EE 330L Energy Systems Lab (Fall 2026)
Laboratory 3 Single-Phase Loads and PF Correction

Introduction

The objective of this lab is to introduce students to AC power in single-phase circuits as well as power factor (PF) correction. A second objective is to continue familiarizing students with the LabVolt system, software, and hardware.

Preliminary

AC loads in commercial and residential settings are typically resistive-inductive (*RL*) in nature. This occurs because the loads that draw the largest amount of current and power are AC motors. As discussed in class, utilities prefer loads with large PFs (ideally PF =1) to minimize power line current which, in turn, lowers line losses and reduces the size of the power lines required.

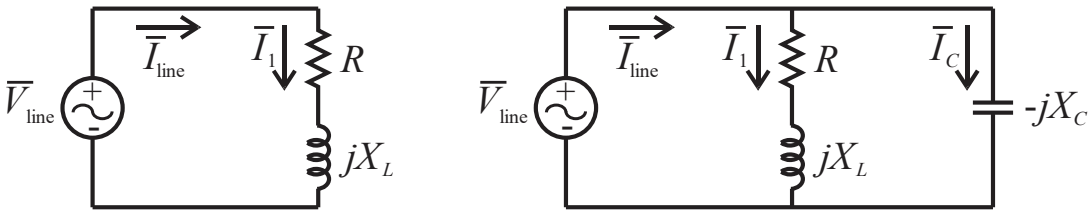


Figure 1 Single-phase AC circuit with *RL* load a) alone and b) with parallel capacitor

For the single-phase AC circuits (Figure 1), the line voltage operates at 60 Hz and has an RMS voltage of 60 V. Assume the line voltage is the phase reference, i.e., has a phase angle of 0°. We will analyze the single-phase AC circuits with just an *RL* load (Figure 1a) as well as when that *RL* load is placed in parallel with a capacitive load (Figure 1b), i.e., PF correction is applied. The *RL* load has R = 300 Ω and X_L = 300 Ω. For PF correction, three parallel capacitive loads with reactances of magnitude X_{C1} = 300 Ω, X_{C2} = 600 Ω, and X_{C3} = 2400 Ω will be analyzed.

1) First, find the inductance L and capacitances C_1, C_2, and C_3 associated with X_L, X_{C1}, X_{C2}, and X_{C3}. Fill in Table 1.

Table 1 Component Values

Component	reactance magnitude (Ω)	Component value
X_L	300	
X_{C1}	300	
X_{C2}	600	
X_{C3}	2400	

2) Next, compute the RMS phasor currents (format $I\angle\theta_I$ with angle in degrees) for the *RL* load alone and when the three capacitive loads are placed in parallel. Fill in Table 2.

Table 2 Phasor Currents

Case	$\overline{I}_1$ (A_{rms})	$\overline{I}_C$ (A_{rms})	$\overline{I}_{line}$ (A_{rms})
1: *RL* alone			
2: *RL* w/ X_{C1} = 300 Ω			
3: *RL* w/ X_{C2} = 600 Ω			
4: *RL* w/ X_{C3} = 2400 Ω			

3) Using the information from the prior step, compute the real, reactive, and apparent powers for the four cases. Fill in Table 3.

Table 3 Apparent, Real, and Reactive Powers

Case	P_1 (W)	Q_1 (var)	S_1 (VA)	P_C (W)	Q_C (var)	S_C (VA)	P_{line} (W)	Q_{line} (var)	S_{line} (var)
1									
2									
3									
4									

4) Using the information from the prior steps, compute the overall PF (don't forget lagging/leading) for each of the four cases, characterize the PF correction (e.g., none, undercorrected, perfect, or overcorrected) as well as the expected percent line loss (*LL*) as a fraction of that for the *RL* load alone (Case 1). [Hint: $LL \propto I_{line}^2$.] Fill in Table 4. Comment on the line current magnitude and LL for the four cases.

