ELECTROMECHANICAL ENERGY CONVERSION- I LAB

(EEE-451)

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CONTENTS

SYLLABUS

(As per syllabus prescribed by MTU, NOIDA.)

Note : Minimum eight experiments are to be performed from the following list :

1. To obtain magnetization characteristics of a d.c. shunt generator.

2. To obtain load characteristics of a d.c. shunt generator and compound generator (a) Cumulatively compounded (b) Differentially compounded.

3. To obtain efficiency of a dc shunt machine using Swinburn's test.

4. To perform Hopkinson's test and determine losses and efficiency of DC machine.

5. To obtain speed-torque characteristics of a dc shunt motor.

6. To obtain speed control of dc shunt motor using (a) armature resistance control (b) field control.

7. To obtain speed control of dc separately excited motor using Conventional Ward-Leonard/Static Ward –Leonard method.

8. To study polarity and ratio test of single phase and 3-phase transformers.

9. To obtain equivalent circuit, efficiency and voltage regulation of a single phase transformer using O.C. and S.C. tests.

10. To obtain efficiency and voltage regulation of a single phase transformer by Sumpner's test.

11. To obtain 3-phase to 2-phase conversion by Scott connection.

12. To determine excitation phenomenon (B.H. loop) of single phase transformer using C.R.O.

STUDY AND EVALUATION SCHEME

SESSIONAL EVALUATION:-

CLASS TEST	**:**	**…. MARKS**
TEACHER'S ASSESMENT	**:**	**….MARKS**
EXTERNAL EXAM	**:**	**…. MARKS**
TOTAL	**:**	**….MARKS**

LIST OF EXPERIMENTS

1. To obtain magnetization characteristics of a d.c. shunt generator.

2. To obtain load characteristics of a d.c. shunt generator and compound generator (a) Cumulatively compounded (b) Differentially compounded.

3. To obtain efficiency of a dc shunt machine using Swinburn's test.

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8. To study polarity and ratio test of single phase and 3-phase transformers.

9. To obtain equivalent circuit, efficiency and voltage regulation of a single phase transformer using O.C. and S.C. tests.

10. To obtain 3-phase to 2-phase conversion by Scott connection.

INDEX

S.NO.	NAME OF EXPERIMENT	DATE OF EVALUATION	GRADE
1	To obtain magnetization characteristics of a d.c. shunt generator.		
2	To obtain load characteristics of a d.c. shunt generator and compound generator (a) Cumulatively compounded (b) Differentially compounded.		
3	To obtain efficiency of a dc shunt machine using Swinburn's test.		
4	To perform Hopkinson's test and determine losses and efficiency of DC machine.		
5	To obtain speed-torque characteristics of a dc shunt motor.		
6	To obtain speed control of dc shunt motor using (a) armature resistance control (b) field control.		
7	To obtain speed control of dc separately excited motor using Conventional Ward-Leonard/Static Ward – Leonard method.		

8	**To study polarity and ratio test of single phase and 3-phase transformers.**		
9	**To obtain equivalent circuit, efficiency and voltage regulation of a single phase transformer using O.C. and S.C. tests.**		
10	**To obtain 3-phase to 2-phase conversion by Scott connection.**		

EXPERIMENT 1

1. OBJECTIVE: To plot the magnetization characteristics of a DC Shunt Generator running at rated speed.

2. APPARATUS REQUIRED:

INSTRUMENTS REQUIRED (TO BE CONNECTED EXTERNALLY)

FOR DC MOTOR :-

- **(i) MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.**
- **(ii) MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No.**
- **(iii) Tubular Rheostat 1.2 A. 260 Ohms – 1 No.**
- **(iv) Indicating light**
- **(v) Educational type insulated terminals**
- **(vi) DPIC Switch 16A, 240V.**
- **(vii) D.C. Starter 3 Point - 1 No.**

FOR DC GENERATOR :

- **(i) MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.**
- **(ii) MC Ammeter 96 x 96 mm flush mounted 0-1 A. – 1 No.**
- **(iii) MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No.**
- **(iv) Tubular Rheostat 1.1 A. 800 Ohms – 1 No.**
- **(v) Indicating light**
- **(vi) Educational type insulated terminals**

3.BRIEF THEORY: The emf generated in the armature winding of a DC generator under no load operation is given by

$$E_g = \frac{P \varphi N Z}{60 A}$$

$$= k \varphi N \text{ Volt} \quad \text{(P, Z and A are constant for a particular generator)}$$

The field flux φ in a DC generator is proportional to the field current I_f. Thus the above equation can be rewritten as

$E = K_1 I_f N$

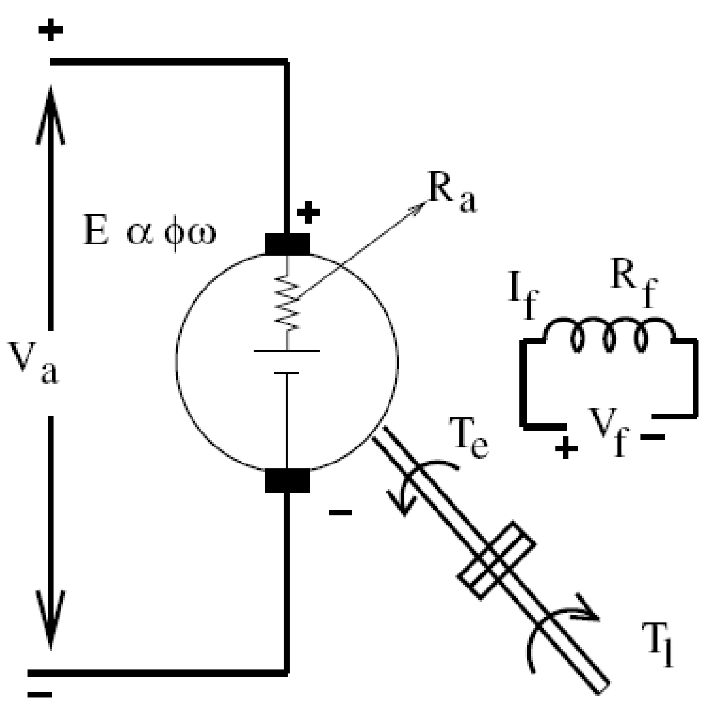
Hence at constant given speed, no load emf, Eg is directly proportional to the flux per pole, φ, which in turn depends upon the field current I_f. The characteristics curve showing the relationship between the fields current, I_t and the generated emf, Eg at no load and at a constant speed is known as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

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

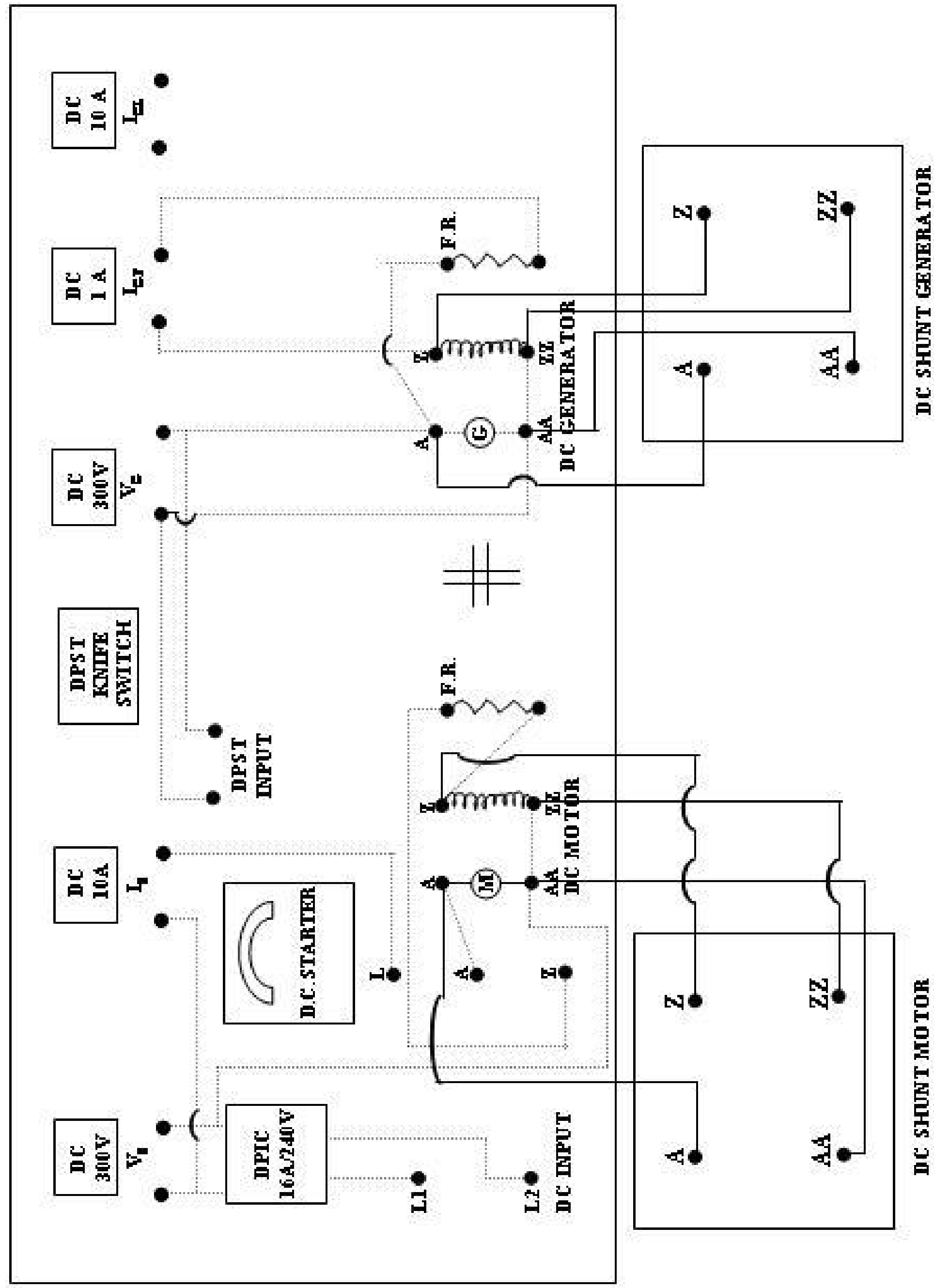
$$\text{No load emf at speed } N_2,\ E_{g2} = E_{g1} \times \frac{N_2}{N_1} \quad (E_g = k' N)$$

It may be noted clearly that Eg1 and Eg2 are the no load emf corresponding to same field current but for different speeds N1 and N2 respectively.

