# Department of Electrical and Electronics Engineering

# Basic Electrical Engineering
# Laboratory Manual


*Gokaraju Rangaraju Institute of Engineering & Technology*
*(Autonomous)*

**BACHUPALLY, HYDERABAD-500090**

# Department of Electrical and Electronics Engineering

## CERTIFICATE

This is to certify that this book is a bonafide record of practical work done in the Basic Electrical Engineering Laboratory in ........semester of………year during the academic year ...................by

Name :-……………………………..

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Branch :-…………………………….

Date:-…………

Signature of the Staff member

Signature of the HOD

Signature of External Examiner

**GOKARAJU RANGARAJU INSTITUTE OF ENGINEERING AND TECHNOLOGY**

**BASIC ELECTRICAL ENGINEERING LAB**

Course Code:GR20A1017 L/T/P/C: 0/0/2/1

**Course Objectives**:

1. Introduce the use of measuring instruments.
2. Analyze a given network by applying various electrical laws
3. Measure and know the relation between basic electrical parameters.
4. Understand the response of electrical circuits for different excitations
5. Summarize the performance characteristics of electrical machines.

**Course Outcomes:**

At the end of this course, students will able to

1. Get an exposure to common electrical components and their ratings.
2. Get an exposure to basic electrical laws.
3. Understand the measurement and relation between the basic electrical parameters
4. Understand the response of different types of electrical circuits to different excitations.
5. Compare the basic characteristics of Electrical machines

TASK-1: Verification of Ohms Law , KVL and KCL

TASK-2: Verification of Thevenin's and Norton's Theorems

TASK-3: Verification of Superposition and Reciprocity Theorems.

TASK-4: Transient Response of Series RL, RC and RLC circuits using DC excitation ,

TASK-5: Resonance in series RLC circuit

TASK-6: Calculations and Verification of Impedance and Current of RL, RC and RLC series circuits

TASK-7: Load Test on Single Phase Transformer (Calculate Efficiency and Regulation)

TASK-8: Three Phase Transformer: Verification of Relationship between Voltages and Currents (Star-Delta, Delta-Delta, Delta-star, Star-Star)

TASK-9: Measurement of Active and Reactive Power in a balanced Three-phase circuit

TASK-10: Performance Characteristics of a Separately Excited DC Shunt Motor

TASK-11: Torque-Slip Characteristics of a Three-phase Induction Motor

TASK-12: No-Load Characteristics of a Three-phase Alternator

## Contents

| S. No | Date | Name of the Experiment | Assessment | Sign |
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# 1. Verification of Ohms Law , KVL and KCL

**Aim:**

To verify Ohm's law, KCL and KVL for the given Circuit Diagrams.

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | DC voltage source | 0-20V | 1 No. |
| 2. | Resistor | 1KΩ,220KΩ,33KΩ | 3 No. |
| 3. | Ammeter | 0 - 200mA | 1 No. |
| 4. | Voltmeter | 0 - 20V | 1 No. |
| 5. | Connecting wires | | Required. |

**Theory:**

**Ohm's Law:**

Ohm's law states that, "At constant temperature current flowing through the conductor is directly proportional to the potential difference existing between the two ends of the conductor. i.e.,

$$V \alpha I$$

$$V = \text{Constant} * I$$

Where

V is the potential difference across the conductor in volts,

I is the current flowing through the conductor in amps

The constant of proportionality = R

Where R is the resistance of the conductor in Ohms.

**Circuit Diagram:**

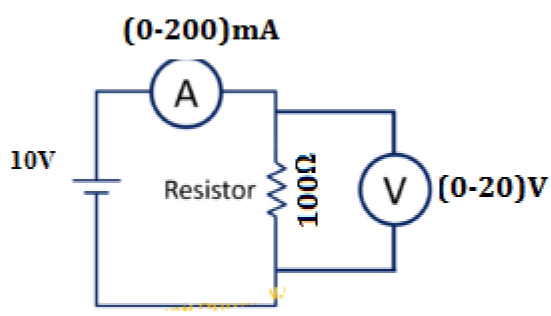


**Fig.1**

**Procedure:**

1. Connect the circuit as shown as in figure 1 with $R_1$
2. Adjust the voltage in steps of 3 volts from 0-20V
3. Record the measured voltage and current in each steps
4. Repeat steps2 and 3 for $R_2$
5. Plot the V – I Characteristics of $R_1$ and $R_2$

**Observations:**

| S.No | Source Voltage (Volts) | $R_1$ (Ohms) | I (mA) | |
|---|---|---|---|---|
| | | | Calculated(V/R) | Measured |
| | | | | |
| | | | | |
| | | | | |
| | | | | |
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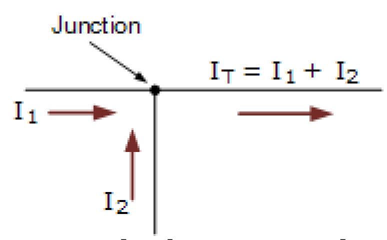
**1. KCL(Kirchoff's Current Law):**

Kirchoff's Current Law states that the sum of the currents flowing towards a node is equal to the sum of current flowing away from that node. i.e in any network, the algebraic sum of currents in all the branches meeting at a node is zero.

$$\Sigma I = 0$$

This idea by Kirchhoff is commonly known as the **Conservation of Charge**, as the current is conserved around the junction with no loss of current.



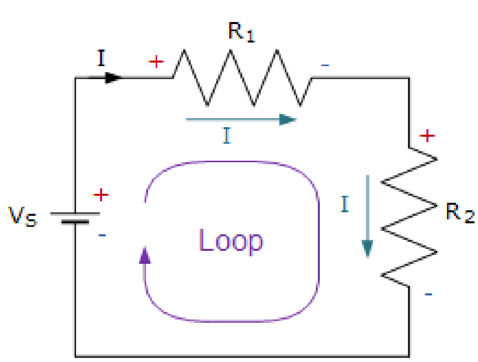

Here in this simple single junction example, the current $I_T$ leaving the junction is the algebraic sum of the two currents, $I_1$and $I_2$ entering the same junction. That is $I_T = I_1 + I_2$.

Note that we could also write this alternatively as the algebraic sum of: $I_T - (I_1 + I_2) = 0$.

**2. KVL(Kirchoff's Voltage Law):**

In any linear, bilateral network the algebraic sum of the voltages around any closed path or closed circuit isalways zero at any instant

**A Single Circuit Loop**




Kirchhoff's voltage law states that the algebraic sum of the potential differences in any loop must be equal to zero as: $\Sigma V = 0$. Since the two resistors, $R_1$ and $R_2$ are wired together in a series connection; they are both part of the same loop so the same current must flow through each resistor.

Thus the voltage drop across resistor, $R_1 = I*R_1$ and the voltage drop across resistor, $R_2 = I*R_2$ giving by KVL:

$$V_S + (-IR_1) + (-IR_2) = 0$$

$$\therefore V_S = IR_1 + IR_2$$

$$V_S = I(R_1 + R_2)$$

$$V_S = IR_T$$

$$\text{Where: } R_T = R_1 + R_2$$

We can see that applying Kirchhoff's Voltage Law to this single closed loop produces the formula for the equivalent or total resistance in the series circuit and we can expand on this to find the values of the voltage drops around the loop.

$$R_T = R_1 + R_2$$

$$I = \frac{V_S}{R_T} = \frac{V_S}{R_1 + R_2}$$

$$V_{R1} = IR_1 = V_S\left(\frac{R_1}{R_1 + R_2}\right)$$

$$V_{R2} = IR_2 = V_S\left(\frac{R_2}{R_1 + R_2}\right)$$

**Circuit Diagram:**

1. **KCL (Kirchoff's Current Law):**

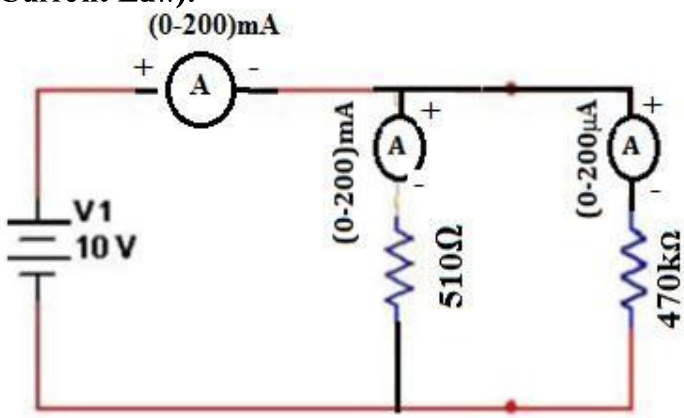



**Figure 2**

## 2. KVL (Kirchoff's Volatge Law):

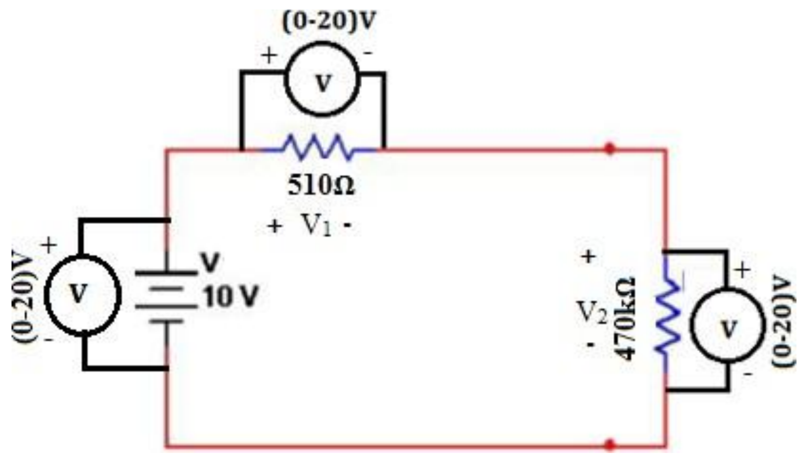



Figure. 3

**Observations:**

### 1.KCL:

| | | Theoritical | | | Practical | | |
|---|---|---|---|---|---|---|---|
| **S.NO** | **SOURCE VOLTAGE(Vs)** | **I1** | **I2** | **I1+I2** | **I1** | **I2** | **I1+I2** |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

### 2.KVL:

| | | Theoritical | | | Practical | | |
|---|---|---|---|---|---|---|---|
| **S.NO** | **SOURCE VOLTAGE(Vs)** | **V1** | **V2** | **V1+V2** | **V1** | **V2** | **V1+V2** |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Procedure:**

**1. KCL (Kirchoff's Current Law):**

1. Connect a DC Voltage of 10V to the given circuit diagram.
2. Choose two different resistors and connect them as shown in the figure 1.
3. Measure the current flowing in each resistor using ammeter.
4. Verify the theoretical calculations with practical values.

**2. KVL (Kirchoff's Voltage Law):**

1. Connect a DC Voltage of 10V to the given circuit diagram.
2. Choose two different resistors and connect them as shown in the figure 2.
3. Measure the voltage across each resistor using voltmeter.
4. Verify the theoretical calculations with practical values.

**Calculations:**

**Result:**

## 2.Verification of Thevenin's and Norton's Theorems

**Aim:**

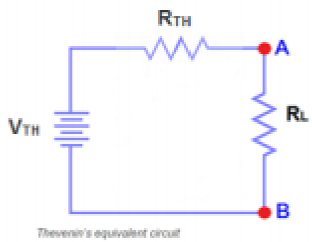
To verify Thevenin's and Nortons theorems and to find the full load current for the given circuit.

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | DC voltage source | 0-20V | 1 No. |
| 2. | Resistor | 100 ohm | 1 No. |
| 3. | Ammeter | 0 - 200mA | 1 No. |
| 4. | Ammeter | 0-200µA | 1 No. |
| 5. | Voltmeter | 0 - 20V | 2 Nos. |
| 6. | Connecting wires | | Required. |

**Statement:**

Thevenin's theorem states that any two output terminals ( A & B ) of an active linear network containing independent sources (it includes voltage and current sources) can be replaced by a simple voltage source of magnitude Vth in series with a single resistor Rth where Rth is the equivalent resistance of the network when looking from the output terminals A & B with all sources (voltage and current) removed and replaced by their internal resistances and the magnitude of Vth is equal to the open circuit voltage across the A & B terminals




**Procedure:**

1. Connections are given as per the circuit diagram.
2. Set a particular value of voltage using RPS and note down the corresponding ammeter readings.

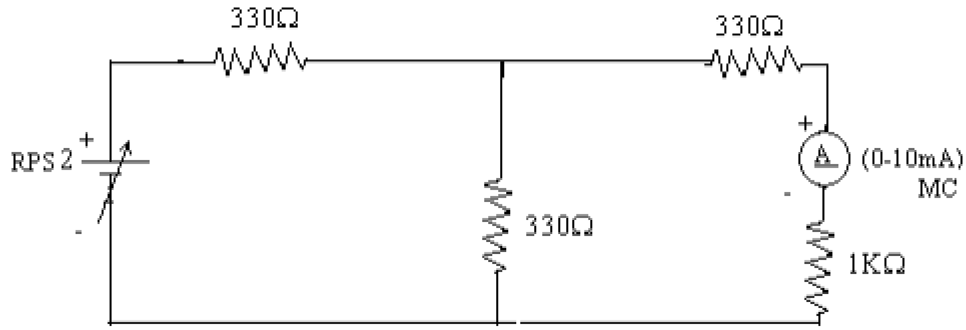
**To find VTH**

3.Remove the load resistance and measure the open circuit voltage using multimeter (VTH).

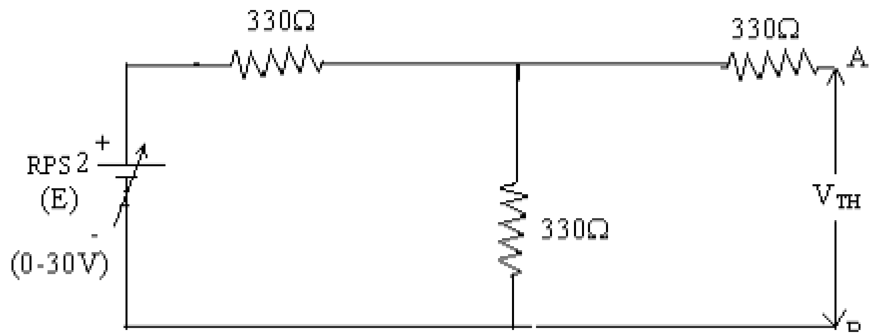
**To find RTH**

4. To find the Thevenin's resistance, remove the RPS and short circuit it and find the RTH using multimeter.
5. Give the connections for equivalent circuit and set VTH and RTH and note the corresponding ammeter reading.
6. Verify Thevenins theorem.

