Name: Archit Agrawal
Student ID: 202052307

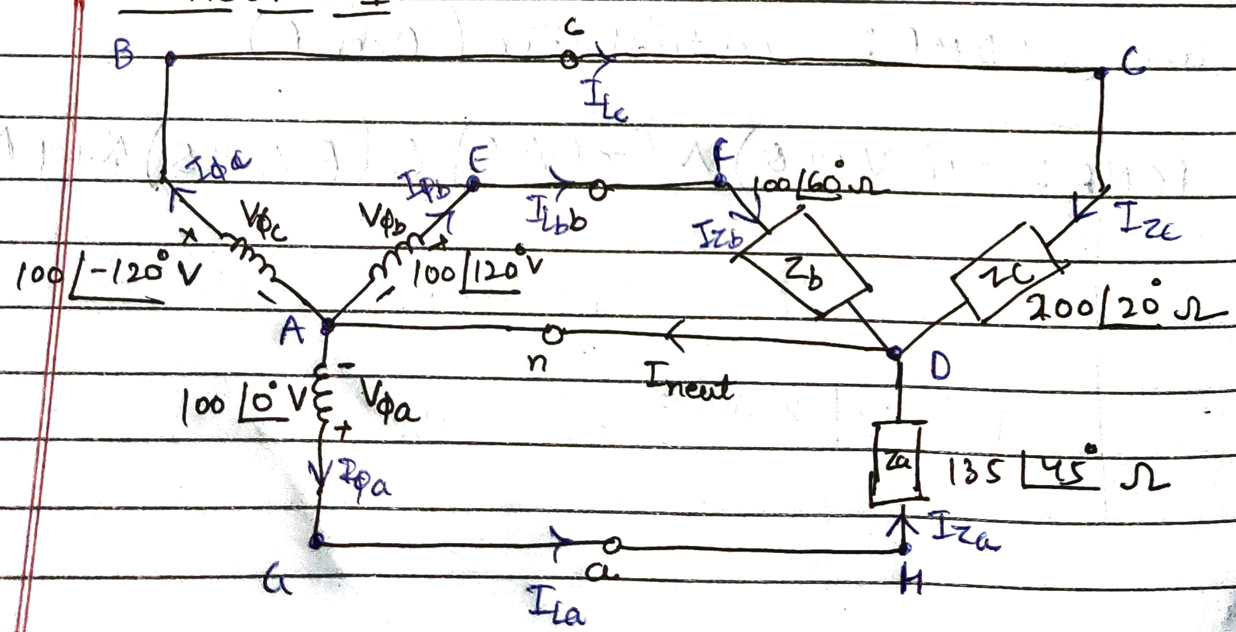
EE160: Experiment 4

Objective:- i) Design and simulate given circuits in SPICE. Plot the phase voltages, line voltages, load voltages, phase currents, line currents and load currents. Find the phase difference between phase voltage and all other voltages and currents from the simulations. Calculate these voltages and currents theoretically. Draw the phasor diagram from the theoretical calculations. Compare the theoretical results with the simulation results. Plot the power for individual load as well as total power of the circuit.

(ii) Perform "Three Phase Power Measurement" experiment on virtual lab.

Mathematical Expressions and Theoretical Calculations

CIRCUIT 1:



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Student ID : 202052307

Date:
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The phase voltages $\overline{V}_{\phi a}$, $\overline{V}_{\phi b}$ and $\overline{V}_{\phi c}$ are given,

$$\boxed{\begin{aligned}\overline{V}_{\phi a} &= 100 \angle 0^\circ \text{ V}\\ \overline{V}_{\phi b} &= 100 \angle 120^\circ \text{ V}\\ \overline{V}_{\phi c} &= 100 \angle -120^\circ \text{ V}\end{aligned}}$$

As the source is Y-balanced, the magnitude of line voltages will be $\sqrt{3}$ times the magnitude of phase voltages. Since, the source is connected in acb sequence, the line voltage will lag corresponding phase voltage by 30°.

$$\boxed{\begin{aligned}\overline{V}_{L(ab)} &= 100\sqrt{3} \angle -30^\circ = 173.2 \angle -30^\circ \text{ V}\\ \overline{V}_{L(bc)} &= 173.2 \angle 90^\circ \text{ V}\\ V_{L(ca)} &= 173.2 \angle -150^\circ \text{ V}\end{aligned}}$$

Applying KVL in loop ABCDA, AEFDA and AGHDA respectively gives

$$\boxed{\begin{aligned}\overline{V}_{Zc} &= \overline{V}_{\phi c} = 100 \angle -120 \text{ V}\\ \overline{V}_{Zb} &= \overline{V}_{\phi b} = 100 \angle 120^\circ \text{ V}\\ V_{Za} &= V_{\phi a} = 100 \angle 0^\circ \text{ V}\end{aligned}}$$

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From the circuit it can be concluded that corresponding phase, line and load currents are equal.

i.e. $\bar{I}_{\phi a} = \bar{I}_{La} = \bar{I}_{Za}$

$\bar{I}_{\phi b} = \bar{I}_{Lb} = \bar{I}_{Zb}$

$\bar{I}_{\phi c} = \bar{I}_{Lc} = \bar{I}_{Zc}$

Now, $\bar{I}_{Za} = \dfrac{\bar{V}_{Za}}{Z_a} = \dfrac{100\angle 0^\circ}{135\angle 45^\circ}$

$\therefore \bar{I}_{Za} = 0.74\angle -45^\circ$ A

and, $\bar{I}_{Zb} = \dfrac{\bar{V}_{Zb}}{Z_b} = \dfrac{100\angle 120^\circ}{100\angle 60^\circ} = 1\angle 60^\circ$ A

$\therefore \bar{I}_{Zb} = 1\angle 60^\circ$ A

and $\bar{I}_{Zc} = \dfrac{\bar{V}_{Zc}}{Z_c} = \dfrac{100\angle -120^\circ}{200\angle 20^\circ} = 0.5\angle -140^\circ$ A

$\bar{I}_{Zc} = 0.5\angle -140^\circ$ A

$$\boxed{\begin{aligned} \therefore\ \bar{I}_{\phi a} &= \bar{I}_{La} = \bar{I}_{Za} = 0.74\angle -45^\circ \text{ A} \\ \bar{I}_{\phi b} &= \bar{I}_{Lb} = \bar{I}_{Zb} = 1\angle 60^\circ \text{ A} \\ \bar{I}_{\phi c} &= \bar{I}_{Lc} = \bar{I}_{Zc} = 0.5\angle -140^\circ \text{ A} \end{aligned}}$$

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Applying KCL at node D

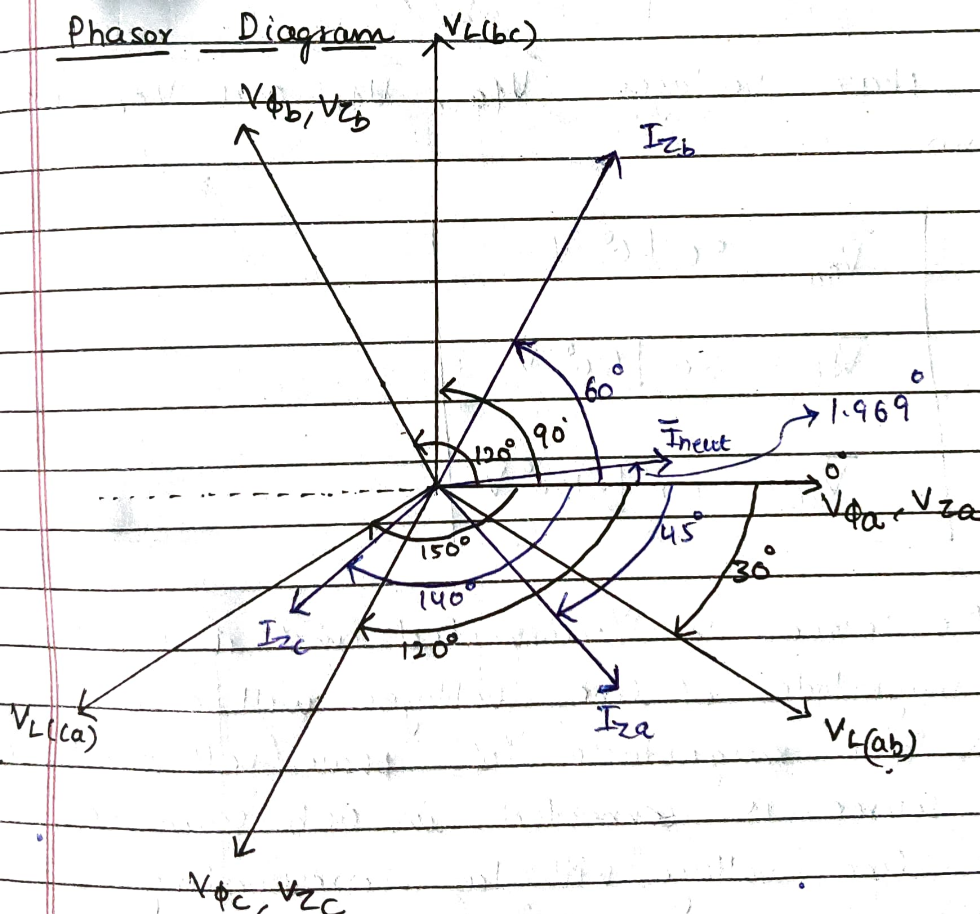
$$\bar{I}_{neut} = \bar{I}_{Za} + \bar{I}_{Zb} + \bar{I}_{Zc}$$

$$= 0.74\angle{-45^\circ} + 1\angle{60^\circ} + 0.5\angle{-140^\circ}$$

$$= (0.523 - j\,0.523) + (0.5 + j\,0.866) + (-0.383 - j\,0.321)$$

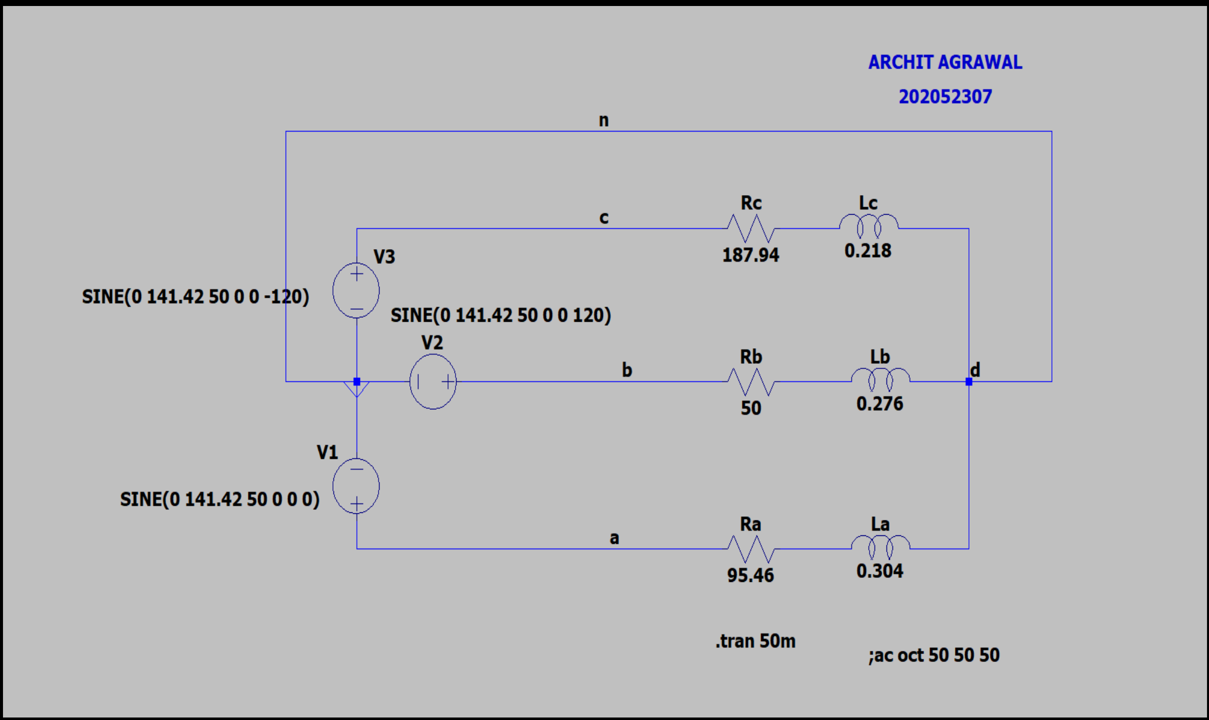
$$\boxed{\begin{aligned} \bar{I}_{neut} &= 0.64 + j\,0.022 \text{ A} \\ \bar{I}_{neut} &= 0.6404\angle{1.969^\circ} \text{ A} \end{aligned}}$$

