SAMRAT ASHOK TECHNOLOGY INSTITUTE (S.A.T.I.) Vidisha

ELECTRO MECHENICAL ENERGY CONVERSION-I LABORATORY (EE1832)

LAB MANUAL

Department of Electrical Engineering

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Experiment 1

OBJECT: -

To obtain the two single-phase supplies from the Three-phase supply by Scott connecting the two transformers

a) Study the loading on the three-phase side due to loading on 2 single phases.
b) Determine the efficiency of the combine set (2 x 2 KVA)

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	MI	0-10 A	4
2	Voltmeter	MI	0-300V,	2
3	Voltmeter	MI	0-600	1
3	Wattmeter	Dynamometer	10/20A, 300/600V	2

SPECIFICATION OF TRANSFORMERS: -

Main Transformer:

Input Winding: 200-0 V (50%), 50Hz
: 0-200V (50%), 50Hz
Output Winding: 0-230V, 50Hz
Teaser Transformer:
Input Winding: 0-115.6V (28.9%), 50Hz
: 346.4V (86.6%), 50Hz
: 400V, 50Hz
Output Winding: 0-230V, 50Hz

THEORY: -

Three phases to two phase conversion or vice versa is essential under the following circumstances.

(i) To supply power to two phase electric furnaces
(ii) To supply power to two - phase apparatus from a 3 - phase source
(iii) To interlink three phase system and two-phase systems.

(iv) To supply power to three phase apparatus from a two-phase source. The common type of connection which can achieve the above conversion is normally called Scott - connection.

Scott - connection transformer Two single phase transformers of identical rating with suitable tapings provided on both, are required for the Scott - connection. Fig shows the circuit diagram of Scott - connection with various details marked on it the two transformers used for this conversion must have the following tapings on their primary windings. Transformer A - 50 percent tapping and is called the main transformer. Transformer B - 86.6 percent tapping and is called the treasure transformer. The phasor diagram of voltages across the primaries and secondaries has been shown in fig. The voltage across the primary, CO of the treasure transformer will be 86.6 percent of the voltage across the primary AB of main transformer. The neutral point of the three-phase system will be on the treasure transformer, such that the voltage between O and N is 28.8 percent of the applied voltage. Thus, the neutral point divided the treasure primary winding, CO in the ratio of 1:2.

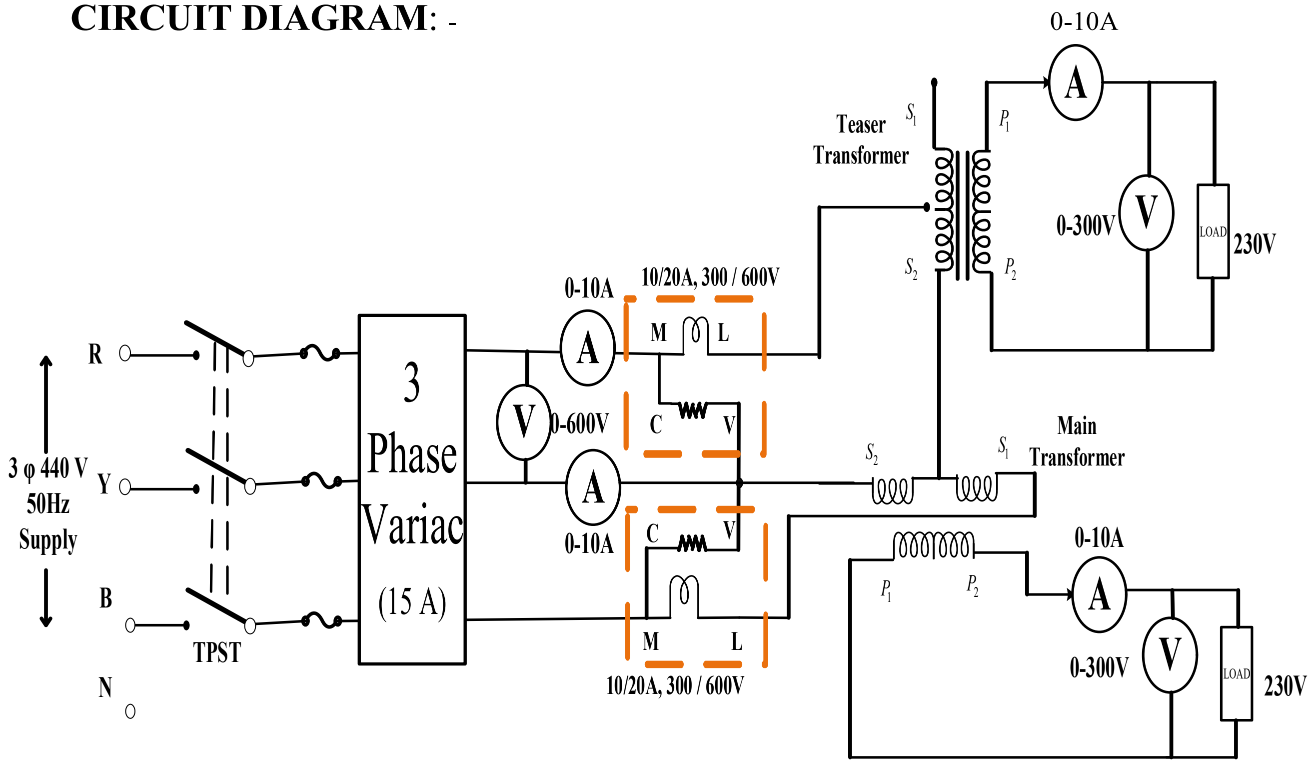
The behaviour of the above circuit can be studied experimentally, under the following different conditions of loading.

(1) **Equal loading on the two secondaries at unity power factor**: If the two secondaries of main and teasure transformers carry equal currents at unity power factor (resistive load), the current flowing the primary windings on three phase side will also will be equal and that too at unity power factor. This fact may be verified experimentally.

(2) **Equal loading on the two secondaries at 0.8 p.f. lagging**: Load the two secondaries with equal current but with inductive load at 0.8 p.f. lagging. Then the currents on the primary side will also be balanced and that too at 0.8 p.f. lagging, a fact which may be verified experimentally.

(3) **Unequal loading on the two secondaries with different power factors**: If both the current and power factor are different in the two secondaries of the transformers used for scott - connection, then the current on the primary side will also be unbalanced, again a fact which can be verified experimentally.

CIRCUIT DIAGRAM: -



OBSERVATION TABLE: -

S.No	W_1	W_2	I_1	V_1	V_2	Balance condition		Unbalanced condition	
						I_2	I_3	I_2	I_3
1									
2									
3									

CALCULATIONS: -

Input = $W_1 + W_2$ watts

Output = $V_1 I_1 + V_2 I_2$ watts

$$\eta = \frac{Output}{Input}$$

CONCLUSION: - The efficiency of Scott connection of transformer set is determined for different single-phase current for balance and unbalanced conditions. A graph of η vs total input power is plotted.

QUESTIONS

1. Is it possible to obtain 3-phase balanced ac system from a 2-phase balanced ac system using Scott connection?
2. Why is it essential that 86.6 percent tapping must be there in teasure transformer?
3. What tapping should be available on the main transformer and why?
4. Draw a simple phasor diagram, showing the primary and secondary voltages of Scott connected transformers.
5. Comment about the iron losses occurring in main and teasure transformer, specially from the consideration of their equality or inequality.

Experiment 2

OBJECT: -

a) To plot the magnetization characteristics of DC shunt generator running at rated speed.
b) To calculate the critical resistance of the field circuit.
c) To deduce the magnetization characteristics at a speed 80 percent of the rated speed.

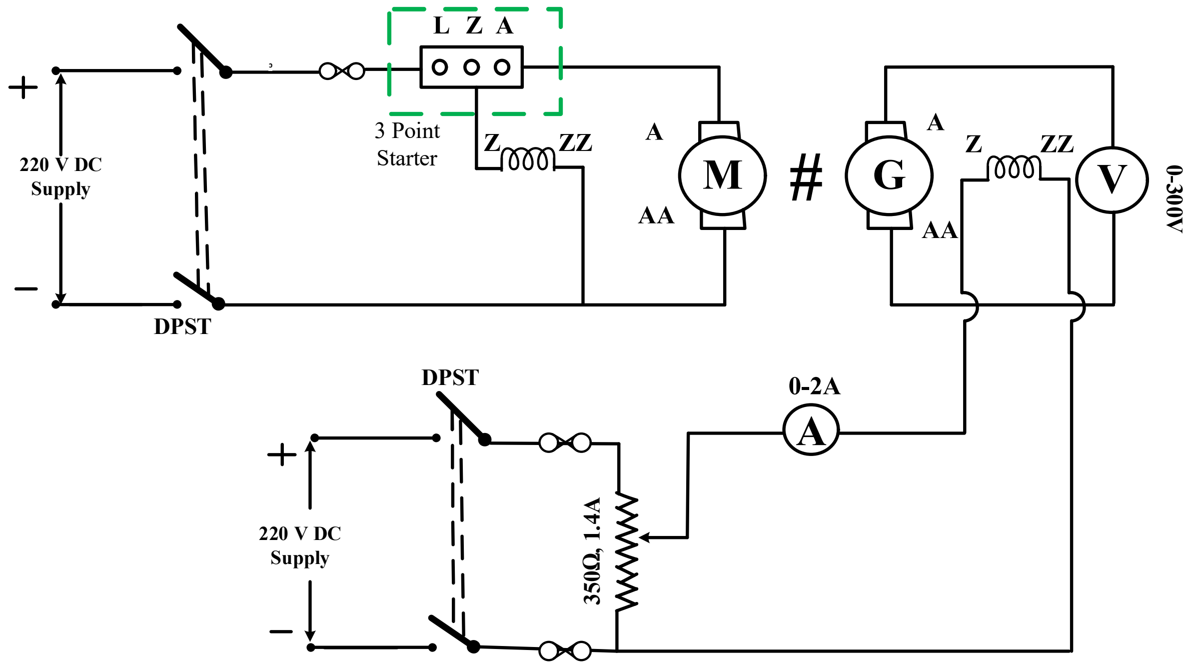
APPARATUS REQUIRED: -

S.no	Name	Type	Range	Supply	Quantity
1	Ammeter	PMMC	0-2 A	DC	1
2	Voltmeter	PMMC	0-300V		1
3	Rheostat		350Ω/1.4A		1

