

**ELECTRICAL MACHINE LAB-I**  
**(EE-215-F)**

**LAB MANUAL**

**III SEMESTER**



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## EXPERIMENT- 1

**AIM:** TO PERFORM THE SUMPNER'S TEST ON TWO IDENTICAL TRANSFORMERS

**APPARATUS:** Two single phase transformers, two ammeters, three voltmeters, wattmeter

### Technical Specifications

**Mains Supply:** 230V  $\pm$ 10%, 50Hz

**Transformers Rating (2Nos.):** 1kVA

**Primary Voltage:** 0-125V, 0-125V

**Secondary Voltage:** 0-125V, 0-125V

**Meters Used:**

Voltmeter (MI type) 2Nos: 100V, 300V

Ammeter (MI type) 2Nos: 1A, 10A

Wattmeter (MI type) 2Nos: 100W, 1000W

**Auto Transformer:** 270V, 10A

### 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.

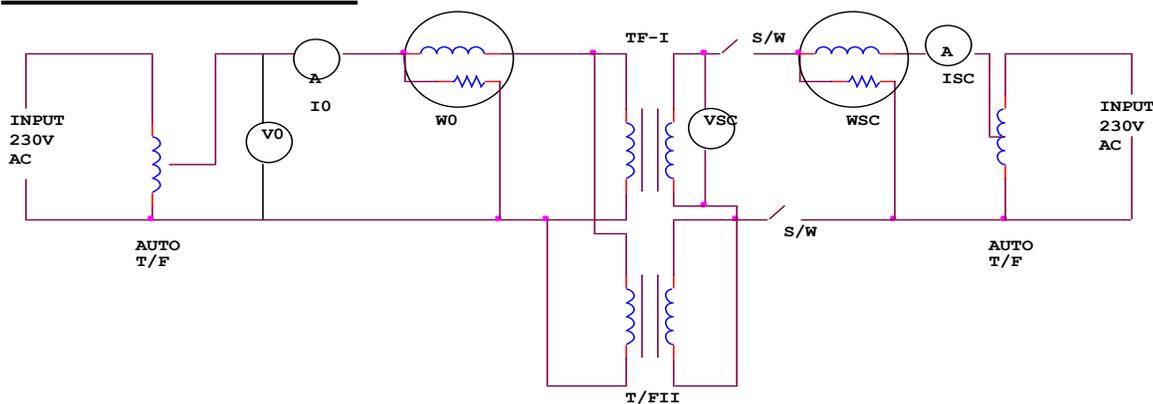
The iron loss of one transformer =  $\frac{1}{2} W_o$

The copper loss of one transformer =  $\frac{1}{2} W_c$

The total losses of one transformer =  $\frac{1}{2} W_o + \frac{1}{2} W_c$

Efficiency at full load =  $\frac{\text{output power}}{\text{Output power} + \text{losses}}$

### CIRCUIT DIAGRAM:



**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  $W_0$ ,  $X_0$  and  $V_0$
4. Full rated current to secondary side.
5. Note down the readings of  $W_{sc}$ ,  $I_{sc}$  and  $V_{sc}$ .
6. Calculate total losses and efficiency using above formulae

**OBSERVATION TABLE:**

S.NO.	$V_0$ (Volts)	$I_0$ (Amp)	$W_0$ (Watts)	$V_{sc}$ (Volts)	$I_{sc}$ (Amps)	$W_{sc}$ (Watt)

**RESULT:**

Total losses of a transformer are equal to sum of iron loss plus copper losses

**PRECAUTIONS:**

1. All connections should be neat and tight.
2. Connecting leads should be perfectly insulated.
3. There should be no error in ammeter and voltmeter.
4. The range of instruments should be carefully chosen.

**QUIZ:**

Q1 How can you determine the efficiency of transformer?

A1 By load test ,open circuit and short circuit test and sumpner's test

Q2 What are the differences in Sumpner's test and open circuit and short circuit test?

A2 The sumpner's test gives the information through one test only.

Q3 Which windings are connected in parallel in this test.

A3 Primary windings

Q4 How much voltage is applied on primary side while conducting the Sumpner's test?

A4 Normal rated voltage

Q5 How much voltage is applied on secondary side while performing the experiment?

A5 10% to 15% of the rated voltage

Q6 How the secondary winding of transformers are connected for conducting the Sumpner's test.

A6 The windings are connected in phase opposition

Q7 How much current flows on primary side and secondary side of transformer while performing the experiment.

A7 5% to 7% of rated current on primary side and full rated current on secondary side

Q8 What do you mean by phase opposition in reference to Sumpner's test on transformer?

A8 When the output voltage is equal to difference of two voltages

Q9 What is the condition to be satisfied by the two transformers to be tested through Sumpner's test?

A9 Two transformers should be identical

Q10 What does the reading of wattmeter on primary side indicate?

A10 Total iron losses of both transformers

## EXPERIMENT-2

**AIM:** TO STUDY THE PARALLEL OPERATION OF SINGLE PHASE TRANSFORMERS

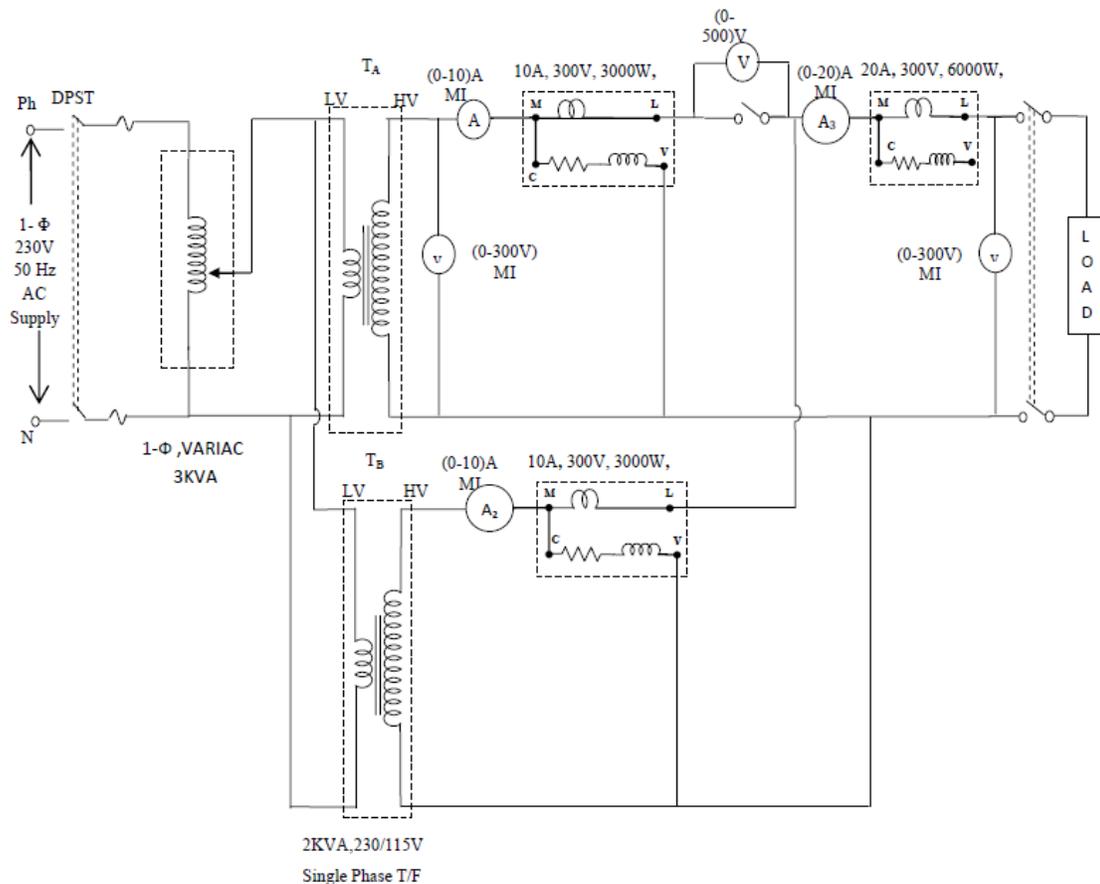
**APPARATUS:** Three ammeters, three wattmeters, single phase load, two transformers, autotransformer

### THEORY:

Parallel operation of transformers is used for load sharing. The transformers are connected in parallel on both primary and secondary side. Following conditions to be satisfied during the parallel operation of transformers

- Same polarities should be connected.
- The two transformers should have same voltage ratio.
- The percentage impedance should be same.
- There should be no circulating current.

### CIRCUIT DIAGRAM:



**PROCEDURE:**

1. connect the circuit as shown in the diagram.
2. Note down the readings of all wattmeters, ammeters and voltmeters for given load.
3. Repeat the above test for different values of load
4. Take atleast three readings.

**OBSERVATION TABLE:**

S.NO.	I <sub>1</sub> (AMPS)	W <sub>1</sub> (WATTS)	I <sub>2</sub> (AMPS)	W <sub>2</sub> (WATTS)	I <sub>L</sub> =I <sub>1</sub> +I <sub>2</sub> (AMPS)	W <sub>L</sub> =W <sub>1</sub> +W <sub>2</sub> (WATTS)
1.						