Table 4 Power Factors and Line Losses

Case	PF	characterize PF correction	I_{line} (A_{rms})	*LL* (%)
1				
2				
3				
4				

Experiment

Here, the user will connect their computer to the LabVolt system, wire the single-phase circuit, 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.
   - Ensuring the power switches located on left side of Power Supply EMS 8525-20 are 0/OFF.
   - 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 9063-00 EMS.

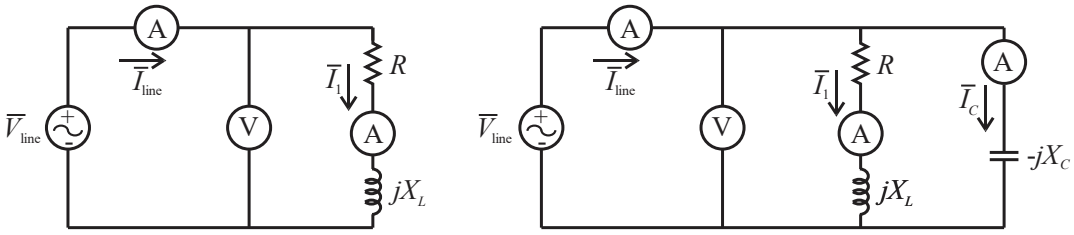
3) Start the LVDAC-EMS software on your computer. When the 'LVDAC-EMS Launcher' screen pops up, select 'Connected Mode'. When the 'LVDAC-EMS Start-up' screen pops up, verify 'Local Network Voltage and Frequency' has '120 V - 60 Hz' selected and click 'OK'. The 'LVDAC-EMS - Document 1' screen should now appear.

4) Set up the circuits shown conceptually in Figures 2a,b. The wiring connections are shown in Figure 2c (some components removed for clarity). The steps are listed as follows:

   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!

   - Connect a blue cord from the red banana jack labeled '4' on the Power Supply 8525-20 EMS to the red banana jack labeled 'I1' (4 A column) in the 'Currents' block of DACI 9063-00 EMS
   - On the DACI 9063-00 EMS, connect a white cord from the red banana jack labeled 'I1' in the 'Currents' block to the red banana jack labeled 'E1' in the 'Voltages' block.
   - Connect a red cord from the black banana jack labeled 'Com' to the left of the red banana jack labeled 'I1' in the 'Currents' block of the DACI 9063-00 EMS to the upper red banana jack on the Resistive Load 8311-00 EMS.
   - Connect a red cord from the black banana jack labeled 'Com' to the left of the red banana jack labeled 'I1' in the 'Currents' block of the DACI 9063-00 EMS to the upper red banana jack on the Capacitive Load 8331-00 EMS.
   - Connect a red cord from the lower red banana jack on the Resistive Load 8311-00 EMS to the red banana jack labeled 'I2' (4 A column) in the 'Currents' block on the DACI 9063-00 EMS.
   - Connect a red cord from the lower red banana jack on the Capacitive Load 8331-00 EMS to the red banana jack labeled 'I3' (4 A column) in the 'Currents' block on the DACI 9063-00 EMS.
   - Connect a yellow cord from the black banana jack labeled 'Com' to the left of the red banana jack labeled 'I2' in the 'Currents' block of the DACI 9063-00 EMS to the upper red banana jack on the Inductive Load 8321-00 EMS.
   - Connect a blue cord from the black banana jack labeled 'Com' to the left of the red banana jack labeled 'E1' in the 'Voltages' block on the DACI 9063-00 EMS to the white banana jack labeled 'N' below the red banana jack labeled '4' on the Power Supply 8525-20 EMS.

- Connect a blue cord from lower red banana jack of Inductive Load 8321-00 EMS to the white banana jack labeled ‘N’ below the red banana jack labeled ‘4’ on Power Supply 8525-20 EMS.
- Connect a blue cord from the black banana jack labeled ‘Com’ to the left of the red banana jack labeled ‘I3’ in the ‘Currents’ block of the DACI 9063-00 EMS to the white banana jack labeled ‘N’ below the red banana jack labeled ‘4’ on Power Supply 8525-20 EMS.
- On the Power Supply 8525-20 EMS, turn the small knob (upper center) to ‘4-N’ position and the large knob (upper right) all the way counterclockwise (CCW) to ‘0’.



