Experiment 1

Aim: To verify Kirchoff's current law and voltage law.

Apparatus

Voltmeter (AC/DC) : 300 V, 3 Nos.
Ammeter (AC/DC) : 0-2 A, 2 Nos.
1-phase Variac: 8A, 220 V, 1 No.
Ammeter (AC/DC) : 5 A, 1 No.
Rheostats : 45 ohm, 4.5 A, 3 Nos.

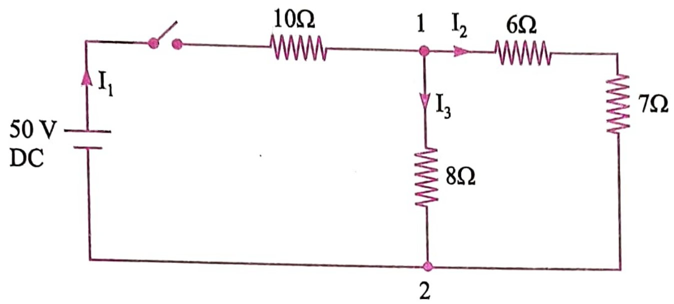


Fig. 1.1

KIRCHOFF'S CURRENT LAW (KCL)

Theory

Kirchoff current law is very simple and fundamental law of electrical circuits.

It states that "*algebraic sum of currents meeting at a Junction of Conductors is zero*". But to study this basic law, we have to keep the directions of currents must meet at that junction.

The point where more than two conductors meet is called a *Junction*. Example in Fig. 1.1, '1' and '2' are *junctions*.

Sign Convention: In the equation of algebraic sum of all the currents meeting at a junction, the currents leaving the junction taken as positive and the currents which are entering into the junction is taken as negative.

Suppose, there are five conductors meeting at a junction (Fig. 1.2)

According to sign convention,

If I_1, I_2, I_5 (leaving the junctions) are positive

then I_3, I_4 (entering the junction) are negative.

So, from Kirchoff's current law:

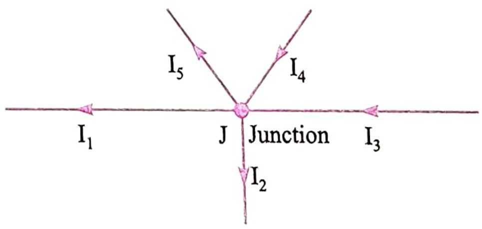


Fig. 1.2

$$I_1 + I_2 + I_5 - I_3 - I_4 = 0 \quad \text{or} \quad \sum_{n=1}^{5} i_n = 0$$

What does this law show: This law basically concludes that, on a junction charge cannot be accumulated i.e. amount of charge leaving the junction (in terms of currents I_1, I_2 and I_5) is equal to amount of charge entering the Junction (in terms of current I_3 and I_4). So, net charge transferred through junction is zero. Thus, KCL proves law of conservation of charge.

Note: *In case of KCL in AC circuits, we take phasor sum instead of algebraic sum. But, for purely resistive circuit in AC, we will use algebraic sum*

Circuit Diagram

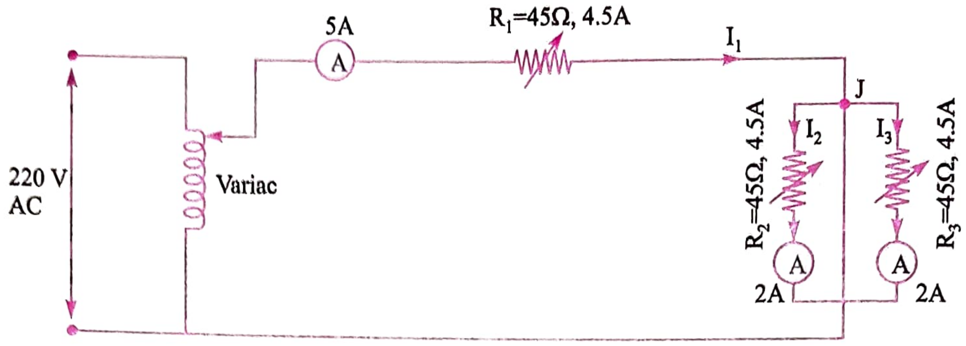


Fig. 1.3

Procedure

Step 1. Connect the circuit as shown in Fig. 1.3

Step 2. Put all the rheostats to their maximum value and switch on the input voltage supply.

Step 3. Adjust the values of Rheostats gradually (Firstly R_1 then R_2 and R_3) to get different readings of three ammeters. Note down those readings.

Step 4. Check that the readings should not exceed the rates values of ammeters and rheostat.

Step 5. Repeat step No. 3 four to five times at different values of rheostat.

Step 6. Switch off the supply.

Observations

Take the readings from given table:

S.No.	I_1 *(amp)*	I_2 *(amp)*	I_3 *(amp)*	*Error* = $I_1 - (I_2 + I_3)$ *(amp)*
1.				
2.				
3.				
4.				
5.				

Calculations

At Junction J,

Current I_1 is entering and I_2 and I_3 are leaving

So, according to KCL

$$I_1 + (-I_2) + (-I_3) = 0$$

or

$$\boxed{I_1 = I_2 + I_3}$$

So, if readings of I_2 and I_3 when added gives the reading of I_1 then KCL will be verified.

Result

From the observation and calculation KCL has been verified.

Precautions

1. Check the connections of rheostat and zero readings of instrument before connecting.
2. All the connections should be tight.
3. Direction of current should be kept in mind. i.e. of current is leaving the junction should have opposite sign to current entering the junction if DC supply is used.

KIRCHOFF'S VOLTAGE LAW (KVL):

Theory

To study this law, firstly we should know the relation between voltage and current.

We know that potential is just like a pump and current is like the flowing water. As water flows from high pressure to lower pressure developed by water pump, in the same way current flows from higher potential to lower potential (or electron flows from lower potential to higher potential) developed by potential difference or voltage or emf. It means current can't flow without application of voltage. If the pump creates high pressure difference water will flow at higher rate. In the same way, if potential difference (voltage) is high, charge flow at higher rate or current is high i.e.

$$V \propto I \quad \text{or} \quad \boxed{V = IR}$$

Kirchoff's voltage law states that "In a closed circuit or MESH, the Algebric sum of all the EMF and the algebric sum of all the voltage drops is zero".

i.e., Algebric sum of all emf + Algebric sum of all voltage drop = 0

Mathematically, $\boxed{\Sigma E + \Sigma V = 0}$

Polarity of the Voltage

1. Algebric sum of EMF and voltage drop is to be taken, we have to determine their signs for tracing a circuit. For this we have to always consider:

   A rise in potential as +ve; and fall in potential as –ve.

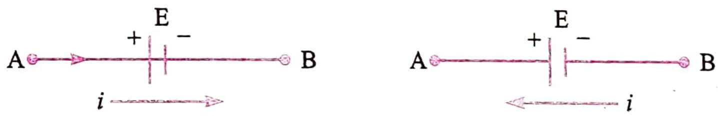


Fig. 1.4

Tracing Branch A to B, E is negative i.e., (–ve) 1.4(a) Tracing Branch B to A, E is positive i.e., (+ve) 1.4(b).

2. To determine the signs of voltage drop; a rise in potential taken as +ve and fall in potential taken as –ve.

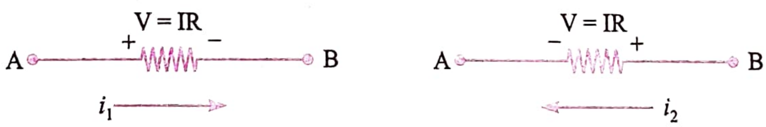


Fig. 1.5

(*i*) Tracing Branch from A to B, V is negative (i.e., –ve)

(*ii*) Tracing Branch from A to B, V is positive i.e., (+ve) rise in potential.

Now, we can write the KVL equation considering clockwise direction for whole mesh (or anticlockwise direction for whole mesh) taking +ve sign and –ve sign for EMFs and drops as mentioned above.

Circuit Diagram:

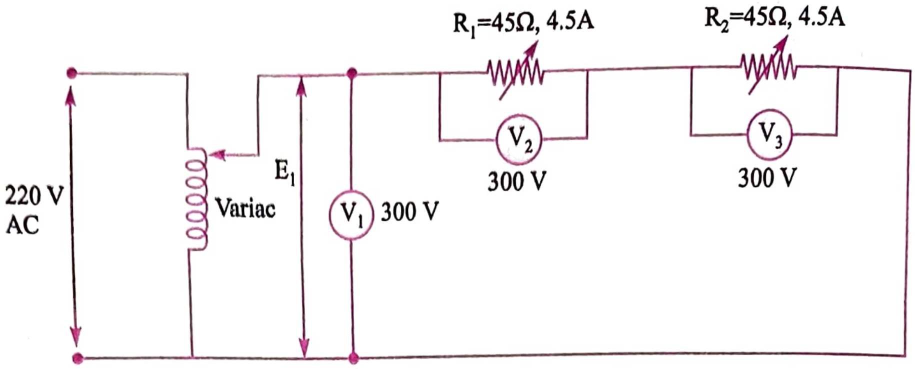


Fig. 1.6

Procedure:

Step 1. Connect the circuit as shown in Fig. 1.6 with variac at zero position.

Step 2. Put the rheostats at maximum value.

Step 3. Switch on the AC supply and note the readings of ammeter and voltmeters.

Step 4. Change the value of rheostats and position of variac in such a way that the ammeter should not exceed rated value (i.e. 5 A) and note the readings of voltmeter and ammeter.

Step 5. Repeat the step No. 4, four to five times.

Step 6. Switch off AC supply.

Observations:

S.No.	*Current I (amp)*	*V_1 (amp)*	*V_2 (amp)*	*V_3 (amp)*	*$V_2 + V_3$ (volts)*	*Error = $V_1 - (V_2 + V_3)$ (volts)*
1.						
2.						
3.						
4.						
5.						

Calculations

According to KVL, total supply voltage should be equal to voltage drops at two resistances.

i.e. $\boxed{V_1 = V_2 + V_3}$

So, if readings of V_2 and V_3 when added gives reading V_1, we can say KVL is being followed.

Result:

From the observation and calculations KVL has been verified.

Aim: To verify Superposition theorem on a linear circuit with atleast one voltage and one current source.

Apparatus

Superposition kit, connecting leads, amp meter (0–20 A).

Theory

This theorem helps us when we have to determine the current in one particular branch containing several voltage sources or current sources or both.