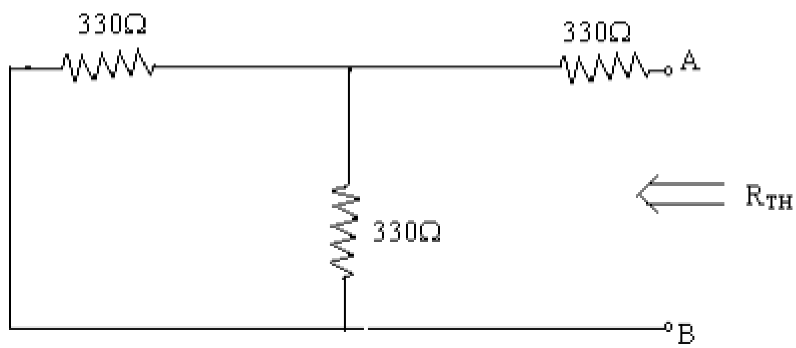
**Circuit - 1 : To find load current**



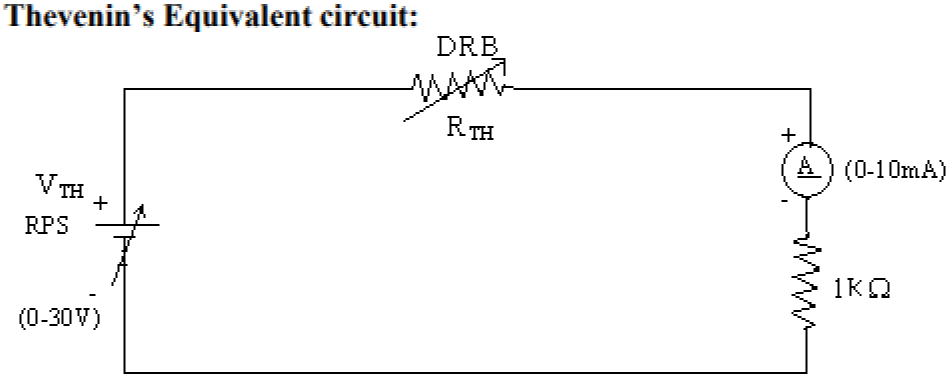

**To find $V_{TH}$**




**To find $R_{TH}$**




**Thevenin's Equivalent circuit:**



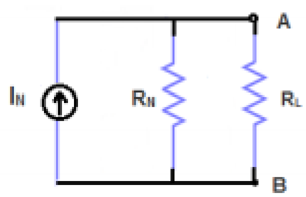
**Calculations:**

**Theoretical and Practical Values**

| | E(V) | $V_{TH}$(V) | $R_{TH}$(Ω) | $I_L$ (mA) | |
|---|---|---|---|---|---|
| | | | | Circuit - I | Equivalent Circuit |
| Theoretical | | | | | |
| Practical | | | | | |

## Norton's Theorem

*Norton's Theorem may be stated as Any Linear Electric Network or complex circuit with Current and Voltage sources can be replaced by an equivalent circuit containing of a single independent Current Source IN and a Parallel Resistance RN.*




**Norton's Equivalent Circuit**

**Procedure**:

1. Connections are given as per circuit diagram.
2. Set a particular value in RPS and note down the ammeter readings in the original circuit.

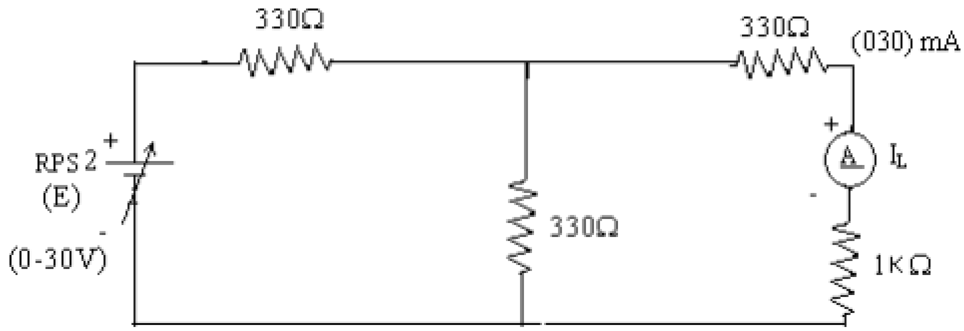
**To Find IN:**

3. Remove the load resistance and short circuit the terminals.
4. For the same RPS voltage note down the ammeter readings.

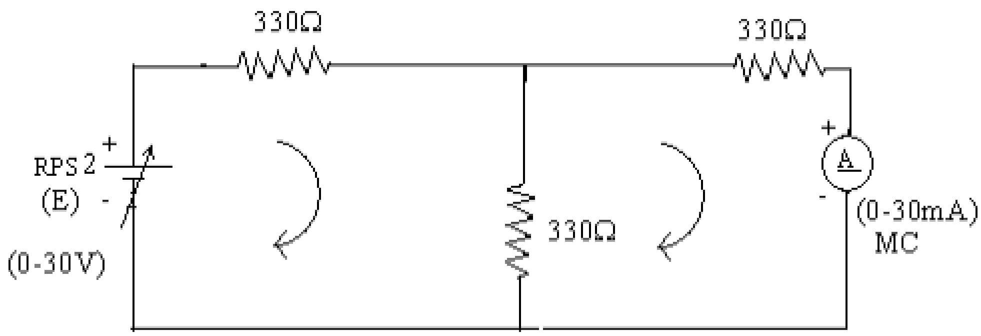
**To Find RN:**

5.Remove RPS and short circuit the terminal and remove the load and note down the resistance across the two terminals. Equivalent Circuit:
6. Set IN and RN and note down the ammeter readings.
7. Verify Norton's theorem.

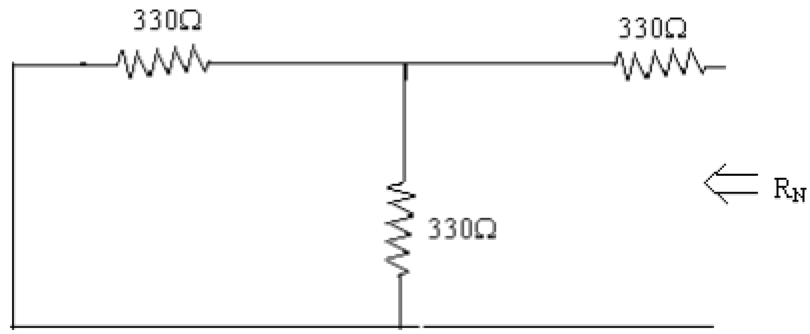
**To find load current in circuit 1:**



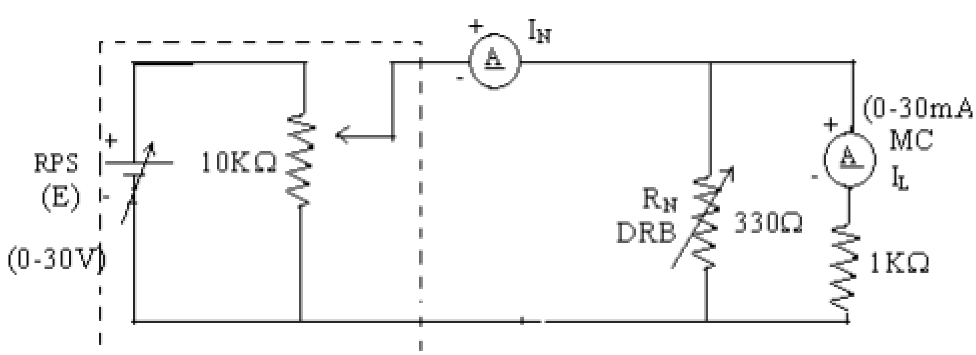

**To find $I_N$**




**To find $R_N$**




**Norton's equivalent circuit**




Constant current source

**Calculations:**

**Theoretical and Practical Values**

| | E(V) | $I_N$ (V) | $R_N(\Omega)$ | $I_L$ (mA) | |
|---|---|---|---|---|---|
| | | | | Circuit - I | Equivalent Circuit |
| Theoretical | | | | | |
| Practical | | | | | |

**Result:**.

# 3: Verification of Superposition and Reciprocity Theorems.

**AIM:** To verify the superposition theorem and Reciprocity theorems for the given circuits.

**APPARATUS REQUIRED:**

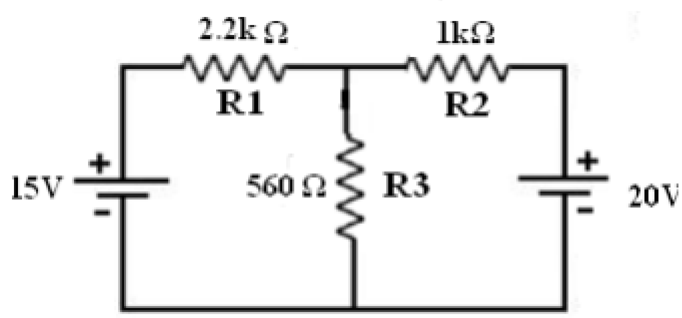
| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | DC voltage source | 0-20V | 1 No. |
| 2. | Resistor | 100 ohm | 1 No. |
| 3. | Ammeter | 0 - 200mA | 1 No. |
| 4. | Ammeter | 0-200µA | 1 No. |
| 5. | Voltmeter | 0 - 20V | 2 Nos. |
| 6. | Connecting wires | | Required. |

**THEORY:**

**SUPERPOSITION THEOREM:**

Superposition theorem states that in a lumped ,linear, bilateral network consisting more number of sources each branch current(voltage) is the algebraic sum all currents ( branch voltages), each of which is determined by considering one source at a time and removing all other sources. In removing the sources, voltage and current sources are replaced by internal resistances.

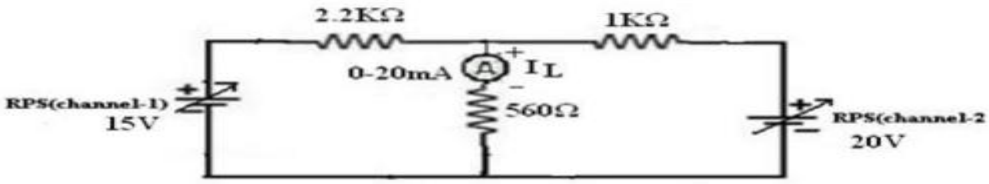
**CIRCUIT DIAGRAM:**




**PROCEDURE:**

1. Connect the circuit as per the fig (1).
2. Adjust the output voltage of sources X and Y to appropriate values (Say 15V and20V respectively).
3. Note down the current (IL) through the 560 0hm resistor by using the ammeter.
4. Connect the circuit as per fig (2) and set the source Y (20V) to 0V.
5. Note down the current ( IL l) through 560ohm resistor by using ammeter.
6. Connect the circuit as per fig(3) and set the source X (15V) to 0V and source Y to 20V.
7. Note down the current (IL ll) through the 560 ohm resistor branch by using ammeter.
8. Reduce the output voltage of the sources X and Y to 0V and switch off the supply.
9. Disconnect the circuit.

When $V_1$ & $V_2$ source acting(To find $I_L$):-




Fig(1)

When $V_1$ Source Acting (To Find $I_L^I$)

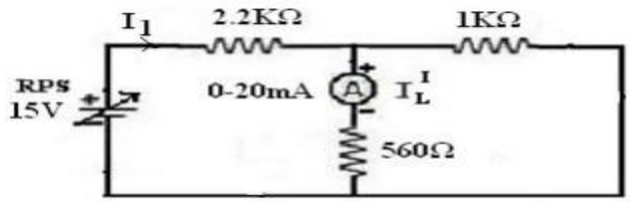



Fig (2)

When $V_2$ source acting (To find $I_L^{II}$):

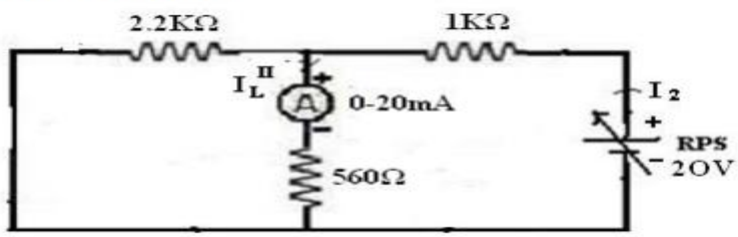



Fig (3)

THEORITICAL CALCULATIONS

From Fig(2)

$$I_1=V_1/(R_1+(R_2//R_3))$$

$$I_L^1=I_1^*R_2/(R_2+R_3)$$

From Fig(3)

$$I_2=V_2/(R_2+(R_1//R_3)$$

$$I_L^{11}=I_2^*R_1/(R_1+R_3)$$

$$I_L = I_L^1 + I_L^{11}$$

**Calculations:**

**Theoretical and Practical Values**

| Source | Theoretical | Practical |
|---|---|---|
| Source 1 | $I_{L1}$ = | $I_{L1}$ = |
| Source 2 | $I_{L2}$ = | $I_{L2}$ = |
| All Sources | $I_{L1}$+ $I_{L2}$ = | $I_{L1}$+ $I_{L2}$= |

## Reciprocity Theorem

**STATEMENT:**

"In a linear bi-lateral single source network ,the ratio of excitation to the response is constant when the position of excitation and response are interchanged".

**CIRCUIT DIAGRAM:**

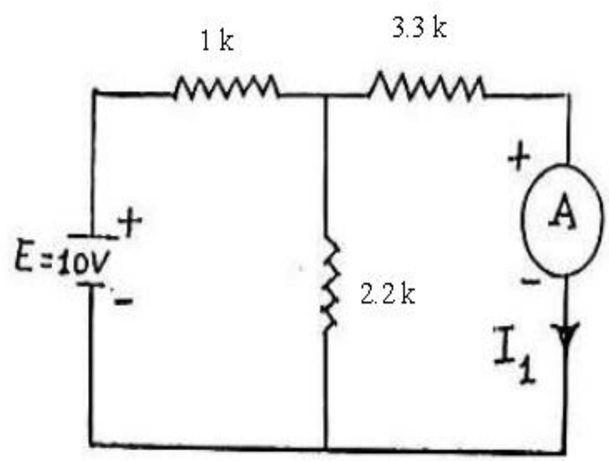



**Figure.1**

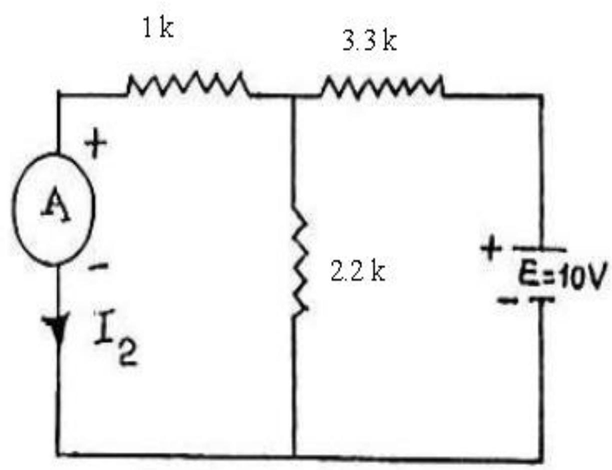



**Figure.2**

**Procedure:**

1. Connect the circuit as per circuit diagram.
2. Adjust the output voltage of R.P.S to an appropriate voltage say 10 V in Figure 1
3. Note down the response of I through 3.3 kΩ resistor and tabulate the values.
4. The circuit connections are changed as per the Figure 2,change the source to load end and replace the source with internal resistance.
5. Note down the response of I through 1 kΩ resistor and tabulate the values.
6. Compare the theoretical & practical values and prove reciprocity theorem

Calculations:

**Observations**

**Theoritical**

| s.no | E in Volts | I1 | I2 | V/I1 = V/I2 |
|---|---|---|---|---|
| | | | | |

**Practical**

| s.no | E in Volts | I1 | I2 | V/I1 = V/I2 |
|---|---|---|---|---|
| | | | | |

**Result :**

## 4.Transient Response of Series RL, RC and RLC circuits using DC excitation

**Aim:**

To study the transient response of a series RL,RC and RLC circuit and understand the time constant concept with DC Power Supply

**Apparatus required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| **1.** | Digital Storage Oscilloscope(DSO) | | 1No |
| **2.** | DC Power Supply | 5V, 2A | 1 No |
| **3.** | Resistor | 1 kΩ | 1 No |
| **4.** | Resistor | 220kΩ | 1 No |
| **5.** | Inductor | 0.1mH | 1 No |
| **6.** | Capacitor | 0.1µF | 1 No |
| **7.** | Bread board | | 1 No |
| **8.** | Connecting wires | | Required |
| **9.** | CRO Probes | | 2 Nos |

**Theory:**

When a circuit is switched from one condition to another either by a change in the applied voltage or a change in one of the circuit elements, there is a transitional period during which the branch currents and voltage drops change from their former values to new ones. After this transition interval called the transient, the circuit is said to be in the steady state.