4. CIRCUIT DIAGRAM:



PANEL FOR MAGNETIZATION CHARACTERISTICS OF DC SHUNT GENERATOR



5. PROCEDURE:

1. Connect the DC Motor and the DC generator (coupled together) as per attached sheet.

2. Adjust the rheostat in the field circuit of the motor, so that the additional resistance in this circuit is minimum.

3. Set the potential divider feeding the field circuit of the generator for zero output voltage.

4. Switch-on the DC supply to the DC Motor and start it using the starter. Move the starter arm slowly, till the motor builds up the speed and finally cut out all the resistance steps of the starter. Starter arm will then be hold up by holding magnet of the starter.

5. Adjust the speed of the DC motor to rated value by varying the resistance in the field circuit.

6. Record the generated emf due to residual magnetism.

7. Vary the field current of generator in steps and record its value and the corresponding generated emf of the generator. Observation should be continued upto the generated voltage.

8. Now reduce the field current with the help of rheostat in steps and record the induced emf for decreasing values of the field current.

6. OBSERVATIONS:

MOTOR		**GENERATOR**		
V_S	I_S	V_G	I_{FG}	**RPM**

7. CALCULATION:

8. RESULT AND DISCUSSION: Plot the graph between field current and terminal voltage Open circuit).

9. Precautions:

1. All connections should be tight.
2. All steps should be followed carefully.
3. Readings and calculation should be taken carefully.
4. Don't touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. What are methods excitations of DC?

2. What are types of DC Generator?

11. POST EXPERIMENT QUESTIONS:

1. What is magnetization characteristics of a DC Shunt Generator**?**

2. What is critical resistance?

3. What is critical speed?

EXPERIMENT 2a

1. OBJECTIVE: To obtain load characteristics of a d.c. shunt generator.

2. APPARATUS REQUIRED:

<u>FOR DC MOTOR</u> :-

1. **MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.**
2. **MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No.**
3. **Tubular Rheostat 1.2 A. 260 Ohms – 1 No.**
4. **Indicating light**
5. **Educational type insulated terminals**
6. **DPIC Switch 16A, 240V.**

<u>FOR DC GENERATOR</u> :

1. **MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.**
2. **MC Ammeter 96 x 96 mm flush mounted 0-5 A. – 1 No.**
3. **Knife Blade Switch DPST -1 No.**
4. **Tubular Rheostat 1.2 A. 260 Ohms – 1 No.**
5. **Indicating light**
6. **Educational type insulated terminals**
7. **Lamp Bank Load 2 KW 230V in steps of 200 watts bulbs.**

<u>PRIME MOVER</u> : D. C. Shunt wound, 3 HP, 220/230V. 1500 RPM.

<u>DC GENERATOR</u> : Self excited – Shunt wound, 1.5 KW,230V, 1500 RPM.

3. THEORY:

The external characteristic (load characteristic) of DC generator represent the graphical relationship between the terminal voltage and the load current, the generator being operated at constant rated speed and with the same excitation as under the no load conditions. The nature of this characteristic depends upon the following factors.

(i) Voltage drop in the armature winding, interpole and compensating windings.

(ii) Voltage drop at the brush contact.

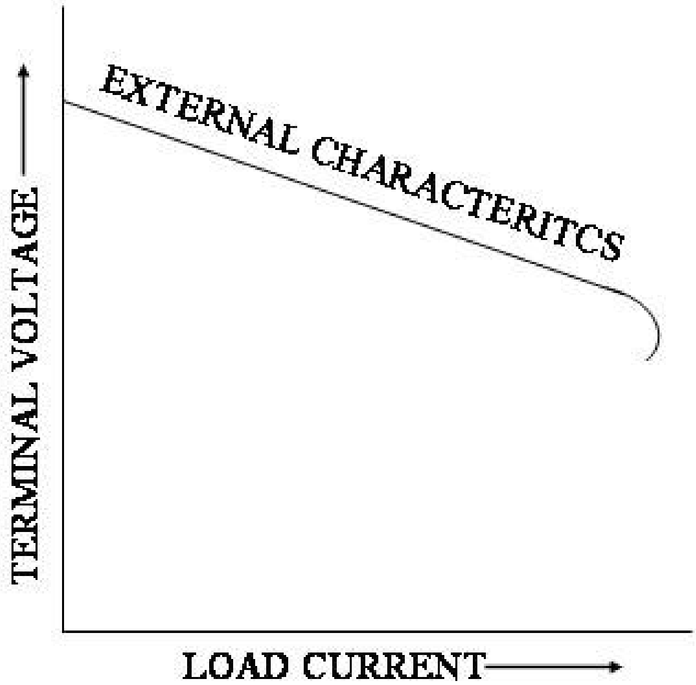
(iii) Voltage drop due to armature reaction.

External characteristic of the generator indicates the fall in the terminal voltage as the load on the generator increases. External characteristic of a shunt generator is more drooping compared to that of separately excited generator. The fall in the terminal voltage due to increase in load can be compensated by an additional winding on the field system and connected in series with the armature winding i.e. by proving series field winding, thus making the generator a compound generator.

EXTERNAL CHARACTERISTICS OF DC SHUNT GENERATOR

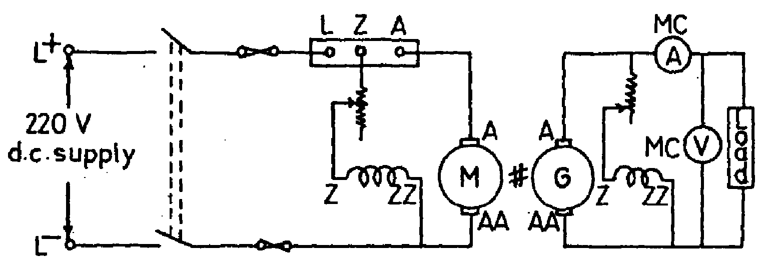
For a shunt generator the external characteristics is obtained with constant resistance in the exciting circuit, the connections necessary for determining the characteristics experimentally. For the normal test the resistance in the field regulator is adjusted as that normal e m f is generated on open circuit and the resistance is not varied during the test which again is carried out at constant speed and with the machine at its usual working temperature.

With the shunt generator the fall that takes place in the terminal voltage when load is put on, is more marked then with the separately excited machine. The increased drop is due to the fact that a drop in the terminal voltage results in a fall in the value of the exciting current with a consequent fall in the value of the flux. When load is put on the shunt generator its voltage thus tends to fall by a process of exactly a reverse nature to that of "building up".

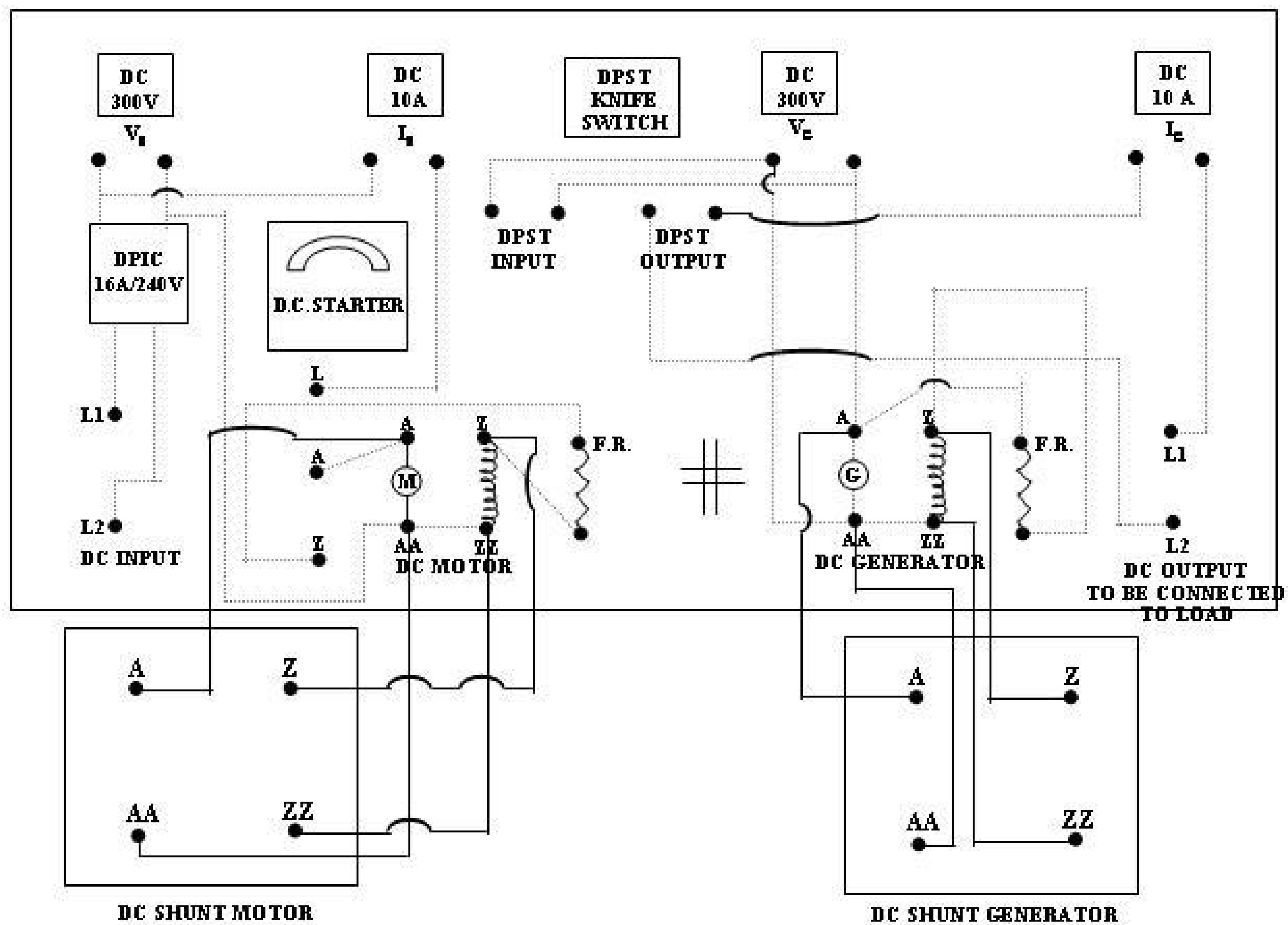


External characteristics of a DC Shunt Generator.

