Work with your term project team consisting of 3 people. The graduate student(s) are expected to provide technical leadership with calculations and possible Matlab programming and/or application of ASPEN, and make themself available as mentors/tutors and technical experts. The undergraduate students are expected to learn and be able to apply the concepts and do the symmetrical component calculations (a basic understanding is essential for this assignment).

Problem Definition:
The main focus in line protection (both for distribution and for transmission) is to determine what the relay will "see" for each possible kind of fault. Review section 4.16.4 in your text, and especially figures 4.34 and 4.35. Figure 3.8 (top part of figure) can also be helpful, since it shows the "three-line" connections of VTs, CTs, and relays. It is important to have a good understanding of how the voltages and currents being monitored by the relay change, how the relay is using these voltages and currents, and then finally to be able to set the relays to properly discern between a no-trip condition (normal system operation or a fault that is outside of the relay's zone of protection) and a trip condition (a fault within its zone of protection).

The simplest way to gain insight about how the voltages and currents monitored by a relay will change for various types of faults is to study the most basic circuit: Line End is Open
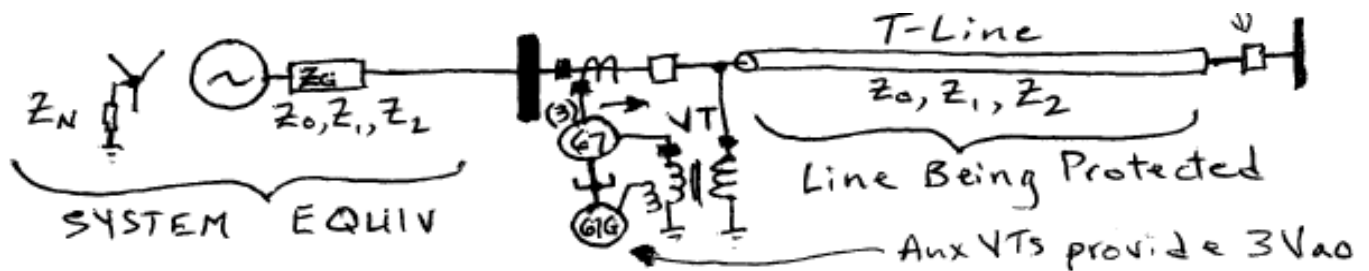
The source impedance Z_S and the line impedance Z_L each can be defined either as phase impedances [Z_P] (i.e. Z_A, Z_B, Z_C, Z_N) or as sequence impedances [Z_S] (i.e. Z_0, Z_1, Z_2). Conversion back and forth between these impedances can be done via the transformation matrix [A].

a) Work together to design/draw a detailed "3-line" diagram that includes the source, line, bus, impedances, VTs, and CTs. Extend the CT and VT secondary connections to a generic relay that is monitoring the line. (These relays are 67, but could be 50/51 or 21). For the source, assume that it is wye-connected with the possibility of a non-zero neutral grounding impedance Z_N. Various types of faults can appear anywhere along the length of the line, and include a fault impedance Z_F.

b) Working with <u>phase domain impedances</u>, develop a strategy for calculating the phase voltages and currents input to the relay for all 4 types of faults, both near- and far-end. You can use MatLab (if that makes sense) and/or ASPEN (if that makes sense), with the goal of learning the most important concepts. Do hand calcs to verify correct calculation is being done.

c) The "deliverable" of this assignment can be achieved either in Matlab or ASPEN: Given the numeric values of source and line impedances, CT and VT ratios, fault location, and fault type (LG, LL, LLG, or 3ph), provide a) a phasor plot of the Vs and Is that each 67-relay element "sees" for each fault. b) Recommend appropriate "max torque angle" setting (i.e. voltage polarization) for phase and ground elements such that every fault will be correctly detected.