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BASIC ELECTRICAL ENGINEERING LAB

[CODE: ESC-EE-102]

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Table of Contents

EXPERIMENT 1

AIM: -To verify Kirchhoff's current and voltage laws.

APPARATUS USED: - DC ammeter (0-20mA), multimeter, resistors (100E, 220E, 470E, 1K), dc power source (12V/1A), connecting wires, bread board.

THEORY: - Kirchhoff's current law states that at any node the algebraic sum of currents is zero, or the amount of current enters a node is equal to the current leaving that node. Kirchhoff's voltage law states that the algebraic sum of voltage drops in a loop is zero.

FORMULAE USED: -

$$\sum_{node} I_i = 0$$

$$\sum_{loop} V_{ij} = 0$$

PROCEDURE: -

For KCL:

- Connected the circuit as per the circuit diagram given in Fig 1 on bread board to verify KCL.
- Placed the ammeter in series with each branch connected to node 'A' to measure the current in the respective branches.
- Took algebraic sum of all the measured currents at node 'A' and verified the KCL.
- Repeated the above steps for nodes 'B' and 'C'.

For KVL:

- Connected the circuit as per the circuit diagram given in Fig 2 on bread board to verify KVL.
- Set the multimeter in dc voltage measurement scale.
- Connected the multimeter across each branch to measure the voltage across the branches.
- Applied the algebraic sum of voltage drops in loops 'a-b-f-g-a', 'b-d-e-f-b', 'b-c-d-b', 'a-b-d-e-f-g-a' and 'a-b-c-d-e-f-g-a' and verified the KVL.

PART A (Kirchhoff's current law):

CIRCUIT DIAGRAM: -

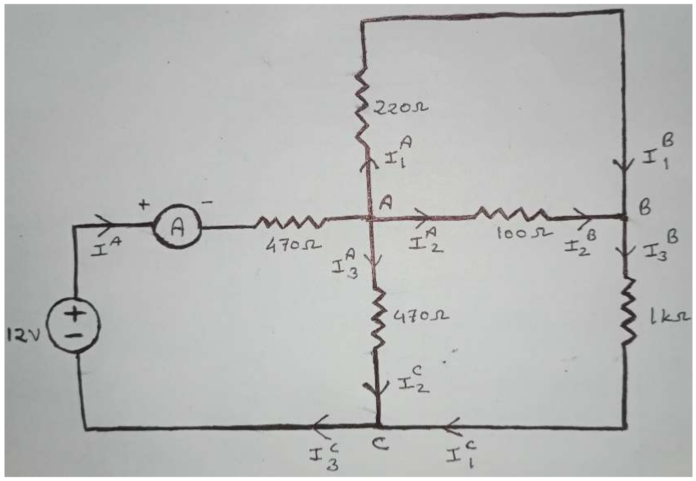


Fig 1: Circuit to verify KCL

OBSERVATIONS AND CALCULATIONS: -

Node	Current (mA)		$\sum_{node} I_i$
A	I^A		$-I^A + I_1^A + I_2^A + I_3^A =$
	I_1^A		
	I_2^A		
	I_3^A		
B	I_1^B		$-I_1^B - I_2^B + I_3^B =$
	I_2^B		
	I_3^B		
C	I_1^C		$-I_1^C - I_2^C + I_3^C =$
	I_2^C		
	I_3^C		

PART B (Kirchhoff's voltage law):

CIRCUIT DIAGRAM: -

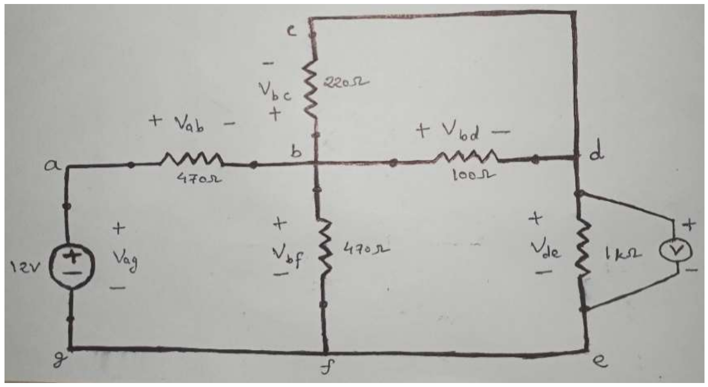


Fig 2: Circuit diagram to verify KVL

OBSERVATIONS AND CALCULATIONS: -

Loop	Branch Voltages (V)		$\sum_{loop} V_{ij}$
a-b-f-g-a	V_{ab}		$V_{ab} + V_{bf} - V_{ag} =$
	V_{bf}		
	V_{ag}		
b-d-e-f-b	V_{bd}		$V_{bd} + V_{de} - V_{bf} =$
	V_{de}		
	V_{bf}		
b-c-d-b	V_{bc}		$V_{bc} - V_{bd} =$
	V_{bd}		
a-b-d-e-f-g-a	V_{ab}		$V_{ab} + V_{bd} + V_{de} - V_{ag} =$
	V_{bd}		
	V_{de}		
	V_{ag}		
a-b-c-d-e-f-g-a	V_{ab}		$V_{ab} + V_{bc} + V_{de} - V_{ag} =$
	V_{bc}		
	V_{de}		
	V_{ag}		

RESULT: - Within the experimental error, the Kirchhoff's current and voltage laws are verified.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the supply when the connections are fully done.
- Keep under consideration of ammeter and voltmeter polarities while using them to measure current and voltage respectively.

EXPERIMENT 2

AIM: -To verify maximum power transfer theorem.

APPARATUS USED: - DC ammeter (0-2mA), DC voltmeter (0-10V), resistors (1K, 2.2K – 2,

4.7K), variable resistor – 10K, dc power source (12V/1A), connecting wires.

THEORY: - Maximum power transfer theorem in case of dc circuit states that the maximum power will be transferred to the load when the load resistance is equal to the internal resistance of the network to which the load is to be connected. The value of this maximum power available at the load is actually one-fourth the power delivered by the source having voltage equal to Thevenin's equivalent voltage of the network measured across the load branch to a resistor equal to the internal resistance of the network.

FORMULAE USED: -

$$R_L = \frac{V_L}{I_L}$$

$$P_L = V_L \, I_L$$

$$P_{max} = \frac{{V_{Th}}^2}{4R_{Th}}$$

CIRCUIT DIAGRAM: -

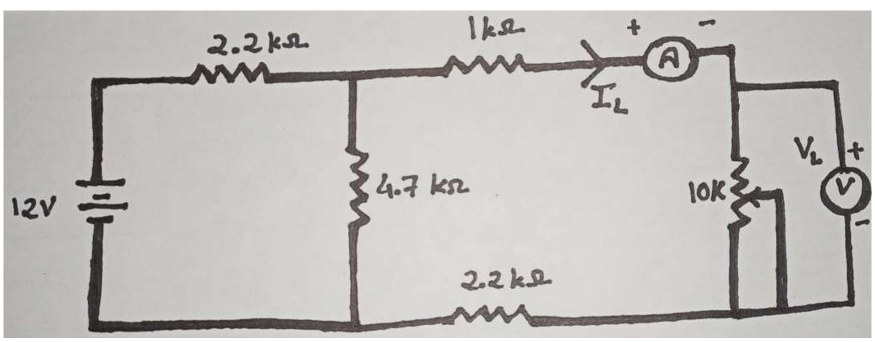


Fig 1: Circuit to verify maximum power transfer theorem

PROCEDURE: -

- Connected the circuit as per the circuit diagram given in Fig 1 to verify maximum power transfer theorem.

