INSTRUCTION MANUAL

OF

BASIC ELECTRICAL LABORATORY

[CODE: EEL-101]

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY, BHILAI.

INSTRUCTIONS:

1. All students must be on or before the scheduled time for Lab-classes and be regular.

2. All students must wear shoes to avoid any electrical shocks. Students without shoes will not be allowed to perform experiments.

3. Students should come into the Lab-classes with required stationaries and calculators.

4. No power supply should be given to the circuit(s) until all the connection and layout are cross-checked by the concerned laboratory instructor in-charge.

5. During the Lab-class, no student should enter or leave the lab without the permission of the concerned Instructor.

6. Students must submit the report in the given time.

7. Students are not allowed to bring water bottles and bags into the lab.

CONTENTS:

EXPERIMENT-1

KCL AND KVL

Objective: To Verify KCL & KVL from the given circuit

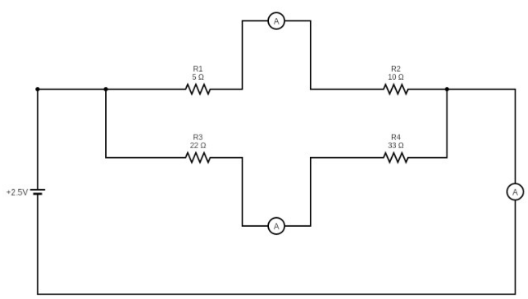
Apparatus:

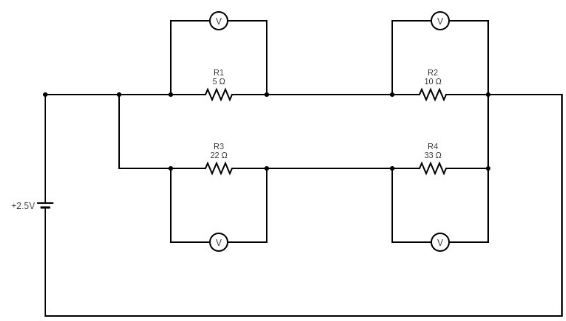
1. DC supplies
2. Voltmeter
3. Ammeter
4. Resistive loads
5. Connecting wires

THEORY:

Kirchhoff's Voltage Law (KVL) states that the algebraic sum of all branch voltages around any closed path in a circuit is always zero at all instants of time.

Kirchhoff's Current Law (KCL) states that the sum of the currents entering into any node/point/junction is equal to the sum of the currents leaving that node/point/junction.





Experimental Procedure:

Verification of KVL (Series Circuit)

1. Preparation: Ensure the "Set Volts" knob is at the minimum position before turning on the "Mains" switch.

2. Circuit Connection: Connect the positive terminal of the 0-3V DC Output to the input of resistor R1 (5Ω).

   Connect resistors R1 and R2 (10Ω) in series by linking terminal B to terminal C.

   Complete the loop by connecting the end of R2 (terminal D) back to the negative terminal of the power supply.

3. Measurement:

   Set the input voltage $(V_{\{in\}})$ to 2V using the "Set Volts" knob.

Connect the Voltmeter across R1 to measure V_1 and across R2 to measure V_2.

4. Verification: Check if $V_{\{in\}} = V_1 + V_2$.

Part B: Verification of KCL (Parallel Circuit)

1. Circuit Connection: Connect the 0-3V DC Output to a common node (Junction A).

   Connect resistor R3 (22Ω) and R4 (33Ω) in parallel from Junction A.

   Insert the mA Ammeter between the power supply and Junction A to measure total current (I_T).

2. Measurement:

   Measure the branch current through R3 (I_1) and through R4 (I_2) by moving the ammeter into each specific branch.

3. Verification: Check if $I_T = I_1 + I_2$.

Observations:

KCL:

Current in branch 1: $i_1 =$ ________ A

Current in branch 2: $i_2 =$ ________ A

Total current: $i_1 + i_2 =$ _____ A

KVL:

Voltage across resistor R_1: $V_1 =$ ________ V

Voltage across resistor R_2: $V_2 =$ ________ V

Voltage across resistor R_3: $V_3 =$ ________ V

Voltage across resistor R_4: $V_4 =$ ________ V

Result: The practical values of voltage drops and branch currents were found to be nearly identical to the theoretical values. Thus, **Kirchhoff's Voltage Law and Current Law are verified** for the given circuit.

