EE 137A Homework #3

due Thursday Sep 20, 2018

1. Three-Phase Definitions

A common transmission line voltage in California is labeled as "230 kV", referring to the rms line-to-line voltage.

(a) What is the rms line-to-neutral voltage?

(b) What is the maximum instantaneous voltage difference between any two phases?

(c) What is the maximum instantaneous voltage difference between any one phase and the transmission tower (which is presumably connected to ground)?

2. Wye and Delta Connections

Three identical impedances $Z = 20\ \angle 30^{\circ}$ are connected in a wye-configuration, where the line-to-neutral voltages are $V_A = 100\ \angle 0^{\circ}$, $V_B = 100\ \angle{-120^{\circ}}$, and $V_C = 100\ \angle 120^{\circ}$.

(a) Find the currents I_A, I_B, and I_C.

(b) Find the total three-phase power S_Y.

(c) Suppose the identical impedances Z are now connected instead in a delta (line-to-line) configuration across these phases, which still carry the same line-to-neutral voltages as before. Now find the current I_{AB}, I_{BC}, and I_{CA} in each load.

(d) Find the total three-phase power S_Δ.

(e) What would the impedance for the delta connection have to be in order to yield the same power as in the wye connection before?

3. Three-Phase Loads

A three-phase load draws 240 kW at a power factor of 0.707 lagging, from a 440-V line (labeled by convention in terms of the line-to-line voltage). You don't have to know whether this load is connected in a delta or wye configuration. In parallel with the previous load is a three-phase capacitor bank that "supplies" 60 kVAR.

(a) Find the total current on any single phase of the line leading to the load-capacitor combination.

(b) Find the power factor of the parallel combination.

(c) Why don't you have to know whether it's delta or wye? (Surely, something would have to be different in either case?!) What is the quantity that would be different, but doesn't affect your answers to (a) and (b)?

4. More Three-Phase Loads

A three-phase motor draws 20 kVA at 0.707 p.f. lagging from a 220-V source.

(a) Find the kVA rating of the capacitors to make the combined power factor 0.90 lagging.

(b) Find the line current (on any one phase) before and after the capacitors are added.

5. Power Transfer Problem

Study the example from a classic textbook (Grainger & Stevenson) illustrated below.

Note that both machines are modeled as voltage sources, but they could be either generating or consuming real and reactive power in any combination (this is known as “four quadrant” operation). Without knowing what’s inside each machine, we simply assume that it has whatever physical resources it needs to maintain the stated voltage under any current flow condition, regardless of the timing of the current with respect to the voltage.

Repeat the example with the same voltages, but taking the impedance between the two machines to be capacitive instead of inductive, with Z = -j5 ohms.

(a) Determine whether each machine is generating or consuming real power.

(b) Determine whether each machine is “generating” or “consuming” reactive power.

(c) Find the amount of reactive power “absorbed” by the impedance. (“Absorb,” “receive” and “consume” reactive power are all synonyms for behaving like an inductor.)

(d) (e) (f) Repeat parts (a) (b) (c) with an impedance of Z = 5 + j10 ohms. Before you work through the arithmetic, try to answer qualitatively how you expect this case to compare to the pure inductive and the pure capacitive cases.

(g) Compare your actual results and discuss briefly. Were the results what you expected?

(h) Why did I put quotation marks around generating or consuming reactive power, but not real power? Explain in your own words. Also, you are welcome to critique the solution by Grainger & Stevenson below. Was it perfectly clear to you, or how could the explanation be improved?

Example 1.1. Two ideal voltage sources designated as machines 1 and 2 are connected, as shown in Fig. 1.10. If $E_1 = 100\angle 0^\circ$ V, $E_2 = 100\angle 30^\circ$ V, and $Z = 0 + j5\ \Omega$, determine (*a*) whether each machine is generating or consuming real power and the amount, (*b*) whether each machine is receiving or supplying reactive power and the amount, and (*c*) the P and Q absorbed by the impedance.