Phasor Diagram

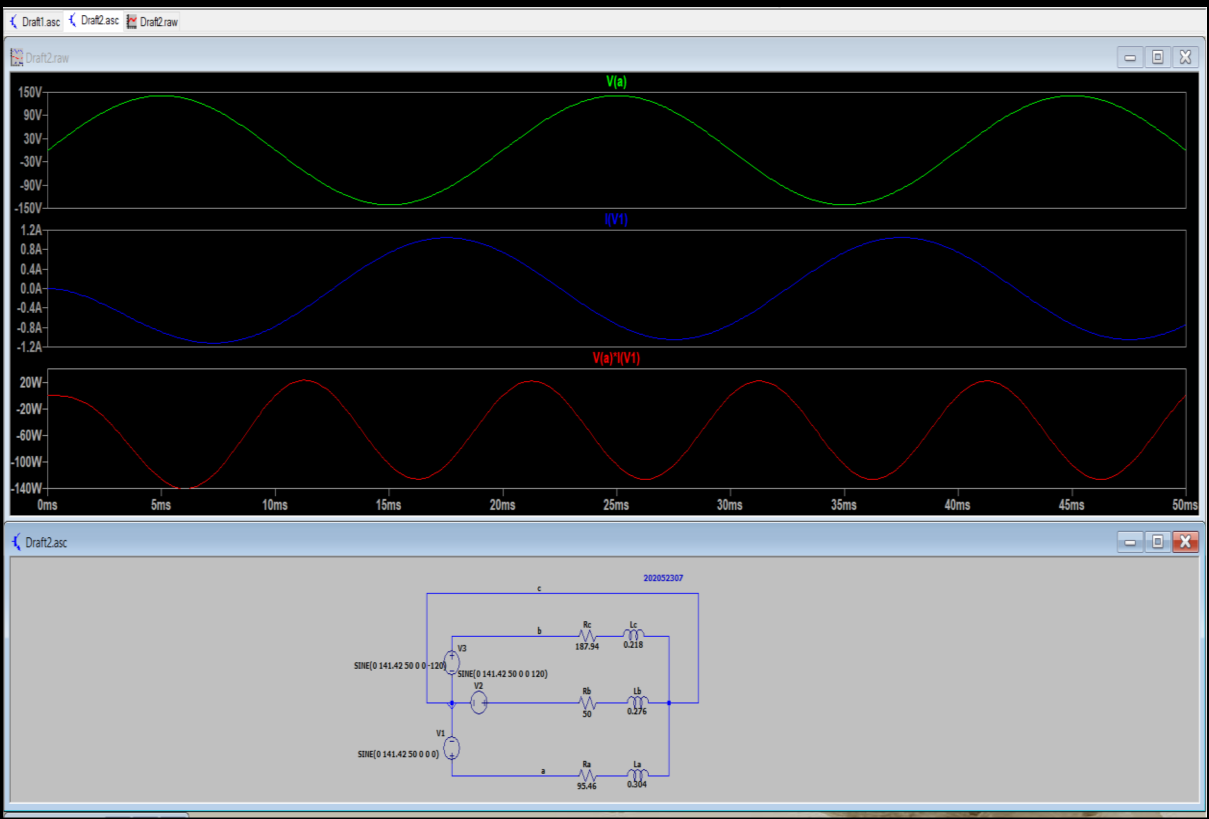


EE160 : Experiment 4

Circuit

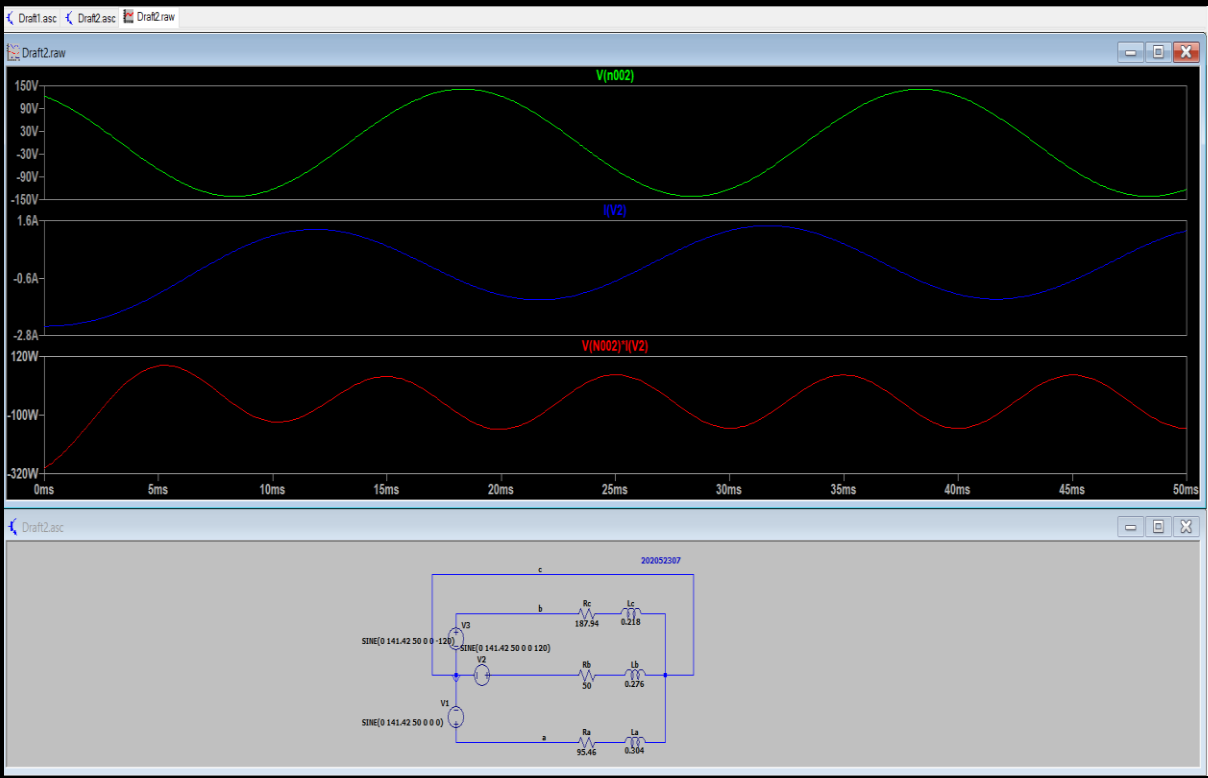


Voltage, Current and Power across source 'a'

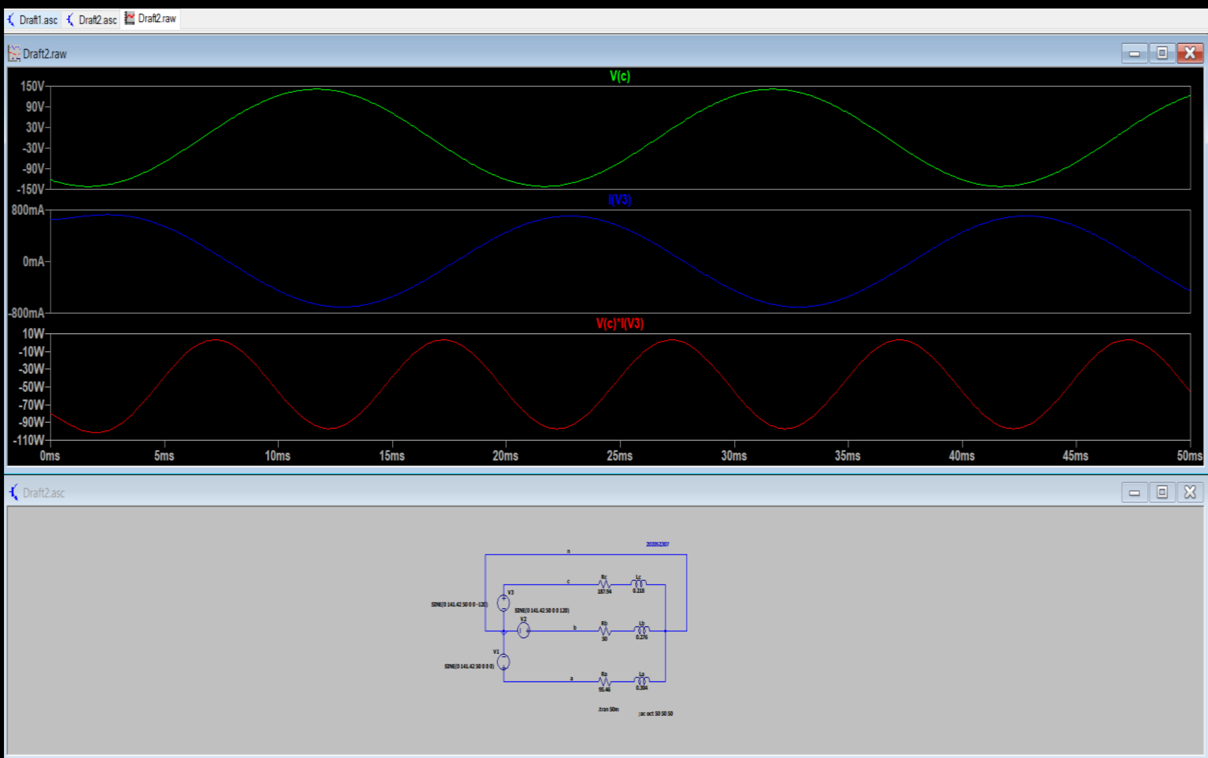


EE160 : Experiment 4

Voltage, Current and Power across source 'b'

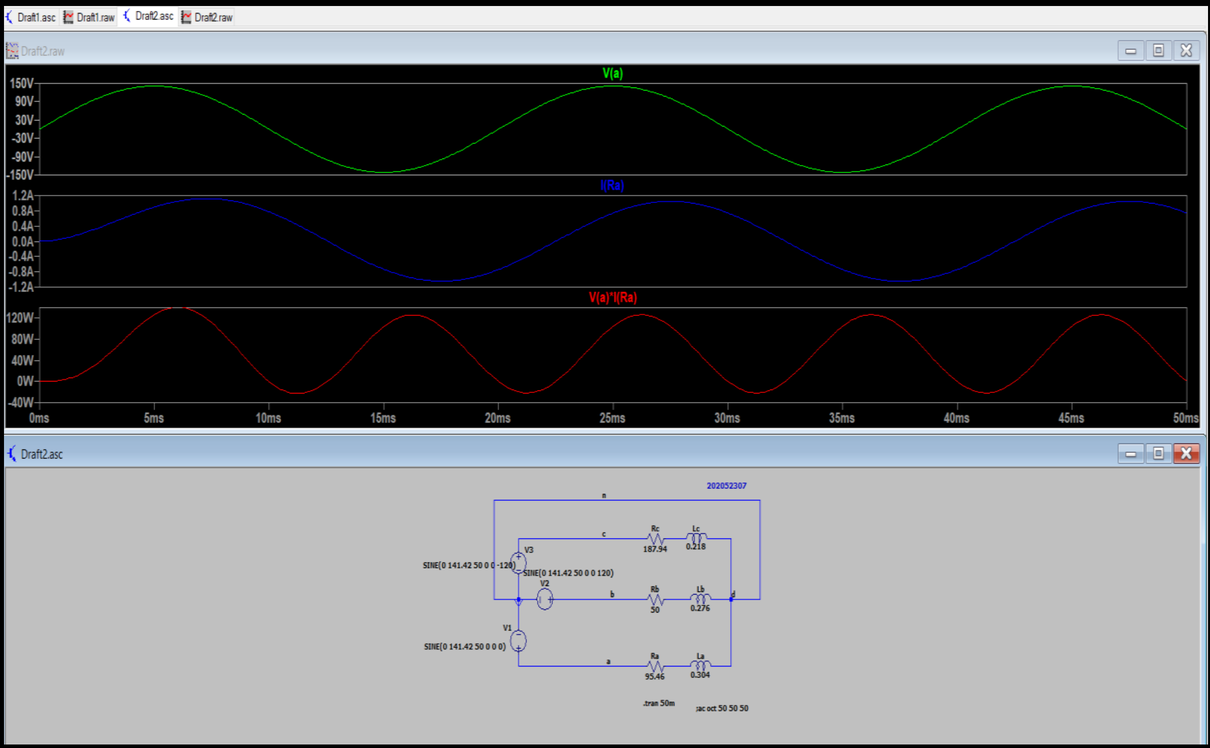


Voltage, Current and Power across source 'c'