SPECIFICATION OF MACHINE: -

Power	5 HP
R.P.M	1450
Volts	220V
Rated current	21 A

CIRCUIT DIAGRAM:



THEORY AND FORMULA: -

The emf generated in the armature winding of a DC generator under no load operation is given by

$$E_b = \frac{P\varphi NZ}{60\ A}$$

$$= k\varphi N$$ (P, Z and A are constant for a particular generator)

Hence at constant given speed, no load emf E_b, is directly proportional to the flux per pole φ which in turn depends upon the field current, I_f The characteristic curve showing the relationship between the field current, I_f and the generated emf, at no load and at a constant speed is known as magnetization characteristic or open circuit characteristic (O.C.C.) of de generator. A small emf hardly of the order of 10 to 15 V is generated by the generator, even when the field current is zero, which is due to the residual magnetism in the poles. This characteristic of de shunt generator is obtained by separately exciting the field.

Critical resistance of the field circuit can be obtained by drawing a tangent to the initial portion of the magnetization characteristic, the slope of which gives the value of the critical resistance.

To plot the field resistance line on the magnetization curve, record the voltage across the shunt field during experimentation.

The magnetization characteristic of a particular generator will be different for different speeds. Various points on the magnetization curve corresponding to a speed $\boldsymbol{N_2}$, can be obtained knowing the emf $\boldsymbol{E_{g1}}$ corresponding to the rated speed $\boldsymbol{N_1}$, and utilizing the equation given by,

No load emf at speed N_2, $E_2 = E_g \times \frac{N_2}{N_1} (E_g = k' N)$

It may be noted clearly that E_n and E_a are the no load emf corresponding to same field current but for different speeds N_1 and N_2 respectively.

OBSERVATION TABLE: -

S.No.	For increasing field current		For decreasing field current	
	$E_g(Volt)$	$I_f(Amp)$	$E_g(Volt)$	$I_f(Amp)$
1				
2				
3				

QUESTIONS: -

1. Define critical resistance of the field circuit of DC generator.
2. Discuss with suitable characteristics the term "critical speed " of the generator.
3. Discuss various conditions for self-excitation of shunt generator.
4. Draw and discuss the magnetization characteristic of a de series generator.
5. If the above generator is running as a shunt generator at 80 percent of its rated speed, to what value of voltage will it excite?

Experiment 3

OBJECT: - To perform Parallel operation of two single phase transformer.

(a) Polarity test

i. Additive polarity ii. Substrative polarity

(b) Load test

i. Balanced load ii. Unbalanced load

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	M.I.	0 -5A	1
2	Ammeter	M.I.	5 -10A	1
3	Voltmeter	M.I.	150 / 300V	1
4	Rheostat	Single tube	4.5Ω, 5 Ω	1

SPECIFICATION OF TRANSFORMER: -

Rated KVA	1KVA
Rated Primary voltage	230V
Rated secondary voltage	110V
Frequency	50Hz

