EE 330L Energy Systems Lab (Fall 2026)
Laboratory 5 Single-Phase Transformers

Introduction

The objective of this lab is to investigate the performance of single-phase transformers. As part of this experiment, the approximate equivalent circuit(s) will be determined by performing the open-circuit and short-circuit tests. One phase of the Three-Phase Transformer Bank 8348-40 Electronics Module System (EMS) (see Figure 1) will be used for this laboratory.

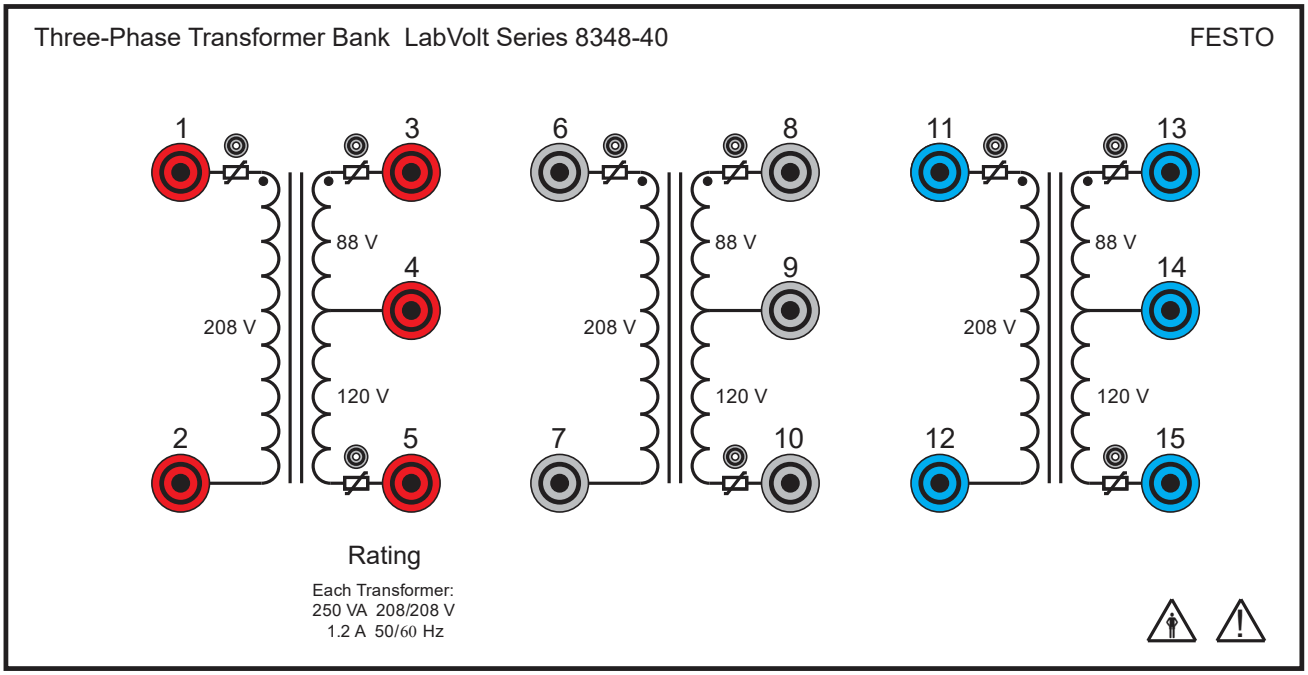


Figure 1 Three-Phase Transformer Bank 8348-40 EMS

Preliminary

Treat terminals 1-2 on the Three-Phase Transformer Bank 8348-40 EMS as the primary for the single-phase transformer and combinations of terminals 3, 4, & 5 as the secondary. Assuming the rated voltage is applied to the primary side, fill in Table 1.

