EE 330L Energy Systems Lab (Fall 2026)
Laboratory 4 Three-Phase Loads- Part 2

Introduction

In this laboratory, the voltages, currents, impedances, phase angles, power factors, and real & reactive power in three-phase systems will be measured and studied. In particular, a balanced 4-wire Y-Y, unbalanced 4-wire Y-Y, balanced 3-wire Y-Y, unbalanced 3-wire Y-Y, and balanced Δ–Δ three-phase systems will be considered. In addition to using three power meters, the two power meter method is introduced.

Experiment

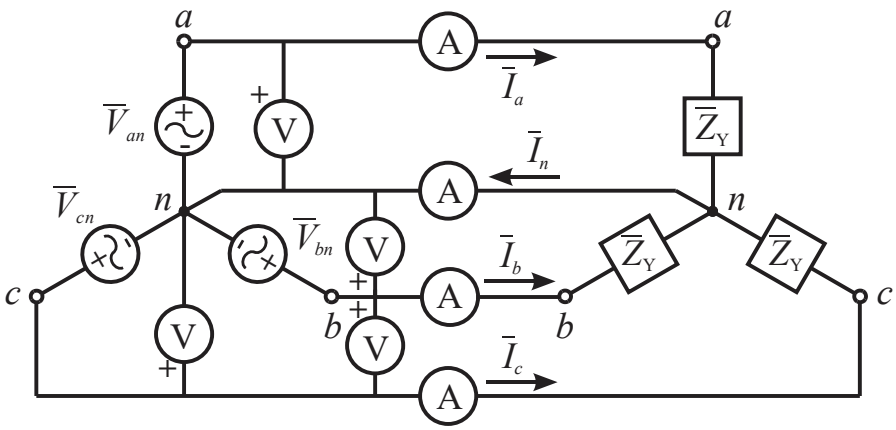
Here, the user will connect their computer to the LabVolt system, wire the three-phase circuits, and take measurements using the LVDAC-EMS software.

1) Check that the LabVolt system is in 'start-up' state by:
   - Verifying large power cord from back of the LabVolt system is plugged into 3-phase plug on wall. Alert instructor/TA if there is an issue, do **not** touch.
   - On the Power Supply 8525-20 EMS, ensure power switches located on left side are 0/OFF, turn small knob (upper center) to '4-N' position, and turn large knob (upper right) all the way counterclockwise (CCW) to '0'.
   - Ensuring all toggle switches on the Resistive Load 8311-00 EMS, Inductive Load 8321-00 EMS, and Capacitive Load 8331-00 EMS are in the down/0/OFF position.
   - Ensuring 'Power Input' jacks on the lower right of the Data Acquisition And Control Interface (DACI) EMS are disconnected.
   - Ensuring 'Power Input' switch is 0/OFF and no AC power cord is connected on lower left of the Four-Quadrant Dynamometer / Power Supply EMS 8960-30.
2) Plug JAMECO AC Adaptor (i.e., 'wall wart') into a 120 V wall outlet and plug cord into one of the 'Power Input' jacks located on the lower right of the DACI 9063-00 EMS. Connect USB cable (USB-A to USB-B) to your computer and the USB jack on the DACI EMS.
3) Start the LVDAC-EMS software on your computer. When the 'LVDAC-EMS Launcher' screen pops up, select 'Connected Mode'. When the 'LVDAC-EMS Start-up' screen pops up, verify 'Local Network Voltage and Frequency' has '120 V - 60 Hz' selected and click 'OK'. The 'LVDAC-EMS - Document 1' screen should now appear.