4. CIRCUIT DIAGRAM:



PANEL LAYOUT FOR LOAD CHARACTERISTICS OF DC SHUNT GENERATOR



5. PROCEDURE:

1. **Connect the circuit of motor and generator as per attached sheet.**
2. **Set the rheostat, so that there is minimum external resistance in the field circuit of the motor.**
3. **Set the rheostat, so that there is maximum external resistance in the field circuit of the generator.**
4. **Switch on the supply to the DC motor and start it with the help of starter. Starter arm should be moved slowly, till the motor builds up its speed.**
5. **Adjust the speed of the motor to rated value by varying the resistance in the field circuit of the motor.**
6. **Adjust the field current of generator by rheostat R_2, so as to obtain rated voltage at no load.**
7. **Switch on the lamp bank load and adjust a certain value of load current, say approximately 10 percent of full load current. Record the load and the terminal voltage.**
8. **Repeat step 7 by various values of load current, till the full load current of the generator.**
9. **Switch off the load on the generator.**
10. **To stop the DC motor, switch off the DC supply.**

6. OBSERVATIONS:

MOTOR		GENERATOR		
V_S	I_S	V_G	I_G	RPM

7. CALCULATION:

8. RESULT AND DISCUSSIONS:

Draw plot between terminal voltage and load current (line current) for DC shunt Generator.

9. PRECAUTION:

1. Never 'START' the DC Shunt Motor against full load of Generator.
2. When the DC machines are put is use after a gap, clean the commutator of DC machine by means of soft sand paper.
3. The position of Rocker Arm of machines should only be shifted, when so required, to run the machine spark-free.
4. Check for proper tension of spring on the Carbon holder. If the Carbons are too short, replace it immediately with the new ones.

10. PRE EXPERIMENT QUESTIONS:

1. What do you mean by external characteristics and internal characteristics of DC generator?

2. What do you mean by load characteristics of DC generator?

11. POST EXPERIMENT QUESTION:

1. What do you concluded from external characteristics and internal characteristics of DC generator?

2. What is the effect of armature reaction on external characteristics and internal characteristics of DC generator?

EXPERIMENT 2b

1. OBJECTIVE: To obtain load characteristics of a d.c. compound generator (a) Cumulatively compounded (b) Differentially compounded.

2. APPARATUS REQUIRED:

FOR DC MOTOR:-

1. MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.
2. MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No.
3. Tubular Rheostat 1.2 A. 260 Ohms – 1 No.
4. Indicating light
5. Educational type insulated terminals
6. DPIC Switch 16A, 240V.
7. DC Starter 3 Point

FOR DC GENERATOR :

1. MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.
2. MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No.
3. Knife Blade Switch DPST -1 No.
4. Tubular Rheostat 1.2 A. 260 Ohms – 1 No.
5. Indicating light
6. Educational type insulated terminals
7. Lamp Bank Load suitable for above generator

PRIME MOVER : D. C. Shunt wound. 220/230V. 1500 RPM.

DC GENERATOR : Self excited – Compound 230V, 1500 RPM.

3. THEORY

The external characteristic of DC generator represent the graphical relationship between the terminal voltage and the load current, the generator being operated at constant rated speed and with the same excitation as under the no load conditions.

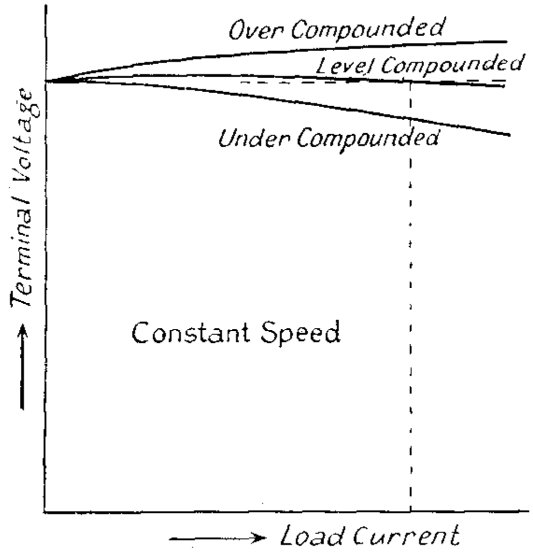
External characteristic of the generator indicates the fall in the terminal voltage as the load on the generator increases. External characteristic of a shunt generator is more drooping compared to that of separately excited generator. The fall in the terminal voltage due to increase in load can be compensated by an additional winding on the field system and connected in series with the armature winding i.e. by proving series field winding, thus making the generator a compound generator.

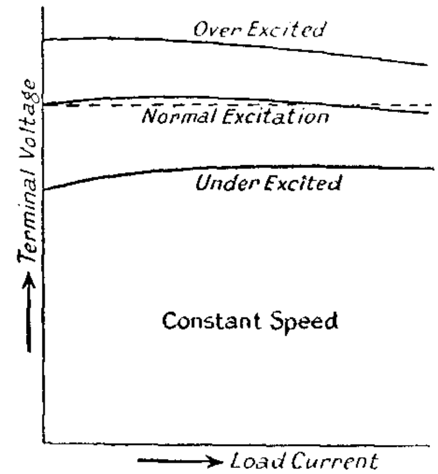
EXTERNAL CHARACTERISTICS OF DC COMPOUND GENERATOR

To maintain consistency of terminals voltage a shunt generator is provided with addition series excitation connected either with armature or the load. These turns are so connected so as to aid the Shunt turns, when the generator supplies load. Thus as the load increase the current through the series winding also increase thereby increasing the flux. Due to the increase in Flux, induced e m f is also increased. Thus by adjusting the number of series amp. turns, this increase in e m f can be made to balance the combined voltage drop in the generator due to Armature reaction and Armature drop.

Under suitable condition the terminal voltage may remain practically (with slight drop in the terminal voltage) constant from no load to full load, or by using relatively strong series windings the terminal voltage may increase with increasing load current. In the first case the machine is said to be "level-compounded" and in the other "over-compounded" (not practically recommended). The load characteristics will then be as shown in fig below. If a level-compounded machine is run at above normal voltage, it will give drooping external characteristics as indicated in fig below (the assumed normal speed of operation).

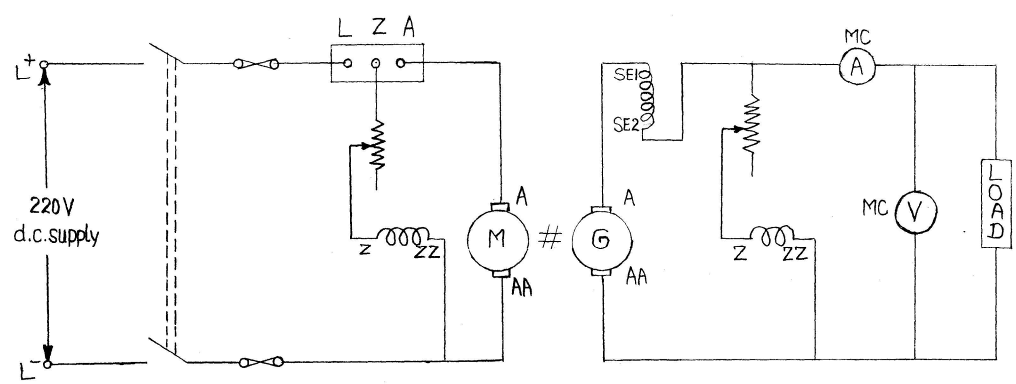
The action of a compound generator is not to be explained as merely equivalent to a combination of shunt and series characteristics. The voltage drop with the shunt generator is largely accounted for by the reduction that takes place in the value of the field current. With a level compound generator the voltage across the shunt winding is almost constant, so that the action of this machine is equivalent to that of a separately excited machine having in addition a few series turns.





External characteristics of a DC Compound Generator.