**RESULT:**

The two transformers connected in parallel share the load equally.

**DISCUSSION:**

The total load current is distributed on two transformers accordingly.

$$I_1 + I_2 = I_L$$

The total wattmeter readings are distributed on two wattmeters accordingly.

$$W_1 + W_2 = W_L$$

**PRECAUTIONS:**

1. Transformers should be connected in such a way that they have same polarity.
2. All connections should be neat and tight.
3. Connecting leads should be perfectly insulated.

**QUIZ:**

Q.1 What is the minimum no. of transformers needed to conduct this exp.?

A1 Two

Q.2 What is the effect of circulating current in the circuit having two transformers in parallel ?

A2 produces additional copper losses

Q.3 when does the circulating current flow in a circuit of two transformers connected in parallel?

A3 If the two transformers have different voltage ratios

Q.4 How much circulating current can be tolerated for parallel operation of transformers?

A4 10% of rated value

Q.5 why the transformer are needed to be operated in parallel.

A5 If the load is more than rated load

Q.6 What will happen if two transformers are connected in parallel with wrong polarity?

A6 Dead short circuit on the transformers

Q.7 What are the different polarities of transformer?

A7 Positive and negative

Q8 What do you mean by impedance of transformer?

A8 combination of resistance and reactance

Q9 What is the working principle of transformer?

A9 Mutual induction

Q10 What do you mean by load sharing?

A10 The total load is distributed on transformers equally.

## **EXPERIMENT NO 3**

**AIM:** TO CONVERT THREE PHASE TO TWO PHASE CONVERSION BY SCOTT-CONNECTION.

**APPARATUS:** Three Transformer, Ammeter, Voltmeter, Oscilloscope

### **Technical Specifications**

#### **Transformer Specifications:**

##### **Main Transformer:**

Input Winding : 200-0 V (50%)  $\pm 10\%$ , 50Hz  
: 0-200V (50%)  $\pm 10\%$ , 50Hz  
Output Winding : 0-230V  $\pm 10\%$ , 50Hz

##### **Teaser Transformer:**

Input Winding : 0-115.6V (28.9%)  $\pm 10\%$ , 50Hz  
: 346.4V (86.6%)  $\pm 10\%$ , 50Hz  
: 400V  $\pm 10\%$ , 50Hz  
Output Winding : 0-230V  $\pm 10\%$ , 50Hz

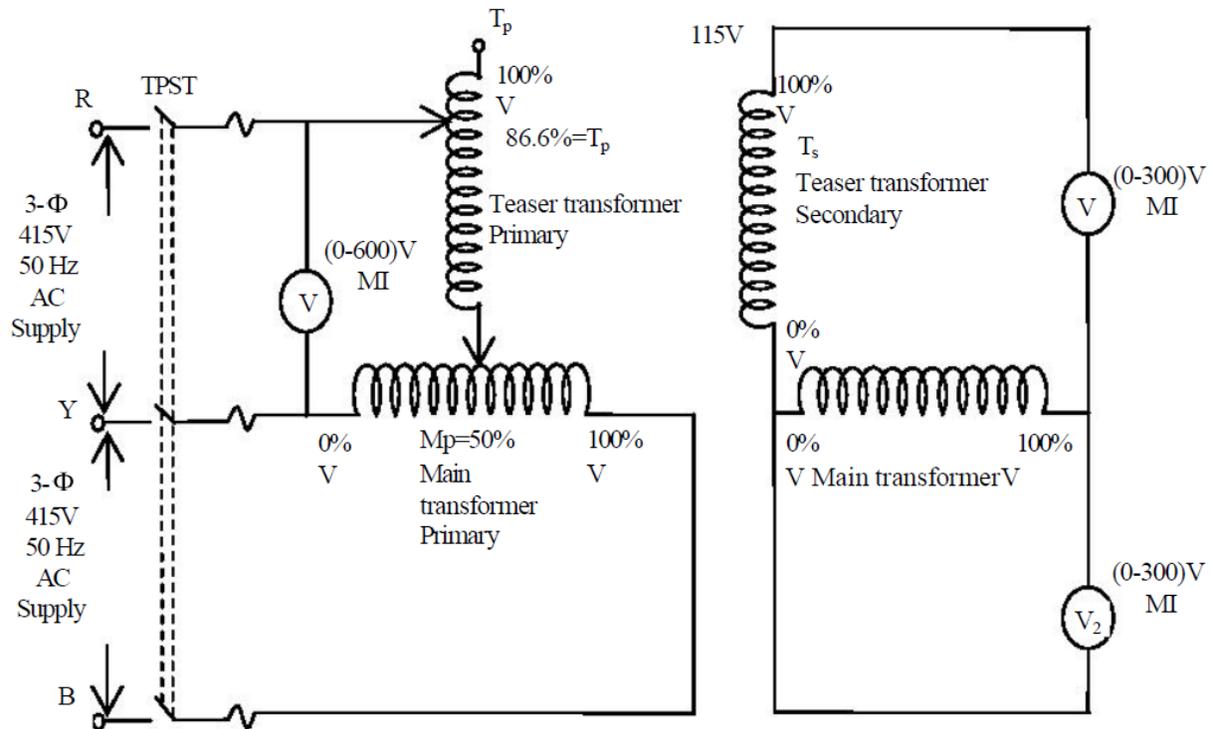
##### **Step Down Transformer:**

Input Winding : 0-230V  $\pm 10\%$ , 50Hz  
Output Winding : 0-18V  $\pm 10\%$ , 50Hz

##### **Meters Used:**

Voltmeter (MI) : 300V (2 Nos.)  
Ammeter (MI) : 1A (2 Nos.)

**THEORY:** In some cases, we may require 2- $\phi$  power instead of 3- $\phi$  or 1- $\phi$  power. For that it is necessary to convert 3- $\phi$  to 2- $\phi$  power (since 3- $\phi$  power is available at every nook corner). Scott connection is one by which 3-phase to 2-phase transformation is accomplished with the help of two identical 1- $\phi$  transformers having same current rating. One transformer has a center tap on primary side and it is known as Main transformer. It forms the horizontal member of the connection. Another transformer has 0.866 tap on primary side and known as Teaser transformer. The 50% tap point on primary side of the main transformer is joined to 86.6% tap on primary of the teaser transformer. Obviously full rating of the transformers is not at all used. Refer to the fig. The main transformer primary winding center tap point D is connected to one end of the primary of the teaser transformer on secondary side, both the main & teaser transformer turns are used (not only 86.6%). Hence the voltage per turn will be equal for both transformer.

**CIRCUIT DIAGRAM:****PROCEDURE:**

1. First of all make sure that the earthing of your laboratory is proper and connected to the terminal provided on back side of the panel.
2. Make sure that the AC Mains and the MCB of your trainer is at 'Off' position.
3. Make sure that all connections should be in a proper sequence.
4. Connect terminal R to terminal 1, similarly Y to 3 and B to 5.
5. Connect neutral terminal N to terminal 8, which is neutral point of Teaser Transformer.
6. Connect terminal 2 to 7, 4 to 10 and 6 to 12.
7. Short terminals 9 and 11.
8. Now connect Load 1 on secondary side of Teaser Transformer, for this connects terminal 14 to 17.
9. Connect terminals 18 to 21 and then 22 to 13.
10. Similarly connect Load 2 on secondary of Main Transformer, for this connects 16 to 19.
11. Connect terminals 20 to 23 and then 24 to 15.
12. Now insert Ammeters in the circuit, for this connect terminals A1 and A2 to terminals 1 and 2 respectively, reading of this Ammeter will give  $I_c$ .
13. Short terminals 3-4 and 5-6.
14. Connect A3 and A4 to 17 and 18 respectively and short 19 and 20, reading of this ammeter will give  $I_{2T}$ .
15. Now insert Voltmeters, for this connect V1 and V2 to terminals 8 to 10, 8 to 12 and 8 to 7 respectively, this will give  $V_{NA}$ ,  $V_{NB}$  and  $V_{NC}$  respectively.

16. Connect  $V_3$  and  $V_4$  to 13 and 14 respectively, this is treated as phase 1 voltage  $V_{CD}$ .
17. Now switch 'On' the three phase mains as well as MCB of your panel. And Record your observations.
18. Make sure that  $V_{NA}$ ,  $V_{NB}$  and  $V_{NC}$  are equal.
19. Now switch 'Off' the MCB of panel and place first Ammeter across terminals 3 and 4, for this remove link connected between 3 and 4 and connect terminals  $A_1$  and  $A_2$  here respectively.
20. Short terminals 1 and 2.
21. Similarly remove links between 19 and 20 and connect  $A_3$  and  $A_4$  here resp and short 17 and 18.
22. Remove links between  $V_3$ ,  $V_4$  to terminals 13, 14 and connect voltmeter across 15 and 16 respectively.
23. Now switch 'On' the MCB. This time reading of first ammeters will give  $I_A$ , and that of second ammeter  $I_{2M}$  as voltmeter gives phase 2 voltage  $V_{AB}$ .
24. Switch 'Off' the MCB of panel.
25. Now to measure  $I_B$ , remove links between 5 and 6 and connect  $A_1$  and  $A_2$  here respectively.
26. Short terminals 3 and 4 again. Switch 'On' the supply and record  $I_B$ .
27. Verify following relations-
 
$$I_c = 1.15K I_{2T}$$

$$I_A - I_B = 2KI_{2M}$$
28. Observe the output waveforms on oscilloscope, connect terminals 25 and 26 to channel 1 of oscilloscope and terminals 27 and 28 to channel 2.
29. Observe the output waveforms and measure phase shift between them which must be 90°.
- Note :** The output voltage you are observing is not the actual voltage of 230V, but it has been stepped down internally in order to see their waveforms on Oscilloscope.
30. Switch 'Off' the supply.