EXPERIMENT-2

NETWORK THEOREMS

Objective: Verification of Network Theorems such as Superposition Theorem, Thevenin's Theorem, Maximum Power Transfer theorem.

Apparatus:

1. Fixed DC voltage supplies.
2. Different types of resistors.
3. Potentiometer
4. Multimeter
5. Connecting Probes

Theory:

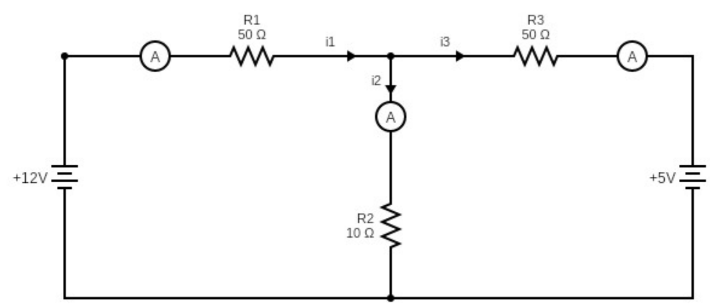
Superposition theorem:

Superposition theorem states that in any linear, active, bilateral network having more than one source, the response across any element is the sum of the responses obtained from each source considered separately and all other sources are replaced by their internal resistance.

The superposition theorem is used to solve the network where two or more sources are present and connected.

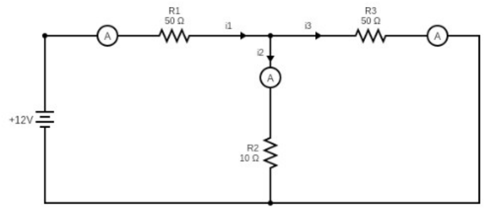
Step-1 :

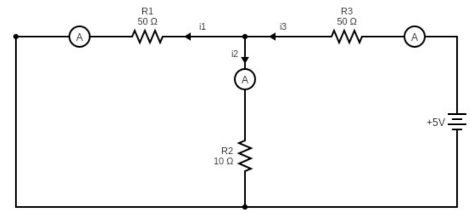
Find response across each branch when all the sources are working together.



Step-2 :

Find the response across each branch when individual sources are working where the other sources are taken as short circuit if voltage source and open circuit if current source.





Experimental Procedure:

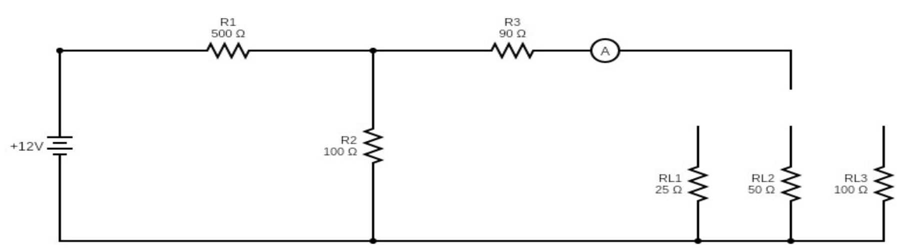
1. Complete the circuit by connecting the probes.
2. Take the ammeter readings in every branch when all sources are working.
3. Consider one source and find the branch responses.
4. Similarly consider the other source and find the branch responses.
5. Compare the responses with theoretical responses.

Calculations:

Observation: Through practical examination we have found out the sum of the responses in any branch when individual sources are working is equal to the response when all sources are working together.

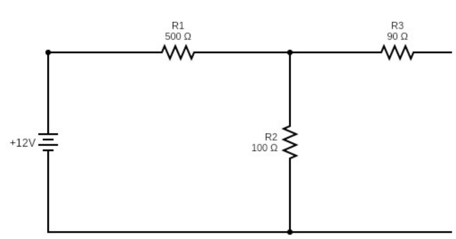
THEVENIN'S THEOREM:

A linear network consisting of a number of voltage sources and resistances can be replaced by an equivalent network having a single voltage source called Thevenin's voltage (V_{th}) and a single resistance called Thevenin's resistance (R_{th}) .