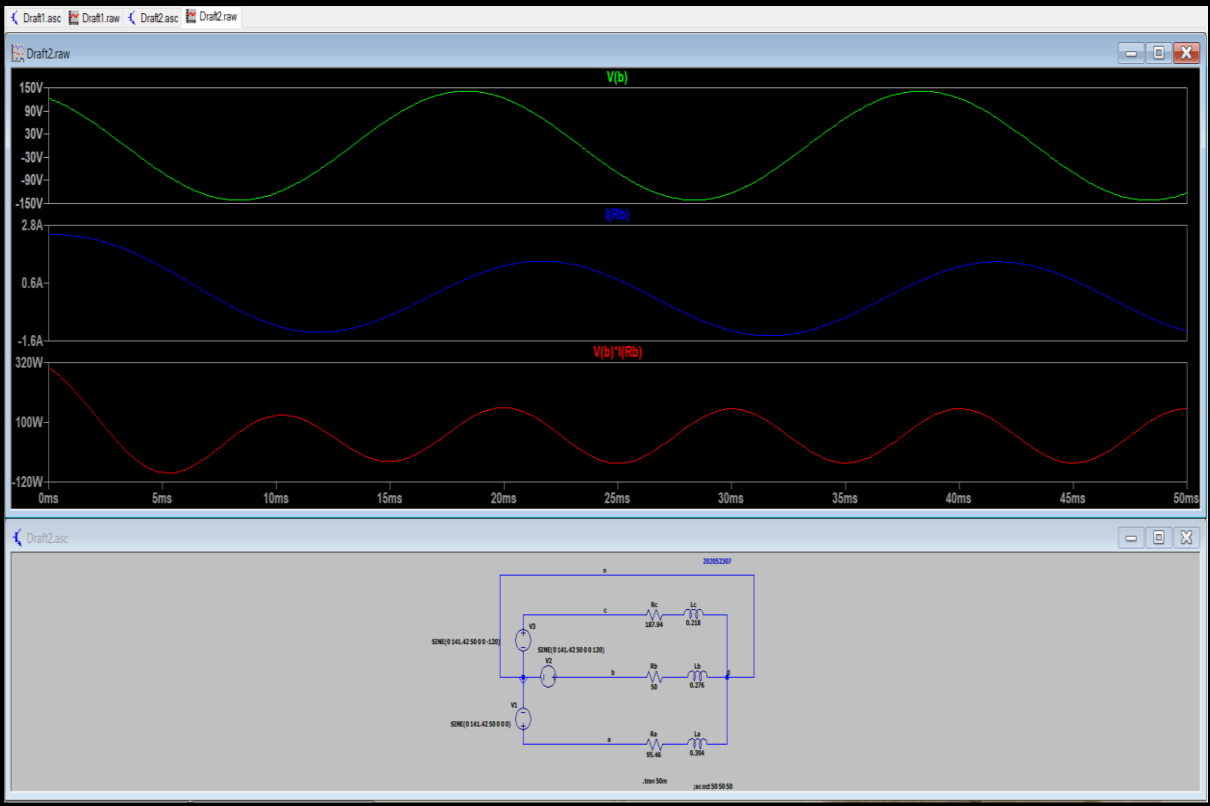


EE160 : Experiment 4

Voltage, Current and Power across load 'a'

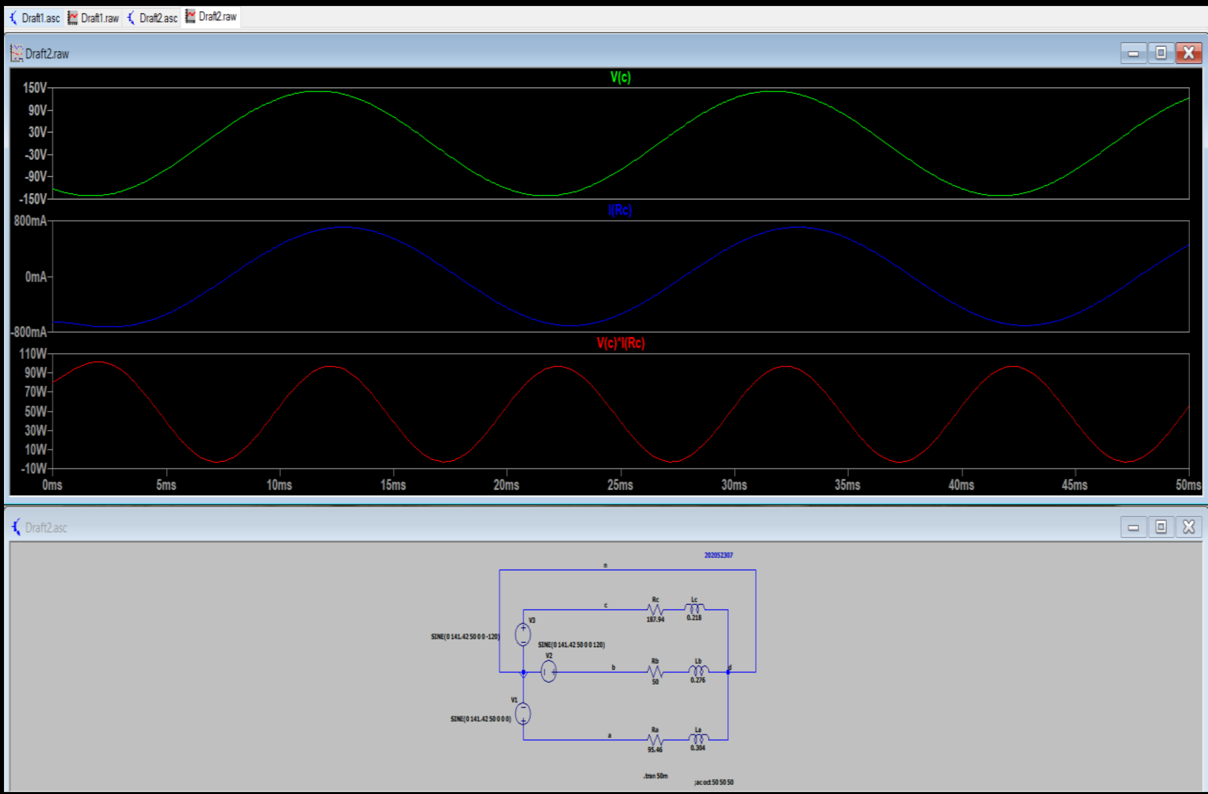


Voltage, Current and Power across load 'b'

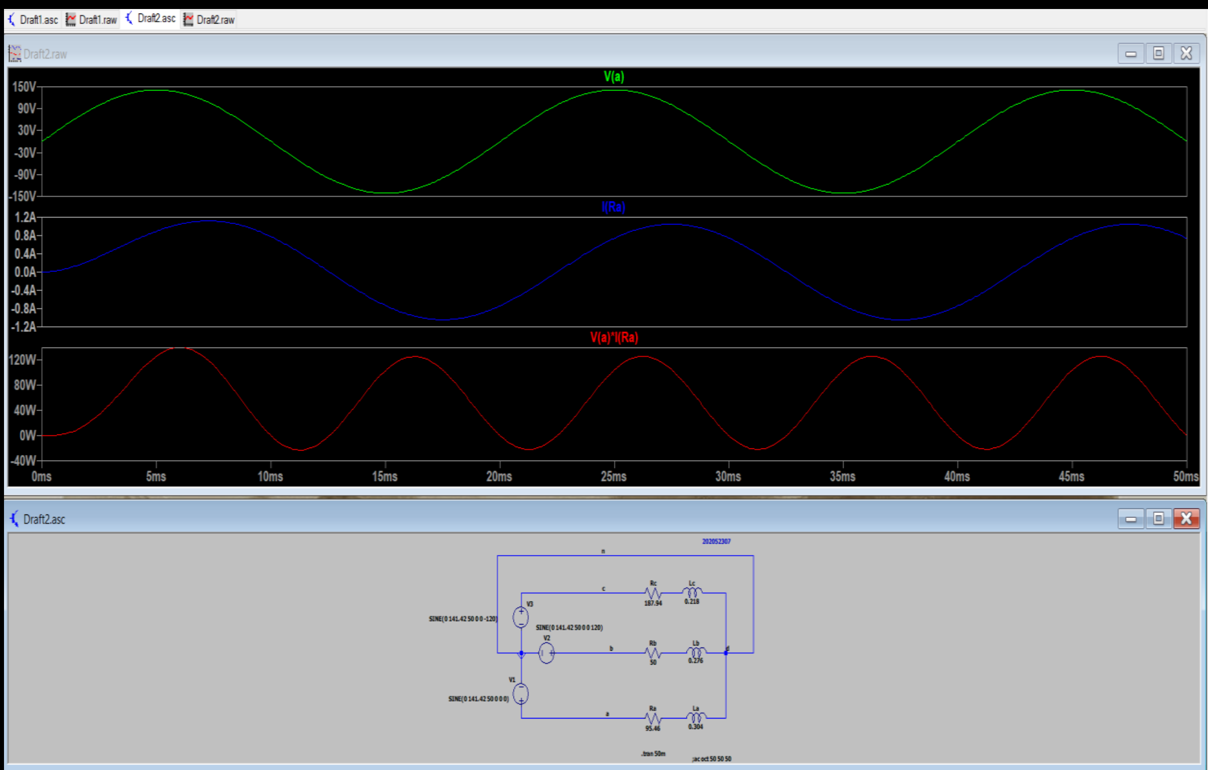


EE160 : Experiment 4

Voltage, Current and Power across load ‘c’

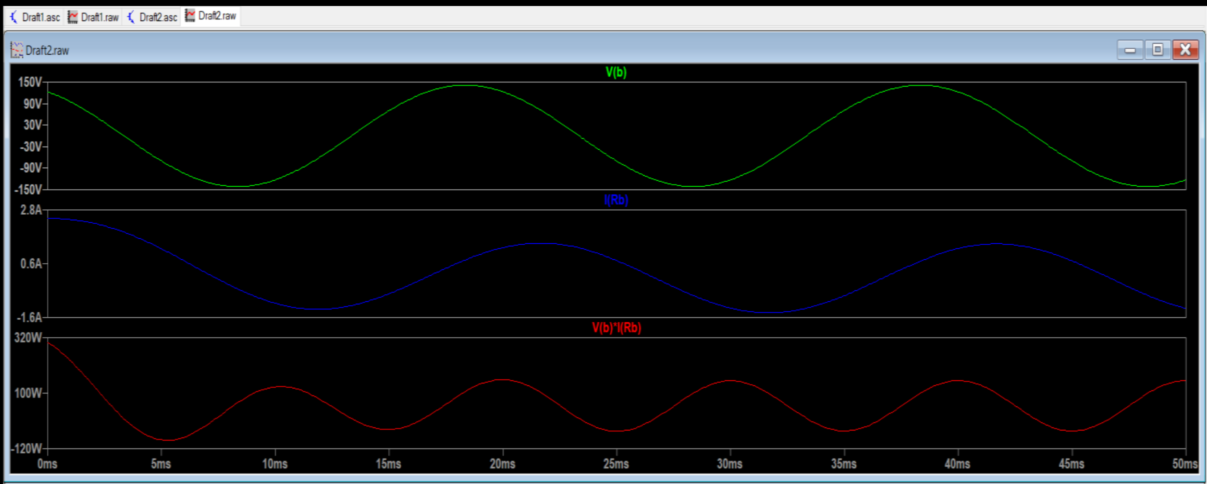


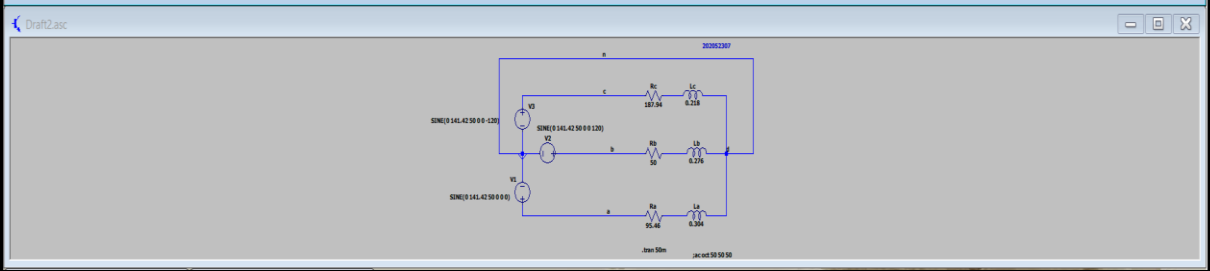
Voltage, Current and Power across load line ‘a’



