EE320 LAB EXERCISE #4
"Three-Phase Circuits"
Fall 2011

Name: ________________________ **Partner(s):** ___________________________

Problem: In this exercise, we will gain experience in building a 3-phase system, establishing anticipated results using per-phase analysis, taking voltage and current measurements, and using the two-wattmeter method to make three-phase power measurements.

The circuit we will investigate is shown in Figure 1. Note that two phases of the power analyzer have already been inserted into the circuit to measure voltage, current and real power.

- Voltmeter V_1 measures the (Line-to-neutral , Line , Phase) Voltage: _______
- Voltmeter V_2 measures the (Line-to-neutral , Line , Phase) Voltage: _______
- Ammeter A_1 measures which Line Current? ________
- Ammeter A_2 measures which Line Current? ________
- Load 1 is connected in (Y , Δ)
- Load 2 is connected in (Y , Δ)

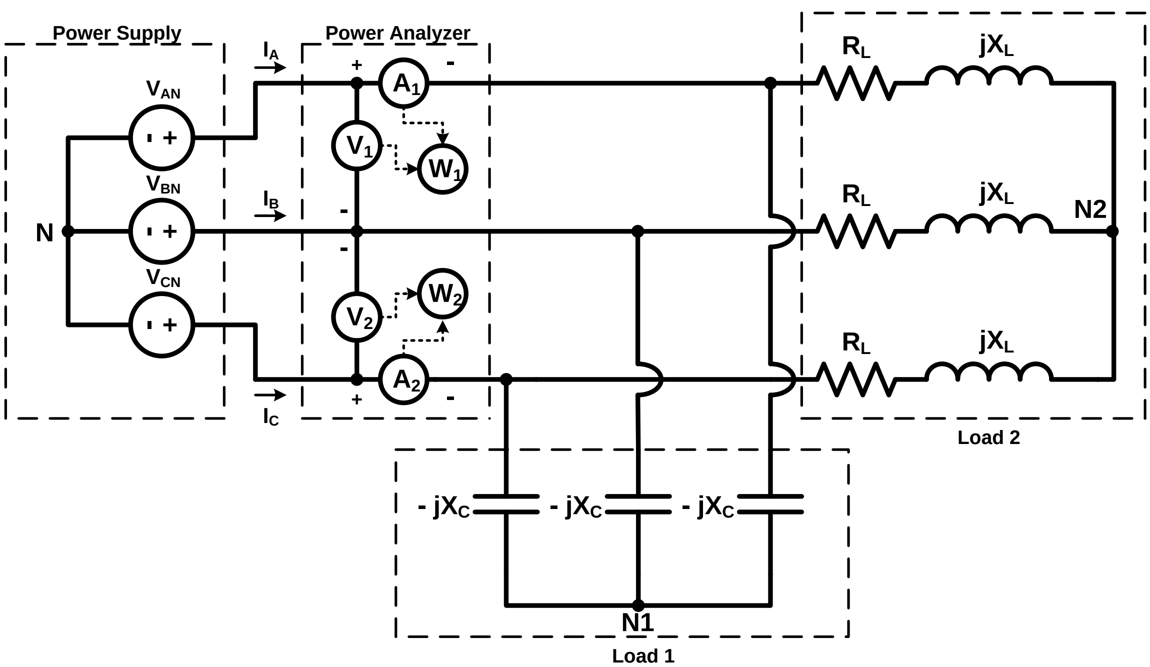

Figure 1: Circuit of Interest

Based on the power analyzer connections, the corresponding Channel 1 and Channel 2 wattmeters will calculate the following real powers

$$W_1 = |\tilde{V}_1||\tilde{I}_1|\cos\left[\angle\tilde{V}_1 - \angle\tilde{I}_1\right]$$
$$W_2 = |\tilde{V}_2||\tilde{I}_2|\cos\left[\angle\tilde{V}_2 - \angle\tilde{I}_2\right]$$

Note, since the voltages are line voltages, these are NOT the real powers absorbed by the A and C phase of the aggregate load. Instead, we will find that the two readings can be used to establish the total three-phase real and reactive powers of the system via

$$P_{3P} = P_A + P_B$$
$$Q_{3P} = \sqrt{3}\left(P_B - P_A\right)$$

Establishing which wattmeter (W_1 and W_2) is which real power (P_A and P_B) will dictate the sign on Q_{3P}. We will determine this by our knowledge of the loads and by experimentation. Let's incrementally build up this circuit with our hardware!