Table 1 Transformer Values

Rated Primary Voltage (V_{rms})	Rated Primary Current (A_{rms})	Rated Secondary Voltage (V_{rms})	Rated Secondary Current (A_{rms})	Turns ratio
V_{12} =	I_{12} =	V_{35} =	I_{35} =	a =
V_{12} =	I_{12} =	V_{34} =	I_{34} =	a =
V_{12} =	I_{12} =	V_{45} =	I_{45} =	a =

Experiment

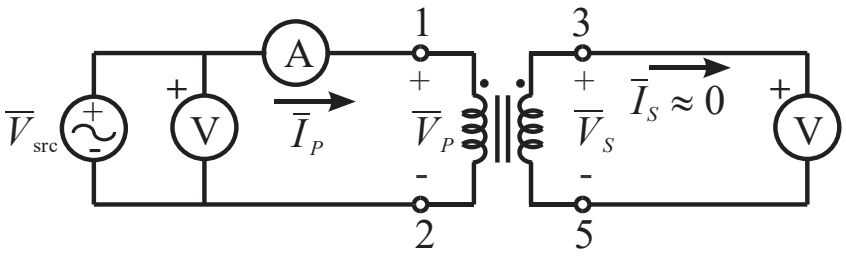
Here, the user will connect their computer to the LabVolt system, wire various single-phase transformer circuits, and take measurements using the LVDAC-EMS software. Treat terminals 1-2 on the Three-Phase Transformer Bank EMS as the primary and terminals 3-5 as the secondary for the single-phase transformer.

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 '**4-5**' 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.

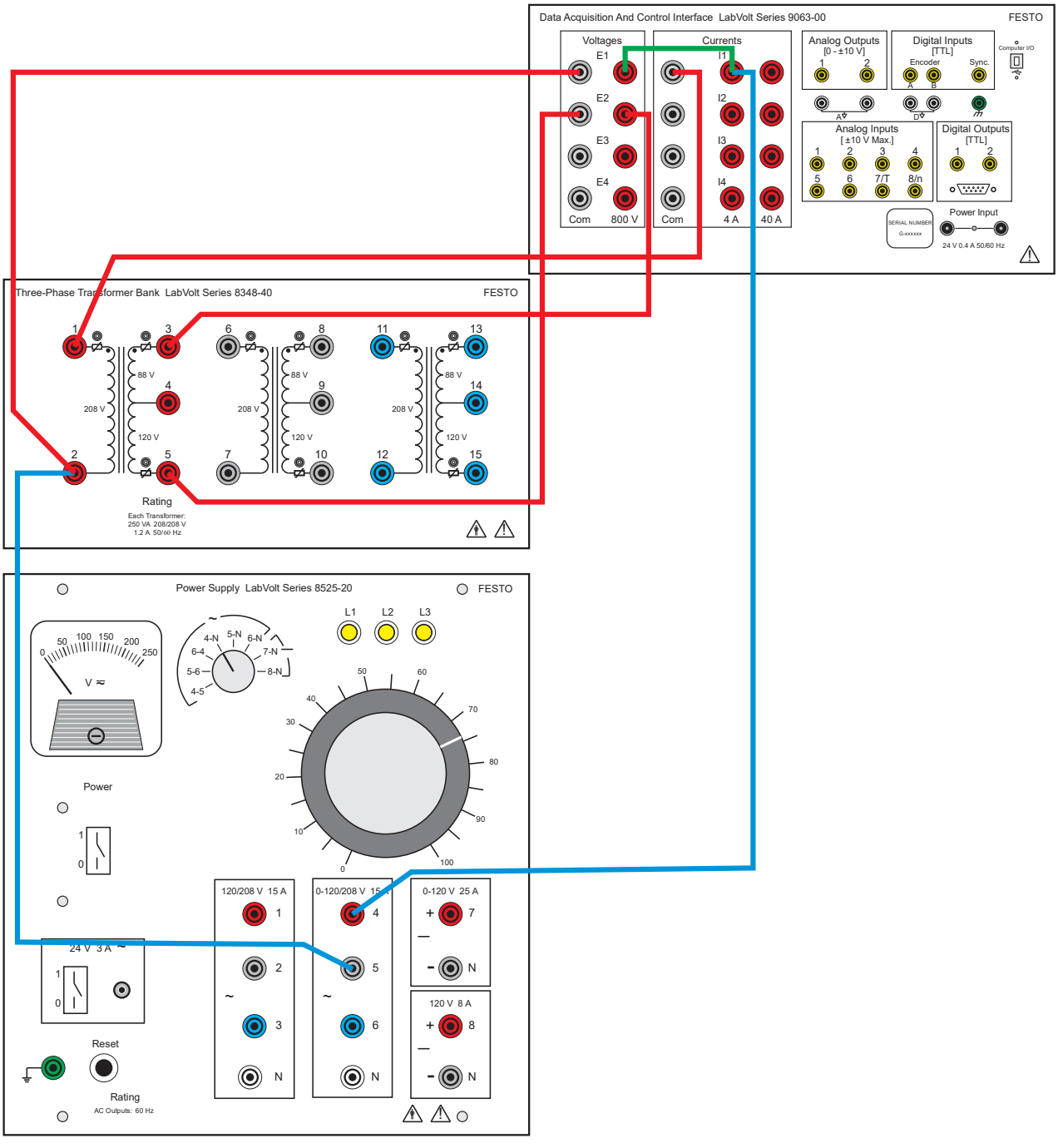
A. Open-Circuit Test (OCT)