4. CIRCUIT DIAGRAM:



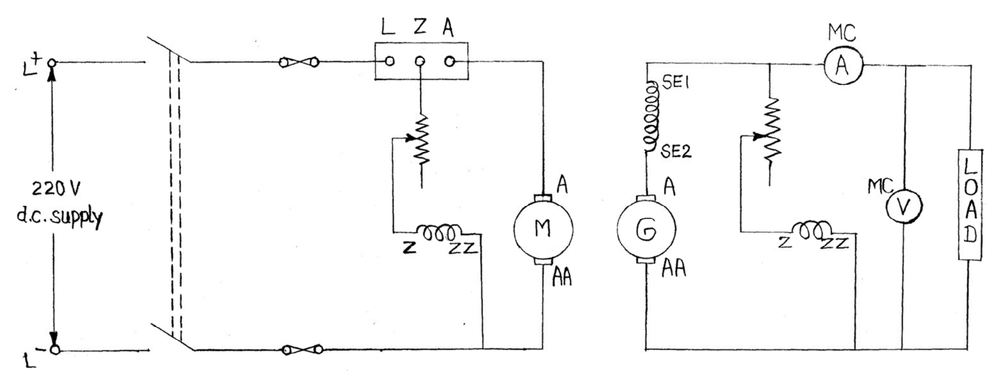
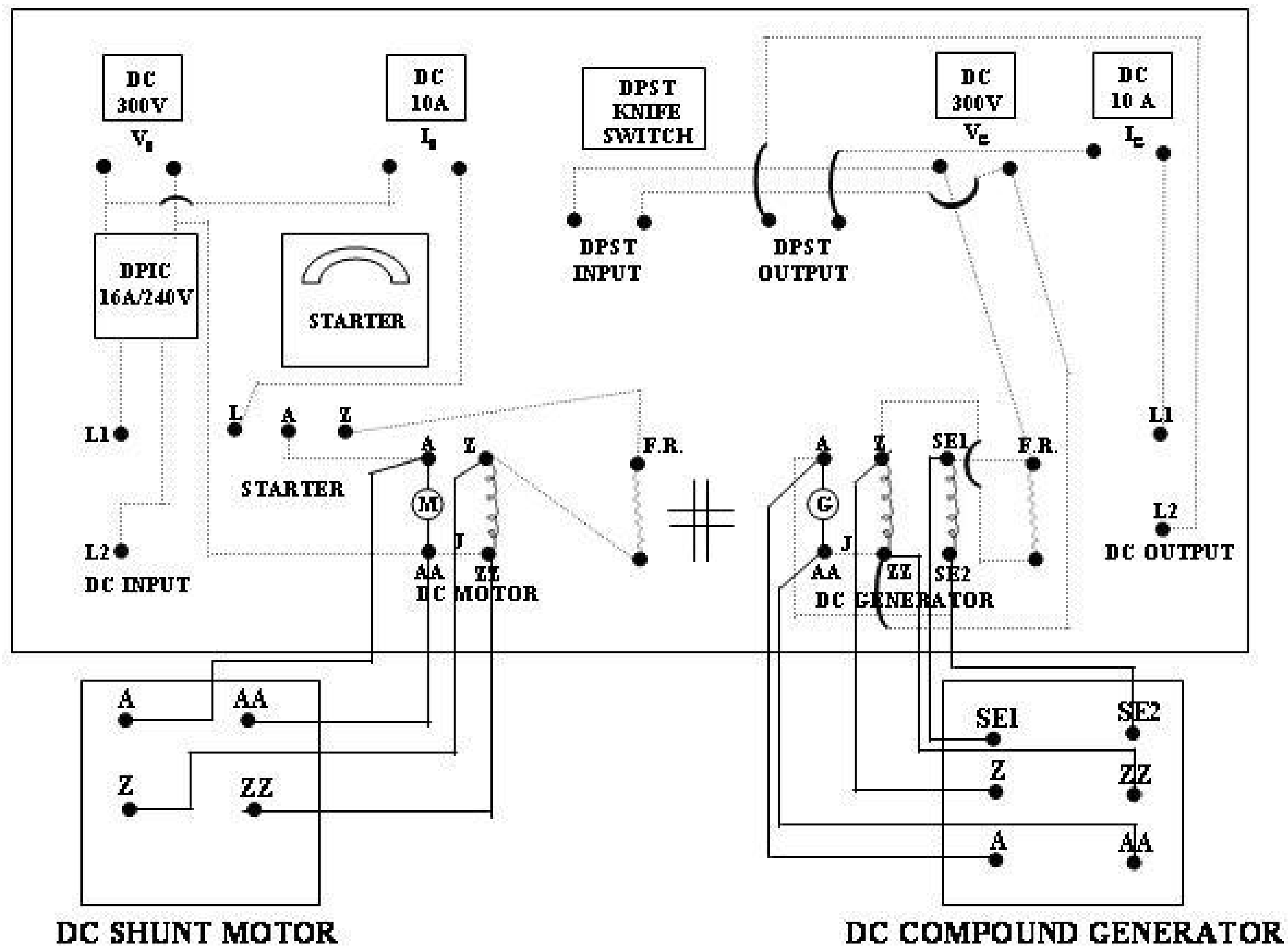


Fig1 : Load test on DC generator.

PANEL FOR LOAD CHARACTERISTICS OF DC COMPOUND GENERATOR



5. PROCEDURE:

1. Connect the circuit of motor and generator as per Fig 1 .
2. Set the rheostat, so that there is not external resistance in the field circuit of the motor.
3. Set the rheostat, so that there is maximum external resistance in the field circuit of the generator.
4. Switch on the supply to the DC motor and start it with the help of starter. Starter arm should be moved slowly, till the motor builds up its speed.
5. Adjust the speed of the motor to rated value by varying the resistance in the field circuit of the motor.
6. Adjust the field current of generator by rheostat R_2, so as to obtain rated voltage at no load.
7. Switch on the lamp bank load and adjust a certain value of load current, say approximately 10 percent of full load current. Record the load and the terminal voltage.
8. Repeat step 7 by various values of load current, till the full load current of the generator.
9. Switch off the load on the generator.
10. To stop the DC motor, switch off the DC supply.

6. OBSERVATIONS:

MOTOR		GENERATOR		
V_S	I_S	V_G	I_G	RPM

7. CALCULATION:

8. RESULT AND DISCUSSIONS: Draw plot between terminal voltage and load current (line current) for DC Generator (a) Cumulatively compounded (b) Differentially compounded.

9. PRECAUTIONS:

1. Never 'START' the DC Shunt Motor against full load of Generator.
2. When the DC machines are put is use after a gap, clean the commutator of D.C. machine by means of soft sand paper.
3. The position of Rocker Arm of machines should only be shifted, when so required, to run the machine spark-free.
4. Check for proper tension of spring on the Carbon holder. If the Carbons are too short, replace it immediately with the new ones.

10. PRE EXPERIMENT QUESTIONS:

1. Draw the load characteristics of DC compound generator.

2. What is armature reaction?

11. POST EXPERIMENT QUESTION:

1. Compare the ideal and experimental load characteristics of DC compound generator.

2. What is voltage regulation of a DC generator?

EXPERIMENT 3

1. Objective: To obtain efficiency of a dc shunt machine using Swinburn's test.

- To perform Swinburne's test on the DC machine, running as SHUNT MOTOR at NO-LOAD.
- To measure the resistance of the armature winding.
- Determine the efficiency of the machine used as motor.

2. Apparatus Used:

DC Motor :

Type : SPDP (Screen Protected)

Capacity : 3 HP, 230V, 11 Amp, 1500 RPM.

Insulation : Class 'B'

INSTRUMENTS REQUIRED ON CONTROL PANEL FOR PERFORMING ABOVE EXPERIMENT :

(a) MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No.

(b) MC Voltmeter 96 x 96 mm flush mounted 0-30V – 1 No.

(c) MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 2 No.

(d) MC Ammeter 96 x 96 mm flush mounted 0-1 Amp, – 1 No.

(e) Tubular Rheostat 1.1A, 330 Ohms – 1 No. (for field control)

(f) Indicating light

(g) Lamp bank load (for armature resistance calculation)

(h) Educational type insulated terminals

(i) DPIC Switch 16A, 240V, HAVELL'S make.

(j) DC Starter face plate type suitable for above motor.

3. 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, where as constant losses are independent of load conditions.

In this method, constant losses are determined experimentally by operating the DC 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 shunt field circuit under no load running be Iao and Ish respectively. Then,

Input power to the armature circuit = V x Iao watts

Input power to the shunt field circuit = V x Ish watts

Total input power to the motor at no load, W0 = V x (Iao + Ish)

Armature copper losses at no load = I^2aoRa

Thus, the constant losses of the machine, Wc = Wo – I^2ao Ra Watts

Hence, The constant losses of DC machine can be determined experimentally by recording Iao, Ish, V and measuring the armature resistance Ra.

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

4. CIRCUIT DIAGRAM:

Fig 'A' shows the circuit diagram for conducting swinburne's test and for measuring the armature resistance respectively, which are self explanatory.

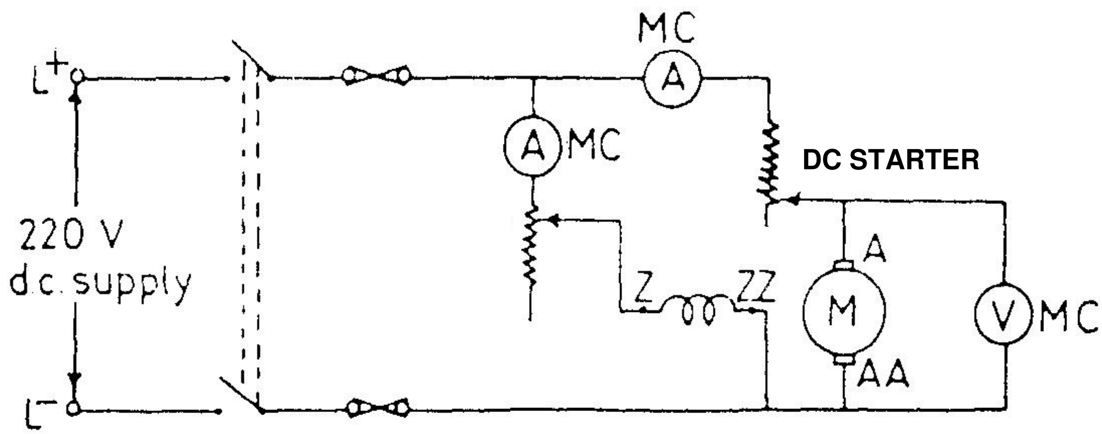


Fig 'A' (i) : Schematic Diagram for Swinburne's test on DC Motor.

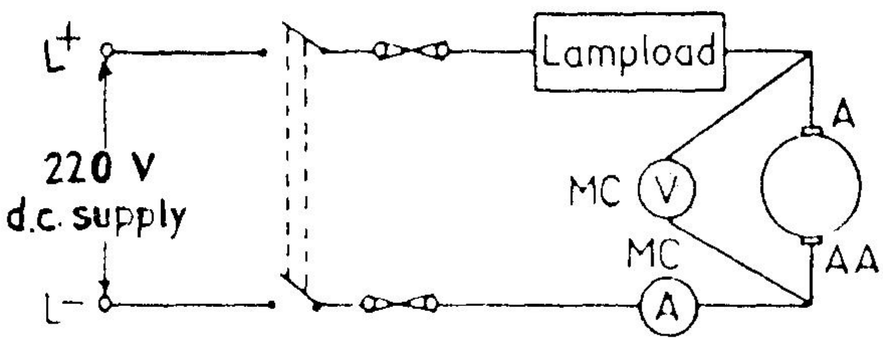


Fig 'A' (ii) : Schematic diagram for Measurement of armature resistance

5. PROCEDURE:

(a) <u>For conducting Swinburne's test</u>

I. Connect the motor with control panel.

II. Ensure that the external resistance in field circuit is zero.

III. Switch ON the DC supply to the motor and start it with the help of starter. Move the handle arm of the starter by few steps till the motor builds up its speed. Ensure that the voltage applied to the motor is of rated value.