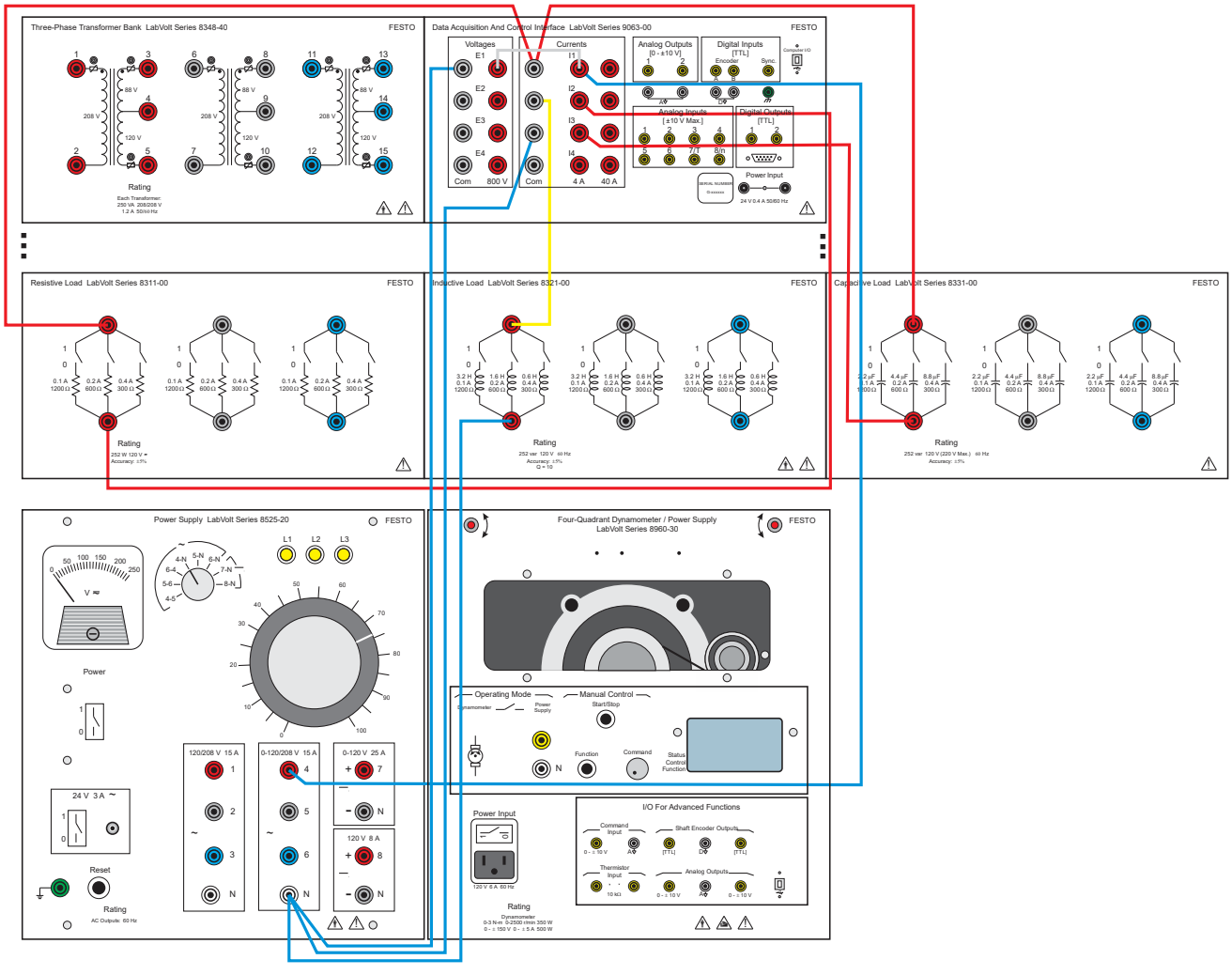


Figure 2 Circuit set up for a) *RL* load, b) *RL* load w/ PF correction, and c) experiment

5) 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.

