EXPERIMENT NO 7

THREE PHASE POWER MEASUREMENT

SUBMITTED BY

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2K20/B17/33

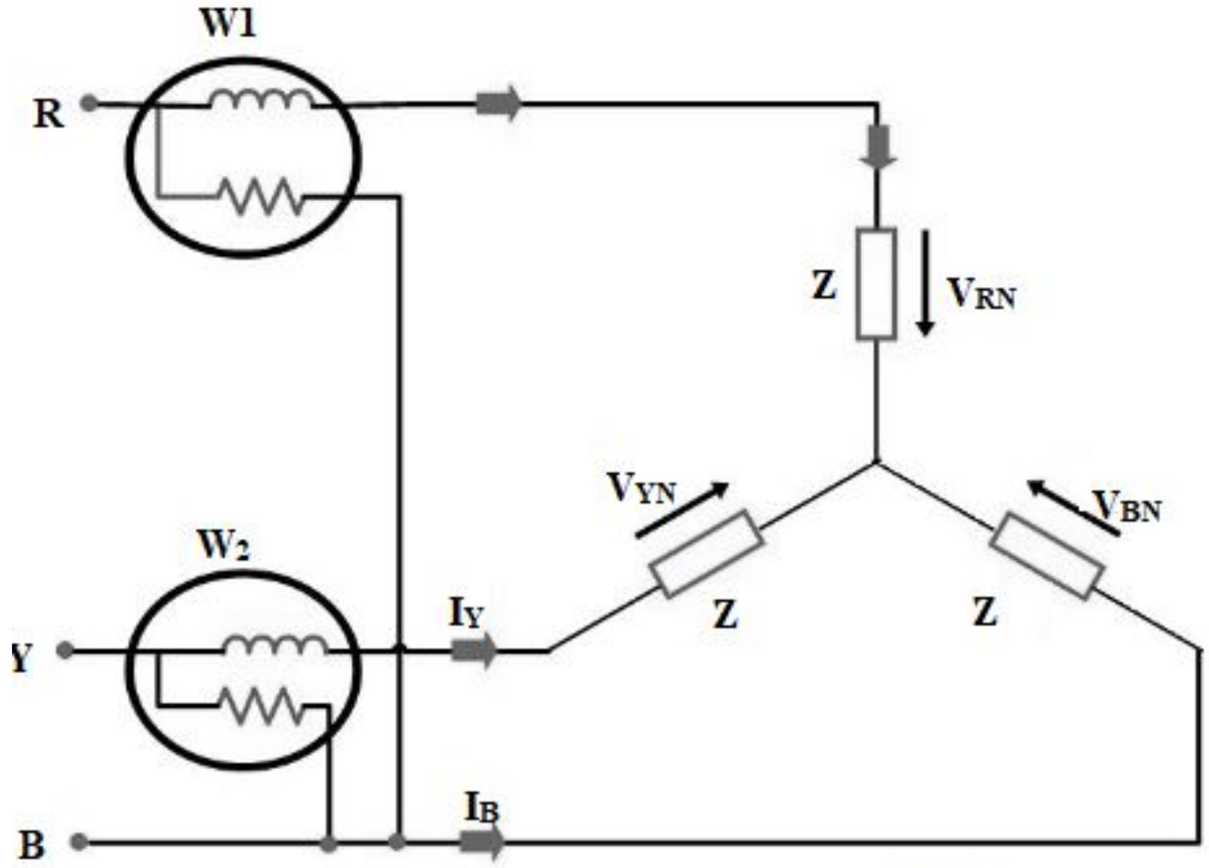
BEE LAB P2

AIM/OBJECTIVE:
Three phase power measurement by two wattmeter method

THEORY:

All the electrical equipment and machines work on supplying electric power and dissipate large amounts of energy. The supplied power is usually measured in terms of watts using a device namely wattmeter. A wattmeter is also called as deflection meter which is mainly used in electrical labs. It not only measure power in terms of watts but also measures in terms of kilowatts and megawatts. The wattmeter usually consists of two coils “CC” current coil which is usually connected in series with load current and a voltage/ pressure / potential coil “PC”, this coil is usually connected across the load circuit. The electrical power can be represented in three forms they are real power, reactive power, and apparent power. The following article describes the two wattmeter method at balanced load condition.

