Department of Electrical Engineering
Govt. Polytechnic,Nuapda Odisha Pin- 766105

LABORATORY

MANUAL

Electrical Machine Lab-I

(4th Semester)

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Experiment -1

Aim- Identification of different terminals of a DC machine by test lamp method and multi-meter method & to measure insulation resistance by megger.

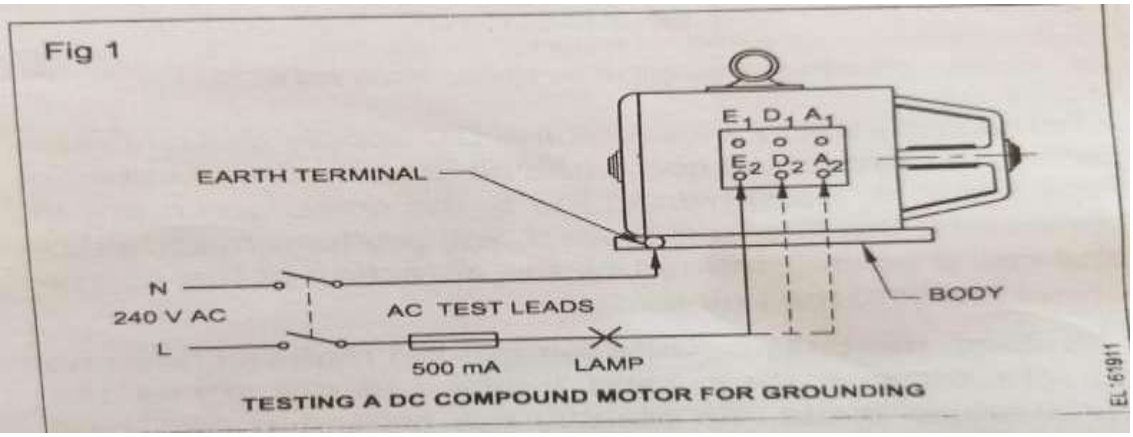
APPARATUS REQUIRED:

Sl.no	Name of the Equipment	Specification	Quantity
1	DC Compound Motor	220v, 1500 RPM	1no
2	Insulated Combination Pliers	150mm	1no
3	Screw driver	200mm	1no
4	Line Tester	1100v, 6''	1no
5	Double ended Spanner	----------	1 Set
6	Ring Spanner`	----------	1Set
7	Mallet	250gm	1no
8	Bearing Puller	----------	1no

Theory:-

Maintenance: - By doing maintenance on electrical machines we can eliminate major failures of the machines, accidents, heavy repair costs, and loss of production time.

Ground Test:- This method is used to locate the ground fault of a dc machine. Megger is the most appropriate one for this ground test. In this method, one prob of the test lamp which is in the neutral line is connected to the earth terminal stud of the machine. The other prob which is in the phase line is connected to the test lamp. The lamp prob should be touched with each terminal of a dc machine. In a good condition machine, the lamp should not light, but if the light glow, them mark the terminal and immediately re-insulate the winding with varnish and tape. If the coil burnt out, which will identified by the decolonization of coil or smell, then rewinding should be done.



Open Circuit Test:- This test is conducted to determine the correctness of winding continuity. This test should be done must before conducting insulation test by the megger, because to sure that circuit will complete before measure the insulation resistance. Depending upon the type of dc machine different tests need to be conducted. In this method the neutral prob should connected to the one end of the winding terminal and the line prob should connected another end of winding terminal. In dc compound motor the light should glow bright.