**Time Constant (τ):** It is a measure of time required for certain changes in voltages and currents in RC and RL circuits. Generally, when the elapsed time exceeds five time constants (5τ) after switching has occurred, the currents and voltages have reached their final value, which is also called steady-state response. The time constant of an RL circuit is the equivalent inductance divided by the Thévenin resistance as viewed from the terminals of the equivalent inductor.

$$\tau = L / R$$

The time constant of an RC circuit is the product of equivalent capacitance and the Thévenin resistance as viewed from the terminals of the equivalent capacitor.

$$\tau = R*C$$

When a circuit is switched from one condition to another either by a change in the applied voltage or a change in one of the circuit elements, there is a transitional period during which the branch currents and voltage drops change from their former values to new ones. After this transition interval called the transient, the circuit is said to be in the steady state.Let us consider the R-L-C circuit as shown below:

Applying KVL, we obtain

$$v(t) = Ri(t) + L\frac{di(t)}{dt} + \frac{1}{C}\int i(t)dt$$

Taking Laplace transform on both sides of the above equation,

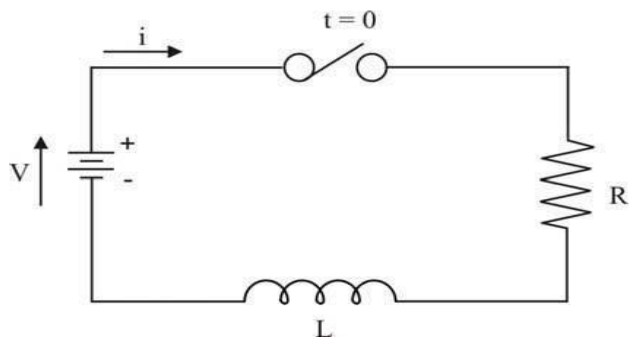
$$V(s) = RI(s) + L[sI(s) - i(0\_)] + \frac{I(s)}{sC} + \frac{v_C(0\_)}{s}$$

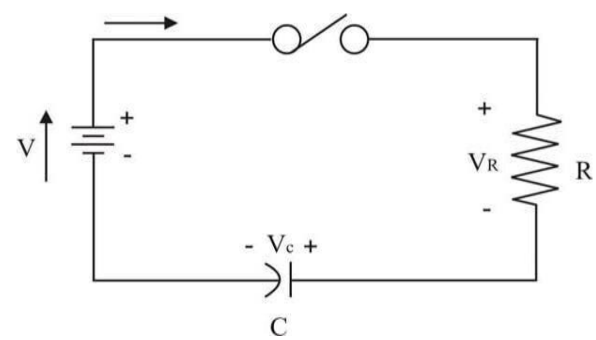
Now as all initial conditions set equal to zero, i.e. $i(0\_) = 0$ and $v_c\ (0\_) = 0$, so the equation becomes,

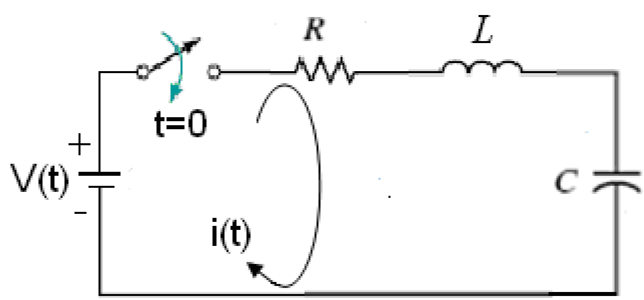
$$V(s) = I(s)\left[R + sL + \frac{1}{sC}\right]$$

Here, $v(t) = u(t)\ \therefore V(s)=1/S$

**Circuit Diagrams :**



**Procedure:**

**RL Circuit:**

Make the connections as shown in figure.

1. Make sure that the toggle switch connected across the DC Supply is in downward position.
2. Connect +5 V DC Power Supply to the input of RL Circuit
3. Now switch 'On' the power supply
4. Switch the toggle switch in upward direction so that DC Supply will connect to the RLcircuit.
5. Connect DSO across inductor.
6. Observe the transient response (firstly sudden increase in voltage and then exponentially decaying)on DSO. Now immediately press RUN/STOP Switch of DSO to hold the response shown on the DSO screen.
7. Now switch the toggle switch in downward direction so that resistor, R will shortwith Inductor, L.
8. Now observe the response till it (first sudden increase of voltage in negative direction andthen exponentially rising towards reference level) reaches reference level of DSO.

**RC Circuit:**

Make the connections as shown in figure.

1. Make sure that the toggle switch connected across the DC Supply is in downwardposition.
2. Connect +5V DC Power Supply to the input of RC Circuit
3. Now switch 'On' the power supply
4. Switch the toggle switch in upward direction so that DC Supply will connect to the RCcircuit.
5. Connect DSO across capacitor
6. Observe the transient response (exponentially rising) on DSO till the steady state (+5VDC level) is achieved.
7. Now switch the toggle switch in downward direction so that resistor, R will shortwith capacitor, C.
8. Now observe the response (exponentially decaying) till it reaches reference level of DSO.

   Now immediately press RUN/STOP Switch of DSO to hold the response shown on the DSO screen.

RLC Circuit

Make the connections as shown in figure.

1. Make sure that the toggle switch connected across the DC Supply is in downward position.
2. Connect +5V DC Power Supply to the input of RC Circuit
3. Now switch 'On' the power supply
4. Switch the toggle switch in upward direction so that DC Supply will connect to the RC circuit.
5. Connect DSO across capacitor
6. Observe the transient response (exponentially rising) on DSO till the steady state (+5VDC level) is achieved.
7. Now switch the toggle switch in downward direction so that resistor, R will short with capacitor, C and inductor L.
8. Now observe the response (exponentially decaying) till it reaches reference level of DSO.

Now immediately press RUN/STOP Switch of DSO to hold the response shown on the DSO

Calculations:

RL Circuit:

Theoretically,

Time Constant, TC = L/R =..................... where

L = 0.1mH, R =1k, f=10kHz

Practically (on DSOscreen),

In the charging circuit, Time Constant is the time by which the capacitor attains the 63.2% of steady state voltage or final value (in our case, +5 V).

Time Constant or Time required to rise to 63.2% of 5 V (i.e. 3.16 V) =…………

In the discharging circuit, Time Constant is time by which the capacitor discharges to 36.8% of its initial steady state voltage (in our case, +5 V).

Time Constant or Time required to decay to 36.8% of 5V (i.e. 1.84 V) = ………….

**1.** Similarly, 2TC is the time required to achieve 86.5% of final or initial value of voltage.

Practically, 2TC = ………. Theoretically, 2TC =……...

**2.** After 5TC, the voltage reach their final values which is also called steady state response.

Practically, 5TC = ………. Theoretically, 5TC =……...

RC Circuit:

Theoretically,

Time Constant, TC = R C =....................where R = 220 k, C = 0.1 μF.

**Practically (on DSOscreen),**

In the charging circuit, Time Constant is the time by which the capacitor attains the 63.2% of steady state voltage or final value (in our case, +5 V).

**Time Constant or Time required to rise to 63.2% of 5 V (i.e. 3.16 V) =…………**

In the discharging circuit, Time Constant is time by which the capacitor discharges to 36.8% of its initial steady state voltage (in our case, +5 V).

**Time Constant or Time required to decay to 36.8% of 5V (i.e. 1.84 V) = ………….**

Similarly, 2TC is the time required to achieve 86.5% of final or initial value ofvoltage.

**Practically, 2TC =……**

**Theoretically, 2TC =…….**

After 5TC, the voltage reach their final values which is also called steady stateresponse

**Practically, 5TC = ……….**

**Theoretically, 5TC =……..**

**RLC Circuit**

To obtain transient response of a series RLC circuit, excited by a unit step input, where L=10mH and C=1µF and for the following conditions:

1. $R < 2\sqrt{\frac{L}{C}}$, under damped case where R=100

2. $R = 2\sqrt{\frac{L}{C}}$, critically damped case where R=200

3. $R > 2\sqrt{\frac{L}{C}}$, over damped case where R=300

Therefore, $1/S = I(S)\left[R + sL + \frac{1}{sL}\right]$ or

$$I(s) = \frac{1/L}{s^2 L + \frac{R}{L}s + \frac{1}{LC}}$$

The roots of the denominator polynomial of the above equation are,

Or

$$s_1 = -\frac{R}{2L} + \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$ and

$$s_2 = -\frac{R}{2L} - \sqrt{\frac{R^2}{4L^2} - \frac{1}{LC}}$$

Let, $\omega_0 = \frac{1}{\sqrt{LC}}$ and $\xi\omega_0 = \frac{R}{2L}$

$$\therefore \ \xi = \frac{R}{2}\sqrt{\frac{C}{L}}$$

Now, $$I(s) = \frac{1/L}{(s-s_1)(s-s_2)} = \frac{\frac{1}{L(s_1-s_2)}}{(s-s_1)} + \frac{\frac{1}{L(s_2-s_1)}}{(s-s_2)}$$

$$I(s) = \frac{1}{2\omega_0 L\sqrt{\xi^2-1}}\left[\frac{1}{(s-s_1)} - \frac{1}{(s-s_2)}\right]$$

**Case - 1**:-

$$\mathrm{R} < 2\sqrt{\frac{L}{C}}$$

i.e

$$\xi < 1$$

**Case - 2**: -

$$\mathrm{R} = 2\sqrt{\frac{L}{C}}$$

i.e., $\xi = 1$

$$i(t) = \frac{1}{L}t.e^{-\omega_0 t}$$

The network is then said to be **Critically Damped.**

**Case -3**:-

$$\mathrm{R} > 2\sqrt{\frac{L}{C}}$$

i.e., $\xi > 1$

$$i(t) = \frac{1}{\omega_0 L\sqrt{\xi^2 - 1}} e^{-\xi\omega_0 t} \sinh\left(\omega_0 t\sqrt{\xi^2 - 1}\right)$$

The network is then said to be **Over Damped.**

**Practically (on DSOscreen),**

**Case 1:-**

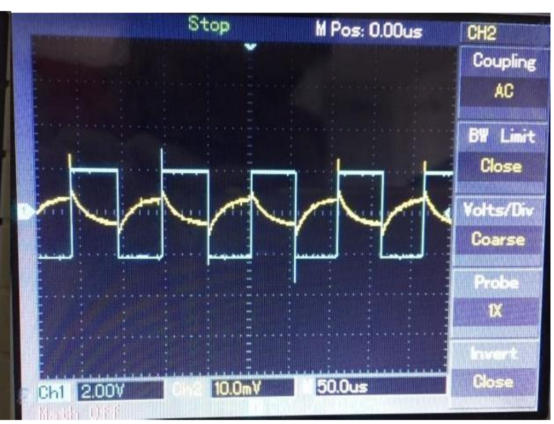
Case 2:-

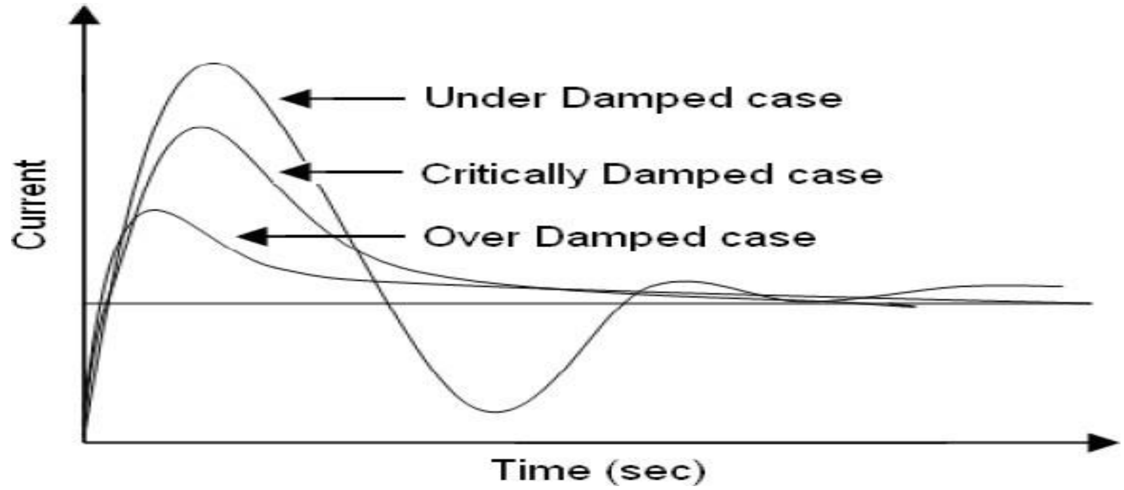
Case 3:-

**Model Graphs:**

**RL Circuit**


**RC Circuit**




Under Damped case
Critically Damped case
Over Damped case
Current
Time (sec)

**Result :**

### 5: Resonance in series RLC circuit

**Aim:**

To determine resonant frequency, band width and Q-factor for Series RLC circuits.

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | AC voltage source. | (0 - 10)V | 1 No |
| 2. | Resistor. | 1KΩ | 1 No |
| 3. | Inductor. | 100mH | 1 No |
| 4. | Capacitor. | 0.1μF | 1 No |
| 5. | Function Generator | (0-1) MHz | 1 No |
| 6. | Ammeter AC | (0 – 20) mA | 1 No |
| 7. | Bread Board | | 1 No |
| 8. | Connecting wires | | Required |

**Theory:**

**Series Resonance:**

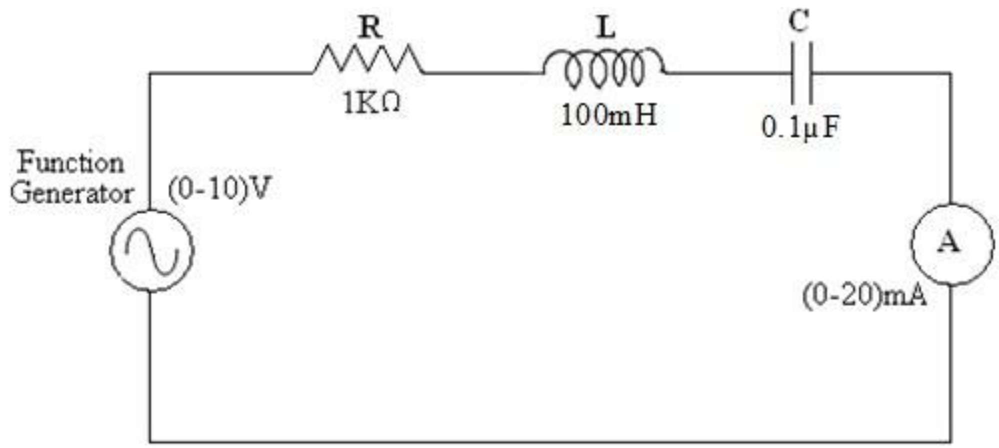
Consider a RLC circuit in which resistor, inductor and capacitor are connected in series across a voltage supply. This series RLC circuit has a distinguishing property of resonating at a specific frequency called resonant frequency. In this circuit containing inductor and capacitor, the energy is stored in two different ways. When a current flows in an inductor, energy gets stored in magnetic field. When a capacitor is charged, energy gets stored in static electric field.