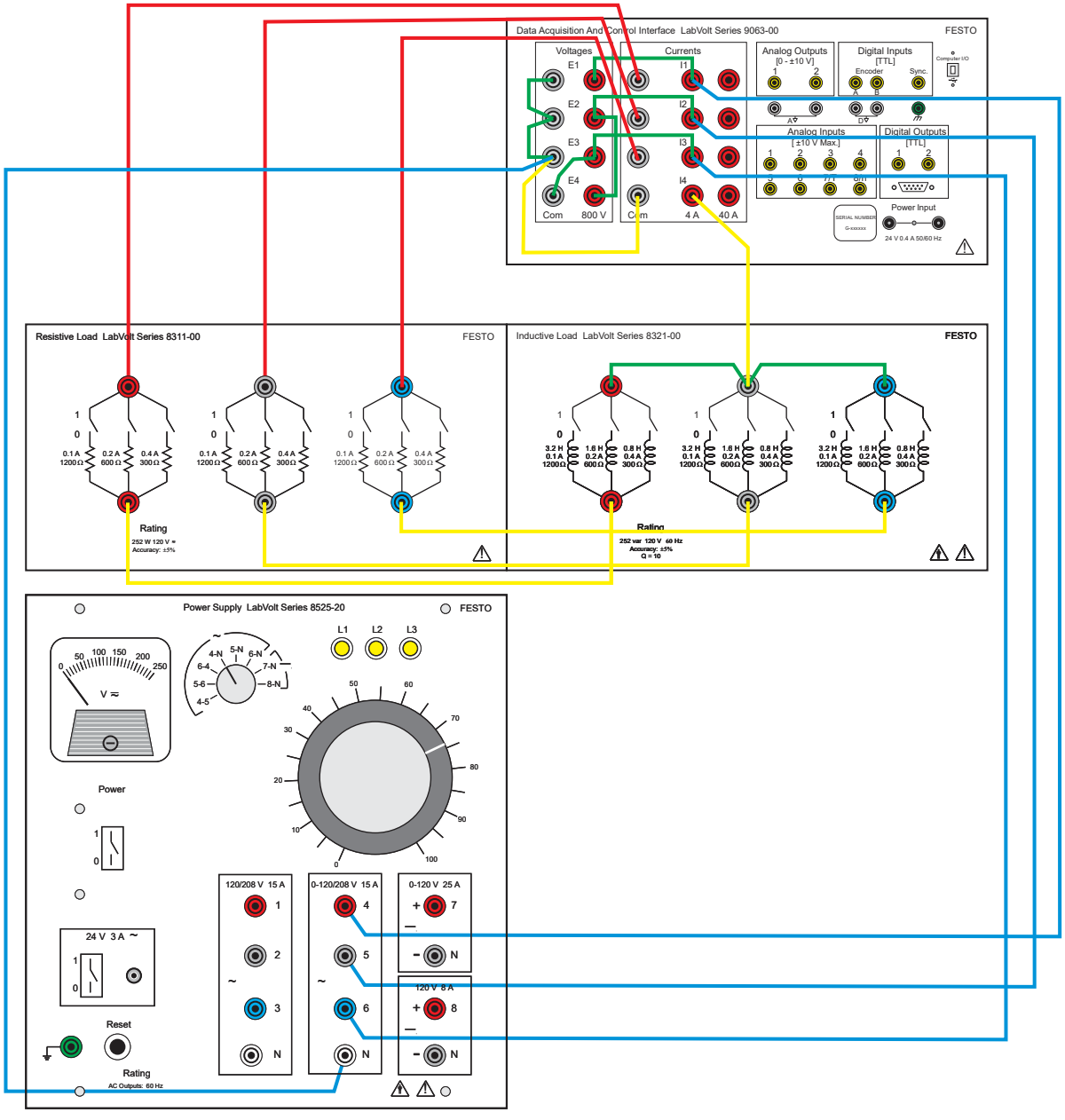
A. Balanced 4-wire Y-Y Three-Phase System

1) Set up the circuit shown conceptually in Figure 1a. The wiring connections are shown in Figure 1b (some components removed for clarity). **For clarity, white cords are shown as green.**

   Note: As a reminder, voltmeters are connected in **parallel** with the component(s) that we wish to measure the voltage across. Ammeters are connected in **series** with the component(s) that we wish to measure the current through. **NEVER** connect an ammeter in parallel!



(a)



(b)

Figure 1 a) Conceptual and b) Wiring Set-ups for Balanced 4-wire Y-Y Three-Phase System

2) Have instructor/TA inspect and approve the completed wiring connections. **Take picture.** Next, toggle the 'Power' switch (center left) to the upper/1/ON position. Three lamps labeled 'L1', 'L2', and 'L3' should light up and the voltage gauge (upper left) needle should be at 0 V.

3) On the 'LVDAC-EMS - Document 1' software screen on your computer, activate/select the 'Metering' instrument by clicking the icon on using the 'Instruments' drop-down menus.

4) By default, meters 'M1' - 'M4' in first row will show AC RMS voltages from 'E1' - 'E4' on DACI EMS. Rename 'M1' to 'Van', 'M2' to 'Vbn', 'M3' to 'Vcn', and 'M4' to 'Vbc' (V_{LL}).

5) By default, meters 'M7' - 'M10' in second row will show AC RMS currents from 'I1' - 'I4' on DACI EMS. Rename 'M7' to 'Ia', 'M8' to 'Ib', 'M9' to 'Ic', and 'M10' to 'In'.

6) By default, meter 'M13' should be measuring 'PQS1(E1,I1)'. Click the 'M13' icon to activate and change label to 'PQS_a'. By default, meter 'M14' should be measuring 'PQS2(E2,I2)'. Click the 'M14' icon to activate and change label to 'PQS_b'. By default, meter 'M15' should be measuring 'PQS3(E3,I3)'. Click the 'M15' icon to activate and change label to 'PQS_c'.

7) To connect the balanced Y-configured loads ($\overline{Z}_Y = 300 + j300\,\Omega$ **),** toggle the switches for 300 Ω resistors (red, black, & blue jacks) on Resistive Load EMS **and** 0.8 H/0.4 A/300 Ω inductors (red, black, & blue jacks) on Inductive Load EMS to the upper/1/ON position.

8) To set $V_\phi = 69.3\ V_{rms}$ on the Power Supply EMS, slowly turn the large knob (upper right) clockwise (CW) until meters 'M1' - 'M3' on the 'Metering' instrument read ~69.3 V.

9) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying P, Q, & S (e.g., Exp_A_P.jpg, Exp_A_Q.jpg, & Exp_A_S.jpg). Click 'Continuous Refresh' icon.