1) 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.**

   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!
2) Have instructor/TA inspect and approve the completed wiring connections. **Take picture.**
3) On the 'LVDAC-EMS - Document 1' software screen on your computer, activate/select the 'Metering' instrument.
4) By default, meters 'M1' - 'M4' in first row will show AC RMS voltages from 'E1' - 'E4' on DACI EMS. Rename 'M1' to 'VP_OC' and 'M2' to 'VS_OC'. Deactivate 'M3' and 'M4'.
5) By default, meters 'M7' - 'M10' in second row will show AC RMS currents from 'I1' - 'I4' on DACI EMS. Rename 'M7' to 'IP_OC'. Deactivate 'M8', 'M9', and 'M10'.
6) By default, meter 'M13' should be measuring 'PQS1(E1,I1)'. Click the 'M13' icon to activate and change label to 'PQS_OC'.



(a)



(b)

Figure 2 a) Conceptual and b) Wiring Set-ups for Open-Circuit Test (OCT)

7) On the Power Supply EMS, toggle the 'Power' switch to ON. Three lamps labeled 'L1', 'L2', and 'L3' should light up and the voltage gauge (upper left) needle should be at 0 V. Then, slowly turn the large knob until meter 'M1' on 'Metering' instrument reads about the **rated primary voltage**.

8) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' successively displaying P, Q, & S (e.g., OCT_P.jpg, OCT_Q.jpg, & OCT_S.jpg). Click 'Continuous Refresh' icon.

9) Activate the 'Oscilloscope' instrument. On 'Oscilloscope Settings', ensure Channel 1 has 'Input E1', 'Scale' set to '100 V/div', 'Invert' is 'off', and 'Coupling' as 'DC'. Change Channel 2 to 'Input E2' with same settings. Then, activate Channel 3 with 'Input I1' has 'Scale' set to '0.1 A/div', 'Invert' is 'off', and 'Coupling' as 'DC'. **Save a screenshot of the 'Oscilloscope' instrument screen** (e.g., OCT_oscope.jpg,).

10) Close the 'Oscilloscope' instrument and select the 'Harmonic Analyzer' instrument. On 'Harmonic Analyzer Settings', ensure input is set as 'E1' and click the drop-down arrow for 'Number of Harmonics' and select '10 Harmonics'. **Save screenshot of 'Harmonic Analyzer' instrument screen** (e.g., OCT_harm_VPOC.jpg,). Next, change input to 'I1'. **Save screenshot of 'Harmonic Analyzer' instrument screen** (e.g., OCT_harm_IPOC.jpg,). Close 'Harmonic Analyzer' instrument.

11) On the Power Supply EMS, toggle the 'Power' switch to OFF, and turn the large knob CCW to 0. Do NOT touch any wiring connections!

B. Short-Circuit Test (SCT)

1) 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.**

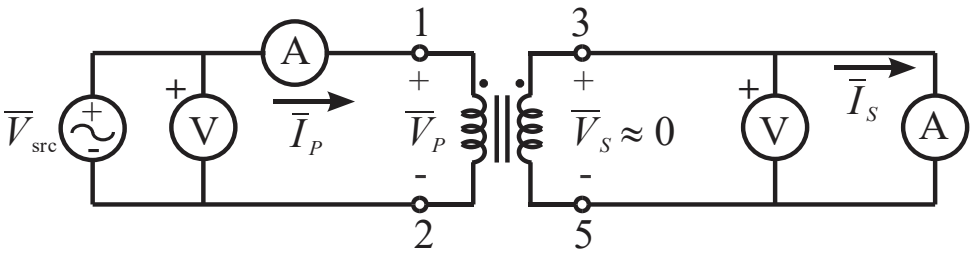
2) Careful examination of Figure 2b and Figure 3b shows that the only wiring changes required are the addition of two cords on the DACI EMS: 1) a white cord should go from the red I2 jack (4 A) to the red E2 jack, and 2) another white cord should go from the black I2 jack (COM) to the black E2 jack (COM). Have instructor/TA inspect and approve the wiring connections. **Take picture.**

3) On the 'Metering' instrument, rename 'M1' to 'VP_SC' and 'M2' to 'VS_SC'. Rename 'M7' to 'IP_SC'. Activate 'M8' and rename to 'IS_SC'. Rename 'M13' to 'PQS_SC'.