6) 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. By default, meters 'M1' - 'M4' in the first row will show AC **RMS** voltages from 'E1' - 'E4' on DACI 9063-00 EMS while meters 'M7' - 'M10' in the second row will show AC **RMS** currents from 'I1' - 'I4' on DACI 9063-00 EMS. The measured values are in highlighted green in the boxes below the meters. Deactivate meters 'M2' - 'M4' and 'M10' (boxes below will turn black).

7) To measure the input **line** voltage, current, and powers, set up meters 'M1', 'M7', and 'M13' in the first column of the 'Metering' instrument screen. By default, meter 'M1' should be measuring 'E1' = V_{line} (change label to 'Vline'), and meter 'M7' should be measuring 'I1' = I_{line} (change label to 'Iline'). By default, meter 'M13' should be measuring 'PQS1(E1,I1)'. Click the 'M13' icon to activate and display the **line** powers for the circuit (change label to 'PQSline'). [Remember: clicking the lower left 'P' icon in the 'M13' meter box will cycle it through P, Q & S.]

8) To set V_{line} on the Power Supply 8525-20 EMS, slowly turn the large knob (upper right) clockwise (CW) until meter 'M1' on the 'Metering' instrument reads ~60 V.

9) To connect the *RL* load alone (Case 1), toggle the switches for the 300 Ω resistor (red jacks) on the Resistive Load 8311-00 EMS and 0.6 H/0.4 A/300 Ω inductor (red jacks) on the Inductive Load 8321-00 EMS to the upper/1/ON position.

10) To measure the current and powers for the ***RL* load**, set up meters 'M8' and 'M14' in the second column of the 'Metering' instrument screen. By default, meter 'M8' should be measuring 'I2' = I_1 (change label to 'I1'). Click the 'PQS2 (E1,I…)' icon to right of the 'M14' icon. On the pop-up 'Meter Settings' screen, select 'PQS (E1,I2)' under 'Input/Function', click 'Apply', and click 'OK'. Then, click 'M14' icon to activate and display the ***RL* load** powers (change label to 'PQS1').

11) Click the 'Single Refresh' icon to freeze the measured values. Save three screenshots of the 'Metering' instrument for Case 1 with meters 'M13' & 'M14' successively displaying P, Q, & S (e.g., Case_1_P.jpg, Case_1_Q.jpg, & Case_1_S.jpg). Click 'Continuous Refresh' icon.

12) To connect capacitive load X_{C1} = 300 Ω in parallel with the *RL* load (Case 2), toggle switch for 8.8 μF/0.4 A/300 Ω capacitor (red jacks) on Capacitive Load 8331-00 EMS to upper/1/ON position.

13) To measure the current and powers for the **parallel capacitor**, we will need to set-up meters 'M9' and 'M15' in the third column of the 'Metering' instrument screen. By default, meter 'M9' should be measuring 'I3' = I_C (change label to 'IC'). Click the 'PQS3 (E3,I…)' icon to right of the 'M15' icon. On the pop-up 'Meter Settings' screen, select 'PQS (E1,I3)' under 'Input/Function', click 'Apply', and click 'OK'. Then, click the 'M15' icon to activate and display the **capacitive load** powers (change label to 'PQSC').

14) Click the 'Single Refresh' icon to freeze the measured values. Save three screenshots of the 'Metering' instrument for Case 2 with meters 'M13', 'M14', & 'M15' successively displaying P, Q, & S (e.g., Case_2_P.jpg, Case_2_Q.jpg, & Case_2_S.jpg). Click 'Continuous Refresh' icon.