**OBSERVATION TABLE:**

$I_c = \dots\dots\dots$  Amp  
 $V_{NA} = \dots\dots\dots$  Volt  
 $V_{NB} = \dots\dots\dots$  Volt  
 $V_{NC} = \dots\dots\dots$  Volt  
 $V_{CD} = \dots\dots\dots$  Volt  
 $I_{2T} = \dots\dots\dots$  Amp  
 $I_A = \dots\dots\dots$  Amp  
 $I_{2M} = \dots\dots\dots$  Amp  
 $V_{AB} = \dots\dots\dots$  Volt  
 $I_B = \dots\dots\dots$  Amp

**RESULT:**

$I_A = I_B = I_C = \dots\dots\dots$  amp  
 $V_{AB} = V_{BC} = V_{CA} = \dots\dots\dots$  voltS

**PRECAUTIONS:**

1. All connections should be tight and correct.
2. Switch off the supply when not in use.
3. Reading should be taken carefully.

**QUESTIONS/ANSWERS:**

**Q.1** What is the effect on the frequency in the transformer?

**A.** No change

**Q.2** What is the medium for the energy conversion from the primary to secondary in the transformer?

**A.** By the flux.

**Q.3** What is the main reason for the generation of harmonics in the transformer?

**A.** Saturation of the core.

**Q.4** Why are the ferrite cores used in the high frequency transformer?

**A.** High resistance

**Q.5** What type of winding is used in the 3-phase shell type transformer?

**A.** Sandwich type

**Q.6** What is increased in step up transformer?

**A.** Voltage

**Q.7** What is the effect on voltage in step down transformer?

**A.** Voltage is decreased

**Q.8** What is the function of bushings in the transformer?

**A.** To make the external connections

**Q.9** What is the principal of transformer?

**A.** Mutual induction.

## EXPERIMENT - 4

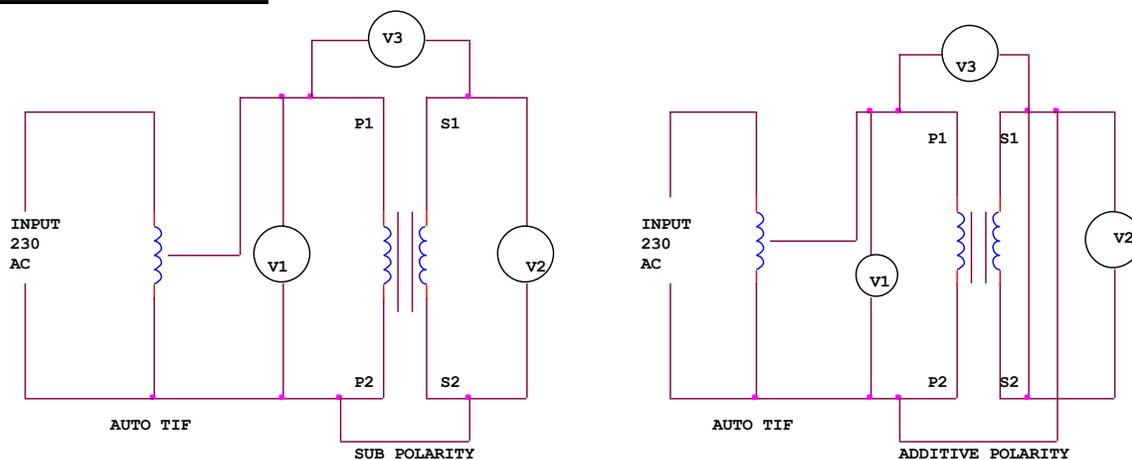
**AIM:** TO FIND THE POLARITY AND TURNS RATIO OF A SINGLE PHASE TRANSFORMER.

**APPARATUS:** One transformer, two voltmeters, one autotransformer

### THEORY:

It is essential to know the relative polarity at any instant of primary and secondary terminals for making correct connections. When the two transformers are to be connected in parallel to share the load on the system. The marking is correct if voltage  $V_3$  is less than  $V_1$ , such a polarity is termed as subtractive polarity. The standard practice is to have subtractive polarity because it reduces the voltage stress between adjacent loads. In case  $V_3 > V_1$ , the EMF induced in primary and secondary have additive relation and transformer is said to have additive polarity.

### CIRCUIT DIAGRAM:



### PROCEDURE:

a) Polarity test:

- Connect the circuit as shown in the diagram.
- Switch on the single phase a.c. supply.
- Record the voltages  $V_1$ ,  $V_2$  and  $V_3$ . In case  $V_3 < V_1$  polarity is subtractive.
- Repeat the step 3 after connecting terminals  $A_1$  and  $A_2$ . In case  $V_3 > V_1$  polarity is additive.
- Switch off the a.c. supply

b) Turn Ratio Test:

- Connect the circuit as shown in the diagram.
- Switch on the a.c. supply.
- Record voltage  $V_1$  across primary and  $V_2$  across various tappings of secondary.
- If  $V_1 > V_2$  then transformer is step down.
- If  $V_2 > V_1$  then transformer is step up.
- Switch off a.c. supply.

**OBSERVATION TABLE:**

**SUB-POLARITY**

S. NO.	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub> =V <sub>2</sub> -V <sub>1</sub>

**ADD-POLARITY**

S.NO.	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub> =V <sub>1</sub> +V <sub>2</sub>

**TURN RATIO**

S.NO.	V <sub>1</sub>	V <sub>2</sub>	Turns Ratio V <sub>1</sub> /V <sub>2</sub>

**RESULT:**

If V<sub>2</sub>>V<sub>1</sub> then transformer is step up otherwise step down.

**PRECAUTIONS:**

1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.

**QUIZ:**

Q1 What is transformer?

A1 Transformer is a static device which is used to change the level of voltage or current without changing the frequency and power .

Q2 What do you mean by turns ratio of transformer?

A2 Turns ratio of a transformer is the ratio of primary turns to the secondary turns.

Q3 What is transformation ratio of transformer?

A3 Transformation ratio is the ratio of secondary side turns to primary side turns.

Q4 What are the different polarities of transformer?

A4 Positive and negative polarity.

Q5 What is the condition of additive polarity?

A5 When the sum of voltages is more than individual voltages, then it is called additive

Q6 What is the condition for subtractive polarity.

A6 When the sum of voltages is less than individual voltages, then it is called subtractive

Q7 What are the different types of transformer?

A7 The different types of transformer are : step up and step down

Q8 What is the use of autotransformer?

A8 Autotransformer is used for increasing or decreasing the voltage with the use of one winding

Q9 What is the use of polarity test?

A9 The polarity test is performed to find the positive and negative polarity of transformer.

**EXPERIMENT-5**

**AIM:** TO STUDY THREE PHASE TO SIX PHASE CONVERSION USING 3 SINGLE PHASE TRANSFORMERS.

**APPARATUS:** Three to Six Phase Conversion Trainer Kit

**Technical Specifications**

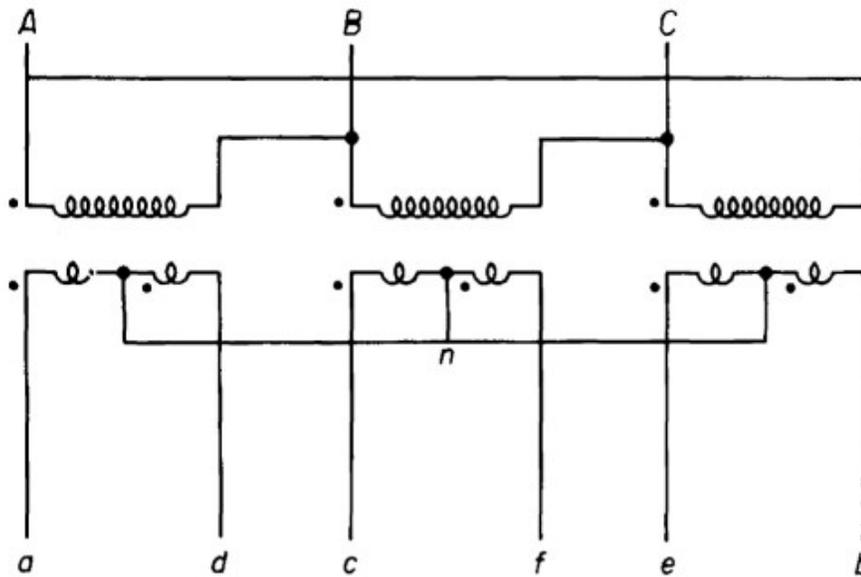
**Mains (three phase) Supply :** 415 V ± 10, 50 Hz

