Rochester Institute of Technology
Electrical Machines & Transformers
Lab #

Name : ....

Program : ....

Lab Partners: ....

Year : 1 2 3 4 5 Semester: FALL $\boxed{\text{SPRING}}$

LABORATORY GRADE

Format (Objective, procedure)	**/10**
Schematics and Diagrams	**/20**
Experimental Data (Tabular, signed-off)	**/20**
Calculations , Plots, Answers to Questions	**/30**
Results & Conclusions	**/20**
Final Grade..............................	**/100**

1 Objective

The aim of this lab is to introduce students to the relationship between voltage and current in wye-wye and wye-delta 3-phase circuits. Students sill also learn to make wye and delta circuit connections. Lastly, students will learn to calculate the power (real, apparent and reactive) in three-phase circuits.

2 Procedure

The lab was divided into three parts shown below with thier respective experimental data and sample calculations.

3 Three phase wye-wye circuit configuration with resistive loads

3.1 Analysis of ideal circuit

The three phase wye-wye circuit with ideal resistance of 400 Ω shown in Figure 1 can be represented by the single phase equivalent circuit shown in Figure 2.

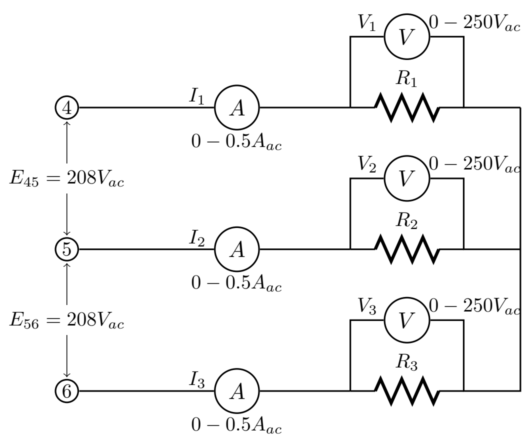

Figure 1: Balanced three phase wye-wye circuit with resistive loads

The current through the resistor (phase current) is calculated by writing the equation for the voltage drop over the resistors:

$$E_{an} = I_p \cdot R_1 \tag{1}$$

Therefore

$$I_p = \frac{E_{an}}{R_1} = \frac{(208\angle 0^\circ/\sqrt{3})}{400\Omega} = 0.3002\ A \tag{2}$$

The power dissipated through the resistive load is given by:

$$P_{an} = (I_p)^2 \cdot R_1 = (0.3002)^2 \cdot 400 = 36.05\ W \tag{3}$$

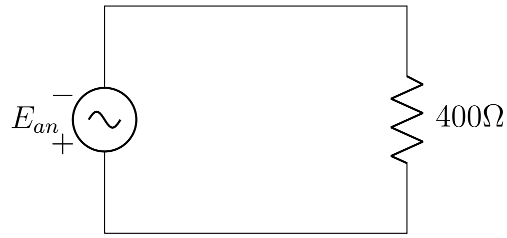

Figure 2: Single phase equivalent of balanced three-phase wye-wye circuit

The ideal total three phase power delivered to the load is:

$$P_T = 3 \cdot P_{an} = 3 \cdot (I_p)^2 \cdot R_1 = (0.3002)^2 \cdot 400 = 108.16\ W \tag{4}$$

3.2 Analysis of measured data

The power delivered to each of the phases of the circuit and the total power delivered to the loads were calculated from measured voltage, line current and resistance.

Table 1: Measured data from the three phase circuit shown in Figure 1

Measured Resistance (Ω)	Line Currents (A)	Load Voltage (V)	Per ϕ Power (W)
$R_1 = 400$	$I_1 = 0.304$	$V_1 = 122$	$P_{\phi 1} = 37.09$
$R_2 = 400$	$I_2 = 0.302$	$V_2 = 121$	$P_{\phi 2} = 36.54$
$R_3 = 400$	$I_3 = 0.308$	$V_3 = 120$	$P_{\phi 3} = 36.96$

Average phase power,

$$P_{\phi_{ave}} = V_{ave} \cdot I_{\phi_{ave}} = 121 \cdot 0.305 = 36.86\ (W) \tag{5}$$

