ECE 3251 – Electromagnetic Energy Conversion

Lab #2: Three-Phase Measurements

Laboratory Goals

- Review safety hazards and procedures to mitigate risk in the laboratory
- Review basic operation of lab benches and operation of LabVIEW data collection and measurement system
- Relate basic principles on voltage, current, impedance, power, and power factor in a three-phase system learned in class to actual hardware used in lab

Safety Protocols:

- **Before starting, be sure you know where the Emergency Cut-Off button for you bench is located.**
- **ALWAYS turn the variac to zero volts BEFORE switching loads**

Three-Phase Power Systems

Most electric power is generated and transmitted in three-phase form. In a balanced three-phase system, whether generator, motor, or passive load, all single-phase components of the network are identical in frequency and magnitude of voltage, current or impedance. The only difference is the phase delay between the three voltages and currents of the individual elements, which are ±120º out of phase with one another.

Shown in **Figure 1** are balanced wye-connected impedances connected to a wye-connected generator. However, the connection (wye or delta) of the load or generator does not affect the power relationships for balanced three-phase circuits.

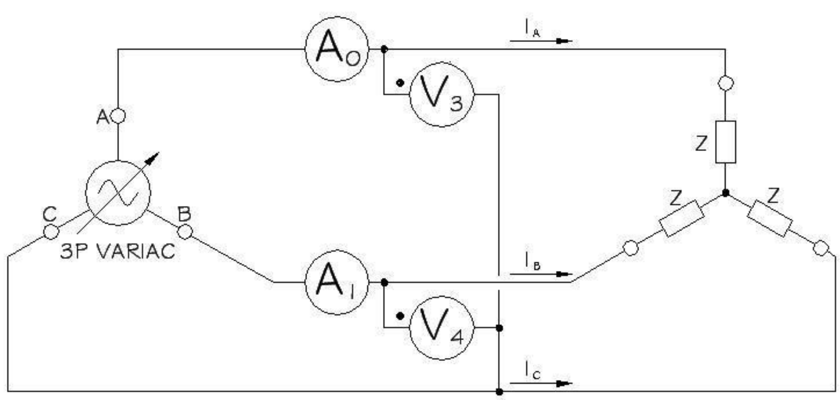

Figure 1. Balanced Y-Connected Impedances connected to a Y-Connected Source

Some helpful Power Relations:

$\boldsymbol{S} = \boldsymbol{VI}^* \rightarrow \text{Units: VA}$

$S = P + jQ$

$P = VI\cos(\theta) = |S|\cos(\theta) \rightarrow \text{Units: W}$

$Q = VI\sin(\theta) = |S|\sin(\theta) \rightarrow \text{Units: VAR}$

Often it may not be known how the source or load is connected. For a balanced system in which the phase currents lag phase voltages by an angle of θ, the wattmeter readings will be:

$$W_A = V_{AC} I_A cos(\theta_{vAC} - \theta_{iA})$$

And

$$W_B = V_{BC} I_B cos(\theta_{vBC} - \theta_{iB})$$

Doing some vector math, we can write:

$$W_A = V_{line} I_{line} \cos(30° + \theta)$$

And

$$W_B = V_{line} I_{line} \cos(30° - \theta)$$

By applying some trigonometry, we get:

$$P_{3P} = W_A + W_B = \sqrt{3} V_{line} I_{line} \cos(\theta)$$

And

$$Q_{3P} = \sqrt{3}|W_A - W_B| = \sqrt{3} V_{line} I_{line} \sin(\theta)$$

We can find the power angle as:

$$\theta = \arctan\left(\frac{Q_{3P}}{P_{3P}}\right) = \arctan\left(\frac{\sqrt{3}|W_A - W_B|}{W_A + W_B}\right)$$

Thus two wattmeters connected as in **Figure 1** can be used to determine all three-phase quantities including the power factor of the system. It is not critical whether the wattmeters are connected in lines A and B (as shown in **Figure 1**), lines B and C, or lines A and C.