- Set the variable resistance to its minimum resistance value i.e., 0Ω.
- Noted down the readings shown by ammeter and voltmeter to measure the current flowing through and the voltage appearing across the load respectively.
- Increased the variable resistance in steps and repeated the above step.
- Computed the load resistance value at each step by dividing voltmeter reading with the ammeter reading.
- Computed the power delivered to the load at each step by multiplying voltmeter and ammeter readings.
- Plotted the variation of power delivered to the load with respect to the load resistance value.
- Took out the load variable resistor from the circuit i.e., the output side of the network was open circuited.
- Noted down the value of voltage appearing across this open circuited branch, this was termed as Thevenin's equivalent voltage.
- Took out the voltage source from the network and the input side of the network was short-circuited.
- Measured the resistance as seen from the output side, this was termed as internal or Thevenin's equivalent resistance.
- Compared this value of internal resistance with the load resistance value corresponding to the maximum power delivered value as observed from the power delivered vs load resistance plot.
- Compared the maximum power measured with the maximum power calculated using the formula.

OBSERVATIONS AND CALCULATIONS: -

Table 1: Measurement and calculation

S.No.	Voltmeter reading, V_L (V)	Ammeter reading, I_L (mA)	Load Resistance, R_L (kΩ)	Load Power, P_L (mW)

Thenvenin's equivalent voltage, V_{Th} = __________

Internal resistance, R_{Th} = ____________________

Maximum power delivered to load, $P_{max} = \frac{{V_{Th}}^2}{4R_{Th}} =$________

PLOT: Power delivered to load vs load resistance.

Table 2: Comparison table

Parameter	From Plot	Calculated	Remarks
Load resistance (corresponding to P_{max})	R_L =	R_{Th} =	
P_{max} (delivered to load)			

RESULT: - Within the experimental error, the maximum power transfer theorem was verified.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the supply when the connections are fully done.
- Keep under consideration of ammeter and voltmeter polarities while using them to measure current and voltage respectively.

EXPERIMENT 3

AIM: -To verify superposition theorem.

APPARATUS USED: - Multimeter, resistors (220E, 470E, 1K, 4.7K), dc power sources (12V/250mA, 5V/250mA-2), connecting wires.

THEORY: - Superposition theorem states that in any linear resistive network, the voltage across or the current through any linear element may be calculated by adding algebraically all the individual voltages or currents caused by the separate independent sources acting alone, will all other independent sources replaced by their internal resistances.

Superposition theorem is applicable only to linear circuits, the circuits consisting of linear circuit elements only, and to voltage and current not to power.

FORMULA USED: -

$$Current\ in\ branch\ i, I_i = \sum_{k=1}^{n} I_i^k \ ; k\ is\ the\ k^{th}\ source\ acting\ alone$$

CIRCUIT DIAGRAM: -

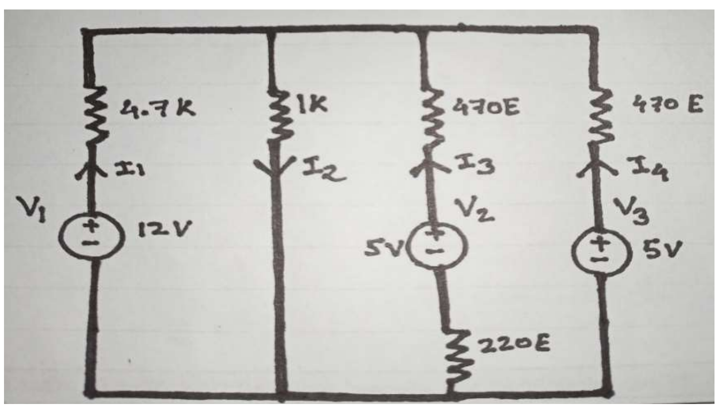


Fig 1: Circuit to verify superposition theorem

PROCEDURE: -

- Connected the circuit as per the circuit diagram given in Fig 1 to verify superposition theorem.
- Measured the current magnitude and direction through each branch using multimeter connecting it in series with respective branch one by one.

- Now, took out the other sources such that only 12V source remained in the circuit, and short circuited the terminals from where the sources were removed.
- Powered on the circuit, and measured the current magnitude and direction through each branch using multimeter.
- Repeated the above two steps for each source.
- Took the algebraic sum of currents computed for respective branches when only one source was acting alone, and compared with the current through the respective branch when all the sources were connected.

OBSERVATIONS: -

S.No.	Source connected	Branch current, I_k (mA)	
1	All sources connected	I_1	
		I_2	
		I_3	
		I_4	
2	V1 (12V) source acting alone	I_1^1	
		I_2^1	
		I_3^1	
		I_4^1	
3	V2 (5V) source acting alone	I_1^2	
		I_2^2	
		I_3^2	
		I_4^2	
4	V3 (5V) source acting alone	I_1^3	
		I_2^3	
		I_3^3	
		I_4^3	

CALCULATIONS: -

S. no.	Branch Current	Measured (mA)	Calculated (mA)		Remarks
1	I_1		$I_1^1 + I_1^2 + I_1^3$		Measured current and calculated current are nearly same
2	I_2		$I_2^1 + I_2^2 + I_2^3$		Measured current and calculated current are nearly same
3	I_3		$I_3^1 + I_3^2 + I_3^3$		Measured current and calculated current are nearly same
4	I_4		$I_4^1 + I_4^2 + I_4^3$		Measured current and calculated current are nearly same

RESULT: - Within the experimental error, the superposition theorem was verified.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the supply when the connections are fully done.
- Disconnect the voltage source from the circuit before short circuiting the terminals at which the source is connected while replacing the source with its internal resistance.

EXPERIMENT 4

AIM: -To verify Thevenin's theorem.

APPARATUS USED: - Multimeter, resistors (100E, 220E, 470E, 1K, 2.2K), fixed dc power sources (12V/250mA, 5V/250mA), variable resistor - 470Ω, variable dc power source – 12V, connecting wires.

THEORY: - Thevenin's theorem states that any linear-bilateral circuit consisting of independent or dependent voltage and current sources can be replaced by an equivalent circuit consisting of a voltage source V_{Th} in series with a resistor R_{Th}, where V_{Th} is the open-circuit voltage at the terminals and R_{Th} is the input or equivalent resistance at the terminals when the independent sources are replaced with their internal resistances.

CIRCUIT DIAGRAM: -

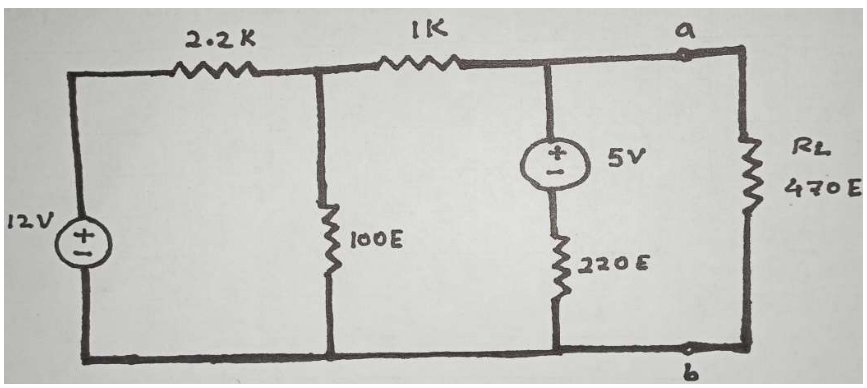


Fig 1: Circuit to verify Thevenin's theorem

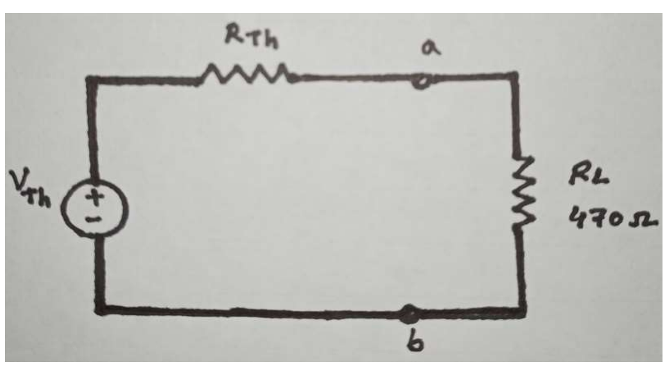


Fig 2: Thevenin's equivalent circuit diagram

PROCEDURE: -

- Connected the circuit as per the circuit diagram given in Fig 1 to verify Thevenin's theorem.