B. Unbalanced 4-wire Y-Y Three-Phase System

1) On the Power Supply EMS, click power switch located on left side OFF and ensure the lamps are dark. Do NOT touch any knobs! No wiring changes are needed.

2) To implement the unbalanced loads Y-configured loads, no changes are required on phase a (red), $\overline{Z}_{Y,a} = 300 + j300\,\Omega$. On phase b (black), toggle switch on Resistive Load EMS for 300 Ω resistor OFF and toggle switch for 600 Ω resistor ON, $\overline{Z}_{Y,b} = 600 + j300\,\Omega$. On phase c (blue), toggle switch on Inductive Load EMS for the 0.8 H/0.4 A/300 Ω inductor OFF and toggle switch for the 1.6 H/0.2 A/600 Ω inductor ON, $\overline{Z}_{Y,c} = 300 + j600\,\Omega$.

3) On the Power Supply EMS, click power switch located on left side ON and ensure meters 'M1' - 'M3' on the 'Metering' instrument still read ~69.3 V.

4) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying P, Q, & S (e.g., Exp_B_P.jpg, Exp_B_Q.jpg, & Exp_B_S.jpg). Click 'Continuous Refresh' icon.

5) On the Power Supply EMS, click power switch located on left side OFF and ensure the lamps are dark. Do NOT touch any knobs! Do NOT touch any wiring connections!

C. Balanced 3-wire Y-Y Three-Phase System

1) Here, you will set up the circuit shown conceptually in Figure 2a. The wiring connections are shown in Figure 2b (some components removed for clarity). **For clarity, white cords are shown as green.**

2) Careful examination of Figure 1b and Figure 2b shows that the only wiring changes required are the removal of two yellow cords, i.e., remove yellow cord between DACI EMS I4 red jack and top black jack of Inductive Load EMS and remove yellow cord between I4 black jack and DACI EMS E3 black jack. Have instructor/TA inspect and approve the completed wiring connections. **Take picture.**

3) On the 'Metering' instrument, deactivate meter 'M10' (no neutral current in 3-wire circuit).

4) To re-connect balanced Y-configured loads ($\overline{Z}_Y = 300 + j300\,\Omega$**),** toggle the switches for 300 Ω resistors (red, black, & blue jacks) on the Resistive Load EMS **and** 0.8 H/0.4 A/300 Ω inductors (red, black, & blue jacks) on the Inductive Load EMS to ON position. All other resistor and inductor switches should be OFF.

5) On the Power Supply EMS, click power switch located on left side ON and ensure meters 'M1' - 'M3' on the 'Metering' instrument still read ~69.3 V.

6) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying source P, Q, & S (e.g., Exp_C_P.jpg, Exp_C_Q.jpg, & Exp_C_S.jpg). Click 'Continuous Refresh' icon.

D. Unbalanced 3-wire Y-Y Three-Phase System

1) On the Power Supply EMS, click power switch located on left side OFF and ensure the lamps are dark. Do NOT touch any knobs! No wiring changes are needed.

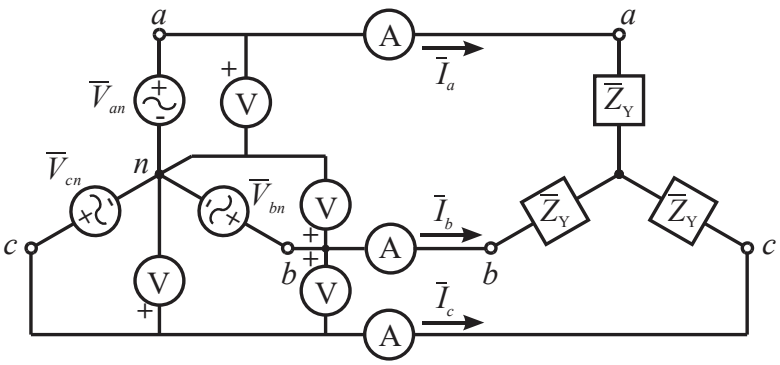
2) To implement the unbalanced loads Y-configured loads, no changes are required on phase a (red), $\overline{Z}_{Y,a} = 300 + j300\,\Omega$. On phase b (black), toggle switch on Resistive Load EMS for 300 Ω resistor OFF and toggle switch for 600 Ω resistor ON, $\overline{Z}_{Y,b} = 600 + j300\,\Omega$. On phase c (blue), toggle switch on Inductive Load EMS for the 0.8 H/0.4 A/300 Ω inductor OFF and toggle switch for the 1.6 H/0.2 A/600 Ω inductor ON, $\overline{Z}_{Y,c} = 300 + j600\,\Omega$.

3) On the Power Supply EMS, click power switch located on left side ON and ensure meters 'M1' - 'M3' on the 'Metering' instrument still read ~69.3 V.