The total three phase power,

$$P_T = 3 \cdot P_{\phi_{ave}} = 3 \cdot 36.86 = 110.59\ (W) \tag{6}$$

3.3 Error Analysis

The error between the ideal and measured data were calculated as shown below and indicated in Table 2.

$$error = \frac{|measured - calculated|}{|calculated|} * 100 \tag{7}$$

Table 2: Error between the ideal and measured data for the three phase circuit shown in Figure 1

	Line Currents (A)	Load Voltage (V)	Per ϕ Power (W)	Total Power (W)
Ave. of measured data	$I_{ave.} = 0.305$	$V_{ave.} = 121$	$P_{\phi ave.} = 36.86$	110.59
Ideal values	$I_{ave.} = 0.300$	$V_{ave.} = 121.1$	$P_{\phi ave.} = 36.05$	108.16
error	1.5%	0.1%	2.3%	2.2 %

4 Three phase wye-delta circuit configuration circuit configuration with resistive loads

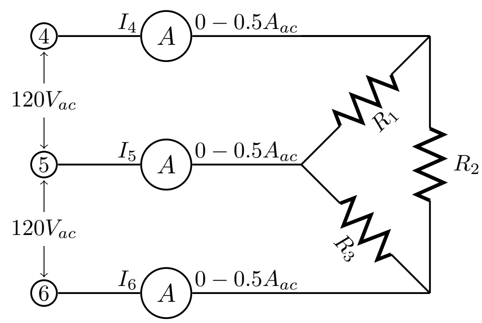

Figure 3: Balanced three phase wye-delta circuit with resistive loads

4.1 Analysis of ideal circuit

The circuit in Figure 3 can be simplfied by converting the three phase delta load to an equivalent three phase Y load using equation 8.

$$Z_Y = \frac{Z_\Delta}{3} \tag{8}$$

After the load conversion, similar analysis used in section 3.1 can be used to solve the equivalent circuit.

4.2 Analysis of measured data

In part 2, the total power delivered to the delta loads was calculated through the measured line currents and resistance.

Average power delivered to each of the loads,

Table 3: Measured data from the three phase circuit shown in Figure 3

Resistance (Ω)		Phase Voltage (V)	Phase Power (W)	Total Power (W)	Phase Current (A)
% Min (-5 %)	126.7	$120/\sqrt{3}$	37.89	113.7	0.547
Nominal	133.3	$120/\sqrt{3}$	36.00	108	0.520
Max (+ 5 %)	140	$120/\sqrt{3}$	34.29	102.9	0.495

Resistance (Ω)	**Currents (A)**	**Per ϕ Power (W)**
$R_1 = 400$	$I_4 = 0.520$	$P_{\phi 1} = 36.05$
$R_2 = 400$	$I_5 = 0.510$	$P_{\phi 2} = 34.68$
$R_3 = 400$	$I_6 = 0.520$	$P_{\phi 3} = 36.05$

$$P_{\phi_{ave}} = V_{ave} \cdot I_{\phi_{ave}} = 120 \cdot \frac{I_{line}}{\sqrt{3}} = 120 \cdot \frac{0.517}{\sqrt{3}} \tag{9}$$

$$= 120 \cdot 0.298 = 35.80 \ (W) \tag{10}$$

The total three phase power delivered to the loads

$$P_T = 3 \cdot P_{\phi_{ave}} = 3 \cdot P_{\phi_{ave}} = 3 \cdot 35.80 = 107.39 \ (W) \tag{11}$$

5 Three phase wye-wye circuit configuration with resistive and inductive loads

5.1 Analysis of ideal circuit

Given that the circuit in Figure 4 is balanced, a single phase representation of the circuit can be drawn as shown in Figure 5.