<u>Step 1:</u> As shown in Figure 2,

- Create the neutral for Load 1 (as shown in Fig. 1) by connecting the bottoms of the capacitor phase legs
- Series connect the resistance phase legs to the inductor phase legs
- Create the neutral for Load 2 by connecting the bottoms of the inductor phase legs

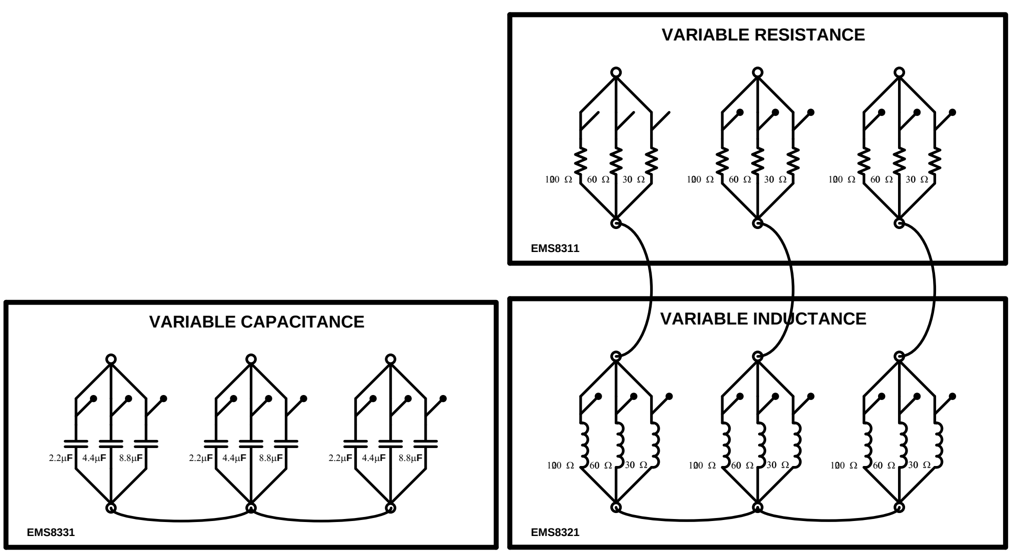

Figure 2: Step 1 Connection Diagram

Step 2: Place the two loads in parallel by connecting the top of the phase legs of the capacitor module to the top of the phase legs of the resistor module as shown in Figure 3.