IV. Record the reading of all the meters connected in the circuit.

V. To stop the motor, switch off the DC supply.

(b) For measurement of armature resistance

I. Connect the measuring instruments externally meant for armature resistance calculation.

II. Put the DPST knife switch and DP switch in ON position. Switch on some bulbs in the lamp bank load, so that the current flowing in the armature circuit is the rated full load current of the DC motor, wait for few minutes with the full load current flowing in the armature winding, so that the temperature of the armature winding approximately becomes equivalent to that obtained under working conditions.

III. Record the reading of both the meters connected in this circuit.

IV. Switch off the DC supply.

6. OBSERVATIONS:

For Swinburne's test				For armature resistance			
S No.	V	I_{ao}	I_{sh}	S No.	V_a	I_a	R_a

7. CALCULATION OF EFFICIENCY AS A SHUNT MOTOR

Efficiency $\eta = \frac{VI_L - P_L}{VI_L} * 100$

Where V= Motor rated voltage, I_L= load current, P_L= Total Loss Constant Loss and variable Loss

8. Results and Discussion:

9. Precautions:

5. All connections should be tight.
6. All steps should be followed carefully.
7. Readings and calculation should be taken carefully.
8. Don't touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. What do you mean by loading and non- loading test on DC Machine?

2. What are different non- loading test on carried DC Machine?

11. POST EXPERIMENT QUESTIONS:

1. What are advantages of Swinburne's test?

2. What are disadvantages of Swinburne's test?

EXPERIMENT 4

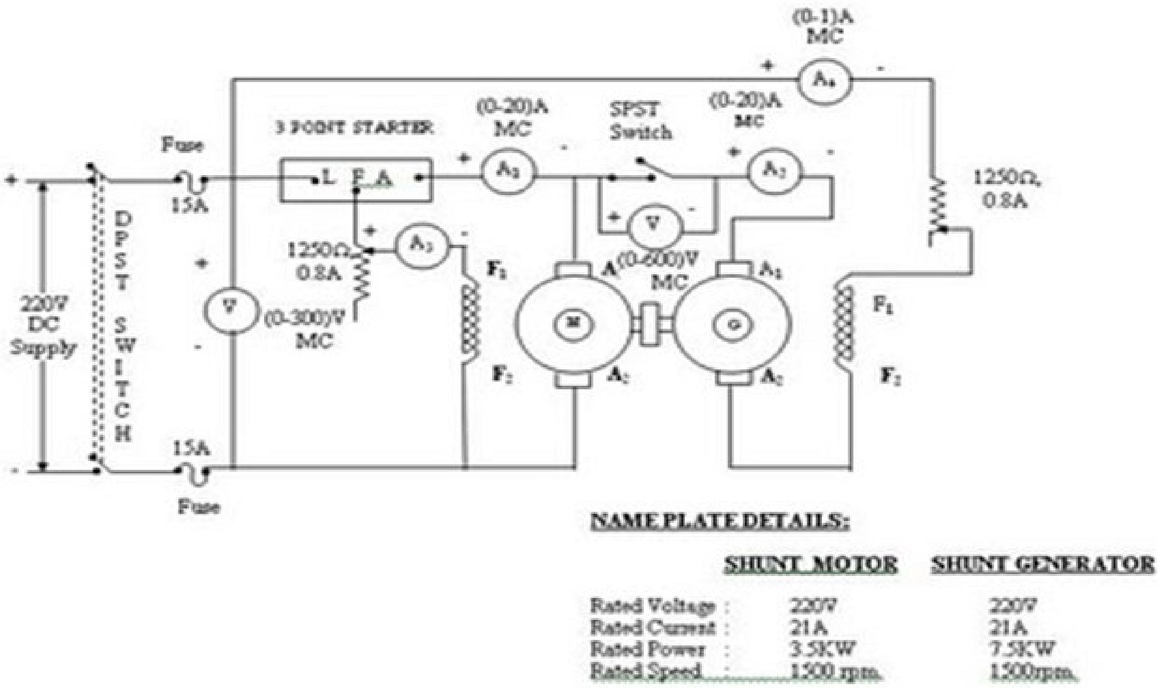
1. Objective: To perform Hopkinson's test and determine losses and efficiency of DC machine.

2. APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-1)A (0-20) A	MC MC	1 2
2	Voltmeter	(0-300) V (0-600)V	MC MC	1 1
3	Rheostats	1250Ω, 0.8A	Wire Wound	2
4	Tachometer	(0-3000) rpm	Digital	1
5	Resistive Load	5KW,230V	-	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

3.Theory: Hopkinson's test is a regenerative test in which two identical DC shunt machines are coupled mechanically and tested simultaneously. One of the machines is made to act as a motor driving the other as a generator which supply electric power to the motor.The set therefore draws only loss power from the mains while the individual machines can be fully loaded.

4.Circut Diagram:



5. Procedure:

I. Connections are made as per the circuit diagram.

II. After checking the minimum position of field rheostat of motor, maximum position of field rheostat of generator, opening of SPST switch, DPST switch is closed and starting resistance is gradually removed.

III. The motor is brought to its rated speed by adjusting the field rheostat of the motor.

IV. The voltmeter V_1 is made to read zero by adjusting field rheostat of generator and SPST switch is closed.

V. By adjusting field rheostats of motor and generator, various Ammeter readings, voltmeter readings are noted.

VI. The rheostats and SPST switch are brought to their original positions and DPST switch is opened.

6. Observations:

Sr. No.	V	I_1	I_2	I_3	Copper Loss	Field Loss	Stray Loss	Total Loss

7. CALCULATION:

8. RESULT AND DISCUSSION:

9. Precautions:

9. All connections should be tight.
10. All steps should be followed carefully.
11. Readings and calculation should be taken carefully.
12. Don't touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. What is stray loss DC Machine?

2. What are different losses in DC Machine?

11. POST EXPERIMENT QUESTIONS:

1. What are advantages of Hopkinson's test?

2. What are disadvantages of Hopkinson's test?

EXPERIMENT 5

1. OBJECTIVE: TO OBTAIN SPEED-TORQUE CHARACTERISTICS OF A DC SHUNT MOTOR.

2. APPARATUS REQUIRED:

S.No.	Apparatus	Type	Range	Quantity
1	Ammeters	PMMC	0-15Amp	1
2	Voltmeter	PMMC	0-300V	1
3	DC Shunt Motor	SPDT (Screen Protected)	-	1
4	Field Regulating Rheostat	-	-	1
5	DC Motor Starter	Three Point	-	1
6	Loading Arrangement	Mechanical	-	1
7	Spring Balance	Longitudinal	50 Kg Each	2

3.Theory: The Load test on DC Motor is performed to obtain its various performance characteristics including efficiency. The motor can be loaded by a belt and pulley. If S1, S2 be tensions in kilograms provided on the two sides of the belts, then the load torque on motor is given by-

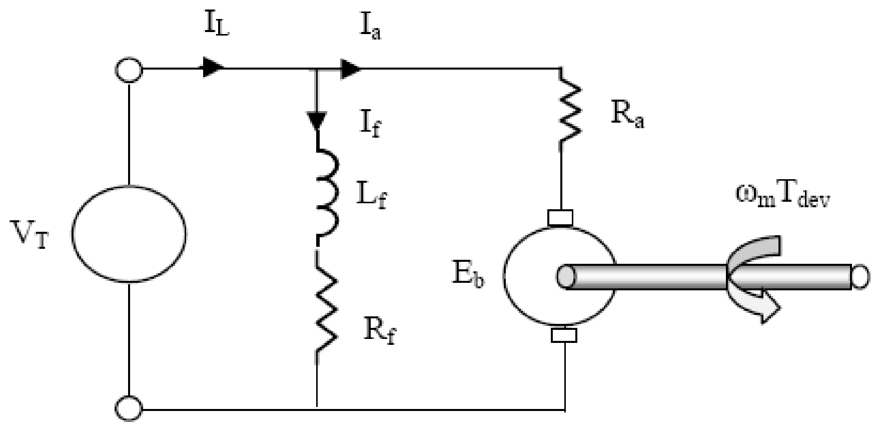
Load Torque Tl = (S1 – S2) x R Kg-m

Where

R - Radius of Pulley

S1 , S2 - Two weights on the belts.

4.Circut Diagram:



5. Procedure:

I. Connections are made as per the circuit diagram.

II. After checking the minimum position of field rheostat of motor, maximum position of field rheostat of generator, opening of SPST switch, DPST switch is closed and starting resistance is gradually removed.

III. The motor is brought to its rated speed by adjusting the field rheostat of the motor.

IV. Motor is loaded by tightening the spring load .

V. Spring balance reading S_1 and S_2 is noted.

VI. Calculate the torque from above mentioned formula.

6. Observations:

Sr. No.	**Speed, N**	**S_1**	**S_2**	**T**

7. CALCULATION:

8. RESULT AND DISCUSSION: The graph between speed of the motor in RPM and torque in Kg-m has been plotted. During the experiment as we go on increasing the load by changing the weight The speed of DC Motor goes on decreasing. This is because of larger torque, larger armature current is required & this has the effect or reducing the gap flux.

9. Precautions:

13. All connections should be tight.
14. All steps should be followed carefully.
15. Readings and calculation should be taken carefully.
16. Don't touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. What is the nature of speed torque characteristics of DC shunt Motor?

2. How does the speed vary by changing the flux in DC shunt Motor?

11. POST EXPERIMENT QUESTIONS:

1. What are the applications of DC shunt Motor?

2. Explain different characteristics of DC shunt Motor?

EXPERIMENT 6

1. OBJECTIVE:

TO STUDY SPEED CONTROL OF A DC SHUNT MOTOR USING

(I) FIELD CURRENT

(II) ARMATURE CURRENT.