CIRCUIT DIAGRAM

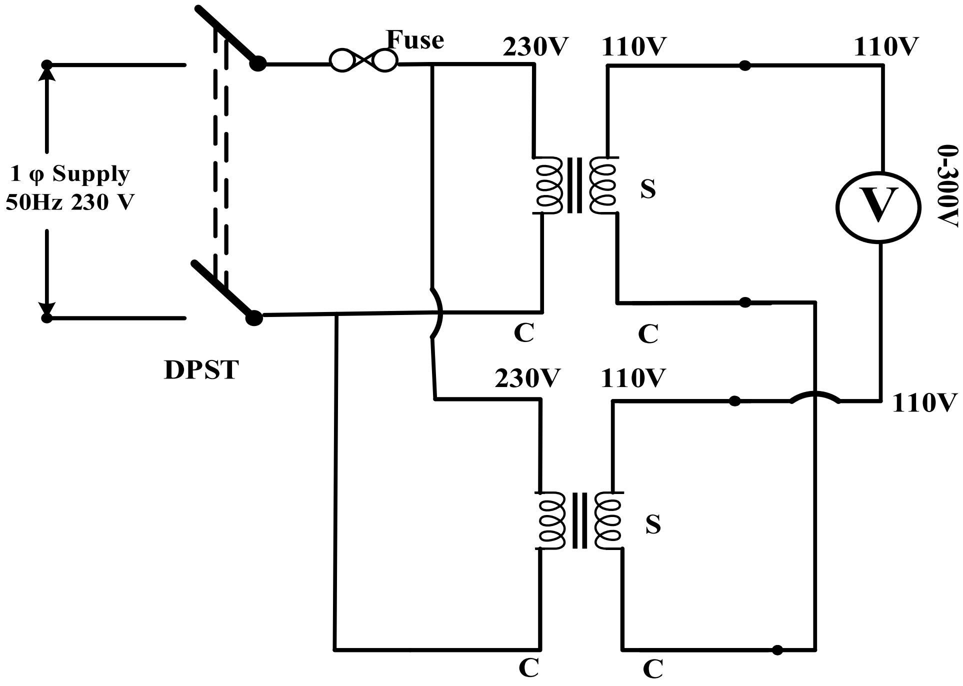


Fig. 1

Subtractive polarity of two single phase transformer

Observation table of Subtractive polarity: -

S.No	V_1	I_1	I_2	I_3
1				
2				
3				
4				

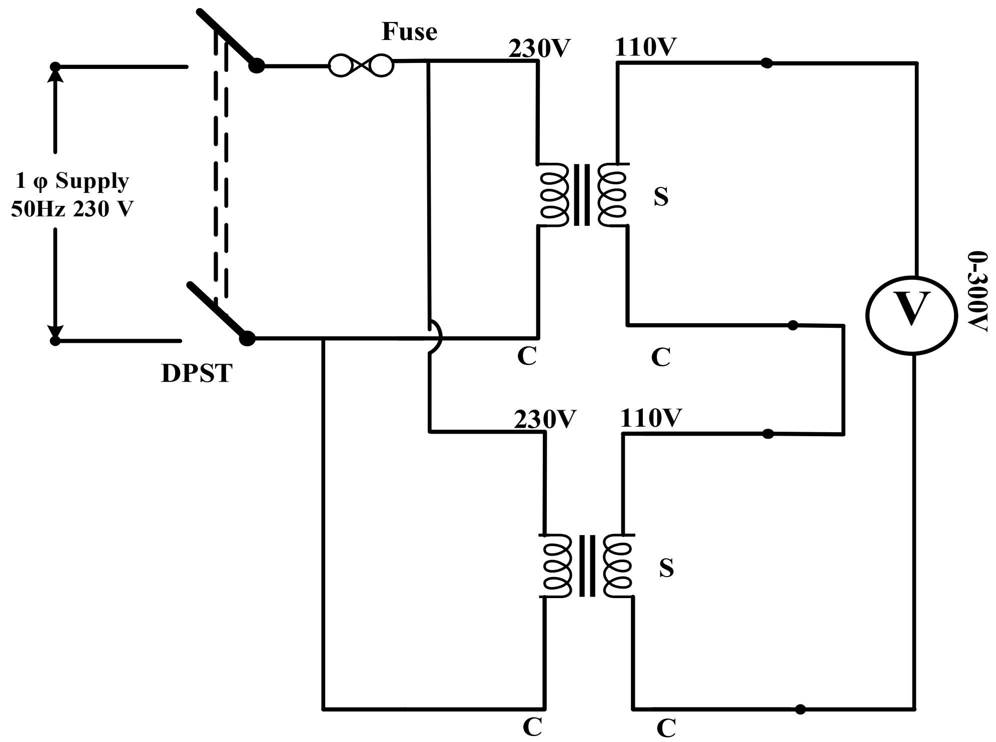


Fig. 2
Additive polarity of two single phase transformer

Observation table of Additive polarity: -

S.No	V_1	I_1	I_2	I_3
1				
2				
3				
4				

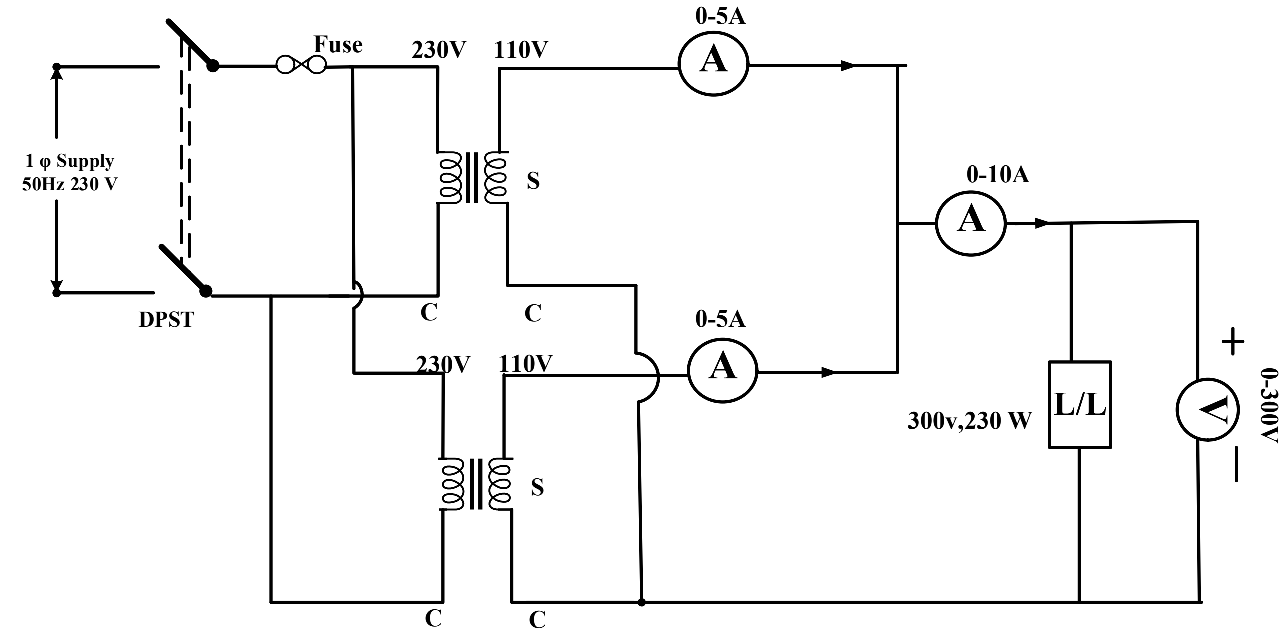


Fig. 3
Balance Load

Observation table of balanced load: -

S.No	V_1	I_1	I_2	I_3	$I_3 = I_1+I_2$ (Balanced)
1					
2					
3					
4					

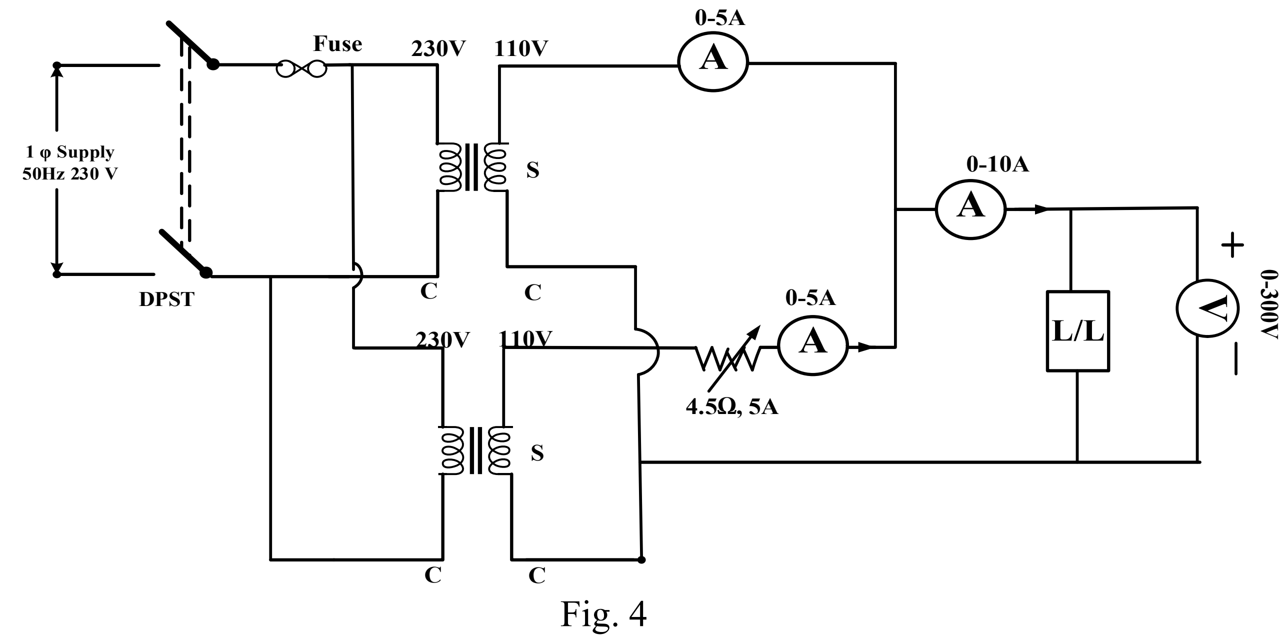


Fig. 4
Unbalance Load

Observation table of unbalanced load: -

S.No	V_1	I_1	I_2	I_3	$I_3 \neq I_1 + I_2$ (Unbalanced)
1					
2					
3					
4					

THEORY: -

Parallel operation of transformers is frequently necessary in the power system network, which consist of a number of transformers installed at generating stations, substations etc. When operating two or more transformers in parallel (on the primary as well as secondary sides), their satisfactory performance require that the following conditions must be satisfied.

(a) For single phase transformers

(1) The same polarity
(2) The same voltage ratio.

(b) For three phase transformers

(i) The same polarity
(ii) Zero - relative phase displacement
(iii) Same phase sequence
(iv) Same voltage ratio.

In addition to the above essential requirements, the transformers to be operated in parallel should have the following for better load sharing and operating power factor. (i) equal per unit impedances (ii) equal ratios of resistance to reactance.

Polarity Test

Each of the terminals of primary as well as secondary winding of a transformer is alternately positive and negative with respect to each other. It is essential to know the relative polarities at any instant of the primary and secondary terminals for making correct connections under the following type of operation of the transformer.

(i) When two single phase transformers are to be connected in parallel to share the total load on the system.
(ii) For connecting three single phase transformers to form a 3-phase bank with proper connections of primary and secondary windings.

Referring fig, if at any instant, the induced emf E, in the primary winding acts from the terminals marked A_2 to A_1, the induced emf E_2 in the secondary winding will act from a2 to a i.e., if at any instant A, is positive and A, negative with respect to the applied voltage V_1 across the primary winding then the terminal voltage V_2 across the secondary winding will be positive at a, and negative at a2. If the two windings are connected by joining A, to a; as shown in fig and an alternating voltage V_1 applied across the primary, then the marking are correct if the voltage V, is less than V_1. Such a polarity is generally termed as subtractive polarity, in which the induced emfs in the primary and secondary windings are subtractive. The standard practice is to have subtractive polarity for transformer connections, because it reduces the voltage stress between the adjacent leads. In case V, is greater than V_1, the emfs induced in the primary and secondary windings have an additive relation and the transformer is said to have additive polarity.

VOLTAGE RATIO: The induced emf per phase in the primary and secondary windings of a transformer is given by,

Induced emf in primary, E_1= 4.44 f φ T_1

Induced emf in secondary, E_2 4.44 f φ T_2

However, $E_1 = V_1$ and $E_2 = V_2$ V_1T_1

Hence, the voltage ratio, = V_2 T_1

QUESTIONS:

1. Under what conditions, the power factor of the load and the internal power factors of the two transformers will be different? Suggest the ways of making these equal.
2. Discuss the essentiality of parallel operation of transformers in a practical system supplying power to a wide area.
3. What is meant by circulating current with regard to parallel operation of transformers? How much percentage of circulating current can be permitted for satisfactory parallel operation? How can it be minimized?
4. Discuss with suitable diagram the importance of polarity for satisfactory parallel operation of two transformers.
5. Explain the additional essential and desirable conditions that should be satisfied for parallel operation of 3 phase transformers compared to single phase transformers.

Experiment 4

OBJECT: -

(a) To perform Swinburne's test on the DC machine, running as shunt motor at no-load.

(b) To measure the resistance of the armature windings.

(c) Determine the efficiency of the machine used as motor at $^1/_4\,th$, $^1/_2\,th$, $^3/_4\,th$, Full and 1.25 times the full load and plot the efficiency Vs Load curve.

(d) Determine the efficiency of the machine used as generator at the above loads a plot the efficiency curve on the same graph.