15) On Capacitive Load 8331-00 EMS, toggle X_{C1} = 300 Ω switch OFF. To connect the capacitive load X_{C2} = 600 Ω in parallel with the *RL* load (Case 3), toggle switch for the 4.4 μF/0.2 A/600 Ω capacitor (red jacks) on the Capacitive Load 8331-00 EMS to the upper/1/ON position.

16) Click the 'Single Refresh' icon to freeze the measured values. Save three screenshots of the 'Metering' instrument for Case 3 with meters 'M13', 'M14', & 'M15' successively displaying P, Q, & S (e.g., Case_3_P.jpg, Case_3_Q.jpg, & Case_3_S.jpg). Click 'Continuous Refresh' icon.

17) On Capacitive Load 8331-00 EMS, toggle X_{C2} = 600 Ω switch OFF. On Power Supply 8525-20 EMS, **toggle the 'Power' switch (center left) to the lower/0/OFF position**.

18) To connect the capacitive load X_{C3} = 2400 Ω in parallel with the *RL* load (Case 4), re-wire the Capacitive Load 8331-00 EMS (close-up shown in Figure 3) by: 1) moving red cord from lower red banana jack to adjacent lower black banana jack, 2) adding a white cord between the lower red banana jack and upper black banana jack of the adjacent capacitor banks, and 3) moving toggle switches for the 2.2 μF/0.1 A/1200 Ω capacitors on red **and** black capacitor banks to the upper/1/ON position. [I.e., we put two 2.2 μF/0.1 A/1200 Ω capacitors in series!]