A three-phase two-watt meter measures the current and voltage from any of the 2 supply lines of 3 phase corresponding to the 3rd supply line of 3 phase. The 3 phase 2 wattmeter is said to be at a balanced load condition if the current in every phase lag at an angle “ϕ” with phase voltage.



Circuit Diagram

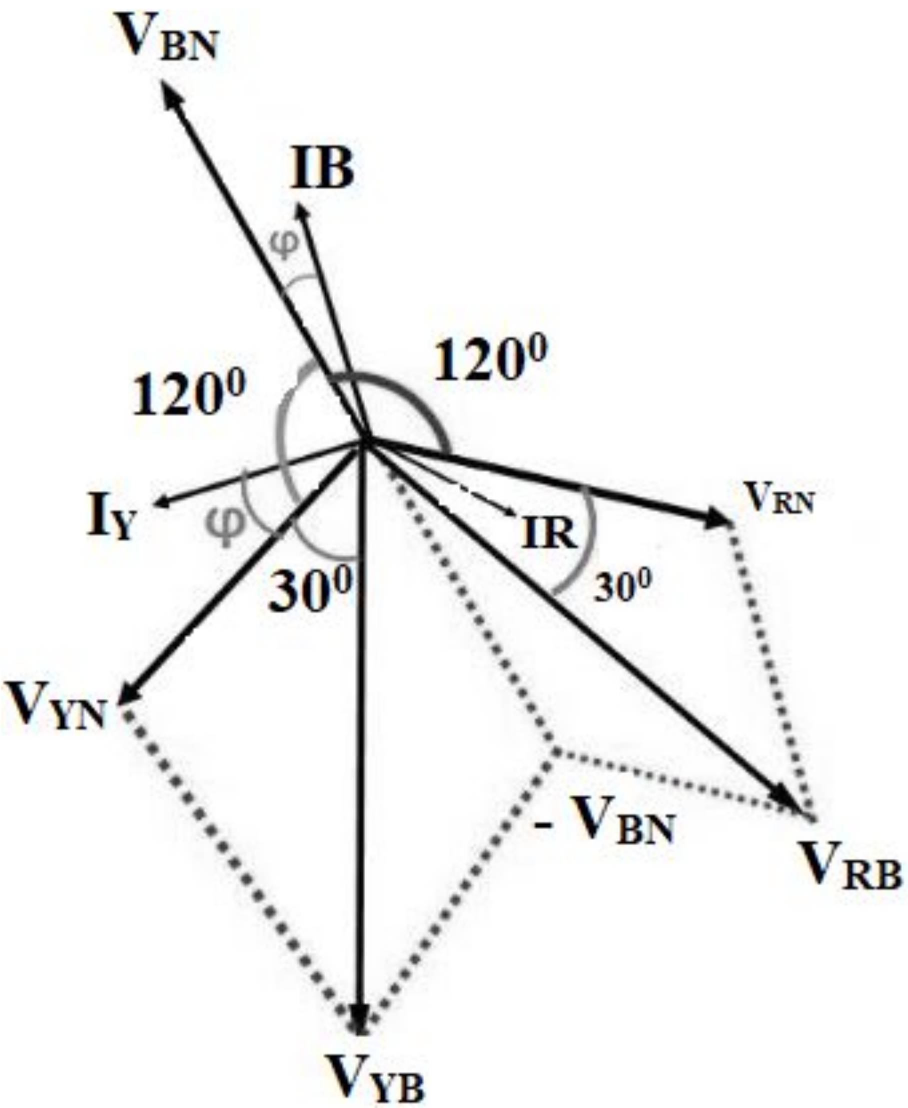
It consists of 2 wattmeters like W1 and W2, where each wattmeter has a current coil 'CC' and a pressure coil 'PC'. Here, one end of wattmeter 'W1' is connected to 'R' terminal whereas one end of wattmeter' W2′ is connected to' Y' terminal. The circuit also consists of 3 inductors 'Z' which are constructed in a star topology. The 2 ends of inductors are connected to 2 terminals of a wattmeter whereas the third terminal of the inductor is connected to B.

Derivation of Two Wattmeter Method

Two Wattmeter is used to determine two main parameters they are,

- Power factor
- Reactive power.

Consider the load used as an inductive load which is represented by following the phasor diagram as shown below.