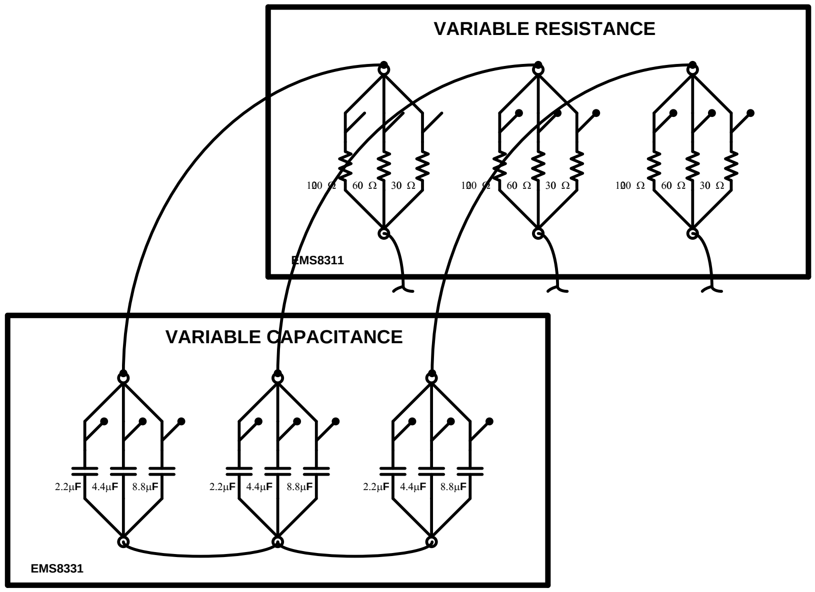

Figure 3: Step 2 Connection Diagram

Step 3A: (IF YOU HAVE THE PM300 POWER ANALYZER) Next, let's complete the connections between the power supply and the power analyzer

- ***THE POWER SUPPLY SHOULD REMAIN OFF***
- The Channel 1 Yellow (positive) voltmeter and ammeter jacks should be connected to Terminal 1 of the Power Supply
- The Channel 2 Yellow (positive) voltmeter and ammeter jacks should be connected to Terminal 3 of the Power Supply
- The Channel 1 & 2 Black (negative) voltmeter jacks should be connected to Terminal 2 of the Power Supply

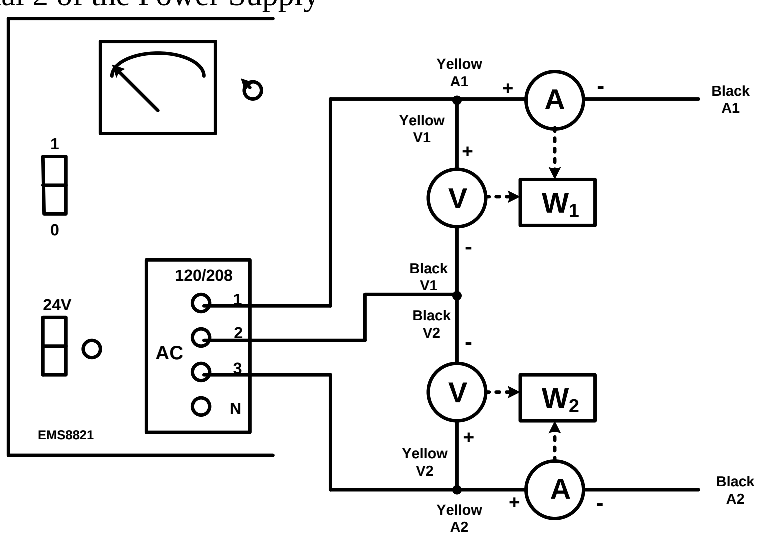

Figure 4A: Step 3A Connection Diagram

<u>Steps 3B-4B:</u> (IF YOU HAVE THE AEMC 3945 POWER ANALYZER) Next, let's complete the connections between the power supply, the power analyzer, and the load

- ***THE POWER SUPPLY SHOULD REMAIN OFF***
- Connect Power Supply terminal 1 to the top right resistor module terminal; clamp current probe L1 on this cable. Attach voltmeter connection L1 to Power Supply terminal 1.
- Connect Power Supply terminal 2 to the top middle resistor module terminal. Attach voltmeter connection N to Power Supply terminal 2.
- Connect Power Supply terminal 3 to the top left resistor module terminal; clamp current probe L2 on this cable. Attach voltmeter connection L2 to Power Supply terminal 3.