Step-1:

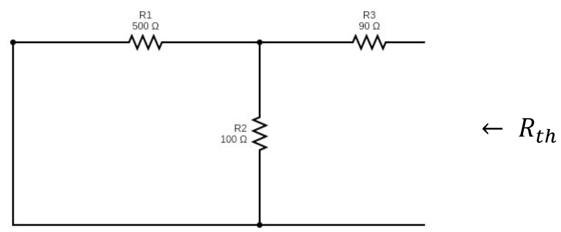
Initially remove the load and find the equivalent voltage across the load terminals:



$\leftarrow V_{th}$

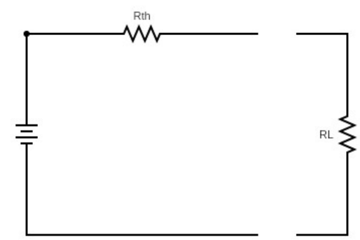
Step-2:

Now find the equivalent resistance across the load terminals by replacing voltage sources with short circuit and current sources with open circuit.



Step-3:

Replace the given circuit with equivalent Thevenin voltage in series with Thevenin resistance and add load.



Experimental Procedure:

1. Complete the circuit by connecting the probes.
2. Find the value of current passing through different loads.
3. Theoretically find the Thevenin voltage and Thevenin resistance.
4. Calculate load current for different loads with Thevenin values.
5. Analyze the practical vs theoretical values.

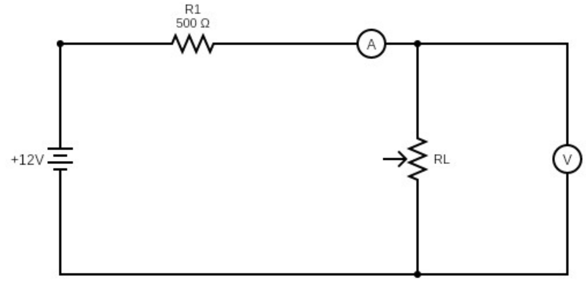
Calculations:

$I_l = \frac{V_l}{R_{th}+R_l}$

Observation: The current through the load can be calculated using Thevenin theorem irrespective of load variations.

MAXIMUM POWER TRANSFER THEOREM:

A resistive load being connected to a DC network receives maximum power when the load resistance is equal to the internal resistance of the source network as seen from load end.



Calculation:

Any circuit can be represented as Thevenin Equivalent circuit and the maximum power transferred through the load terminals can be derived by knowing the current across Thevenin load terminal.

i.e. $I_l = \frac{V_l}{R_{th}+R_l}$

Power across the load is $P_l = [I_l]^2 R_l$.

$P_l = \left(\frac{V_l}{R_{th}+R_l}\right)^2 R_l$

To get maximum power across load resistance we have to differentiate Power w.r.t R_l and equate it to zero.

$\frac{d}{dR_l}(P_l) = 0.$

$\frac{d}{dR_l}(P_l) = \left(\frac{V_l}{R_{th}+R_l}\right)^2 R_l = 0$

The maximum power can be transferred through the load terminals when $R_{th} = R_l$.

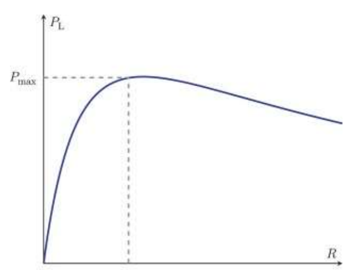
Experimental Procedure:

1. Complete the circuit by connecting the probes.
2. Vary the potentiometer and note the values of voltmeter and ammeter.
3. Take minimum of 10 readings.
4. Calculate the power utilized by the load.
5. Draw a graph between the power vs load.

Observation Table:

SL.NO.	V_l	I_l	R_l	P_l
1.				
2.				
3.				

