Massachusetts Institute of Technology
Department of Electrical Engineering and Computer Science
6.061 Introduction to Power Systems

Problem Set 5

Problem 1: Shown in Figure 1 is a length of transmission line which is 600 km long. It is driven in the middle by a current source as shown: we assume this current source is a short pulse, 10,000 A in magnitude and of duration $100\mu S$. The line is shorted at one end and terminated by an impedance equivalent to it's characteristic, or *surge* impedance which is 250Ω. Assume that the phase velocity for waves on the line is the speed of light: $C = 3 \times 10^8$ m/S.
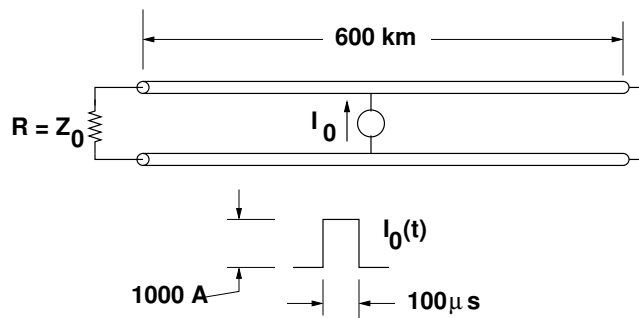

Figure 1: Transmission Line Example

1. What is the current in the short at the right-hand end of the problem?
2. What is the voltage across the terminating resistor at the left-hand end?

Your answers to both of these parts should be labeled, dimensioned sketches. Assume the current surge starts at time $t = 0$.

Problem 2: The same transmission line is to be operated at 60 Hz and with a voltage, at the sending end, of 500 kV (RMS). (Note there are no real 500 kV, single phase lines, but just give us a little space here...)

1. If the line is *open* at the receiving end, what is the magnitude of current drawn at the sending end?
2. If the line is terminated with a resistance equivalent to the surge impedance: $R_L = Z_0$, what are the receiving end voltage and sending end current? What are real and reactive power at the sending end?
3. Make the same estimates for a resistive load $R_L = \frac{Z_0}{.8}$
4. Make the same estimates for a resistive load $R_L = \frac{Z_0}{1.2}$

5. **For 6.979**: Calculate and plot receiving end voltage for real power loads of between zero and surge impedance loading, assuming unity power factor at the receiving end.

6. **For 6.979**: Now, assume that we can provide reactive compensation at the receiving end. Calculate and plot receiving end voltage for a reasonable range of compensating reactive VARs for real power loads of 80%, 100% and 120% of surge impedance loading. (You may do these for equivalent real admittance as the answer is really only important when voltage is nearly nominal).

Problem 3: A delta-wye transformer connection is shown in schematic form in Figure 2, This transformer is a step-down arrangement from 4.2 kV, line-line, to 600 V, line-line, both RMS. See Figure 3. The resistor on the wye side is drawing 100 A.
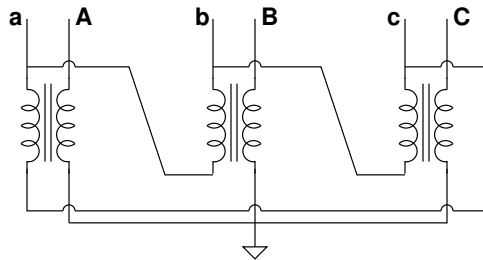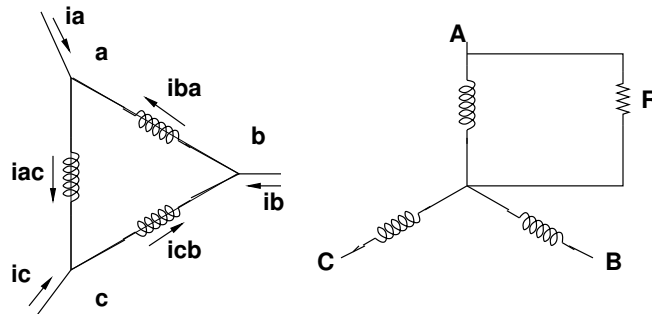

Figure 2: Transformer Hookup

Figure 3: Single-Phase Loaded Transformer Connection

1. How much power is being drawn on the wye side from each of the three transformer secondaries? (Yes, this is a simple question, don't get hung up on it).

2. What is the turn's ratio between the physical transformers that make up the three-phase transformer bank?

3. What are the three currents in the primary side of each of the three transformers? Show them in a reasonably proportioned vector diagram. Show as well the voltages across those transformer windings.

4. Now, what are the three currents into the terminals of the delta-connected transformer primary? Show them in a well proportioned vector diagram.

5. Assuming the source on the 4.2 kV side is wye connected, how much real and reactive power are being drawn from each phase? Does this correspond with power drawn by the load?

Problem 4: For 6.979: Now the situation is reversed as shown in Figure 4. This, too, is a 4.2 kV (line-line, RMS) to 600 V transformer, but this time the wye side is on the high voltage and the delta is on the low voltage. A single resistor, drawing 100 A, is connected across two of the terminals of the 600 V secondary. Initially the wye side of the transformer is *ungrounded*.
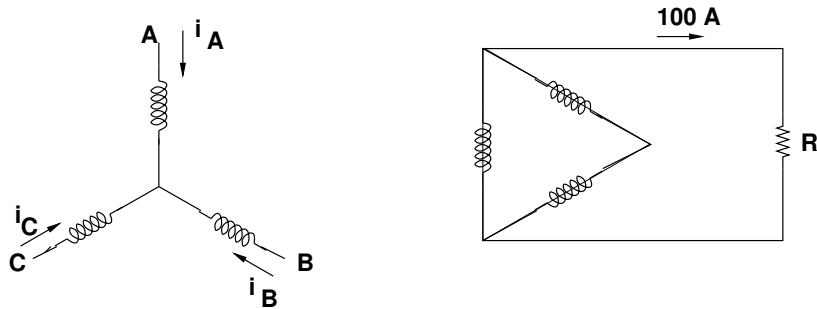

Figure 4: Voltage Source and Load

1. What is the physical turn's ratio of these transformers?

2. Assuming that the wye side of the transformer is connected to a voltage source, draw currents in the primary windings i_A, i_B and i_C, in relationship to the voltages on the wye side.

3. Show that the sum of real and reactive powers on the wye side matches the same quantities on the delta side.

4. Now the wye side of the transformer is grounded. What changes?