- Measured the voltage across the 470Ω resistor using multimeter set to voltmeter range.
- Now, to apply Thevenin's theorem, took out the load resistor 470Ω to open circuit the branch a-b.
- Measured the open circuit voltage V_{Th} across the branch a-b using multimeter set to voltmeter range.
- Took out the voltage sources from the circuit and replaced them with short-circuit.
- Measured the equivalent resistance R_{Th} seen from the opened branch a-b using multimeter set to ohmmeter range.
- Set the variable resistor value equal to R_{Th} and variable voltage source to V_{Th}.
- Connected the load resistor 470Ω in series with variable resistor and variable voltage source.
- Measured the voltage across the load resistor using multimeter set to voltmeter range.

OBSERVATIONS: -

Load voltage V_L before applying Thevenin's theorem	Thevenin's equivalent voltage, V_{Th}	Thevenin's equivalent resistance, R_{Th}	Load voltage V_L after applying Thevenin's theorem	Remark

RESULT: - Within the experimental error, the Thevenin's theorem was verified.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the supply when the connections are fully done.
- Disconnect the voltage source from the circuit before short circuiting the terminals at which the source is connected while replacing the source with its internal resistance.

EXPERIMENT 5

AIM: -To verify Norton's theorem.

APPARATUS USED: - Multimeter, resistors (100E, 220E, 470E, 1K, 2.2K), fixed dc power sources (12V/250mA, 5V/250mA), variable resistor - 470Ω, variable dc power source – 12V, connecting wires.

THEORY: - Norton's theorem states that any linear-bilateral circuit consisting of independent or dependent voltage and current sources can be replaced by an equivalent circuit consisting of a current source I_{sc} in parallel with a resistor R_{int}, where I_{sc} is the short-circuit current in the short circuited branch across which the theorem is to be applied and R_{int} is the input or equivalent resistance seen from the opened terminals on which the theorem is to be applied when the independent sources are replaced with their internal resistances.

CIRCUIT DIAGRAM: -

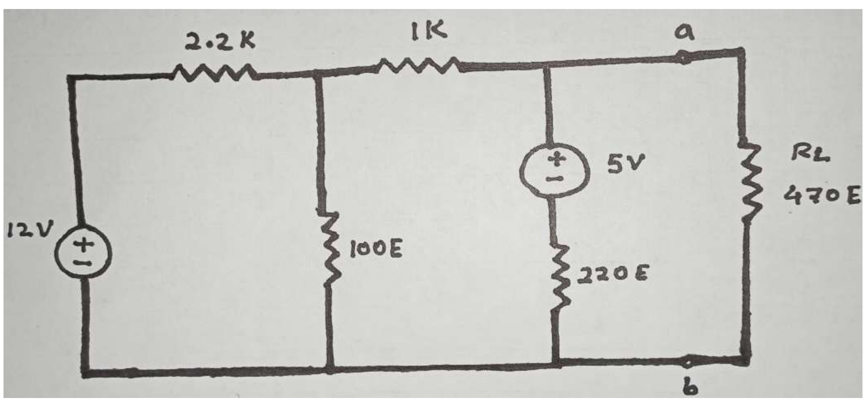


Fig 1: Circuit to verify Norton's theorem

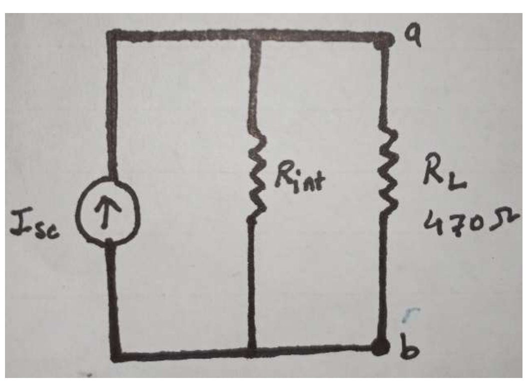


Fig 2: Norton's equivalent circuit diagram

PROCEDURE: -

- Connected the circuit as per the circuit diagram given in Fig 1 to verify Norton's theorem.
- Measured the current flowing through the 470Ω resistor using multimeter set to ammeter range.
- Now, to apply Norton's theorem, took out the load resistor 470Ω from the circuit and short circuited the terminals a-b.
- Measured the short circuit current I_{sc} through the branch a-b using multimeter set to ammeter range.
- Took out the voltage sources from the circuit and replaced them with short-circuit.
- Measured the equivalent resistance R_{int} seen from the opened branch a-b using multimeter set to ohmmeter range.
- Set the variable resistor value equal to R_{int}.
- Connected the load resistor 470Ω in parallel with the variable resistor and variable voltage source.
- Connected the multimeter set to ammeter range in the source branch. Varied the voltage supply till the current in the branch equals the I_{sc}.
- Measured the current flowing through the load resistance branch using multimeter set to ammeter range.

OBSERVATIONS: -

Load current I_L before applying Norton's theorem	Norton's equivalent short circuit current, I_{sc}	Norton's equivalent resistance, R_{int}	Load current I_L after applying Norton's theorem	Remark

RESULT: - Within the experimental error, the Norton's theorem was verified.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the supply when the connections are fully done.
- Disconnect the voltage source from the circuit before short circuiting the terminals at which the source is connected while replacing the source with its internal resistance.
- Set the variable voltage supply to 0V before connecting it to the circuit.

EXPERIMENT 6

AIM: - To measure power and power factor in a single-phase ac circuit, and hence obtain impedance, resistance and reactance of the circuit.

APPARATUS USED: - 1 phase supply (220V), wattmeter (300V, 5A), ac voltmeter (0-300V), ac ammeter (0-5A), inductance coil (8A rating), 4 steps-resistive load (1kW, 220V) and connecting wires.

THEORY: - In single phase circuits, wattmeter measures the active power. Voltmeter and ammeter measure rms voltage and current respectively. Inductance in the circuit makes the current to lag behind the voltage. The amount the current lag in the circuit is measured in terms of power factor. Higher the inductive reactance, lower will be the power factor. The power factor must not be too low, otherwise the system will become more lossy.