Some other reason of open circuit in DC machine:-

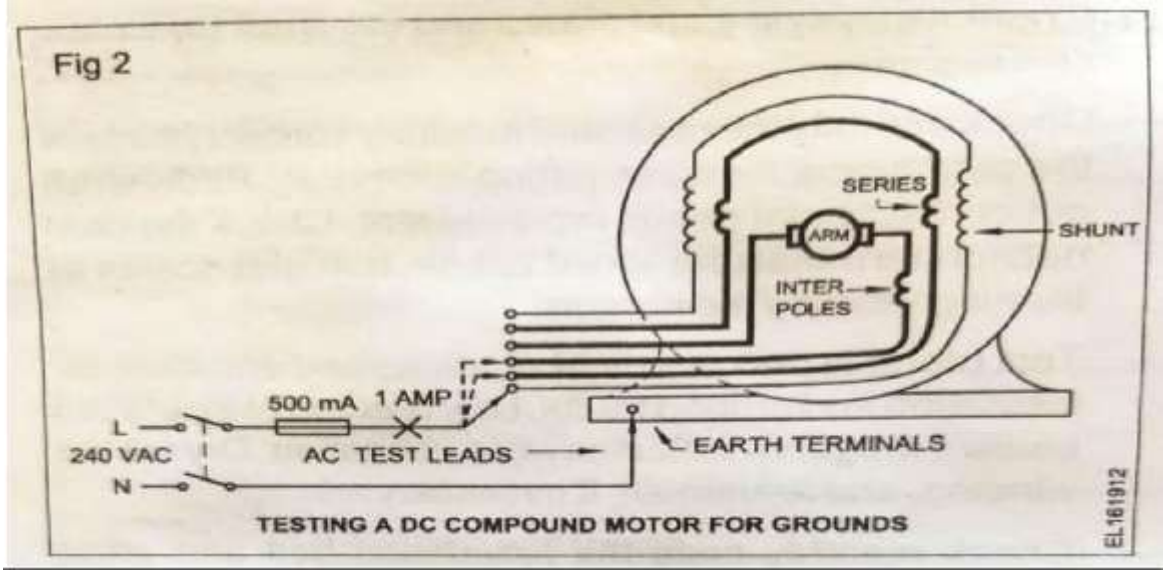
(i) The brushes not making proper contact with the commutator.

(ii) Dirty or severely pitted commutator.

(iii) Break in the pigtail connection or jumper connection of the brushes.

(iv) Break in the field circuit.

(v) Break in the armature winding.



Procedure:-

a. We should take all the tools & instrument for this experiment.
b. Open the terminal box with the help of screw driver.
c. Disconnect the supply of DC shunt motor.
d. Switch ON the test lamp and connect the motor terminal according to the circuit diagram.
e. Then measure the insulation resistance with the help of megger.
f. Note the insulation resistance of the motor.

Tabulation:-

Name of methods	Series fieldwinding (R_{sc}) in ohm	Shunt field winding (R_{sh}) in ohm	Armature winding (Ra) in ohm
By Multimeter			
By Megger			

Conclusion:- From this experiment, we learnt about the identification of different terminals of a DC machine.

Experiment -2

Aim: - Dimensional & material study of various part of DC machine.

APPARATUS REQUIRED:

Sl. No	Name of the Equipment	Specification	Quantity
1	DC Compound Motor	220v, 1500 RPM, 1KW	1no
2	Insulated Combination Pliers	150mm	1no
3	Screw driver	200mm	1no
4	Line Tester	1100v, 6''	1no
5	Double ended Spanner	----------	1 Set
6	Lamp	100w	1no
7	Multimeter	Digital Type	1no
8	Megger	500v DC	1No
9	Connecting Wires	2.5 sq mm	As Per Required

Theory:-

Machine:- A piece of equipment with moving parts that is designed to do a particular job. A machine usually needs electricity, gas, steam etc. in order to work.

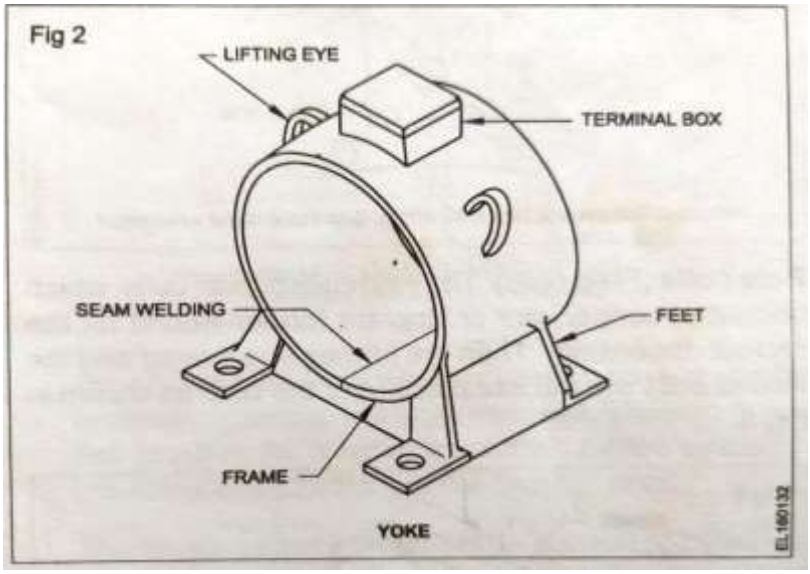
DC Machine:- The machine which works on dc supply is called dc machine.