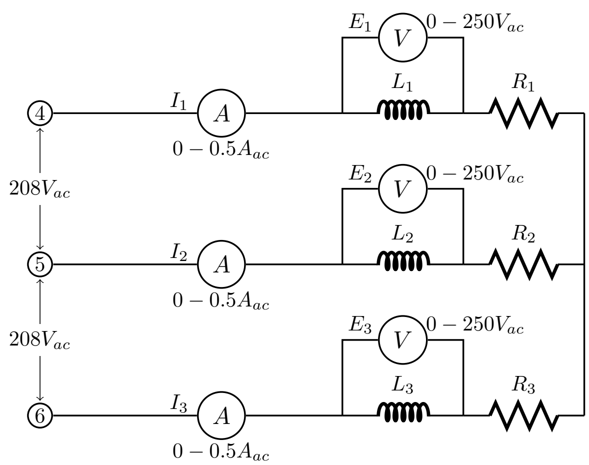

Figure 4: Balanced three phase wye-wye circuit with resistive and inductive loads

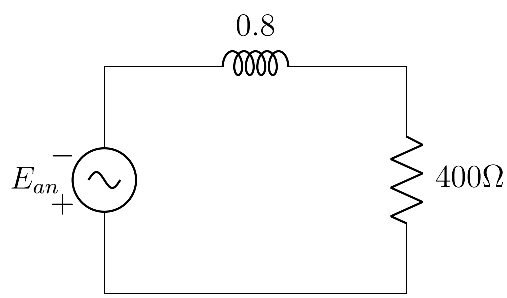

Figure 5: Single phase equivalent of balanced three-phase wye-wye circuit

$$R = 400\Omega \tag{12}$$

$$X_L = 2 \cdot \pi \cdot f \cdot L \tag{13}$$

$$Z = \sqrt{R^2 + {X_L}^2} \tag{14}$$

$$I_\phi = \frac{E_{an}}{Z} \tag{15}$$

$$P_\phi = \frac{E_{an}^2}{R} \tag{16}$$

$$Q_\phi = \frac{E_{an}^2}{X_L} \tag{17}$$

$$S = \sqrt{P^2 + Q^2} \tag{18}$$

Table 4: Theoretical analysis of the circuit in Figure 4

	R Ω	X_L Ω	Z Ω	E_ϕ (V)	I_ϕ (mA)	P_ϕ (W)	Q_ϕ (var)	S_ϕ (VA)	pf	P_T (W)	Q_T (var)	S_T (VA)
Min (-5 %)	380	286.5	475.9	120	252	37.9	50.3	62.9	0.602	113.7	150.8	188.8
Nominal	400	301.6	501.0	120	240	36.0	47.7	59.8	0.602	108.0	143.2	179.4
Max (+ 5 %)	420	316.7	526.0	120	228	34.3	45.5	56.9	0.602	102.9	136.4	170.8

where

$$P_T = 3 \cdot P_\phi \tag{19}$$

$$Q_T = 3 \cdot Q_\phi \tag{20}$$

$$S_T = 3 \cdot S_\phi \tag{21}$$

5.2 Analysis of measured data

Table 5: Measured data from the circuit shown in Figure 4

Measured Current	**Inductive Voltage**	**Resistive Voltage**
$I_1 = 0.225$	$V_{L_1} = 72$	$V_{R_1} = 90$
$I_2 = 0.225$	$V_{L_2} = 69$	$V_{R_2} = 90$
$I_3 = 0.230$	$V_{L_3} = 70$	$V_{R_3} = 90$

Table 6: Measured data from the circuit shown in Figure 4

Real Power (W)	**Reactive Power (var)**	**Apparent Power (VA)**	**pf**
$P_{R_1} = 20.25$	$Q_{L_1} = 16.2$	$S_{\phi_1} = 25.93$	$pf = 0.78$
$P_{R_2} = 20.25$	$Q_{L_2} = 15.53$	$S_{\phi_1} = 25.52$	$pf = 0.79$
$P_{R_3} = 20.7$	$Q_{L_3} = 16.1$	$S_{\phi_1} = 26.22$	$pf = 0.79$

6 Conclusions

The aim of this lab were to become familiar with the laboratory equipment and to review basic three-phase power relationships. In the balanced wye-wye circuits (part 1), the power delivered to each load and the total power delivered to the three loads was calculated using equations 1 and 2 based on the measured data. The resulting experimental power was compared to ideal three phase wye-wye circuits yielding a 2.2 % error which is withing the $\pm$ 5 % tolerances of the equipment. The analysis also confirms that the three-phase circuits is merely a combination of three single phase circuits.