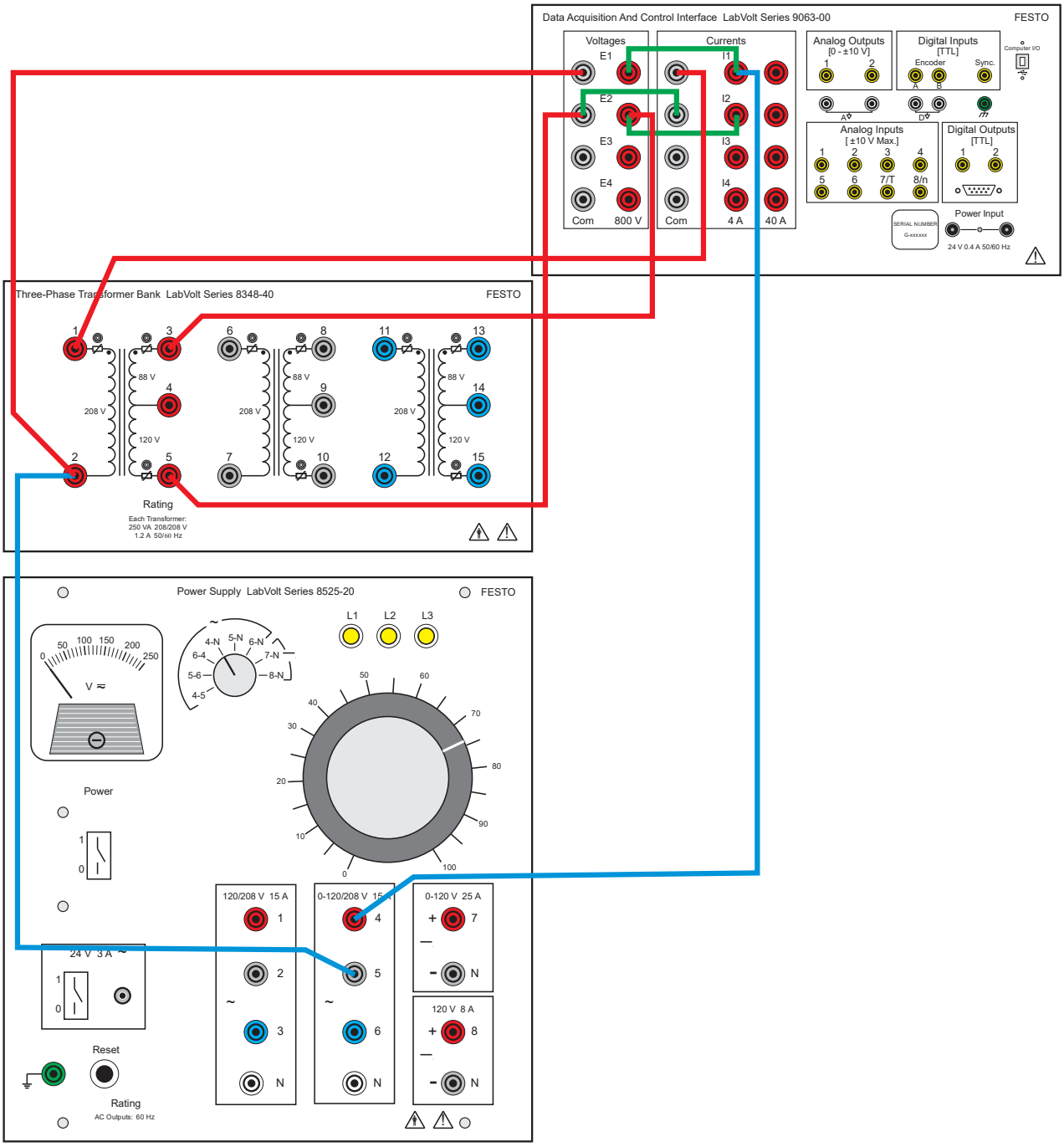
4) On the Power Supply EMS, toggle the 'Power' switch to ON and **super slowly** turn the large knob until meter 'M8' on the 'Metering' instrument reads about the **rated primary current**. [It should take **less than 10 V**! DO NOT BLOW A FUSE!!]