MODEL GRAPH:



Observation: when the load is being increased it has been observed when the load resistance is equal to the Thevenin resistance the power transferred through load is maximum.

Result: Network theorems have been practically examined and verified.

EXPERIMENT-3

SERIES AND PARALLEL RESONANCE IN RLC CIRCUIT

Objective: To determine the resonant frequency of a series and parallel RLC circuit and to observe the effect on circuit current and voltage.

Apparatus:

6. RLC Resonance Trainer Kit
7. Patch cords for connections
8. Function Generator (Sine wave)
9. Digital Frequency Counter
10. AC Ammeter
11. AC Voltmeter

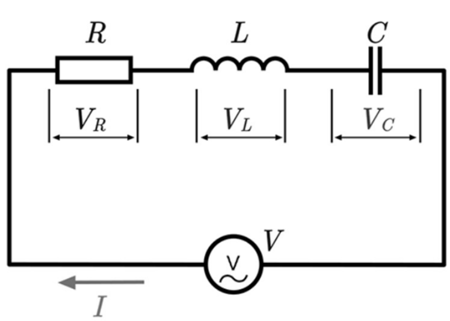
Theory:

Resonance occurs in an AC circuit when the inductive reactance (X_L) and capacitive reactance (X_C) are equal in magnitude but opposite in phase, effectively cancelling each other out.

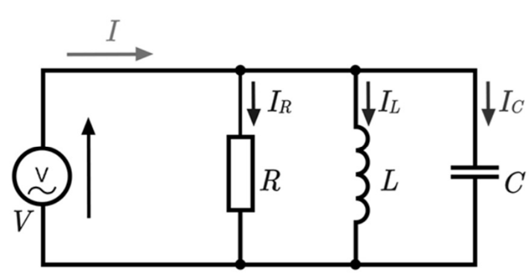
- Inductive Reactance: $X_L = 2\pi fL$
- Capacitive Reactance: $X_C = \frac{1}{2\pi fC}$
- Resonant Frequency (f_r):

$$f_r = \frac{1}{2\pi\sqrt{LC}}$$

Series RLC Circuit



Parallel RLC Circuit



Key Characteristics:

Series Resonance: Impedance is at its minimum ($Z = R$); therefore, the current is at its maximum.

Parallel Resonance: Impedance is at its maximum; therefore, the line current is at its minimum.

Experimental Procedure:

Part A: Series Resonance

1. **Selection:** Choose values for Resistance (R), Capacitance (C), and Inductance (L) using the rotary switches on the left panel.
2. **Connections:** Connect the **0-100kHz Sine Wave** output in series with the R, L, and C components using the patch cords on the breadboard section.

   Insert the **AC Ammeter** into the loop to measure the total circuit current.
3. **Frequency Sweep:** Turn on the power. Set the "Select Frequency" range and use the "Frequency Control" knob to vary the frequency from low to high.

   Keep the "Amplitude Control" constant throughout the experiment.
4. **Observation:** Record the current (I) for different frequency (f) readings from the digital displays.
5. **Identify Resonance:** Note the frequency where the current reaches its peak.

Part B: Parallel Resonance

1. **Connections:** Connect the L and C components in parallel with each other. Connect this parallel combination in series with the Sine Wave source and the AC Ammeter.
2. **Frequency Sweep:** Vary the frequency and observe the AC Ammeter.
3. **Identify Resonance:** Note the frequency where the current reaches its minimum value (the "dip").

Observation Table:

FREQUENCY (HZ)	CURRENT (MA) - SERIES	CURRENT (MA) - PARALLEL
500		
1K		
...		
f_r (RESONANT)	(PEAK CURRENT)	(MINIMUM CURRENT)