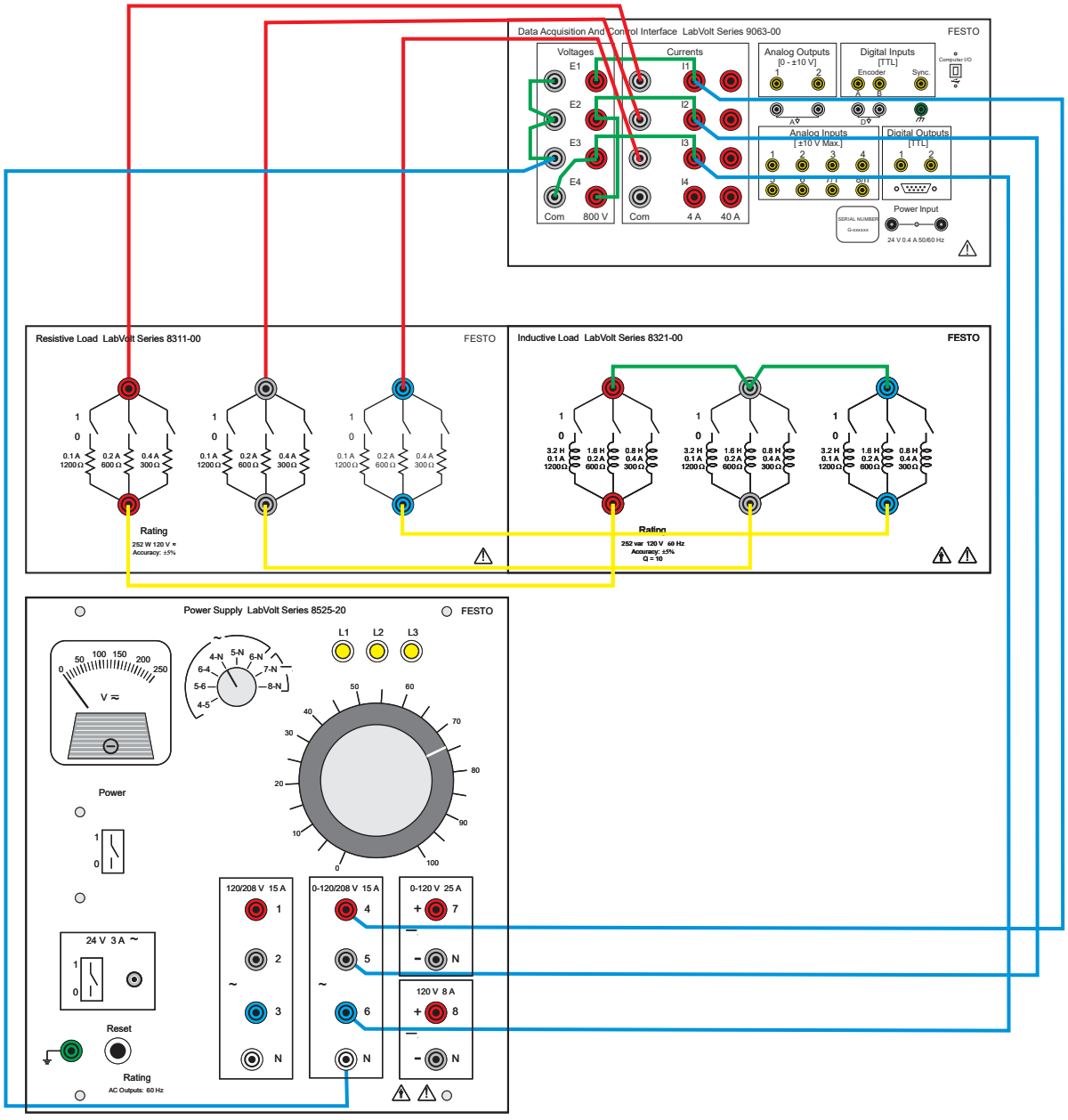
4) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying source P, Q, & S (e.g., Exp_D_P.jpg, Exp_D_Q.jpg, & Exp_D_S.jpg). Click 'Continuous Refresh' icon.

5) On the Power Supply EMS, click power switch located on left side OFF (ensure lamps are dark).

6) On the Power Supply EMS, turn large knob (upper right) all the way counterclockwise (CCW) to '0'. Disconnect circuit wiring connections.



(a)



(b)

Figure 2 a) Conceptual and b) Wiring Set-ups for Balanced 3-wire Y-Y Three-Phase System

E. Balanced Δ-Δ Three-Phase System (three power meter)

1) Here, you will set up the circuit shown conceptually in Figure 3a. The wiring connections are shown in Figure 3b (some components removed for clarity). **For clarity, white cords are shown as green.**

2) Have instructor/TA inspect and approve the completed wiring connections. **Take picture.**

3) On Metering instrument, rename 'M1' to 'Vab', 'M2' to 'Vbc', and 'M3' to 'Vca'. Deactivate 'M4'.

4) On Metering instrument, rename 'M7' to 'Iab', 'M8' to 'Ibc', 'M9' to 'Ica'. Activate 'M10' and rename to 'Ia'.

5) On Metering instrument, rename 'M13' to 'PQS_ab', 'M14' to 'PQS_bc', and 'M15' icon to 'PQS_ca'.