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	M.C.	0-2A, 0-5A ,0-20A	3
2	Voltmeter	M.C.	0-30V ,0-300V	2
3	Rheostat	Single tube	350Ω, 1.4 A	1

SPECIFICATION OF MACHINE: -

Power	5 HP
R.P.M	1450
Volts	220V
Rated current	21 A

CIRCUIT DIAGRAM: -

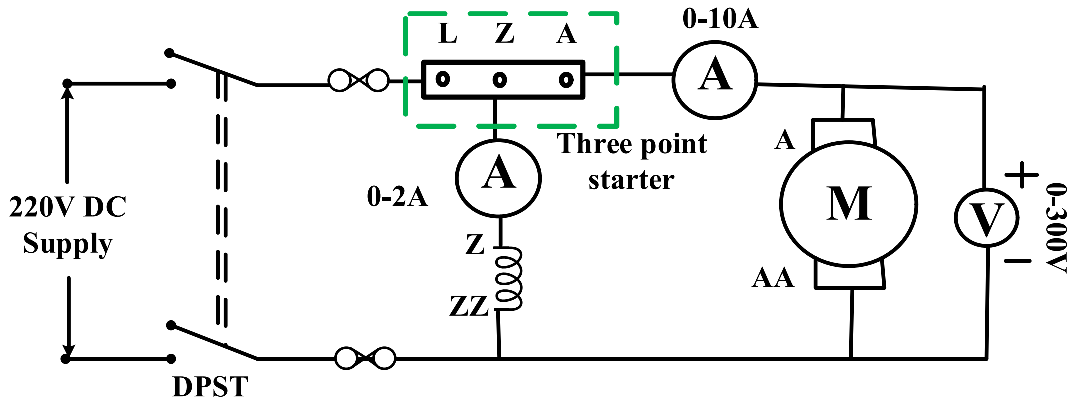


Fig. 1
Swinburne's Test on DC machine

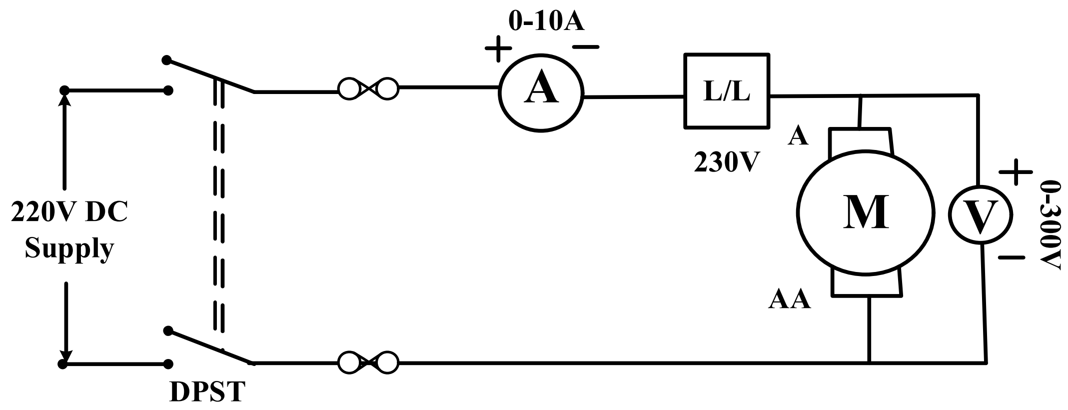


Fig. 2
Measurement of armature resistance

THEORY: -

Swinburne's test is an indirect method (without loading) for finding out the efficiency of DC machine. Various losses occurring in a dc machine can be classified as (i) constant losses and (ii) variable losses. Variable losses are directly proportional to the square of armature current or approximately the load current, whereas constant losses are independent of load conditions. In this method, constant losses are determined experimentally by operating the de machine as motor running at no load. Variable losses occurring on load are calculated from the known specifications of the machine. Let the voltage applied to the shunt motor be V volts and the current flowing in the armature and shun field circuit under no load running be Iso and I_{sh} respectively. Then,

Input power to the armature circuit $= V \; X \; I_{a0}$ watts

Input power to the shunt field circuit = $V \; X \; I_{sh}$ watts

Total input power to the motor at no load, $W_0 = V \text{ x } (I_{a0} + I_{sh})$

Armature copper losses at no load = ${I_{a0}}^2 R_a$

Thus, the constant losses of the machine, $W_c = W_0 - {I_{a0}}^2$watts.

Hence, the constant losses of de machine can be determined experimentally by recording I_{a0}, I_{sh} V and measuring the armature resistance R_a.

The Swinburne's test should be performed at rated voltage and at rated speed.

Calculation of efficiency as a shunt motor: -

Let the output of the motor as taken from name plate specifications =P_0watts

Approximate value of full load efficiency assumed η = 85 %

Thus, input power to the motor = $\frac{P_0}{0.85}$ Po = V X I_{a0}

Hence, line current drawn by the motor under full load condition, $I_{a0} = \frac{P_0}{0.85 X V}$

Armature current under full load $I_a = I_L - I_{Sh}$

Thus, armature copper losses at full load = ${I_{a0}}^2 R_a$

Total losses at full load = $W_c + {I_{a0}}^2 R_a$

Hence, efficiency of the motor at full load $\eta_{mf} = \frac{P_0}{P_0 + W_c + {I_{a0}}^2 R_a}$ X 100 %

Similarly, efficiency at 50 % full load

$$\eta_{mf/2} = \frac{P_0/2}{P_0/2 + W_c + {1/2}^2\, {I_{a0}}^2 R_a} \text{ X } 100\ \%$$

Efficiency at all other loads can be calculated in a similar way.

Calculation of efficiency as a shunt generator: -

Full load output of the generator, Po ' and its rated terminal voltage, V are obtained from the name - plate specifications of the machine

Full load output of the generator, $P_0' = V' X I_L'$

Thus, full load current, $I_L' = \frac{P_0'}{V'}$

Armature current at full load, $I_a' = I_L' + I_{sh}$

Full load armature copper losses, ${I_{a0}}'^2 R_a$

Thus, total losses at full load = $W_c + {I_{a0}}'^2 R_a$

Hence, the efficiency of the generator full load,

$$\eta_{Gf} = \frac{P_0'}{P_0' + W_c + {I_{a0}}'^2 R_a} \text{ X } 100\ \%$$

Similarly, efficiency at 50 % full load

$$\eta_{Gf/2} = \frac{P_0'/2}{P_0'/2 + W_c + {1/2}^2 \, I_{a0}'^2 R_a} \text{ X } 100\ \%$$

Efficiency at all other loads can be calculated in a similar way.

OBSERVATION: -

Swinburne's test				Armature resistance			
S.No	**V**	I_{a0}	I_{sh}	**S.no,**	V_a	I_a	R_a
1							
2							
3							
4							

QUESTIONS

1. Discuss various losses occurring in de machine under the loaded conditions.
2. What are the various parts of the dc machine, in which iron losses take place?
3. Where do the copper losses take place in a dc machine?
4. What is the major advantage of this method compared to direct loading?
5. Discuss various components of iron losses along with their variation with frequency of flux reversal, flux density etc.

Experiment 5

OBJECT: -

(a) To study the speed control of DC motor below the normal range (Rated speed) by armature resistance control and plot speed vs armature voltage characteristics.

(b) To study the speed control of DC motor above the normal range (Rated speed) by field control (FW) and plot speed vs Field current characteristics.

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	M.C.	0-2 A	1
2	Ammeter	M.C.	0-10A	1
3	Voltmeter	M.C.	0-300V	1
4	Rheostat	Single tube	350Ω, 1.4 A	1
5	Rheostat	Single tube	45Ω, 5 A	1
6	Techometer	Digital	0-2000 rpm	1

SPECIFICATIONS OF DC MOTOR: -

Power	5 HP
R.P.M	1450
Volts	220V
Rated current	21 A

CIRCUIT DIAGRAM: -

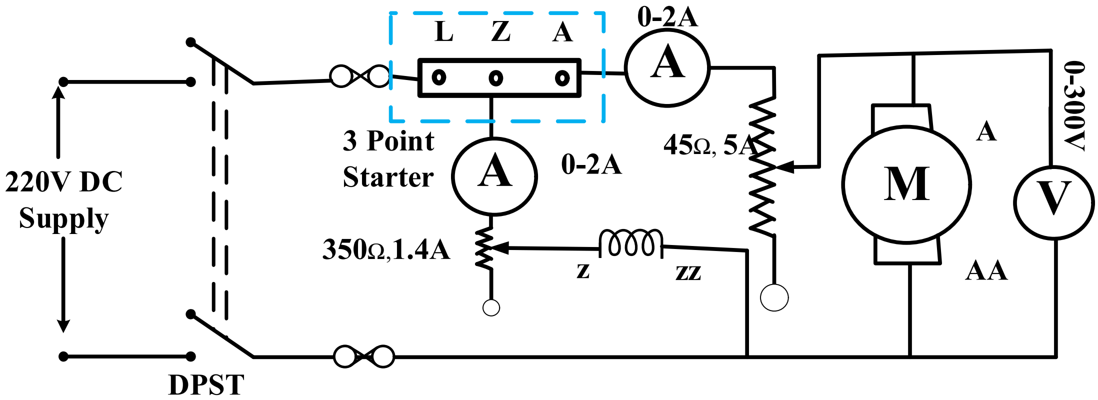


Fig. 1
Speed control of DC motor

THEORY: -

The back emf for a de motor is given by,

$$\text{Back emf, } E_b = \frac{P\varphi NZ}{60\ A}$$

The number of poles, P the armature conductors, Z and the number of parallel paths, A are constant for a particular machine. Thus, the speed of de motor is given by,

$$\text{Speed of the motor, } N= K\,\frac{E_b}{\varphi} = K\,\frac{V - I_a R_a}{\varphi}$$

The equation for the speed of the motor clearly indicates the following,

(i) Speed of the de motor can be controlled below the normal range of speed by varying the resistance in the armature circuit included in the form of a rheostat as a variable resistance (armature control).

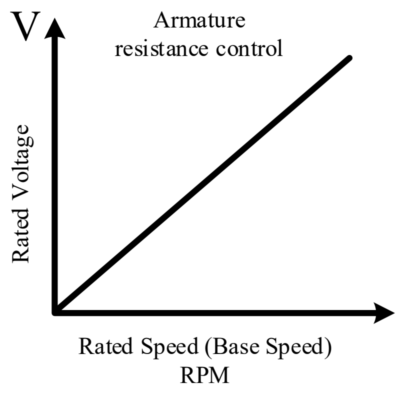
(ii) Speed of the de motor can be controlled above the normal range of speed by decreasing the flux p i.e., by decreasing the current in the field circuit by including an external resistance in the form of a rheostat as variable resistance (field control)

Armature Control

Let the external resistance in the armature circuit of de shunt motor be R ohms, then the speed equation modifies to

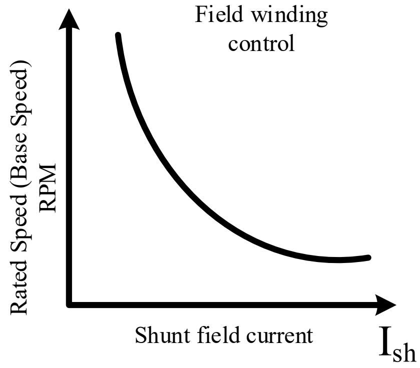
$$N= K\,\frac{V - I_a(R_a + R)}{\varphi}\ \text{rpm}$$

Hence the speed of the motor decreases with an increase in the value of external resistance R. Thus, reduced speeds lower than the no load speed can be obtained by this method. However, there is an excessive wastage of power in the additional resistance, which lowers the efficiency of the motor considerably.