**Transformers**

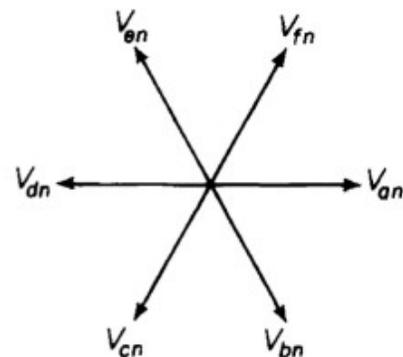
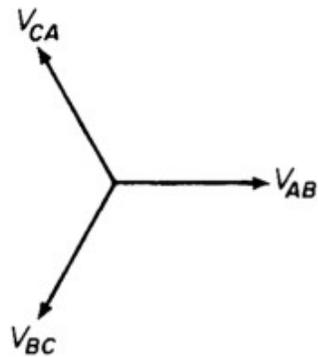
Primary voltage : 230V ± 10%

Secondary voltage : 30V-0V-30V

**CIRCUIT DIAGRAM:**



(a)



(b)

**THEORY:** In certain applications like thyristors and rectifiers six phase supply is required. Therefore it becomes necessary to convert three phase a.c. supply into six phase. By using three identical single phase transformers suitably interconnected this can be achieved. The primary winding is connected in delta whereas its secondary winding is split up into two halves. Thus conversion from 3 phase to six phase can be obtained by having two similar secondary windings for each of the primaries of the three phase transformer. This is showing in the Fig.

The three phase supply is given to primaries of the three transformers and six phase output can be obtained from the six secondaries as shown. There are many ways of connecting these secondaries. Some of them are

i) double delta ii) double star iii) dimetrical.

The dimetrical connection is generally used in practice.

**PROCEDURE:**

1. First make sure that the earthing of your laboratory is properly connected to the control panel.
2. Now ensure that three phase mains switches of your laboratory are 'Off'.
3. Connect the mains socket of the panel to three phase mains of your lab using the three phase cable.
4. Three phase supply would be available across terminals R, Y and B with
5. neutral N provided at control panel by the time user's switches "On" the MCB.
6. Now connect phase R to terminal 1 of any of the three single phase transformers.
7. Connect neutral N to terminal 2.
8. Make short terminals 1 and A.
9. Now connect terminal 2 to voltmeter terminal V1 and terminal V2 to terminal B.
10. Switches 'On' the three phase supply.
11. Observe and record the voltage of the voltmeter into the observation table.
12. Switches 'Off' the three phase supply and disconnect three phase mains socket to the control panel.
13. Now disconnect Voltmeter connection and also disconnect terminal 1 to A.
14. Connect terminal 1 to B and connect Voltmeter terminals V1 & V2 across terminal 2 & A.
15. Switches 'On' the three phase supply.
16. Now observe and record the voltage of the voltmeter into the observation table.
17. Switches 'Off' the three phase supply and disconnect three phase mains socket to the control panel.

**RESULTS:** We have studied the three phase to six phase conversion

**PRECAUTIONS:**

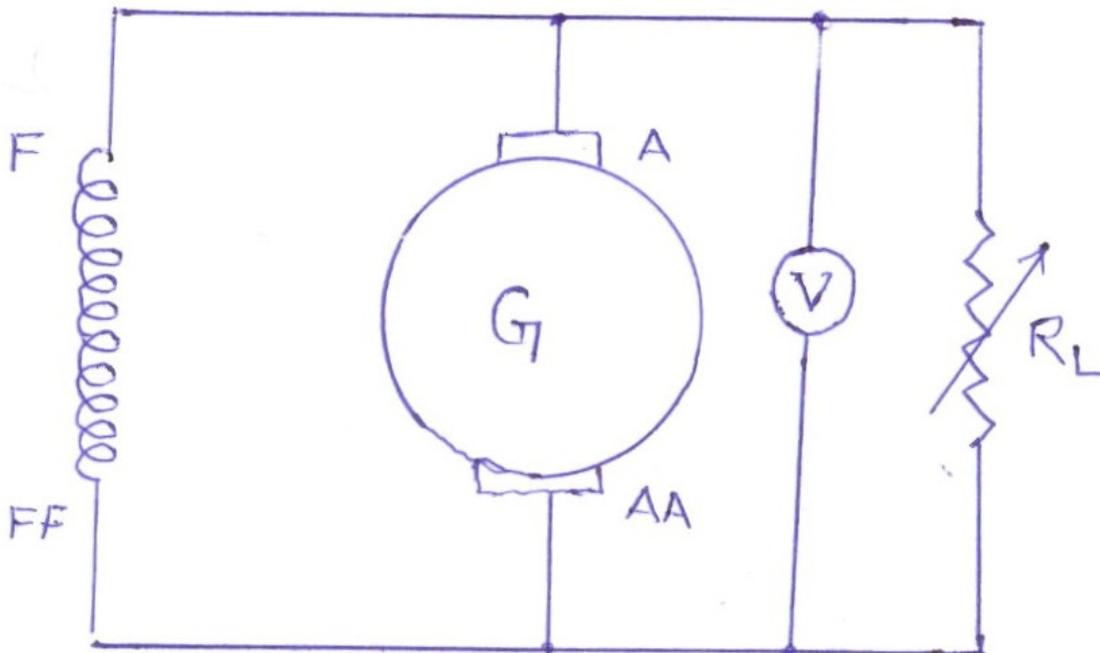
1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.

**EXPERIMENT-6**

**AIM:** TO PERFORM DIRECT LOAD TEST OF A D.C.SHUNT GENERATOR AND PLOT LOAD VOLTAGE V/S LOAD CURRENT

**APPARATUS:** D.C.SHUNT GENERATOR, D.C.AMMETER 0-20A, D.C.VOLTMETER 0-300V, VARIABLE LOAD 5 KW, RHEOSTAT 1000OHM,1.2 A

**THEORY:** The variation of terminal voltage  $V$  across the armature with load current is known as load characteristics or external characteristics. It is seen that the terminal voltage falls as the load current increases. This is mainly due to the ohmic drop.

**CIRCUIT DIAGRM:****PROCEDURE:**

1. Connect the circuit as shown in fig.
2. Keep the load open, adjust the field rheostat so that the emf generated corresponds to the rated voltage of the generator.
3. Note this value of the generated emf.
4. Connect the load, note the readings of ammeter which gives the load current, and the voltmeter which now, gives the value of terminal voltage  $V$ .

**OBSERVATION TABLE:**

S.NO	Load Current $I_L$ (Amp)	Terminal voltage ( Volts )

**PRECAUTIONS:**

1. All the connections should be neat and tight.
2. While performing experiment, take care that the instrument readings should not exceed the ratings of the machine under test.
3. Switch off the supply when not in use

**QUESTIONS/ANSWERS:-**

Q.1 What is the resistance of the field winding of a d.c. shunt generator kept low?

A. If the field resistance of a d.c. generator is more than particular value (critical resistance), The generator will fail to build up the voltage. For this reason, the field resistance of a d.c. shunt generator is kept low.

Q.2 What do you understand by external characteristics of a d.c. generator?

A. The graph between the terminal voltage and load current is known as external characteristics of a d.c. generator, provided speed and field current remain constant.

Q.3 what will happen if the d.c. machine is operated below rated speed?

A. This will result in overheating due to two reasons; first, more field current has to be maintained in order to produce the rated voltage. Second, decrease in fanning action due to decrease in speed.

Q.4 What is the most important precaution in any experiment with d.c. shunt motor?

A. Before switching on d.c. supply, a sufficient resistance should be put in series with the armature of the d.c. shunt motor.

Q.5 What range of speed can you get with the field control method of speed control of d.c. shunt motor?

A. Speed higher than rated speed can be obtained by using this method.

Q.6 What range of speed can you get with the armature control method of speed control of d.c. shunt motor?

A. Speed lower than the rated speed can be obtained by the armature control method.

Q.7 Does the direction of rotation of d.c. shunt motor would get reversed if the armature current and field current both are reversed?

A. No.

Q.8 If the rated speed of a d.c. shunt motor is 1440 r.p.m, which method of speed control would you suggested to obtain a speed of 1500 r.p.m?

A. Field control method of speed control is suggested.

Q.9 What will happen if the d.c. shunt motor running on no-load has its shunt field winding opened accidentally?

A. The field will be reduced to only to the value of residual flux. The speed will be very high. The parts of motor may even fly apart.

Q.10 What is the most essential condition for the voltage build up for a d.c. shunt generator?