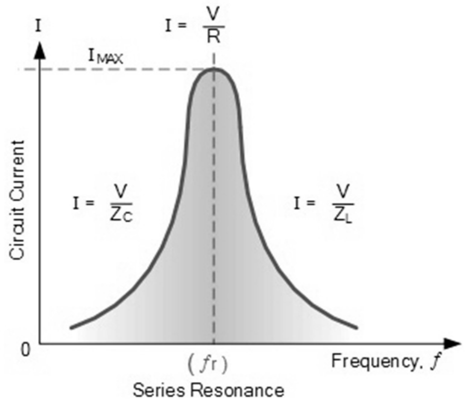
Calculation & Graph

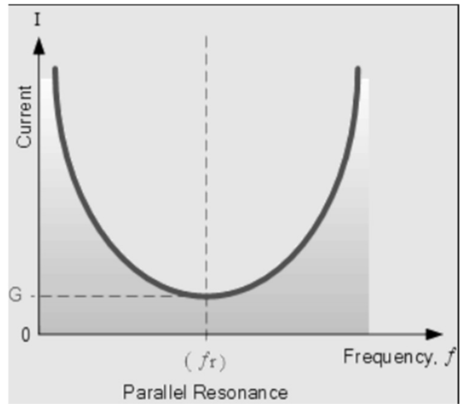
1. Calculate the theoretical resonant frequency using $f_r = \frac{1}{2\pi\sqrt{LC}}$ based on the component values you selected.
2. Plot a graph of Current (I) vs. Frequency (f).

   For Series: The curve will be bell-shaped (upward).

   For Parallel: The curve will be a "V" or "U" shape (downward dip).

MODEL GRAPH:





Result: The experiment successfully demonstrates the concept of resonance in series and parallel RLC circuits and verifies theoretical relationships experimentally.

EXPERIMENT - 4

Objective: Measurement of Power and Power Factor in Series RL and Series RLC Circuits & study of improvement of Power factor by Capacitor.

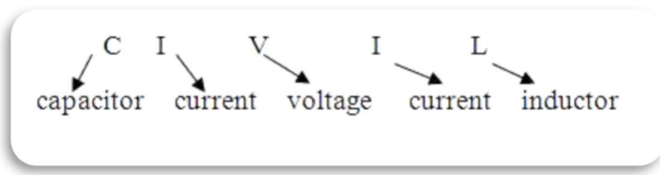
Apparatus

Single-phase AC supply with Variac, Resistor (R), Inductor (L), Capacitor (C), Voltmeter, Ammeter, Multifunction meter, Connecting leads, Multi-meter.

Theory

In AC circuits, real power (P) is measured using a Multifunction meter, while power factor ($cos\varphi$) indicates the phase difference between voltage and current. For series RL and RLC circuits, power factor depends on circuit impedance and reactive components.

The mnemonic provided in the image, **"CIVIL",** helps remember the phase relationships in AC circuits:



- In a Capacitor, the I (current) come before the V (voltage), or the current leads the voltage.
- In an L (inductor), the V (voltage) comes before the I (current), or the voltage leads the current.
- The "I" is shared between "CI" and "IL", representing the common current flow in series circuits.

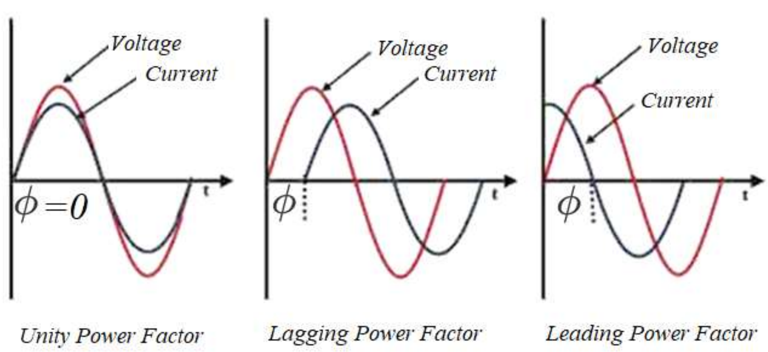
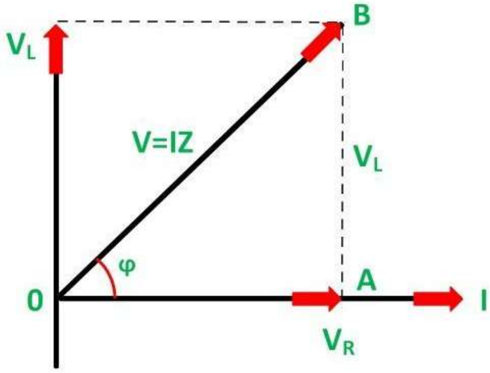