Parts of DC Machine:-

(i) Frame or Yoke
(ii) Field poles and pole-shoes
(iii) Field coils or Field winding
(iv) Armature Core

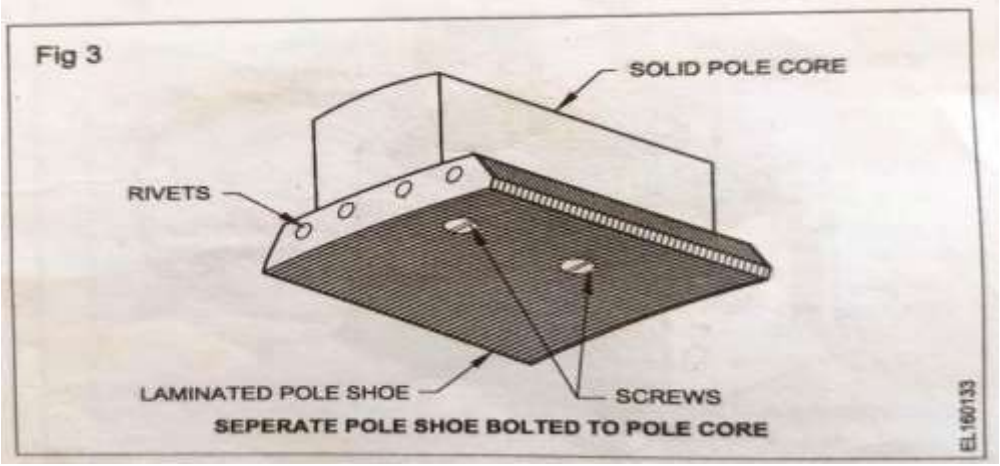
(v) Armature Winding/Armature Conductor
(vi) Commutator
(vii) Brushes
(viii) Bearing & End plate
(ix) Cooling fan
(x) Shaft
(xi) Terminal Box
(xii) Name Plate

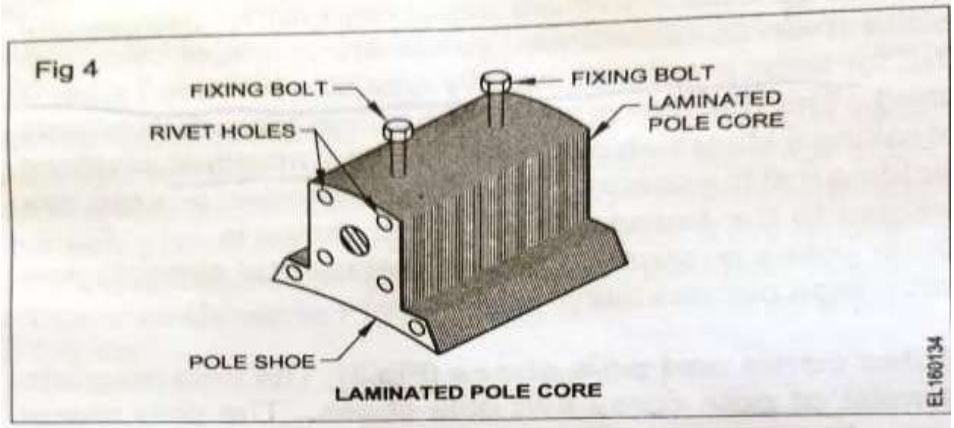
Frame or Yoke:- The outer frame or yoke serves a dual purpose. Firstly, it provides mechanical support for the poles and acts as a protecting cover for the whole machine. Secondly, it allows the magnetic circuit to complete through it. In small generators where cheapness rather than weight is the main consideration, yokes are made of cast iron. But for large machines usually cast steel or rolled steel is used. Yokes possess sufficient mechanical strength and have high permeability.