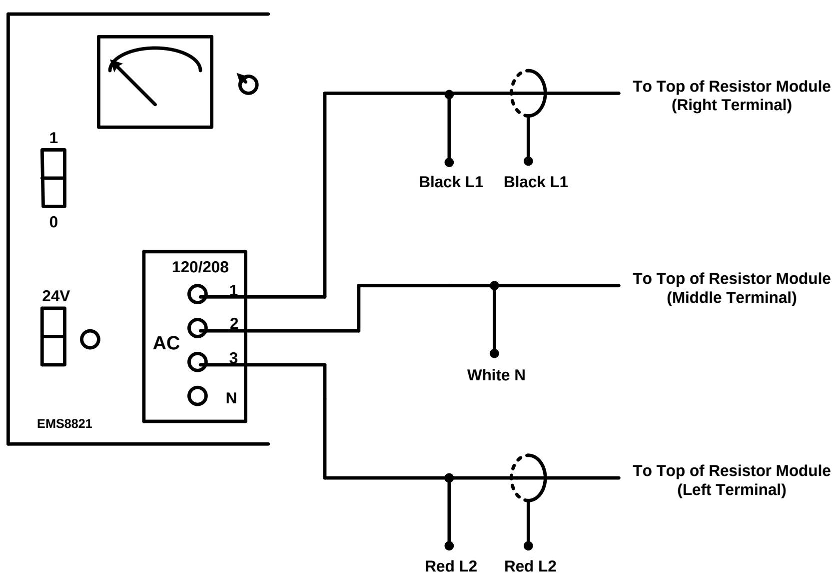

Figure 4B: Step 3B-4B Connection Diagram

<u>Step 4A:</u> (IF YOU HAVE THE PM300 POWER ANALYZER) Finally, we can couple the Power Analyzer connections to the Loads as shown in Figure 5

- The Black (negative) A1 terminal of the power analyzer ammeter should connect to the top left terminal of the resistance module
- The Black (negative) A2 terminal of the power analyzer ammeter should connect to the top right terminal of the resistance module
- The top middle terminal of the resistance module should connect back to where the Black V1 and V2 (negative) terminals of the voltmeter are connected to terminal 2 of the Power Supply

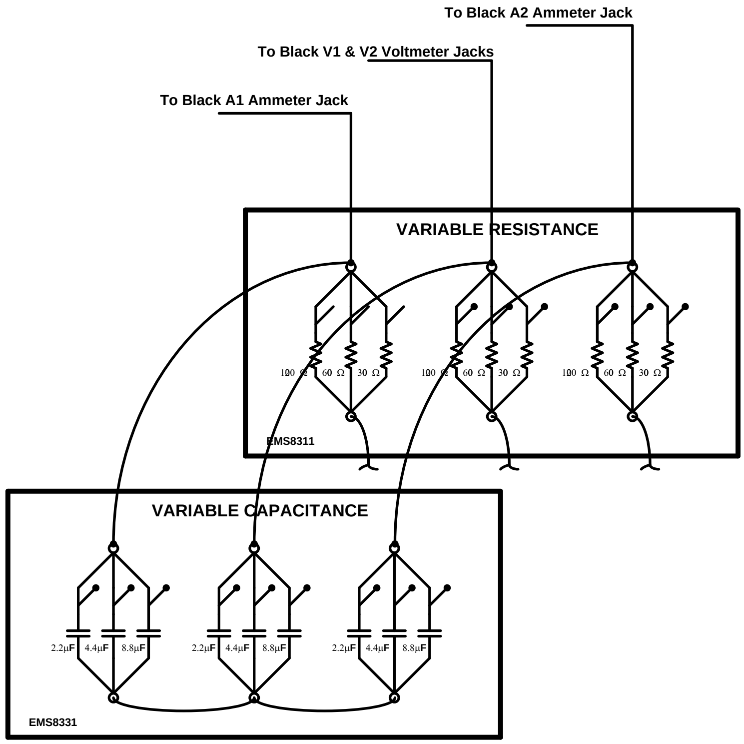

Figure 5: Step 4 Connection Diagram

Step 5: Set the Variable Resistor/Inductor/Capacitor Modules as follows

- All switches up (ON) per leg of the resistance module
  What is the per-phase resistance with this setting? ________________
- All switches UP (ON) per leg of the inductance module
  What is the per-phase inductive reactance with this setting? ________________
- All switches DOWN (OFF) per leg of the capacitance module
  What is the per-phase capacitive reactance with this setting? ________________