Field Control

The speed of the dc motor can be increased beyond the no load speed by inserting an external resistance in the shunt field circuit. The current in the external resistance is very low, hence the losses occurring in the additional resistance is quite small.



OBSERVATION: -

Armature Control ($I_f = const$)			**Field Control ($I_a = const$)**		
S.No	**Armature voltage**	**Speed (rpm)**	**S.no,**	**Field current $A(I)$**	**Speed (rpm)**
1					
2					
3					
4					

CALCULATION & RESULTS: -

Observation of speed control of DC motor is done and graph is plotted in both armature control and field control method.

QUESTIONS

1. What is approximately the back emf developed by the motor, when it is running at the rated speed and connected across a dc supply of 220 volts?
2. Is it possible to obtain the speed higher than the rated speed by armature control, discuss?
3. Why speed control is essential from industrial point of view?
4. Discuss with suitable diagram, any other method of speed control giving wide range of speed control.
5. Is it possible to obtain speeds lower than the rated value by using field control?

6. What are the various factors to control speed of DC motor?
7. What happens when Back emf becomes zero?
8. During field weakening method suddenly motors stopes, what is the reason?

Experiment 6

OBJECT: -

(a) Perform no load and block rotor test on 3 phase induction motor.
(b) Using the data obtained above, draw the circle diagram complete in all respect.
(c) Find out, input current, power factor, slip, torque and efficiency, corresponding to full load, using the above circle diagram.
(d) Compute (i) Max power (ii) Max torque (iii) Starting torque and best power factor, utilizing the above circle diagram

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	M.I.	0-10/20 A	1
2	Voltmeter	M.I.	0-300/600V	1
3	Wattmeter	dynamometer	10/20 A, 200/400V	2
4	3Phase variac	Fully variable	15 A, 400/0-400V	1

SPECIFICATIONS OF DC MOTOR: -

Power	1 HP
R.P.M	1420
Volts	415V
Frequency	50 Hz
Rated current	7 A

CIRCUIT DIAGRAM: -

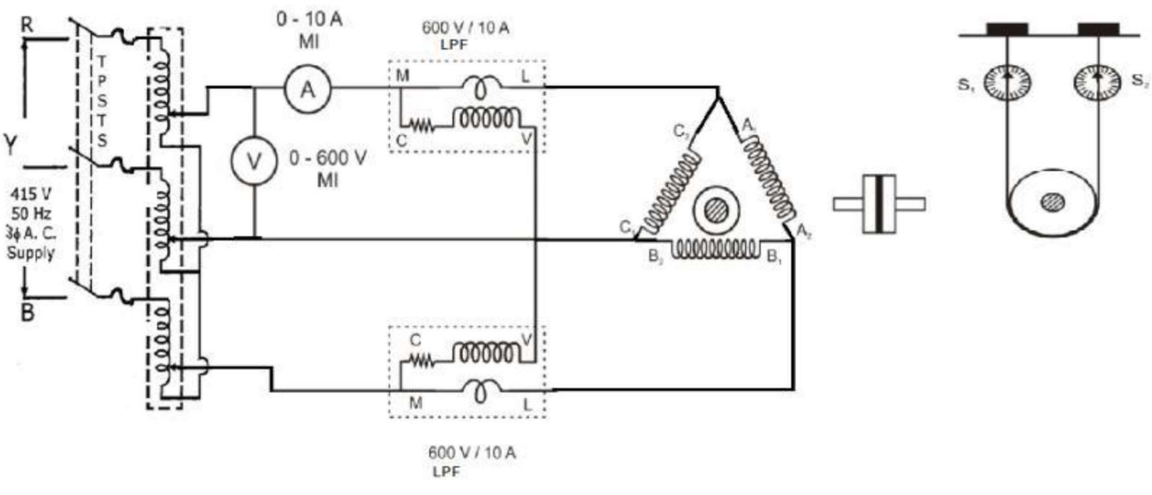


Fig 1.
No-Load and Block Rotor Tests on Three Phase Induction Motor

THEORY: -

To draw the circle diagram of a 3-phase induction motor, following data is essential.

(i) No load current, I_0 and its power factor angle, φ_0
(ii) Short circuit current, I_{sc}' corresponding to rated voltage and its power factor angle, φ_{sc}

NO LOAD TEST

To obtain no load current and its power factor angle, φ_0, no load test is performed at rated voltage and frequency. Let the readings of ammeter, voltmeter, and two wattmeters connected in the circuit be, I_0, V_0, W_{01} and W_{02} respectively c no load test. Then,

$$\tan \varphi_0 = \sqrt{3}\,\frac{W01-W02}{W01+W02}$$

Hence, no load power factor angle, φ_0, can be calculated from the readings of two wattmeter. No load current, I_0 has been directly measured by the ammeter.

BLOCK ROTOR TEST

To obtain short circuit current and its power factor angle, block rotor test is performed on the motor. In this test, rotor is not allowed to move (blocked either by tightening the belt, in case provided or by hand) and reduced voltage (25 to 30 percent of the rated voltage) of rated frequency is applied to the stator winding. This test is performed with rated current flowing in the stator winding. Let the readings of ammeter, voltmeter and two wattmeters be, I_{sc}, V_{sc}, W_{sc1} and W_{sc2} respectively under block rotor condition. Then,

$$\tan \varphi_{sc} = \sqrt{3}\,\frac{Wsc1-Wsc2}{Wsc1+Wsc2}$$

Thus, short circuit power factor angle, φ_{sc} can be calculated from the above equation.

Short circuit current, I_{sc} observed during the block - rotor test corresponds to reduced applied voltage, V, which should be converted to rated voltage of the motor for plotting the circle diagram. The relation between the short circuit current and the applied voltage is approximately a straight line. Thus, short circuit current, I_{sc}' corresponding to rated voltage, V of the motor is given by,

$$\text{Short circuit current, } I_{sc}' = \frac{V}{Vsc} \times Isc$$

It may be remembered, that the power factor of the motor is quite low at no load as well as under blocked rotor condition. Thus, one of the wattmeter connected in the circuit will give negative reading in both the test, which may be recorded by reversing the terminals of the pressure coil or the current coil.

PROCEDURE

No Load Test

1. Connect the circuit as per fig.
2. Ensure that the motor is unloaded and the variac is set at zero position.
3. Switch - on the supply and increase the voltage gradually, till the rated voltage of the motor. Thus, the motor runs at rated speed under no load.
4. Record the reading of all the meters connected in the circuit.
5. Switch - off the ac supply to stop the motor.

Block Rotor Test

1. Readjust the variac at zero position.
2. Change the ranges of all the instruments for block rotor test as suggest in the discussion on circuit diagram.
3. Block the rotor either by tightening the belt firmly or by hand.
4. Switch - on the ac supply and apply reduced voltage, so that the input current drawn by the motor under blocked rotor condition is equal to the full load current of the motor.
5. Record the readings of all the meters, connected in the circuit.
6. Switch - off the ac supply fed to the motor.
7. Measure the resistance per phase of the stator winding, following ohm's law concept.

CONSTRUCTION OF CIRCLE DIAGRAM:

1. Draw horizontal axis OX and vertical axis OY. Here the vertical axis represents the voltage reference.

2. With suitable scale, draw phasor OA with length corresponding to $I0$ at an angle $\Phi 0$ from the vertical axis. Draw a horizontal line AB.

3. Draw OS equal to ISN at an angle ΦSC and join AS.

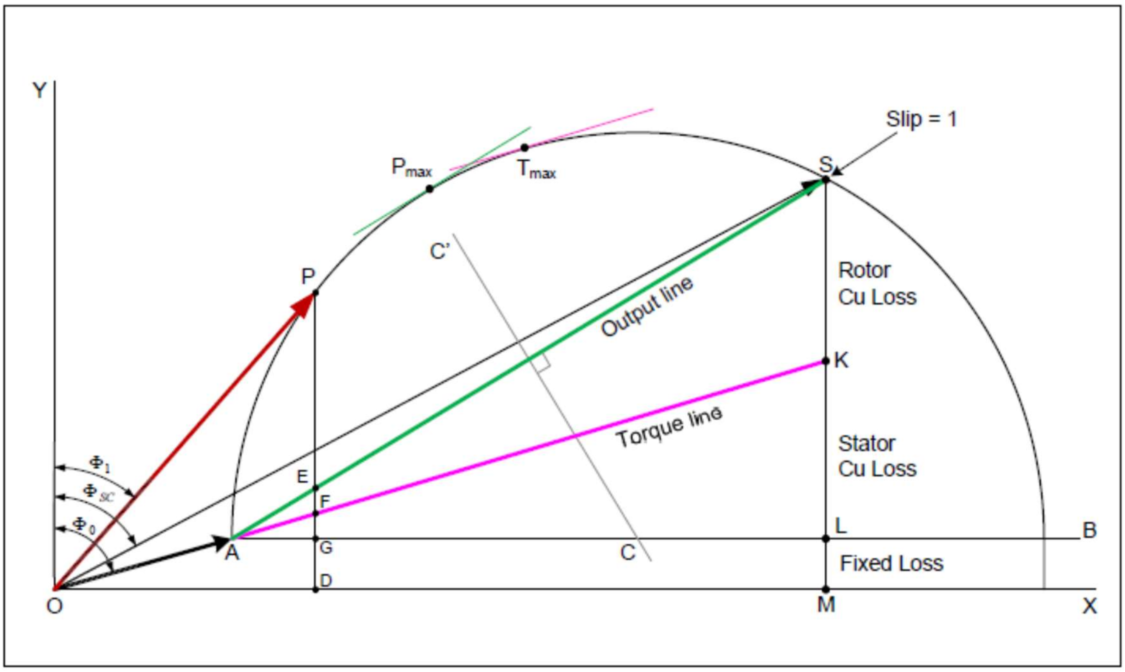
4. Draw the perpendicular bisector to AS to meet the horizontal line AB at C.