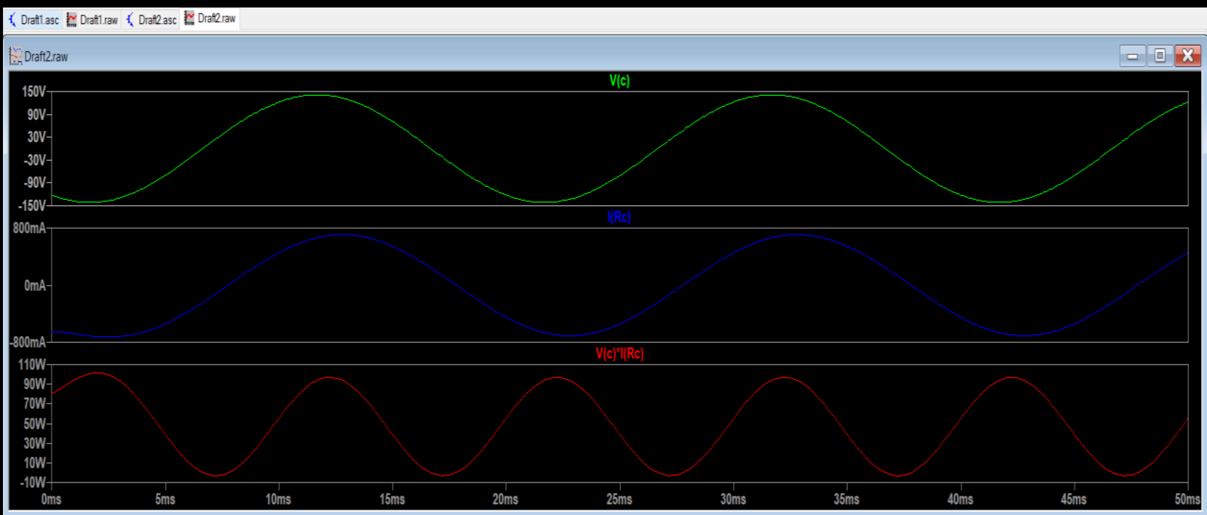
EE160 : Experiment 4

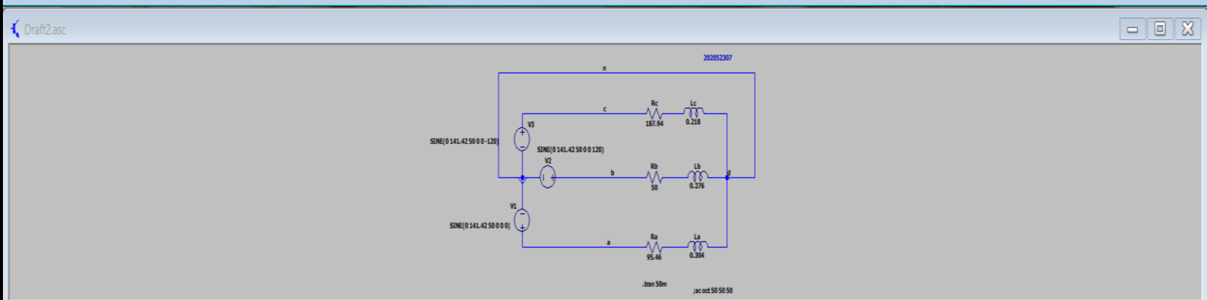
Voltage, Current and Power across load line ‘b’





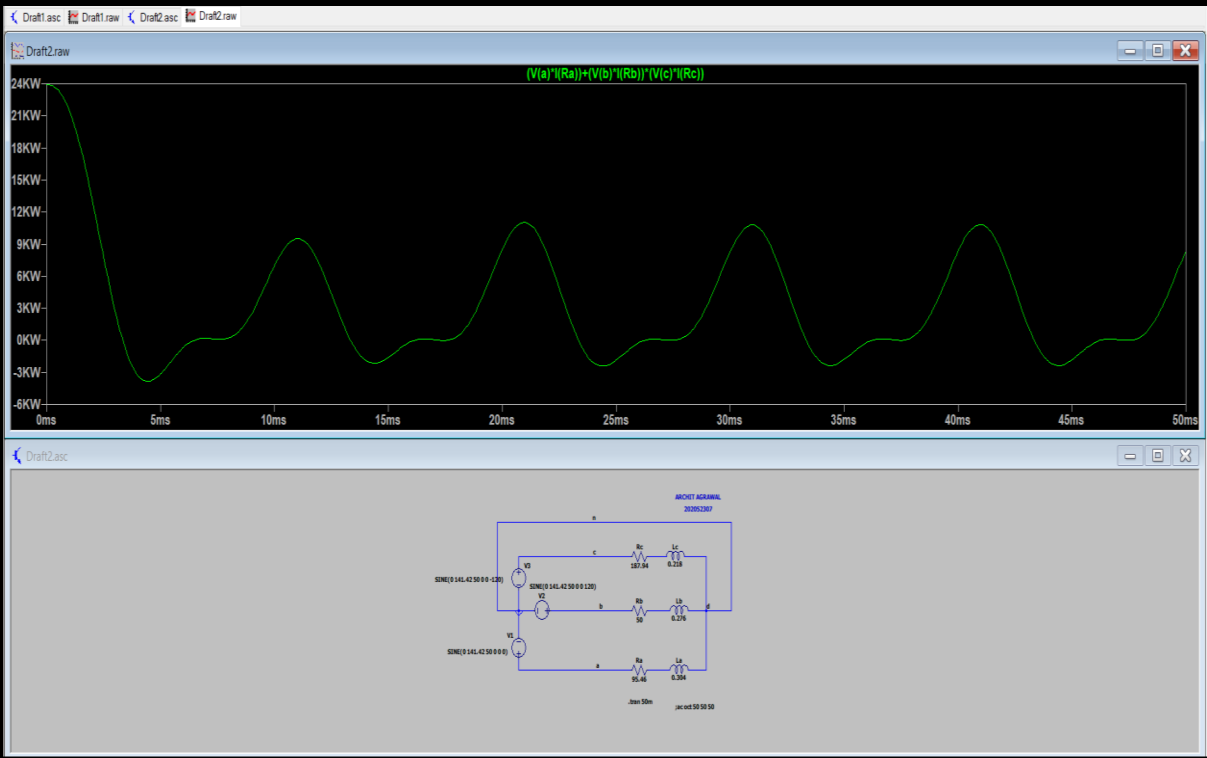
Voltage, Current and Power across load line ‘c’



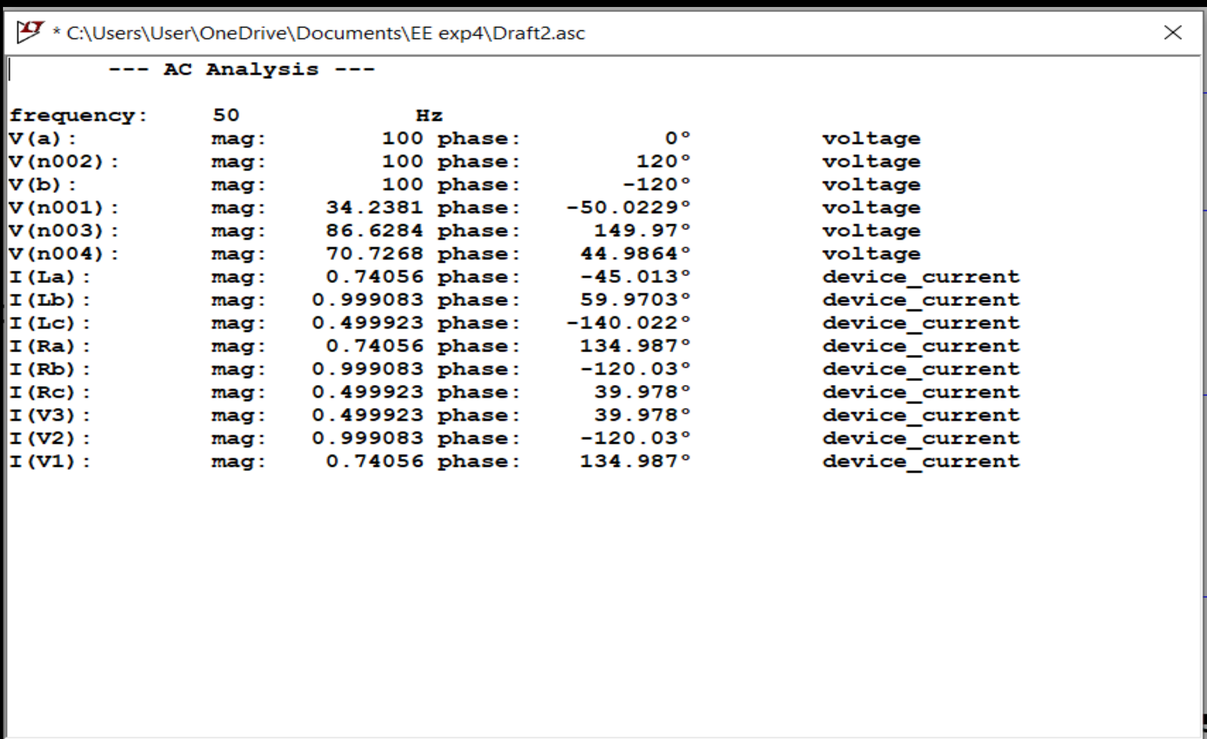


EE160 : Experiment 4

Total Power of Circuit



AC Analysis



```
* C:\Users\User\OneDrive\Documents\EE exp4\Draft2.asc
       --- AC Analysis ---

frequency:     50              Hz
V(a):          mag:        100 phase:          0°        voltage
V(n002):       mag:        100 phase:        120°        voltage
V(b):          mag:        100 phase:       -120°        voltage
V(n001):       mag:    34.2381 phase:   -50.0229°        voltage
V(n003):       mag:    86.6284 phase:     149.97°        voltage
V(n004):       mag:    70.7268 phase:    44.9864°        voltage
I(La):         mag:    0.74056 phase:    -45.013°        device_current
I(Lb):         mag:   0.999083 phase:    59.9703°        device_current
I(Lc):         mag:   0.499923 phase:   -140.022°        device_current
I(Ra):         mag:    0.74056 phase:    134.987°        device_current
I(Rb):         mag:   0.999083 phase:    -120.03°        device_current
I(Rc):         mag:   0.499923 phase:     39.978°        device_current
I(V3):         mag:   0.499923 phase:     39.978°        device_current
I(V2):         mag:   0.999083 phase:    -120.03°        device_current
I(V1):         mag:    0.74056 phase:    134.987°        device_current
```

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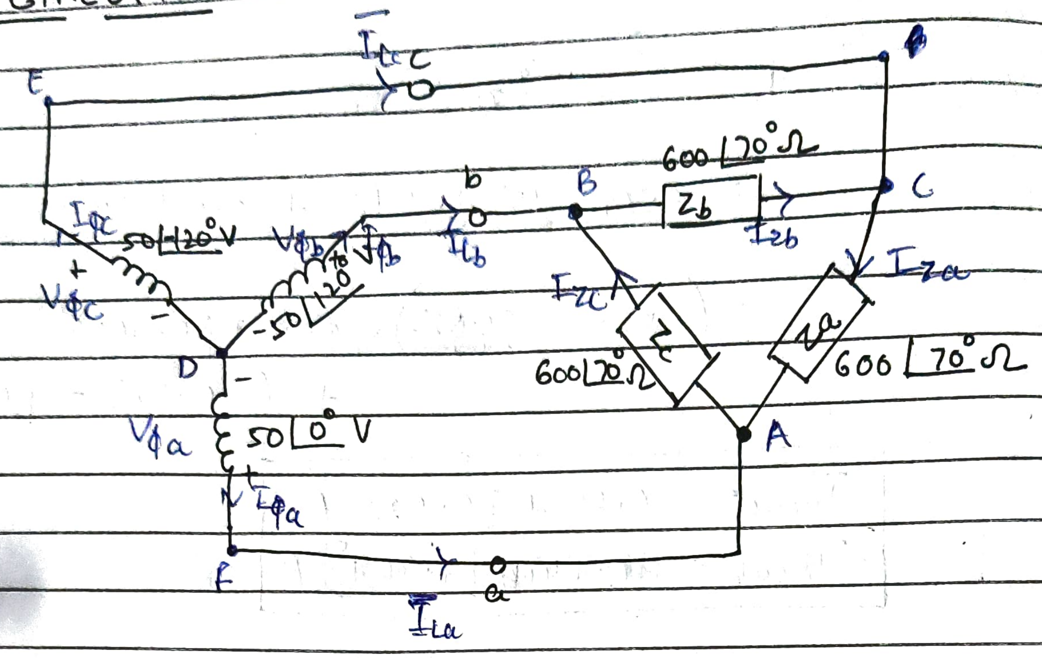
CIRCUIT - 2



The phase voltages $\bar{V}_{\phi a}$, $\bar{V}_{\phi b}$ and $\bar{V}_{\phi c}$ are given

$$\boxed{\begin{aligned} \bar{V}_{\phi a} &= 50\angle 0^\circ \text{ V} \\ \bar{V}_{\phi b} &= 50\angle 120^\circ \text{ V} \\ \bar{V}_{\phi c} &= 50\angle -120^\circ \text{ V} \end{aligned}}$$

As the source is Y-connected and it is balanced, the magnitude of line voltages will be $\sqrt{3}$ times the magnitude of phase voltages. Since the source is connected in acb sequence, the line voltage will lag corresponding phase voltage by 30°.