Phasor Diagram

The voltages V_{RN}, V_{YN}, and V_{BN} are electrically 120^0 in phase with one other, we can observe that the current phase lags at the "ϕ^0" angle with voltage phase.
The current in wattmeter W_1 is represented as

$$\mathbf{W_1 = I_R \text{ …….. } (1)}$$

where I_R is current
The potential difference across the wattmeter W1 coil is given as

$$\mathbf{W_1 = \sim V_{RB} = [\sim V_{RN} - \sim V_{BN}] \text{ ……… } (2)}$$

Where **V_{RN} and V_{BN}** are voltages
The phase difference between the voltage 'V_{YB}' and current 'I_Y' is given as $(30^0 + \phi)$
Hence the power measured by wattmeter is given as

$$\mathbf{W_2 = V_{YB} I_Y \cos (30^0 + \phi) \text{ ………….. } (3)}$$

At balanced load condition,

$$\mathbf{I_R = I_Y = I_B = I_L \text{ and ………….. } (4)}$$

$$\mathbf{V_{RY} = V_{YB} = V_{BR} = V_L \text{ ………… } (5)}$$

Therefore we obtain wattmeter readings as

$$\mathbf{W_1 = V_L I_L \cos(30^0 - \phi) \text{ and ……………. } (6)}$$

$$\mathbf{W_2 = V_L I_L \cos (30^0 + \phi) \text{ …………….. } (7)}$$

Total Power Derivation

The total wattmeter reading is given as

$$\begin{aligned}
\mathbf{W_1 + W_2} &= \mathbf{V_L I_L \cos(30^0 - \phi) + V_L I_L \cos (30^0 + \phi) \text{ ………….. } (8)} \\
&= \mathbf{V_L I_L [\cos(30^0 - \phi) + \cos (30^0 + \phi)]} \\
&= \mathbf{V_L I_L [\cos 30^0 \cos \phi + \sin 30^0 \sin \phi + \cos 30^0 \cos \phi - \sin 30^0 \sin\phi} \\
&= \mathbf{V_L I_L [2 \cos 30^0 \cos \phi]} \\
&= \mathbf{V_L I_L [(2 \sqrt{3} / 2) \cos 30^0 \cos \phi]} \\
&= \mathbf{\sqrt{3} \; [V_L I_L \cos \phi] \text{ ……… } (9)}
\end{aligned}$$

$$\mathbf{W1 + W2 = P \text{ ….. } (10)}$$

Where '**P**' is the total observed power in a 3-phase balanced load condition.

Power Factor Derivation

Definition: It is the ratio between actual power observed by the load to apparent power flowing in the circuit.
The power factor of three phase balanced load condition can be determined and derived from wattmeter readings as follows

From equation 9

$W1 + W2 = \sqrt{3}\, V_L\, I_L \cos\phi$
Now,
$W1 - W2 = V_L\, I_L\, [\cos(30^0 - \phi) - \cos(30^0 + \phi)]$
$= V_L\, I_L\, [\cos 30^0 \cos\phi + \sin 30^0 \sin\phi - \cos 30^0 \cos\phi + \sin 30^0 \sin\phi$
$= 2\, V_L\, I_L \sin 30^0 \sin\phi$
$= V_L\, I_L \sin\phi$ ………….. (11)

Dividing equations 11 and 9

$[W1 - W2 \backslash W1 + W2] = V_L\, I_L \sin\phi / \sqrt{3}\, V_L\, I_L \cos\phi$

$\text{Tan}\,\phi = \sqrt{3}\, [W1 - W2 \backslash W1 + W2]$

The power factor of the load is given as

$\cos\phi = \cos \tan^{-1} [\sqrt{3}]\, [W1 - W2 \backslash W1 + W2]$ ………(12)

<u>Reactive Power Derivation</u>

Definition: It is the ratio between complex power corresponding to storage and revival of energy rather than consumption.
To obtain reactive power, we multiply equation 11 with
$\sqrt{3}\, [W1 - W2] = \sqrt{3}\, [V_L\, I_L \sin\phi] = P_r$
$P_r = \sqrt{3}\, [W1 - W2]$ ………… (13)
Where P_r is the reactive power obtained from 2 wattmeters.

Advantages of Two Wattmeter

- ◊ The following are the advantages
- ◊ Both balanced and unbalanced load can be balanced using this method
- ◊ In a star connected load, it is optional to connect neutral point and wattmeter
- ◊ In a delta, connected load connections need not be opened to connect wattmeter
- ◊ 3 phase power can be measured using two wattmeter's
- ◊ Both power and power factor is determined on a balanced load condition.

