EE 330/330L Energy Systems (Spring 2012)
Laboratory 1 Three-Phase Loads

Introduction/Background

In this laboratory, you will measure and study the voltages, currents, impedances, phase angles, power factors, and real & reactive power in balanced three-phase systems. In particular, balanced Y-Y (Fig. 1a) and Δ–Δ (Fig. 1b) three-phase systems will be studied. Also, an unbalanced Y-Y system is examined.

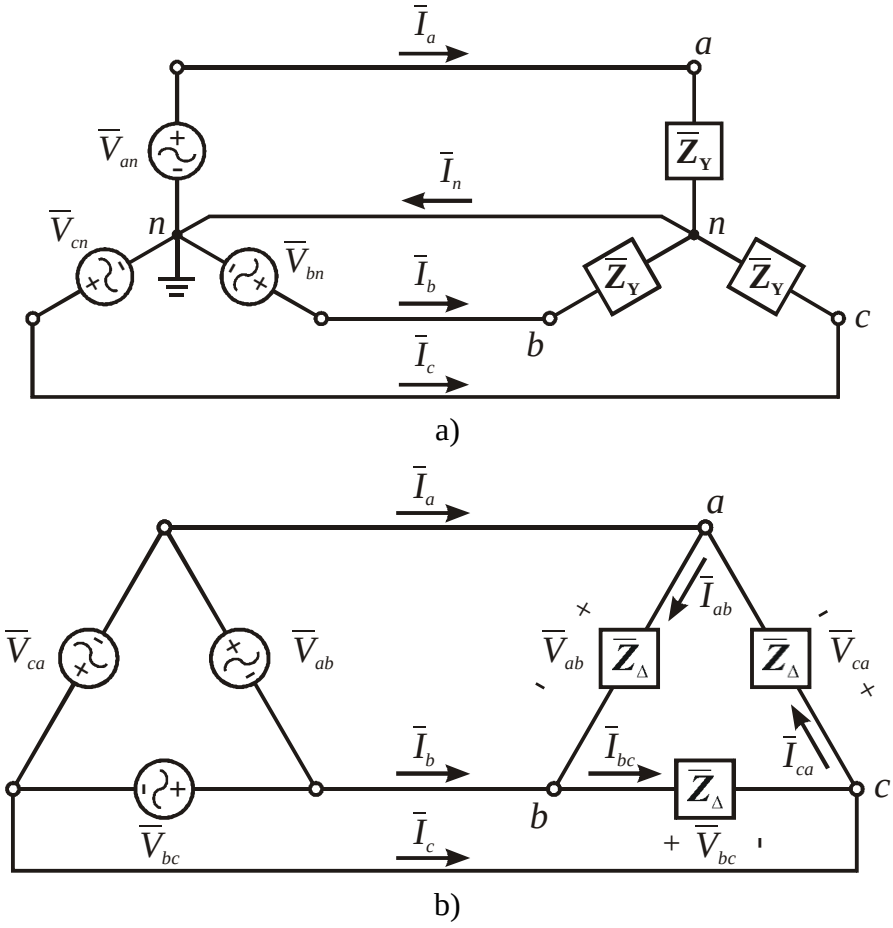

Figure 1 Balanced a) Y-Y (4-wire) and b) Δ–Δ three-phase systems.

Preliminary

1) For the balanced Y-Y three-phase circuit shown in Fig. 1a, the phase voltages V_{an}, V_{bn}, & V_{cn} are 63.5 V_{rms}. For a load impedance $\bar{Z}_Y = 100\,\Omega$, determine the line/phase currents $I_L = I_a = I_b = I_c$, neutral current I_n, line-to-line voltages $V_{LL} = V_{ab} = V_{bc} = V_{ca}$, phase apparent powers $S_a = S_b = S_c$, total apparent power S, phase powers $P_a = P_b = P_c$, total power P, phase reactive powers $Q_a = Q_b = Q_c$, total reactive power Q, phase power factors $pf_a = pf_b = pf_c$, and overall power factor pf.
2) Assuming a frequency of 60 Hz, repeat part 1 when inductors with a wire resistance of 15 Ω and inductance of 0.175 H are placed in series with the loads of part 1. What is the new load impedance $\bar{Z}_Y$? Tabulate answers from parts 1 & 2 (e.g., column 1 quantity name, column 2 part 1 answer, and column 3 part 2 answer).
3) For the balanced Δ–Δ three-phase circuit shown in Fig. 1b, the line-to-line/phase voltages V_{ab}, V_{bc}, & V_{ca} are 90 $V_{rms.}$ The load impedance $\bar{Z}_\Delta$ is $100\,\Omega$ in series with inductors with a wire resistance of 15 Ω and inductance of 0.175 H. Assuming a frequency of 60 Hz, determine the phase currents I_ϕ =