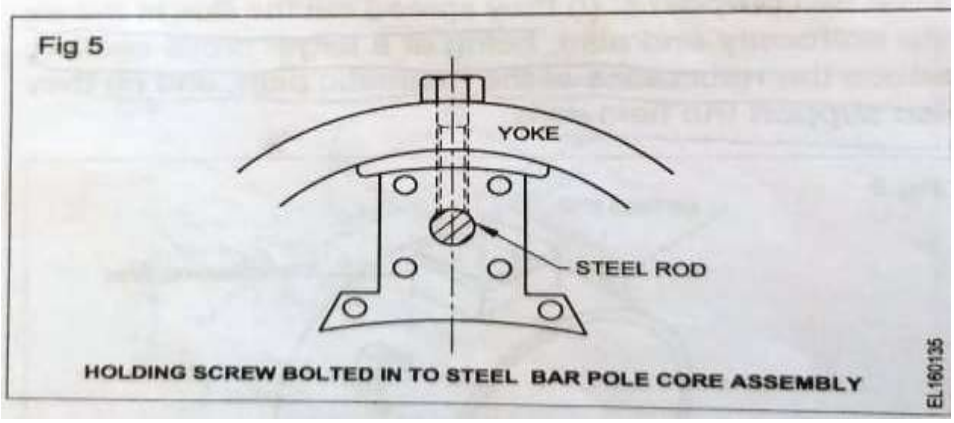


Field poles and pole-shoes:- The field magnets consist of pole cores and pole shoes. The pole shoes serves two purposes; (i) they spread out the flux in the air gap uniformly and also, being of a large cross-section reduce the reluctance of the magnetic path, and (ii) they also support the field coils. There are two main types of pole construction. The pole core itself may be solid piece made out of either cast iron or cast steel but the pole shoe is laminated and is fastened to the pole face by means of countersunk screws. In modern design, the complete

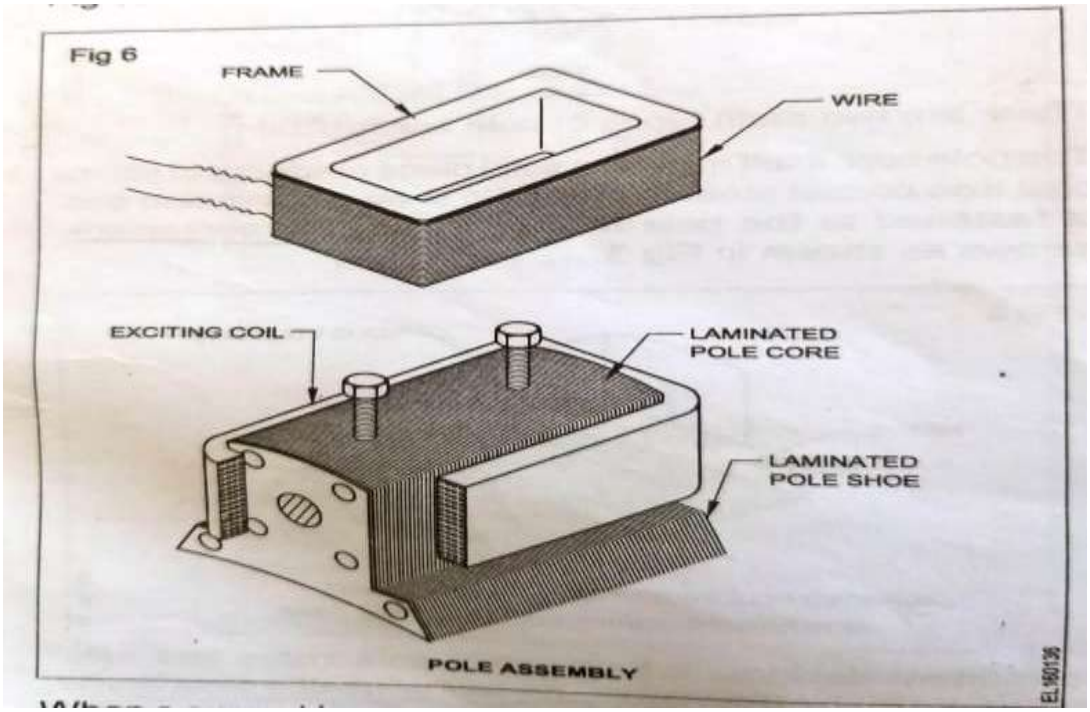
pole cores and pole shoes are built of thin laminations of annealed steel which are riveted together under hydraulic pressure. The thickness of laminations varies from 1mm to 0.25mm.