In some cases, at certain frequency called resonant frequency, the inductive reactance of the circuit becomes equal to capacitive reactance which causes the electrical energy to oscillate between the electric field of the capacitor and magnetic field of the inductor. This forms a harmonic oscillator for current. In RLC circuit, the presence of resistor causes these oscillation to die out over period of time and is called damping effect of resistor.

At resonance in series RLC circuit, two reactance become equal and cancel each other. So in resonant series RLC circuit, the opposition to the flow of current is due to resistance only. At resonance, the total impedance of series RLC circuit is equal to resistance i.e $Z = R$, impedance has only real part but no imaginary part and this impedance at resonant frequency is called dynamic impedance and this dynamic impedance is always less than impedance of series RLC circuit.

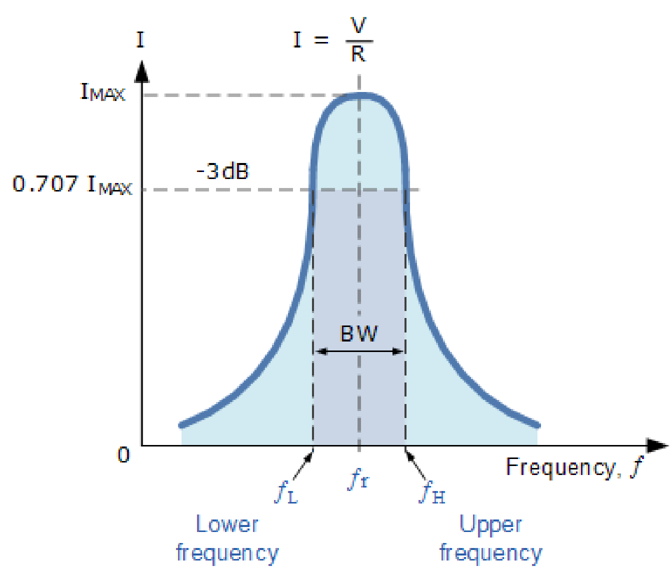
Before series resonance i.e before frequency, fr capacitive reactance dominates and after resonance, inductive reactance dominates and at resonance the circuit acts purely as resistive circuit causing a large amount of current to circulate through the circuit.

**Circuit Diagram:**




**Model Graphs:**

**Current Vs Frequency**




**Tabular Column:**

| | $F_r$ (Hz) | $F_H$ (Hz) | $F_L$ (Hz) | Band Width | Quality Factor |
|---|---|---|---|---|---|
| Theoretical | | | | | |
| Practical | | | | | |

**Procedure:**

1. Connect the circuit as per the circuit diagram.
2. Apply 20V (peak to peak) from the function generator.
3. Note down the readings of the milli-Ammeter by varying the input frequency in suitable steps. (Starting from 1 KHz to 10 KHz in steps of 500Hz).
4. Calculate Impedance Z
5. Plot the graphs for I vs Frequency and Z vs Frequency.
6. Identify the values of fr, f1 and f2 from the graph, calculate Q-factor and Bandwidth.
7. Compare with theoretical values.

**Tabular Form:**

| S.No | Frequency (Hz) | I (mA) |
|---|---|---|
| | | |

**Theoretical Calculations:**

Resonant Frequency ($f_r$) = $\frac{1}{2\Pi\sqrt{LC}}$

Lower cut-off Frequency ($f_1$) = $f_r - \frac{R}{4\Pi L}$

Upper cut-off Frequency ($f_2$) = $f_r + \frac{R}{4\Pi L}$

Band-width $= f_2 - f_1$

Quality Factor (Q) = $f_r / (f_2 - f_1)$

**Result:**

**6: Calculations and Verification of Impedance and Current of RL, RC and RLC series circuits**

**Aim:**

To study RL, RC and RLC series circuit.

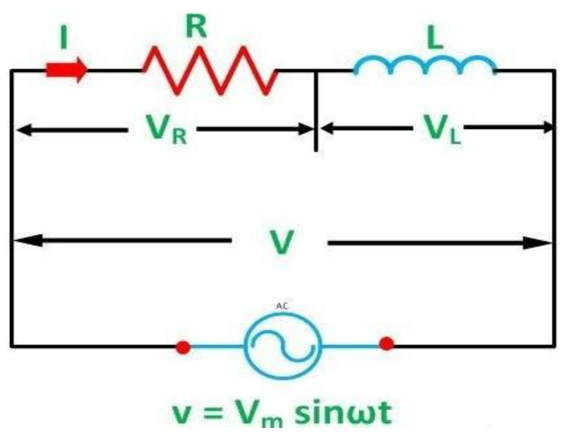
**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | AC voltage source. | (0 - 10)V | 1 No |
| 2. | Resistor. | 1KΩ | 1 No |
| 3. | Inductor. | 10 mH | 1 No |
| 4. | Capacitor. | 0.1μF | 1 No |
| 5. | Function Generator | (0-1) MHz | 1 No |
| 6. | Ammeter AC | (0 – 200) mA | 1 No |
| 7. | Voltmeter (AC) | (0 – 20)V | 2No.s |
| 8. | Connecting wires | | Required |

**Theory:**

**RL Series Circuit:**

A circuit that contains a pure resistance R connected in series with a coil having pure inductance of L is known as **RL Series Circuit**. When an AC supply voltage V is applied the current, I flows in the circuit. $I_R$and $I_L$ will be the current flowing in the resistor and inductor respectively, but the amount of current flowing through both the elements will be same as they are connected in series with each other. The circuit diagram of RL Series Circuit is shown below




Where,

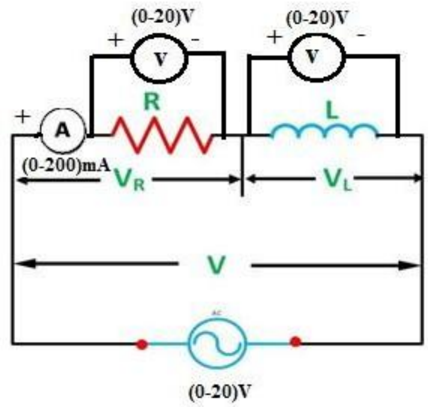
$V_R$ – voltage across the resistor R

$V_L$ – voltage across the inductor L

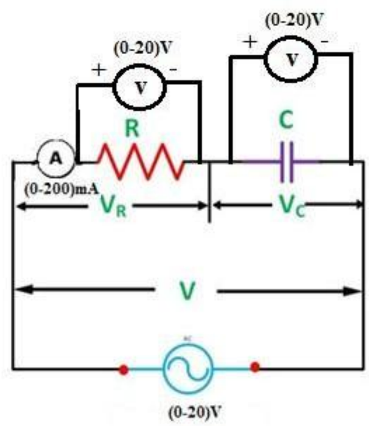
V – Total voltage of the circuit

**Circuit Diagram:**

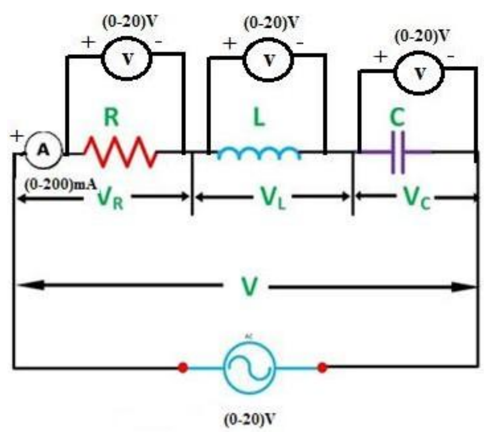
**RL Circuit:**




**RC Circuit:**

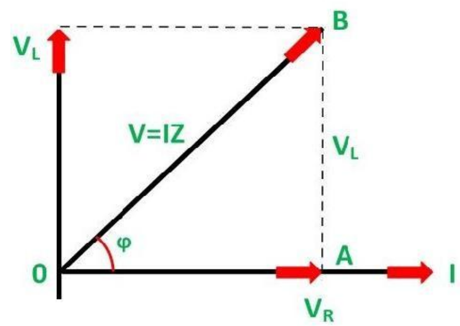



**RLC Circuit:**




**Phasor Diagram of the RL Series Circuit:**

The phasor diagram of the RL Series circuit is shown below




$V_R = I_R$ and $V_L = IX_L$ where $X_L = 2\pi fL$

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

$$V = I\sqrt{R^2 + X_L^2} \quad \text{or}$$

$$I = \frac{V}{Z}$$

Where,

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

Z is the total opposition offered to the flow of alternating current by an RL Series circuit and is called impedance of the circuit. It is measured in ohms (Ω).

**Phase Angle :**

In RL Series Circuit the current lags the voltage by 90-degree angle known as phase angle. It is given by the equation

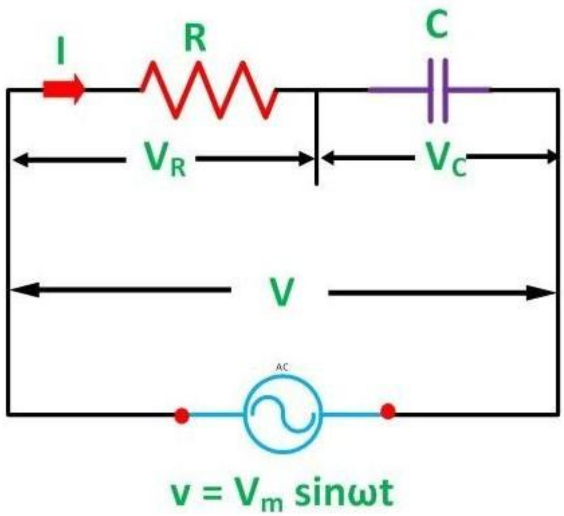
$$\tan\varphi = \frac{V_L}{V_R} = \frac{IX_L}{IR} = \frac{X_L}{R} \quad \text{or}$$

$$\varphi = \tan^{-1}\frac{X_L}{R}$$

**RC Circuit:**

A circuit that contains pure resistance R ohms connected in series with a pure capacitor of capacitance C farads is known as RC Series Circuit. A sinusoidal voltage is applied to and current I flows through the resistance (R) and the capacitance (C) of the circuit.The RC Series circuit is shown in the figure below

In this experiment, we are mainly interested in verification of Kirchhoff's voltage law for AC circuit.




Where,

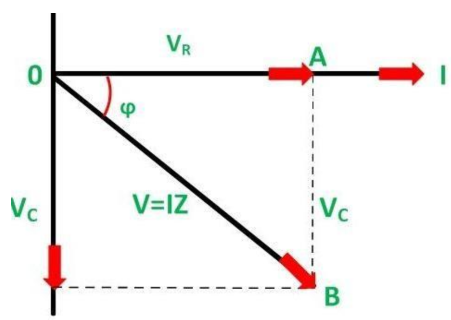
$V_R$ – voltage across the resistance R

$V_C$ – voltage across the capacitor C

V – total voltage across the RC Series circuit

**Phasor Diagram of RC Series Circuit:**

The phasor diagram of the RC Series circuit is shown below




Now, $V_R = I_R$ and $V_C = IX_C$

Where, $X_C = I/2\pi fC$

In right triangle OAB

$$V = \sqrt{(V_R)^2 + (V_C)^2} = \sqrt{(IR)^2 + (IX_C)^2}$$

$$V = I\sqrt{R^2 + X_C^2} \quad \text{or}$$

$$I = \frac{V}{\sqrt{R^2 + X_C^2}} = \frac{V}{Z}$$

Where,

$$Z = \sqrt{R^2 + X_C^2}$$

Z is the total opposition offered to the flow of alternating current by an RC Series circuit and is called impedance of the circuit. It is measured in ohms (Ω).

**Phase angle:**

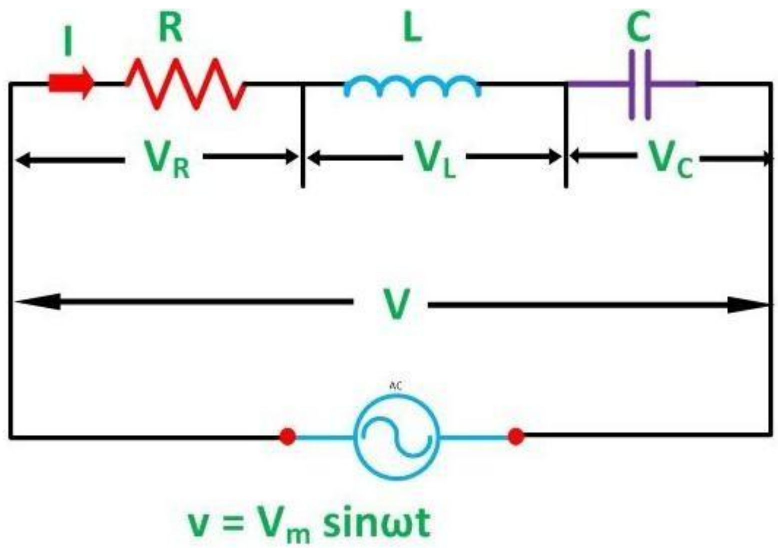
From the phasor diagram shown above it is clear that the current in the circuit leads the applied voltage by an angle ϕ and this angle is called the phase angle.

$$\tan\varphi = \frac{V_C}{V_R} = \frac{IX_C}{IR} = \frac{X_C}{R} \quad \text{or}$$

$$\varphi = \tan^{-1}\frac{X_C}{R}$$

**RLC Series Circuit:**

The RLC Series Circuit is defined as when a pure resistance of R ohms, a pure inductance of L Henry and a pure capacitance of C farads are connected together in series combination with each other. As all the three elements are connected in series so, the current flowing in each element of the circuit will be same as the total current I flowing in the circuit.




In the RLC Series Circuit

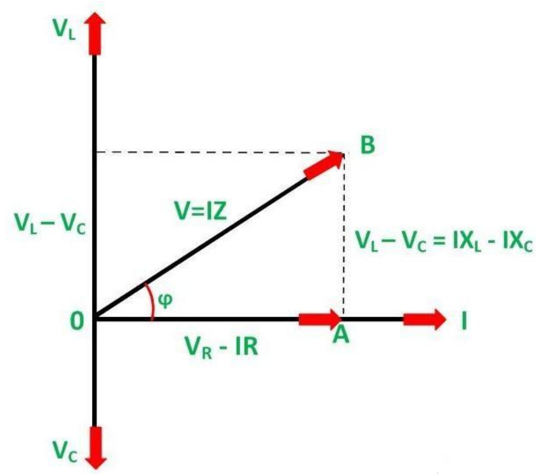
$X_L = 2\pi fL$ and $X_C = 1/2\pi fC$

When the AC voltage is applied through the RLC Series Circuit the resulting current I flows through the circuit, and thus the voltage across each element will be

- $V_R$ = IR that is the voltage across the resistance R and is in phase with the current I.
- $V_L = IX_L$ that is the voltage across the inductance L and it leads the current I by an angle of 90 degrees.
- $V_C = IX_C$ that is the voltage across the capacitor C and it lags the current I by an angle of 90 degrees.