2. APPARATUS REQUIRED:

Serial No.	Equipment	Specification	Quantity	Remark
1	DC shunt motor	250V, 2kW	1	
2	PMMC ammeter	0 –10A	2	
3	Rheostats		2	
3	Tachometer		1	
4	3-point starter		1	
5	DPIC switch		1	
6	Connecting Leads			

3. THEORY:

We know that, in DC Shunt motor, the back emf is given by

$$Eb = V - IaRa = \frac{\phi ZNP}{60A}$$

So Speed

$$N = (V-IaRa) / Z\Phi P \times 60A \qquad (1)$$

N α 1/ Φ and N α 1/ Ra (N is speed in RPM)

Where Φ is flux per pole & Ra is armature resistance.

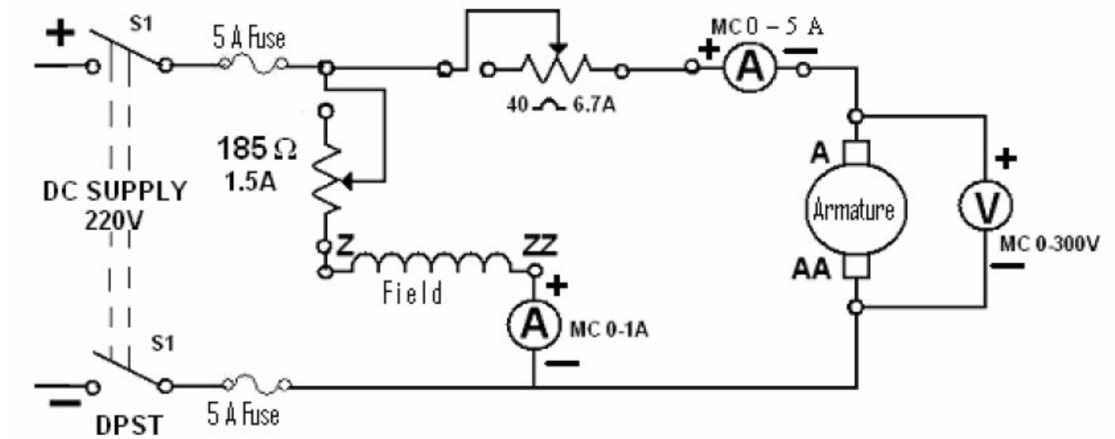
(a) <u>Field Control Method:</u>

This method is applied, where we have to obtain the speed greater than normal rated speed. If we insert a resistance in field winding, field current becomes less, consequently flux also becomes less & speed increases.

<u>(b) Armature Control Method:</u>

If we need the speed less than the rated speed, we use this method. When we insert a resistance in the series of armature, IaRa will increase; therefore the speed of shunt motor reduces by the equation (1)

4. CIRCUIT DIAGRAM:



5. PROCEDURE:

(i) Connect the circuit as shown in circuit diagram.
ii) Start the motor with maximum resistance in the armature circuit and minimum resistance in the field circuit.
iii) Bring the motor to the rated speed, first by decreasing the resistance in the armature circuit and then by increasing the resistance in the field circuit.
iv) Vary the resistance in the field circuit and take readings of speed and field current, keeping the armature voltage constant at a particular value.
v) Change armature voltage to another value and repeat the procedure given in – (iv)
vi) Then change the resistance in the armature circuit and take reading of speed and armature voltage, keeping the field current constant at a particular value.
vii) Change the field current to another value, repeat the procedure given in (vi).
viii) Take three sets of readings for each method of variation.

6. OBSERVATION TABLE:

Table I: Variation of speed with field excitation.

Sl. No.	Field current(A)	Speed(rpm)	Constant Armature Voltage (V)

Table II : Variation of speed with armature voltage.

Sl. No.	Armature voltage (V)	Speed(rpm)	Constant field Current (A)

7. CALCULATION:

8. RESULT AND DISCUSSIONS:

1. With the increase in resistance in the field circuit, the field current decreases so speed increases.

2. With the increase in resistance in the armature circuit, voltage drop in armature increases i.e. back emf E_b decreases and, therefore, speed decreases.

3. Plot speed against field current for different sets of constant armature voltage on a graph paper.

4. Plot speed against armature voltage for different sets of constant field current on another graph paper.

9. PRECAUTIONS:

1. All connections should be tight.
2. Don't touch live terminals.
3. Don't insert the resistance in field winding, when motor begins to start.
4. Reading should be obtained carefully.

10. PRE EXPERIMENT QUESTIONS:

1. What is the function of DC motor?
2. What is working principle of DC motor?
3. What is Back EMF ?

11. POST EXPERIMENT QUESTIONS:

1. What are the methods for speed control of DC shunt motors?
2. In order to increase the speed above rated speed, which method of speed control is used in DC shunt motor?
3. In order to decrease the speed below rated speed, which method of speed control is used in DC shunt motor?

EXPERIMENT 7

1. Objective: To obtain speed control of dc separately excited motor using Conventional Ward-Leonard/Static Ward –Leonard method.

2. APPARATUS REQUIRED:

1. 1 HP THREE PHASE AC INDUCTION MOTOR - 1 Nos
2. 1 HP DC SHUNT GENERATOR - 1 Nos
3. 1 HP DC SHUNT MOTOR - 1 Nos
4. THREE PHASE 3 POLE MCB - 1 Nos
5. STAR - DELTA STARTER - 1 Nos
6. DC MCB - 2 Nos
7. RHEOSTAT 220S / 2A - 1 Nos
8. AMMETER (0 - 2)A - 2 Nos
9. VOLTMETER (0- 300)V - 1 Nos
10. FUSE - 5 Nos
11. 1 HP THREE PHASE INDUCTION MOTOR - 1 Nos
12. 1 HP DC SHUNT MOTOR - 1 Nos
13. 1 HP DC SHUNT GENERATOR - 1 Nos
14. WARD LEONARD SPEED CONTROL SYSTEM STUDY TRAINER
15. AMMETER (0 - 10)A MC - 1 Nos
16. VOLTMETER (0 - 300)V MC - 1 Nos

3. THEORY: This system is used where an unusually wide and very sensitive speed control is required as for colliery winders, electric excavators, elevators and the main drives in steel mills and blooming and paper mills. M1 is the main motor whose speed control is required. The field of this motor is permanently connected across the dc supply lines. By applying a variable voltage across its armature, any desired speed can be obtained. This variable voltage is supplied by a motor-generator set which consists of either a dc or an ac motor M2 directly coupled to generator G. The motor M2 runs at an approximately constant speed. The output voltage of G is directly fed to the main motor M1. The voltage of the generator can be varied from zero up to its maximum value by means of its field regulator. By reversing the direction

of the field current of G by means of the reversing switch RS, generated voltage can be reversed and hence the direction of rotation of M1. It should be remembered that motor generator set always runs in the same direction.

We know that, in DC Shunt motor, the back emf is given by

$$Eb = V - IaRa = \frac{\phi ZNP}{60A}$$

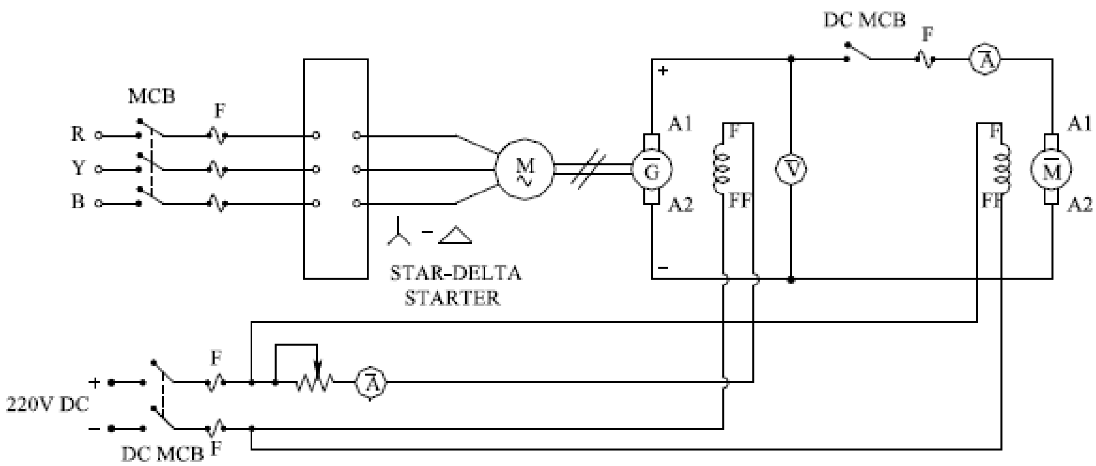
So Speed

$N = (V\text{-}IaRa) / Z\Phi P \times 60A$ (1)

$N \alpha 1/\Phi$ and $N \alpha 1/Ra$ (N is speed in RPM)

Where Φ is flux per pole & Ra is armature resistance.

4. CIRCUIT DIAGRAM:



5. PROCEDURE:

(i) Connect the circuit as shown in circuit diagram.
ii) At base speed motor armature is fed at rated voltage.
iii) Field current is adjusted to the maximum value.
(iv) For obtaining speeds below base speed armature voltage is reduced.
iv) For obtaining speeds above base speed field is gradually weakened.

6. OBSERVATION TABLE:

Table I: Variation of speed below base speed.

Sl. No.	Armature Voltage (V))	Speed(rpm)

Table II : Variation of speed above base speed.

Sl. No.	field Current (A)	Speed(rpm)

7. CALCULATION:

8. RESULT AND DISCUSSIONS: Draw Power vs Speed and Torque Vs speed Characteristics.

9. PRECAUTIONS:

5. All connections should be tight.
6. Don’t touch live terminals.
7. Don’t insert the resistance in field winding, when motor begins to start.
8. Reading should be obtained carefully.

10. PRE EXPERIMENT QUESTIONS:

1. What are different methods of speed control of DC motor?
2. Draw Power vs Speed and Torque Vs speed Characteristics for Ward –Leonard method.?