Solution

$$I = \frac{E_1 - E_2}{Z} = \frac{100 + j0 - (86.6 + j50)}{j5}$$

$$= \frac{13.4 - j50}{j5} = -10 - j2.68 = 10.35\angle 195^\circ \text{ A}$$

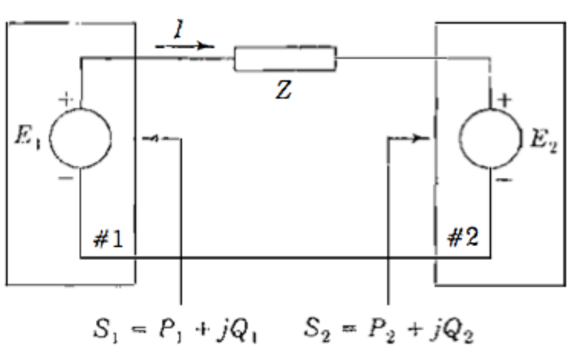


FIGURE 1.10
Ideal voltage sources connected through impedance Z.

The current entering box 1 is $-I$ and that entering box 2 is I so that

$$S_1 = E_1(-I)^* = P_1 + jQ_1 = 100(10 + j2.68)^* = 1000 - j268\,\text{VA}$$

$$S_2 = E_2 I^* = P_2 + jQ_2 = (86.6 + j50)(-10 + j2.68) = -1000 - j268\,\text{VA}$$

The reactive power absorbed in the series impedance is

$$|I|^2 X = 10.35^2 \times 5 = 536\,\text{var}$$

Machine 1 may be expected to be a generator because of the current direction and polarity markings. However, since P_1 is positive and Q_1 is negative, the machine consumes energy at the rate of 1000 W and supplies reactive power of 268 var. The machine is actually a motor.

Machine 2, expected to be a motor, has negative P_2 and negative Q_2. Therefore, this machine generates energy at the rate of 1000 W and supplies reactive power of 268 var. The machine is actually a generator.

Note that the supplied reactive power of 268 + 268 is equal to 536 var, which is required by the inductive reactance of 5 Ω. Since the impedance is purely reactive, no P is consumed by the impedance, and all the watts generated by machine 2 are transferred to machine 1.

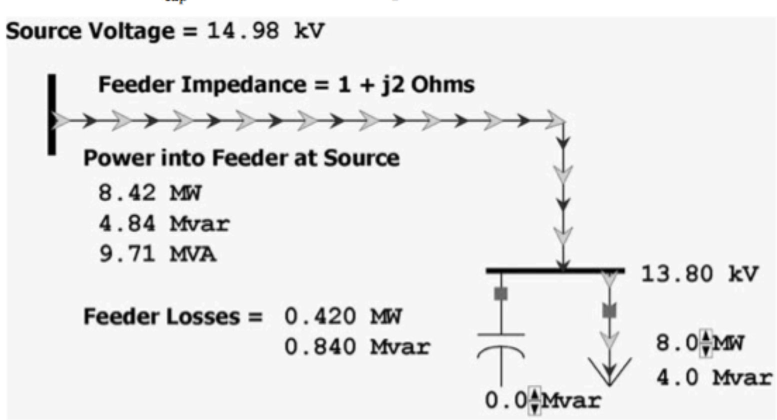
6. Capacitors in PowerWorld

Do Problems 2.32, 2.33 and 2.34 in GOS. Summarize your results, but don't worry about the exact numerical answers. For each question, state your observations about how the case changes when you adjust the parameters, and what concept you think each problem was supposed to teach.

PW **2.32** In PowerWorld Simulator Problem 2.32 (see Figure 2.28) a 8 MW/4 Mvar load is supplied at 13.8 kV through a feeder with an impedance of $1 + j2\ \Omega$. The load is compensated with a capacitor whose output, Q_{cap}, can be varied in 0.5 Mvar steps between 0 and 10.0 Mvars. What value of Q_{cap} minimizes the real power line losses? What value of Q_{cap} minimizes the MVA power flow into the feeder?

FIGURE 2.28

Screen for Problem 2.32



PW **2.33** For the system from Problem 2.32, plot the real and reactive line losses as Q_{cap} is varied between 0 and 10.0 Mvars.

PW **2.34** For the system from Problem 2.32, assume that half the time the load is 10 MW/5 Mvar, and for the other half it is 20 MW/10 Mvar. What single value of Q_{cap} would minimize the average losses? Assume that Q_{cap} can only be varied in 0.5 Mvar steps.

Recommended for additional practice (don't submit):

Problems 2.23, 2.24, 2.25 and 2.25 in GOS

Download the Power Quality Teaching Toy from
https://www.powerstandards.com/resources/teaching-toy/
Play with different displacement angles of the current relative to the voltage. When is reactive power in the power triangle negative? Does current magnitude matter for power factor? How does Alex's notation differ from that in our textbook?

Begin looking at the symmetrical components. You'll get to play with them more next week!