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$\therefore \quad \overline{V}_{L(ab)} = 50\sqrt{3} \angle -30^\circ$

$$\boxed{\begin{aligned} \overline{V}_{L(ab)} &= 86.6 \angle -30^\circ \text{ V} \\ \overline{V}_{L(bc)} &= 86.6 \angle 90^\circ \text{ V} \\ \overline{V}_{L(ca)} &= 86.6 \angle -150^\circ \text{ V} \end{aligned}}$$

Applying KVL in loop DEGBD,

$$\overline{V}_{\phi c} + \overline{V}_{Zb} - \overline{V}_{\phi b} = 0$$

$$\overline{V}_{Zb} = \overline{V}_{\phi b} - \overline{V}_{\phi c}$$

$$\overline{V}_{Zb} = \overline{V}_{L(bc)} \qquad (\because \overline{V}_{\phi b} - \overline{V}_{\phi c} = \overline{V}_{L(bc)})$$

Similarly $\quad \overline{V}_{Za} = \overline{V}_{L(ca)}$

and $\quad \overline{V}_{Zc} = \overline{V}_{L(ab)}$

$$\therefore \quad \boxed{\begin{aligned} \overline{V}_{Za} &= 86.6 \angle -150^\circ \text{ V} \\ \overline{V}_{Zb} &= 86.6 \angle 90^\circ \text{ V} \\ \overline{V}_{Zc} &= 86.6 \angle -30^\circ \text{ V} \end{aligned}}$$

Now, the load currents,

$$\overline{I}_{Za} = \frac{\overline{V}_{Za}}{Z_a} = \frac{86.6 \angle -150^\circ}{600 \angle 70^\circ} \text{ A}$$

$$\boxed{\overline{I}_{Za} = 144.33 \angle -220^\circ \text{ mA}} \text{ or } 144.33 \angle 140^\circ \text{ mA}$$

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$$\boxed{\begin{aligned}\overline{I_{zb}} &= 144.33\angle 20^\circ \text{ mA}\\ \overline{I_{zc}} &= 144.33\angle -100^\circ \text{ mA}\end{aligned}}$$

Applying KCL at node A,

$$\overline{I_{La}} = \overline{I_{zc}} - \overline{I_{za}}$$

$$\overline{I_{La}} = 144.33\angle -100^\circ - 144.33\angle -220^\circ$$

$$\overline{I_{La}} = (-25.06 - j\,142.14) - (-110.56 + j\,92.77)$$

$$\overline{I_{La}} = 85.5 - j\,234.91 \text{ mA}$$

$$\overline{I_{La}} = 249.986\angle -70^\circ \text{ mA}$$

Similarly, $\overline{I_{Lb}} = 249.986\angle 50^\circ$ mA

and, $\overline{I_{Lc}} = 249.986\angle 170^\circ$ mA

From the circuit, it is clear that,

$$\boxed{\begin{aligned}\overline{I_{\phi a}} &= \overline{I_{La}} = 249.986\angle -70^\circ \text{ mA}\\ \overline{I_{\phi b}} &= \overline{I_{Lb}} = 249.986\angle 50^\circ \text{ mA}\\ \overline{I_{\phi c}} &= \overline{I_{Lc}} = 249.986\angle 170^\circ \text{ mA}\end{aligned}}$$

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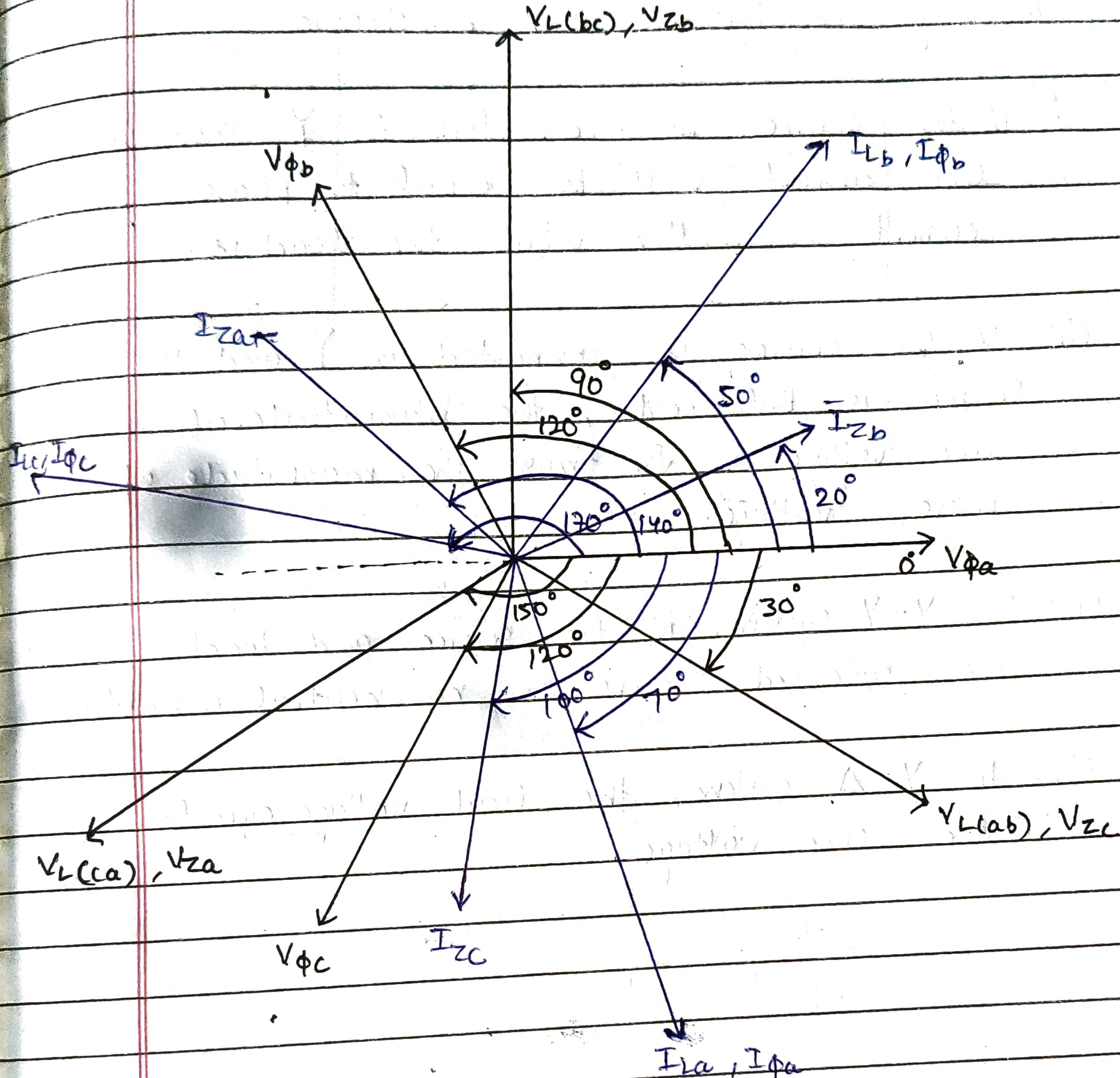
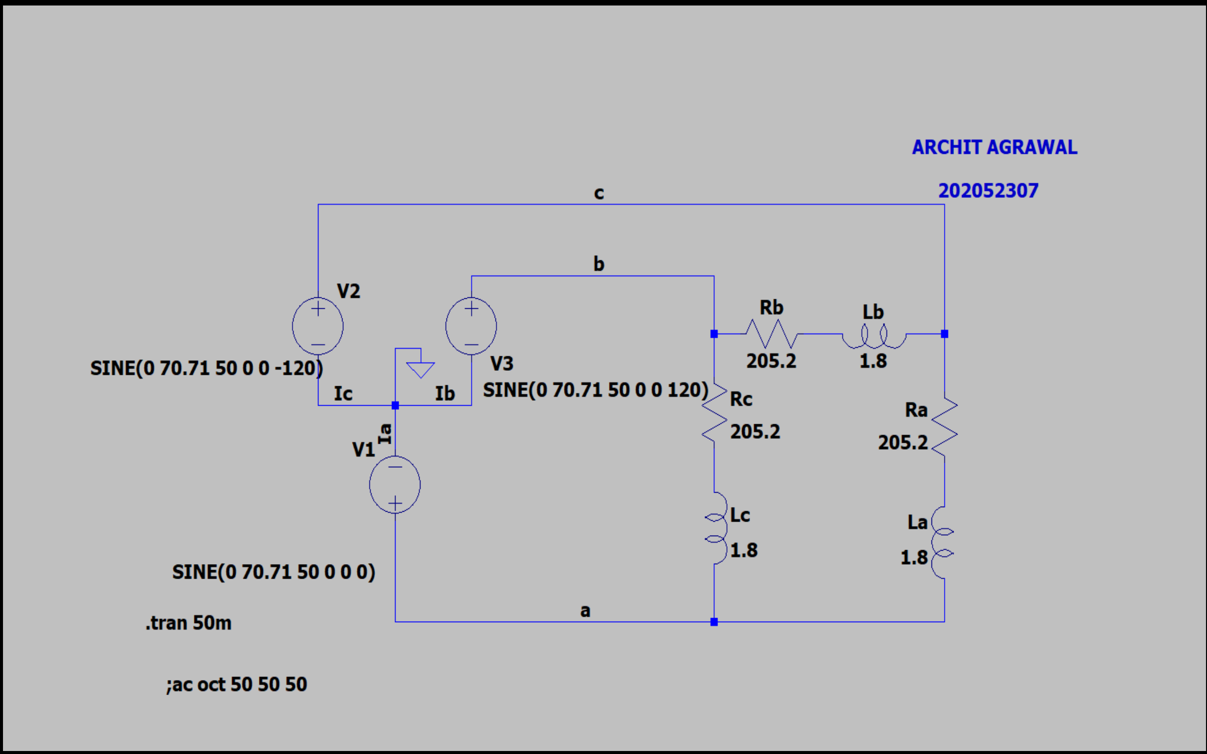
Phasor Diagram