FORMULAE USED: -

- $P = VI\ cos\phi$
- $Q = P\ tan\phi$
- $|Z| = \frac{|V|}{|I|}$
- $R = |Z|\ cos\phi$
- $X = |Z|\ sin\phi$

CIRCUIT DIAGRAM: -

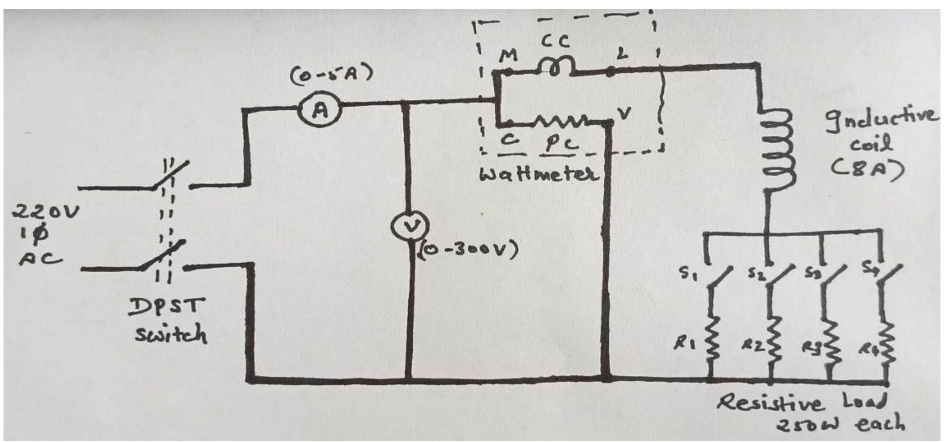


Fig: Circuit diagram for measurement of power and power factor of 1 phase ac circuit

PROCEDURE: -

- Connected the circuit as per the circuit diagram.
- Switched on the supply.
- Switched on the switch fuse unit (SFU) of the resistive load.

- Switched on the resistor one by one in steps and noted down the readings of voltmeter, ammeter and wattmeter.
- Computed the power factor, reactive power (Q), impedance (|Z|), resistance (R) and reactance (X).
- Switched off the SFU and mains supply.

OBSERVATIONS AND CALCULATIONS: -

S.No.	$V_i\ (V)$	$\mathrm{I}((A))$	$P\ (W)$	$\cos\phi$	ϕ	Q (Var)	$\lvert Z\rvert$ (Ω)	R (Ω)	X (Ω)

RESULT: - Within the experimental error if was found out that the power is consumed only by circuit resistance. As the resistance in the circuit increases, the power factor of the circuit improves.

PRECAUTIONS: -

- All the connections should be tight.
- Switch on the mains only after the connections are fully done.
- Switch off the SFU when the experiment is done.

EXPERIMENT 7

AIM: To reverse the direction of rotation of a

i. Three phase Induction motor

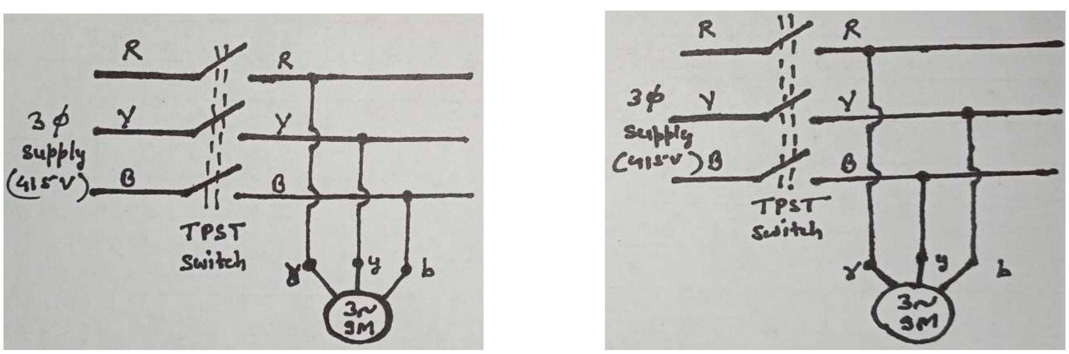
ii. DC motor

APPARUTUS USED: 3-ϕ AC supply (415v), 3-ϕ Induction motor, DC Shunt motor, DC 3point starter, DC Supply (220V), connecting leads.

THEORY: The direction of rotation of a 3-phase induction motor can be reversed by interchanging any two of the three motor supply lines. Let the phase sequence of the three-phase voltage applied to the stator winding is R-Y-B. If this sequence is changed to R-B-Y, it is observed that direction of rotation of the field is reversed i.e., the field rotates counterclockwise rather than clockwise. However, the number of poles and the speed at which the magnetic field rotates remain unchanged. Thus, it is necessary only to change the phase sequence in order to change the direction of rotation of the magnetic field. For a three-phase supply, this can be done by interchanging any two of the three lines.

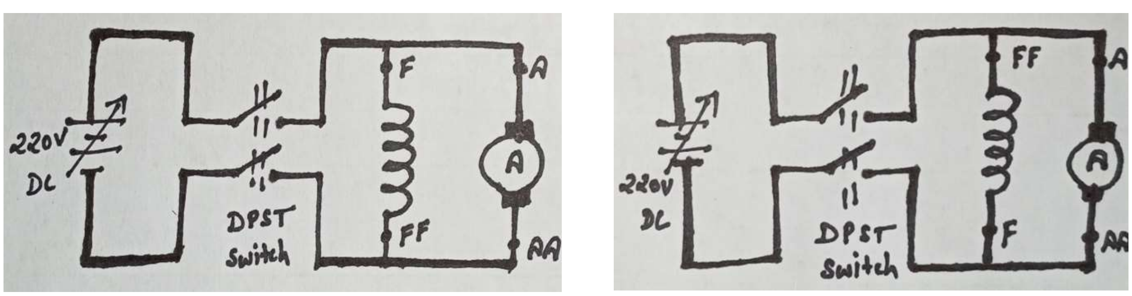
For DC motor by interchanging leads of either the field winding or the Armature winding. Generally changing direction of field is easier, because it carries lesser current as compared to armature current. However, the reversal should not be done while armature is excited.

CIRCUIT DIAGRAM:



(a) (b)

Figs. 1: Three phase Induction motor with phase (a) RYB (b) RBY.



(a) (b)

Figs. 2: DC motor (a) without changing field winding (b) with changing field winding

PROCEDURE:

For 3-ϕ induction motor:

- Made the connections as shown in Fig.1a.
- Switched on the supply.
- Started the 3-ϕ induction motor.
- Observed the direction of rotation of the motor.
- Stopped the motor by pushing stop button.
- Interchanged the leads of phase of two terminals as shown in Fig. 1b.
- Now again switched on the switch and start the motor and observed the direction rotation of the motor.
- Switched off the supply and disconnected the connections.

For DC motor:

- Made the connections as shown in Fig. 2a.
- Switched on the supply.
- Noted down the direction of motor.
- Switched off the power supply.
- Now interchanged the field winding connections or armature windings connections.
- Noted down the direction of motor.
- Switched off the supply and disconnected the connection.

OBSERVATION TABLE:

<table>
<tr><th>S. No</th><th colspan="2">Connections</th><th>Direction of Rotation</th><th>Remarks</th></tr>
<tr><td rowspan="9">Three phase induction motor</td><td>Supply R</td><td>Motor R</td><td rowspan="3"></td><td rowspan="9">When any two phases are interchanged, the direction of motor gets reversed.

When all the phases are interchanged, the direction of motor remains same.</td></tr>
<tr><td>Supply Y</td><td>Motor Y</td></tr>
<tr><td>Supply B</td><td>Motor B</td></tr>
<tr><td>Supply R</td><td>Motor R</td><td rowspan="3"></td></tr>
<tr><td>Supply Y</td><td>Motor B</td></tr>
<tr><td>Supply B</td><td>Motor Y</td></tr>
<tr><td>Supply R</td><td>Motor Y</td><td rowspan="3"></td></tr>
<tr><td>Supply Y</td><td>Motor B</td></tr>
<tr><td>Supply B</td><td>Motor R</td></tr>
<tr><td rowspan="4">DC Motor</td><td>Armature A</td><td>+ve</td><td rowspan="4"></td><td rowspan="4">When either armature or field windings terminals polarities are changed, the motor rotation gets reversed.</td></tr>
<tr><td>Armature AA</td><td>-ve</td></tr>
<tr><td>Field F</td><td>+ve</td></tr>
<tr><td>Field FF</td><td>-ve</td></tr>
</table>

	Armature A Armature AA Field F Field FF	-ve +ve +ve -ve		If both the armature and field windings terminals polarities are changed, the direction of motor rotation remains same.
	Armature A Armature AA Field F Field FF	+ve -ve -ve +ve		
	Armature A Armature AA Field F Field FF	-ve +ve -ve +ve		

RESULT: The direction of rotation of the 3-ϕ induction motor gets reversed by interchanging any two phases and direction of DC motor also get reversed either by interchanging the polarities of field winding terminals or armature winding terminals.