Fig. 1: Voltage & Current Waveforms

A. Series RL Circuit



In ΔOAB

$$V_R = IR, V_L = IX_L$$

$$V = \sqrt{V_R^2 + V_L^2}$$

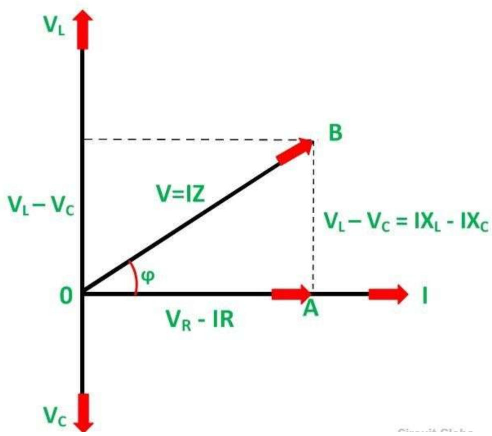
$$V = \sqrt{(IR)^2 + (IX_L)^2}$$

$$I = \frac{V}{Z}, Where\ Z = \sqrt{R^2 + X_L^2}$$

$\emptyset = \tan^{-1}\frac{X_L}{R}$, power factor $cos\emptyset = \frac{R}{Z}$

Fig. 2: Phasor diagram of Series RL circuit

B. Series RLC Circuit



In ΔOAB

$$V = \sqrt{V_R^2 + (V_L - V_c)^2}$$

$$V = \sqrt{(IR)^2 + (IX_L - IX_C)^2}$$

$$I = \frac{V}{Z}, Where\ Z = \sqrt{R^2 + (X_L - X_c)^2}$$

$\emptyset = \tan^{-1}\frac{X_L - X_c}{R}$, power factor $cos\emptyset = \frac{R}{Z}$

- $Active\ Power = VIcos\emptyset$
- $Reactive\ Power = VIsin\emptyset$
- $Apparant\ Power = VI$

Fig 3: Phasor diagram of RLC circuit when $X_L > X_c$.

The three cases of RLC Series Circuit

- When $X_L > X_C$, the phase angle ϕ is positive. The circuit behaves as RL series circuit in which the current lags behind the applied voltage and the power factor is **lagging.**
- When $X_L < X_C$, the phase angle ϕ is negative, and the circuit acts as a series RC circuit in which the current leads the voltage and power factor is **leading.**
- When $X_L = X_C$, the phase angle ϕ is zero, as a result, the circuit behaves like a purely resistive circuit. In this type of circuit, the current and voltage are in phase with each other. The value of the power factor is **unity**.

Procedure

A. Procedure for Series RL Circuit

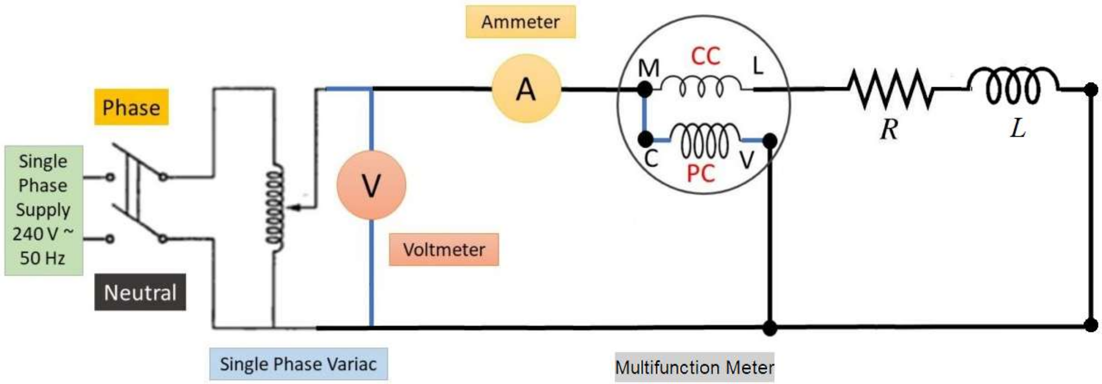


Fig.4: Circuit Diagram of Series RL circuit.