5) Click the 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' successively displaying P, Q, & S (e.g., SCT_P.jpg, SCT_Q.jpg, & SCT_S.jpg). Click 'Continuous Refresh' icon.

6) On the Power Supply 8525-20 EMS, toggle the 'Power' switch to the OFF, and turn the large knob CCW to 0. Do NOT touch any wiring connections!



(a)

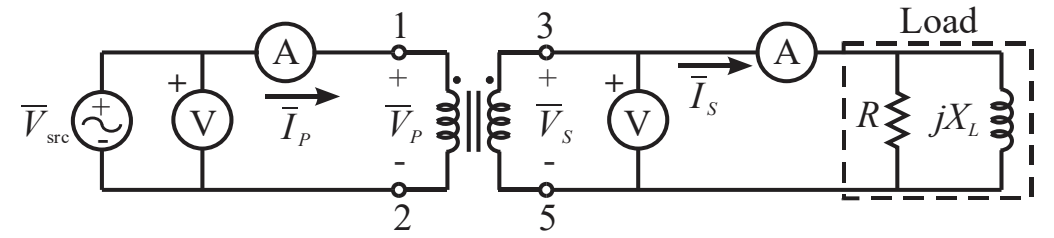


(b)

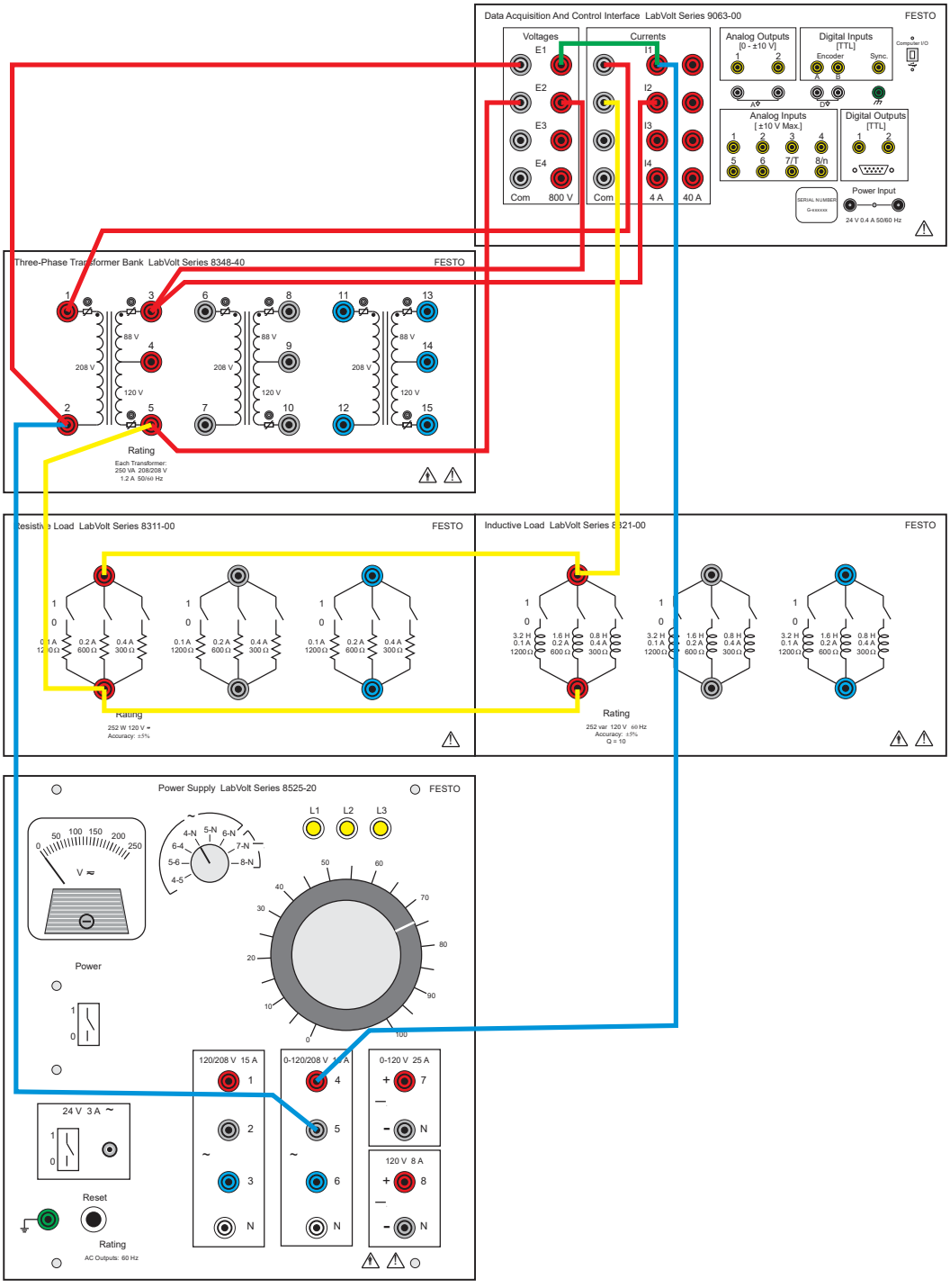
Figure 3 a) Conceptual and b) Wiring Set-ups for Short-Circuit Test (SCT)