$I_{ab} = I_{bc} = I_{ca}$, line currents $I_L = I_a = I_b = I_c$, phase apparent powers $S_{ab} = S_{bc} = S_{ca}$, total apparent power S, phase powers $P_{ab} = P_{bc} = P_{ca}$, total power P, phase reactive powers $Q_{ab} = Q_{bc} = Q_{ca}$, total reactive power Q, phase power factors $pf_{ab} = pf_{bc} = pf_{ca}$, and overall power factor pf. Tabulate answers.

4) Read through the following experiments and determine which equations will be needed for the calculations.

Experiment 1

1) Connect a balanced Y-Y three-phase circuit with load impedances of $\bar{Z}_Y \approx 100\Omega$ (use rheostats). A block diagram of the necessary connections, including wattmeters and ammeter, is shown in Fig. 2. Do **NOT** plug in the power cord at this point. Using an ohmmeter (multimeter), measure and record the dc resistances R_a, R_b, and R_c of the loads.

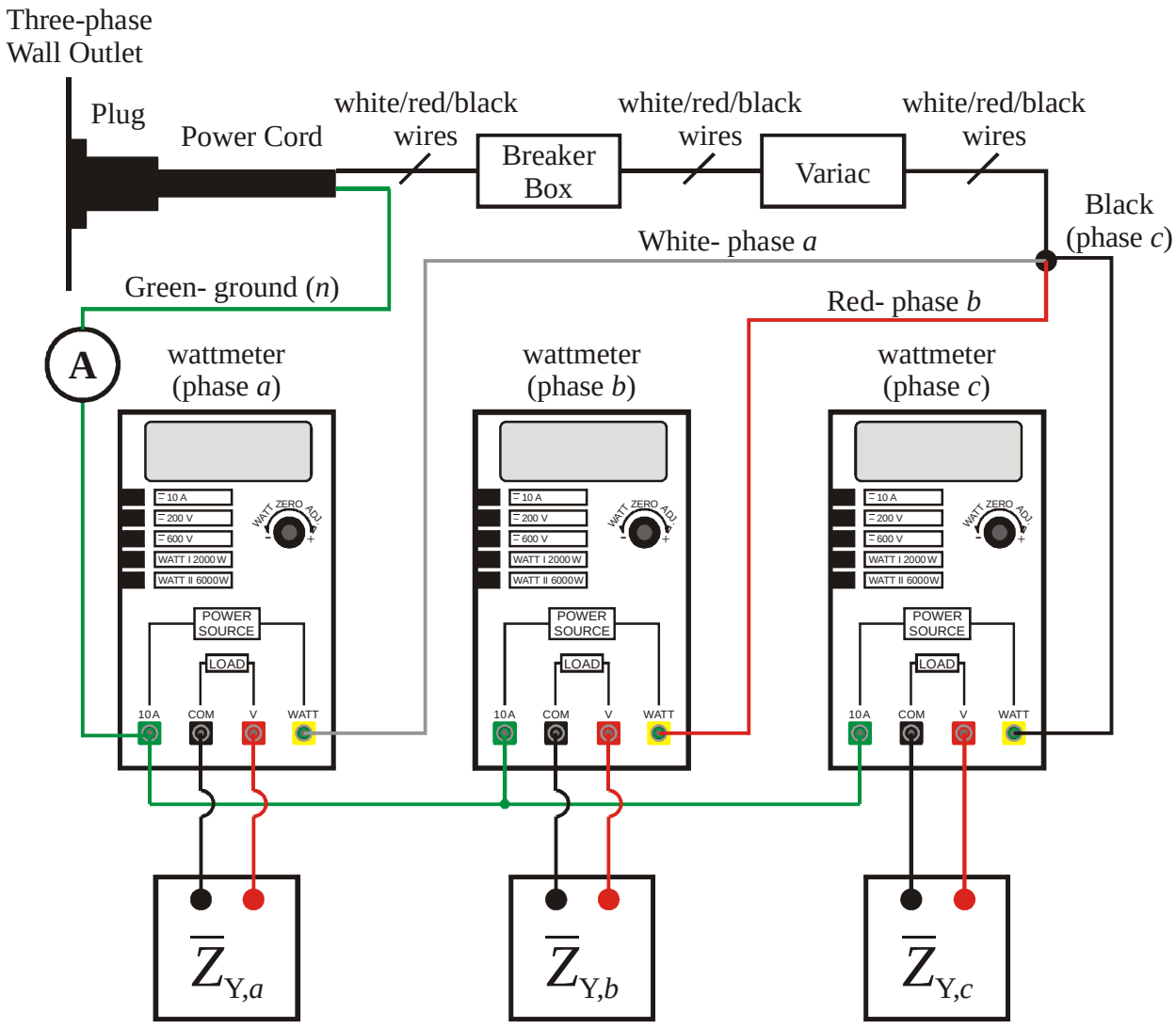

Figure 2 Balanced Y-Y three-phase circuit for Experiment 1.

2) After ensuring the breaker box is 'off' and that the variac is set to 0 (all the way CCW), plug in the power cord. Designate the white wire as phase a, red wire as phase b, and black wire as phase c (totally arbitrary). Use a voltmeter (multimeter) to measure the wall outlet line-to-line voltages V_{ab}, V_{bc}, & V_{ca} and phase voltages V_{an}, V_{bn}, & V_{cn} at the breaker box input jacks. Use the frequency measurement capability of the multimeter to verify that the frequency is ~60 Hz.