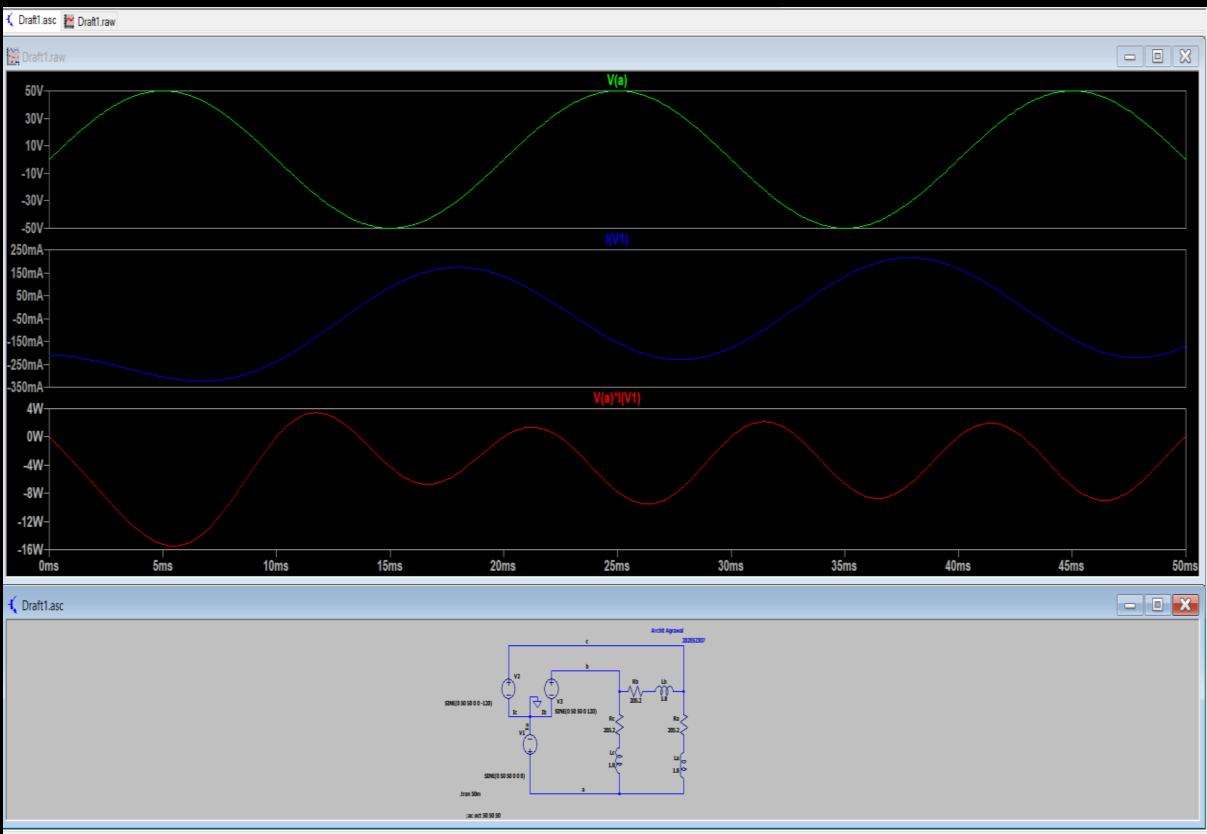


EE160 : Experiment 4

Circuit

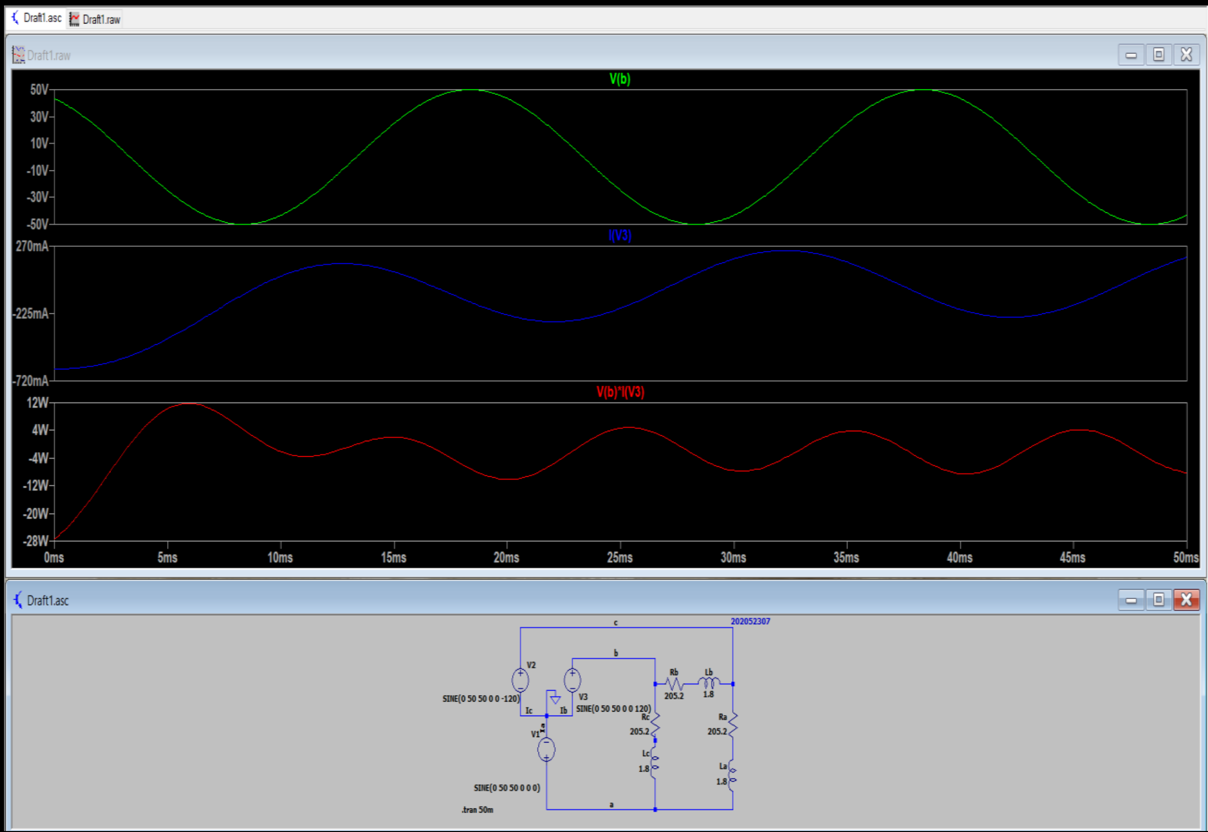


Voltage, Current and Power across source 'a'

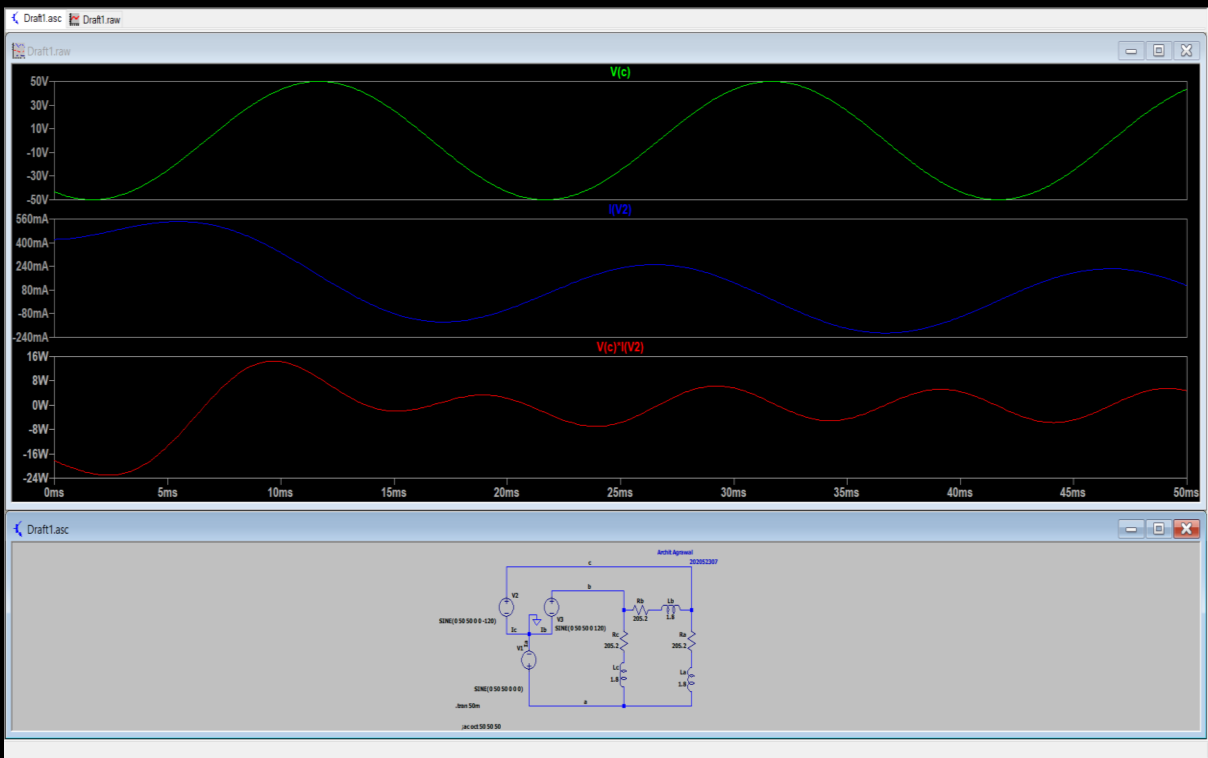


EE160 : Experiment 4

Voltage, Current and Power across source ‘b’

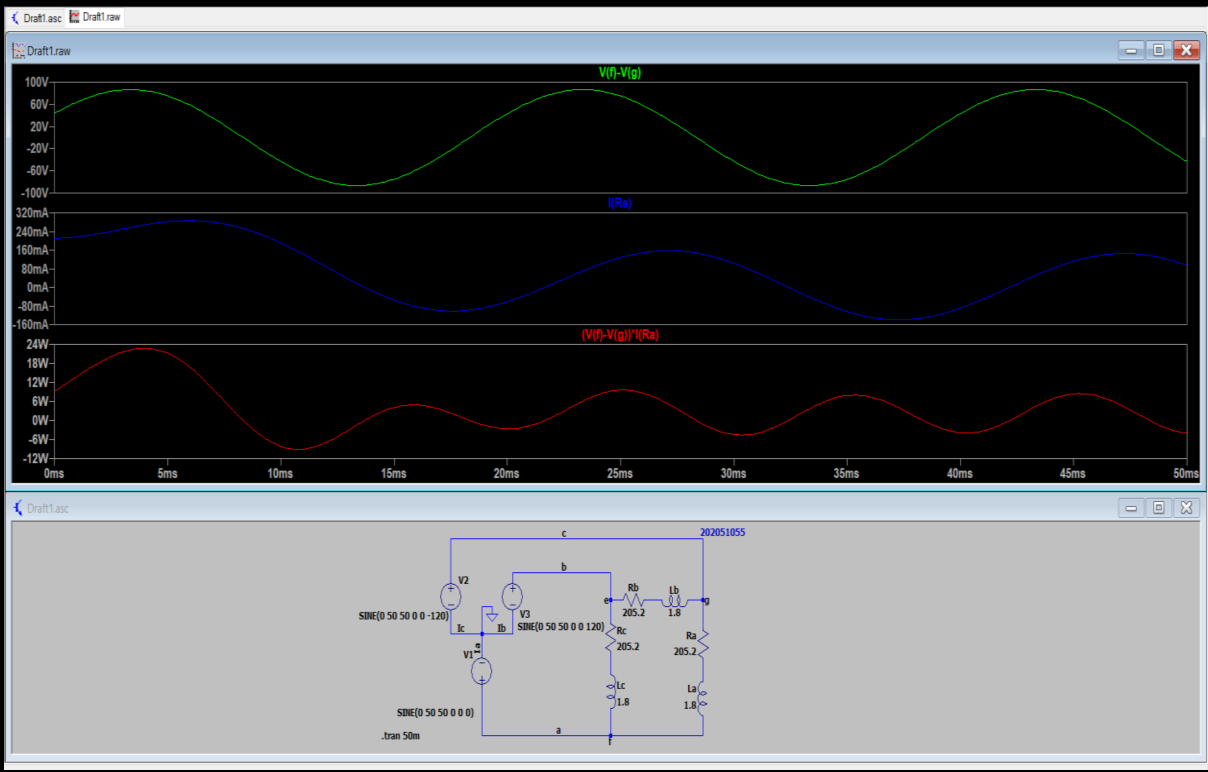


Voltage, Current and Power across source ‘c’

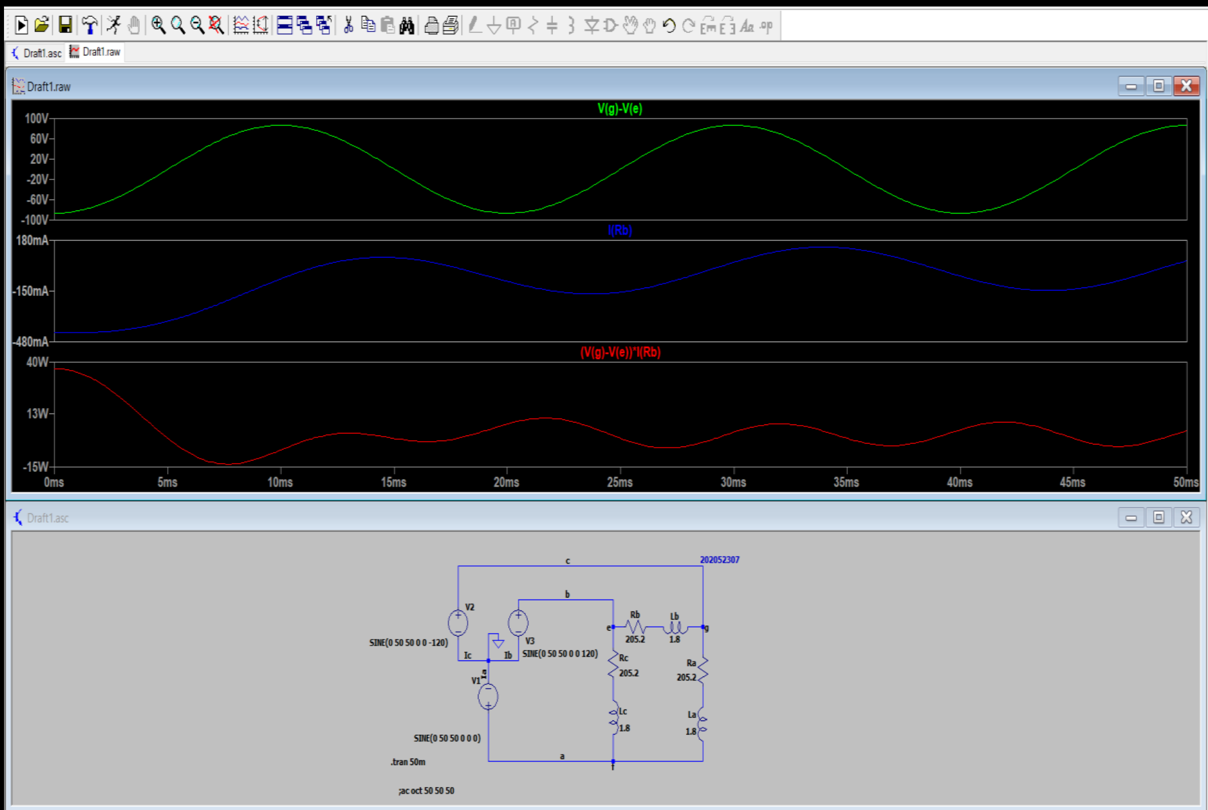


EE160 : Experiment 4

Voltage, Current and Power across load ‘a’