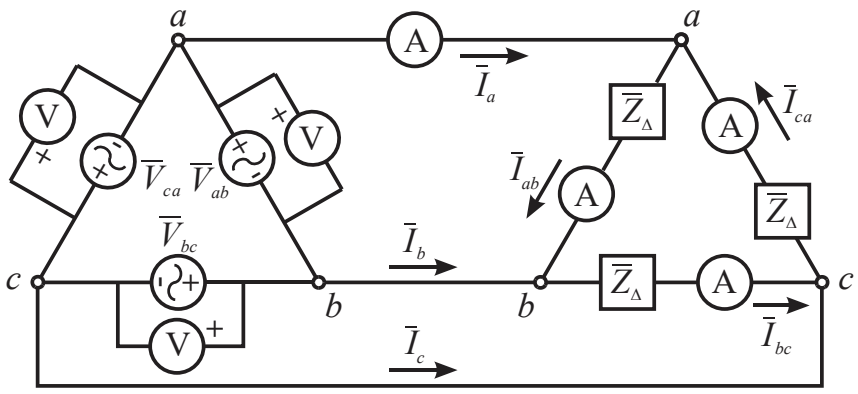
6) To connect the balanced Δ-configured loads ($\overline{Z}_{\Delta} = 300 + j300\,\Omega$ **),** toggle the switches for 300 Ω resistors (red, black, & blue jacks) on the Resistive Load EMS **and** 0.8 H/0.4 A/300 Ω inductors (red, black, & blue jacks) on the Inductive Load EMS to ON position. All other resistor and inductor switches should be OFF.

7) On Power Supply EMS, toggle the 'Power' switch (center left) to ON. Three lamps labeled 'L1', 'L2', and 'L3' should light up and the voltage gauge (upper left) needle should be at 0 V.

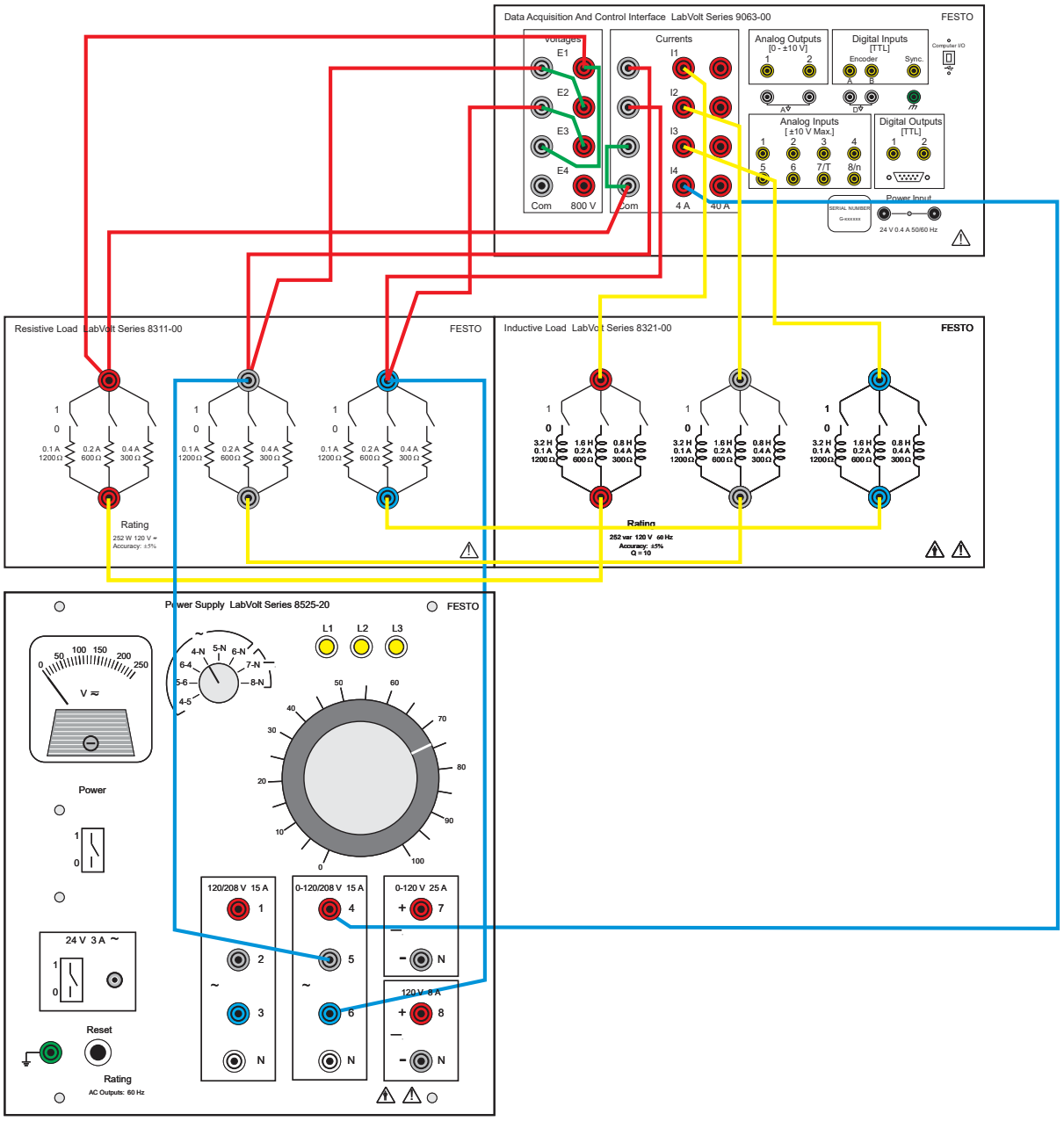
8) To set $V_{\phi} = 120\ V_{rms}$ on the Power Supply EMS, slowly turn the large knob (upper right) clockwise (CW) until meters 'M1' - 'M3' on the 'Metering' instrument read ~120 V. Ensure the currents are finite!

9) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying load P, Q, & S (e.g., Exp_E_3_meter_P.jpg, Exp_E_3_meter_Q.jpg, & Exp_E_3_meter_S.jpg). Click 'Continuous Refresh' icon.

10) On the Power Supply EMS, click power switch (center left) to OFF (ensure lamps are dark). Disconnect circuit wiring connections. Leave large knob (upper right) alone! Leave switches on Resistive Load EMS and Inductive Load EMS alone!



(a)



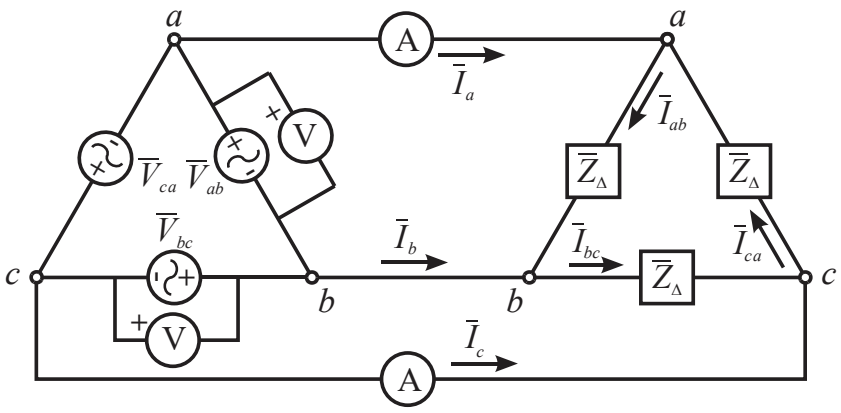
(b)

Figure 3 a) Conceptual and b) Wiring Set-ups for Balanced Δ-Δ 3-Phase System (three power meter)

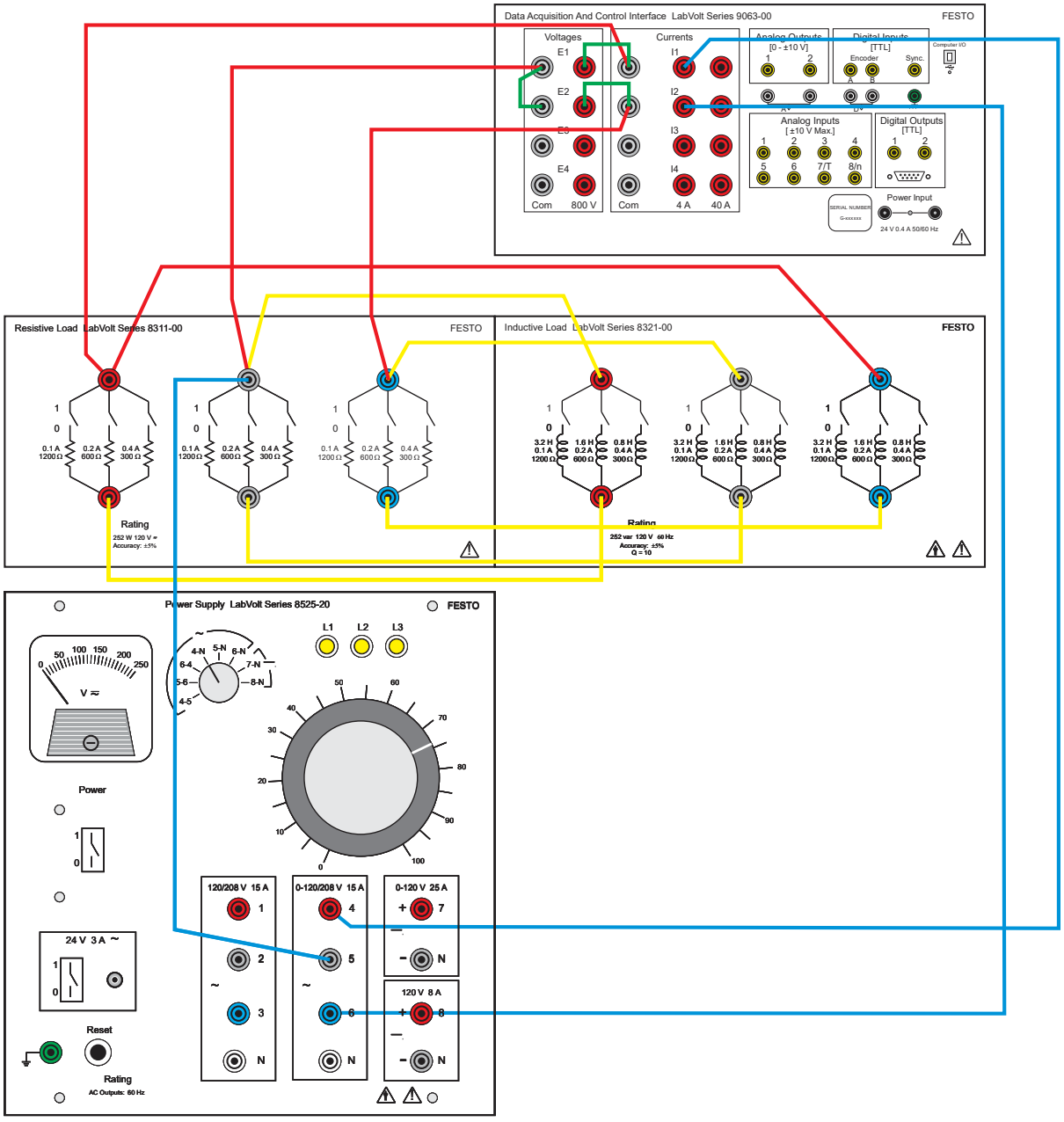
E/F. Balanced Δ-Δ Three-Phase System (two power meter)

