_1.



Tutorial 9: Fault Analysis

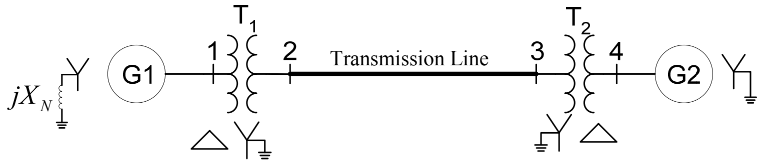
9.1: The one-line diagram for a power system is given in the following figure. The parameters of the generators and transformers are given as:

G1 and G2: 100MVA, 20kV, $X_1 = X_2 = 20\%, X_0 = 6\%$ and X_N=5%

Transformers T_1 and T_2: 100MVA, $20\Delta / 345\text{Y kV}$ and X=10%

Line (on bases 100MVA, 345kV): $X_1 = X_2 = 10\%,\ X_0 = 25\%$

A bolted single line-to-ground fault occurs on phase *a* at bus 2. $V_f=1\angle 0^0$ pu.



a) Draw the sequence networks.
b) Calculate the per unit sequence and phase currents at the fault point.
c) Determine the per unit phase currents flowing from Y side of T_1 to fault point.
d) Determine the per unit current flowing out of phase b of G1.

9.2: A bolted double line-to-ground fault between phase *b* and *c* occurs at bus 2 in the power system shown in question 9.1.

a) Calculate per unit sequence currents at the fault point.
b) Calculate the per unit phase voltages at bus 3.

9.3 (Homework) A double line fault between phase *b* and *c* with the fault impedance X_f=0.1pu occurs at bus 1 in the power system shown in question 9.1.

a) Calculate the per unit sequence currents through transmission line.
b) Calculate the per unit sequence voltages at bus 3.

Tutorial 10: Protection Zone and Overcurrent Protection

10.1: The system is shown in the following figure. Assuming that all the circuit breakers operated correctly, determine the fault locations for each of the following cases.

Case 1: B2 and B3

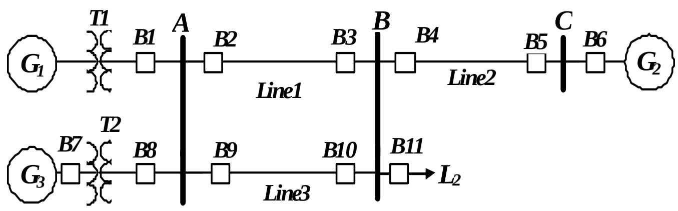
Case 2: B7, B8, B1, B2 and B9

Case 3: B6

Case 4: B11

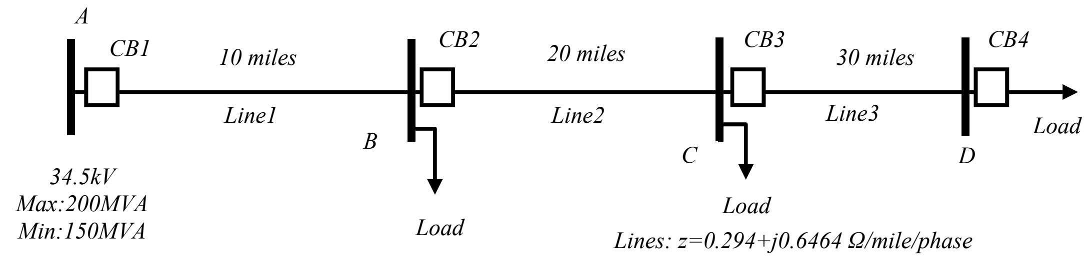
Case 5: B2, B3, B4, B10and B11

Case 6: B3, B4, B10and B11



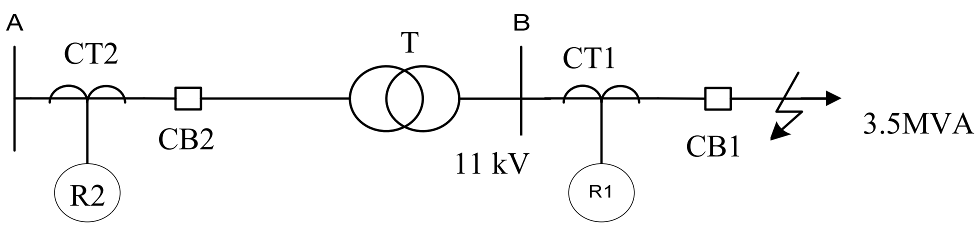
10.2: A 50-Hz radial distribution system and the data are shown in the figure. The maximum and minimum fault levels at bus A are 200 MVA and 150 MVA, respectively. The maximum and minimum loads for each of the three load points are 5 MVA and 3MVA, respectively. The power factors of the loads are the same. The CO-8 relays are selected to protect load and lines. The coordination time interval (CTI) for two adjacent relays is 0.3s. Ignore transmission losses when calculate the maximum load current. Ignore the operating time of the breakers.

1) Select the CT ratio for the related relay at each bus.
2) Select current plug settings (PSs) for all the relays.
3) Select time dial settings (TDSs) for the phase relays R2 at bus B and R3 at bus C.
4) Calculate the operating time of R2 and R3 if a three phase to ground fault occurs at 10 miles to Bus C on line3 for the minimum system capacity.



10.3: A 3.5 MVA rated load is supplied from 33 kV system bus through a 40MVA and 33Δ/11Y kV transformer with a leakage reactance of 15%. The fault level at 33 kV is 2000MVA. The relays R1 and R2 are IDMT relays with 5A rating. The time-current curve of the relay is represented by $t = \frac{0.14}{M^{0.02} - 1} TDS$. The TDSs are from 0.1 to 1 in the step of 0.1. The plug settings are from 50% to 200% of the relay rating in the step of 25%. The CT ratios for CT1 and CT2 are 400:5 and 300:5 respectively.

a. Determine the PSs and the TDSs of the phase relays if the required discrimination time or CTI between R2 and R1 is 0.4s.
b. Find the fault location and the minimum operating time of R2 based on the relay settings from part a.



Tutorial 11: Differential Protection

11.1: A Y-connected generator is connected to a 230 kV system through a Δ-Y 33/230 kV transformer as shown in the following figure. The system parameters are also shown in the figure. The positive and negative impedances are the same for all components. A differential protection is used to protect generator.

a) Select CT ratio.
b) Calculate the currents through restraint windings and operating winding for the single phase to ground faults at *F1* and *F2*.