A. There should be a residual magnetism in the poles of the d.c.shunt generator.

**EXPERIMENT-7**

**AIM:** TO PERFORM SPEED CONTROL OF DC SHUNT MOTOR BY ARMATURE CONTROL

**APPARATUS:** Tachnometer, DC supply of 200V (fixed), 200V (variable), Rheostat, Connecting Leads

**Technical Specifications**

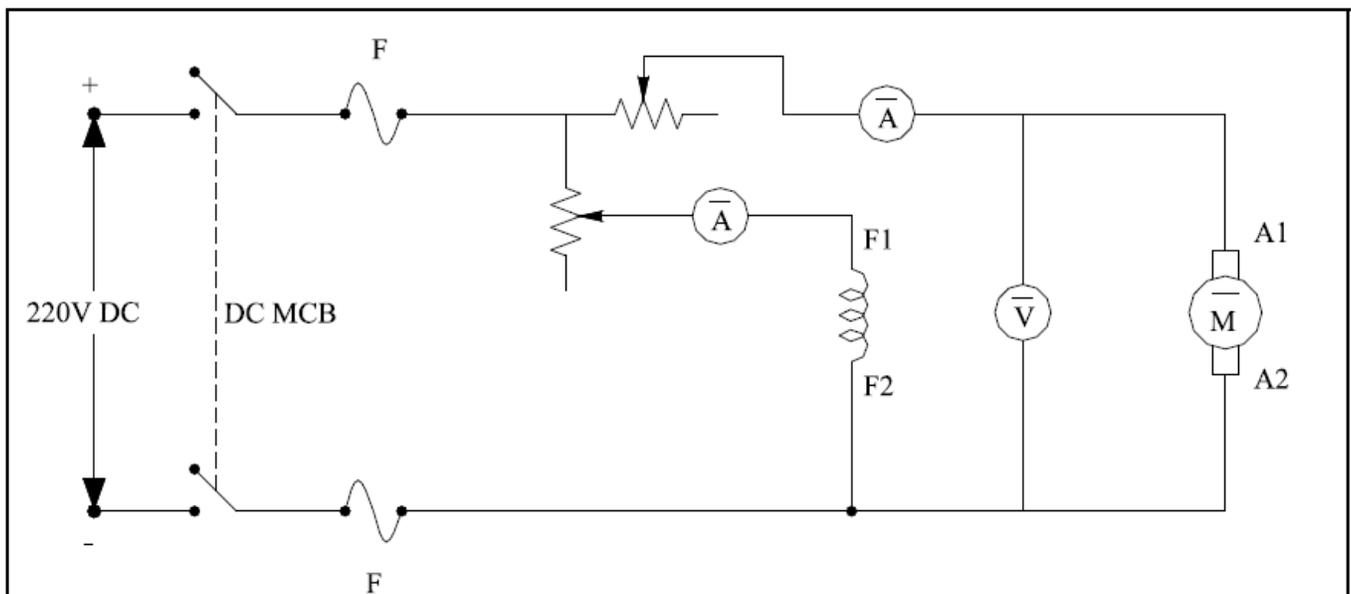
**Input** : 180-200V Fixed DC  
0-180/200V Variable DC  
(Please refer specifications on the motor)

**DC Machine Specifications**

Type: DC Shunt  
RPM: 1500(No Load)

**Meters used**

Machines Rating	Ammeter	Voltmeter
½ HP	0-1A DC 0-5A DC	0-300V DC
1 HP	0-1A DC 0-5A DC	0-300V DC
2 HP	0-1A DC 0-10A DC	0-300V DC
3 HP	0-2A DC 0-10A DC	0-300V DC

**CIRUIT DIAGRAM:**

**THEORY:** Speed control means intentional change of the drive speed to a value required for performing the specific work process. Speed control is a different concept from speed regulation where there is natural change in speed due change in load on the shaft. Speed control is either done manually by the operator or by means of some automatic control device.

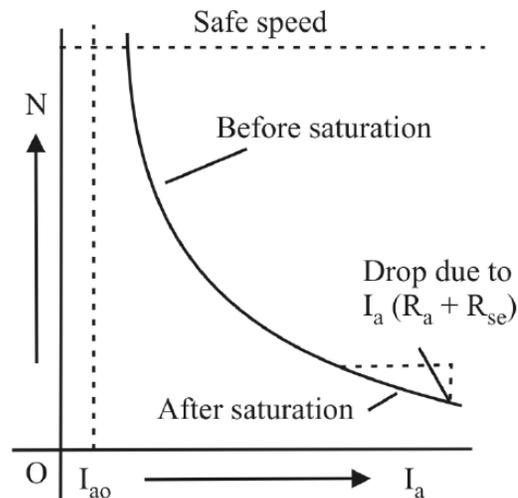
One of the important features of dc motor is that its speed can be controlled with relative ease. We know that the expression of speed control dc motor is given as,

$$N = KV - \frac{I_a(R_a + R)}{\phi}$$

Therefore speed (N ) of 3 types of dc motor – SERIES, SHUNT AND COMPOUND can be controlled by changing the quantities on RHS of the expression. So speed can be varied by changing

- (i) Terminal voltage of the armature  $V_o$
- (ii) External resistance in armature circuit  $R$  and
- (iii) Flux per pole  $\phi$ .

○ **Speed and Armature Current Characteristic :**



**PROCEDURE:**

1. Make sure that the DC supply is off and knob of its Variac is at zero position.
2. Connect fixed DC supply to the corresponding terminals provided on the panel namely Fixed DC Supply Input.
3. Now connect points of variable supply to their terminals provided on panel namely Variable DC Supply Input.
4. Connect motor to the panel for this connect A and AA terminals of panel to A and AA terminals on the motor, similarly connect F and FF panels on the panel to F and FF terminals of motor.
5. Connect +ve of Variable DC Supply Input to A terminal of DC Motor.
6. Connect AA terminal to A7 and A8 to -ive of Variable DC Supply Input.
7. Connect Voltmeter across armature, for this connect V3 and V4 across A and AA terminals of DC Motor.

8. Connect +ve of Fixed DC Supply Input to F of DC Motor.
9. Connect its FF to A3 and connect A4 to –ve of Fixed DC Supply Input.
10. Switch ON the DC supply.
11. Now slowly vary the armature voltage and find change in motor speed note the voltage at which motor just starts rotating, note this voltage as  $V_s$
12. Observe the voltage in voltmeter and measure the corresponding speed using Tachometer.
13. Record your observations into the observation table.
14. Take no. of readings and draw graph between armature voltage and motor speed.
15. Switch off the DC Supply.

**OBSERVATION TABLE:**

S. No.	Field Current in (Constant in Amp.)	Armature voltage in (Volts)	Speed (RPM)
1.			
2.			
3.			
4.			
5.			

**RESULT:** Hence, we have studied the speed control of DC shunt motor by armature control method.

**PRECAUTIONS:**

1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.

**EXPERIMENT-8**

**AIM:** TO STUDY AND OBTAIN THE EFFICIENCY OF DC SHUNT MOTOR BY SWINBURN'S TEST

**APPARATUS:** Connecting leads, 0-200V Variable supply, Tachometer.

**Technical Specifications**

**Input:** 180-200V Fixed DC  
0-180/200V Variable DC  
(Please refer specifications on the motor)

**DC Machines Specification:** DC Shunt  
Voltage Rating : 200 V  
RPM : 1500 (No Load)  
Insulation : Class 'B'

**Meters used**

Machines Rating	Ammeter	Voltmeter
1 HP	0-5A DC	0-300V DC
2 HP	0-10A DC	0-300V DC
3 HP	0-10A DC	0-300V DC

**THEORY:**

Swinburne's test is the most commonly used method for testing of D.C machines. It is an indirect method of testing D.C machines. In this method, the no load losses of the machine are determined experimentally and the additional losses on load are estimated from the known data of the machine, and with the help of the losses and input power the efficiency at any desired load is predetermined.

For a D.C. shunt motor change of speed from no load to full load is quite small. Therefore, mechanical loss can be assumed to remain same from no load to full load. Also if field current is held constant during loading, the core loss too can be assumed to remain same. In this test, the motor is run at rated speed under no load condition at rated voltage.