**PhasorDiagramof RLC Series Circuit:**

The phasor diagram of the RLC Series Circuit when the circuit is acting as an inductive circuit that means ($V_L > V_C$) is shown below and if ($V_L < V_C$) the circuit will behave as a capacitive circuit.



$$V = \sqrt{(V_R)^2 + (V_L - V_C)^2} = \sqrt{(IR)^2 + (IX_L - IX_C)^2} \quad \text{or}$$

$$V = I\sqrt{R^2 + (X_L - X_C)^2} \quad \text{or}$$

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

Where,

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

It is the total opposition offered to the flow of current by an RLC Circuit and is known as Impedance of the circuit.

**Phase Angle:**

From the phasor diagram, the value of phase angle will be

$$\tan\varphi = \frac{V_L - V_C}{V_R} = \frac{X_L - X_C}{R} \quad \text{or}$$

$$\varphi = \tan^{-1}\frac{X_L - X_C}{R}$$

**The three cases of RLC Series Circuit**

- When $X_L > X_C$, the phase angle $\phi$ is positive. The circuit behaves as a 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 $\phi$ is negative, and the circuit acts as a series RC circuit in which the current leads the voltage by 90 degrees.
- When $X_L = X_C$, the phase angle $\phi$ 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 power factor is unity.

**Procedure:**

**RL Circuit:**

Use peak-to-peak readings for all voltage and current measurements in this experiment.

1. Construct a table for recording experimental data:

| R kΩ | L Mh | *f* *Hz* | $V_S$ *(gen) Volts* | $V_S$ *(Osc) Volts* | $V_R$ *Volts* | $V_L$ *Volts* | *I* *mA* | $X_L$ Ω | $Z_T$ Ω | *Phase angle (Φ) Degree* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *meas* | *Calc* |
| | | | | | | | | | | | |

2. Connect the circuit by selecting a 5 kΩ resistor and 50 mH inductor as shown in Figure.
3. With the circuit connected, adjust the function generator's frequency f to 10 kHz with an output voltage of 4.0 VPP. Record the actual values of f and VS (generator).
4. Using the 2-channel oscilloscope, connect CHANNEL 0 to measure $V_S$, the voltage across the source . Connect CHANNEL 1 to measure $V_R$, the voltage across theresistor . Be sure that the ground leads are both connected to the samepoint . Record $V_S$ *(Oscilloscope)* and$V_R$.
5. With the oscilloscope still connected as in step 5, measure the phase angle $\varphi$ between$V_R$and $V_S$.. You may use the AUTOSCALE button to ensure the waveforms are approximately the same height and press STOP to improve accuracy when taking cursor measurements. Record this value as $\varphi_{meas}$in thetable.
6. Calculatethepeak-to-peakcurrentinthecircuitbyapplyingOhm'slawtotheresistor. That is, $I = \frac{VR}{R}$.Record the calculated current *I* in thetable.
7. Calculate the inductive reactance $X_L$by applying Ohm's law to the inductor. That is,$XL = \frac{VL}{I}$. Record the calculated reactance in the table.
8. Calculatethetotalimpedance $Z_T$byapplyingOhm'slawtotheentirecircuit. $ZT = \frac{VS}{I}$. Record the value of $Z_T$ in the table.
9. Compute the phase angle $\varphi$ between $V_S$ and $V_R$. Recall that $\varphi = arctan\left(\frac{VL}{VR}\right)$.Record this value as $\varphi calc$ in the table, and compare it to the value measured on the oscilloscope.
10. Record this value as $\varphi calc$in the table, and compare it to the value measured on the oscilloscope.

**RC Circuit:**

1. Construct a table for recording experimental data:

| R kΩ | C µF | *f* *Hz* | $V_S$ *(gen) Volts* | $V_S$ *(Osc) Volts* | $V_R$ *Volts* | *Vc* *Volts* | *I* *mA* | $X_L$ Ω | $Z_T$ Ω | *Phase angle (Φ) Degree* | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | *meas* | *Calc* |
| | | | | | | | | | | | |

2 Using the resistor R and capacitor $C_1$, connect the series RC circuit shown in Figure. With the circuit connected, adjust the supply voltage $V_S$ to 2.0 V peak-to-peak at 500 Hz. Checkthevoltage $V_S$ onCHANNEL0oftheoscilloscopeandrecorditsvalueintable

3 Connect CHANNEL 1 of the oscilloscope across capacitor $C_1$. Be sure that the groundleads of CHANNEL 1 and CHANNEL 0 are connected to ground. Measure $V_{C1}$. Record the value in table

4 ConnectCHANNEL1oftheoscilloscopeacrossresistorRandmeasure $V_R$.

5 Measure the phase angle $\varphi$ between $V_R$ and $V_S$.

6 Computethepeak-to-peakcurrent $I_{pp}$ from $I_{pp}=V_R/R$.Remember,thecurrentisthesame throughout the circuit, so this current also flows through thecapacitor.

7 Compute the capacitor's reactance $X_{C1}$ from $X_{C1}= V_{C1}/I_{PP}$. Compute $C_1$ from the measured $X_{C1}$ and compare to your earliermeasurement

8 Compute the total impedance $Z_{Total}$ by applying Ohm's law to the circuit. Use the supply voltage set in step 3 and the current found in step 4. Remember, the impedance has both a magnitude and a phase angle (measured relative to theresistor).

9 Draw impedance and voltage phasors.

**RLC Circuit:**

Use peak-to-peak readings for all voltage and current measurements in this experiment.

1. Construct a table for recording experimental data:

| R kΩ | L mH | *f* *Hz* | $V_S$ *(gen) Volts* | $V_S$ *(Osc) Volts* | $V_R$ *Volts* | $V_L$ *Volts* | $V_C$ *Volts* | *I* *mA* | $X_L$ Ω | $X_C$ Ω | $Z_T$ Ω | *Phase angle (Φ) Degree* | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | | *Meas* | *Calc* |
| | | | | | | | | | | | | | |

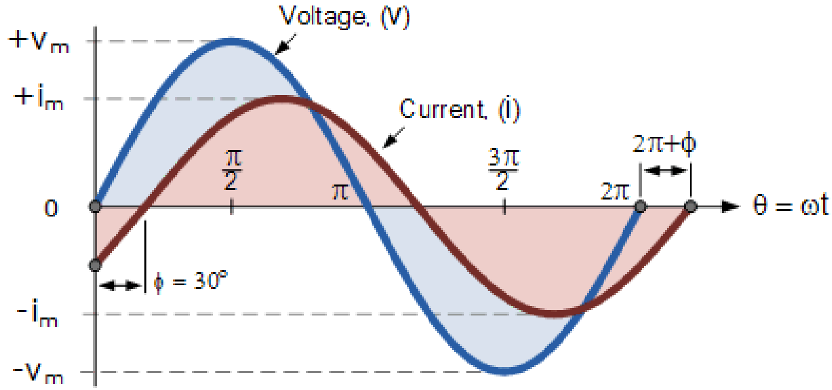
2. Connect the circuit by selecting a 5 kΩ resistor, 50 mHinductorand 0.1µF capacitor as shown in Figure.

3. With the circuit connected, adjust the function generator's frequency f to 10 kHz with an output voltage of 4.0 VPP. Record the actual values of f and VS (generator).
4. Using the 2-channel oscilloscope, connect CHANNEL 0 to measure $V_S$, the voltage across the source . Connect CHANNEL 1 to measure $V_R$, the voltage across theresistor . Be sure that the ground leads are both connected to the samepoint . Record $V_S$ *(Oscilloscope)* and$V_R$.
5. With the oscilloscope still connected as in step 5, measure the phase angle $\varphi$ between$V_R$and $V_S$.. You may use the AUTOSCALE button to ensure the waveforms are approximately the same height and press STOP to improve accuracy when taking cursor measurements. Record this value as $\varphi_{meas}$ in thetable.
6. Calculatethepeak-to-peakcurrentinthecircuitbyapplyingOhm'slawtotheresistor. That is, $I = \frac{VR}{R}$.Record the calculated current $I$ in thetable.
7. Calculate the inductive reactance $X_L$by applying Ohm's law to the inductor. That is, $XL = \frac{VL}{I}$. Record the calculated reactance in the table.
8. Calculatethetotalimpedance $Z_T$byapplyingOhm'slawtotheentirecircuit. $ZT = \frac{VS}{I}$. Record the value of $Z_T$ in the table.
9. Compute the phase angle $\varphi$ between $V_S$ and $V_R$. Recall that $\varphi = arctan\left(\frac{VL}{VR}\right)$.Record this value as $\varphi calc$ in the table, and compare it to the value measured on the oscilloscope.
10. Record this value as $\varphi calc$in the table, and compare it to the value measured on the Oscilloscope

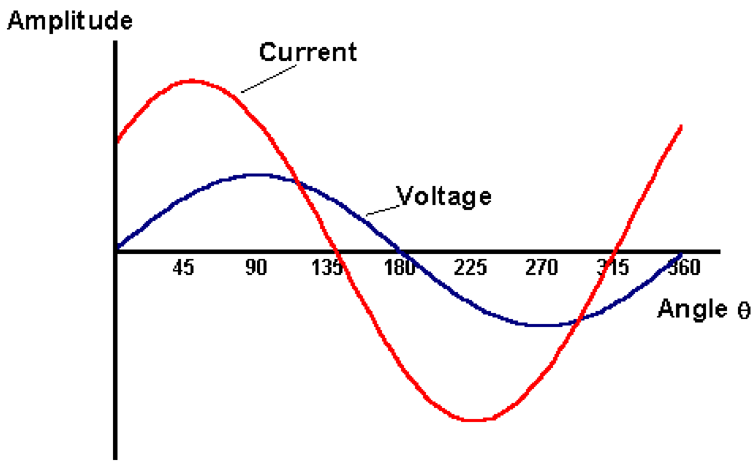
**Calculations:**

**Model graphs:**

**RL circuit:**



**RC circuit:**




**Result:**

**7: Load Test on Single Phase Transformer (Calculate Efficiency and Regulation)**

**Aim:**

To calculate Efficiency and regulation of Single phase transformer by conducting load test on Single phase transformer

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | Single phase transformer | | 1 No |
| 2. | 2 Single phase variac | 0-230v | 1 No |
| 3. | Ammeter | 0-2 A | 1 No |
| 4. | Ammeter | 0-20 A | 1 No |
| 5. | Voltmeter | 0-300 V | 1 No |
| 6. | U.P.F. type Wattmeter | 0-3.0 KW | 2 Nos |
| 7. | Connecting wires | | Required |

**Transformer Ratings :**

Power:2 KVA,
Primary/Secondary :230/415 Volts,8.69/4.82 Amps.

**Theory:**

A transformer is a static apparatus used to transform a.c. electrical power from one voltage to another voltage. It works on the principle of mutual induction.In a transformer there are two windings primary winding & secondary winding. Both these windings are having their internal resistance & leakage current. When the transformer is loaded there will be voltage drop in the transformer due to the resistance & reactance of the windings.When the secondary winding of the transformer is completed through a load an voltage V is applied to the primary winding ,the transformer is said to operate under load condition.

Under this condition transformer copper loss increase with increase in current, due to that efficiency changes. At half load efficiency is reaches to maximum, it gradually decreases when further load increases. This is because at half load Cu loss is less and iron loss is also less, but below half load iron loss will be more which results in less efficiency. This situation happens when transformer is distribution transformer.

When load increase beyond half load Cu loss will increase which again reduces the efficiency. This test is performed to determine the efficiency and regulation of a transformer at different load conditions.

REGULATION: If E0 is the load voltage of the secondary side & V, is the terminal voltage of the secondary side.When it is loaded: Then,

E0 – V = Voltage drop in the transformer when it is loaded.

=Change in the terminal voltage of the transformer when it is loaded.

**Circuit Diagram:**

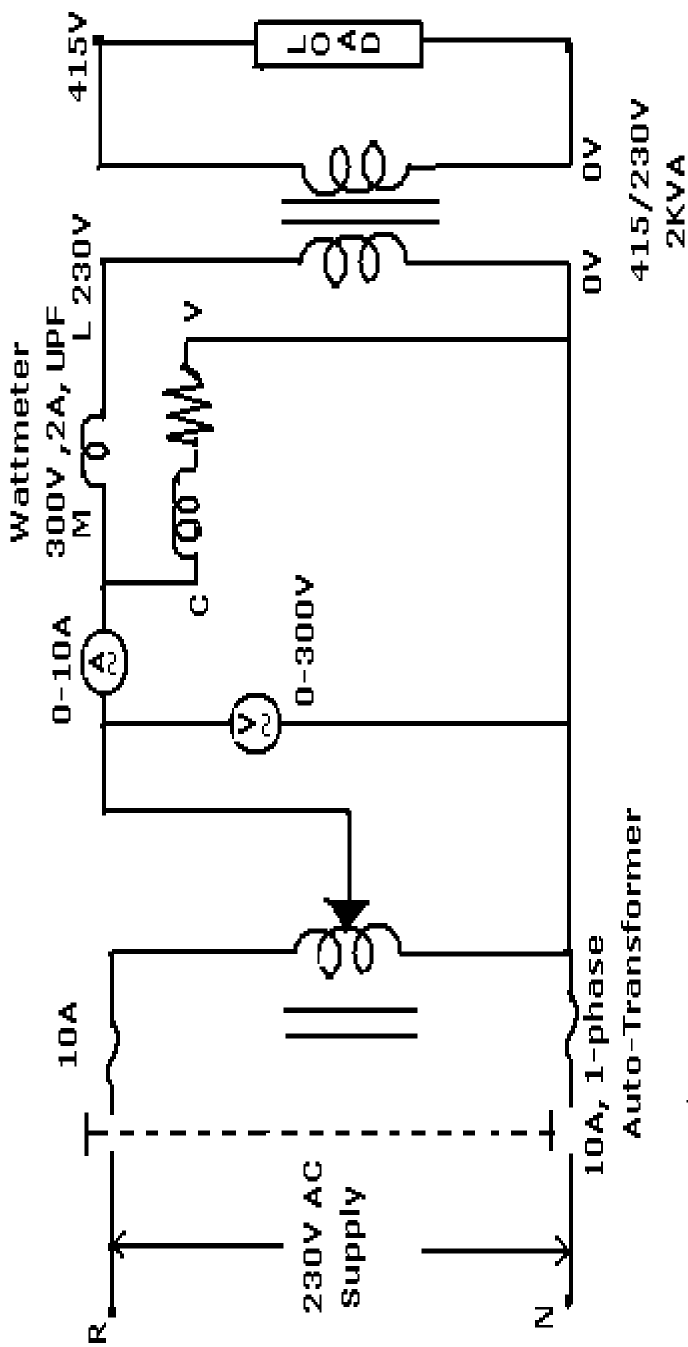



Fig.1.3: Load Test

Voltage regulation of a transformer is the ratio of change in the terminal voltage of the secondary from no load to load condition.
To its rated voltage, at a particular load current.

i.e % Regulation = $\frac{E0 - V}{V \text{ rated}} \times 100$

As the load current increases, the voltage drop in the transformer windings also increases & hence the voltage regulation increases. The Regulation of a transformer should not more than 8%. In a transformer lower percentage regulation is a better regulation.