3) Turn on and zero the wattmeters in WATT I mode. Then, put the wattmeters in 200 V mode to measure the phase voltages. Turn on and ensure the ammeter (multimeter) is properly connected and set for ac current. Turn the breaker box 'on' and **slowly** increase the variac setting until phase voltages of ~63.5 V_{rms} are achieved.
4) Measure and record the actual phase voltages V_{an}, V_{bn}, and V_{cn}. Put the wattmeters in 10 A mode. Measure and record the phase currents I_a, I_b, and I_c. Put the wattmeters in 2000 W mode. Measure and record the phase powers P_a, P_b, and P_c.
5) Using the ammeter, measure and record the neutral current I_n.
6) Using a voltmeter (multimeter), measure and record the line-to-line voltages V_{ab}, V_{bc}, and V_{ca}.
7) Set the variac to 0 (i.e., rotate dial/knob all the way CCW), turn breaker box off, and unplug the power cord. Do **NOT** disassemble circuit.
8) Using the preceding measurements, determine the total power P, apparent powers S_a, S_b, & S_c, total apparent power S, power factors pf_a, pf_b, & pf_c, overall power factor pf, impedance phase angles θ_a, θ_b, & θ_c, load impedance magnitudes Z_a, Z_b, & Z_c, complex impedances $\bar{Z}_a$, $\bar{Z}_b$, & $\bar{Z}_c$ (put in rectangular form), reactive phase powers Q_a, Q_b, & Q_c, and total reactive power Q.
9) Tabulate nominal values and calculated answers from part 1 of the preliminary and experiment 1 (e.g., column 1- quantity name, column 2- part 1 answer, column 3- experiment 1 answer, & column 4- % difference, except for complex numbers). List in order measured/calculated in experiment 1. How do the calculated and measured quantities compare? Discuss discrepancies.