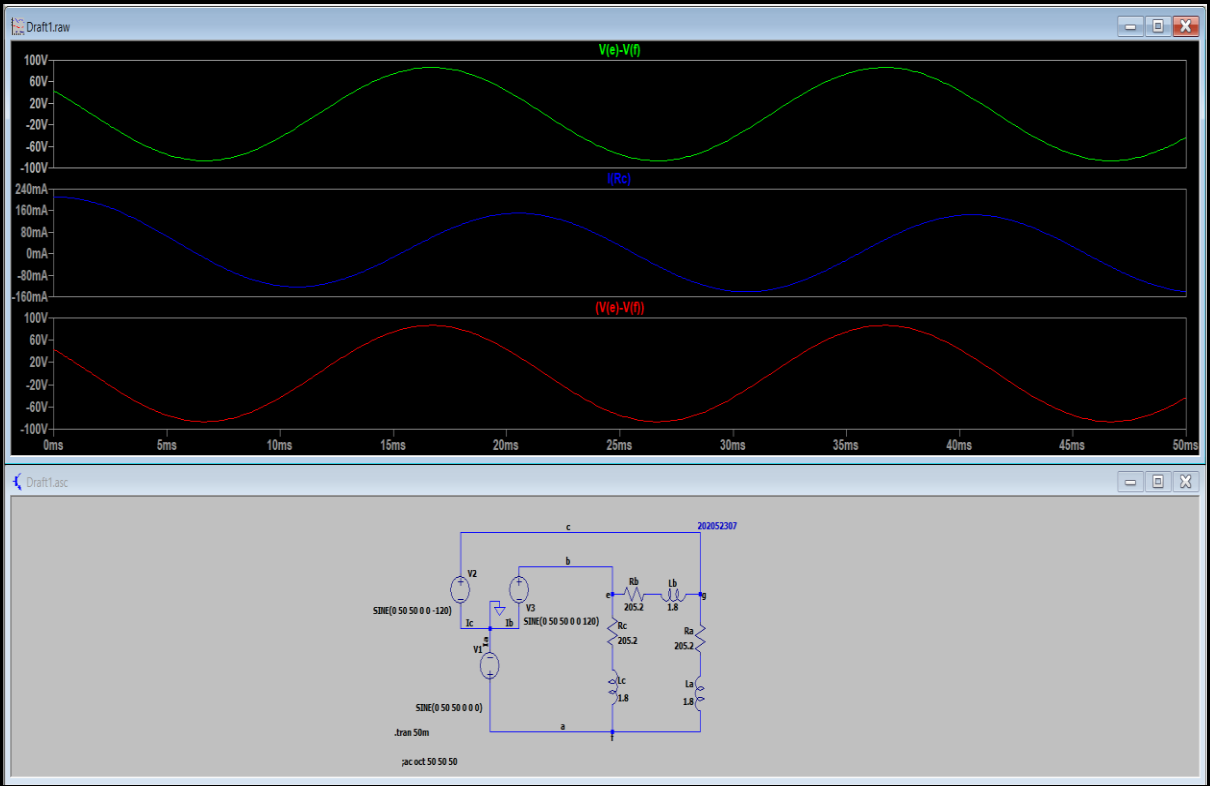


Voltage, Current and Power across load ‘b’

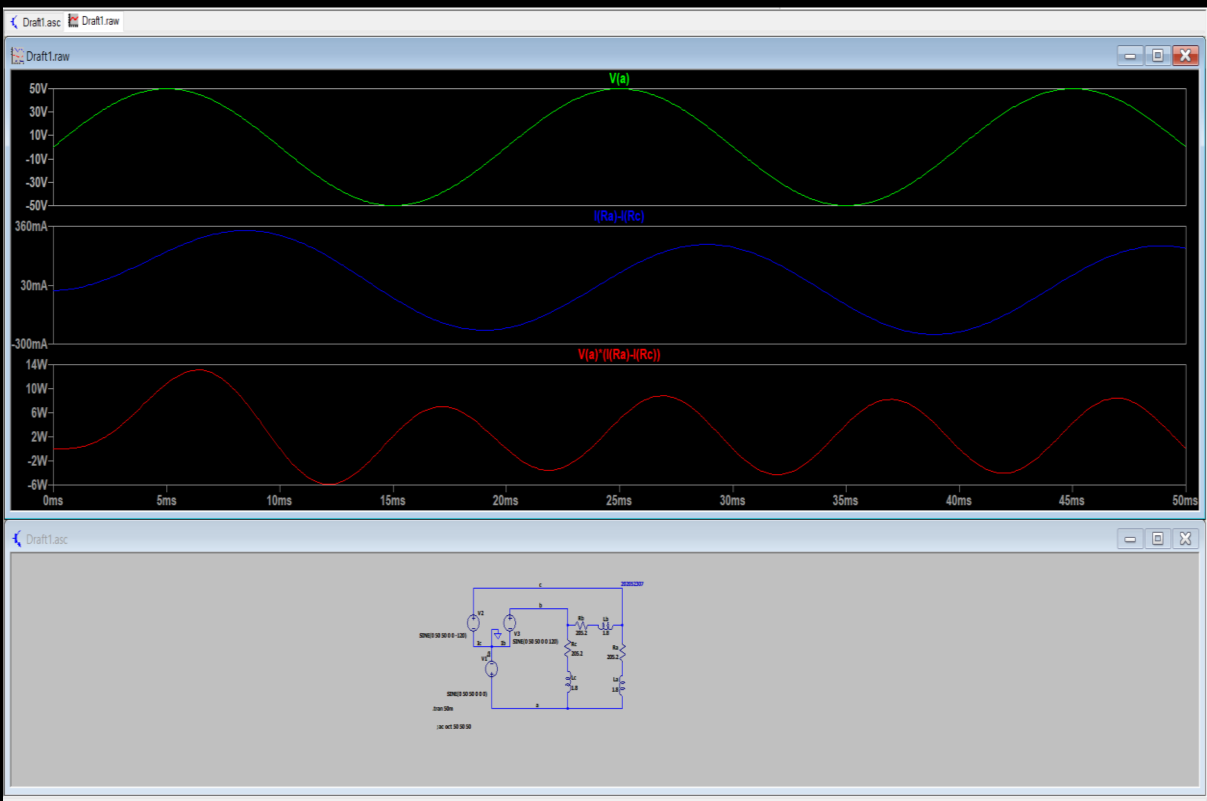


EE160 : Experiment 4

Voltage, Current and Power across load ‘c’

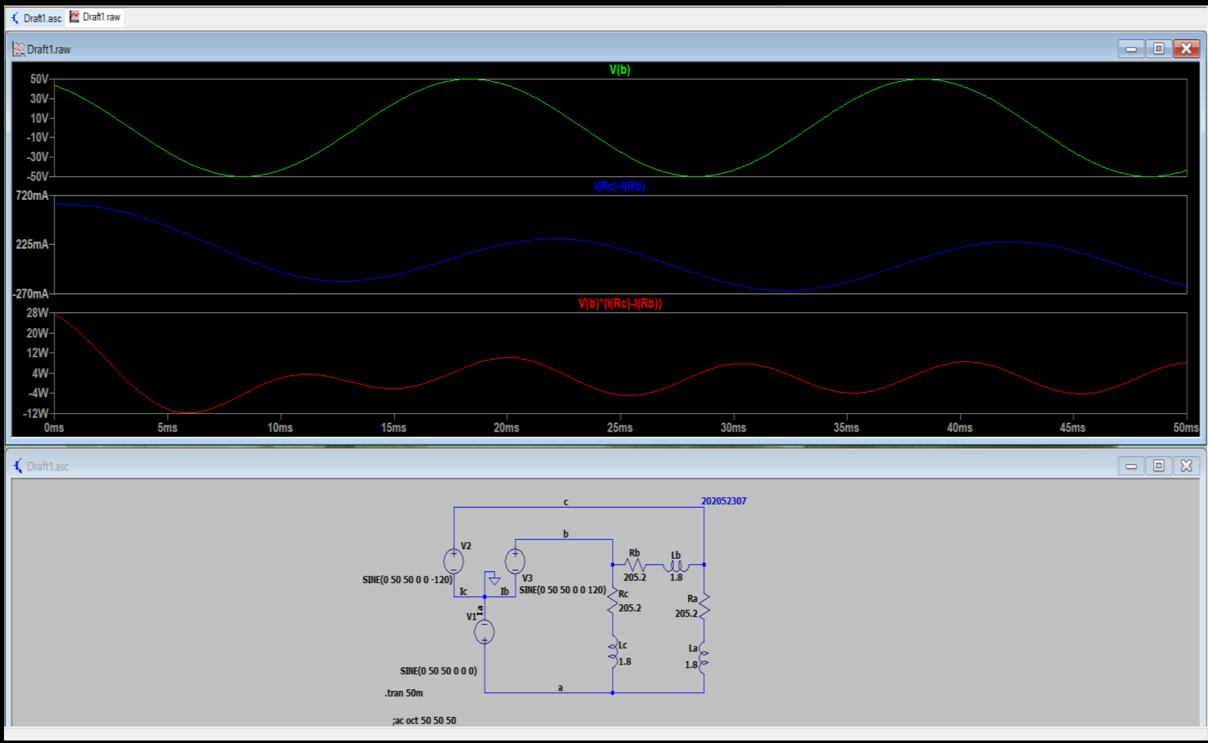


Voltage, Current and Power across load line ‘a’