This theorem states that in *a linear network containing two or more voltage sources, the current though any element (resistance) may be determined by adding together algebraically the currents produced by each source acting alone when all other voltage sources are replaced by their internal resistance at that time.*

Circuit Diagram

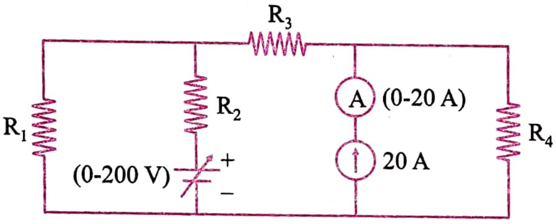


Fig. 3.1.1

Procedure

Step 1. **200 V Source Acting Alone:** Firstly, we consider the case when 200 V voltage source is acting alone as shown in Fig. 3.1.2. Note that, this current source is replaced by open. The total resistance R_T presented to the voltage source R_2 in series with the parallel combination of $(R_3 + R_4)$. Therefore, value of R_T is given by

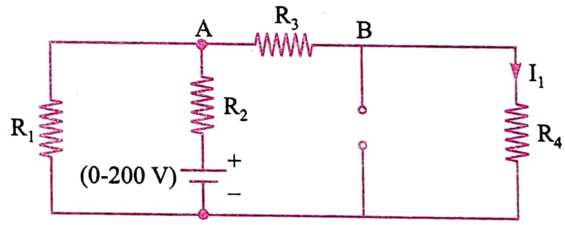


Fig. 3.1.2

$$R_T = R_2 + [R_1 \mid\mid (R_3 + R_4)]$$

$$20 \times \frac{R_{ev}}{R_{eq} + R_4}$$

Step 2. Now we will calculate total current in a circuit $I_T = V/R_T$

Step 3. Now, we will calculate current I_1 through resistor R_4.

$$I_1 = I_T \times R_1 \mid\mid (R_3 + R_4)$$

Step 4. Now, **20 A current source acting alone,** In this case voltage source is replaced by short circuit (SC) because its internal resistance assumed zero. The internal resistance R_{eq} to the left of the current source is as shown in Fig. 3.1.3.

$$R_{ev} = R_3 + (R_1 \mid\mid R_3)$$

Step 5. Now, we will calculate current I_2 through resistor R_4

$$I_2 = 20 \times \frac{R_{ev}}{R_{eq} + R_4}$$

$\therefore$ Direction of I_1 and I_2 both in same direction.

Step 6. Now, we will calculate total current I through R_4 resistor.

$$I = I_1 + I_2$$

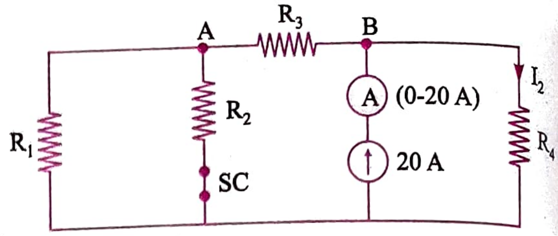


Fig. 3.1.3

OBSERVATION TABLE

S. No.	I (mA)	I_1(mA)	I_2(mA)	I_1+I_2 (mA)	Error % = $I_3 - (I_1+I_2)$ (mA)
1.					
2.					
3.					
4.					

Calculations

According to superposition theorem I_3 should be $= I_3' + I_3''$

Results

From the observations and calculation, superposition theorem has been verified.

Precautions

1. Voltage control knob should be at minimum position.
2. Current control knob should be at maximum position.
3. Directions of current should be correctly identified.
4. Check zero setting of instruments before connection, rheostat terminals, connection should be tight.
5. Ratings of currents to be kept in mind.

Aim: To verify Thevenin's theorem and linear circuit with at least one voltage and one current source.

Apparatus:

Resistance 50 ohm – 2 Nos.	Resistance 10 ohm – 1 No.
DC voltmeter 15 V – 1 No.	DC Milli ammeter 250 mA – 1 No.
DC source 12 V (Battery) – 1 No.	DC source 5 V (Battery) – 1 No.

THEVENIN'S THEOREM

Theory

This theorem helps us to determine the response (*current, voltage* or *power* and generally current) in a single load resistance of network. Accept the load resistance, remaining of the network is replaced by a simple equivalent circuit to make the calculations easier. This theorem states that

"Any network composed of linear passive and active elements may be replaced by a simple equivalent circuit consisting of an equivalent voltage source V_{OC} in series with an equivalent resistance R_{th}. Where the voltage source V_{OC} is equal to the open circuit voltage between the two terminals and the equivalent resistance looking back into network at terminals with all the sources within the network made inactive and replaced by their internal impedance is R_{th}."

Circuit Diagram

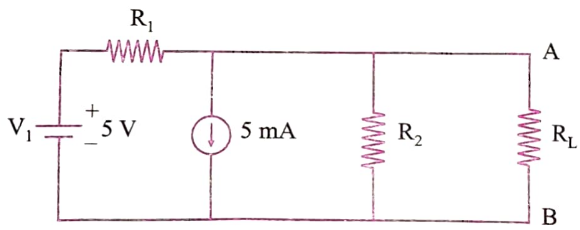
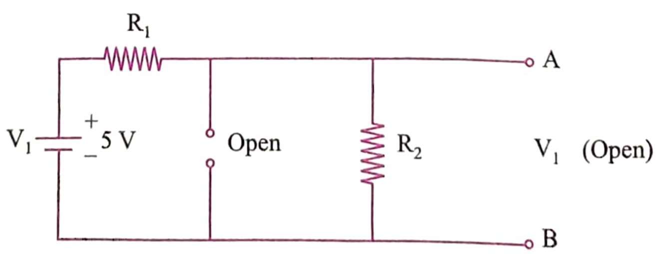


Fig. 2.1.1

Procedure

Step 1. Firstly, we find the open circuited voltage V_{TH} at terminals AB. For this purpose we remove the current source (open circuit). We find voltage V_1 due to the 5 V source acting alone as shown in Fig. 2.1.2 since V_1 is the voltage across R_2 resistor we have by voltage divider rule.

$$V_1 = 5 \times \frac{R_2}{R_1 + R_L}$$



$V_1 =$

Fig. 2.1.2

Step 2. Now, we will find the voltage V_2 due to current source acting alone is found by shorting 5 V voltage source as shown in Fig. 2.1.3. By current divide rule.

$$I_1 = (\text{current in } R_2) = 5mA \times \frac{R_1}{R_1 + R_2}$$

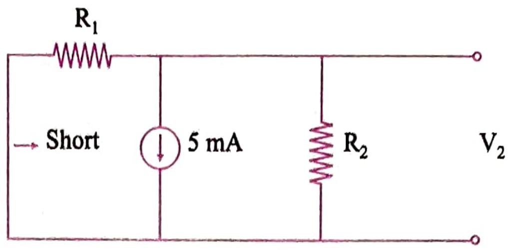


Fig. 2.1.3

Step 3. Now, we will calculate $V_2 = V_1 I_1$ after this we will calculate $V_{TH} = V_1 - V_2$.

∴ Note that V_1 and V_2 have opposite polarities.

Step 4. Now, we will find R_{TH} (Thevenin's Resistance), for this purpose we replace the 5 V voltage source by a source current and 5 mA current source by a open circuit as shown in Fig. 2.1.4.

$$R_{th} = R_1 \,||\, R_2$$

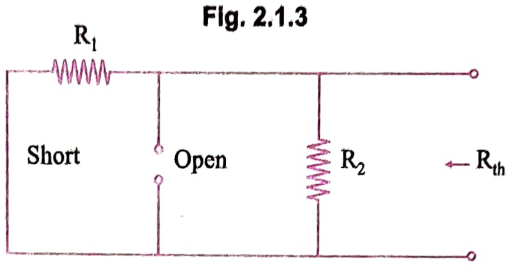


Fig. 2.1.4

Step 5. Now, we draw the thevenin's equivalent circuit and calculate the voltage across R_L.

$$\boxed{R_{th} = V_{th} \times \frac{R_L}{R_{th} + R_L}}$$

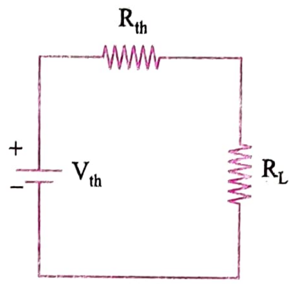


Fig. 2.1.5

Observations

	Step I	Step II			Step III		
S.No.	$V_{OC} = V_{th}$	V	I	R_{th}	I_L	I_{L1}	$Error = I_L - I_{L1}$
1.							
2.							
3.							
4.							

Calculations

Thevenin theorem will be proved if I_{L1} (calculated value) = I_L (observed value)

$$I_{L1} = \text{calculated value of load current} = \frac{V_{OC}}{R_L + R_{th}} = \frac{V_{th}}{R_L + R_{th}}$$

Results

Calculated values of I_L should be equal to observed value of I_L.

Precautions

1. Meters should be used within proper range.
2. We must use neat and tight connections.
3. Zero setting of all meters should be checked before giving the input supply.

Aim: To verify Norton's theorem on a linear circuit with atleast one voltage and one current source.

Apparatus

Resistance 50 ohm – 2 nos	Resistance – 10 ohm 1 nos
DC voltmeter 15 V – 1 no	DC multimeter – 250 mA, 1 no.
Current source 5 mA – 1 no	DC source 5 V buttery) 1 no

Theory:

Norton's theorem states that:

"Any two terminals XY of a network composed of linear passive and active elements may be replaced by a simple equivalent circuit consisting of an equivalent current source I_{SC} in parallel with an equivalent resistance R_N called Norton's equivalent resistance."

where, I_{SC}: (*fictitious current*) is the current which would flow through the terminals XY if external resistance or load resistance between XY is replaced by a short circuit.

R_N (*Norton's equivalent resistance*) is the resistance measured 'looking back' into the original circuit after load resistance (R_L) has been removed.

Circuit Diagram:

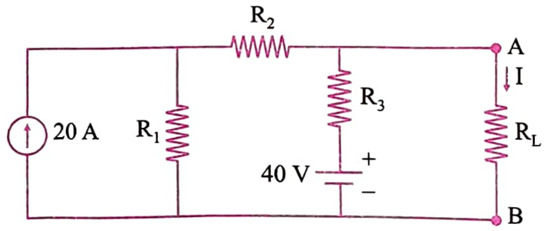


Fig. 2.2.1

PROCEDURE:

In order to find Norton's current I_N, short circuit terminals A and B after removing load R_L. The circuit then becomes as shown in fig. 2.2.2. The current flowing in the short circuit is the Norton current I_N.

$$20 \times \frac{R_1}{R_1 + R_2}$$

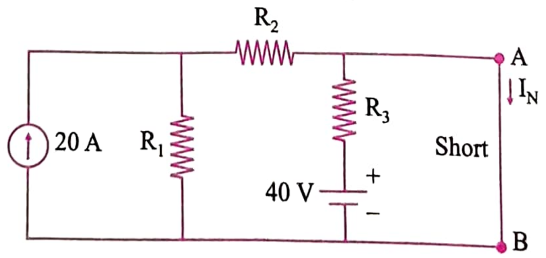


Fig. 2.2.2

Step 1. When current source is acting alone.

In this case, we short the voltage source. So that, only current source acting the circuit as shown in Fig. 2.2.3.