Experiment 2

1) Obtain three inductors from the instructor or teaching assistant (TA). Record the labeled inductance values of L_a, L_b, and L_c.
2) Modify the circuit of Experiment 1 by inserting the inductors in series with the ~100 Ω load impedances (rheostats). Then, measure and record the DC resistances of the inductors in series with the 100 Ω loads, i.e., $R_a + R_{w,a}$, $R_b + R_{w,b}$, and $R_c + R_{w,c}$.
3) After ensuring the breaker box is 'off' and that the variac is set to 0, plug in the power cord. If necessary, turn on and zero the wattmeters in WATT I mode. Then, put the wattmeters in 200 V mode to measure the phase voltages. Turn on and ensure the ammeter is properly connected and set for ac current. Turn the breaker box 'on' and **slowly** increase the variac setting until phase voltages of ~63.5 V_{rms} are achieved.
4) Measure and record V_{an}, V_{bn}, V_{cn}, I_a, I_b, I_c, P_a, P_b, P_c, I_n, V_{ab}, V_{bc}, and V_{ca}.
5) Set the variac to 0 (i.e., rotate dial/knob all the way CCW), turn breaker box off, and unplug the power cord. Do **NOT** disassemble circuit.
6) Using the preceding measurements, determine P, S_a, S_b, S_c, S, pf_a, pf_b, pf_c, pf, θ_a, θ_b, θ_c, Z_a, Z_b, Z_c, $\bar{Z}_a$, $\bar{Z}_b$, $\bar{Z}_c$ (put in rectangular form), Q_a, Q_b, Q_c, and Q.
7) Using $\bar{Z}_a$, $\bar{Z}_b$, and $\bar{Z}_c$, determine the measured values of L_a, L_b, and L_c. How do they compare with the labeled values? Does $\mathrm{Re}\left(\bar{Z}_a\right) = R_a + R_{w,a}$, $\mathrm{Re}\left(\bar{Z}_b\right) = R_b + R_{w,b}$, and $\mathrm{Re}\left(\bar{Z}_c\right) = R_c + R_{w,c}$?
8) Tabulate nominal values and calculated answers from part 2 of the preliminary and experiment 2 (e.g., column 1- quantity name, column 2- part 2 answer, column 3- experiment 2 answer, & column 4- % difference, except for complex numbers). List in order measured/calculated in experiment 2. How do the calculated and measured quantities compare? Discuss discrepancies.

Experiment 3

1) Connect a balanced Δ-Δ three-phase circuit with load impedances $\bar{Z}_{\Delta}$ each consisting of ~100 Ω load impedances in series with an inductor. Record the labeled values of L_{ab}, L_{bc}, and L_{ca}. Measure and record the dc resistances of the ~100 Ω loads in series with the inductors, i.e., $R_{ab} + R_{w,ab}$, $R_{bc} + R_{w,bc}$, and $R_{ca} + R_{w,ca}$. A block diagram of the necessary connections, including wattmeters and ammeters, is shown in Fig. 3. Do **NOT** plug in the power cord.