Disadvantages of Two Wattmeter

The following are the disadvantages

- ◊ Not suitable for 3 phase, 4 wire system
- ◊ Primary windings W1 and secondary windings W2 must be identified correctly to prevent incorrect results.

Applications of Two Wattmeter

Wattmeters are used to measure the power consumption of any electrical appliances and verify their power ratings.

PROCEDURE

BALANCED LOAD :

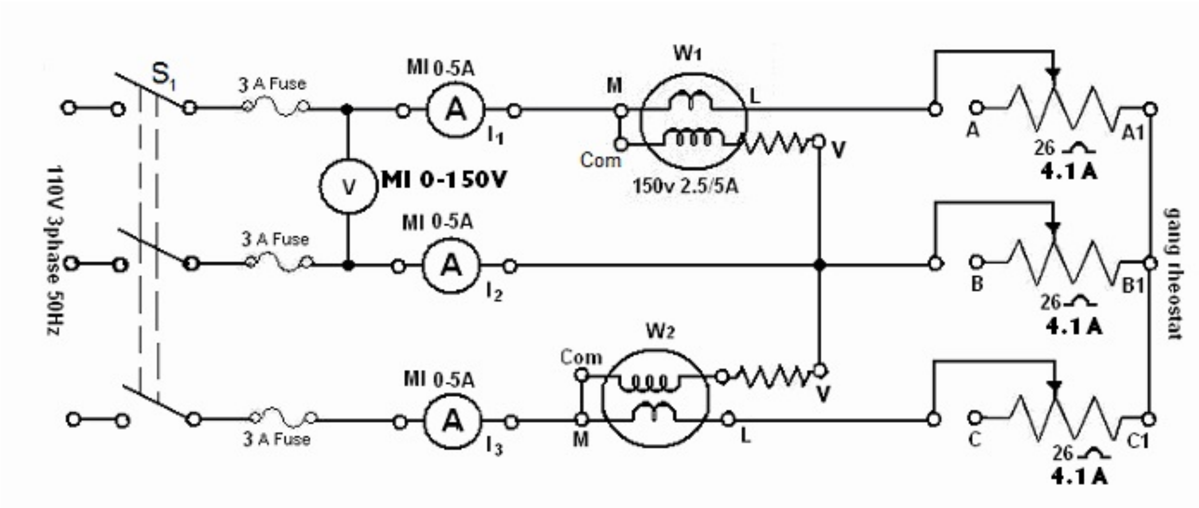


Fig. 1. Three phase power measurement circuit under balance condition

1. Connect the circuit as shown in Fig. 1.
2. Adjust the ganged rheostat for the maximum resistance.
3. Switch on the supply.
4. Close switch S1S1.
5. Read the meters to obtain VL,I1,I2VL,I1,I2 and I3I3. Note the wattmeter reading W1W1 and W2W2(Note the multiplying factor on the wattmeter).
6. Vary the load resistance and obtain at least five sets of observations, the current should not exceed the limit (4.1 A).