PRECAUTIONS:

- Connections should be neat and tight.
- Do not touch bare joints or terminals while the power supply is on.
- Make sure the switch is in off state while the terminals are interchanged.

EXPERIMENT 8

AIM: -To measure power and power factor in three phase system by two wattmeter method.

APPARATUS USED: - Three phase load (resistive – 1kW), three phase Induction motor (3hp), A.C. Wattmeter – 2 nos. (600V, 5A), ammeter (5A), multimeter, connecting wires, 3 phase supply.

THEORY: - Two wattmeter method is used to determine the power consumed by and the power factor of 3 phase load or a three-phase circuit. The three-phase circuit may be star connected or delta connected. This method is applicable to measure the power consumed by a balanced circuit as well as unbalanced circuit. The current coils of the two wattmeters are connected in series with two of the phases and the pressure coils are connected between that phase and reference phase.

CIRCUIT DIAGRAM: -

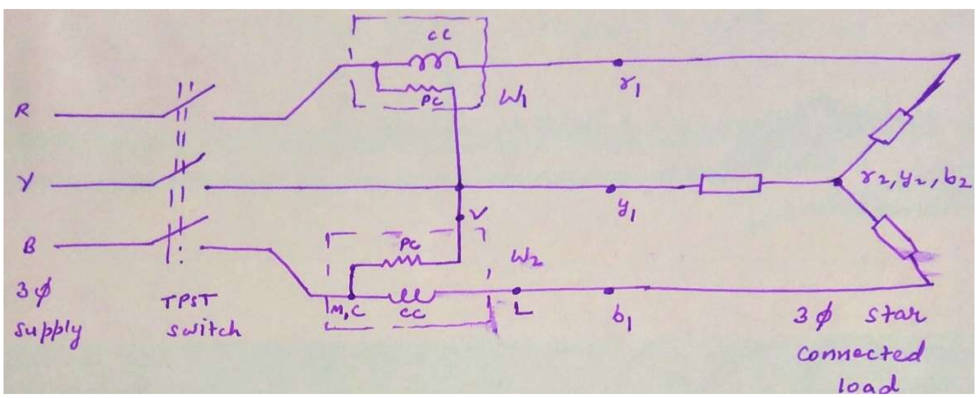


Fig: Two wattmeter method to measure power and pf

FORMULAE USED: -

$$P = W_1 + W_2$$

$$\phi = tan^{-1}\left[\sqrt{3}\left(\frac{W_2 - W_1}{W_2 + W_1}\right)\right]$$

$$pf = cos\phi$$

PROCEDURE: -

- Connect the circuit as per the circuit diagram shown, taking load - 3 phase induction motor and resistive load one at a time.
- Switch on the main supply.

- If any of the wattmeter's pointer moves in reverse direction from zero, reverses its current coil connection.
- Note down readings of wattmeters, ammeter and voltmeter.
- Switch off all the loads and supply.

OBSERVATIONS: -

S.No.	W1	W2	W	ϕ	pf

RESULT: - The power and power factor of 3 phase load was measured using two wattmeter method.

PRECAUTIONS: -

- All the connections should be tight.
- The current should not exceed the current ratings of wattmeters.
- With negative deflection in wattmeter, the connections of current coil should be reversed.

EXPERIMENT 9

AIM: To perform open circuit and short circuit tests of a transformer.

APPARATUS USED: 1 phase transformer (1kVA, 220V/146V), AC voltmeter – 1 nos. (0-300V), AC ammeter – 1 nos. (0-5A), AC wattmeter – 1 nos. (0-250V, 5A), connecting wires, variac (0-300V).

THEORY: Open circuit and short circuit tests are performed to determine the efficiency of transformer. Open circuit test provides core losses occurring in the transformer. It is performed on low voltage (LV) side of transformer keeping high voltage (HV) side open. Short circuit test provides the full load copper losses and is performed on 'HV' side of transformer keeping 'LV' side short circuit. The core losses are independent of load, depend upon voltage and frequency, hence are constant losses but copper losses are load dependent and hence named as variable losses.

CIRCUIT DIAGRAM:

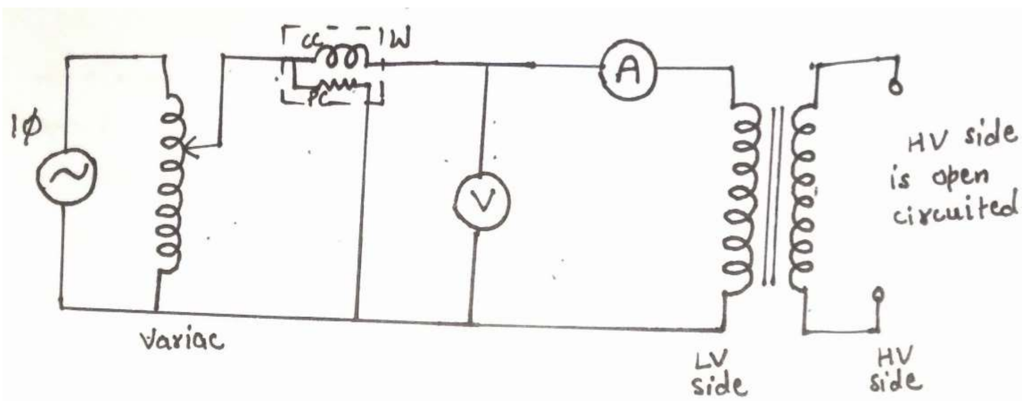


Fig. 1: Circuit diagram for open circuit test of single-phase transformer

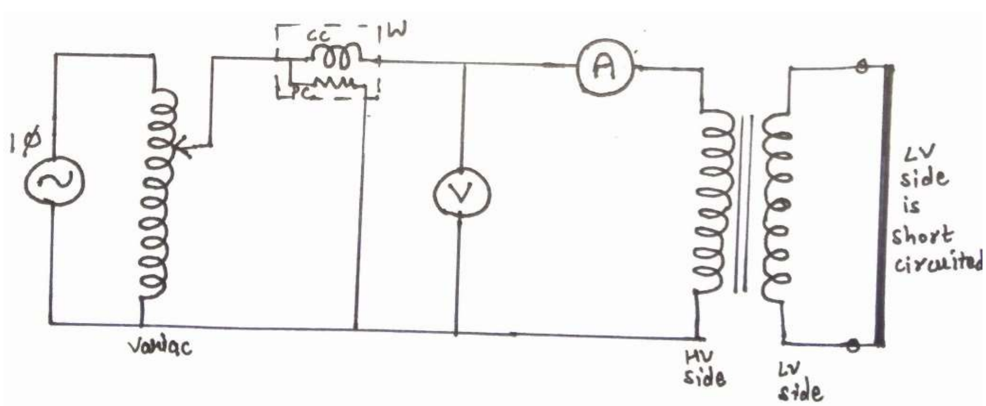


Fig. 2: Circuit diagram for short circuit test of single-phase transformer

FORMULAE USED:

Open Circuit Test:-

Parameters referred to lv side of transformer:

$$I_e = \frac{P_i}{V_o}$$

$$R_0 = \frac{P_i}{I_e^2}$$

$$I_m = \sqrt{I_o^2 - I_e^2}$$

$$X_m = \frac{V_o}{I_m}$$

Short Circuit Test:-

Parameters referred to hv side of transformer:

$$R_{eq} = \frac{P_{Cu}}{I_{sc}^2}$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}}$$

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

Equivalent Circuit parameters referred to lv side (secondary side) of given transformer: -

$$R_{2eq} = \left(\frac{N_{lv}}{N_{hv}}\right)^2 R_{eq}$$

$$X_{2eq} = \left(\frac{N_{lv}}{N_{hv}}\right)^2 X_{eq}$$

PROCEDURE:

Open Circuit Test:

- Connections are made as per circuit diagram shown in Fig. 1.
- By keeping variac voltage at zero, the supply is switched on.
- Vary the variac voltage gradually and apply rated voltage to the LV side of the transformer keeping the HV side open.
- The readings of all the meters are noted down.
- The variac is brought back to its initial zero output position and the supply is switched off.