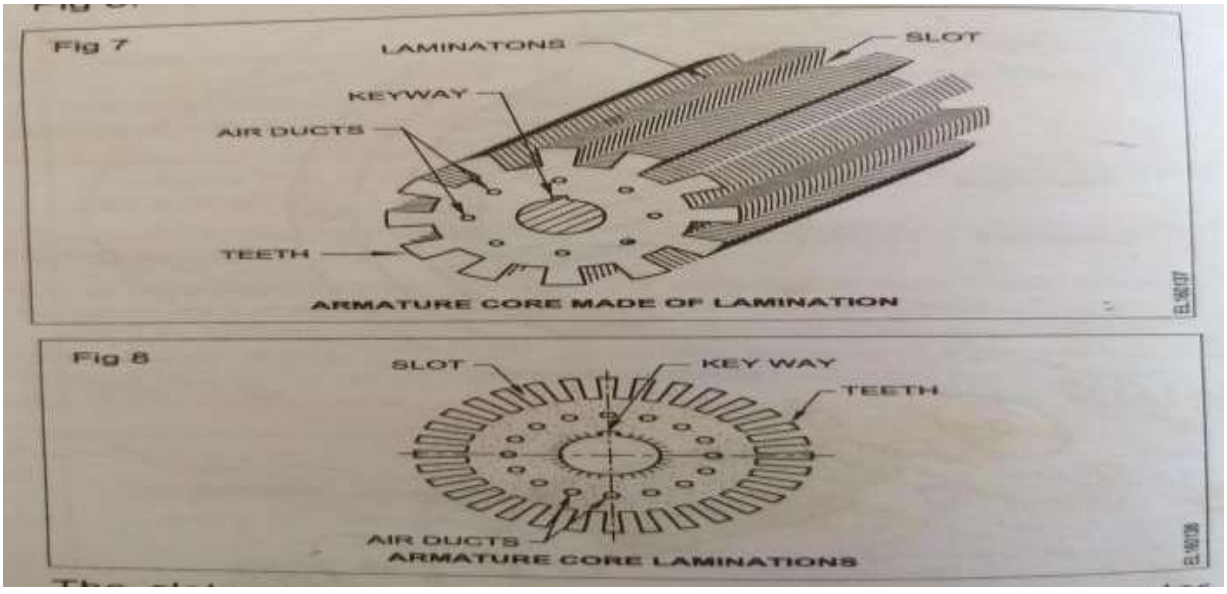




Field coils or Field winding :- The field coils or pole coils which consist of copper wire are wound on a former for correct dimension. Then the former is removed and the wound coils are put into place over the core. When a current is passed through the coils, they magnetize the poles which produce the necessary flux that is cut by revolving armature conductors.