UNBALANCED LOAD

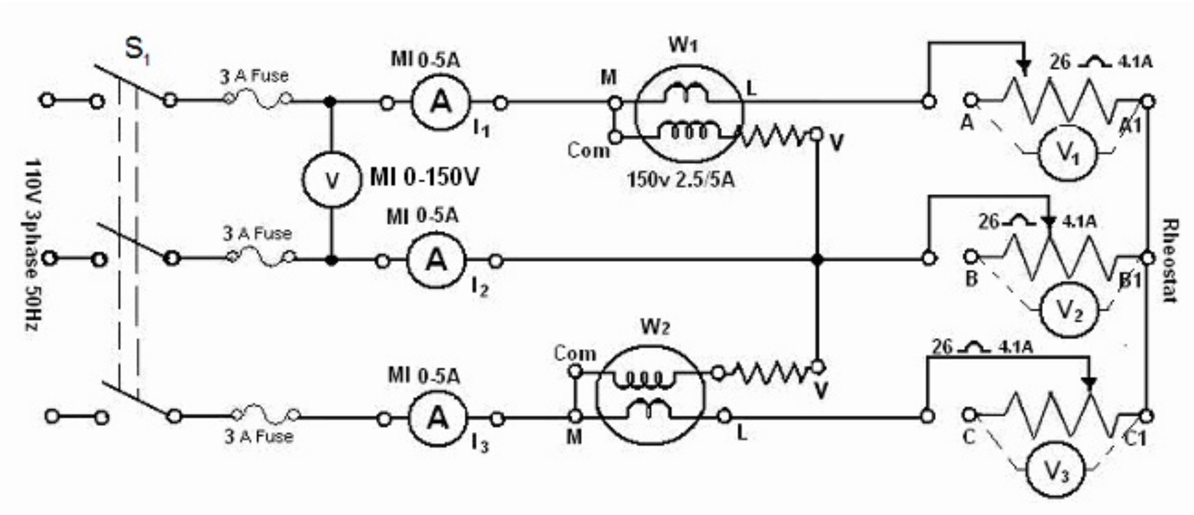
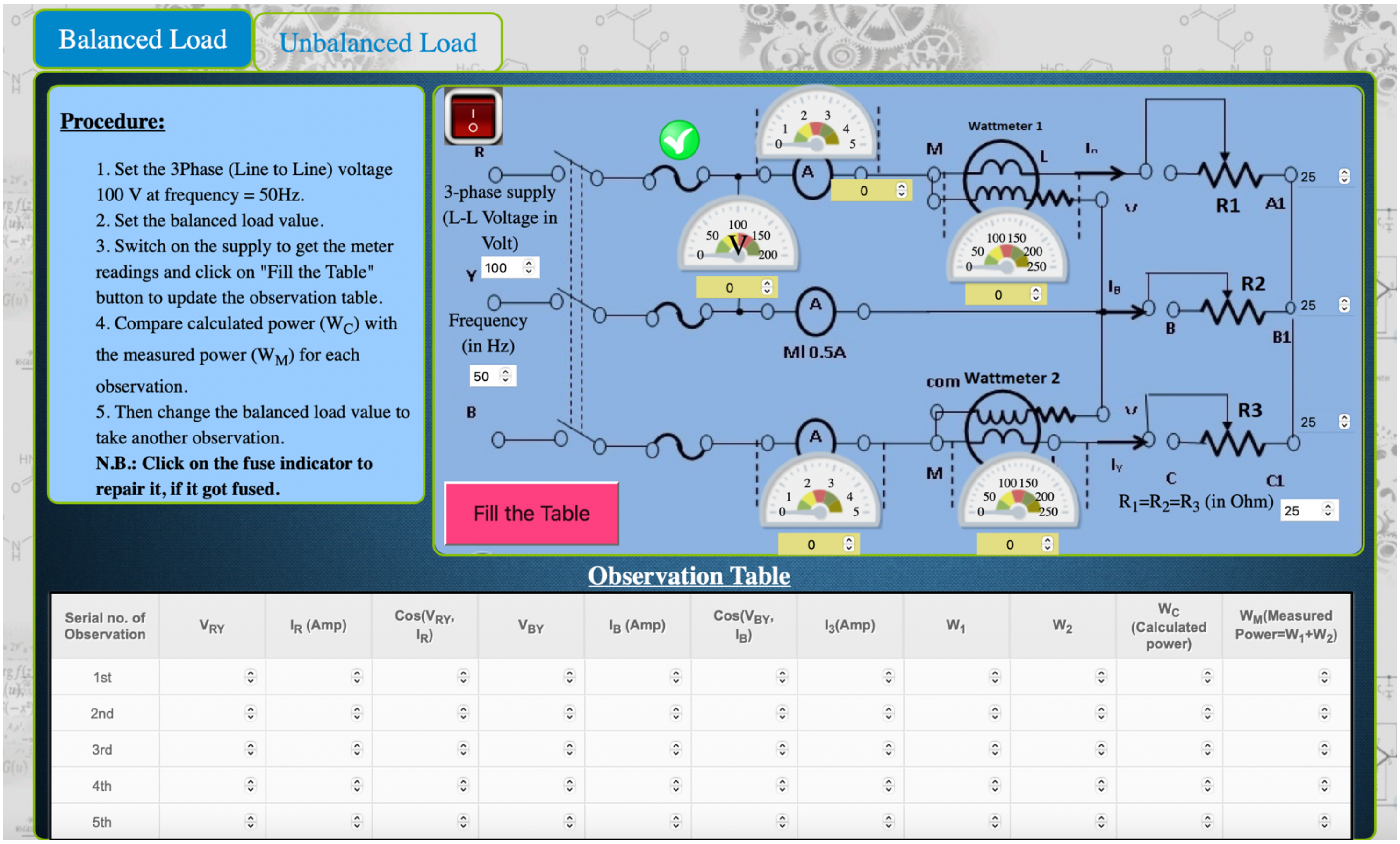