HAVE THE INSTRUCTOR VERIFY YOUR SETUP: ____________________

Step 6: Energize the power supply and record the Power Analyzer measurements

	CH1	CH2	$\sum$
V			**X**
I			**X**
P			

- Is the configured aggregate load inductive or capacitive? ________________
- Should the three-phase reactive power absorbed by the aggregate load be positive or negative? __________________
- Based on two wattmeter discussion on page 2, which channel wattmeter must correspond to P_B (W_1 or W_2)? _________
- Determine the three-phase real power: __________________
- Determine the three-phase reactive power: _________________
- Compute the average of the measured line voltages, then calculate the corresponding line-to-neutral voltage (show the equation that you used):
- Sketch the per-phase equivalent circuit using the voltage value above and the theoretical impedance values

- Compute the expected line current from the previous circuit. Is this reasonably close to the measured value?

<u>Step 7:</u> Next let's investigate the neutral current.

- ***DE-ENERGIZE THE POWER SUPPLY***
- Using the hand-held Fluke meter (as an ammeter), make a connection between the *neutral of the power supply* (terminal N) and the *neutral of the RL-load*

<u>HAVE THE INSTRUCTOR VERIFY YOUR SETUP</u>: ____________________

- Energize the power supply
- Record the Fluke ammeter reading: _____________

  What is the anticipated reading?

- Next change the setting of one phase of the *inductor module*. Instead of all three switches UP, set only the 1200Ω switch UP (NOTE, for only one phase of the three-phase connection). This will make the load unbalanced.

- Record the Fluke ammeter reading: _____________

- How does this value compare with the measured line currents from the power analyzer?

- ***DE-ENERGIZE THE POWER SUPPLY***

- ***RETURN THE INDUCTANCE MODULE TO ITS BALANCED SETTING WITH ALL SWITCHES UP***

<u>Step 8:</u> We will next investigate how the measured values change as the capacitance module is adjusted

- Set the Capacitance Module so that $X_C = 1200\Omega$ per leg (Note the capacitor impedance is $Z_C = -jX_C$)
- Energize the power supply
- Record the Power Analyzer data

	CH1	**CH2**	$\sum$
V			**X**
I			**X**
P			

- Compute the three-phase real and reactive powers (show the equation you used)

P_{3P} =__________________________________=______________

Q_{3P} =__________________________________=______________

- Compute the average line voltage from your measurements and then calculate the corresponding line-to-neutral voltage

- Using the per-phase equivalent circuit, compute the expected line current. How close is this to the measured value?

<u>Step 9:</u> Adjust the capacitance module again

- ***DE-ENERGIZE THE POWER SUPPLY***
- Set the Capacitance Module so that $X_C = 400\Omega$ per leg
- Energize the power supply
- Record the Power Analyzer data

	CH1	**CH2**	$\sum$
V			**X**
I			**X**
P			

- Compute the three-phase real and reactive powers (show the equation you used)

P_{3P} =__________________________________=______________

Q_{3P} =__________________________________=______________

- Compute the average line voltage from your measurements and then calculate the corresponding line-to-neutral voltage

- Using the per-phase equivalent circuit, compute the expected line current. How close is this to the measured value?

<u>Step 10:</u> Adjust the capacitance module one last time

- ***DE-ENERGIZE THE POWER SUPPLY***
- Set the Capacitance Module so that $X_C = 171\Omega$ per leg
- Energize the power supply
- Record the Power Analyzer data

	CH1	CH2	$\sum$
V			**X**
I			**X**
P			

- Compute the three-phase real and reactive powers (show the equation you used)

$P_{3P} =$ ___________________________________ = ______________

$Q_{3P} =$ ___________________________________ = ______________

- Compute the average line voltage from your measurements and then calculate the corresponding line-to-neutral voltage

- Using the per-phase equivalent circuit, compute the expected line current. How close is this to the measured value?

Step 11: De-energize the power supply and disconnect all connection cabling

Follow-up Problem: Assuming a balanced set of 3-phase voltages for the source, compute the neutral current for the unbalanced conditions specified in Step 7, where we have not yet included any capacitance in the circuit. (**Hint**: KVL will allow you to find each phase current then apply KCL to get the neutral current. The ammeter essentially looks like a short circuit between the neutrals.)