Lab Procedures

1. Read the safety protocols at the beginning of this document. Yes, again. Be sure to turn the variac back to zero before switching loads!
2. **Three Phase Voltage** – Connect the three-phase portion of the "BENCH POWER PANEL" to the "AC HIGH VOLTAGE" inputs to the DATA ACQUISITION PANEL, first in a wye configuration, then wired for a delta configuration. Observe the three-phase voltages simultaneously on the LabVIEW voltage graph for both wye and delta configurations. Take a screen shot of each configuration and also record the RMS voltages measured in each case. Do the relative voltages between the two configurations make sense?
3. **Three-Phase Power Measurement** – Wire one of the Three-Phase variac ("AC-DC POWER & AC LOAD PANEL") to the Three-Phase Load ("AC LOAD PANEL") as shown in **Figure 2**. Measure the voltage, current, and power for each channel for a resistive load at 60V and 120V (phase voltage).

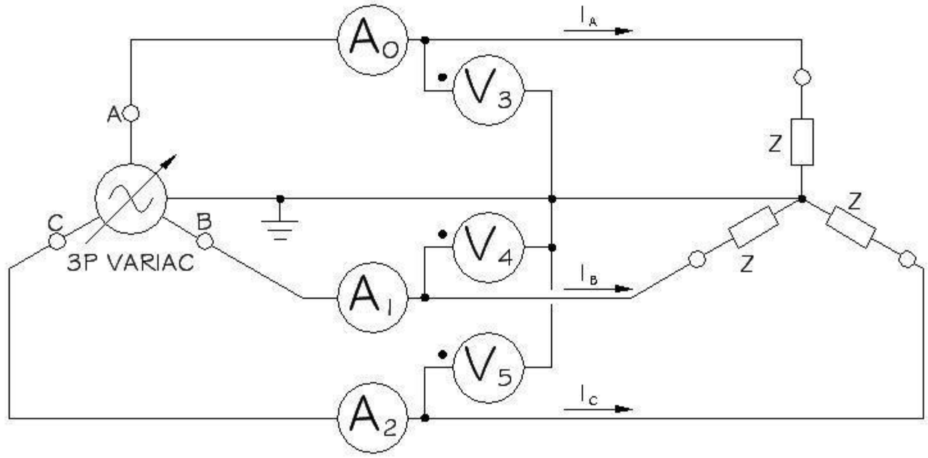

Figure 2. Three-Phase Power Measurement

Turn the variac to zero and then switch on the inductive load only. Observe and record (screen shot) of the graph of the three-phase current at 120V. Next, turn the power off and disconnect the neutral from the AC LOAD PANEL and then restore the power. Observe the graph of the three-phase current. For both of these cases (with and without neutral), record voltage, current, and power on all three phases.

4. **Two Wattmeter Method** – Change the configuration of the voltage/current measurement devices to the two watt-meter method as shown in **Figure 1**. Measure both resistive and resistive/inductive three-phase loads at 60V and 120V. Note that the *phase* voltages should be 60V and 120V, but the two-wattmeter measurement is looking at *line* voltages, so be sure to set the voltage correctly. For each load determine the following quantities: three-phase P and Q, θ, PF (lag/lead), R, Z, and X. Does the total three-phase power measured with the two-wattmeter method match the total three-phase power measured in the previous step?
5. **Clean up** – Turn off the power to your bench (both circuit breakers) and return all cables to the racks in an orderly fashion.

Grading

- Formal report: Organization, neatness, clear writing, proper formatting of graphs, figures, tables, etc. (15 points)
- Lab Participation: Contributions from each lab partner are fairly distributed and documented (10 points)
- Introduction: What is the purpose of this lab? (5 points)
- Procedures: Brief account of the steps to obtain results (10 points)
- Results: Measurements and calculations for each lab step (40 points)
- Conclusions: Analysis and explanation of data (20 points)