Fig. 2. Three phase power measurement circuit under unbalance condition

1. Connect the circuit as shown in Fig. 2.
2. Replace the ganged rheostat by three separate rheostats of 26 Ω, 4.1 A and connect in a star.
3. Adjust the three rheostats at the maximum values.
4. Switch on the supply and set the autotransformer to 110 V.
5. Close switch S_1 and take five sets of observation for different rheostat settings such that the reading of I1I1, I2I2and I3I3 in each set is appreciably different to create unbalanced loading condition. The current should not exceed the limits in each arm.

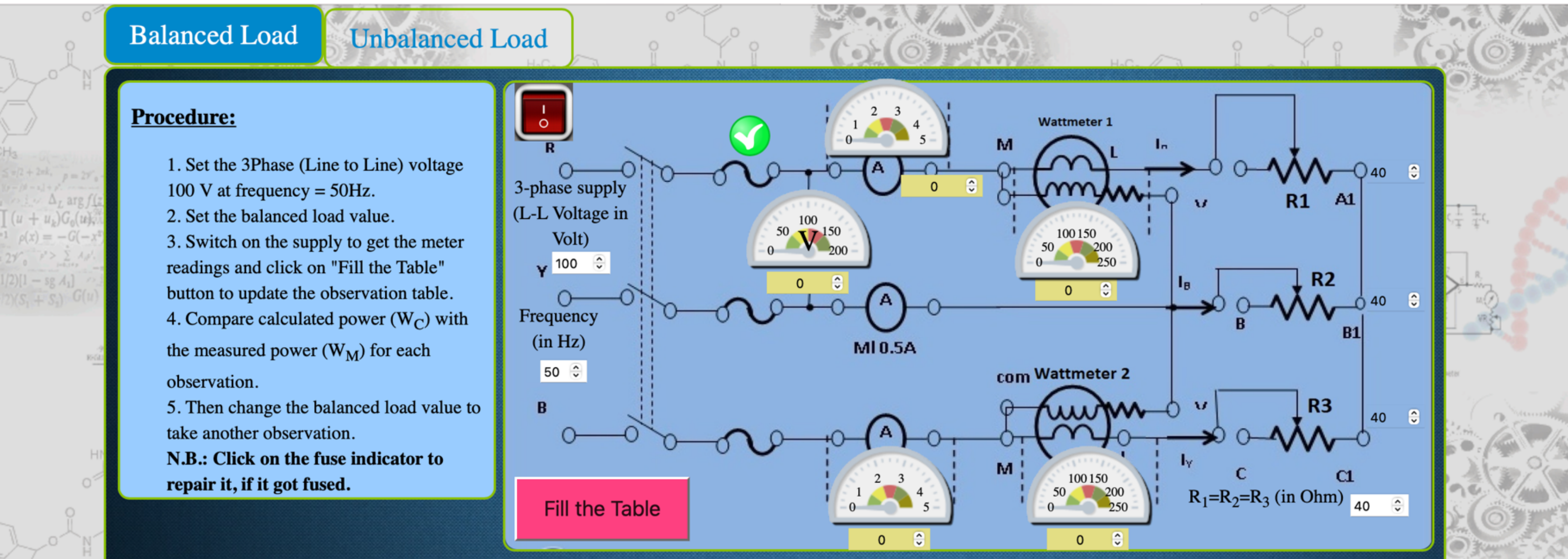
OBSERVATIONS



THIS IS THE SS OF THE VLAB ON WHICH THIS EXPERIMENT WAS PERFORMED

OBSERVATION TABLE

BALANCED LOAD



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(Measured Power=W_1+W_2)
1st	100	2.88674721	0.86522804	100	2.88674721	0.86691905	2.88674721	249.769463	250.2576174	499.998569	500.0270812
2nd	100	2.30939777	0.86522804	100	2.30939777	0.86691905	2.30939777	199.8155710	200.206093	399.998855	400.0216650
3rd	100	1.92449814	0.86522804	100	1.92449814	0.86691905	1.92449814	166.5129759	166.8384116	333.332379	333.3513875
4th	100	1.64956983	0.86522804	100	1.64956983	0.86691905	1.64956983	142.7254079	143.0043524	285.713468	285.7297607
5th	100	1.44337360	0.86522804	100	1.44337360	0.86691905	1.44337360	124.8847319	125.1288087	249.999284	250.0135400