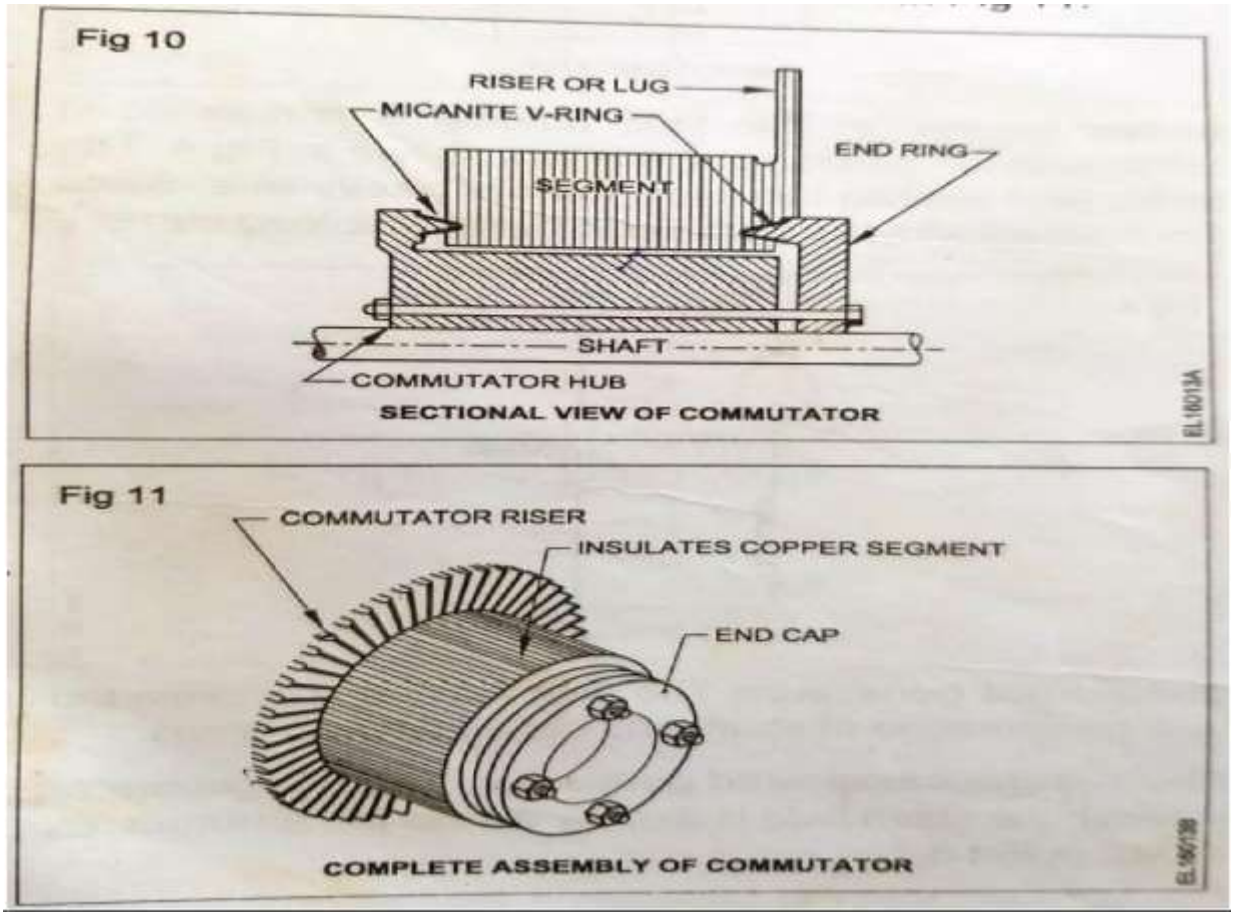


Armature Core :- The armature core houses the armature conductors. Those conductors are rotate in the magnetic field which cut the magnetic flux. The most important function is to provide a path of very low reluctance to the field flux and allowing the magnetic circuit to complete through the yoke and the poles. The armature core is cylindrical or drum shaped and is build up of circular sheet steel dices or laminations which have 0.5mm thickness.



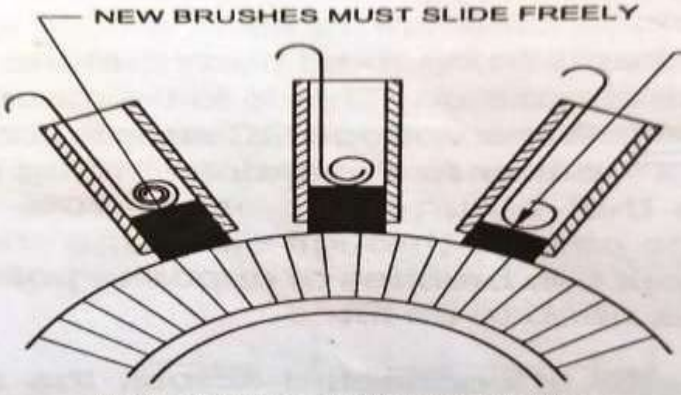
Armature Winding/Armature Conductor:- the armature windings are usually former-wound. These are first wound in the form of flat rectangular coils and are then pulled into their proper shape with a coil puller. Various conductors of the coils are insulated from each other. The conductors are placed in the armature slots which are lined with tough insulating material. After placing the conductors in the slot, this slot insulation is folded over the armature conductors, and is secured in place by special, hard, wooden or fiber wedges.