Due to time limitations, we will only compare the three power meter and two power meter results for the balanced Δ-Δ three-phase system.

1) Here, you will set up the circuit shown conceptually in Figure 4a. The wiring connections are shown in Figure 4b (some components removed for clarity). **For clarity, white cords are shown as green.**
2) Have instructor/TA inspect and approve the completed wiring connections. **Take picture.**
3) On Metering instrument, rename 'M2' to 'Vcb'. 'M1' should be 'Vab'. Deactivate 'M3'.
4) On Metering instrument, rename 'M7' to 'Ia' and 'M8' to 'Ic'. Deactivate 'M9' and 'M10'.
5) On Metering instrument, rename 'M13' to 'PQS_VabIa' and 'M14' to 'PQS_VcbIc'. Deactivate 'M15'.
6) Confirm the balanced Δ-configured loads ($\overline{Z}_{\Delta} = 300 + j300\,\Omega$ **)** are still set for 300 Ω resistors on the Resistive Load EMS **and** 0.8 H/0.4 A/300 Ω inductors on the Inductive Load EMS. All other resistor and inductor switches should be OFF.
7) On the Power Supply EMS, click power switch located on left side ON. Ensure meters 'M1' and 'M2' on the 'Metering' instrument still read ~120 V.
8) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' - 'M15' successively displaying P, Q, & S (e.g., Exp_E_2_meter_P.jpg, Exp_E_2_meter_Q.jpg, & Exp_E_2_meter_S.jpg).
9) Lastly, shut down the LabVolt system by:
   - On the Power Supply, toggle the 'Power' switch (center left) to the lower/0/OFF position, and turn the large knob CCW to 0.
   - On the Resistive Load EMS, Inductive Load EMS, and Capacitive Load EMS, toggle all switches to the lower/0/OFF position.
   - Disconnect all cords and return to rack on side of the LabVolt system.
   - Disconnect the DACI EMS as a USB device from your computer. Then, disconnect the USB cable from the computer and DACI EMS.
   - Unplug JAMECO AC Adaptor from wall outlet and 'Power Input' jack on DACI EMS.
10) **Make an 'Equipment List' table** (include descriptions, model #s, & brands; only list EMS used).



(a)



(b)

Figure 4 a) Conceptual and b) Wiring Set-ups for Balanced Δ-Δ 3-Phase System (two power meter)

Post Lab Analysis

Requirements/hints/prompts:

A. Balanced 4-wire Y-Y Three-Phase System

1) Use saved screenshots to complete Table 1 with RMS magnitudes (not phasors).

Table 1 Currents and Voltages for Balanced 4-wire Y-Y Three-Phase System

Quantity	Value
I_a	
I_b	
I_c	
I_n	
V_{an}	
V_{bn}	
V_{cn}	
$V_{bc} = V_{LL,\text{exp}}$	

2) Compute average phase voltage, i.e., $V_{\phi,\text{exp}} = (V_{an} + V_{bn} + V_{cn}) / 3$. Compute the ratio $V_{LL,\text{exp}} / V_{\phi,\text{exp}}$. Is the ratio consistent with the text (give text equation)?

3) Does $I_a = I_b = I_c$ as predicted by theory? Is $I_n = 0$ as predicted by theory? Comment.

4) Use saved screenshots to complete Table 2 with measured real, reactive, & apparent powers and power factors (PFs).

Table 2 Powers and PFs for Balanced 4-wire Y-Y Three-Phase System

Phase/Total	*P* (W)	*Q* (var)	*S* (VA)	PF
a				
b				
c				
total				

5) Are the phase powers equal as predicted by theory? Comment.