C. Load Test (LDT)

1) Set up the circuit shown conceptually in Figure 4a (R = 300 Ω & $jX_L = j300$ Ω). The wiring connections are shown in Figure 4b (components removed for clarity). **For clarity, white cords are shown as green.** Ensure all switches are **OFF** on Resistive Load and Inductive Load EMS.
2) Careful examination of Figures 3b and 4b shows that only minor wiring changes required (see below). Have instructor/TA inspect and approve completed wiring connections. **Take picture.**
   - Remove two white cords added during the SCT to the DACI EMS, i.e., white cord from red I2 jack to red E2 jack and white cord from black I2 jack to black E2 jack.
   - Add yellow cord connecting top red jack on Resistive Load EMS to top red jack on Inductive Load EMS.
   - Add yellow cord connecting bottom red jack on Resistive Load EMS to bottom red jack on Inductive Load EMS.
   - Add yellow cord connecting top red jack on Inductive Load EMS to black I2 jack (COM) on DACI EMS.
   - Add yellow cord connecting bottom red jack on Resistive Load EMS to bottom red jack labeled '5' on Three-Phase Transformer Bank EMS.
   - Add red cord connecting top red jack labeled '3' on Three-Phase Transformer Bank EMS to red I2 jack (4 A) on DACI EMS.
3) On the 'Metering' instrument, rename 'M1' to 'VP_NL', 'M2' to 'VS_NL', 'M7' to 'IP_NL', 'M8' to 'IS_NL', and 'M13' to 'PQS_NL_P'. Activate 'M14' and rename 'PQS_NL_S'.
4) On the Power Supply EMS, toggle the 'Power' switch to ON. Then, **slowly** turn large knob until meter 'M2' reads about 116 V. ALL resistive and inductive loads remain OFF (i.e., No Load).
5) Click 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' and 'M14' successively displaying P, Q, & S (e.g., LDT_P_NL.jpg, LDT_Q_NL.jpg, & LDT_S_NL.jpg). Click 'Continuous Refresh' icon.
6) On the 'Metering' instrument, rename 'M1' to 'VP_FL', 'M2' to 'VS_FL', 'M7' to 'IP_FL', 'M8' to 'IS_FL', and 'M13' to 'PQS_FL_P'. Activate 'M14' and rename 'PQS_FL_S'.
7) Toggle switches for 300 Ω resistor (red jacks) on Resistive Load EMS **and** 0.8 H/0.4 A/300 Ω inductor (red jacks) on the Inductive Load EMS to ON position (i.e., Full Load).
8) Click 'Single Refresh' icon to freeze the measured values. **Save three screenshots** of the 'Metering' instrument with meters 'M13' and 'M14' successively displaying P, Q, & S (e.g., LDT_P_FL.jpg, LDT_Q_FL.jpg, & LDT_S_FL.jpg). Click 'Continuous Refresh' icon.
9) Close the 'Metering' instrument. Then, close the LVDAC-EMS software.
10) Lastly, shut down the LabVolt system by:
    - On the Power Supply EMS, toggle the 'Power' switch to OFF and turn large knob CCW to 0.
    - On Resistive Load EMS and Inductive Load EMS, toggle all switches to OFF.
    - Disconnect all cords and return to rack on side of the LabVolt system.
    - Disconnect DACI EMS as a USB device from your computer. Then, disconnect USB cable from the computer and DACI EMS.
    - Unplug JAMECO AC Adaptor from wall outlet and 'Power Input' jack on DACI EMS.
11) **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 Load Test (LDT)

Post Lab Analysis

A. Open-Circuit Test

1) Use saved screenshots to fill in Table 2. Comment on results.