Commutator:- The function of the commutator is to collection of current from the armature conductors. It rectifies i.e. converts the alternating current induced in the armature conductors into unidirectional current for the external load circuit. It is shape like cylindrical structure and made of hard drawn or drop-forged copper. Its segments are insulated from each other by thin layer of mica.



Brush:- The main function of brush is to collect current from the commutator. These are made of carbon and graphite and are in shape of rectangular block.

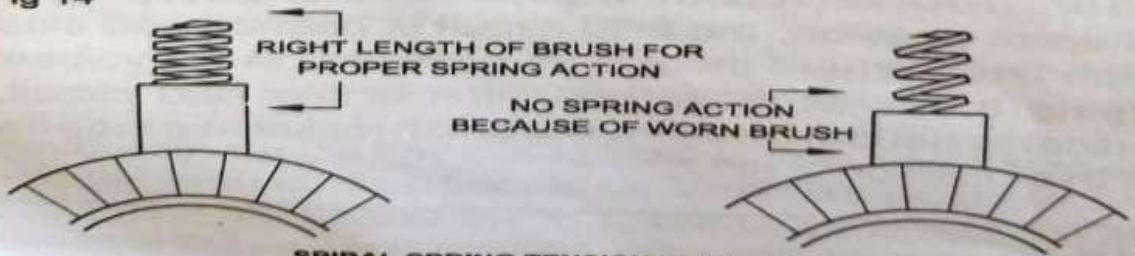
Fig 13



LEAF SPRING TENSION VARIATION

EL16191D

Fig 14



SPIRAL SPRING TENSION VARIATION

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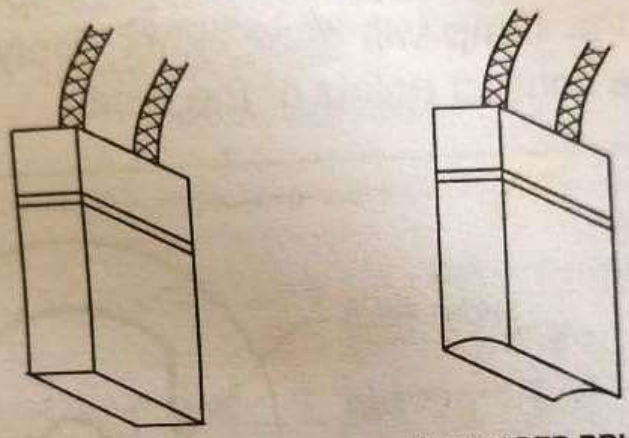
Fig 15