1. Connect the resistor (R) and inductor (L) in series with the single-phase AC supply as per the circuit diagram (ref fig.4)..
2. Connect the **multifunction meter** to measure voltage, current, real power, and power factor.
3. Switch ON the AC supply and gradually increase it to the rated voltage.
4. Note down the voltage (V), current (I), real power (P), and power factor (cosφ from the meter) for each value of inductor (L).
5. Switch OFF the supply after completing the observations (ref. Table 1) after reducing the AC supply gradually to zero.
6. Plot the graph between Power Factor vs Inductance Value.

B. Procedure for Series RLC Circuit

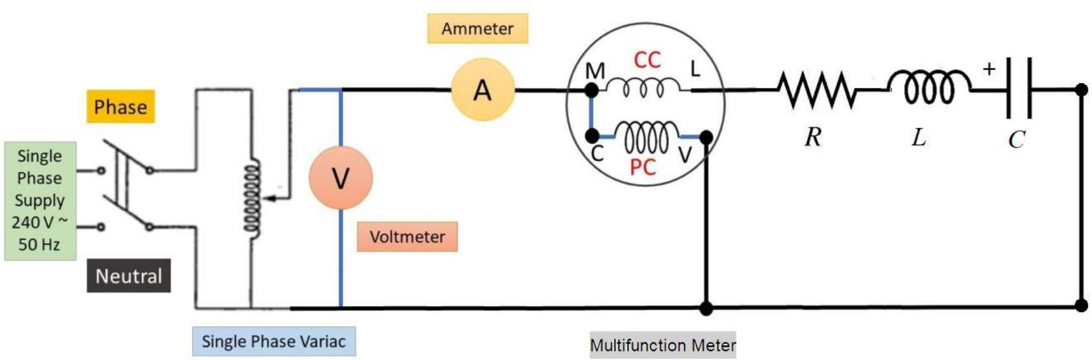


Fig.5: Circuit Diagram of Series RLC circuit.

1. Connect the resistor (R), inductor (L), and capacitor (C) in series with the single-phase AC supply as per the circuit diagram (ref fig.5).
2. Connect the **multifunction meter** to measure voltage, current, real power, and power factor.
3. Switch ON the AC supply and adjust it to the rated voltage.
4. Record the voltage (V), current (I), real power (P), and power factor (cosφ from the meter) for each value of inductor (L) and adjust the capacitor (C) such that you have positive power factor nearest to 1. (Do not go for negative power factor)
5. Switch OFF the supply after taking all readings (ref. Table 2) after reducing the AC supply gradually to zero.
6. Plot the graph between Power Factor vs Capacitance Value for each value of inductor.

Observations

Table 1: Observations for Series RL Circuit

S. No.	Multifunction Reading		Voltage	Current	R	L	XL=2πfL	$Z=\sqrt{R^2+X_L^2}$	Power Factor	P=VI cosφ
	Power Factor	Active Power (Watts)	V (Volts)	I (Amps)	(Ohm)	(mH)	(Ohm)	(Ohm)	(cosφ)	Active Power (Watts)
1										
2										
3										

Table 2: Observations for Series RLC Circuit

S. No.	Multifunction Reading		V	I	R	L	C	$X_L=2\pi fL$	$X_C=1/2\pi fC$	$Z=\sqrt{R^2+(X_L-X_c)^2}$	pf	P=VI cosφ
	pf cosφ	Active Power (Watts)	Volts	Amps	(Ω)	(mH)	(μF)	(Ω)	(Ω)	(Ω)	cosφ	Active Power (Watts)
1												
2												
3												

Result

The power and power factor of the series RL and series RLC circuits were measured and calculated successfully.