11. POST EXPERIMENT QUESTIONS:

1. Explain Power vs Speed and Torque Vs speed Characteristics for Ward –Leonard method.?
2. In order to increase the speed above rated speed, which method of speed control is used in DC shunt motor?
3. In order to decrease the speed below rated speed, which method of speed control is used in DC shunt motor?

EXPERIMENT 8

1. **OBJECTIVE: DETERMINATION OF POLARITY AND VOLTAGE RATIO OF A SINGLE PHASE TRANSFORMER.**

2. **APPARATUS REQUIRED:**

Serial No.	Equipment	Specification	Quantity	Remark
1	Transformer		1	
2	AC Voltmeter	0-500V	3	
3	Variac		1	
3	Connecting leads			

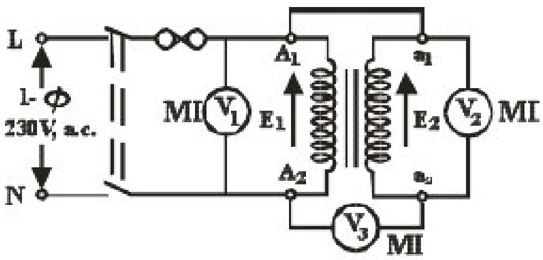
3. **THEORY:**

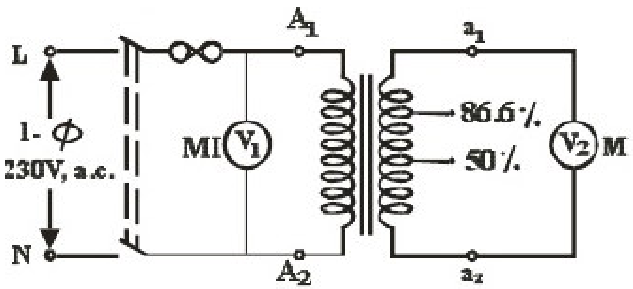
Polarity Test: On the primary side of a two winding transformer, one terminal is positive with respect to the other one at any instant. At the same instant, one terminal of the secondary winding is positive with respect to the other one. Polarity test is performed to determine the terminals having the same instantaneous polarity. The relative polarities of the primary and secondary terminals at any instant must be known for connecting windings of the same transformer in parallel, or series, or for interconnecting two or more transformers in parallel, or for connecting single phase transformers for polyphase transformation of voltages.

In subtractive polarity, the voltage between A_1 and a_1 is reduced. The leads connected to these terminals and the two windings are, therefore, not subjected to high voltage stress. On the other hand in additive polarity the two windings and leads connected to A_1, A_2, a_1 and a_2 are subjected to high voltage stresses. This is the reason that subtractive polarity is preferred over additive polarity.

Voltage ratio Test: the true ratio is based on turn-ratio. If the secondary and primary voltages are measured on no load, their ratio is very nearly equal to the true value. Measurement of primary and secondary currents in short –circuit test also gives fairly accurate result (voltage ratio = $\frac{V_2}{V_1} = \frac{I_1}{I_2}$), especially if the transformer has little leakage flux and low core reluctance.

4.CIRCUIT DIAGRAM:





5.PROCEDURE:

<u>Polarity Test:</u>

1. As per circuit diagram, terminals A_1 and A_2 are marked plus and minus arbitrarily.

2. Now terminal A_1 is connected to one end of secondary winding and a voltmeter is connected between A_2 and other end of secondary winding.

3. A voltage V_3 of suitable value is applied to the high voltage winding.

4. Measure E_1 and E_2 by connecting voltmeters V_1 and V_2 across two windings.

5. If the voltmeter V_3 reading, measured in step 3 , is equal to E_1 - E_2 , then secondary terminal connected to A1 is +ve and another terminal –ve.

6. If the voltmeter V_3 reading is equal to $E_1 + E_2$, then secondary terminal connected to A_1 is -ve and another terminal +ve.

6. OBSERVATION:

Subtractive Polarity:

Sr. No.	Reading for V_1	Reading for V_2	Reading for V_3	$V_3 = V_2 - V_1$

Additive Polarity:

Sr. No.	Reading for V_1	Reading for V_2	Reading for V_3	$V_3 = V_2 + V_1$

<u>Voltage ratio:</u>

Procedure:

1. Connect one voltmeter on the primary and the other on the secondary side, on open circuit.

2. Note down readings of both voltmeters.

Observation:

Sr. No.	Reading for V_1	Reading for V_2	Voltage ratio= $\frac{V_2}{V_1}$

7. CALCULATION:

8. RESULT AND DISCUSSIONS:

When the voltmeter reads the difference E1-E2 , the transformer is said to possess a subtractive polarity and when the voltmeter reads E1+E2 , the transformer is said to possess a additive polarity.

The voltage ratio of a transformer is obtained from the readings of the two voltmeters one on the primary, and the other on the secondary side, on open circuit.

Voltage ratio= $\frac{V_2}{V_1}$ on open circuit

9.PRECAUTION:

1. All connections should be tight.
2. All steps should be followed carefully.
3. Readings and calculation should be taken carefully.
4. Don’t touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. Define Transformer.

2. What do you understand by step-up and step-down transformer?

3. What are the properties of ideal transformer?

11. POST EXPERIMENT QUESTIONS:

1. What is the difference between ideal and practical transformer?

2. What happens when a transformer is connected with DC supply?

3. What is the need for performing polarity test on a transformer?

4. What is the need for performing voltage ratio test on a transformer?

EXPERIMENT 9

1. OBJECTIVE: TO OBTAIN EQUIVALENT CIRCUIT, EFFICIENCY AND VOLTAGE REGULATION OF A SINGLE PHASE TRANSFORMER USING O.C. AND S.C. TESTS.

2. APPARATUS REQUIRED:

Serial No.	Equipment	Specification	Quantity	Remark
1	Single-phase transformer			
2	MI voltmeter	0-300V		
3	MI ammeter	0-5 A	1	
4	Dynamometer Type wattmeter	5 A,240 V	1	
5	Auto-transformer or Variac	0- 300 V	1	
6	Connecting leads			

3. THEORY:

Transformer is a high efficiency, static machine. It transfers the power from one circuit to other circuit at same frequency. The efficiency of small rating transformer can be found by directly loading method, but in case of large transformer, it cannot. Because it is impossible to full load the large transformers in laboratory and it is also costly. So we perform the open circuit test & short circuit test on a transformer to measure its losses by which we can calculate efficiency and voltages regulation of the transformer.

Open Circuit Test:

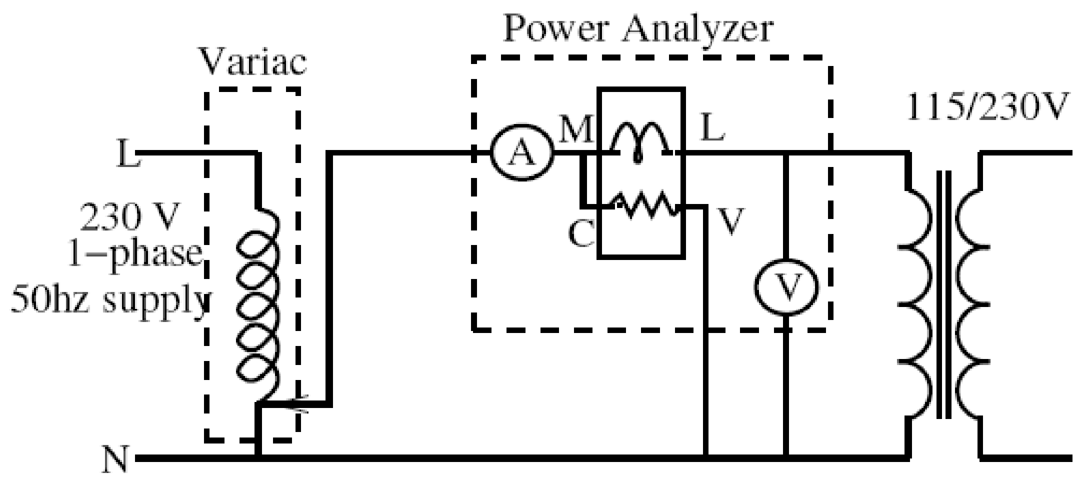
This test performed to find out the no load losses (iron losses) and no load current. Since, at the no load condition or open circuit secondary condition, load current in primary is very less, so copper losses can be neglected.

In this test, primary winding (generally LV side) energized with rated voltage & secondary winding (HV Side) is open circuited. The connected apparatus i.e. voltmeter, ammeter and wattmeter, in primary side measures, voltage across primary terminals, no load current and no load losses respectively.

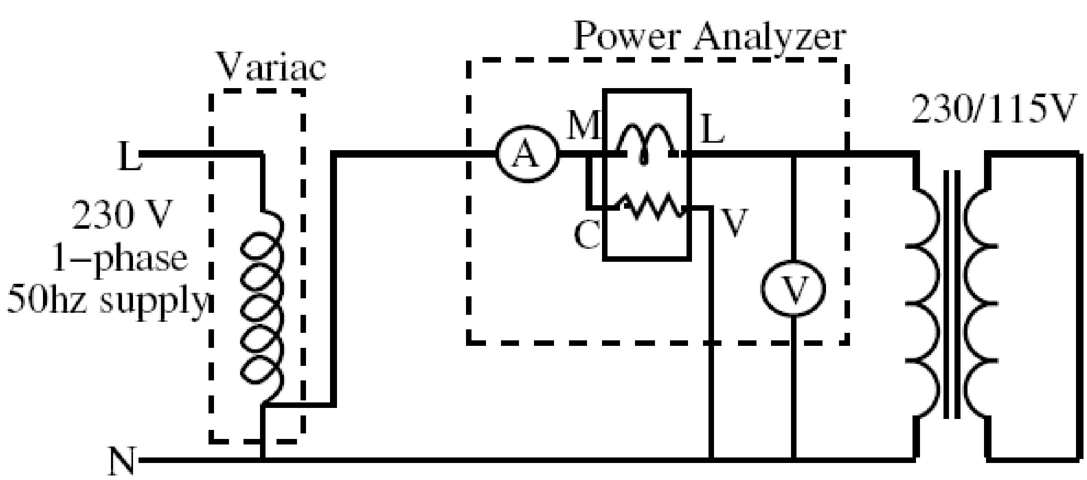
Short Circuit Test:
The main purpose of this test is to find out the copper losses. This test is performed by keeping LV winding short circuited with a wire or ammeter and energized HV side with its full load current. Since, this full load current is started flowing at the low voltage (generally 5 to 10% of rated voltage), so less magnetic flux produced; due to this reason core losses or iron losses can be neglected. The apparatus i.e. ammeter, voltmeter & wattmeter connected in HV side, measures the full load current, short circuit voltage and full load copper losses respectively.