Short Circuit Test:

- Connections are made as per circuit diagram shown in Fig. 2.

- Keeping variac voltage at zero, the supply is switched on.
- By varying the variac, a low voltage is applied to HV side of the transformer such that the rated current flows through it keeping the LV side of the transformer short circuited.
- The readings of all the meters are noted down.
- The variac is brought back to its initial zero output position and the supply is switched off.

OBSERVATIONS:

1. **Transformer rating**: -
   LV Side rated voltage –
   HV Side rated voltage –
   Rated kVA –

2. **Open Circuit Test**

V_0 (V)	I_0 (A)	W_0 (W)

3. **Short Circuit Test**

V_{sc} (V)	I_{sc} (A)	W_{sc} (W)

CALCULATIONS:

Ie =

Im =

Ro =

Xm =

Req.hv =

Xeq.hv =

Req.lv =

Xeq.lv =

EQUIVALENT CIRCUIT DIAGRAM:

RESULT: The equivalent circuit parameters were obtained using open and short circuit test conducted on given 1phase transformer.

PRECAUTIONS:

- Vary the variac gradually.
- The variac should be at zero output position before switching on the supply.
- Do not increase the current and voltage beyond the ratings of the transformer.
- An LPF wattmeter should be used for conducting open circuit test and HPF wattmeter should be used for conducting short circuit test.

EXPERIMENT 10

AIM: - To perform direct load test of a transformer and to plot efficiency vs load characteristic.

APPARATUS USED: - 1 phase transformer (1kVA, 220V/146V), Wattmeter – 2 nos. (0-250V, 4A), Voltmeter (0-300V), variac (0-270V), Ammeter (0-5A), connecting wires, Rheostat (100 Ω, 5A).

THEORY: - In transformer, the primary is fed with input supply and load is connected at secondary side. The transformer working on mutual induction principle transfers energy from input side to output side along with changing its voltage (if required). During this process of energy transfer, some energy gets lost in the form of constant core losses (hysteresis loss and eddy current loss) and variable copper losses. Thus, efficiency depends upon the load current. The maximum efficiency occurs at the load at which copper losses are equal to core losses.

CIRCUIT DIAGRAM: -

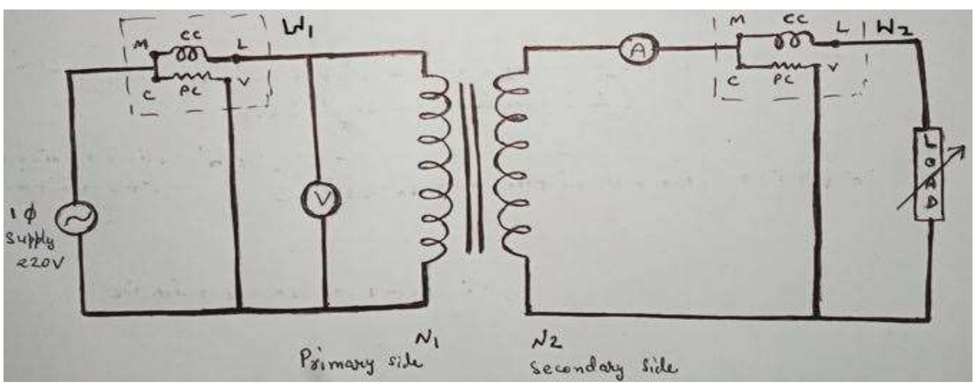


Fig: Circuit diagram for direct loading and measuring efficiency of 1phase transformer at different loading conditions

FORMULA USED: -

$$\eta = \frac{P_{out}}{P_{in}} \times 100$$

PROCEDURE: -

- Connect the circuit as per the circuit diagram shown.
- Switch on the main supply.
- Increase the input voltage slowly through variac to rated voltage of primary side (220V).
- For different load currents, output and input wattmeter readings are noted down.

- Different load currents are obtained by decreasing the resistance of the rheostat.
- Bring variac to 0V and switch off the main supply.
- Plot efficiency vs load current graph.

OBSERVATIONS: -

S.No.	Load current I_2 (A)	Input power Pin (W)	Output power Pout (W)	Efficiency (%)

RESULT: - Within the experimental error, the max efficiency was found to be approximately _______ at ________ load. The efficiency decreased as we move away from this point in either direction.

PRECAUTIONS: -

- All the connections should be tight.
- The variac should be at zero position before switching on the supply.
- Vary the variac gradually.
- Do not increase the current and voltage beyond the ratings of the transformer, various meters and rheostat, i.e., 220V and 4A.

EXPERIMENT 11

AIM: -To measure the speed of D.C. shunt motor as a function of load torque at rated armature voltage.

APPARATUS USED: - D.C. shunt motor (220V, 8A), ammeter (0-10A), 3-point dc starter, connecting wires, spring balance, tachometer and ruler.

THEORY: - D.C. shunt motors are the self-excited dc motors. The armature and field windings of the motor are connected in shunt. This motor is given constant supply voltage and thus, constant field current flows through field winding making constant flux. With increase in mechanical load on shaft of motor, armature current increases. This increase in armature current reduces the flux through armature reaction, tending to increase in speed but due to increase in drop across internal resistance of armature because of increased armature current, the back emf decreases, tending to decrease in speed. Thus, speed of shunt motors decreases with increase in load.

CIRCUIT DIAGRAM: -

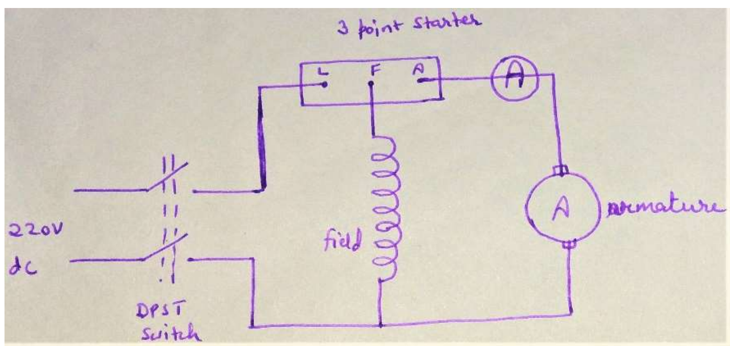


Fig: Circuit diagram to measure speed as a function of load torque in case of dc shunt motor

PROCEDURE: -

- Connected the circuit as per the circuit diagram shown.
- Switched on the main supply.
- Started the dc motor through 3-point starter.
- At the rated armature voltage, noted down the readings of spring balance.
- Measured the speed of the motor using tachometer.
- Increased the mechanical load on shaft in steps (not more than the ammeter reading 8A) and repeated steps 4 and 5.
- Measured the diameter of the brake drum using ruler.
- Plotted the speed vs torque characteristics.