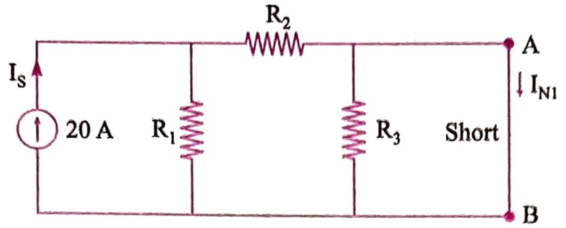


Fig. 2.2.3

It is clear that $I_{N1} = 20 \times \frac{R_1}{R_1 + R_2}$

Step 2. When voltage source is acting alone.

In this case, we open circuit the current source so that only voltage source acts in the circuit. The circuit then becomes as shown in Fig. 2.2.4.

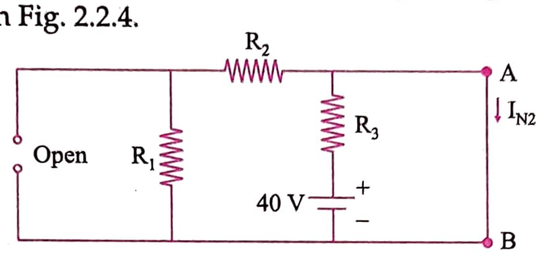


Fig. 2.2.4

It is clear that $I_{N2} = \frac{40}{R_3}$

Step 3. Now, we will calculate that Norton current ($I_N = I_{N1} + I_{N2}$)

Step 4. Now, we will calculate R_N by open circuit the load resistance R_L and replace current source by open circuit and voltage source by short circuit. Then circuit becomes as shown in Fig. 2.2.5.

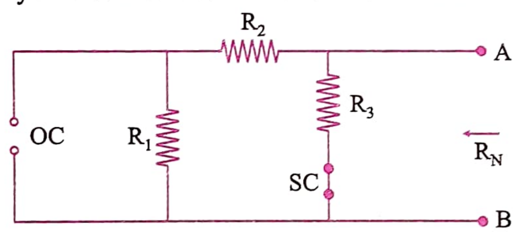


Fig. 2.2.5

$$R_N = R_3 \parallel (R_1 + R_2)$$

Step 5. Now, we draw the Norton's equivalent circuit of terminals AB is a current source parallel with R_N. When load resistor R_L is connected across Norton's equivalent circuit, then circuit becomes as shown in Fig. 2.2.6.

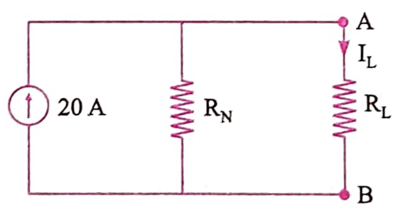


Fig. 2.2.6

Load current, $I_L = I_L = I_N \times \frac{R_N}{R_N + R_L}$

Observation Table

Step I	Step II	Step III				
I_L	I_S	V	I	$R_{th} = R_N$	$I_L = (R_N \cdot I_S) / R_N + R_L$	$Error = I_L - I_{L2}$

Calculations

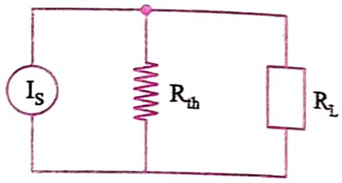


Fig. 2.2.7

Calculated value of load current

$$I_{L2} = I_S \cdot \frac{R_N}{R_N + R_L}$$

Observed value of load current I_L will be taken through procedure.

Results

If $I_{L2} = I_L$, Norton's theorem is verified.

Precautions

1. Meters should be used within proper range.
2. We must use neat and tight connections.
3. Zero setting of all meters should be checked before giving the input supply.

Aim: To measure power in a 3-phase system by two wattmeter method.

APPARATUS

Wattmeter: 0–150W, 2 Nos. Ammeter: 0 – 5A, 3 Nos.

Voltmeter: 0-600 V, 2 Nos. Load : 0-1000W

Theory

Using this method, only two single phase wattmeters together, measure power in a three phase balanced circuit. Any single phase wattmeter has two coils one is called *current coil* and other is called *potential coil* which respectively show current flowing and voltage applied across the load and their combined arrangement i.e. *wattmeter* measures power consumed by load.

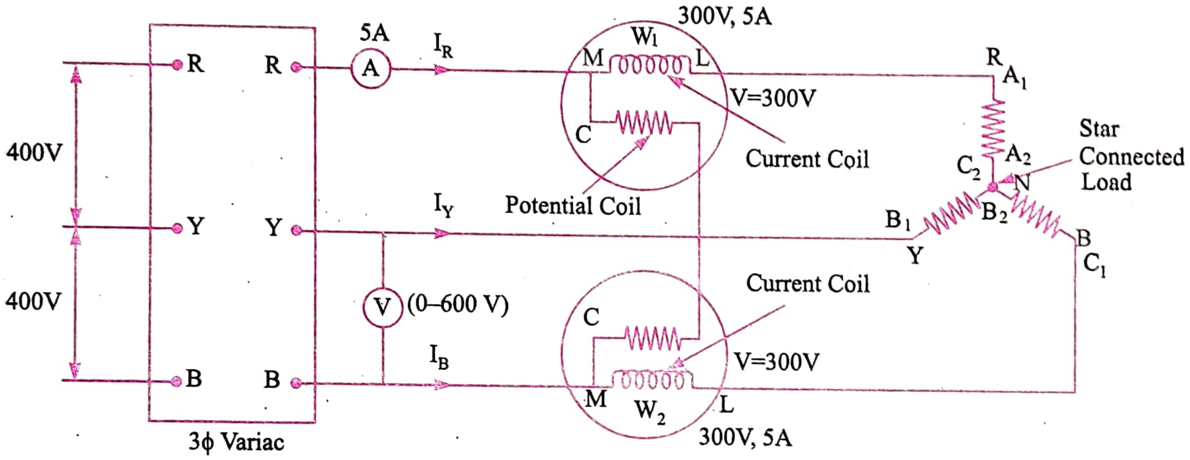


Fig. 5.1 (a)

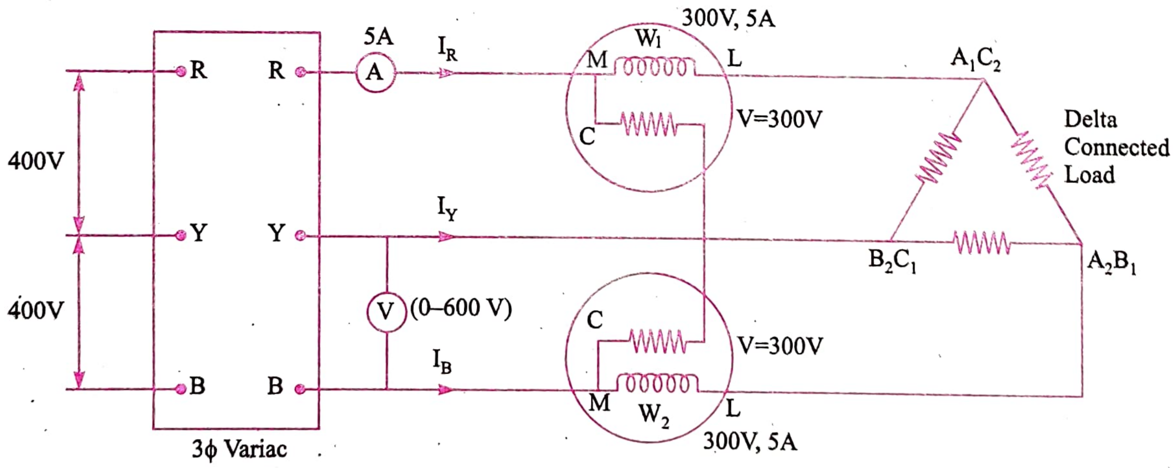


Fig. 5.1 (b)

To measure power in a three phase circuit the current coils of two wattmeters are connected in series with any of the two lines say R and Y (or R and B or Y and B)

We may note that:

These current coils carry the line current I_R and I_Y respectively.

The pressure (or voltage) coils of the two wattmeters are connected between that line and the third line i.e. B line.

Consider a balanced three phase load at a power factor cos φ lagging (it means load is inductive) due to which three lines currents will have same magnitude and there currents will be lagging by respective voltages.

Also for star connected system

$$\text{Line voltage} = V_{RY} \text{ or } V_{YB} \text{ or } V_{RB} = \sqrt{3}\,V_{ph} = \sqrt{3}\,V_R \text{ or } \sqrt{3}\,V_Y \text{ or } \sqrt{3}\,V_B$$

But for three phase star connected system, applying KVL in Fig. 5.3

$$\text{Line voltage } V_{RB} = V_R - V_B \quad \text{and} \quad V_{YB} = V_Y - V_B$$

Using phasor diagram

(*i*) V_{RB} lags V_R by 30°.

(*ii*) V_{YB} leads V_Y by 30°.

(*iii*) Phase angle between line voltage V_{RB} and line current I_R is $30° - \phi$

(*iv*) Phase angle between line voltage V_{YB} and line current I_Y is $30° + \phi$

Determination of power in three phase balanced load from Fig. 5.1 (a and b)

$$W_1 = V_{RB}\,I_R \cos(30° - \phi) = \sqrt{3}\,V_{ph}\,I_{ph}\cos(30° - \phi) \quad \text{....(5.1)}$$

(∵ Wattmeter W_1 is connected between R and B, so voltage considered is V_{RB}.

$$W_2 = V_{YB}\,I_Y \cos(30° + \phi) = \sqrt{3}\,V_{ph}\,I_{ph}\cos(30° + \phi) \quad \text{....(5.2)}$$

Addition of these two wattmeter given

$$W_1 + W_2 = \sqrt{3}\,V_{ph}\,I_{ph}\,[\cos(30°-\phi) + \cos(30°+\phi)]$$

$$= \sqrt{3}\,V_{ph}\,I_{ph}\,[2\cos 30° \cos\phi] = \sqrt{3}\,V_{ph}\,I_{ph}\left[2\cdot\frac{\sqrt{3}}{2}\cos\phi\right]$$

$$= 3\,V_{ph}\,I_{ph}\cos\phi \quad \text{....(5.3)}$$

= Total power consumed is 3-phase balanced system

In terms of line voltage

$$W_1 + W_2 = \sqrt{3}\,V_L\,I_L\cos\phi \quad \text{....(5.4)}$$

Determination of load power factor:

Also,

$$\frac{W_1}{W_2} = \frac{\sqrt{3}V_{ph}I_{ph}\cos(30-\phi)}{\sqrt{3}V_{ph}I_{ph}\cos(30-\phi)} = \frac{\cos(30-\phi)}{\cos(30+\phi)}4$$

$$\frac{W_1 - W_2}{W_1 + W_2} = \frac{\cos(30-\phi)-\cos(30+\phi)}{\cos(30-\phi)+\cos(30+\phi)} = \frac{2\sin 30°\sin\phi}{2\cos 30°\cos\phi} = \tan 30°\tan\phi = \frac{1}{\sqrt{3}}\tan\phi$$

or

$$\tan\phi = \sqrt{3}\left[\frac{W_1 - W_2}{W_1 + W_2}\right] \qquad \cos\phi = \cos\left[\tan^{-1}\sqrt{3}\left\{\frac{W_1 - W_2}{W_1 + W_2}\right\}\right] \quad \text{....(5.5)}$$

Points to be noted:

When, we use two singly phase wattmeter for measurement of power in a three phase circuit as mentioned above, one may get a negative deflection in one of the wattmeter. In that case, connections of either the current coil or the pressure coil of that wattmeter are reversed. The wattmeter will start giving a positive deflection.