5. With C as centre, draw a semi-circle passing through A and S. This forms the circle diagram which is the locus of the input current.

6. From point S, draw a vertical line SL to meet the line AB.

7. Fix the point K as below.

For wound rotor machines where equivalent rotor resistance *R2′* can be found out:
Divide SL at point K so that SK: KL = equivalent rotor resistance: stator resistance.
For squirrel cage rotor machines: Find Stator copper loss using *ISN* and stator winding resistance *R1*. Rotor copper loss = total copper loss – stator copper loss. Divide SL at point K so that SK: KL = rotor copper loss: stator copper loss



OBSERVATION: -

S.No	No Load test				Block Rotor Test			
	V_0	I_0	W_{01}	W_{02}	V_{sc}	I_{sc}	W_{sc1}	W_{sc2}
1								
2								
3								
4								

CALCULATIONS:

The input Power = W1 + W2 = P0

Stator copper loss = $3I_{02}^2 R_1$

We have no load input power $P_0=\sqrt{3}\ VI_0 \cos\Phi_0$

$\cos\Phi 0 = P_0 / (\sqrt{3}\ VI_0)$

In phase component of load current = $I_0 \cos\Phi_0$

Magnetizing component of load current = $I_0 \sin\Phi_0$

Resistance in Magnetizing circuit = voltage per phase/$I_0 \cos\Phi_0$

Magnetizing reactance = voltage per phase/ $I_0 \sin\Phi_0$

QUESTIONS:

1. Find out various losses occurring under full load condition, using the circle diagram draw.
2. Mark clearly the stable and unstable region on the circle diagram, drawn on the basis of experimental data.
3. Discuss the fact that the input power factor of the motor increases with increase load. Draw an approximate curve to indicate this increase in power factor with load.
4. Why the no load current of an induction motor is so high, as compared to a transformer of identical rating?
5. Utilizing the information obtained in this experiment, find out the parameters of the equivalent circuit of 3 - phase induction motor.
6. Even though there is no-load, why wattmeter reading is not zero?
7. Comment on the slip of the machine when operated at rated voltage.
8. How to obtain the no-load input power to an induction motor when two-wattmeter method of measuring power used?
9. Can a three-phase induction motor be started from a single-phase supply?
10. No load test is conducted at (a)rated current, (b)rated voltage, (c)high voltage, (d)high current

Experiment 7

OBJECT: - To perform Load test on single phase transformer and to determine the following,

(a) Efficiency at different Loads and to plot efficiency (η) Vs (I_L) load current.

(b) Regulation of the transformer and to plot voltage regulations I_L load current curve.

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Wattmeter	Dynamometer	5/10A, 150 / 300V	1
2	Ammeter	M.I.	5 / 10A	1
3	Voltmeter	M.I.	150 / 300V	1

SPECIFICATION OF TRANSFORMER: -

Rated KVA	1KVA
Rated Primary voltage	230V
Rated secondary voltage	110V
Frequency	50Hz

CIRCUIT DIAGRAM: -

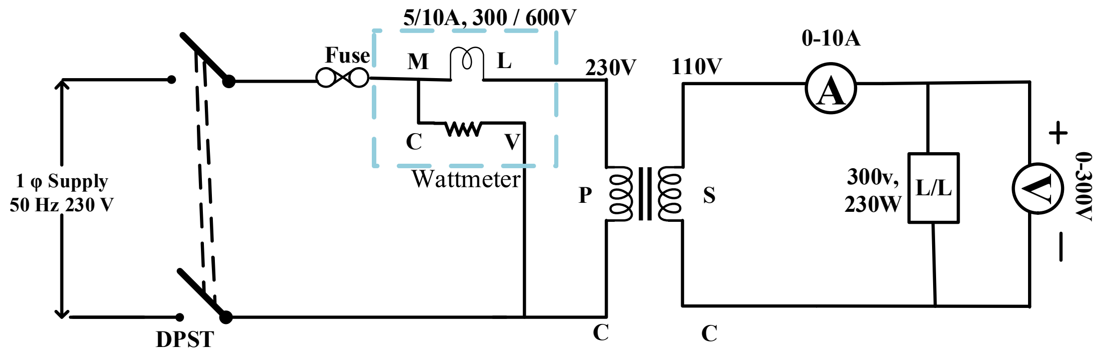


Fig. 1
Load test on single phase transformer

FORMULA AND THEORY: -

$$\text{Wattmeter constant} = \frac{\text{Voltage Range X Current Range}}{\text{Full scale deflection of the Inst.}}$$

The load test is performed on a single-phase transformer, to find out its efficiency and regulation. In this method, a resistive load is connected to the transformer and it's loaded up to the rated current. This is direct loading method and can be applied to transformers with a rating less than 5kVA.

Load test

Performance of the transformer can be determined as follows from the observations of load test.

Power input to the transformer = W_1 (reading of wattmeter)

Power output of transformer = VI watts (cosφ being unity for lamp bank load)

Thus, efficiency at a particular load, η = (VI/W_1) x 100 percent

No load voltage across secondary = E_2

Terminal voltage across secondary at a particular load =V_2

Then, regulation of the transformer at that load = $\frac{E_2-V_2}{E_2}$ x 100%

Voltage Regulation

When a transformer is supplied at a constant voltage and frequency, the secondary voltage keeps on changing depending upon the loading condition. If there is no load, the secondary terminal voltage corresponds to the induced voltage and as we load the transformer, the secondary voltage changes depending upon the load

No load secondary voltage = E2

Secondary voltage at a particular load = V2

$$\%\text{Voltage regulation} = \frac{E_2-V_2}{E_2} \text{ X } 100\%$$

The efficiency of a transformer is defined as the ratio of output power to input power and is denoted by $\boldsymbol{\eta}$

$$\eta = \frac{\text{Output Power X 100}}{\text{Input Power}}$$

OBSERVATION: -

S.No	**Input power**	**Output power**	$\boldsymbol{W_1}$	$\boldsymbol{I_2}$	$\boldsymbol{V_2}$	$\boldsymbol{V_2 I_2}$	**%** $\boldsymbol{\eta}$	**% Reg**
1								
2								
3								
4								

QUESTIONS:

1. Why the terminal voltage across the load decreases with increase in load on the transformer?
2. What is normally the range of efficiency of large rating power transformer?
3. Why the efficiency of a transformer is much higher compared to a rotating machine of similar rating?
4. Can this method be applied to determine the efficiency of large rating transformer, discuss with reasoning
5. Define regulation of the transformer and comment upon its usual values for medium and large rating transformers.
6. What is the condition at which maximum efficiency occurs, drive the condition?

Experiment 8

OBJECT: -

a) To perform short circuit test and short circuit test on single phase transformer.
b) Calculate the complete parameters of the equivalent circuit of this transformer.
c) To find the efficiency at $^1/_4\,th$, $^1/_2\,th$, $^3/_4\,th$, Full and 1.25 times the full load and plot the efficiency Vs Load curve, take the operating power factor as 0.85 lagging.
d) Evaluate the regulation at full load and at following power factor (i) 0.85 lagging (ii) unity (iii) 0.85 leading.