**Losses :**

We are using the term machine in the discussion of power losses owing to the fact that no distinction need be made between the losses in the D.C generator and the motor. The law

of conservation of energy dictates that the input power must always be equal to the output power plus the losses in the machine. There are three major categories of losses:

1. Mechanical losses
2. Iron losses
3. Copper losses

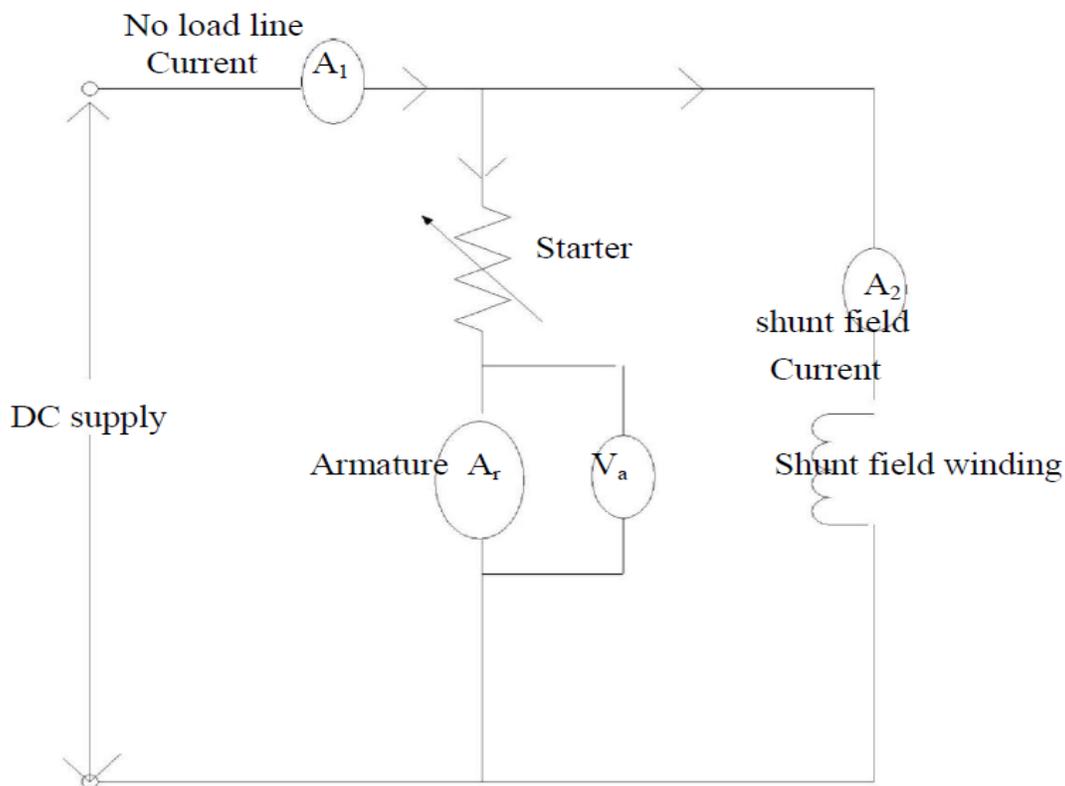
#### Advantages of Swinburne's Test

- This test is very convenient and economical as it is required very less power from supply to perform the test.
- Since constant losses are known, efficiency of Swinburne's test can be pre-determined at any load.

#### Disadvantages of Swinburne's Test

- Iron loss is neglected though there is change in iron loss from no load to full load due to armature reaction.
- We cannot be sure about the satisfactory commutation on loaded condition because the test is done on no-load.
- We can't measure the temperature rise when the machine is loaded. Power losses can vary with the temperature.
- In dc series motors, the Swinburne's test cannot be done to find its efficiency as it is a no load test.

#### CIRCUIT DIAGRAM:

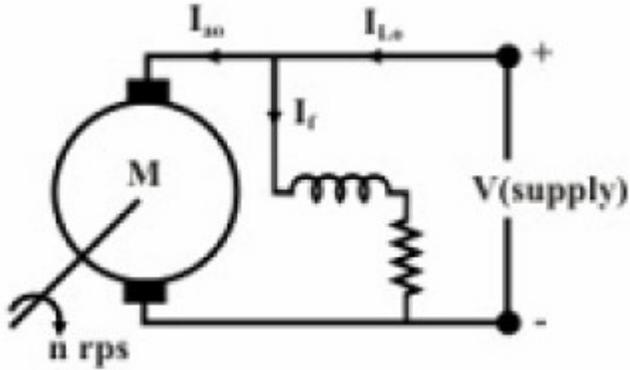


**PROCEDURE:**

1. Make sure that the DC Variable Supply is off and its knob is at zero position.
2. Now start making the connections
3. Connect motor terminal provided at the top of the motor to the control panel. For
4. this connect field and armature terminals of the motor (F-FF and A-AA) to
5. corresponding field and armature terminal provided at the control panel
  
6. Connect variable DC Supplies to their corresponding terminals provided on the panel.
7. Connect + terminal of Variable DC Supply Input to terminal 1 and –ve terminal is connected to terminal 2.
8. Connect terminal 1 to terminal A1 of the ammeter and terminal A2 of the ammeter to terminal F of the control panel.
  
9. Connect terminal 2 to terminal FF of the field winding of the motor.
10. Connect terminal F of the motor to terminal A3 of the ammeter and terminal A4 of the ammeter to terminal A of the armature winding of the motor at the control panel.
11. Connect terminal FF of the field winding to terminal AA of the armature winding
12. Connect voltmeter terminals V1 and V2 across armature winding terminals A and AA at the control panel.
13. Ensure that the belt being used for loading the motor is free so that the motor run at without load
14. Verify these connections with the connections as shown in the circuit diagram
15. If all the connections are proper then switch on the Variable DC supply.
16. Increase the armature voltage to attain the rated speed (1500 rpm).
17. Observe and record the field current, armature current and armature voltage of the motor into the observation table.
18. Also check the speed on the motor when the motor runs at without load.
19. Now switch off the Variable DC Supply.
20. Now put the load on the motor by just tighten the screws up-to the rated current (that is 4A for 1 HP Motor) through the mechanical belt arrangement provided at the control panel.
21. Now switch On the Variable DC Supply.
22. Observe and record the field current, armature current and armature voltage of the motor into the observation table.
23. Also check the speed on the motor when the motor runs at loaded condition
24. Switch off the Variable DC Supply

**Observation Table:**

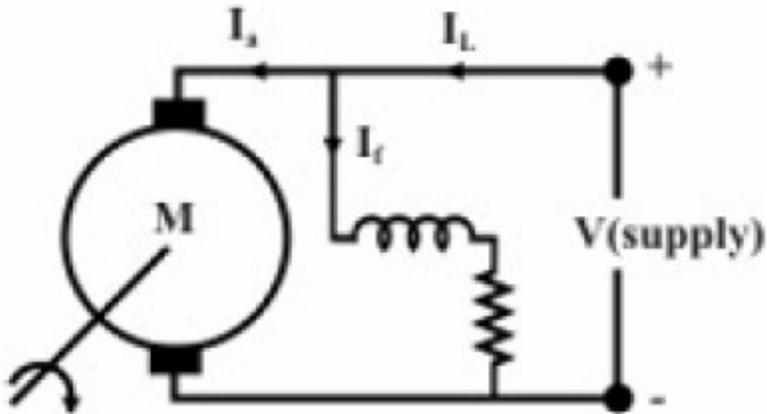
**Without Load Condition**



**Motor under no load**

S.NO	Field Current (in Amps)	Armature Current $I_{a0}$ (in Amps)	Armature Voltage $V$ (in Volts)	Speed No in R.P.M

**Under Loaded Condition**



**Motor Loaded**

S.NO	Field Current (in Amps)	Armature Current $I_{a0}$ (in Amps)	Armature Voltage V (in Volts)	Speed No in R.P.M

**Calculations:**

Since the motor is run at rated speed under no load condition at rated voltage V. The current drawn from the supply is  $I_{L0}$  and the field current is  $I_f$ .

Hence,

Input power to the motor,  $P_{in} = VI_{L0}$

Power input to the armature,  $= V (I_L - I_f) = VI_{a0}$

Copper loss in the field circuit,  $P_{fl} = VI_f$

Copper loss in the armature circuit  $= (I_{a0})^2 R_a$

Gross power developed by armature  $= VI_{a0} - (I_{a0})^2 R_a$

Since the motor is operating under no load condition, hence the gross power developed by the armature must supply the core loss and friction & windage losses of the motor and it remains practically constant from no load to full load, the sum of these losses is called constant rotational loss. Therefore,

Constant rotational loss,  $Prot = VI_{a0} - (I_{a0})^2 R_a$

Let the motor be loaded such that new current drawn from the supply is  $I_L$  and the new armature current is as  $I_a$

To estimate the efficiency of the loaded motor we proceed as follows:

Input power to the motor,  $P_{in} = VI_L$

Power input to the armature,  $= V (I_L - I_f) = VI_a$

Cu loss in the field circuit,  $P_{fl} = VI_f$

Cu loss in the armature circuit  $= (I_a)^2 R_a$

Gross power developed by armature  $= VI_a - (I_a)^2 R_a = E_b I_a$

Net mechanical output power,  $P_{netmech} = E_b I_a - Prot$

Therefore efficiency of the loaded motor,  $\eta = P_{netmech} / P_{in}$

**PRECAUTIONS:**

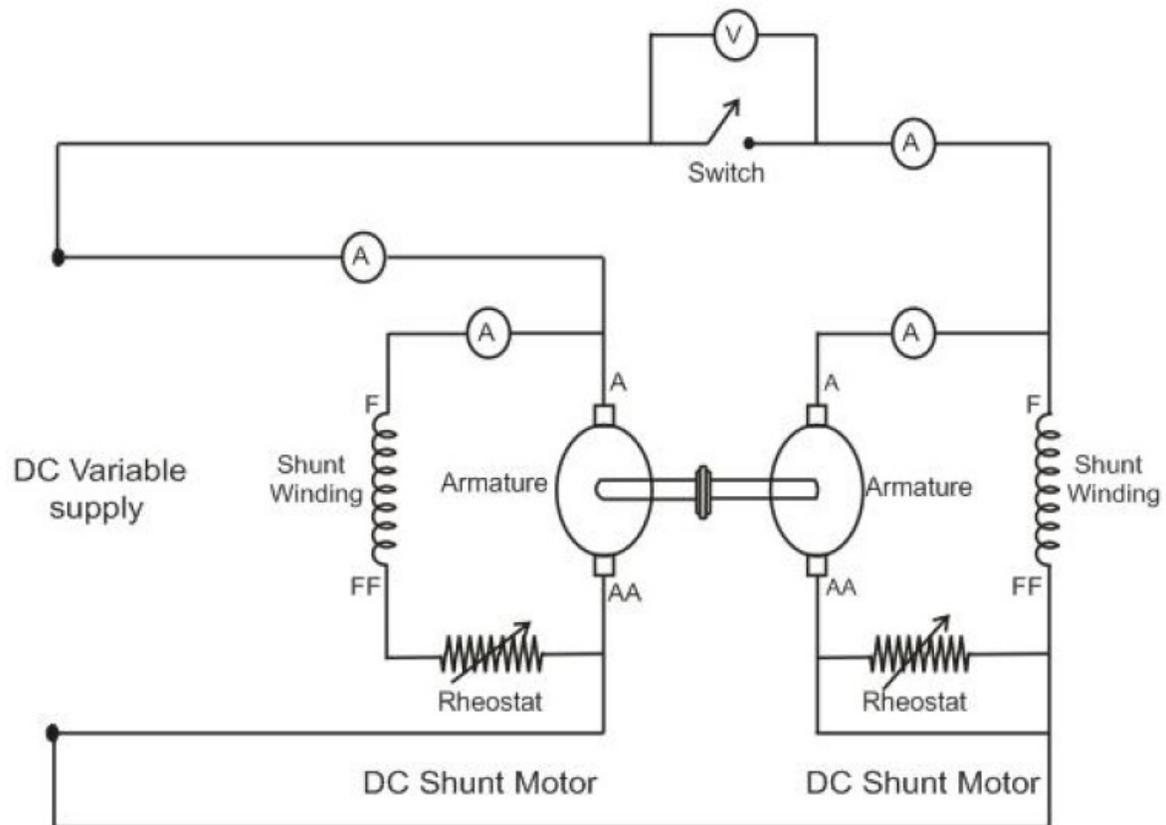
1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.

## EXPERIMENT-9

**AIM:** TO STUDY AND OBTAIN THE LOSSES AND EFFICIENCY OF A DC SHUNT GENERATOR BY HOPKINSON'S TEST

**APPARATUS:** Connecting leads, 0-200V Variable supply, Rheostat, Tachometer.

### CIRCUIT DIAGRAM:



### THEORY:

This is an elegant method of testing DC machines. Here it will be shown that while power drawn from the supply only corresponds to no load losses of the machines, the armature physically carries any amount of current (which can be controlled with ease). Such a scenario can be created using two similar mechanically coupled shunt machines. Electrically these two machines are eventually connected in parallel and controlled in such a way that one machine acts as a generator and the other as motor. In other words two similar machines are required to carry out this testing which is not a bad proposition for manufacturer as large numbers of similar machines are manufactured.

By this test, full load test can be carried out on two shunt machines, preferably identical once, without wasting their outputs. Two machines are mechanically coupled and are so adjusted electrically that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator and the electrical output of generator is used in supplying the greater part of input to the motor. If there were no losses in the machines they would have run without any external power supply. But due to these losses, generator output is not sufficient to drives the motor and vice-versa.

**PROCEDURE:**

1. Make sure that the DC supply is “Off” and its knob is at zero position.
2. Connect motor terminals i.e. F-FF and A-AA to corresponding terminals on the control panel.
3. Connect Generator terminal F to terminal FF provided on panel.
4. Again connect Generator terminal FF to terminal F provided on panel.
5. Now connect generator terminal A-AA to corresponding terminals A-AA provided on the panel.
6. Connect variable DC Supply to their corresponding terminals provided on the panel i.e. Variable DC Supply Inputs.
7. Connect positive terminal of Variable DC Supply Input to terminal A3 and terminal A4 to terminal A of the DC motor.
8. Connect negative terminal of Variable DC Supply Input to terminal AA of the armature of DC motor.
9. Connect ammeter terminal A1 to terminal A of the DC motor and terminal A2 to the terminal F of the DC motor.
10. Connect Rheostat terminal R1 and R2 to terminal FF and AA of the DC Motor respectively.
11. Connect terminal A of the generator to terminal A5 of the ammeter and terminal A6 to terminal F of the generator.
12. Connect Rheostat terminals R3 and R4 to terminals AA and FF of the generator.
13. Connect ammeter terminal A7 to the terminal 2 of the switch & terminal A8 to the terminal A of second motor (generator) respectively.
14. Connect the positive terminal of the variable DC supply to terminal 1 of the switch and negative terminal of the DC variable supply to terminal AA of the second motor (generator) as shown in fig.
15. Connect voltmeter terminal V1 and V2 across terminal 1 and 2 of the switch.
16. Connect one Rheostat across terminals R1 and R2 and another rheostat across terminal R3 and R4 provided at the control panel.
17. Make sure that switch connected in the circuit is at “Open” position.
18. Ensure that the rheostat1 is at minimum position.
19. Adjust rheostat 2 at slightly less then maximum value to avoid the heating of rheostat.
20. If all the connections are proper then switch “On” the Variable DC supply
21. Ensure that the Voltmeter connected across the switch reads minimum Volts (ideally 2 to 5 Volts).
22. Adjust the generator armature voltage 1v or 2v more than the supply voltage by varying the value of rheostat 1 towards the maximum position.

23. Now, make the switch at short position so that the generator can be connected to bus bar.
24. Increase the excitation of generator by varying the rheostat 2 to its minimum value. On the same time decrease the excitation of motor by varying the rheostat 1 to its maximum position, so that back EMF reduces & line current of motor increases.
25. Record the readings of all the meters provided on the panel & note them on observation table.
26. Switch “Off” the DC variable supply.
27. Calculate efficiency as per calculation given below.

**Note:**

1. User can also calculate the efficiency on half load by changing the position of knob of rheostat at the middle position.
2. During this test supply voltage is maintained constant at the rated value & the test should be carried out at rated speed.
3. Generator field terminals F & FF are interchanged so that both the machine can rotate in opposite direction i.e. clockwise & anticlockwise. This is done to avoid locking as both the machines are connected back to back.

**OBSERVATION TABLE**

S.No	DC Motor			DC Generator		
	Shunt field current $I_{shm}$	Armature current $I_{am}$	Armature resistance $R_{am}$	Shunt field current $I_{shg}$	Armature current $I_{ag}$	Armature current $I_{ag}$

**RESULT & CALCULATION:**

Let the current drawn from the supply be  $I_L$ . Total power drawn from supply is  $V I_L$ . which is equal to the total losses of both the machine.

Where,

$V$  = Supply Voltage

$I_L$  = Current drawn from the supply

$I_m$  = Motor intake current

$I_{shm}$  = Shunt field current of DC Motor

$I_{am}$  = Armature current of DC Motor ( $I_{am} = I_m - I_{shm}$ )

$I_g$  = Generator output current

$I_{shg}$  = Shunt field current of DC Generator

$I_{ag}$  = Armature current of DC Generator ( $I_{ag} = I_g + I_{shg}$ )

$R_{am}$  = Armature resistance of DC Motor

$R_{ag}$  = Armature resistance of DC Generator

Now, **Motor current  $I_m = I_L + I_g$ .**

Power drawn from supply =  $V I_L$

Shunt field copper loss in motor =  $V I_{sh_m}$

Shunt field copper loss of in generator =  $V I_{sh_g}$

Armature copper loss in motor =  $(I_{a_m})^2 R_{a_m}$

Armature copper loss in generator =  $(I_{a_g})^2 R_{a_g}$

Total copper losses =  $(I_{a_m})^2 R_{a_m} + (I_{a_g})^2 R_{a_g} + V I_{sh_m} + V I_{sh_g}$

**Stray power losses of both the machines**

$P_s = V I_L - [(I_{a_m})^2 R_{a_m} + (I_{a_g})^2 R_{a_g} + V I_{sh_m} + V I_{sh_g}]$

**Stray power losses of each machine =  $P_s/2$**

Once  $P_s$  is estimated for each machine we can proceed to calculate the efficiency of the machines as follows,

**Efficiency of the Motor:**

Motor intake =  $V I_m$

Total losses in motor = Armature loss + Shunt field loss + Stray power loss  
 =  $(I_{a_m})^2 R_{a_m} + V I_{sh_m} + P_s/2$

Motor output =  $V I_m - [(I_{a_m})^2 R_{a_m} + V I_{sh_m} + P_s/2]$

**Motor efficiency = (Output/Input) x 100**

**Efficiency of the Generator:**

Generator output =  $V I_g$

Total losses in generator = Armature loss + Shunt field loss + Stray power loss  
 =  $(I_{a_g})^2 R_{a_g} + V I_{sh_g} + P_s/2$