Phasor Diagram

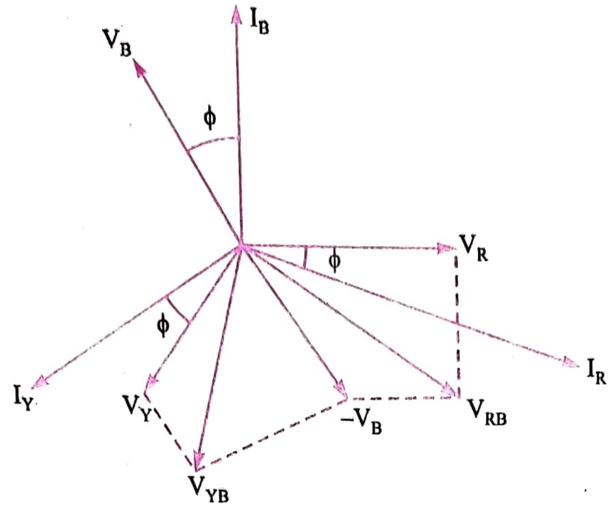


Fig. 5.2

Circuit Diagram

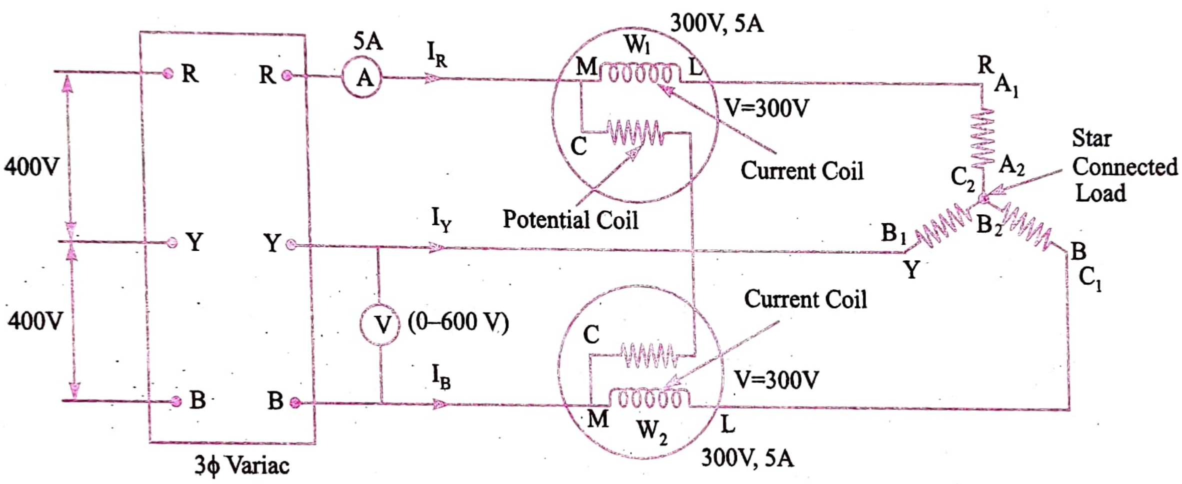


Fig. 5.3 (a)

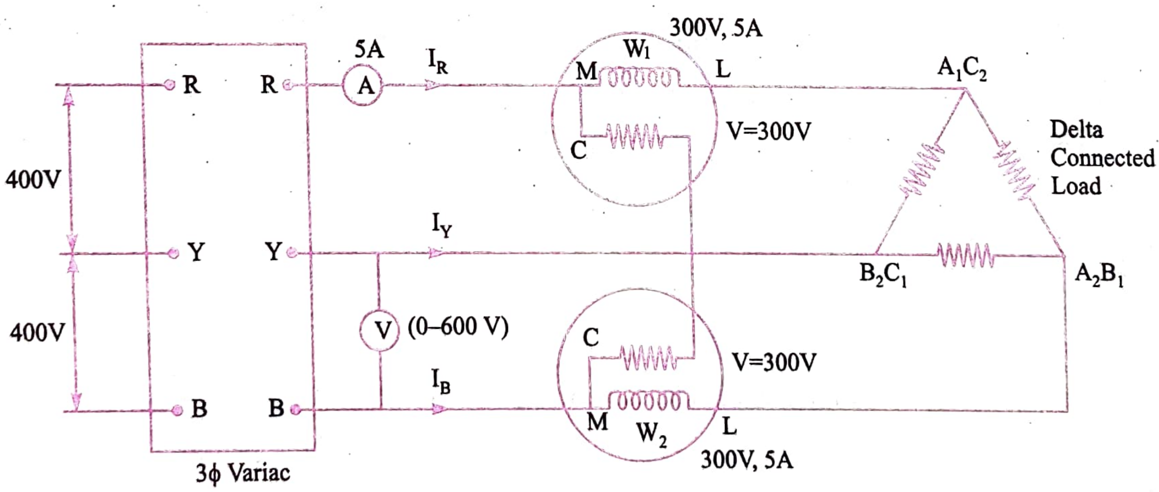


Fig. 5.3 (b)

Procedure

1. Star Connected Load:

Step (*a*) Make the connection as shown in Fig. 5.3. It is provided with a load. There are six out put / input terminals i.e. A_1, A_2, B_1, B_2, C_1 and C_2.

Step (*b*) Connect A_2 and B_2, B_2 and C_2. Feed the I/P at $A_1B_1C_1$ by the three phases (RYB) respectively.

Step (*c*) Take the readings for balanced loads and calculate power.

2. Delta: Repeat the same procedure for delta connected load.

Observations

Star Connected Load

S.No.	V_R (Volts)	I_Y (Amp)	I_B (Amp)	V_{RY} (Volt)	I_R (Amp)	W_1 (Watt)	W_2 (Watt)	$W_1 + W_2$ (Watt)

Calculations

Total power consumed $P = W_1 + W_2$ (It has been already explained in theory).

If in any wattmeter (say W_2) any coils is reversed, $\boxed{P = W_1 - W_2}$ (see precautions)

$\cos\phi$ can be calculated using formula given in theory.

Result

Using observations and calculations 3 phase power consumed by star connected and delta connected load respectively can be calculated.

Precautions

1. All the connections should be tight and clean.
2. The readings in ammeters should not exceed the current ratings of wattmeters.
3. With negative deflection in wattmeter the connection should be reversed.

Aim: To perform Open Circuit (O.C.) and Short Circuit (S.C.) test on a single phase transformer.

OPEN CIRCUIT TEST

Apparatus

(I) For Open Circuit

Ammeter: 0-1A, 1 No. — Voltmeter: 0-300V, 1 No.

Wattmeter: 0-150W, 1 No. (LPF) — Connecting leads

(II) For Short Circuit

Ammeter: 0-5A, 1 No. — Voltmeter: 0-50V, 1 No.

Wattmeter: 0-400W, 1 No. (HPF) — Connecting leads

Theory

Transformer has mainly two types of losses i.e. *iron losses* and *copper losses*. By measuring these losses, efficiency can be calculated. Iron losses are calculated by open circuit and copper losses are calculated by short circuit test.

In open circuit test, since the secondary is opened so, secondary current is zero also primary takes very small current from supply called I_0, no load current I_0 and iron loss W_{OC} are calculated using open circuit test. From there, R_{OC} and X_{OC} of equivalent circuit can be calculated.

One of the winding (secondary) of transformer is open circuited. The rated voltage of rated frequency is applied to the other winding. Generally, H.T. winding (high tension or high voltage) side is kept open circuited and rated voltage is applied to L.T. winding side.

As we have to give rated voltage to primary. Also L.T. winding required very small rated voltage as compared to H.T. winding. The connections are made as shown in Fig. 6.1. Rated voltage is supplied through an *auto transformer*.

Iron losses are function of voltage and copper losses are function of current. But secondary current is zero, also primary current is very small i.e. no load current I_0 thus copper losses are negligible.

Wheras primary voltage is (L.T. side) full rated voltage and there is induced full rated voltage on secondary winding (H.T. side) so iron loss will be very high because they are proportional to voltage.

Thus, wattmeter gives iron losses W_{OC}

$$\therefore \quad P_i = W_{OC} \qquad ...(6.1)$$

Now, load I_0 has two components:

(*i*) I_m = magnetizing component

(*ii*) I_w = Loss component

Also these can be calculated as follows:

$$I_W = \frac{W_{OC}}{V_{OC}} \qquad ...(6.2)$$

$$I_m = \left(I_0^2 - Iw^2\right)^{1/2}$$

$$R_{OC} = \frac{V_{OC}}{Iw}$$

$$X_{OC} = \frac{V_{OC}}{\text{Im}}$$

Circuit Diagram

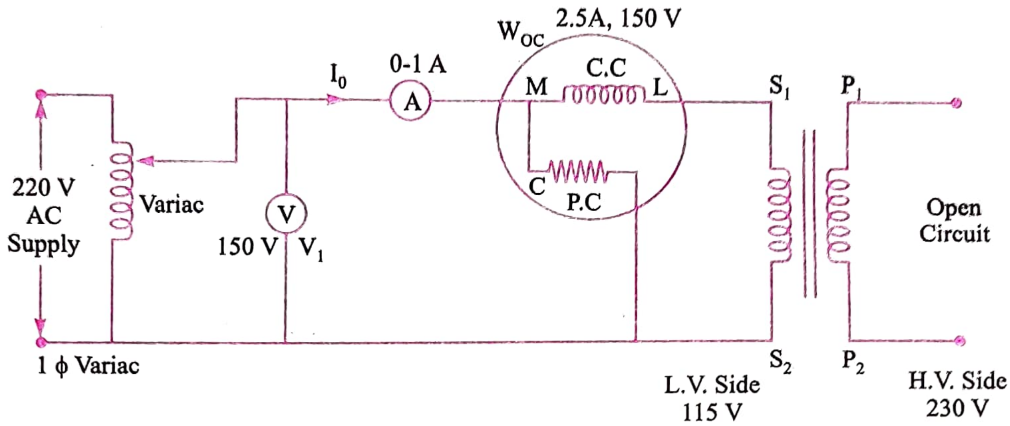


Fig. 6.1. Open Circuit Test

Procedure

Step 1. Make the connections as shown in Fig. 6.1.