**EFFICIENCY:**

The ratio of output power to the input power of a transformer is called the efficiency of the transformer up to certain amount of load, efficiency increases with the increases in load and the onward slightly decreases.

$$\text{EFFICIENCY} = \frac{\text{OUTPUT}}{\text{INPUT}} = \frac{V2\ I2\ \cos\Phi}{\text{IN PUT POWER}}$$

The above formula shows that efficiency depends not on the value of load current, but also on the power factor (COSΦ) of the load current.If the load is purely resistive, the power factor i.e. cosΦ =1.

.

$$\text{EFFICIENCY} = \frac{V2\ I2}{\text{IN PUT POWER}}$$

The efficiency of a transformer is generally more. Compared to other rotation machines, as it is a static apparatus, involving no frictional losses. Generally efficiency of a good transformer is more than 90% at full load.
A load test is performed in the laboratory to check its performance before it is actually used on site.For getting the values of regulation & efficiency at different power factor, the different types of loads that is inductive or capacitive load should be used.

**Formula Used:**

$$\%\eta = (W_2 / W_1)*100$$

$$\%reg = \{(V_{rated} - V_2) / V_{rated}\} * 100$$

**Procedure:**

1. Connect the circuit diagram such that the supply on LV side and load on HV side as shown in the fig
2. Gradually increase the voltage using auto transformer till the voltmeter reads the rated voltage, 230v on LV side and also record the voltage on HV side.
3. Maintain the voltage V to be constant for all loads.
4. Switch on the load switches one by one and record the ammeter, voltmeter and wattmeter readings. (The load current should not be exceed the rated current,4.82A.)
5. Switch off the supply and set the auto-transformer at zero position.

**Observations:**

| S.No | Primary | | | Secondary | | | %η | % reg |
|---|---|---|---|---|---|---|---|---|
| | $V_1$ (Volt) | $I_1$ (Amp) | $W_1$ (kW) | $V_2$ (Volt) | $I_2$ (Amps) | $W_2$ (kW) | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |
| | | | | | | | | |

**Calculations:**

**Result:**

## 8. Three Phase Transformer: Verification of Relationship between Voltages and Currents (Star-Delta, Delta-Delta, Delta-star, Star-Star)

**Aim:**
To verify the relationship between voltages and currents in a three phase transformer for Star Delta Connection

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | 3 Phase Auto transformer | | 1 No |
| 2. | Ammeter | 0-20 A | 2 Nos |
| 3. | Voltmeter | 0-300 V | 2 Nos |
| 4. | Resistive Load | | Suitable |
| 5. | 1 Φ Transformer | 1KVA, 230/415V | 3 Nos |
| 6. | Connecting wires | | Required |

**Theory:**
In this type of transformer connection, then primary is connected in star fashion while the secondary is connected in delta fashion as shown in the Figure 1 below.

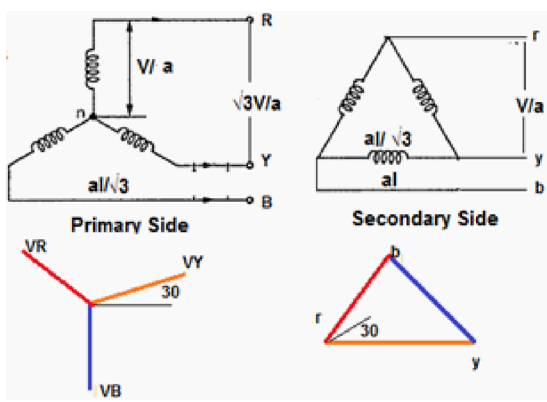



Figure 1 – Transformer Connection – Star-Delta

The voltages on primary and secondary sides can be represented on the phasor diagram as shown in the ***Figure 2*** below.

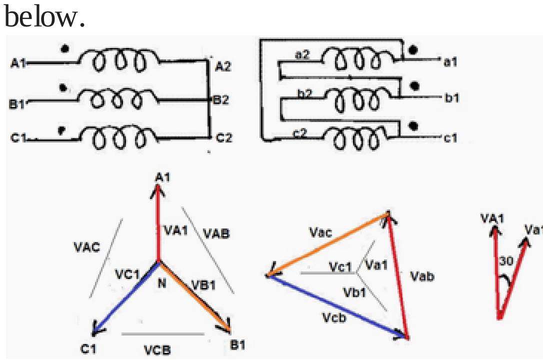
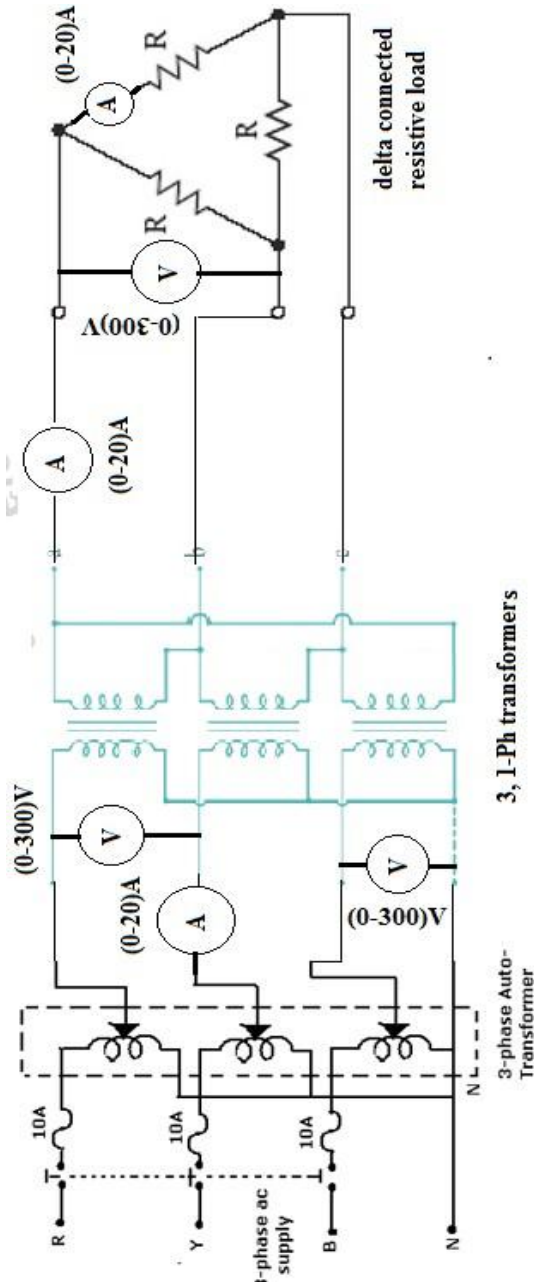



Figure 2 – Phasor diagram with voltages on primary and secondary sides

**Circuit Diagram:**



**Key points**

**As Primary in Star connected:**

Line voltage on Primary side = $\sqrt{3}$ X Phase voltage on Primary side. So

Phase voltage on Primary side = Line voltage on Primary side / $\sqrt{3}$

Now Transformation Ration (K) = Secondary Phase Voltage / Primary Phase Voltage

Secondary Phase Voltage = K X Primary Phase Voltage.

**As Secondary in delta connected:**

Line voltage on Secondary side = Phase voltage on Secondary side.

Secondary Phase Voltage = K X Primary Phase Voltage.

=K X (Line voltage on Primary side / $\sqrt{3}$)

Secondary Phase Voltage = (K/ $\sqrt{3}$ ) X Line voltage on Primary side.

There is s +30 Degree or -30 Degree Phase Shift between Secondary Phase Voltage to Primary Phase Voltage

**Advantages of Star Delta Connection:**

1. The primary side is star connected. Hence fewer numbers of turns are required. This makes the connection economical for large high voltage step down power transformers.
2. The neutral available on the primary can be earthed to avoid distortion.
3. The neutral point allows both types of loads (single phase or three phases) to be met.
4. Large unbalanced loads can be handled satisfactory.
5. The Y-D connection has no problem with third harmonic components due to circulating currents inD. It is also more stable to unbalanced loads since the D partially redistributes any imbalance that occurs.
6. The delta connected winding carries third harmonic current due to which potential of neutral point is stabilized. Some saving in cost of insulation is achieved if HV side is star connected. But in practice the HV side is normally connected in delta so that the three phase loads like motors and single phase loads like lighting loads can be supplied by LV side using three phase four wire system.
7. **As Grounding Transformer**: In Power System Mostly grounded Y- Δ transformer is used for no other purpose than to provide a good ground source in ungrounded Delta system. Take, for example, a distribution system supplied by Δ connected (i.e., ungrounded) power source.If it is required to connect phase-to-ground loads to this system a grounding bank is connected to the system, as shown in Figure 3 below:

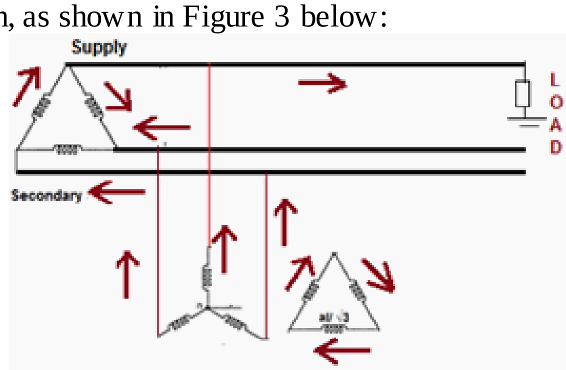



Figure 3 – Y-D Grounding transformer

8. This system a grounding bank is connected to the system, as shown in Figure 3. Note that the connected winding is not connected to any external circuit in Figure 3.

9. With a load current equal to 3 times i, each phase of the grounded Y winding provides the same current i, with the -connected secondary winding of the grounding bank providing the ampere-turns required to cancel the ampere-turns of the primary winding.

**Procedure:**

1. Connect the Circuit as per circuit diagram.
2. Adjust the Auto transformer till it reaches 230V and measure primary and secondary voltages and currents.
3. Repeat the above step for different input voltages
4. Note down the values of phase(voltages and currents) and line(voltages and Currents)
5. Compare the measured values with theoretical values.

**Observations:**

| S.No | Primary | | | | Secondary | | | |
|---|---|---|---|---|---|---|---|---|
| | Phase | | Line | | Phase | | Line | |
| | I | V | I | V | I | V | I | V |
| | | | | | | | | |
| | | | | | | | | |

**Calculations:**

**Result:**

.

**9: Measurement of Active and Reactive Power in a balanced Three-phase circuit**

**Aim:**
To measure active and reactive power using 2-wattmeters for balanced loads in a 3- phase circuit.

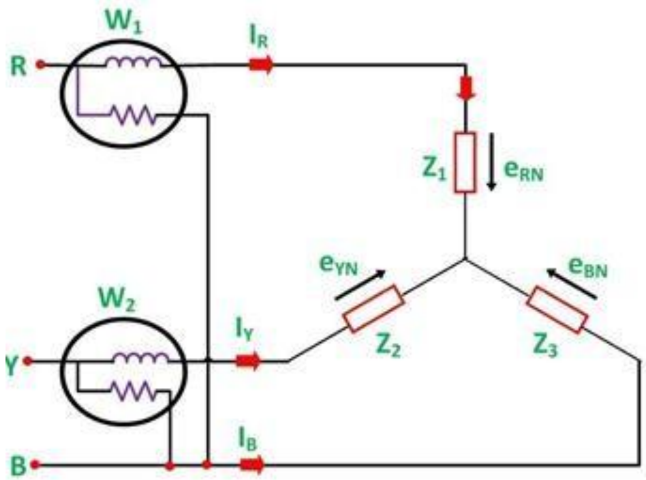
**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | 3 Phase Auto transformer | | 1 No |
| 2. | Ammeter | 0-20 A | 2 Nos |
| 3. | Voltmeter | 0-300 V | 2 Nos |
| 4. | Resistive Load | | Suitable |
| 5. | 1 Φ Transformer | 1KVA, 230/415V | 3 Nos |
| 6. | Connecting wires | | Required |

**Theory:**
In a 3-phase, 3-wire system, power can be measured using two wattmeter's for balance loads. This can be verified by measuring the powerconsumed in each phase. In this circuit, the pressures coils are connected between two phasesuch that one of the line is coinciding for both the meters.

$P_1 + P_2 = 3\, V_{Ph} I_{Ph} COSø$

Power factor $Cosø = Cos\,(tan^{-1} \sqrt{3}\,((P_1 – P_2)/(P1 + P_2)))$




Considering the above figure (A) in which Two Wattmeter $W_1$ and $W_2$ are connected, the instantaneous current through the current coil of Wattmeter, $W_1$ is given by the

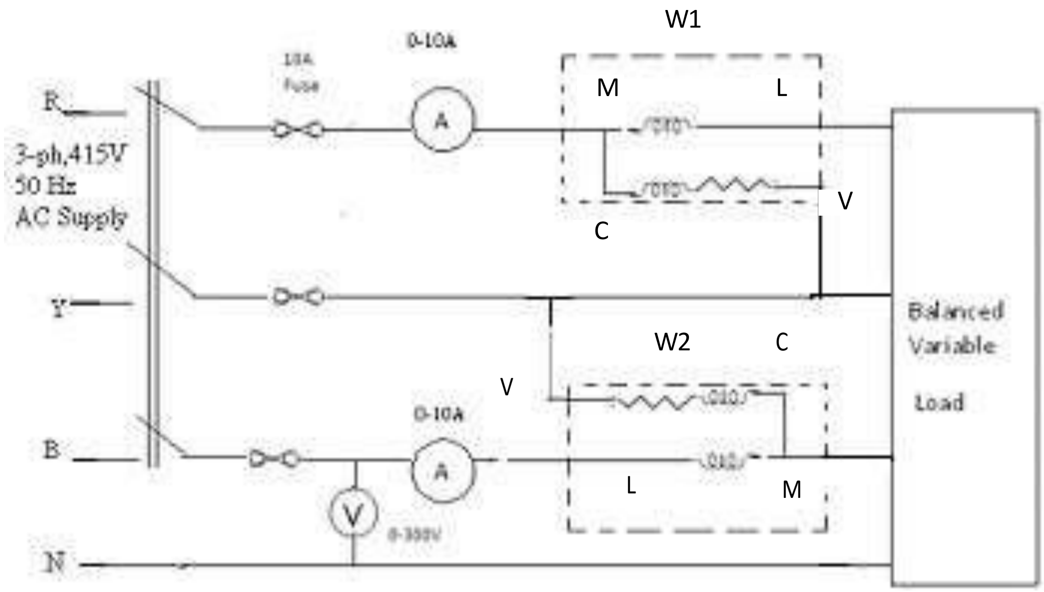
$$W_1 = i_R$$

below.

Instantaneous potential difference across the potential coil of Wattmeter, $W_1$ is given as

$$W_1 = e_{RN} - e_{BN}$$

**Circuit Diagram:**




**Observations:**

| TYPE OF LOAD | W1 (W) | W2 (W) | I1 (mA) | I2 (mA) | Vph (V) | W1+W2 (W) | P (KW) |
|---|---|---|---|---|---|---|---|
| | | | | | | | |

Instantaneous power measured by the Wattmeter, $W_1$ is

$$W_1 = i_R (e_{RN} - e_{BN}) \quad \ldots\ldots\ldots (1)$$

The instantaneous current through the current coil of Wattmeter, $W_2$ is given by the equation

$$W_2 = i_Y$$

Instantaneous potential difference across the potential coil of Wattmeter, $W_2$ is given as

$$W_2 = e_{YN} - e_{BN}$$

Instantaneous power measured by the Wattmeter, $W_2$ is

$$W_2 = i_Y (e_{YN} - e_{BN}) \quad \ldots\ldots\ldots..(2)$$

Therefore, the Total Power Measured by the Two Wattmeters $W_1$ and $W_2$ will be obtained by adding the equation (1) and (2).

$$W_1 + W_2 = i_R (e_{RN} - e_{BN}) + i_Y (e_{YN} - e_{BN})$$

$$W_1 + W_2 = i_R e_{RN} + i_Y e_{YN} - e_{BN} (i_R + i_Y) \quad \text{or}$$

$$W_1 + W_2 = i_R e_{RN} + i_Y e_{YN} + i_B e_{BN} \qquad (\text{i.e.}\, i_R + i_Y + i_B = 0)$$

$$W_1 + W_2 = P$$

Where P – the total power absorbed in the three loads at any instant.

