EELE 354 Lab Assignment 7: AC Power Measurement and Power Factor Correction

LAB OVERVIEW:

In Lab 6, we learned about the implications of reactive circuit components (capacitors and inductors) on the relationship between the current and voltage through the circuit. In this lab, we will learn about the implications of a reactive load on the power requirements. As mentioned in class, an inductive load, e.g. an induction motor, causes the current supplied to the load to lag the applied voltage. This is because the inductive load requires **reactive power** for operation. In an induction motor, energy is stored in the magnetic field required for the motor's operation, and returned to the power source, e.g. the electric grid, during times when the instantaneous current has an opposite sign than that of the source voltage. This power flow operation was discussed in lecture.

The **real power** demanded by a load is the power consumed by the load in performing useful work. It is generally measured in Watts (W). The **reactive power** is power that is required by the load for operation, but is returned to the power source following storage in the form of energy (recall that power is the time rate of energy transfer). This type of power is usually measured in volt-amperes reactive (VAR). The **apparent power** is the vector sum of these two and is measured in volt-amperes (VA).

The utility is concerned about this total apparent power because even though its reactive power component is not consumed by the load, in fact it is returned, it causes an increase in the magnitude of the current required by the load. This increased current leads to larger losses in transmission due to the resistance of the transmission lines (recall Lab 3 where we learned about voltage drop in an extension cable). Thus, inductive loads require larger and more expensive components in generation and transmission systems in order to accommodate the larger currents. For example, to avoid excessive losses due to increased current in power transmission, larger cables with less resistance are required (we will discuss conductor sizing later in class). Due to this, utilities will often charge premium rates to industrial and commercial consumers (residential consumers are generally too small to worry about) who have a low **power factor**, usually below 0.9. This power factor is the ratio of real power to apparent power.

In this lab, you will use a small cooling fan to represent an inductive load. You will observe and measure the real, reactive, and apparent power requirements of this load when connected to a 120 V ac, 60 Hz voltage source. Additionally, you will learn about power factor correction. As you will see in this lab, by placing a capacitor in parallel with the fan, you can reduce the reactive power required of the voltage source which will in turn reduce to the total current required of the power source and increased the total load power factor.

Objectives:

The objectives of this laboratory assignment are:

- Observe and measure the real, reactive, and apparent power requirements of a typical inductive load.

- Observe and measure the effects of power factor correction through the use of a capacitor bank.

- Further familiarize yourself with AC circuits and machines, and their analysis.

Pre-lab Assignment:

Read through the entire lab assignment.

Part I: Below, draw the schematic diagram for a cooling fan (AC motor) connected to the 120 V ac, 60-Hz single-phase supply through a power analyzer. Table 1-1E of your text book gives you a symbol for an AC motor.

Part II: Draw the schematic diagram for the same circuit as Part I, except also show the presence of a capacitor **in parallel** with the motor. As in Lab 6, we will initially use a current limiting resistor in series with the capacitor so ensure you include that resistor in your diagram.

LAB EXPERIMENT PART I: POWER FACTOR

1. Once your schematic diagram from Part I of the pre-lab is approved, construct the circuit.

2. **Have your instructor approve your circuit.** Energize your circuit and turn the fan on to the high-power setting.

3. In the table below, record the supply voltage magnitude, $|V_{in}|$, the total circuit current magnitude, $|I|$, the real power consumed by the load, P, the reactive power required by the load, Q, the apparent power supplied by the source, S, and the resulting power factor, PF. **Note: In your book, the variables, P_L and P_{app} are used for the inductive reactive power and apparent power, respectively. However, in industry, Q and S are far more commonly used so ensure you know their meaning.**

	Supply Voltage $|V_{in}|$	Circuit Current $|I|$	Real Power P	Reactive Power Q	Apparent Power S	Power Factor PF
High speed						
Low speed						

4. Set the fan speed to low and repeat step 3.

5. De-energize the circuit and in the spaces below, draw the phasor diagram for the circuit voltage and current under both speeds. Your diagrams should use the supply voltage phasor as a reference by plotting it on the positive horizontal axis. Additionally, label the angle between phasors. You will need to calculate this angle from the equation, $PF = \cos(\phi)$ where ϕ is the angle between current and voltage.

High speed phasor diagram   **Low speed phasor diagram**

6. Draw the power phasor diagram for the circuit at both speeds. This diagram should show the real power phasor (as the reference on the positive horizontal axis), the reactive power phasor, and the resulting apparent power phasor. The angle of the apparent power phasor, which is the same as the angle between current and voltage, should be labeled.

   High speed phasor diagram   **Low speed phasor diagram**

7. To correct the power factor of the fan to be around 100% (unity) when operating at high speed, we can add an appropriately sized capacitor to the circuit in parallel with the motor. This is accomplished by adding a capacitor with a reactance equal in magnitude to that of the circuit's inductance. That is, the capacitive reactive power is equal to that of the inductive reactive power, but with an opposite angle (due to inductance current *lagging* and capacitance current *leading* the voltage). Calculate this ideal capacitance value by solving the following equations for C.

   a. Set Q_C (reactive power of capacitor) equal to that of the AC motor, Q.

   $$Q_C = Q$$

   b. Solve for capacitive reactance, X_C.

   $$Q_C = \frac{|V_{in}|^2}{X_C}$$

   c. Solve for capacitance, C.

   $$X_C = \frac{1}{2\pi f C}$$

   $Q_C =$ _____ VAR, $X_C =$ _____ Ω, $C =$ _____ F

Lab Experiment Part II: Power Factor Correction

8. From the capacitors at your lab bench, choose the one that is closest in value to what you calculated in step 7. Insert this capacitor into your circuit, along with a series connected current limiting resistor, in parallel with the fan. **Have your lab instructor approve your circuit; then energize it in front of your instructor.**

9. After a few seconds, short the resistor you have in series with the capacitor and record all data as you did in steps 4 and 5 into the table below.

	Supply Voltage $|V_{in}|$	Circuit Current $|I|$	Real Power P	Reactive Power Q	Apparent Power S	Power Factor PF
High speed with capacitor						
Low speed with capacitor						

10. Using the data above, re-draw your current and voltage phasor diagrams showing the effect of connecting the capacitor in parallel with the motor. These diagrams should show the phasor voltage as reference along with the circuit current phasor and the angle between the two.

   High speed phasor diagram　　　　　　**Low speed phasor diagram**

11. Re-draw your power phasor diagrams below.

   High speed phasor diagram   **Low speed phasor diagram**

12. Compare the fan data without and with the capacitor connected. Did the addition of the capacitor increase or decrease the current magnitude supplied by the source? Did it increase or decrease the apparent power? Explain.

Name and initial of lab partners:

Lab Partner 1: _____

Lab Partner 2: _____

Lab Partner 3: _____