Step 2. Check the primary should be at L.T.

Step 3. Switch on the supply after setting zero input voltage with variac.

Step 4. Adjust the primary voltage equal to rated voltage with the help of variac and record voltage input, no load power and no load current.

Step 5. Keep the variac at zero position and switch off the supply.

Observations

S.No.	*V input, V_{OC}*	*No load current, I_0*	*Iron loss w_0*
1.			
2.			
3.			
4.			

Calculations

Loss components I_w of no load current $I_0 = \frac{W_0}{V_{in}} = \frac{W_0}{V_{OC}}$;

$$I_w = \frac{W_0}{V_{OC}}$$

$$I_m = \sqrt{I_0^2 - I w^2}$$

$$R_{OC} = \frac{V_{OC}}{Iw} \quad \text{and} \quad X_{OC} = \frac{V_{OC}}{Im}$$

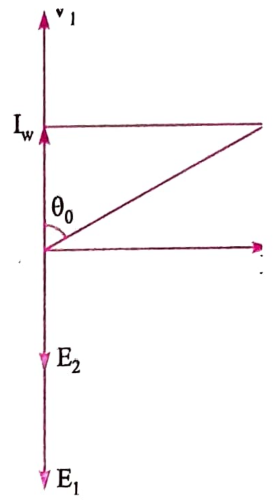


Fig. 6.2

Result

Equivalent circuit parameters, R_{OC} and X_{OC} were calculated along with iron loss.

Precautions

1. Ranges of different voltmeters, ammeters, wattmeters should be kept in mind.
2. Circuit should have tight connections.

SHORT CIRCUIT TEST

Theory

This test is performed to calculate:

(*i*) Copper losses

(*ii*) Equivalent resistance of transformer.

(*iii*) Leakage reactance of transformer.

Connections are made as shown in Fig. 6.3. L.T. winding is taken as secondary and short circuited. H.T. winding is taken as primary and connected to the supply.

We are concerned with high value of copper losses or high value of current. In short circuit mode current is highest. Also L.T. side has very high current as compared to H.T. side. So, when L.T. side (high current side) will be short circuited, it will give highest current and highest copper losses instead of short circuiting H.T. side.

We know that when L.T. winding is short circuited and H.T. winding is an primary side and connected to supply. H.T. side has low rated current as compared to L.T. side. We do not give full H.T. voltage but only very small fraction of input rated voltage to get full load current.

Here we get two conclusions:

1. We know that iron losses are proportional to voltage. But L.T. side is short circuited, so, its voltage is zero. Also H.T. side takes very small fraction of its rated value from supply to get full load current. Hence voltage on primary side is also low resulting in low values of iron losses.
2. We know that copper losses are proportional to current. As already mentioned that secondary has short circuit current (highest value) and primary has full load current (very high value) so copper losses are very high as compared to iron losses. Hence wattmeter gives copper losses.

Let the various readings be W_{SC}, I_{SC} and V_{SC}, then

Equivalent resistance: $R = \dfrac{W_{SC}}{I_{SC^2}}$

Equivalent impedance: $Z = \dfrac{V_{SC}}{I_{SC}}$

Equivalent leakage reactance: $X = \sqrt{Z^2 - R^2}$

Also power W_{OC} in open circuit test gives iron loss P_i, power W_{SC} in short circuit test gives copper losses, P_C.

Power output on full load, $P_0 = V\,I\cos\phi$

$$\text{Efficiency, } \eta = \frac{P_0}{P_0 + P_i + P_C} = \frac{P_O}{P_O + W_{OC} + W_{SC}}$$

Circuit Diagram

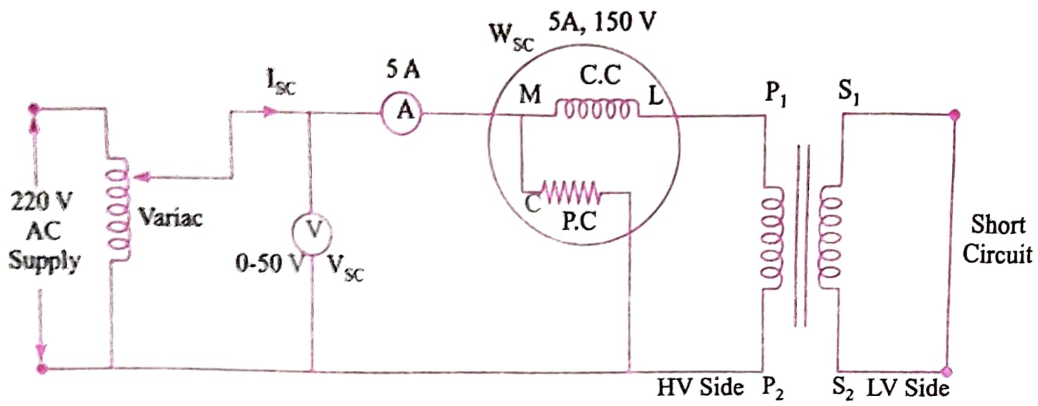


Fig. 6.3 Short Circuit Test

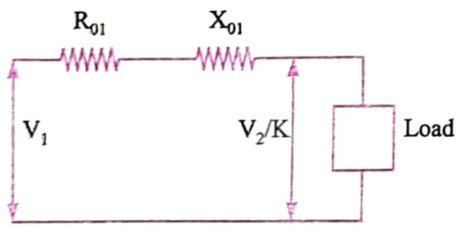


Fig. 6.4

Procedure

Step 1. Connect the circuit as shown in Fig. 6.3.

Step 2. Set the variac at zero position.

Step 3. Switch on the supply.

Step 4. Gradually, increase the voltage by variac to make primary current equal to rated current.

Step 5. Note down the readings of ammeter, voltmeter and wattmeter.

where, Ammeter gives: I_{SC}

Voltmeter gives V_{SC}

Wattmeter Cu losses = W_{SC}

Step 6. Keep the variac at zero position and switch off supply.

Observation

S.No.	V_{sc} (V)	I_{sc} (A)	W_{sc} (W)
1.			
2.			
3.			
4.			

Calculations

Equivalent resistance required $R_{eq} = \frac{W_{SC}}{I_{SC^2}}$

Equivalent impedance required $Z_{eq} = \frac{V_{SC}}{I_{SC}}$

Equivalent leakage reactance $X_{eq} = \sqrt{Z_{eq}{}^2 - R_{eq}{}^2}$

Result

Equivalent parameters *i.e.* R_{eq} and X_{eq} were calculated along with copper loss.

Precautions

1. All the connections should be tight and clean.
2. Special care should be taken while selecting the ranges of the meters for conducting short-circuit test.
3. While conducting the short-circuit test, the voltage applied should be initially set at zero, and then increase slowly. If a little higher voltage than the required voltage be applied (by mistake), there is a danger of transformer being damaged.

Aim: To perform starting and reversal of direction of a three phase (3-ϕ) induction motor.

Theory

A 3-phase induction motor is theoretically self-starting. The stator of an induction motor consists of 3-phase windings, which when connected to a 3-phase supply creates a rotating magnetic field. This will link and cut the rotor conductors which in turn will induce a current in the rotor conductors and create a *rotor magnetic field*. The magnetic field created by the rotor will interact with the rotating magnetic field in the stator and produce rotation.

Therefore, 3-phase induction motors employ a starting method not to provide a starting torque at the rotor, but because of the following reasons;

1. Reduce heavy starting currents and prevent motor from overheating.
2. Provide overload and no-voltage protection.

There are many methods in use to start 3-phase induction motors. Some of the common methods of starting 3-ϕ I.M.

1. For slip ring motors: Rotor resistance starting.
2. For squirrel cage motors
   (*i*) Direct on line starting
   (*ii*) Start delta starting
   (*iii*) Auto transformer starting.

There are two important factors to be considered in starting of induction motors:

- The starting current drawn from the supply, and
- The starting torque.

The starting current should be kept low to avoid overheating of motor and excessive voltage drops in the supply network. The starting torque must be about 50 to 100% more than the expected load torque 't' ensure that the motor runs up in a reasonably short time.

(i) Rotor resistance starting

By adding eternal resistance to the rotor circuit any starting torque up to the maximum torque can be achieved; and by gradually cutting out the resistance a high torque can be maintained throughout the starting period. The added resistance also reduces the starting current, so that a starting torque in the range of 2 to 2.5 times the full load torque can be obtained at a starting current of 1 to 1.5 times the full load current.

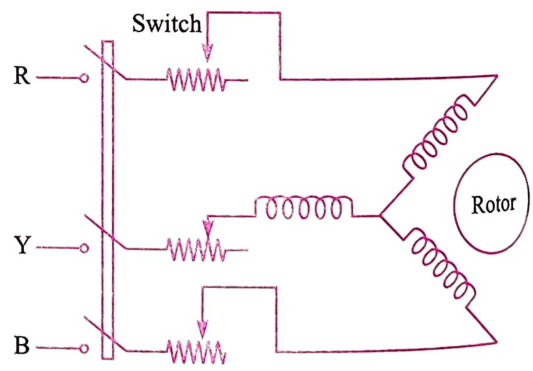


Fig. 19.1. Rotor resistance starting.

(ii) Direct-on-line starting

This is the most simple and inexpensive method of starting a squirrel cage induction motor. The motor is switched on directly to full supply voltage. The initial starting current is large, normally about 5 to 7 times the rated current but the starting torque is likely to be 0.75 to 2 times the full load torque. To avoid excessive supply voltage drops because of large starting currents the method is restricted to small motors only.

To decrease the starting current cage motors of medium and larger sizes are started at a reduced supply voltage. The reduced supply voltage starting is applied in the next two methods.

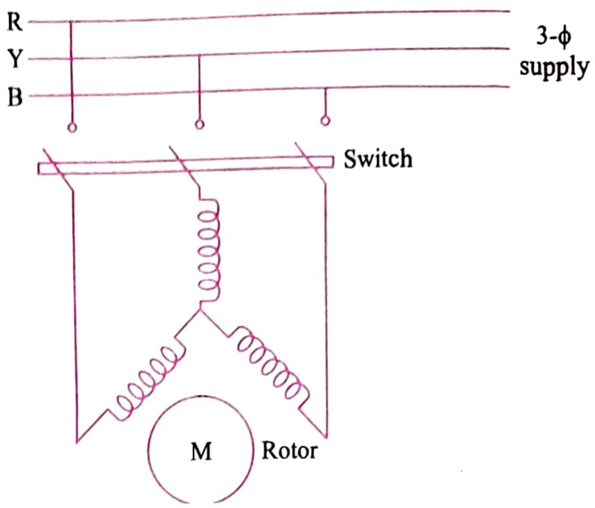


Fig. 19.2. Direct on-line (DOL) starting.

(iii) Star-Delta starting

This is applicable to motors designed for delta connection in normal running conditions. Both ends of each phase of the stator winding are brought out and connected to a 3-phase change -over switch. For starting, the stator windings are connected in star and when the machine is running the switch is thrown quickly to the running position, thus connecting the motor in delta for normal operation.