OBSERVATIONS: -

Diameter of the brake drum = ___________

Radius of the brake drum, r = ___________

S.No.	W1 (kg)	W2 (kg)	W=W1-W2 (kg)	Force = W x g (N)	Torque = Force x r (Nm)	Speed (rpm)

GRAPH:-

Speed vs torque characteristics.

RESULT: - The variation of speed vs torque in case of dc shunt motor was seen. The speed decreased as the load on the shaft of the motor was increased.

PRECAUTIONS: -

- All the connections should be tight.
- Use of starter to start the dc motor is must.
- Do not apply the load more than the rating of the armature winding of the shunt motor.
- Check for the zero error in case of spring balance.

EXPERIMENT 12

AIM: - Speed control of DC shunt motor (i) Armature control method, (ii) Field control method.

APPARATUS USED: - 220V DC supply, 3-point starter, DC shunt motor (220V, 8A), ammeter (0-1A) – 2 nos., multimeter, connecting wires, rheostat (5A,45Ω for armature control method and 1.1A,260Ω for field control method).

THEORY: - The speed of dc motors can be varied using any of these three methods – varying the resistance in the armature circuit, varying the field flux and varying the armature terminal voltage.

Armature control method: In the case of armature control method, an external variable resistance is inserted in series with the armature circuit. In case of dc shunt motor, the flux almost remains constant, thus by increasing the resistance of the armature circuit, the armature current falls. This results into fall in electromagnetic torque. As load torque remains constant, thus, speed of motor decreases resulting into fall in back emf. This will again increase the armature current until electromagnetic torque does not become equal to load torque, i.e. until same armature current will not flow. Hence, this method is used to obtain speeds below the base speed. The disadvantage of this method is power loss in the external armature resistance.

Field control method: In the case of field control method, an external variable resistance is inserted in series with the field circuit. With the increase in the field circuit resistance, the field current decreases and hence the field flux. This result into fall in back emf, due to which armature current increases as applied armature voltage is constant. This increase in current results into rise in electromagnetic torque beyond load torque, and hence the speed increases. With this back emf rises and armature current decreases until again electromagnetic torque does not become equal to load torque. Thus, this method of speed control is used to obtain speeds above the base speeds. As the field current is lesser, hence the power loss is comparatively lesser in this method, therefore, this method is advantageous.

CIRCUIT DIAGRAM: -

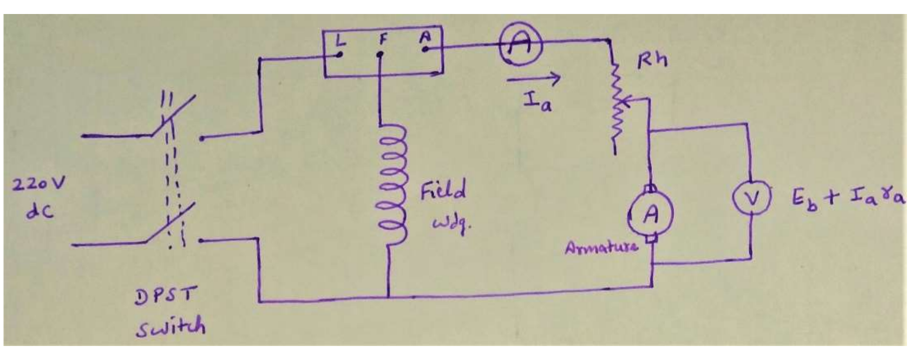


Fig 1: Circuit diagram for armature speed control method for dc shunt motors

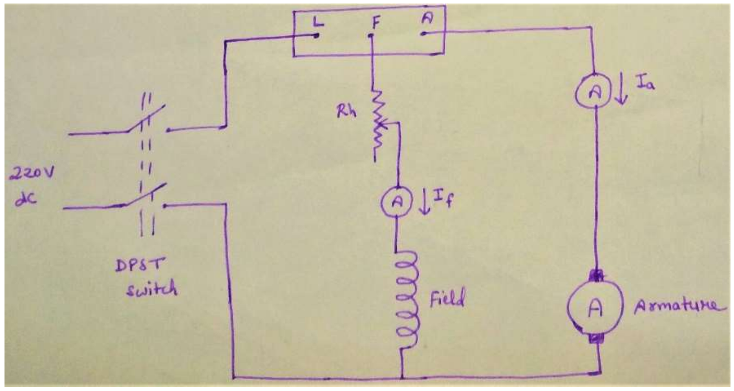


Fig 2: Circuit diagram for field speed control method for dc shunt motors

PROCEDURE: -

a. Armature control method:

- Connected the circuit as per the circuit diagram shown in Fig 1.
- Switched on the main supply and start the motor using 3 point starter keeping the armature rheostat at 0Ω position.
- Measured the armature current through the ammeter, voltage across armature through multimeter and speed using tachometer.
- Measured the voltage across the rheostat using multimeter.
- Now increased the armature circuit resistance through rheostat, and again measured armature current, voltage across armature, speed and voltage across the rheostat.
- Repeated the step 5 for different values of armature circuit resistance.
- Stopped the motor through starter.
- Switched off the main supply.
- Analyzed the speed variation with armature circuit resistance.
- Drew speed vs armature voltage curve.

b. Field control method:

- Connected the circuit as per the circuit diagram shown in Fig 2.
- Switched on the main supply and start the motor using 3-point starter keeping the field circuit rheostat at 0Ω position.
- Measured the field current through the ammeter connected in series with the field, armature current through the ammeter connected in series with the armature, and speed using tachometer.
- Measured the voltage across the rheostat using multimeter.
- Now increased the field circuit resistance through rheostat, and again measured field current, armature current, speed and voltage across the rheostat.
- Repeated the step 5 for different values of field circuit resistance.
- Stopped the motor through starter.
- Switched off the main supply.
- Analyzed the speed variation with field circuit resistance.

1. Drew speed vs field current curve.

OBSERVATIONS: -

Table1: Armature control method for speed variation for dc shunt motors

S.No.	I_a	V_{rh}	R_a Ext. $= \frac{V_{rh}}{I_a}$	$E_b + I_a r_a$	Speed, N

As the armature circuit resistance increased, the speed of the dc shunt motor ________________.

Armature current ________________ with the increase in armature circuit resistance.

Back emf ___________________ with the increase in armature circuit resistance.

Speed (N) vs Armature voltage ($E_b + I_a r_a$) curve:

Table2: Field control method for speed variation for dc shunt motors

S.No.	I_f	V_{rh}	R_f Ext. $= \frac{V_{rh}}{I_f}$	I_a	Speed, N

As the field circuit resistance increased, the speed of the dc shunt motor ___________________.

Armature current ________________ with the increase in field circuit resistance.

Field current ___________________ with the increase in field circuit resistance.

Speed (N) vs Field current (I_f) curve:

RESULT: - Armature control method for speed variation in dc shunt motors is used to have speed below base speed. Armature current and hence input power remains same for all speeds at steady state. Back emf reduces to increase the electromagnetic torque equal to load torque.

Field control method is used to have speed above base speed. Armature current and hence input power remains same for all speeds at steady state.

PRECAUTIONS: -

- All the connections should be tight.
- The starter must be used to start the motor.
- Do not increase the speed too much in case of field control method, as at high speeds field will be weak causing unstable operation due to weakening of electromagnetic torque.

EXPERIMENT 13

AIM: - To study the phase relationship among three phases in three-phase system and to verify the line-phase relationship of voltages and currents in three-phase star and delta connections.