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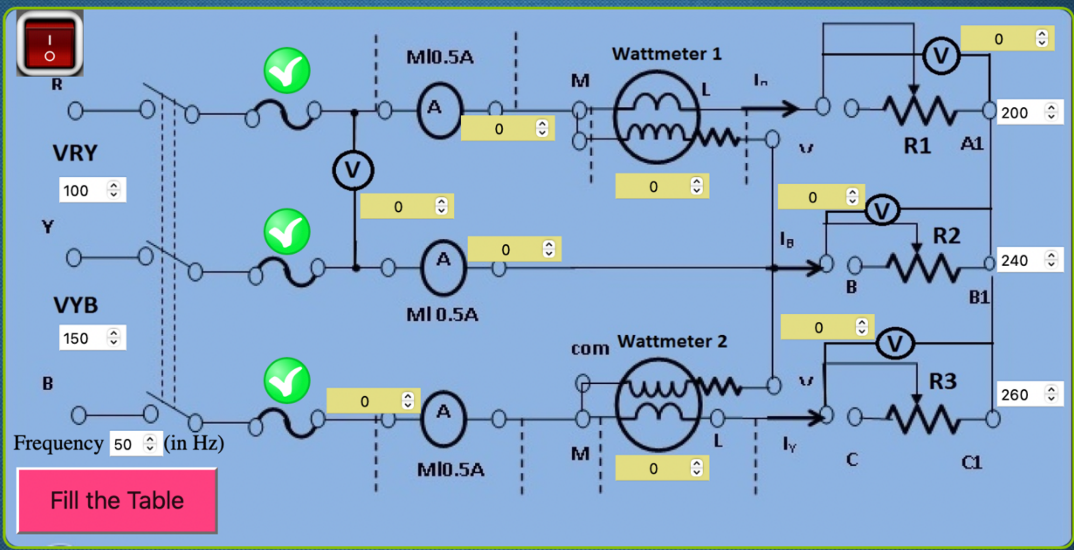
UNBALANCED LOAD

Balanced Load | Unbalanced Load

Procedure:

1. Set the 3Phase (Line to Line) voltage to 100 V at frequency =50Hz.
2. Set different values for R_1, R_2 and R_3.
3. Switch on the supply to get the meter readings and click on "Fill the Table" button to update the observation table.
4. Compare calculated power (W_C) with the measured power (W_M) for each observation.
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(Measured Power=W_1+W_2)
1st	87.0523815	119.298007	134.210258	0.72543547	0.745611481	0.745611481	252.169559	128.084779	125.784779	253.869559
2nd	88.7931373	119.269373	132.5215261	0.63423578	0.66260668	0.66260668	223.1541182	113.5770591	111.2770591	224.854118
3rd	90.15481417	119.2717596	131.198935	0.56346678	0.59635794	0.59635794	200.169432	102.0847161	99.7847161	201.869432
4th	91.2496316	119.289922	130.134461	0.50694167	0.54222614	0.54222614	181.502662	92.7513314	90.4513314	183.202662
5th	92.1493425	119.3159358	129.258930	0.46074605	0.49714902	0.49714902	166.036197	85.0180988	82.7180988	167.7361976

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1st	87.0523815	119.298007	134.210258	0.72543547	0.745611481	0.745611481	252.169559	128.084779	125.784779	253.869559
2nd	88.7931373	119.269373	132.5215261	0.63423578	0.66260668	0.66260668	223.1541182	113.5770591	111.2770591	224.854118
3rd	90.15481417	119.2717596	131.198935	0.56346678	0.59635794	0.59635794	200.169432	102.0847161	99.7847161	201.869432
4th	91.2496316	119.289922	130.134461	0.50694167	0.54222614	0.54222614	181.502662	92.7513314	90.4513314	183.202662
5th	92.1493425	119.3159358	129.258930	0.46074605	0.49714902	0.49714902	166.036197	85.0180988	82.7180988	167.7361976

RESULT/CONCLUSION

WE HAVE SUCCESSFULLY MEASURED THE VALUE OF POWER DISSIPATED DUE TO A THREE PHASE CIRCUIT BY TWO WATTMETER