Precautions

1. Ensure all connections are made as per the circuit diagram before switching ON the supply.
2. Verify correct terminal connections of the **multifunction meter** for voltage, current, and power measurement.
3. Increase the supply voltage gradually using a variac.
4. Avoid loose connections to prevent fluctuation in readings.
5. Take readings only after the meter display becomes stable.
6. Switch OFF the supply immediately in case of abnormal heating or noise in components.
7. Discharge the capacitor properly before modifying the RLC circuit connections.
8. Handle measuring instruments carefully to avoid damage.
9. Switch OFF the power supply after completing the experiment.

Conclusion

This experiment verifies the effect of inductance and capacitance on power and power factor in AC circuits.

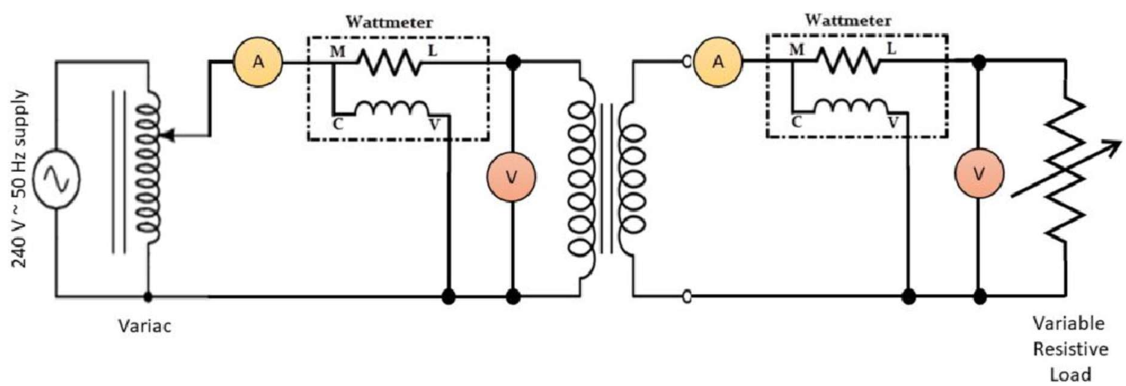
EXPERIMENT-5

LOAD TEST ON SINGLE PHASE TRANSFORMER

Objective: To conduct load test on single phase transformer and to find efficiency and percentage regulation.

Apparatus:

12. Auto transformer
13. Voltmeter
14. Ammeter
15. Wattmeter
16. Resistive loads
17. Connecting wires



Formulae:

1. Transformer Efficiency (η)

Efficiency is defined as the ratio of output power to input power.

General Formula

$$\eta = \left(\frac{Output\ Power}{Input\ Power}\right) \times 100\%$$

2. Voltage Regulation (V.R.)

Voltage regulation is the change in secondary terminal voltage from no-load to full-load, expressed as a percentage of the rated voltage.

Basic Formula

$$\%VR = \frac{V_{2NL} - V_{2F}}{V_{2FL}} \times 100\%$$

Experimental Procedure:

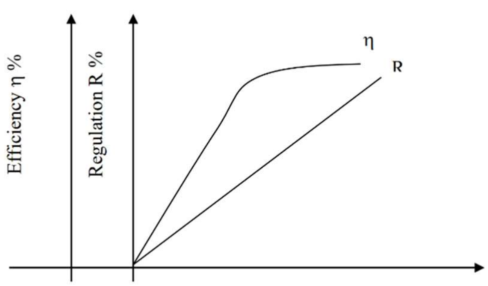
6. Complete the circuit by connecting the probes.
7. Vary the potentiometer according to the input ratings of transformer used.
8. Note the no load voltage on the secondary.

9. Increase the load step by step and note the values of voltage, current and wattmeter readings from the panel.
10. Calculate input power, output power, efficiency and voltage regulation.
11. Draw the graph for efficiency vs load current and voltage regulation vs load current.

Observation Table:

SL.NO.	V_P	I_P	W_P	W_S	V_S	I_S	P_{in}	P_{out}	$\eta = \frac{P_{out}}{P_{in}} \times 100$	$VR\%$
1.										
2.										
3.										
4.										
5.										
6.										

MODEL GRAPH:



Result: Thus the load test on single phase transformer is conducted.