6) How do the results in Tables 1 & 2 compare with those from the Preliminary? [**Note:** Do NOT assume the reader will know/remember the preliminary results. Provide necessary information needed for comparisons.]

B. Unbalanced 4-wire Y-Y Three-Phase System

1) Use saved screenshots to complete Table 3 with RMS magnitudes (not phasors).

Table 3 Currents and Voltages for Unbalanced 4-wire Y-Y Three-Phase System

Quantity	Value
I_a	
I_b	
I_c	
I_n	
V_{an}	
V_{bn}	
V_{cn}	
$V_{bc} = V_{LL,\text{exp}}$	

2) Use saved screenshots to complete Table 4 with real, reactive, & apparent powers and PFs.

Table 4 Powers and PFs for Unbalanced 4-wire Y-Y Three-Phase System

Phase/Total	P (W)	Q (var)	S (VA)	PF
a				
b				
c				
total				

3) How do the results in Tables 3 & 4 compare with those from the Preliminary? [**Note:** Provide necessary information needed for comparisons.]

C. Balanced 3-wire Y-Y Three-Phase System

1) Use saved screenshots to complete Table 5.

Table 5 Currents and Voltages for Balanced 3-wire Y-Y Three-Phase System

Quantity	Value
I_a	
I_b	
I_c	
V_{an}	
V_{bn}	
V_{cn}	
$V_{bc} = V_{LL,\text{exp}}$	

2) Does $I_a = I_b = I_c$ as predicted by theory? Comment.

3) Use saved screenshots to complete Table 6 with real, reactive, & apparent powers and PFs.

Table 6 Powers and PFs for Balanced 3-wire Y-Y Three-Phase System

Phase/Total	*P* (W)	*Q* (var)	*S* (VA)	PF
a				
b				
c				
total				

4) How do the results in Tables 5 & 6 compare with those from the Preliminary? [**Note:** Provide necessary information needed for comparisons.]

D. Unbalanced 3-wire Y-Y Three-Phase System

1) Use saved screenshots to complete Table 7 with RMS magnitudes.

Table 7 RMS Currents and Voltages for Unbalanced 3-wire Y-Y Three-Phase System

Quantity	Value
I_a	
I_b	
I_c	
V_{an}	
V_{bn}	
V_{cn}	
$V_{bc} = V_{LL,\text{exp}}$	

2) Use saved screenshots to complete Table 8 with real, reactive, & apparent powers and PFs.

Table 8 Source Powers and PFs for Unbalanced 3-wire Y-Y Three-Phase System

Phase/Total	P (W)	Q (var)	S (VA)	PF
a				
b				
c				
total				

3) How do the results in Tables 7 & 8 compare with those from the Preliminary? [**Notes:** Provide necessary information needed for comparisons. We are skipping Table 9 as we did not collect that data.]

E. Balanced Δ-Δ Three-Phase System (three power meter)

1) Use saved screenshots to complete Table 10 (skipped Table 9) with RMS magnitudes.

Table 10 Currents and Voltages for Balanced Δ-Δ Three-Phase System

Quantity	Value
I_{ab}	
I_{bc}	
I_{ca}	
$I_a = I_{L,\text{exp}}$	
V_{ab}	
V_{bc}	
V_{ca}	

2) Compute average phase current, i.e., $I_{\phi,\text{exp}} = (I_{ab} + I_{bc} + I_{ca}) / 3$. Compute the ratio $I_{L,\text{exp}} / I_{\phi,\text{exp}}$. Is the ratio consistent with the text (give text equation)?

3) Does $I_{ab} = I_{bc} = I_{ca}$ as predicted by theory? Comment.

4) Use saved screenshots to complete Table 11 with real, reactive, & apparent powers and PFs.

Table 11 Load Powers and PFs for Balanced Δ-Δ Three-Phase System (three power meter)

Phase/Total	*P* (W)	*Q* (var)	*S* (VA)	PF
ab				
bc				
ca				
total				

5) How do the results in Tables 10 & 11 compare with those from the Preliminary? [**Note:** Provide necessary information needed for comparisons.]

E/F. Balanced Δ-Δ Three-Phase System (two power meter)

1) Use saved screenshots and Table 11 to complete Table 12 with real, reactive, & apparent powers and PFs.

2) How well do the three power meter and two power meter totals compare?

Table 12 Powers and PFs for Balanced Δ-Δ Three-Phase System (two power meter)

Meter/Total	***P*** **(W)**	***Q*** **(var)**	***S*** **(VA)**	**PF**
PQS_VabIa				
PQS_VcbIc				
total*				
Table 11 totals				

* Compute $S_{tot} = (P_{tot}^2 + Q_{tot}^2)^{0.5}$. It is unlikely that $S_{tot} = S_{VabIa} + S_{VabIa}$

Each group should write and submit one hard copy of a lab report on Lab 4- Part 2 to the instructor following guidelines given in lab syllabus.

Due Wednesday October 13, 2026 by 4 pm to instructor's office or EECS mailbox.