**Calculations:**

**Result:**

## 10.Performance Characteristics of a Separately Excited DC Shunt Motor

**Aim:**

To obtain the performance characteristics of a DC shunt motor by load test.

1. Output ~ Armature current
2. Output ~ Speed
3. Output ~ Torque
4. Output ~ efficiency

**Name Plate Details:**

Power = 5.0 hp
Armature voltage = 220 volts
Armature current = 19.0 amps
Speed = 1500 rpm

Field voltage = 220 volts
Field current = 1.0 amps
Field Winding = shunt

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | DC Voltmeter | 0-300V | 1 No |
| 2. | DC Ammeter | 0-20A | 1 No |
| 3. | DC Ammeter | 0-2A | 1 No |
| 4. | Variable rheostat | 0-200Ω | 1 No |
| 5. | Speed Indicator | 0-2000rpm | 1 No |
| 6. | Spring Balance | 0-10Kg | 2Nos |
| 7. | Connecting wires | | Required |

**Theory:**

This is a direct method of testing a dc machine. It is a simple method of measuring motor output,speed and efficiency etc., at different load conditions. A rope is wound round the pulley and itstwo ends are attached to two spring balances $S_1$ and $S_2$.The tensions provided by the springbalances $S_1$ and $S_2$ are $T_1$ and $T_2$. The tension of the rope can be adjusted with the help of swivels.The force acting tangentially on the pulley is equal to the difference between the readings of thetwo spring balances in Kg - force.

The induced voltage $E_b = V - I_aR_a$ and $E_b = K\Phi N$, Thus, $K\Phi = \frac{E_b}{N}$

Where V = applied voltage,
$I_a$= armature current,
$R_a$ = armature resistance.

Total power input to the motor $P_{in}$ = field circuit power + Armature power
$= V_fI_f + V_aI_a$

If "r" is the radius of the pulley, then torque at the pulley is given by

$$T_{shaft} = 9.81(T_1 \sim T_2)\, r = 1.5(T_1 \sim T_2) \text{ N-m}$$

Motor output power $P_{out} = T_{shaft} * \omega = \frac{1.5(T \sim T)2N\pi}{60}$

$\%Efficiency = \frac{P_{out}}{P_{in}} * 100$

A dc shunt motor rotates due to the torque developed in the armature when the armature and field terminals are connected to the dc supply. The direction of rotation can be explained withhelp of Fleming‟s left hand principle.

A counter emf or back emf ($E_b$) is induced in the armature conductors while the armature (rotor)rotating in the magnetic field. The direction of the induced emf can be explained with the help ofFleming‟s right hand principle and Lenz‟s law. The direction this induced emf is such that itopposes the applied voltage (V). This induced emf is also called as back emf$E_b$.

The equation of the motor is $V = E_b + I_aR_a$

$$\text{Where } E_b = \left(\frac{\Phi Z N}{60}\right)\left(\frac{P}{A}\right)$$

$$I_a = \frac{(V - E_b)}{R_a}.$$

The value of “$E_b$” is zero while starting the motor. Hence, the voltage across the armature has to be increased gradually.The power developed in the rotor (armature) $= E_bI_a = T\omega$

Where $\omega = \frac{2\pi N}{60}$ is the angular velocity of the pulley, in rad/sec.

In a dc motor $T \alpha \Phi I_a$,

Where $\Phi$= Flux produced by the shunt field per pole

$I_a$= Armature current

***Armature current ~ Speed characteristics:***

The armature current $I_a$increases with increase in the load at the shaft. Hence $I_aR_a$drop increasesand counter emf ($E_b$) decreases.

$E_b = V - I_aR_a$,Where $R_a$is armature resistance and $E_b \alpha \Phi N$.

If $\Phi$ is constant in the shunt motor, by neglecting the armature reaction; the speed falls as $E_b$ falls.In a dc motor $R_a$ is very small, hence $I_aR_a$is a small value and fall in $E_b$with increase in load issmall. Thus, the speed falls slightly as $I_a$increases.

***Armature current ~ Torque characteristics:***

If $\Phi$ is constant, developed torque increases with increase in $I_a$.

$T = K\Phi I_a$

In actual condition, $\Phi$ slightly falls with increase in $I_a$due to the effect of armature reaction.

***Armature current ~ induced emf (back emf):***

Induced emf (back emf$E_b$) falls slightly with increase in $I_a$as per the equation

$E_b = V - I_aR_a$

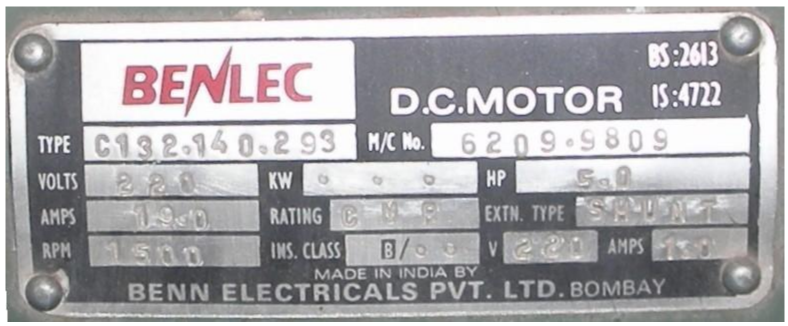
s

***Output ~ Efficiency:***

The graph between Output ~ Efficiency indicates that max torque occurs when armature copper losses is equal to the constant losses. (Sum of field copper losses, mechanical losses and Iron losses).

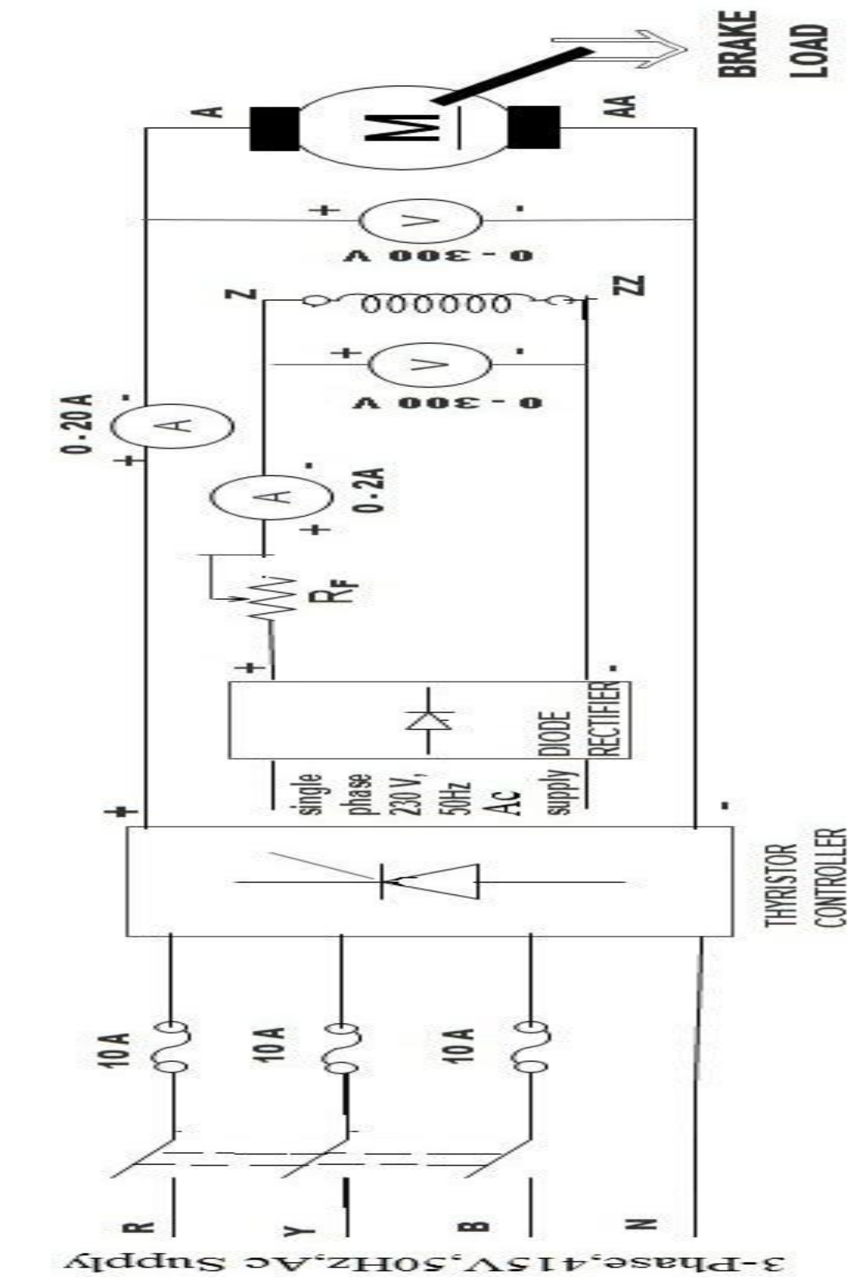
**Panel Board:**


**Name Plate Details:**




**Brake drum arrangement:**

**Circuit Diagram:**



**Procedure:**

1. Note down the name plate details.
2. Keep the dc drive potentiometers and field control rheostat at minimum resistanceposition.
3. Loosen the rope on the brake drum and put some water inside the rim of the brakedrum.
4. Connect the circuit as shown in the circuit diagram.
5. Switch on the motor and adjust the potentiometers till the armature attains the ratedvoltage and increase the field rheostat till the motor attains the rated speed.
6. Record the readings of the instruments at no-load condition.
7. Gradually, increase the load on the brake drum and record the readings as per thegiven table.
8. Do not exceed the armature current more than its rated value.
9. Gradually, reduce the load and switch off the supply.
10. Maintain Constant armature voltage and constant field current during the totalexperiment.

**Observations:**

Armature voltage = Volts
Field voltage = Volts
Field current = Amps
No load speed = rpm

**Tabular Column:**

| S.No | $I_a$ Amp | N RPM | $T_1$ Kg | $T_2$ Kg | Input ($P_{in}$) Watts | Shaft Torque (j/rad) | W(rad/ sec) | Shaft Output (watts) | %ή | E(volts) | K Vs/r |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |
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**Sample Calculations:**

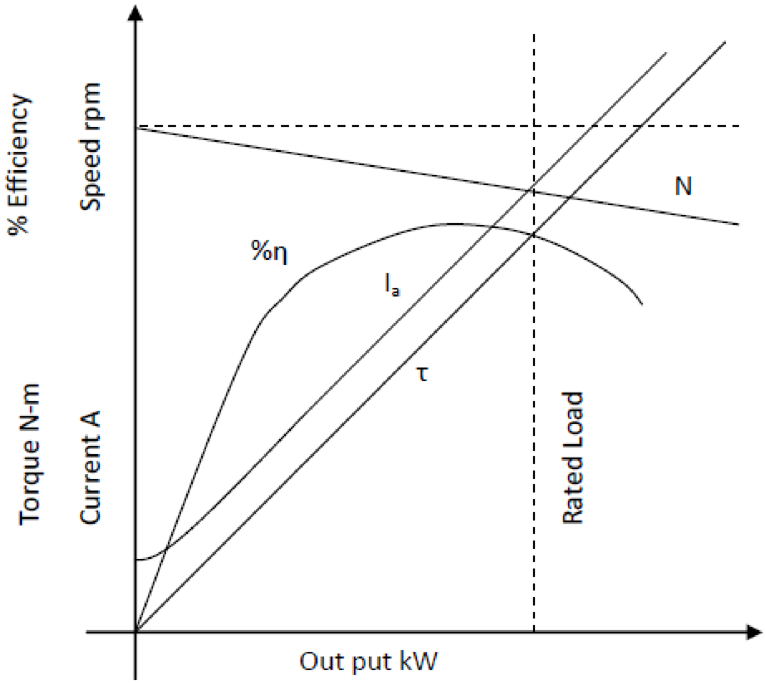
Armature voltage = 220 volts
Field voltage = 200 volts
No load speed = 1500 rpm
$T_1 \sim T_2$ = 4 kgs.

Armature Current $I_a$ = 4.9 amps
Field current = 0.73 amps
Actual Speed N = 1498 rpm
Armature Resistance Ra = 2.3 ohms

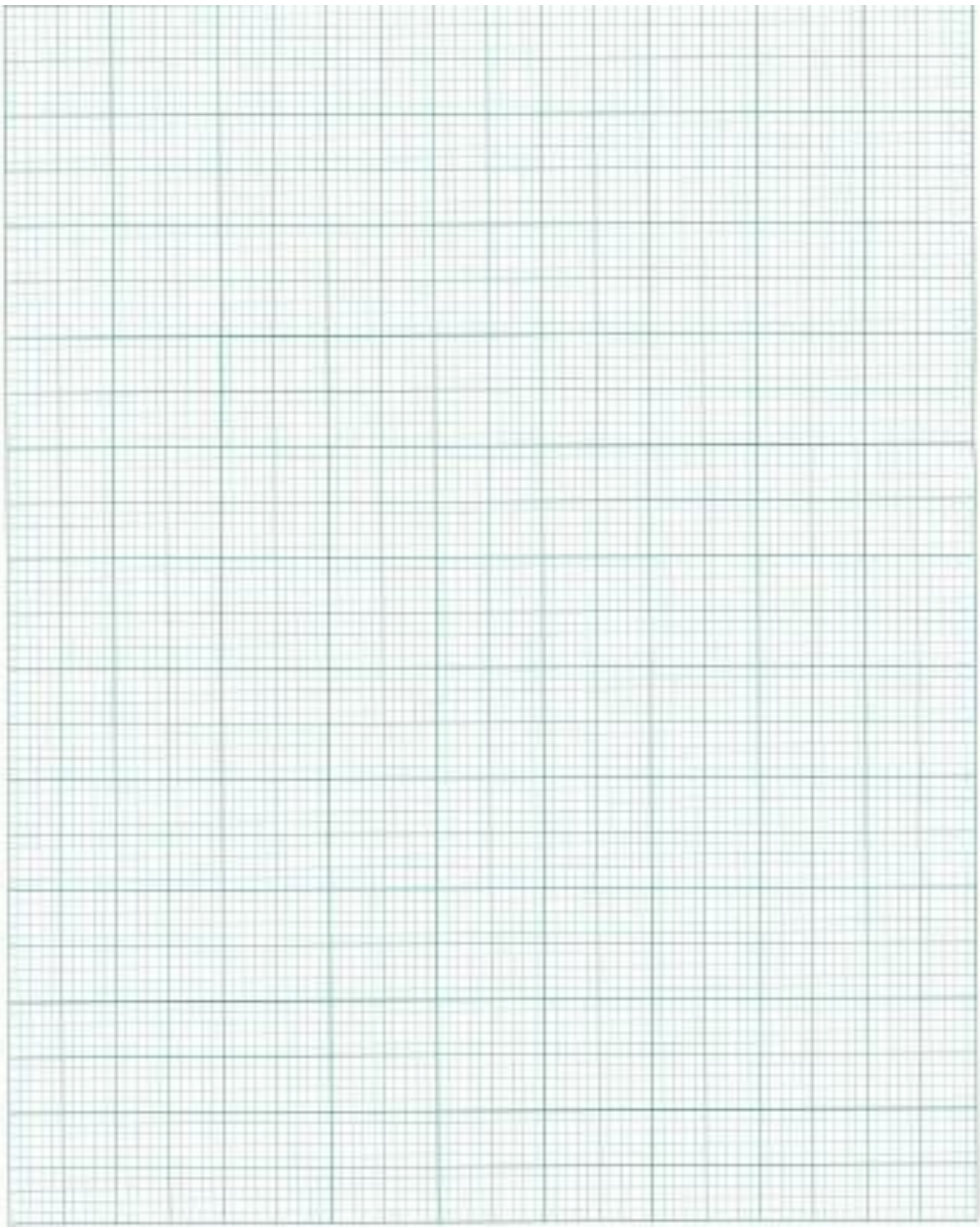
**Graphs:**

(a) Speed ~ Output (b) Torque ~ Output (c) Current ~ Output (d) Efficiency ~ output