Generator input =  $V I_g + (I_{a_g})^2 R_{a_g} + V I_{sh_g} + P_s/2$

**Generator efficiency = (Output/Input) x 100**

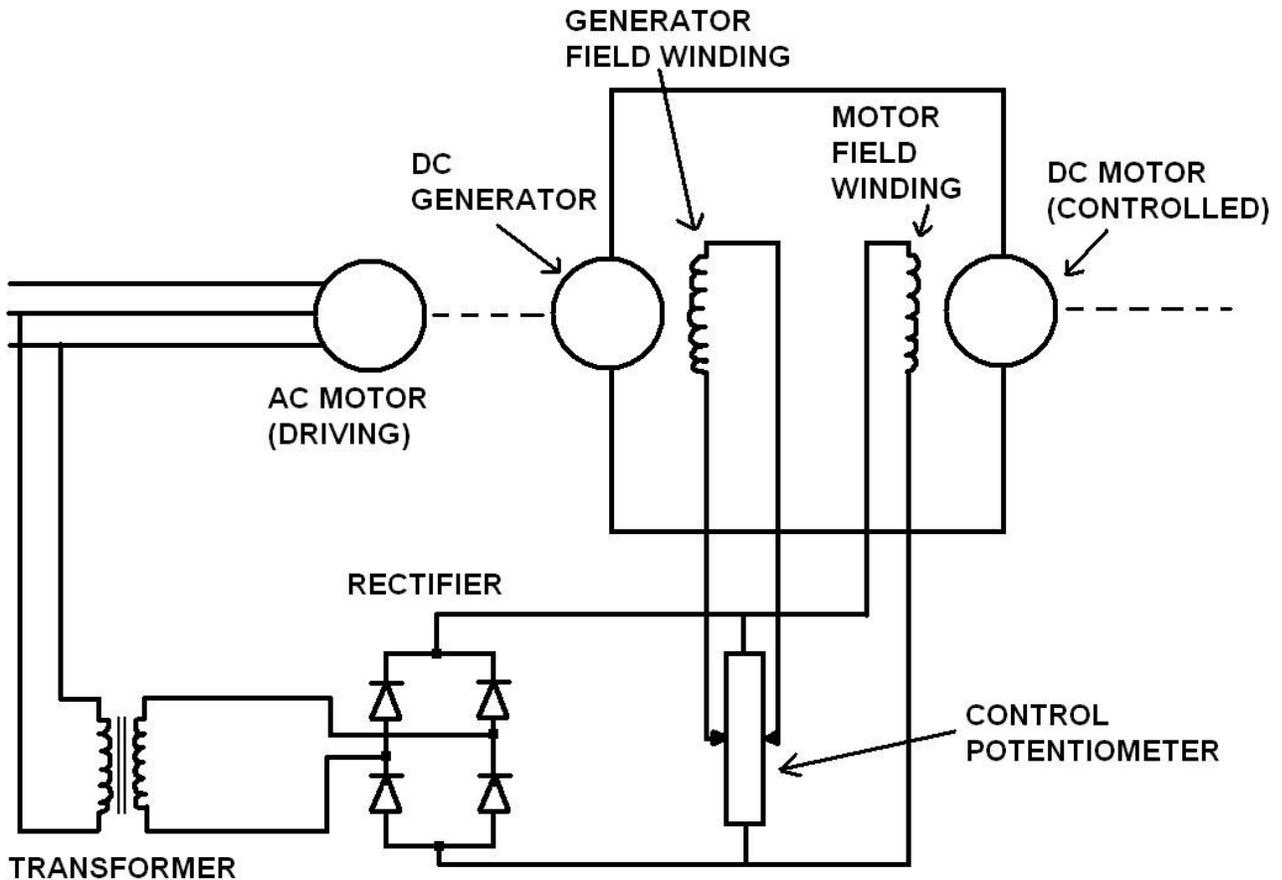
**PRECAUTIONS:**

1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.

**EXPERIMENT-10**

**AIM:** TO STUDY SPEED CONTROL OF SEPARATELY EXCITED DC SHUNT MOTOR BY WARD-LEONARD METHOD

**APPARATUS:** Connecting leads, Three Phase Variac 10A, Rheostat 220 Ohm 2.8A

**CIRCUIT DIAGRAM:****THEORY**

This method is actually armature voltage control of speed with constant field excitation. Variable DC supply or Variac is recent innovation. In earlier time, creating a variable DC supply was not so easy and a separately excited DC generator for this purpose. The output DC is controlled by changing the field strength or speed of rotation. This particular method is applied in Ward Leonard method. The variable DC from the generator is utilized to supply the motor armature. A prime mover is required for rotating the generator shaft and generating the DC voltage. A 3 phase induction motor is acts like the prime mover for the DC generator as shown in the given circuit diagram. The 3 phase induction motor is energized from a

3 phase AC source. There is a separate field circuit for the generator and a rheostat is connected in series with the field circuit. By controlling the rheostat or variable resistance, the field current of the generator is controlled. In this way, the generated emf is varied into a certain range. Hence  $V_a$ , that is the generated voltage from the DC generator can be varied. A potential divider connection uses two rheostats connected in parallel connection. This potential divider is used to reversal of the generator field current instantly.

Initially the induction motor is started with generator field current zero, which is done by adjusting the jockey positions of the rheostats of generator field. After that the field supply of the motor is turned on with motor field rheostat set to zero. The applied voltage to the motor  $V_a$ , can now be gradually increased to the rated value by slowly increasing the field current of the generator. Therefore, the starting current of the motor is ranged into a certain limit. So, no starter device is required for the DC motor as the applied voltage to the armature is gradually increased by changing the field current of the generator. When the DC motor is operating below the base speed, then the speed of the DC motor is varied by changing the field excitation of the DC generator. Whereas, when the motor is operating above the base speed, then the field current of the DC motor is varied by maintaining constant  $V_a$ , to control the speed. Reversal of direction of rotation of the motor can be obtained by changing the field rheostats, which are provided in the field of the DC generator. In this way, the speed of the DC motor is controlled just by varying the applied armature voltage.

#### **Advantages of using Ward Leonard method**

- Great Flexibility of speed control over a wide range from crawling to full speed in either direction.
- Rapid reversibility of direction of rotation even for heavy machines.
- Uniform acceleration.
- The speed regulation is quite smooth and good.

#### **Drawbacks of Ward Leonard method**

- The initial cost of is high because two additional machines are required for this methods, a DC generator and an AC Motor.
- This method required more floor area.
- The overall efficiency is lesser.

### **PROCEDURE**

1. Make sure that the Three Phase Mains is off and the MCB of panel is also at off position.
2. Connect R, Y and B terminal of Three Phase Supply to Three phase Induction Motor terminals R, Y and B.
3. Now insert the Voltmeter in the circuit for this connects V1 and V2 to terminal R and Y as shown in fig
4. Connect terminal A and AA of DC Shunt Generator to A and AA of DC Shunt Motor.
5. Now insert the voltmeter in the circuit for this connects V3 and V4 to terminal A and AA of DC Shunt Generator.
6. Connect terminal F of DC shunt generator to Rheostat1 terminal R1 and FF to terminal R2.

7. Now insert the Rheostat terminals (Optional) in the circuit for this connects R1, R2 and R3 of Rheostat1.
8. Connect terminal R2 and R3 of Rheostat to terminal S1 of Reversing Switch.
9. Connect terminal S2 to FF of DC shunt motor and insert the Ammeter in the circuit for this connects A1 and A2 to S2 and F respectively.
10. Now insert the Three Phase Induction Motor terminals R, Y and B in the circuit for this connect R, Y and B of Three Phase Induction Motor DC Shunt Generator's circuit.
11. Connect the DC shunt Generator terminal A and AA to Three Phase Induction Motor DC Shunt Generator circuit's terminal A and AA respectively.
12. Similarly connect the DC Shunt Generator terminal F and FF to Three Phase Induction Motor DC Shunt Generator circuit's terminal F and FF respectively.
13. Now connect the terminal A to F and AA to FF of DC Shunt Generator.
14. Connect the DC Shunt Motor terminals A, AA, F and FF to DC Shunt Motor's circuit terminals A, AA, F and FF respectively.
15. Check all the connections as per diag. before switch on the supply.
16. Rheostat position should be minimum at the time of starting.
17. Switch ON the Three Phase Mains if all the connections are right.
18. The variable voltage across the terminals of the generator or across the motor is obtained by varying the exciting current of the generator.
19. Take no. of readings by varying the rheostat position. and change the direction of motor with the help of reversing switch.
20. Switch off the supply.

**OBSERVATION TABLE:**

S.No.	Field current in Amp	DC Motor Speed in RPM
1		
2		
3		

**RESULT:** we have studied the speed control of separately excited dc shunt motor by ward-leonard method

**PRECAUTIONS:**

1. All connections should be tight.
2. The circuit should be according to circuit diagram.
3. The power should be on when the circuit is checked completely.