The phase voltages & the phase currents of the motor in star connection are reduced to $\frac{1}{\sqrt{3}}$ of the direct-on-line value in delta. The line current is $\frac{1}{3}$ of the value in delta.

A disadvantage of this method is that the starting torque (which is proportional to the square of the applied voltage) is also reduced to 1/3 of its delta value.

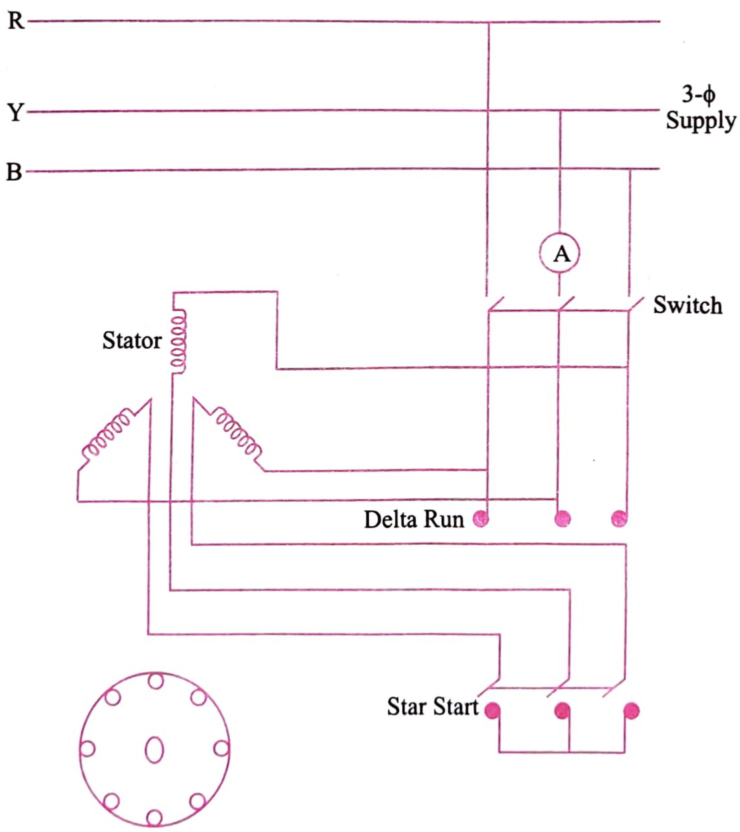


Fig. 19.3. Star Delta Starting.

(iv) Auto-transformer starting

This method also reduces the initial voltage applied to the motor and therefore the starting current and torque. The motor, which can be connected permanently in delta or in star, is switched first on reduced voltage from a 3-phase tapped auto-transformer and when it has accelerated sufficiently, it is switched to the running (full voltage) position. The principle is similar to star/delta starting and has similar limitations. The advantage of the method is that the current and torque can be adjusted to the required value, by taking the correct tapping on the autotransformer. This method is more expensive because of the additional autotransformer.

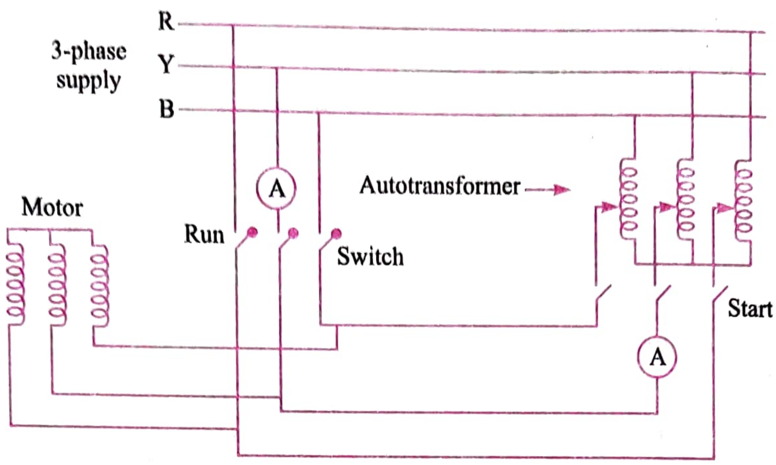


Fig. 19.4. Autotransformer starting.

Procedure

Step 1. Study the construction and the various parts of the 3-phase induction motor.

Step 2. For rotor resistance starting, connect the slip-ring motor as shown in Fig. 19.1. Start the motor with full starting resistance and then decrease the resistance in steps down to zero. Take observations of the stator & rotor currents.

Step 3. For direct-on-line starting, connect the cage motor as shown in Fig. 19.2.

Step 4. For star-delta starting, connect the cage motor to the terminals of the star-delta switch Fig. 19.3.

Step 5. For autotransformer starting, connect the cage motor as shown in Fig. 19.4. Take care at starting that the "Run" switch is open and that it is not closed before the "Start" switch is opened.

Step 6. In each case observe the starting currents by quickly reading the maximum indication of the ammeters in the stator circuit.

Reversing the direction of 3-ϕ induction motor: Reversing the connection of any two of the three motor terminals can reverse the direction of rotation of 3-ϕ induction motor as shown in Fig. 19.5.

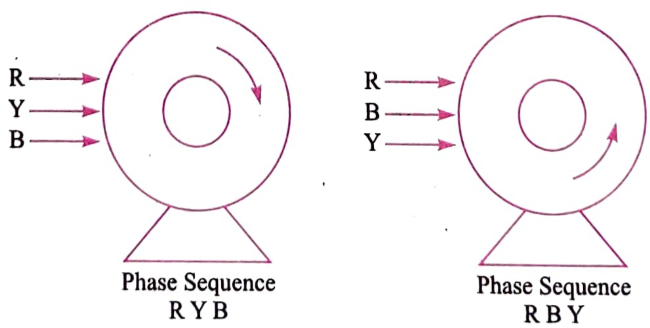


Fig. 19.5

Procedure

Step 1. Connect the circuit as shown in Fig. 19.4.

Step 2. Ensure that the dimmerstat is at zero position.

Step 3. Switch ON the 3-phase AC supply.

Step 4. Increase the output voltage of the dimmerstat slowly upto 50 V.

Step 5. The rotor of Induction Motor rotates in one direction.

Step 6. Make the output of dimmerstat zero.

Step 7. Now, interchange any two phases. Now phase sequence of applied voltage is RBY.

Step 8. Increase the output voltage of the dimmerstat slowly upto 50 V.

Step 9. Now, the rotor of induction motor rotates in opposite direction.

Precautions

1. All connections should be perfectly tight.
2. Do not switch on the supply until and unless the connections are checked by the teacher.
3. Ensure the dimmer stat at zero position before switching the supply ON.

Conclusion

It is observed that the direction of rotation of 3 phase induction motor can be changed by interchanging two supply phase with each other.

Experiment No. 8

Aim: To study the VI Characteristics of the P-N Diode in Forward and Reverse Bias and find the threshold voltage from the VI Curve.

Apparatus: The experiment was performed using the Basic Electronics Virtual Lab developed by IIT Kharagpur via https://be-iitkgp.vlabs.ac.in/. All instruments and components were simulated within the virtual environment.

Theory:

The diode is a device formed from a junction of n-type and p-type semiconductor material. The lead connected to the p-type material is called the anode, and the lead connected to the n-type material is the cathode. In general, the cathode of a diode is marked by a solid line on the diode.

Function of a P-N junction diode in Forward Bias:

The positive terminal of the battery is connected to the P side (anode), and the negative terminal of the battery is connected to the N side (cathode) of a diode. The holes in the p-type region and the electrons in the n-type region are pushed toward the junction and start to neutralize the depletion zone, reducing its width. The positive potential applied to the p-type material repels the holes, while the negative potential applied to the n-type material repels the electrons. The change in potential between the p side and the n side decreases or switches sign. With increasing forward-bias voltage, the depletion zone eventually becomes thin enough that the zone's electric field cannot counteract charge carrier motion across the p–n junction, which, as a consequence, reduces electrical resistance. The electrons that cross the p–n junction into the p-type material (or holes that cross into the n-type material) will diffuse into the nearby neutral region. The amount of minority diffusion in the near-neutral zones determines the amount of current that may flow through the diode.

Function of a P-N junction diode in Reverse Bias

The positive terminal of the battery is connected to the N side (cathode), and the negative terminal of the battery is connected to the P side(anode) of a diode. Therefore, very little current will flow until the diode breaks down. The positive terminal of the battery is connected to the N side(cathode), and the negative terminal of the battery is connected to the P side (anode) of a diode. The 'holes' in the p-type material are pulled away from the junction, leaving behind charged ions and causing the width of the depletion region to increase. Likewise, because the n-type region is connected to the positive terminal, the electrons will also be pulled away from the junction, with a similar effect. This increases the voltage barrier, causing a high resistance to the flow of charge carriers, thus allowing minimal electric current to cross the p–n junction. The increase in resistance of the p–n junction results in the junction behaving as an insulator. The strength of the depletion zone electric field increases as the reverse-bias voltage increases. Once the electric field intensity increases beyond a critical level, the p–n junction depletion zone breaks down and current begins to flow, usually by either the Zener or the avalanche breakdown processes. Both of these breakdown processes are non-destructive and are reversible, as long as the amount of current flowing does not reach levels that cause the semiconductor material to overheat and cause thermal damage.

Procedure:

For Forward Bias Diode:

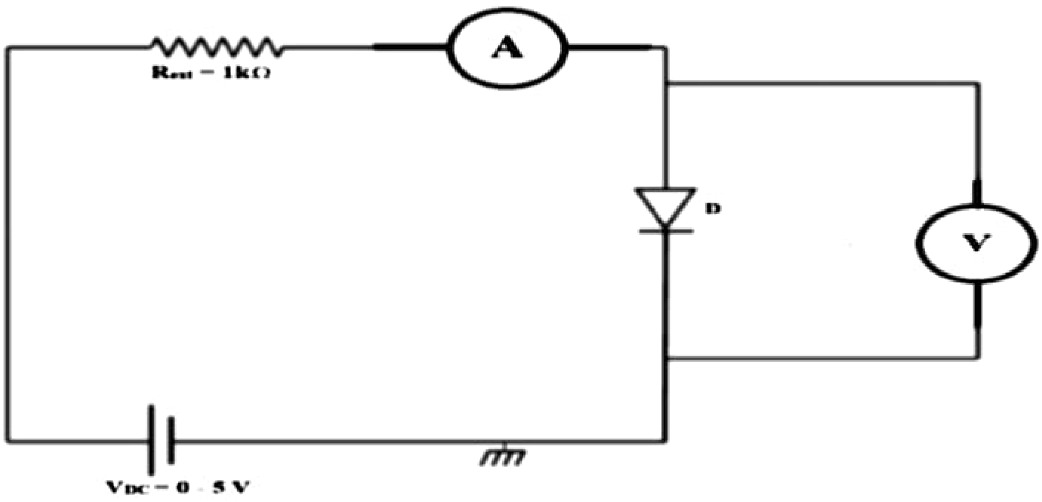
1. Set DC voltage to 0.2 V.
2. Select the diode.
3. Set the resistor.
4. Voltmeter is placed parallel to the Silicon diode and ammeter series with a resistor.
5. The positive side of the battery to the P side (anode) and the negative side of the battery to the N side (cathode) of the diode.
6. Now vary the voltage up to 5V and note the Voltmeter and Ammeter readings for a particular DC voltage.
7. Take the readings and note the Voltmeter reading across the Silicon diode, and the Ammeter reading.
8. Plot the V-I graph and observe the change.
9. Calculate the dynamic resistance of the diode. $Rd=\Delta V/\Delta I$
10. Therefore, from the graph, we see that the diode starts conducting when the forward bias voltage exceeds around 0.6 volts (for a Si diode). This voltage is called the cut-in voltage.