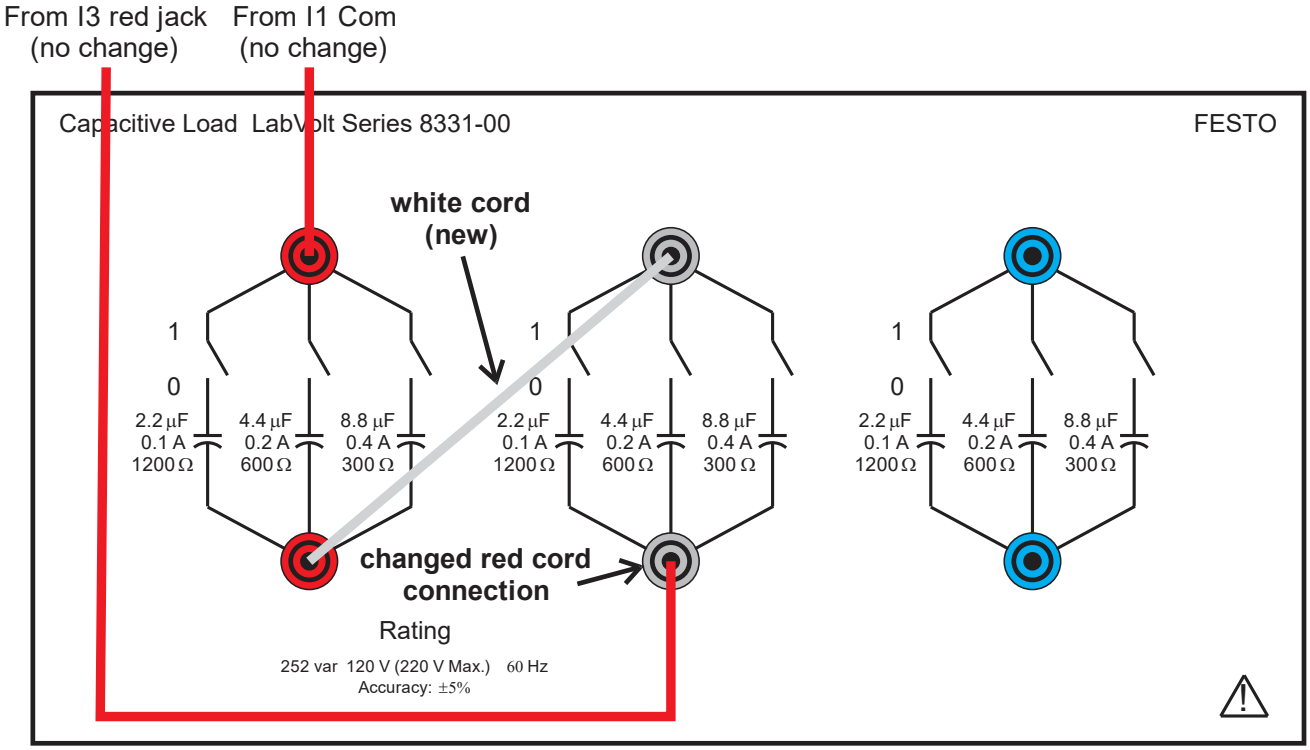


Figure 3 Capacitive Load 8331-00 EMS wiring changes for Case 4.

19) On the Power Supply 8525-20 EMS, toggle the 'Power' switch (center left) to the upper/1/ON position. Click the 'Single Refresh' icon to freeze the measured values. Save three screenshots of the 'Metering' instrument for Case 4 with meters 'M13', 'M14', & 'M15' successively displaying P, Q, & S (e.g., Case_4_P.jpg, Case_4_Q.jpg, & Case_4_S.jpg).

20) Close the 'Metering' instrument. Then, close the LVDAC-EMS software.

21) Make an 'Equipment List' table (include descriptions, model #s, & brands; only list EMS used).

22) Lastly, shut down the LabVolt system by:
- On the Power Supply 8525-20 EMS, toggle the 'Power' switch (center left) to the lower/0/OFF position, and turn the large knob CCW to 0.
- On the Resistive Load 8311-00 EMS, Inductive Load 8321-00 EMS, and Capacitive Load 8331-00 EMS, toggle all switches to the lower/0/OFF position.
- Disconnect all patch cords and return to rack on side of the LabVolt system.
- Disconnecting the DACI 9063-00 EMS as a USB device from your computer. Then, disconnect the USB cable from the computer and DACI 9063-00 EMS.
- Unplug JAMECO AC Adaptor from wall outlet and 'Power Input' jack on DACI 9063-00 EMS.

Post Lab Analysis

Requirements/hints/prompts:

1) Use saved screenshots for Cases 1- 4 to fill out Tables 5 and 6.

Table 5 Measured Line Voltage and Currents

Case	V_{line} (V_{rms})	I_{line} (A_{rms})	I_1 (A_{rms})	I_C (A_{rms})
1				
2				
3				
4				

Table 6 Measured Apparent, Real, and Reactive Powers

Case	P_{line} (W)	P_1 (W)	P_C (W)	Q_{line} (var)	Q_1 (var)	Q_C (var)	S_{line} (VA)	S_1 (VA)	S_C (VA)
1									
2									
3									
4									

2) In a perfect theoretical world, V_{line}, I_1, P_1, Q_1, & S_1 would be constant for Cases 1 - 4. Use information from Tables 5 & 6 to complete Table 7 where Δ = Max - Min and var = (Δ/Ave)*100%. Comment on results.

Table 7 Fluctuations in Measured Circuit Parameters

	Max	**Min**	**Δ**	**Ave**	**var (%)**
V_{line} **(V$_{rms}$)**					
I_1 **(A$_{rms}$)**					
P_1 **(W)**					
Q_1 **(var)**					
S_1 **(VA)**					

3) Compute the measured overall PF for each of the four cases, characterize the PF correction as well as the expected percent line loss (*LL*) as compared to that for the *RL* load alone (Case 1) using the data from Tables 5 and 6. Fill in Table 8. Compare results shown in Table 8 to those computed for Table 4. Comment on the line current magnitude and *LL* for the four cases.

Table 8 Measured Power Factors and Line Losses

Case	**PF**	**characterize PF correction**	I_{line} **(A$_{rms}$)**	***LL* (%)**
1				
2				
3				
4				

Each group should write and submit one hard copy of a lab report on Lab 3 to the instructor following guidelines given in lab syllabus.

Due Monday September 28, 2026 by 4 pm to instructor's office or EECS mailbox.