EE 137A Homework #4

due Thursday, Sep 27, 2018

1. Symmetrical Components

Open the Sequence Vectors Teaching Toy.

(a) By dragging the control buttons, create the scenario corresponding to $I_{1A} = 1 \angle 0^o$, $I_{2A} = 1 \angle 0^o$ and $I_{0A} = 0$ (that is, equal positive- and negative-sequence components in phase with each other, and no zero-sequence). Describe the resulting ABC phase currents, and draw a phasor addition diagram that illustrates how the addition of symmetrical components gives you the three phase currents.

(b) Now create the scenario corresponding to $I_{1A} = 1 \angle 0^o$, $I_{2A} = 0$ and $I_{0A} = 0.5 \angle 0^o$ Describe the resulting ABC phase currents, and draw a phasor addition diagram that illustrates how the addition of symmetrical components gives you the three phase currents.

(c) What happens if you change the relative angle of the zero-sequence component, I_0?

2. Harmonics and Power Factor

(a) Open the Harmonic Power Flow Teaching Toy and observe the scenario corresponding to $v(t) = \sqrt{2} \cdot 276 \cos(377\, t)$ and the third harmonic current $i_3(t) = \sqrt{2} \cdot 0.5 \cos(1131\, t)$. Stated more simply, $V_{rms} = 276$ V and $I_{3rms} = 0.5$ A. What are the real and apparent power transferred to the load?

(b) Now consider the case where V remains the same as before but the total current is described by $i(t) = \sqrt{2}\,\{\cos \omega t + 0.5 \cos 3\omega t\}$, or $I_{1rms} = 1$A and $I_{3rms} = 0.5$ A. (You can't show this in the Teaching Toy, by the way.) What is the total harmonic distortion (THD)? What are the real and apparent power transferred to the load, and what is the true power factor?

(c) Does the third harmonic current affects real power transferred into the load? Why, or why not?

3. Harmonics and Source Impedance

Suppose an industrial customer has a large nonlinear load that creates current harmonics.

(a) Why would this customer or their neighbors be concerned about the source impedance and its effect?

(b) What difference does it make whether the source impedance is resistive or inductive?

4. Brainteaser

A single-phase load draws 20A at 240V and delivers 3.36kW of real power.

(a) Based on this information, what is the power factor?

(b) Without giving too much thought to the exact nature of the load, the owner decides to install a parallel capacitor for reactive compensation adjacent to the load, with a kVAR rating intended to correct the power factor to 1.0 under the above assumptions. What is that kVAR rating? Draw a diagram illustrating P, Q and S for the load and capacitor.

(c) What is the current in the capacitor under these conditions?

(d) What is the new expected current for the load-capacitor combination?

(e) The current is measured again after the capacitor is installed and the load is the same as before, but to your considerable surprise, the current does not appear to have changed very much at all: the ammeter still reads about 20A. Nothing is wrong with the capacitor or with your instrument, but of course it only measures the magnitude of the current, not the angle. How can you explain this situation? Draw a new diagram based on your hypothesis.

(f) If your hypothesis above was correct, what would have been the best kVAR rating for the capacitor?

5. Power Transfer

Consider the situation shown in the diagram, where two voltages sources are connected by an impedance $Z = jX$. The voltage sources could represent generators or loads; all we know about them is that they maintain a certain voltage, but the power flow into or out of them could vary. The purely inductive impedance between them represents a simple transmission line. This is a generalization and extension of a previous homework problem.

(a) Write down general expressions for P_{12} and Q_{12}, the real and reactive power transferred from Source 1 to Source 2, in terms of the voltages at either end of the transmission line.

(b) Determine the condition for maximum real power transfer P_{12} to occur.

(c) Let $\delta_1 = 30^\circ$, $\delta_2 = 0^\circ$, and the magnitudes $V_1 = V_2 = 10$ V and $X = 1\ \Omega$. Determine the current, and the real and reactive power injected or consumed by each source, and by the transmission link. Does it all add up? Describe the whole scenario in a sentence.

(d) Change the angle of Source 1 to $\delta_1 = 45^\circ$ and leave everything else the same as in part a. How do the current and power transfer among the circuit components change? Discuss.

(e) Keep $\delta_1 = 30^\circ$, $\delta_2 = 0^\circ$ and change the voltage magnitudes to $V_1 = 8.36$ and $V_2 = 4.18$ V. Using these new source voltages, how does power transfer change compared to part a.? What stays the same?

(f) Draw a phasor diagram describing the three scenarios above.