For Reverse Bias Diode:

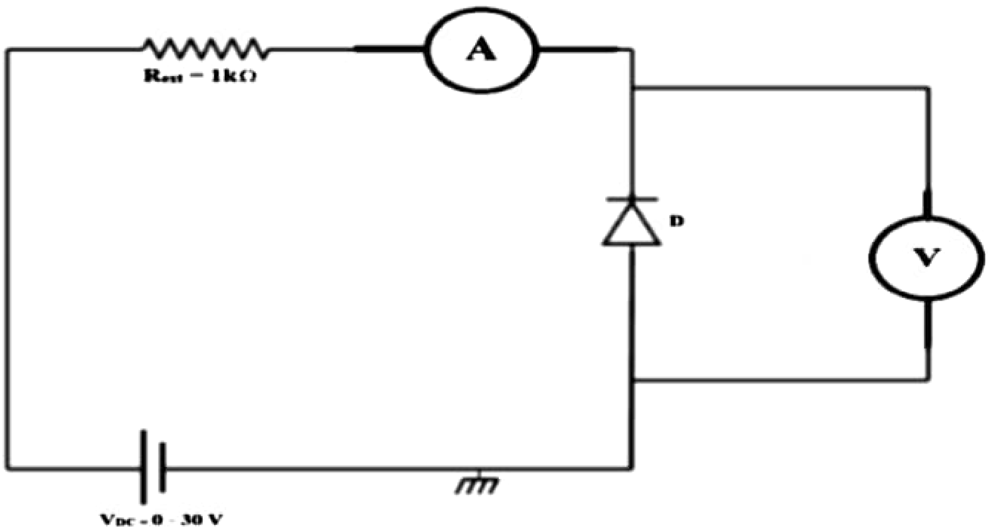
1. Set DC voltage to 0.2 V.
2. Select the diode.
3. Set the resistor.
4. The voltmeter is placed parallel to the Silicon Diode and the ammeter in series with a resistor.
5. The positive terminal of the battery is connected to the N side (cathode), and the negative terminal of the battery is connected to the P side (anode) of a diode.
6. Now vary the voltage up to 30V and note the Voltmeter and Ammeter readings for DC voltage.
7. Take the readings and note the Voltmeter reading across the Silicon Diode and the Ammeter reading.
8. Plot the V-I graph and observe the change.

Circuit Diagram:

For Forward Bias Diode:



For Reverse Bias Diode:



Observations:

For Forward Bias Diode:

S. No.	Source Voltage, V_{DC} (V)	Forward Voltage (V)	Forward Current (mA)	Dynamic Resistance, R_D (kΩ)
1.	0.2	0	0	--
2.	0.6	0.530	0.100	5.300
3.	1	0.539	0.400	1.347
4.	1.5	0.549	0.900	0.610
5.	2	0.557	1.40	0.398
6.	2.5	0.563	1.90	0.296
7.	3	0.567	2.40	0.236
8.	3.5	0.571	2.90	0.197
9.	4	0.575	3.40	0.169
10.	4.5	0.578	3.90	0.148
11.	5	0.581	4.40	0.132

For Reverse Bias Diode:

S. No.	Source Voltage, V_{DC} (V)	Reverse Voltage (V)	Reverse Current (µA)
1.	0.2	0.161	0.100
2.	2	1.75	0.100
3.	4	3.59	0.100
4.	8	7.35	0.100
5.	10	9.26	0.100
6.	15	14.1	0.100
7.	20	18.9	0.100
8.	25	23.9	0.100
9.	28	26.8	0.100
10.	30	28.8	23.076

Graph:

Make graphs for Forward Bias and Reverse Bias. Taking Voltage (Forward / Reverse) on the X-axis and Current (Forward / Reverse) on the Y-axis.

Results: The V-I characteristics of the diode were successfully plotted using virtual lab data. In forward bias, the current increased sharply after the threshold voltage (~0.53 V), confirming conduction behaviour. In reverse bias, current remained nearly constant (~0.1 µA) until the avalanche breakdown at 28.8 V, where it rose sharply to 23.076 µA, demonstrating the diode's rectifying and breakdown properties.

Experiment No. 9

Aim: To study the operation of half-wave and full-wave rectifiers and observe the output waveform.

Apparatus: The experiment was performed using the Basic Electronics Virtual Lab developed by IIT Kharagpur via https://be-iitkgp.vlabs.ac.in/. All instruments and components were simulated within the virtual environment.

Theory:

A rectifier is a device that converts alternating current (AC) to direct current (DC), a process known as rectification. Rectifiers are essentially of two types: half-wave rectifiers and full-wave rectifiers.

Half-Wave Rectifier:

A basic half-wave rectifier consists of a single PN junction diode connected in series with a load resistor. The diode functions like a one-way valve for electric current, allowing flow in only one direction. This unidirectional property makes the diode ideal for rectification, which is the process of converting alternating current (AC) into direct current (DC).
Rectification is one of the most fundamental applications of a PN junction diode. The diode conducts current only when it is forward-biased, meaning it allows current to pass during the positive half-cycles of the AC input. During the negative half-cycles, the diode becomes reverse-biased and blocks current flow.
In a typical setup, the AC input is first stepped down using a transformer. The reduced voltage is then applied across the diode (D) and load resistor (RL). During the positive half-cycle, the diode conducts, and current flows through RL, producing a significant output. During the negative half-cycle, the diode blocks current, resulting in zero or negligible output.
Thus, the output across RL consists only of the positive half-cycles of the input waveform, forming a pulsating DC signal. This process is known as half-wave rectification

Full-Wave Rectifier:

A full-wave rectifier is designed to convert the entire cycle of alternating current (AC) into pulsating direct current (DC). Unlike half-wave rectifiers, which utilize only one half of the input waveform, full-wave rectifiers make use of both the positive and negative half-cycles. This results in a smoother and more efficient DC output, making full-wave rectification ideal for applications that require a steady power supply. There are two common types of full-wave rectifiers: the centre-tap full-wave rectifier and the bridge rectifier.
In a centre-tap full-wave rectifier, the AC input is first stepped down using a transformer with a centre-tapped secondary winding. The ends of the secondary winding are connected to the anodes of two diodes, while the centre tap serves as a common ground. During the positive half-cycle of the AC input, the upper half of the secondary winding becomes positive, forward-biasing the first diode and allowing current to flow through the load. During the negative half-cycle, the lower half of the winding becomes positive, forward-biasing the second diode and

again allowing current to flow through the load in the same direction. This alternating conduction produces a continuous pulsating DC output across the load resistor.
A bridge rectifier, on the other hand, uses four diodes arranged in a bridge configuration and does not require a centre-tapped transformer. When AC input is applied, the diodes conduct in pairs depending on the polarity of the input signal. During the positive half-cycle, terminal A becomes positive and terminal B becomes negative. Diodes D1 and D3 are forward-biased and conduct current, while D2 and D4 are reverse-biased and block current. The current flows from A through D1, the load, D3, and back to B. During the negative half-cycle, the polarity reverses, terminal B becomes positive, and terminal A becomes negative. Diodes D2 and D4 now conduct, while D1 and D3 block current. The current flows from B through D2, the load, D4, and back to A. In both cases, the current through the load flows in the same direction, resulting in a full-wave rectified output.

Ripple Factor:

The ac components present in the output of a rectifier are called Ripple. It is a measure of the AC components present in the output of the rectifier.

$$Ripple\ Factor = \frac{RMS\ Value\ of\ AC\ Components}{RMS\ Value\ of\ DC\ Components}$$

$$Ripple\ Factor = \sqrt{\left(\frac{V_{RMS}}{V_{DC}}\right)^2 - 1}$$

The ripple factor varies depending on the type of rectifier used. For a half-wave rectifier, the ripple factor is approximately **1.21**, indicating a high level of AC fluctuations in the output. In contrast, a full-wave rectifier, whether centre-tap or bridge configuration, has a significantly lower ripple factor of about **0.48**. This means that full-wave rectifiers provide a much smoother DC output compared to half-wave rectifiers, making them more suitable for applications that require a steady and reliable power supply.

<u>Procedure</u>:

For Half-Wave Rectifier:

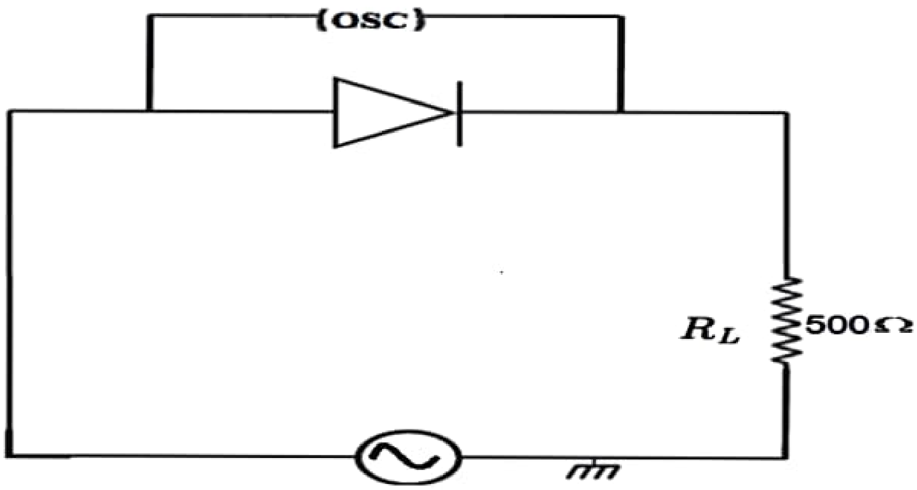
1. Set the resistor RL.
2. Click on the 'ON' button to start the experiment.
3. Click on the 'Sine Wave' button to generate the input waveform
4. Click on the 'Oscilloscope' button to get the rectified output.
5. Vary the Amplitude, Frequency, and volt/div using the controllers.
6. Click on the "Dual" button to observe both waveforms.
7. Channel 1 shows the input sine waveform; Channel 2 shows the output rectified waveform.
8. Calculate the Ripple Factor. Theoretical Ripple Factor = 1.21.