4. CIRCUIT DIAGRAM:

(a) Open Circuit Test:



(b) Short Circuit Test:



5. PROCEDURE:

Open Circuit Test:

1. Connect all the apparatus as the circuit diagram.

2. ON the switch of power supply and adjust rated voltage across L.V. Side.

3. Record No-load current, voltage applied and no load power factor of the transformer winding in observation table.

4. Switch OFF the supply after recording the readings.

Short Circuit Test:

1. Connect all the apparatus and instruments according to circuit diagram.
2. Adjust the variac at zero.
3. ON the switch of power ac supply.
4. Increase the applied voltage slowly, till the full load current in corresponding winding.
5. Note down the ammeter, voltmeter and wattmeter readings in the observation table.
6. Switch off the supply after taking the readings

6. OBSERVATION TABLE:

S.No.	**Open Circuit Test**			**Short Circuit Test**		
	Input voltage (V1) volts	**No-Load Current (Io)**	**Iron losses (Wo)**	**Short Circuit Volatge (Vsc) Volts**	**Full laod Current (Isc) Amps.**	**Cu-Losses (Wsc) watts or Psc.**

7. CALCULATIONS:

For OC Test:

Iron Loss, $P_i = W_0$ Watts

No – load current = I_0 amperes

$$\cos\phi_0 = \frac{W_0}{V_1 I_0}$$

Loss component of current, $I_e = I_0 cos\phi_0 = \frac{W_0}{V_1}$

Magnetizing component of current, $I_m = \sqrt{I_0{}^2 - I_e{}^2}$

Equivalent circuit Parameter, $R_0 = \frac{V_1}{I_e} = \frac{V_1^2}{W_0}$

Equivalent circuit Parameter, $X_0 = \frac{V_1}{I_m} = \frac{V_1}{\sqrt{I_0{}^2 - I_e{}^2}}$

SC Test:

Full load copper loss, $P_c = I_{sc}{}^2 R_{eq} = W_{sc}$

Equivalent resistance , $R_{eq} = \frac{W_{sc}}{I_{sc}{}^2}$

Equivalent impedance, $Z_{eq} = \frac{V_{sc}}{I_{sc}}$

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

Percentage efficiency = $\eta = \frac{VI\cos\phi}{VI\cos\phi + W_0 + W_{sc}} \times 100$

Percentage voltage regulation= $\frac{V_0 - V_{fl}}{V_{fl}} * 100$

8. RESULT AND DISCUSSION: Iron loss is given by open circuit test and copper loss is given by short circuit test.

9. PRECAUTIONS:

9. All connections should be tight.
10. Don't touch live terminals.
11. Don't insert the resistance in field winding, when motor begins to start.
12. Reading should be obtained carefully.

10. PRE EXPERIMENT QUESTIONS:

1. What is magnetizing and loss component of current?

2. What is condition for maximum efficiency in a transformer?

11. POST EXPERIMENT QUESTIONS:

1. Why is HV side open- circuited for open circuit test?

2. Why is LV side short- circuited for open circuit test?

3. Which loss is given by open- circuit test in transformer?

4. Which loss is given by short -circuit test in transformer?

EXPERIMENT 10

1. OBJECTIVE: TO OBTAIN 3-PHASE TO 2-PHASE CONVERSION BY SCOTT CONNECTION.

2. APPARATUS USED:

S No.	Name	Type	Range	Quantity
1.	Voltmeter	MI	0-300/600V	1
2.	Ammeter	MI	0-20A	5
3.	3 phase variac		400/0-400V, 25A	1
4.	Lamp bank load	Resistive	250 V, 3 KW	2
5.	Transformer	single phase, tappings at 28.8%, 50% & 86.6% on primary side	1KVA or 2KVA	1
5.	Transformer	single phase, tappings at 50% & 86.6% on primary side	1KVA or 2KVA	1

3. THEORY

Three phase to two phase conversion or vice versa is essential under the following circumstances :-

(i) To supply power to two 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 apparatus from a two phase source.

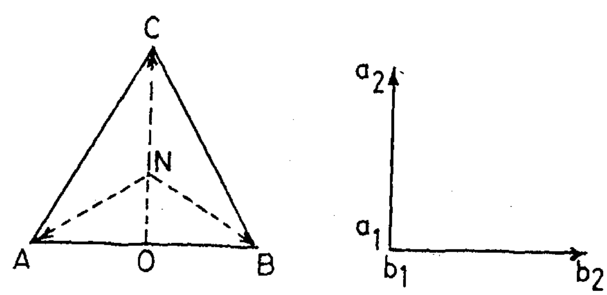
The common type of connection which can achieve the above conversion is normally called scott-connection.

Two single phase transformers of identical rating with suitable tappings provided on both, are required for the scott-connection. Fig 'B' shows the circuit diagram of scott-connection with various details marked on it. The two transformers used for this conversion must have the following tappings on their primary windings.

Transformer A – 50 percent tappings and is called the main transformer.

Transformer B – 86.6 percent tappings and is called the teasure transformer.

The phasor diagram of voltages across the primaries and secondaries has been shown in Fig 'A'. The voltage across the primary, CO of the teasure 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 teasure transformer, such that the voltage between O AND n is 28.8 percent of the applied voltage. Thus the neutral point divided the teasure primary winding, CO in the ratio of 1:2.



(a) Primary voltages (b)Secondary voltages

Fig 'A' : Phasor Diagram for scott coneection

The voltages across the two secondaries a_1 a_2 and b_1 b_2 should be same in magnitude but in phase quadrature, which may be verified experimentally by recording the voltage across the two secondaries V_{a1a2}, V_{b1b2} and the voltage across a_2 b_2 with a_1 and b_1 connected together. The voltage V_{a1a2} and V_{b1b2} will be in phase quadrature, if the following relationship holds good between the three voltages.

$$V_{a2b2} = \sqrt{V^2_{a1a2} + V^2_{b1b2}}$$

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

(i) **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 in the primary windings on three phase side will also be equal and that too at unity power factor. This fact may be verified experimentally.

(ii) **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.

(iii) **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.

4. CIRCUIT DIAGRAM:

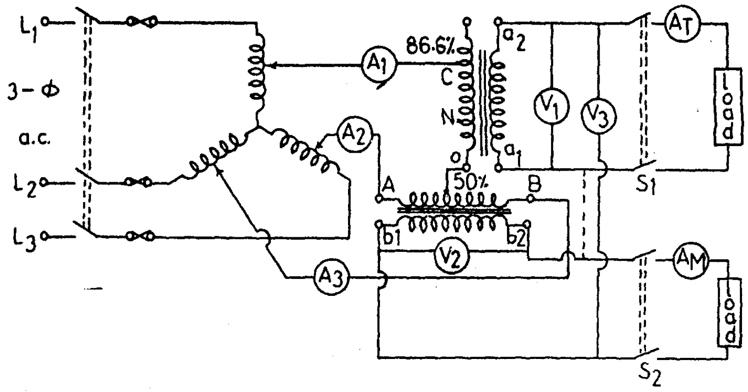


Fig. B. Scott Cnnection

Fig 'B' shows the circuit diagram of scott connection for converting a 3 phase AC system into two phase balanced AC system. Various instruments connected in the circuit serve the purpose indicated against each.

1. 3 Phase Variac – to reduce the voltage applied to the primaries of the transformers as per their voltage rating.

2. Ammeter – to measure load current on each secondary and the currents in all the lines on the primary side.

3. Voltmeter – to measure voltages across each secondary, primary and also when secondaries are connected. It is advisable to use a single voltmeter with probes to measure different voltages.

4. Lamp bank load – to load the secondaries.

5. PROCEDURE:

I. Connect the circuit as per figure 'B'.

II. Ensure that the switches S_1 and S_2 are open.

III. Adjust the 3 phase Variac for minimum voltage in its output circuit.

IV. Switch on the AC supply and apply rated voltage across the primaries of the transformers.

V. Record voltage V1, V2 and V3 and verify that the output is a balanced two phase supply.

VI. Switch off the AC supply and remove the dotted connection of the two secondaries and the voltmeter V3. Adjust the Variac to minimum output voltage.

VII. Switch on the AC supply again. Adjust the output voltage of the Variac as per the rated voltage of the primaries of the transformer.

VIII. Close the switch S1 and S2 to load both the secondaries. Adjust equal loading of both the secondaries. Record the readings of all the meters connected in the circuit (Primaries as well as secondaries).

IX. Repeat step 8 for various equal loading condition on the two secondaries.

X. Repeat step 8 for various unequal loading condition on the two secondaries.

XI. Switch off the load from both the secondaries and adjust the Variac, so that its output voltage is minimum.

XII. Switch off the AC supply.

6. OBSERVATIONS:

For balanced two phase supply				Under load connections							
S No.	V_1	V_2	V_3	S No.	I_{2m}	I_{2T}	I_1	I_2	I_3	V_1	V_2

8. CALCULATION:

9.RESULTS AND DISCUSSION:

9. PRECAUTIONS:

17. All connections should be tight.
18. All steps should be followed carefully.
19. Readings and calculation should be taken carefully.
20. Don’t touch the live terminals.

10. PRE EXPERIMENT QUESTIONS:

1. What does Scott Connection do?

2. How to obtain balanced two phase supply from a 3 phase balanced system.

11. POST EXPERIMENT QUESTIONS:

1. Explain Phase Group I (0^0), Group II (180^0), Group III (30^0) and Group IV (-30^0) in 3-phase transformer.

2. Explain Scott Connection in transformer?