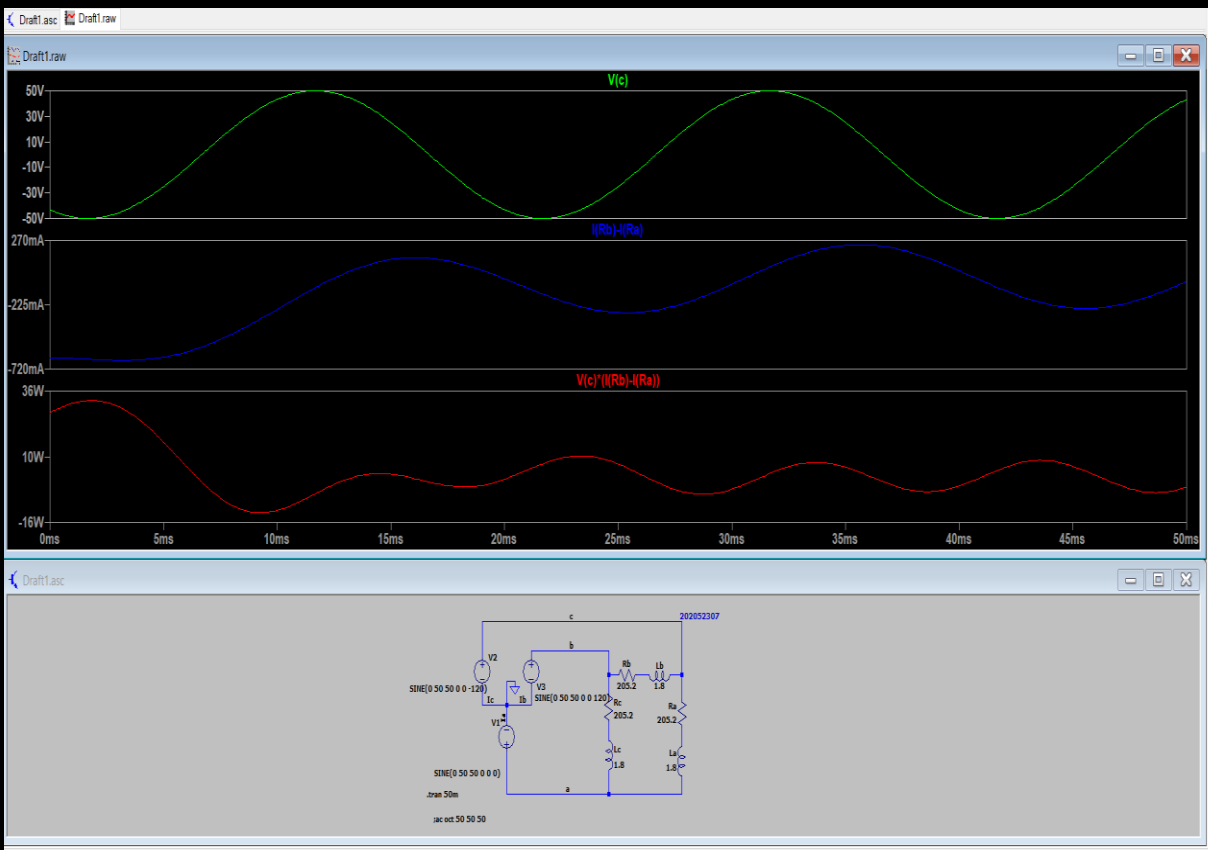


EE160 : Experiment 4

Voltage, Current and Power across load line 'b'

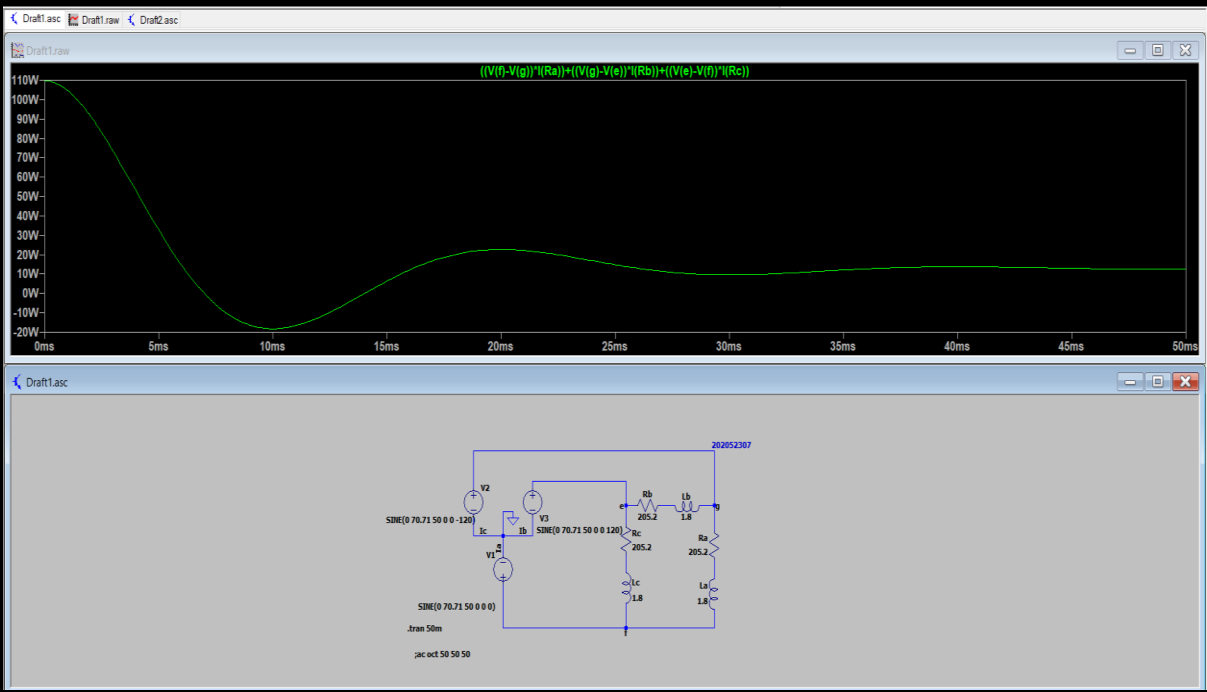


Voltage, Current and Power across load line 'c'



EE160 : Experiment 4

Total Power of Circuit



AC Analysis

```
        --- AC Analysis ---

frequency:     50            Hz
V(n003):     mag:    62.3575 phase:    -92.1954°        voltage
V(c):        mag:         50 phase:        -120°        voltage
V(n001):     mag:    62.3575 phase:     147.805°        voltage
V(b):        mag:         50 phase:         120°        voltage
V(n002):     mag:    33.3397 phase:     154.764°        voltage
V(a):        mag:         50 phase: -2.03555e-015°      voltage
I(Lc):       mag:   0.143962 phase:    -100.055°        device_current
I(Lb):       mag:   0.143962 phase:     19.9446°        device_current
I(La):       mag:   0.143962 phase:    -40.0554°        device_current
I(Rc):       mag:   0.143962 phase:    -100.055°        device_current
I(Rb):       mag:   0.143962 phase:    -160.055°        device_current
I(Ra):       mag:   0.143962 phase:    -40.0554°        device_current
I(V3):       mag:   0.249349 phase:    -130.055°        device_current
I(V2):       mag:   0.249349 phase:    -10.0554°        device_current
I(V1):       mag:   0.249349 phase:     109.945°        device_current
```

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Student ID: 202052307

Conclusion :- Performing the simulations following conclusions can be drawn:

(i) If the source is connected in Y, then the line current will be equal to phase current. no matter what the load is.

(ii) If the source is connected in Y and the source is balanced, the magnitude of line voltage is $\sqrt{3}$ times the magnitude of phase voltage.

(iii) In Y-Y system, if the source and load are balanced, there is no neutral current.

(iv) In Y-Δ system, the load voltage equals the line voltage.

VIRTUAL

LAB

SIMULATIONS

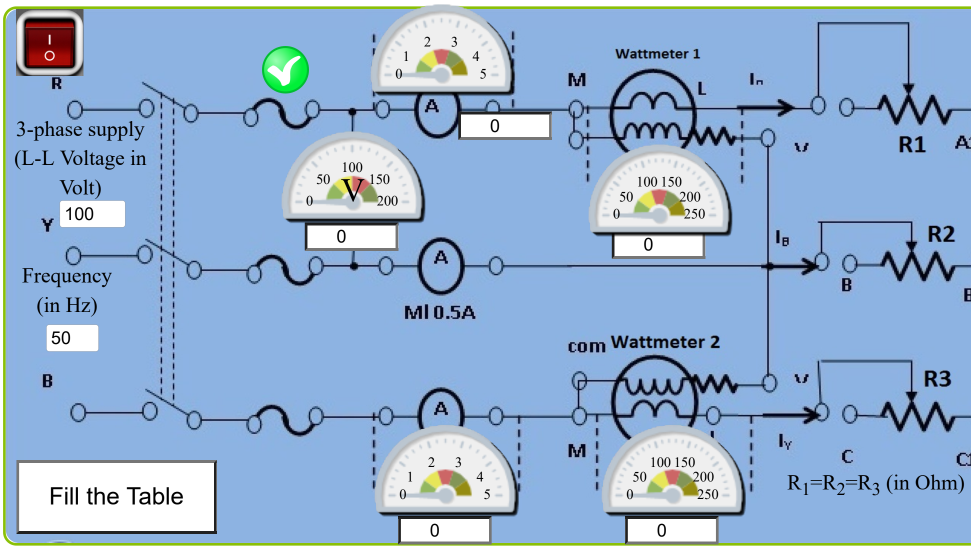
Three Phase Power Measurement

Balanced Load | Unbalanced Load

Procedure:

1. 1. Set the 3Phase (Line to Line) voltage 100 V at frequency = 50Hz.
2. 2. Set the balanced load value.
3. 3. Switch on the supply to get the meter readings and click on "Fill the Table" button to update the observation table.
4. 4. Compare calculated power (W_C) with the measured power (W_M) for each observation.
5. 5. Then change the balanced load value to take another observation.

N.B.: Click on the fuse indicator to repair it, if it got fused.



Observation Table

Serial no. of Observation	V_{RY}	I_R (Amp)	Cos(V_{RY}, I_R)	V_{BY}	I_B (Amp)	Cos(V_{BY}, I_B)	I_3(Amp)	W_1	W_2	W_C (Calculated power)	W_M(M Power
1st	100	2.3093977	0.8652280	100	2.3093977	0.8669190	2.3093977	199.81557	200.20609	399.99885	400.0
2nd	100	1.8624175	0.8652280	100	1.8624175	0.8669190	1.8624175	161.14158	161.45652	322.57972	322.5
3rd	100	1.5193406	0.8652280	100	1.5193406	0.8669190	1.5193406	131.45761	131.71453	263.15714	263.1
4th	100	1.1546988	0.8652280	100	1.1546988	0.8669190	1.1546988	99.907785	100.10304	199.99942	200.0
5th	100	0.5773494	0.8652280	100	0.5773494	0.8669190	0.5773494	49.953892	50.051523	99.999713	100.0

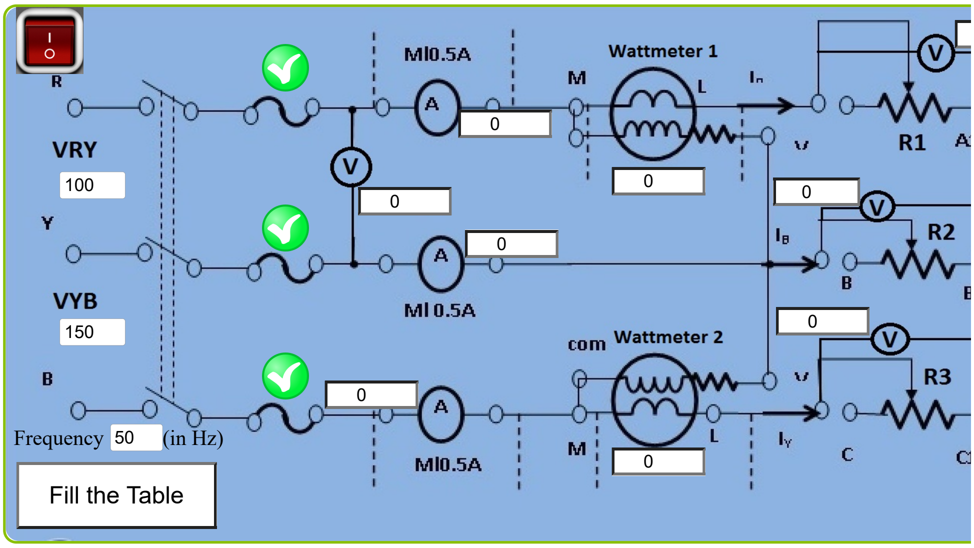
Three Phase Power Measurement

Balanced Load | Unbalanced Load

Procedure:

1. 1. Set the 3Phase (Line to Line) voltage to 100 V at frequency =50Hz.
2. 2. Set different values for R_1, R_2 and R_3.
3. 3. Switch on the supply to get the meter readings and click on "Fill the Table" button to update the observation table.
4. 4. Compare calculated power (W_C) with the measured power (W_M) for each observation.
5. 5. Change the values of R_1, R_2 and R_3 to take another observation.

N.B.: Click on the fuse indicator to repair it, if it got fused.



Observation Table

Serial no. of Observation	V_R	V_y	V_b	I_R (Amp)	I_Y (Amp)	I_B (Amp)	W_C (Calculated power)	W_1	W_2	W_M(Meas Power=W_1
1st	87.052381	119.29800	134.21025	0.7254354	0.7456114	0.7456114	252.16955	128.08477	125.78477	253.8695
2nd	87.366976	97.560490	134.92408	0.6720527	0.6919173	0.6919173	219.57533	111.78766	109.48766	221.2753
3rd	89.234978	145.52641	131.25911	0.9105596	0.9511516	0.9511516	344.51880	174.25940	171.95940	346.2188
4th	96.315480	142.17707	124.40494	0.6421022	0.7108843	0.7108843	251.35338	127.67669	125.37669	253.0533
5th	98.290085	142.85410	122.44637	0.5850591	0.6583129	0.6583129	232.15625	118.07812	115.77812	233.8562