APPARATUS REQUIRED: -

For O.C. Test					For S.C. Test			
S.no	**Name**	**Type**	**Range**	**Quantity**	**Name**	**Type**	**Range**	**Quantity**
1	Ammeter	M.I.	0-2 A	1	Ammeter	M.I.	0-5 A, 0-10 A	1
2	Voltmeter	M.I.	0-300V, 0-150V	1	Voltmeter	M.I.	0-50V	1
3	Variac		270 V ,50A	1	Variac	Single tube	270Ω, 50A	1
4	Wattmeter	Dynameter	2.5/5A, 150/300V	1	Wattmeter	Dynameter	2.5/5A, 150/300V	1

SPECIFICATION OF TRANSFORMER: -

For open circuit test

Rated KVA	1KVA
Rated Primary voltage	110V
Rated secondary voltage	230V
Frequency	50Hz

For short circuit test

Rated KVA	1KVA
Rated Primary voltage	230V
Rated secondary voltage	110V
Frequency	50Hz

CIRCUIT DIAGRAM: -

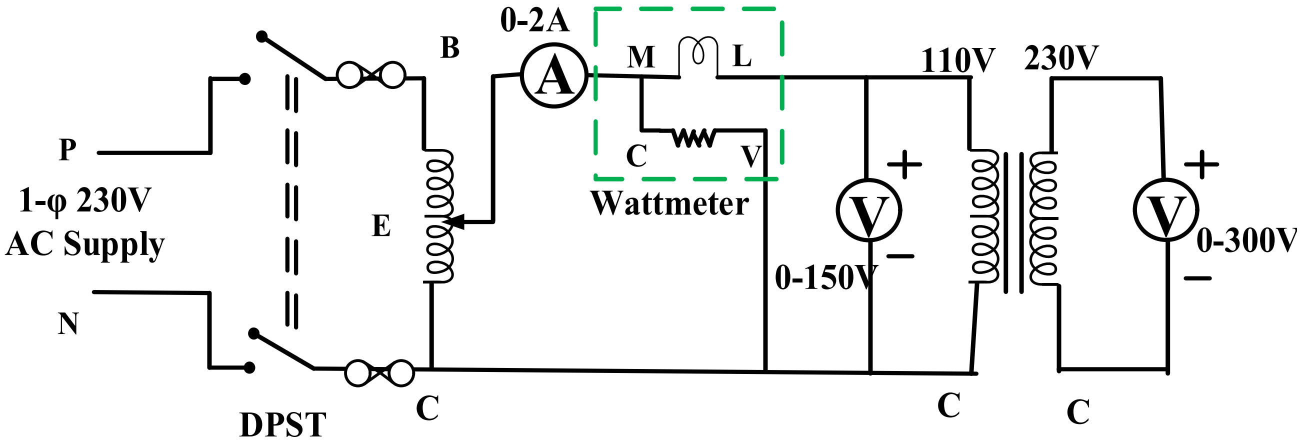


Fig. 1
Open circuit test

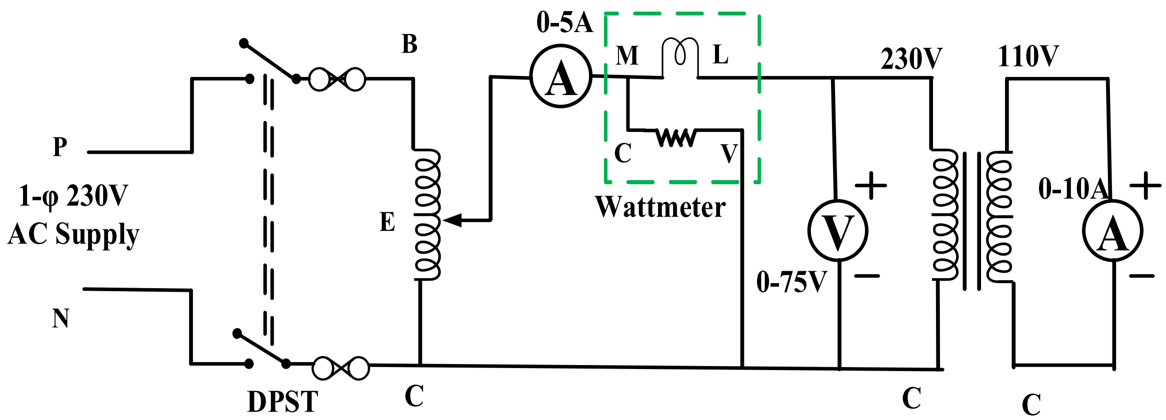


Fig. 2
Short circuit test

THEORY AND FORMULA USED: -

Open circuit test

In this test low voltage winding (primary) is connected to a supply of normal voltage and frequency (as per the rating of transformer) and the high voltage winding (secondary) is left open as shown in fig. The primary winding draws very low current hardly 3 to 5 percent of full load current (may be up to 10 % for very small rating transformers used for laboratory purposes) under this condition. As such copper losses in the primary winding will be negligible. Thus, mainly iron losses occur in the transformer under no load or open circuit condition, which are indicated by the wattmeter connected in the circuit

Hence, total iron losses = w_0 (Reading of wattmeter)

From the observations of this test, the parameters $\boldsymbol{R_0}$ and $\boldsymbol{X_m}$ of the parallel branch of the equivalent circuit can also be calculated, following the steps given below:

Power drawn, $W_0 = V_0 I_0 \text{ Cos } \varphi_0$

Thus, no load power factor, $\text{Cos } \varphi_0 = \frac{W_0}{V_0 I_0}$

Core loss component of no-load current, $I_W = I_0 \text{Cos } \varphi_0$

And, magnetizing component of no-load current, $I_m = I_0 \sin \varphi_0$

Equivalent resistance representing the core loss, $R_0 = \frac{V}{I_W}$

Magnetizing reactance representing the magnetizing current, $X_m = \frac{V}{I_m}$

Short circuit test

In this test, low voltage winding is short circuited and a low voltage hardly 5 to 8 percent of the rated voltage of the high voltage winding is applied to this winding. This test is performed at rated current flowing in both the windings. Iron losses occurring in the transformer under this condition is circuit as shown in fig. negligible, because of very low applied voltage. Hence the total losses occurring under short circuit are mainly the copper losses of both the winding, which are indicated by the wattmeter connected in the circuit as shown in the fig,

Thus, total full load copper losses = W_{sc} (reading of wattmeter)

The equivalent resistance $\boldsymbol{R_{eq}}$, and reactance $\boldsymbol{X_{eq}}$ referred to a particular winding can also be calculated from the observations of this test, following the steps given below.

Equivalent resistance referred to H.V. winding, $R_{eq} = \frac{W_{sc}}{{I_{sc}}^2}$

Also, equivalent impedance referred to HV. winding, $Z_{eq} = \frac{V_{SC}}{I_{SC}}$

Thus, equivalent reactance referred to H.V. winding, $X_{eq} = \sqrt{{Z_{eq}}^2 - {R_{eq}}^2}$

Performance calculations

Complete performance of the transformer can be calculated based on the above observations of open - circuit and short - circuit test following the steps given by,

1. Efficiency at different loads:

(a) Efficiency at full load:

Total losses at full load, = $\boldsymbol{W_0} + \boldsymbol{W_{sc}}$

Let the full load output power of the transformer in KVA be $\boldsymbol{P_0}$

Then percentage efficiency at full load $\eta_f = \frac{P_0 \ \times 1000 \times \cos}{P_0 \ \times 1000 \times \cos\varphi + W_0 + W_{sc}} \times 100$

(b) Efficiency at half the full load,

Iron losses at half the full load = W_0 (constant)

Total copper losses at half the full load = $(1/2)^2 W_{sc}$

Output power at half full load = $\frac{1}{2}\ P_0$KVA

Thus, percentage efficiency at half the full load,

$$\eta_{\frac{1}{2}f} = \frac{\frac{1}{2}P_0 \ \times 1000 \times \cos\varphi}{\frac{1}{2}P_0 \ \times 1000 \times \cos\varphi + W_0 + \frac{1}{4}W_{sc}} \times 100$$

OBSERVATION TABLE: -

	For O.C. Test							For S.C. Test						
	V_1	V_0	I_0	W_0	Cos φ=$\frac{W_1}{V_1 I_1}$	X_0	R_0	V_1	I_1	I_2	W_1	Cos $\varphi_{SC}=\frac{W_1}{V_1 I_1}$	$R_1 = R_2 = \frac{R_{eq}}{2}$	$X_1 = X_2 = \frac{X_{eq}}{2}$
1														
2														
3														

QUESTIONS: -

1. Why indirect testing of large size transformers in a must?
2. Justify that the power drawn by the transformer under no load is equal to the iron losses and under short circuit the full load copper losses.

3. What will happen to the transformer, if a sufficient voltage is applied during the short circuit test?
4. Discuss the components of iron losses along with their variation occurring in a transformer and mention the parts, in which these occur.
5. A transformer designed for 50 Hz is operated in the laboratory at 40Hz. The voltage applied is of rated value. Discuss the relative magnitude of iron losses and copper losses at 40 Hz compared to that at 50 Hz operatio.

Experiment 9

OBJECT: -

To conduct a back-to-back test (Sumpner's Test) on two identical transformer and evaluate the efficiency (η) and Voltage regulation of the transformer.

APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	MI	0-2 A 0-120 A	1
2	Voltmeter	MI	300-600V, 30-75V, 75-150	1
3	Wattmeter	Dynamometer	5/10A, 300/600V	1
4	Wattmeter	Dynamometer	10/20A 75/180V	1

SPECIFICATION OF TRANSFORMERS: -

Rated KVA	1KVA
Rated Primary voltage	230V
Rated secondary voltage	110V
Frequency	50Hz

THEORY: -

Transformer is a static device, which is used to convert AC electricity from one voltage to another without any change in frequency. Sumpner's test is also known as back-to-back test. This test requires two identical transformers and is connected as shown in circuit diagram. By this test, the equivalent Circuit parameters, efficiency, regulation & heating of both the TRANSFORMER can be determined. Each TRANSFORMER is loaded on the other and both are connected to same supply. The primaries of Two TRANSFORMERs are connected in parallel across same supply and the Wattmeter connected in Primaries reads the core losses (Iron losses) of both transformers. The secondary windings are so connected such that their potentials are in opposite to each other.