**Model Graphs:**




**Calculations:**



**Result:**

## 11: Torque-Slip Characteristics of a Three-phase Induction Motor

**Aim:**

To perform the brake test on a 3-ϕ slip ring induction motor and obtain its torque slip characteristics

**Nameplate details:**

**AC slip ring induction motor**

| | **Stator** | **Rotor** |
|---|---|---|
| Voltage | 415V | 200v |
| Current | 7.5A | 11.0A |
| Winding | Star | Star |
| Power | 5.0 h.p | |
| Speed | 1440 r.p.m | |

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | Ammeter | 0-10 A | 1 No |
| 2 | Voltmeter | 0-300 V | 1 No |
| 3. | Wattmeter | 0-5KW | 1 No |
| 4. | Tachometer | 0-9999rpm | 1 No |
| 5. | Connecting wires | | Required |

**Theory:**

The slip ring induction motor consists of two main parts. They are stator and rotor.

**Stator:** It is a star connected 3- ϕ winding. Each phase winding is separated by $120^0$ electrical, 3-ϕ supply is connected to the stator, it produces a rotating magnetic field in the stator core.

**Rotor:** It is also a star connected 3- ϕ winding and wound for the same number of poles as the stator. Its external terminals are short-circuited. Due to the relative speed between the rotating flux in the stator and the stationary flux in the rotor. The rotor rotates nearer to the synchronous speed maintaining a low slip.The synchronous speed of the rotating flux in the stator $N_s = \frac{120f}{P}$

Where 'f is the supply frequency in Hz and 'P' is the number of poles.

**Slip** : It is the relative speed of the rotor with respect to synchronous speed of the rotating magnetic field.

Percent Slip = $\frac{(Ns - N)}{Ns} X100$

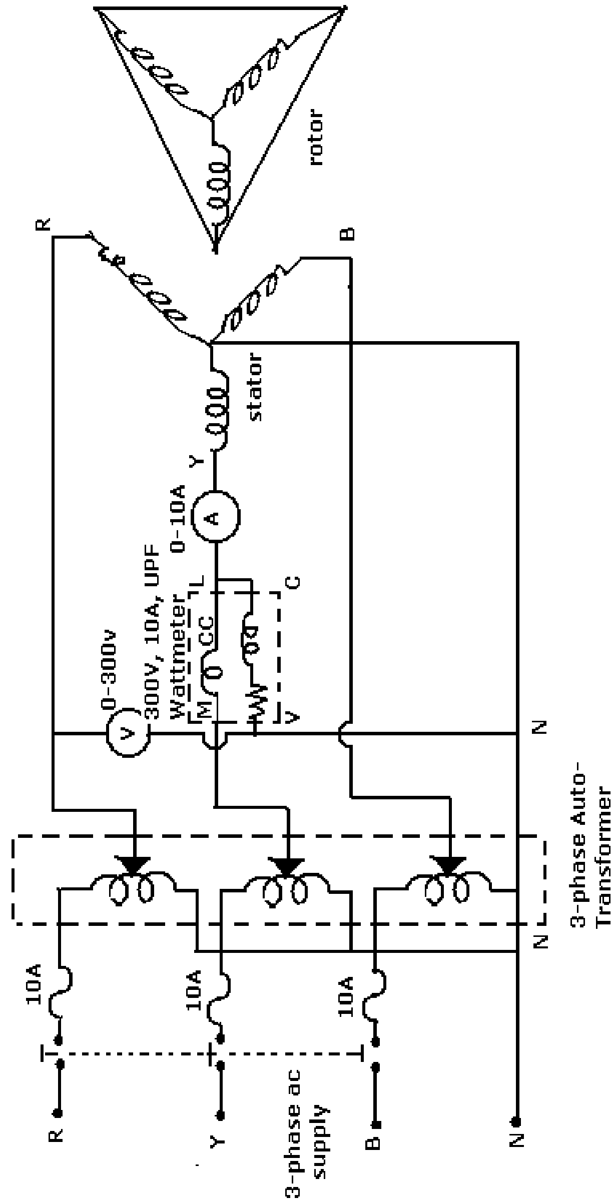
Torque $\tau = 9.81(\tau_1 - \tau_2)$. R, Where R is at the radius of the brake drum.

Output = $\frac{2\pi N\tau}{60} watts$

%ŋ = $\frac{output}{input} x100$

Power factor = cosϕ = $\frac{Pph}{Vph.Iph}$ (Where '$P_{ph}$' is the input power per phase)

**Circuit Diagram:**



**Procedure:**

1. Connect the circuit diagram as shown in fig.
2. Keep the 3-ф auto transformer at zero voltage position.
3. Loosen the rope on the brake drum and set the tension meters at zero position.
4. Switch - ON the motor and increase the auto - transformer gradually till the voltmeter reads the rated phase voltage 230V.
5. Note down the readings of the voltmeter, ammeter, tachometer, spring balances and wattmeter readings at no-load.
6. Now increase the load gradually by tightening the rope till the ammeter reads the rated current. Pour some water in side the break drum for cooling.
7. Note down $V_{ph}$, $I_{ph}$, $P_{ph}$, $T_1$, $T_2$ and speed.
8. Switch – OFF the supply and adjust the 3-ф auto - transformer at zero position.

**Observations :**

| S.No | $V_{Ph}$ (Volt) | $I_{Ph}$ (Amps) | N (rpm) | $T_1$ (KG) | $T_2$ (KG) | $\tau = 1.5*(T_1 \;\; T_2)$ N- m | % Slip |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
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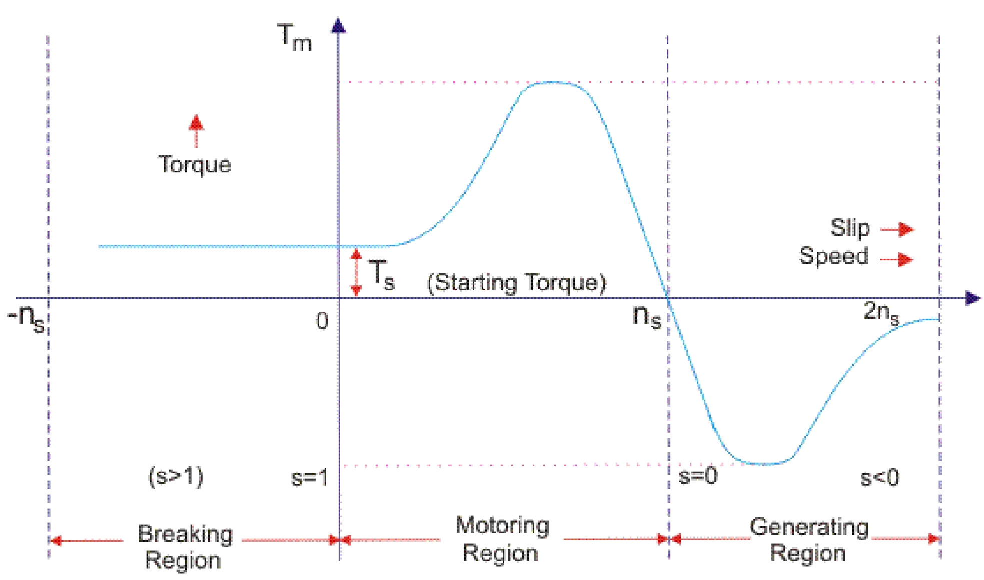
**Model Graph:**




**Torque Slip Curve for Three Phase Induction Motor**

**Calculations:**

**Result:**

## 12: No-Load Characteristics of a Three-phase Alternator

**Aim:**

To plot No load charecteristics of Three phase alternator.

**Apparatus Required:**

| S.No | Apparatus | Range | Quantity |
|---|---|---|---|
| 1. | Dc Voltmeter | 0 - 300 V | 1 No |
| 2. | DC Ammeter | 0 - 10 amps | 1 No |
| 3. | DC Ammeter | 0 - 2 amps | 2 Nos |
| 4. | AC Ammeter | 0 - 10 amps | 1 No |
| 5. | Ac Voltmeter | 0 - 300 V | 1 No |
| 6. | Tachometer | 0 - 2000 rpm | 1 No |
| 7. | Connecting wires | | Required |

**Motor Ratings:**

| DC Motor | Alternator |
|---|---|
| Voltage : 220V | Voltage: 415 V |
| Current : 19 Amps | current: 5 Amps |
| Power: 3.7 KW | Power: 3.5 KVA |
| | Speed: 1500 rpm |

**Theory:**

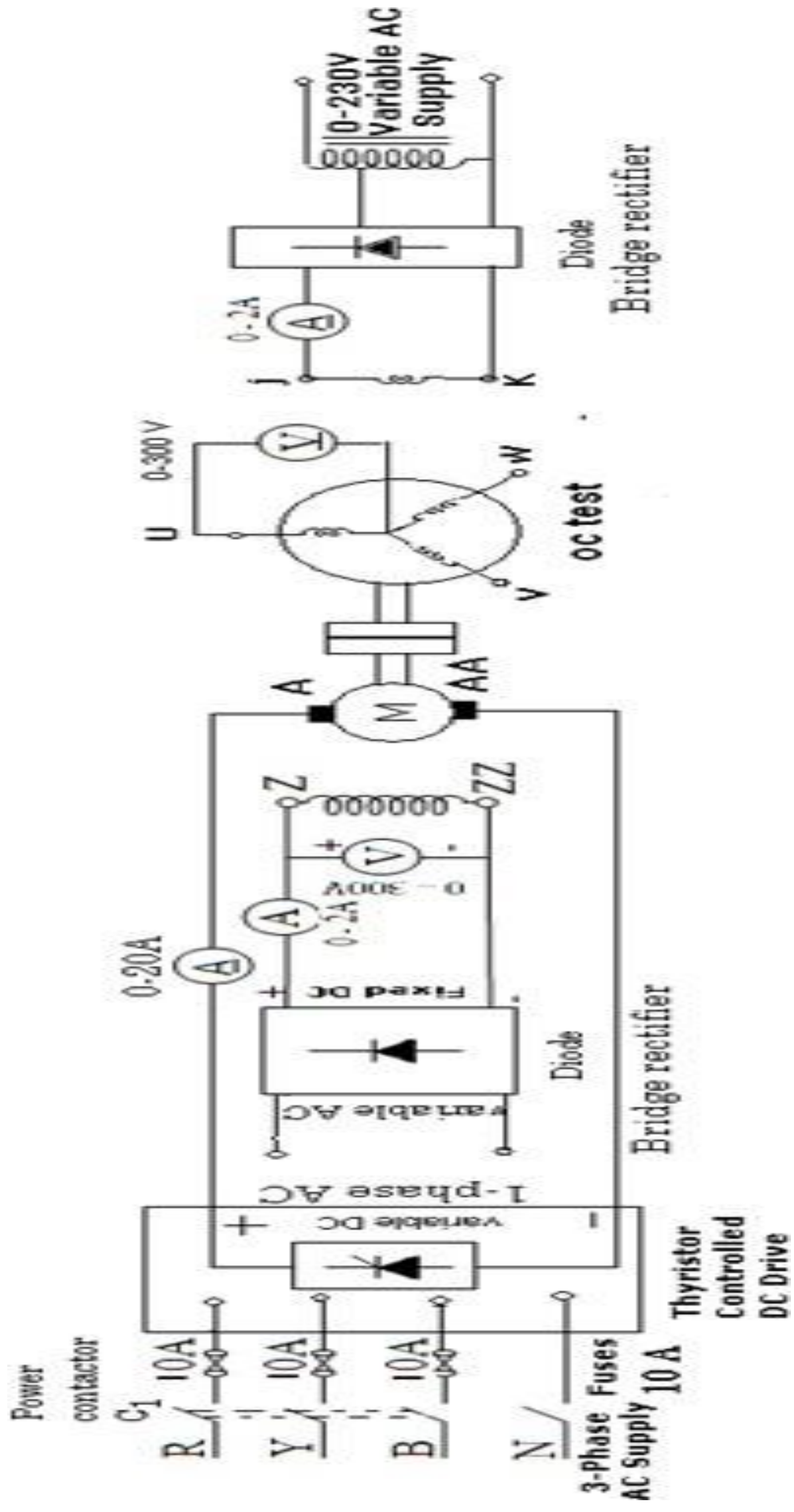
**O.C.C:**

Open Circuit Characteristics is plotted from the given data as shown as in D.C Machines, this is plotted by running the machine on no-load and by noting the values of induced voltage and field excitation current. It is just like a B-H curve.

The output voltage of an alternator depends essentially upon the total flux in the air gap. At no load, this flux is established and determined exclusively by the dc field excitation.Under load, however, the air gap flux is determined by the ampere-turns of the rotor and the ampere-turns of the stator. The latter may aid or oppose the MMF (magneto motive force) of the rotor depending upon the power factor of the load. Leading power factors assist the rotor, and lagging power factors oppose it.

Because the stator MMF has such an important effect upon the magnetic flux, the voltage regulation of alternators is quite poor, and the dc field current must continuously be adjusted to keep the voltage constant under variable load conditions.If one phase of a three-phase alternator is heavily loaded, its voltage will decrease due to the IR and IXL drops in the stator winding. This voltage drop cannot be compensated by modifying the dc field current because the voltages of the other two phases will also be changed. Therefore, it is essential that three-phase alternators do not have loads that are badly unbalanced.

**Circuit diagram:**



**Procedure:**

1. Connect the circuit as shown in the figure for O.C. Test.
2. Keep the dc drive potentiometers and auto - transformer of the alternator field at zero position.
3. Switch - on the supply and slowly increase, the dc motor speed, (prime mover) to its rated speed.
4. After attaining the rated speed, gradually increase the auto -transformer and record the field current and phase voltage of the alternator.
5. When the phase voltage is reached to the rated value 230V, switch - off the supply and keep the potentiometers and auto - transformer at zero position

**Tabular column: <u>OC Test</u>**

| $I_f$ (Amps) | $E_{oc}$ (Volts) |
|---|---|
| | |

**Result:**