APPARATUS USED: - Three-phase supply, voltmeter (0-600V) – 2 in nos., ammeter (0-2A) – 2 in nos., digital storage oscilloscope (DSO), bulbs (100W/220V) – 6 in nos., star-connected three-phase transformer bank (220V/9V-500mA), oscilloscope probes and connecting wires.

THEORY: - Three-phase system uses three phases to transmit electric power. Three-phase system is more efficient than single-phase system and capable of transmitting three times the power than that of single-phase system. The three-phase system makes the ac motors self-starting, whereas single-phase motors are not self-starting.

In balanced three-phase supply system the magnitude of voltages of the three phases are equal and displaced by 120° in phase with respect to each other. There are two types of connections of three-phase systems viz. star connection and delta connection. In balanced three-phase star connection system the line voltage magnitude is $\sqrt{3}$ times the phase voltage magnitude, and line current is same as that of phase current, whereas in balanced three-phase delta connection system the line current magnitude is $\sqrt{3}$ times the phase current magnitude, and line voltage is same as that of phase voltage.

CIRCUIT DIAGRAM: -

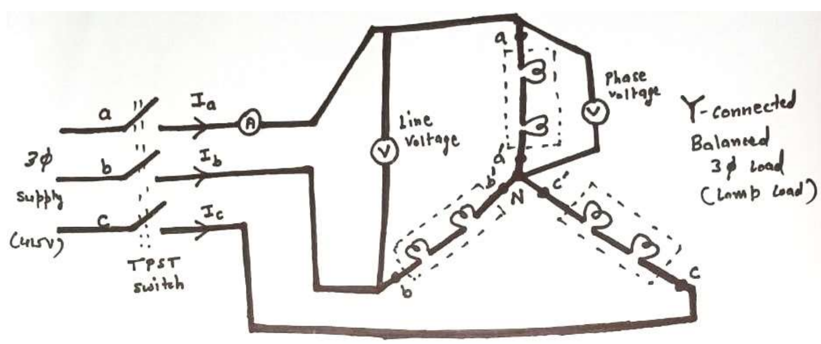


Fig 1: Circuit connection for star-connected 3ϕ system

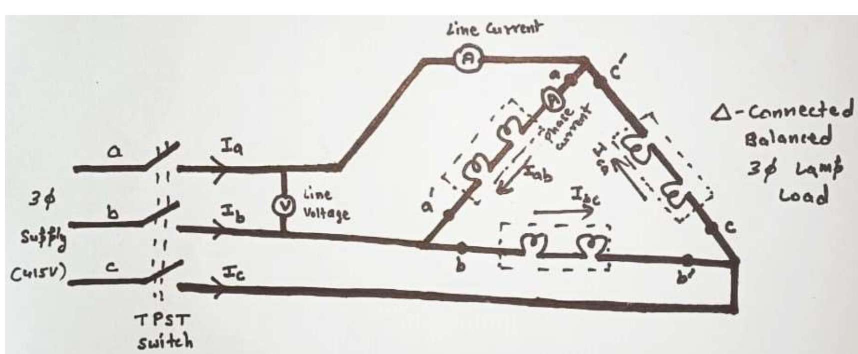


Fig 2: Circuit connection for delta-connected 3ϕ system

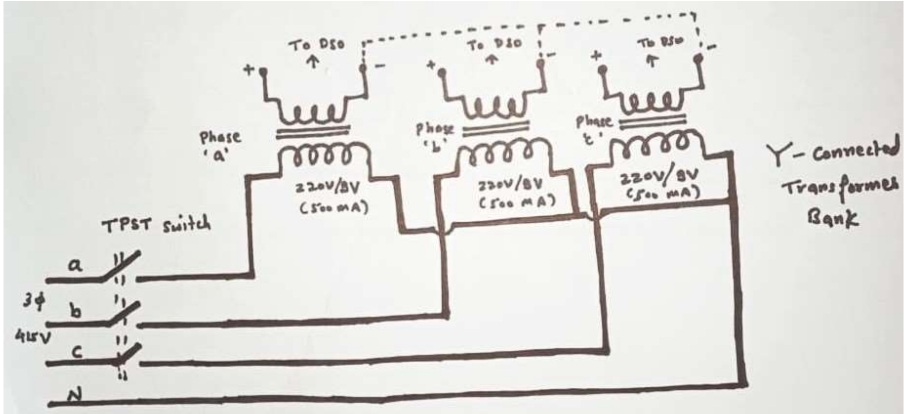


Fig 3: Circuit connection to measure phase difference between phase voltages in 3ϕ system

PROCEDURE: -

CASE A: Three-phase star connection

- Connected the circuit as per the circuit diagram given in Fig 1 to implement the three-phase star connection and switched on the three-phase supply.
- Measured the voltage between the two phases (line voltage) using voltmeter and between a phase and the star point.
- Measured the current in any phase using ammeter.
- Switched off the three-phase supply.

CASE B: Three-phase delta connection

- Connected the circuit as per the circuit diagram given in Fig 2 to implement the three-phase delta connection and switched on the three-phase supply.
- Measured the voltage between the two phases using voltmeter.
- Measured the current in line and phase using ammeter.
- Switched off the three-phase supply.

CASE C: Phase difference measurement

- Connected the circuit as per the circuit diagram given in Fig 3.
- Connected the DSO probes across the low voltage (lv) side of two transformers of transformer bank.
- Switched on the three-phase supply.
- Traced the waveforms displayed on DSO on a trace paper and noted down the scale of voltage and time.
- Determined the voltage level, frequency and phase difference between the two phases.
- Switched off the three-phase supply.

OBSERVATIONS AND CALCULATIONS: -

	Phase/ Line Current	**Line Voltages magnitude $\lvert V_L \rvert$**	**Phase Voltages magnitude $\lvert V_P \rvert$**	$\frac{\lvert V_L \rvert}{\lvert V_P \rvert}$	**Remarks**
STAR-Connection	$I_A =$	$V_{AB} =$	$V_A =$		Line currents and phase currents are same. Line voltages are $\sqrt{3}$ times the phase voltages In case of balanced supply and balanced load, magnitude of phase currents and voltages of all the phases are equal
	$I_B =$	$V_{BC} =$	$V_B =$		
	$I_C =$	$V_{CA} =$	$V_C =$		

	Phase/ Line Voltage	**Line Currents magnitude $\lvert I_L \rvert$**	**Phase Currents magnitude $\lvert I_P \rvert$**	$\frac{\lvert I_L \rvert}{\lvert I_P \rvert}$	**Remarks**
DELTA-Connection	$V_{AB} =$	$I_A =$	$I_{AB} =$		Line voltages and phase voltages are same. Line currents are $\sqrt{3}$ times the phase currents In case of balanced supply and balanced load, magnitude of phase currents and voltages of all the phases are equal
	$V_{BC} =$	$I_B =$	$I_{BC} =$		
	$V_{CA} =$	$I_C =$	$I_{CA} =$		

WAVEFORMS:

	Voltage (V)			**Frequency**	**Phase Difference**
	Peak sec. side of Transformer	**RMS sec. side** $\frac{Peak\ value}{\sqrt{2}}$	**RMS Prim. side** $Turn\ ratio,\ n = \frac{220}{9}$		
Phase a					
Phase b					
Phase c					

RESULT: - Within the experimental error, the line and phase voltages and currents relationship in star and delta connected three-phase system was verified. The phase differences among the phases of a balanced three-phase supply are 120^o.

PRECAUTIONS: -

1. All the connections should be tight.
2. Switch on the supply when the connections are fully done.
3. Do not connect the DSO probes to 220V or 415V AC directly.
4. Switch off the three-phase supply before replacing the ammeter to different phases.