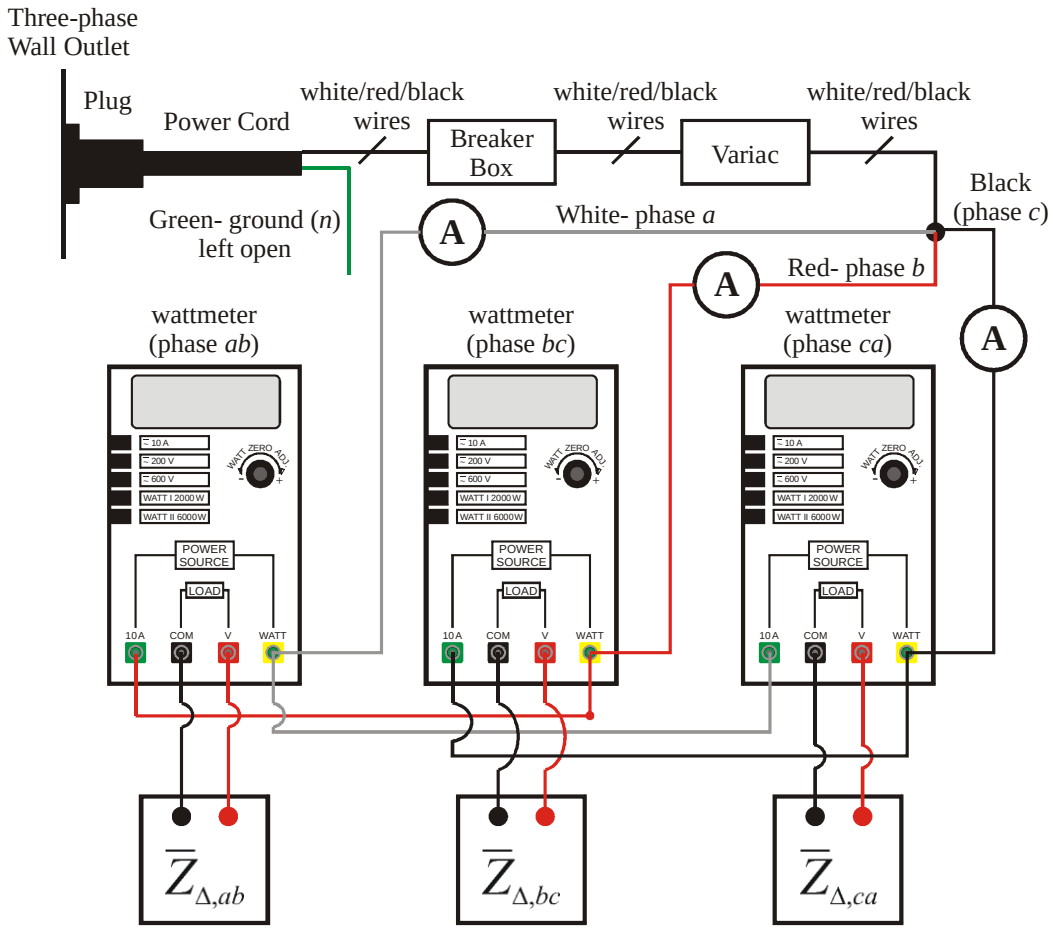

Figure 3 Balanced Δ-Δ three-phase circuit for experiment 4.

2) After ensuring the breaker box is 'off' and that the variac is set to 0 (all the way CCW), plug in the power cord. If necessary, turn on and zero the wattmeters in WATT I mode. Then, put the wattmeters in 200 V mode to measure the line-to-line/phase voltages. Turn on and ensure each ammeter (multimeter) is properly connected and set for ac current. Turn the breaker box 'on' and **slowly** increase the variac setting until line-to-line voltages of ~90 V_{rms} are achieved.
3) Measure and record the actual line-to-line/phase voltages V_{ab}, V_{bc}, & V_{ca}. Put the wattmeters in 10 A mode. Measure and record the phase currents I_{ab}, I_{bc}, & I_{ca}. Put the wattmeters in 2000 W mode. Measure and record the phase powers P_{ab}, P_{bc}, & P_{ca}.
4) Using the ammeters, measure and record the line currents I_a, I_b, and I_c.
5) Set the variac to 0 (i.e., rotate dial/knob all the way CCW), turn breaker box off, and unplug the power cord. Do **NOT** disassemble circuit.
6) Using the preceding measurements, determine the total power P, apparent powers S_{ab}, S_{bc}, & S_{ca}, total apparent power S, power factors pf_{ab}, pf_{bc}, & pf_{ca}, overall power factor pf, impedance phase

angles θ_{ab}, θ_{bc}, & θ_{ca}, load impedance magnitudes Z_{ab}, Z_{bc}, & Z_{ca}, complex impedances $\bar{Z}_{ab}$, $\bar{Z}_{bc}$, & $\bar{Z}_{ca}$ (put in rectangular form), reactive phase powers Q_{ab}, Q_{bc}, & Q_{ca}, and total reactive power Q.

7) Using $\bar{Z}_{ab}$, $\bar{Z}_{bc}$, & $\bar{Z}_{ca}$, determine the measured values of L_{ab}, L_{bc}, and L_{ca}. Compare with the labeled values. Does $\mathrm{Re}\left(\bar{Z}_{ab}\right) = R_{ab} + R_{w,ab}$, $\mathrm{Re}\left(\bar{Z}_{bc}\right) = R_{bc} + R_{w,bc}$, and $\mathrm{Re}\left(\bar{Z}_{ca}\right) = R_{ca} + R_{w,ca}$?

8) Tabulate nominal values and calculated answers from part 3 of the preliminary and experiment 3 (e.g., column 1- quantity name, column 2- part 3 answer, column 3- experiment 3 answer, & column 4- % difference, except for complex numbers). List in order measured/calculated in experiment 3. How do the calculated and measured quantities compare? Discuss discrepancies.

Summary and Conclusions

Summarize and discuss significant findings. Are your results consistent with theory? Why/why not?

Lab Report

- The results should be organized into a typed short report consisting of a Cover Page, Introduction, a Body broken down into subsections/paragraphs based on the steps in the laboratory, and a Summary & Conclusions. Where possible tabulate results.
- Unless otherwise specified, follow format guidelines contained in course syllabus.
- Put the calculations, results, and plots/figures in the body of the report in the order specified. Appendices are **NOT** to be used as a "dumping ground" for the calculations, results, and figures. However, long mathematical derivations may be attached as Appendices **if referenced in the text** of the report. Your logbook is definitely a reference item.

Due Monday, February 6, 2012 by 3 pm.

Deliver lab report and logbook at class, to my office (EP325), or mailbox in ECE office.