Table 2 Measured Values for Open-Circuit Test

Parameter	Value
$V_{P,OC}$ (V_{rms})	
$V_{S,OC}$ (V_{rms})	
$I_{P,OC}$ (A_{rms})	
P_{OC} (W)	
Q_{OC} (var)	
S_{OC} (VA)	

2) Use data in Table 2 to compute the experimental turns ratio from voltages, power factor, core resistance and magnetizing reactance. Fill in Table 3. Comment on results.

Table 3 Computed Values from Open-Circuit Test

Parameter	Value
$a_{exp,OC}$	
PF_{OC}	
$R_{C,P}$ (Ω)	
$X_{M,P}$ (Ω)	

3) Insert oscilloscope and harmonic analyzer screenshots taken during open-circuit test. Analyze and discuss what they show regarding the magnetization current of the transformer.

B. Short-Circuit Test

1) Use saved screenshots to fill in Table 4. Comment on results.

Table 4 Measured Values for Short-Circuit Test

Parameter	Value
$V_{P,SC}$ (V_{rms})	
$V_{S,SC}$ (V_{rms})	
$I_{P,SC}$ (A_{rms})	
$I_{S,SC}$ (A_{rms})	
P_{SC} (W)	
Q_{SC} (var)	
S_{SC} (VA)	

2) Use data in Table 4 to compute the experimental turns ratio from currents, power factor, and series resistance & reactance. Fill in Table 5. Comment on results.

Table 5 Computed Values from Short-Circuit Test

Parameter	Value
$a_{exp,SC}$	
PF_{SC}	
$R_{eq,P}$ (Ω)	
$X_{eq,P}$ (Ω)	

3) Draw approximate **primary** side equivalent circuit model of transformer.

4) Compare the experimental turns ratios from Tables 3 & 5. Are they consistent/similar? If not which one is most accurate? Why?

5) Draw approximate **secondary** side equivalent circuit model of transformer.

6) Find $Z_{base,P}$ for primary side. Then, calculate the **per-unit** core resistance, magnetizing reactance, and series resistance & reactance. Fill in Table 6. Comment on results.

Table 6 Per-Unit Transformer Parameters

Parameter	Value	Typical range
$R_{C,pu}$		
$X_{M,pu}$		
$R_{eq,pu}$		
$X_{eq,pu}$		

7) Draw approximate **per-unit** equivalent circuit model of transformer.

C. Load Test

1) Use saved screenshots to fill in Table 7. Comment on results.

Table 7 Measured Values from Load Test w/ No Load

Parameter	No-Load Value	Full-Load Value
V_P (Vrms)		
V_S (Vrms)		
I_P (Arms)		
I_S (Arms)		
P_P (W)		
Q_P (VA)		
S_P (VA)		
P_S (W)		
Q_S (var)		
S_S (VA)		

2) Use data in Table 7 to compute the power factors $PF_{P,FL}$ & $PF_{S,FL}$, transformer efficiency η, and voltage regulation (VR) under the full load conditions.

3) Use an approximate secondary-side equivalent circuit model of transformer to compute the expected transformer efficiency and voltage regulation (VR) under the full load conditions. [Hints: For computations, use measured values of $P_{S,FL} = P_{out,}$ $V_{S,FL}$ with phase angle of 0° to get $\overline{V}_S$, $I_{S,FL}$ and θ_I from $PF_{S,FL}$ to get $\overline{I}_S$. Then, compute $\overline{V}_P / a$, P_{core}, and P_{wire} from circuit.]

4) Fill in Table 8. Comment on results.

Table 8 Measured Values from Load Test w/ No Load

Parameter	Experimental Value	Approximate Equivalent Circuit Value
η (%)		
VR (%)		

Each group should write and submit one hard copy of a lab report on Lab 5 to the instructor following guidelines given in lab syllabus.

Due Monday October 26, 2026 by 4 pm to instructor's office or EECS mailbox.