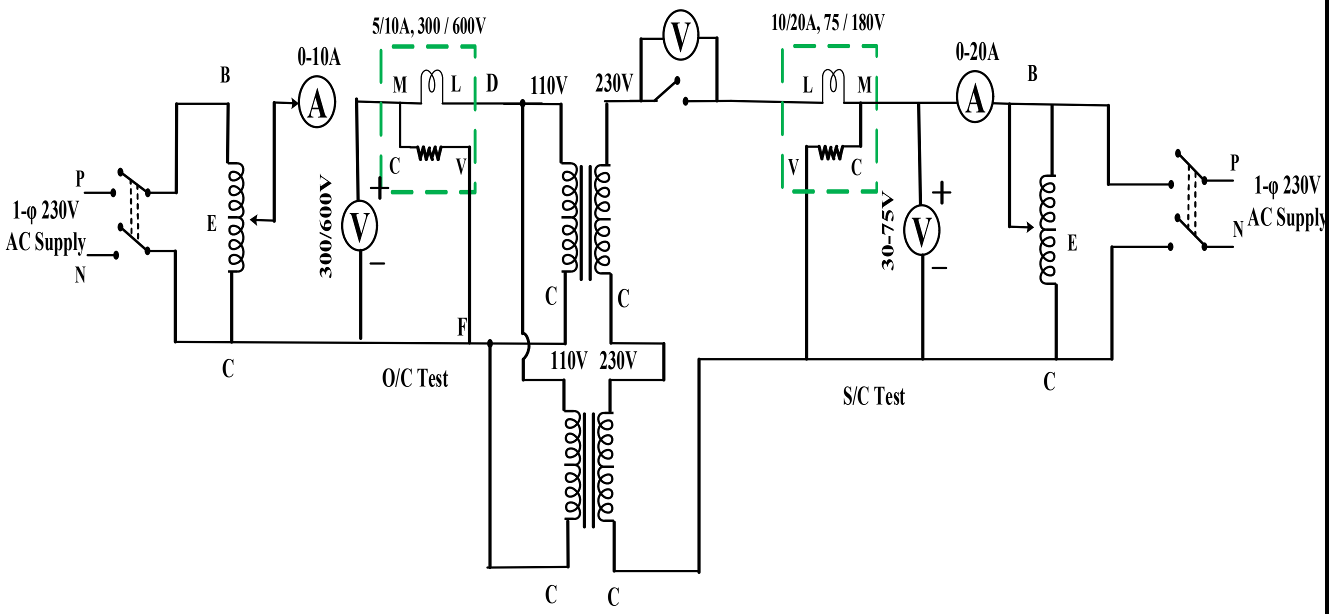
By connecting so there would be no secondary current flowing around the loop formed by the two secondary windings.
The iron loss of one transformer =1/2 W_o

The copper loss of one transformer=1/2 W_c

The total losses of one transformer=1/2 W_o+1/2 W_c

Efficiency at full load= output power/ (Output power + losses)

CIRCUIT DIAGRAM: -



OBSERVATION TABLE: -

O.C. Test						S.C. Test				
S.No	X_0	R_0	$2W_O$	$2I_2$	V_0	X_{eq}	R_{eq}	$2W_C$	I_{SC}	$2V_{SC}$
1										
2										
3										

PROCEDURE:

1. Connect the circuit as shown in the diagram
2. Apply 230v A.C. supply to primary side.
3. Note down the readings of Wo, Xo and Vo
4. Full rated current to secondary side.
5. Note down the readings of Wsc, Isc and Vsc.
6. Calculate total losses and efficiency using above formula.

QUESTIONS

1. Why two transformers, and that too identical, are needed in this test?
2. Discuss various losses occurring in a transformer along with their variation with respect to loading condition and the parts in which these occur.
3. If the iron losses and copper losses at full load in a single phase, 30 KVA, 1100/250 V, 50 Hz.
4. transformer are 300 watts and 400 watts respectively. Find out these losses at 3 / 4th of the full load. Based on the data of the above question, find out the load at which the efficiency of the transformer will be maximum and also calculate the maximum efficiency.
5. Using the data obtained in this test, find out the equivalent resistance and reactance of each transformer referred to secondary.

Experiment 10

OBJECT: -

(a) To perform Hopkinson's test on two identical DC machine.
(b) To determine the efficiency of the motor at 25 %, 50 %, 75 %, 100 % and 125 % of full load and plot its efficiency curve.
(c) To determine the efficiency of the generator at the above loads and plot the efficiency curve on the same graph

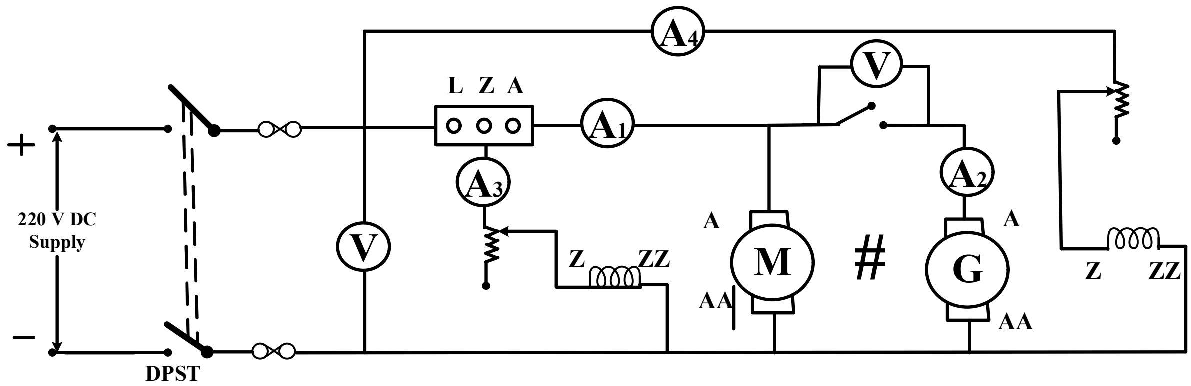
APPARATUS REQUIRED: -

S.no	Name	Type	Range	Quantity
1	Ammeter	M.C.	0-2 A	1
2	Ammeter	M.C.	0-10A	1
3	Voltmeter	M.C.	0-300V	1
4	Rheostat	Single tube	350Ω, 1.4 A	1
5	Rheostat	Single tube	45Ω, 5 A	1
6	Tachometer	Digital	0-2000 rpm	1

SPECIFICATIONS OF DC MOTOR: -

Power	5 HP
R.P.M	1450
Volts	220V
Rated current	21 A

CIRCUIT DIAGRAM: -



THEORY: -

The efficiency of the de machine can be accurately determined by the regenerative method, normally known as Hopkinson's test. This test overcomes the drawback of Swinburne's test, which does not take any account of the stray load losses occurring in de machines under loaded conditions. As such the efficiency, calculated by Swinburne's test is comparatively higher than the actual one. Hopkinson's test needs two identical de machines coupled mechanically and connected electrically as shown in fig. One of the machines is operated as motor, driving the other machine as a generator. The output power of the generator is fed to the motor. Thus, the power drawn from the supply is only to overcome the losses of both the machines. By varying the field currents of generator and motor i.e., I_4 and I_3, any desired load can be adjusted on these two machines. Referring the circuit diagram of fig.

following expressions can be established for this case.

Armature copper losses in the generator = $I_2{}^2 r_g$

Armature circuit copper losses in the motor=$(I_1 + I_2)^2 r_m$

Total power drawn by the armature circuit of the motor= V x I_1 watts

Let the sum of iron losses and mechanical losses of each machine be Wc, then

$$V \times I_1 = 2W_c + I_2{}^2 r_g + (I_1 + I_2)^2 r_m$$

$$\text{Thus, } W_c = \frac{1}{2}[V \times I_1 - I_2{}^2 r_g - (I_1 + I_2)^2 r_m]$$

Efficiency of the motor

Shunt field copper losses of the motor = V x I_3

Hence, total losses of the motor = $W_c + (I_1 + I_2)^2 r_m + V \times I_3$

Total power input to the motor, P_i=V x $(I_1 + I_2 + I_3)$

$$\text{Thus, efficiency of the motor, } \eta_m = \frac{V\ (I_1+I_2+I_3)-[W_c+(I_1+I_2)^2 r_m + V\, I_3]}{P_0/2 + W_c + 1/2^2\ I_{a0}{}^2 R_a} \text{ X } 100\ \%$$

Efficiency of generator

Shunt field copper losses of generator = V x I_4

Total losses of the generator = $W_c + I_2{}^2 r_g + VI_4$

Total power output of the generator = V x I_2

$$\text{Thus, efficiency of generator, } \eta_G = \frac{V\, I_2}{V\, I_2 + (W_c + I_2{}^2 r_g + VI_4)} \text{ X } 100\ \%$$

Hence, the efficiency of the motor and the generator at various loads can be worked out, recording the various currents and voltage during the experiment and measuring the resistance of armature of both the machines.

The major advantages of this test are as follows:

1. Power drawn from the supply is low.
2. Both the de machines are operating under loaded conditions, as such stray load losses are taken into account. Moreover, final temperature rise of the machines can be checked.

OBSERVATION: -

S.No	V	I_1	I_2	I_3	I_4	W_c	η_m	η_G
1								
2								
3								
4								

QUESTIONS

1. In what respects, Hopkinson's test is better as compared to Swinburne's test?
2. What is meant by regenerative test and why Hopkinson's test is called as regenerative test?
3. Compare Hopkinson's test and Swinburne's test from the aspect of net power drawn from the supply.
4. Is it possible to perform Hopkinson's test on two dc machines, which are not exactly identical?
5. Two similar dc machines A and B of 7.5 kw, 220 V, 1500 rpm, 4 pole have been used for Hopkinson's test. The field current of machine A is 1.1 A, while that of machine B is 1.0 A.

   (i) Which of the machines is running as a motor and why?

   (ii) Is it possible to run the motoring machine as a generator, if so, how?