For Full-Wave Rectifier:

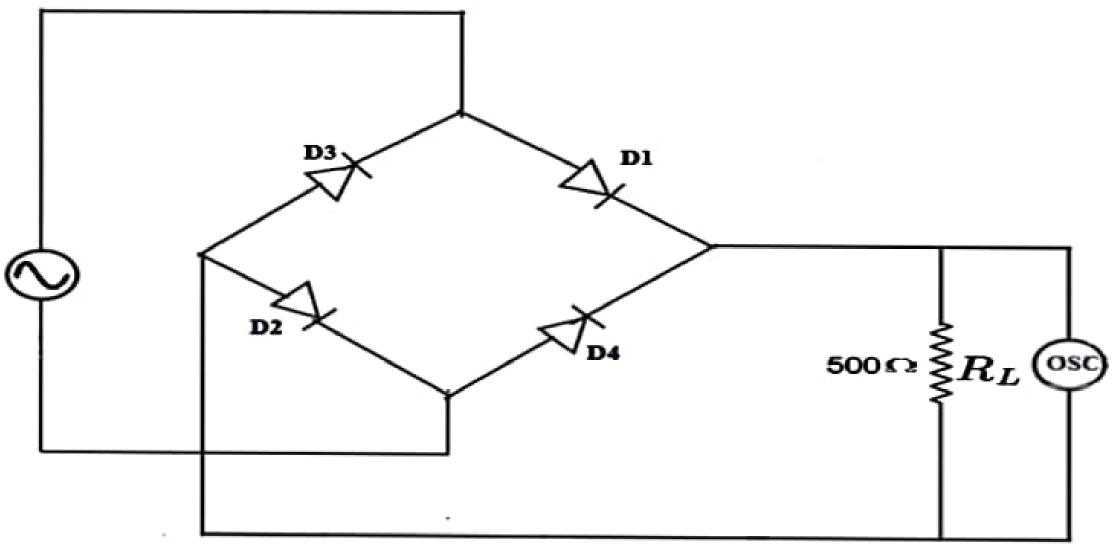
1. Set the resistor RL.
2. Click on the 'ON' button to start the experiment.
3. Click on the 'Sine Wave' button to generate the input waveform
4. Click on the 'Oscilloscope' button to get the rectified output.
5. Vary the Amplitude, Frequency, and volt/div using the controllers.
6. Click on the "Dual" button to observe both waveforms.
7. Channel 1 shows the input sine waveform; Channel 2 shows the output rectified waveform.
8. Calculate the Ripple Factor. Theoretical Ripple Factor =0.483.

Circuit Diagrams:

For Half-Wave Rectifier:

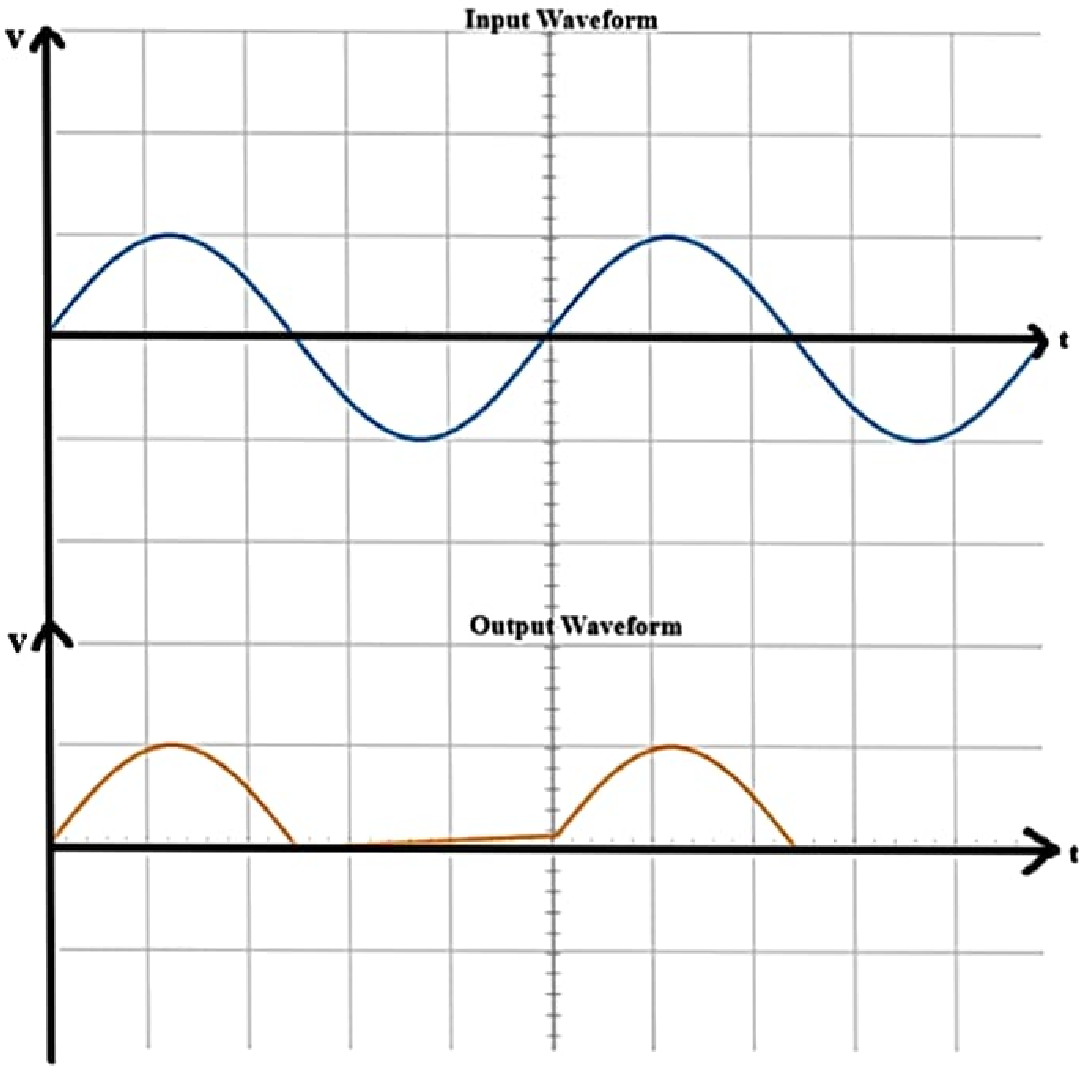


For Full-Wave Rectifier:



Observations:

For Half-Wave Rectifier:



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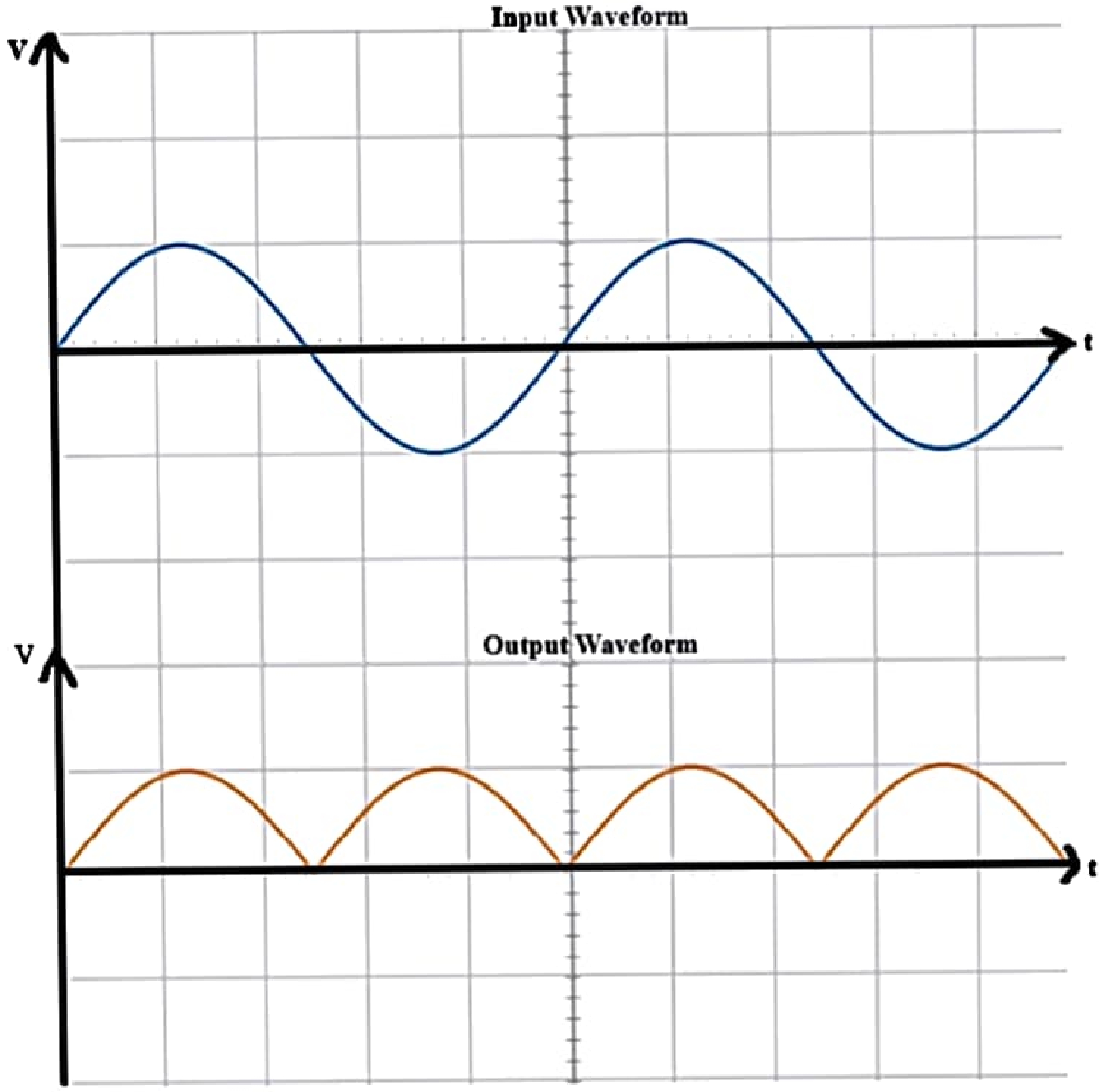
For Full-Wave Rectifier:



Results:

The output waveform of the half-wave rectifier showed conduction only during the positive half-cycles of the input AC signal. The negative half-cycles were blocked, resulting in a discontinuous pulsating DC output with high ripple.
The output waveform of the full-wave rectifier showed conduction during both positive and negative half-cycles. The current through the load remained unidirectional, producing a continuous pulsating DC output with reduced ripple compared to the half-wave rectifier.
The observed waveforms matched the expected theoretical behaviour, confirming successful rectification in both cases