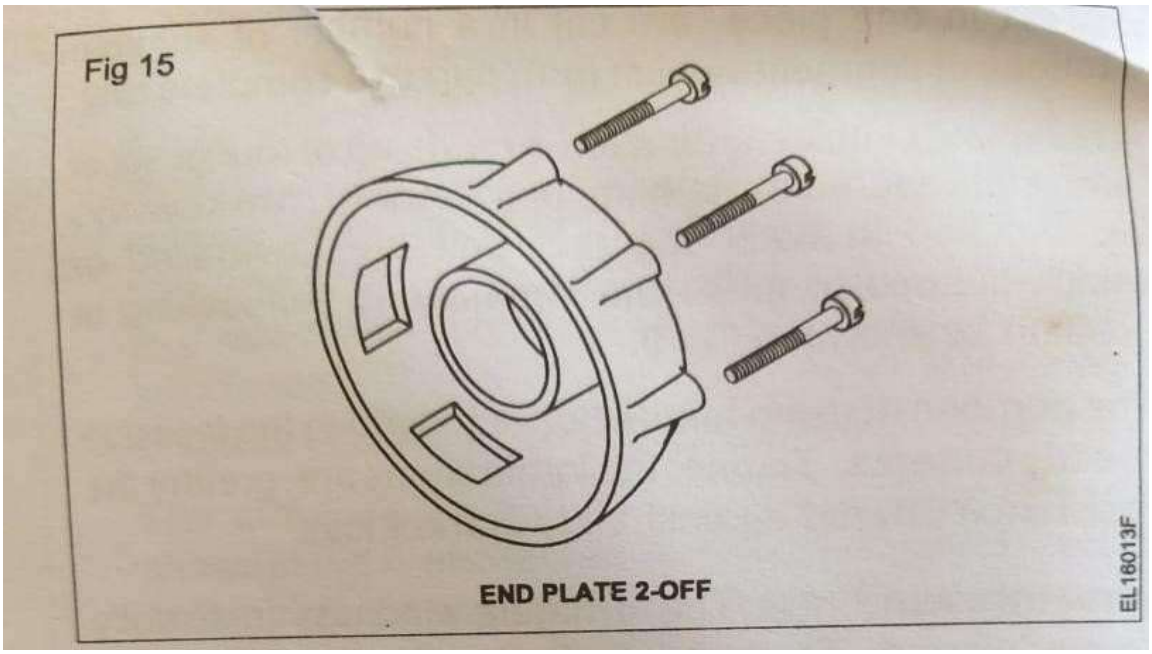


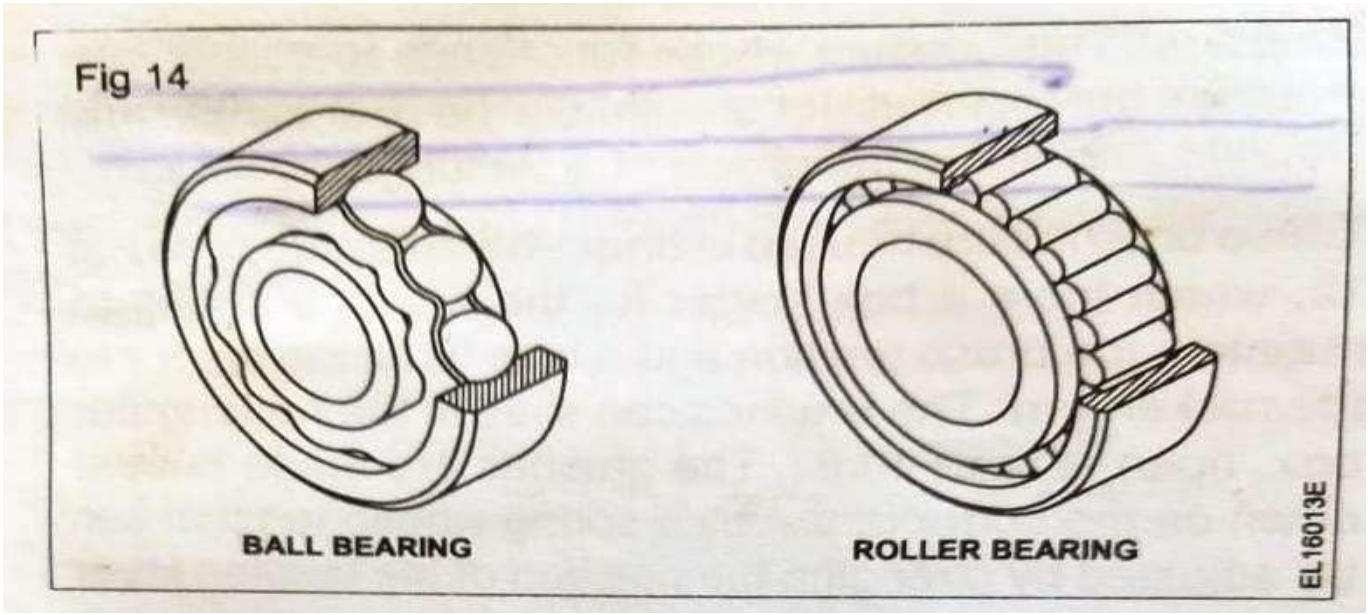
a) FLAT BRUSH

b) SHAPED BRUSH

EL16191F

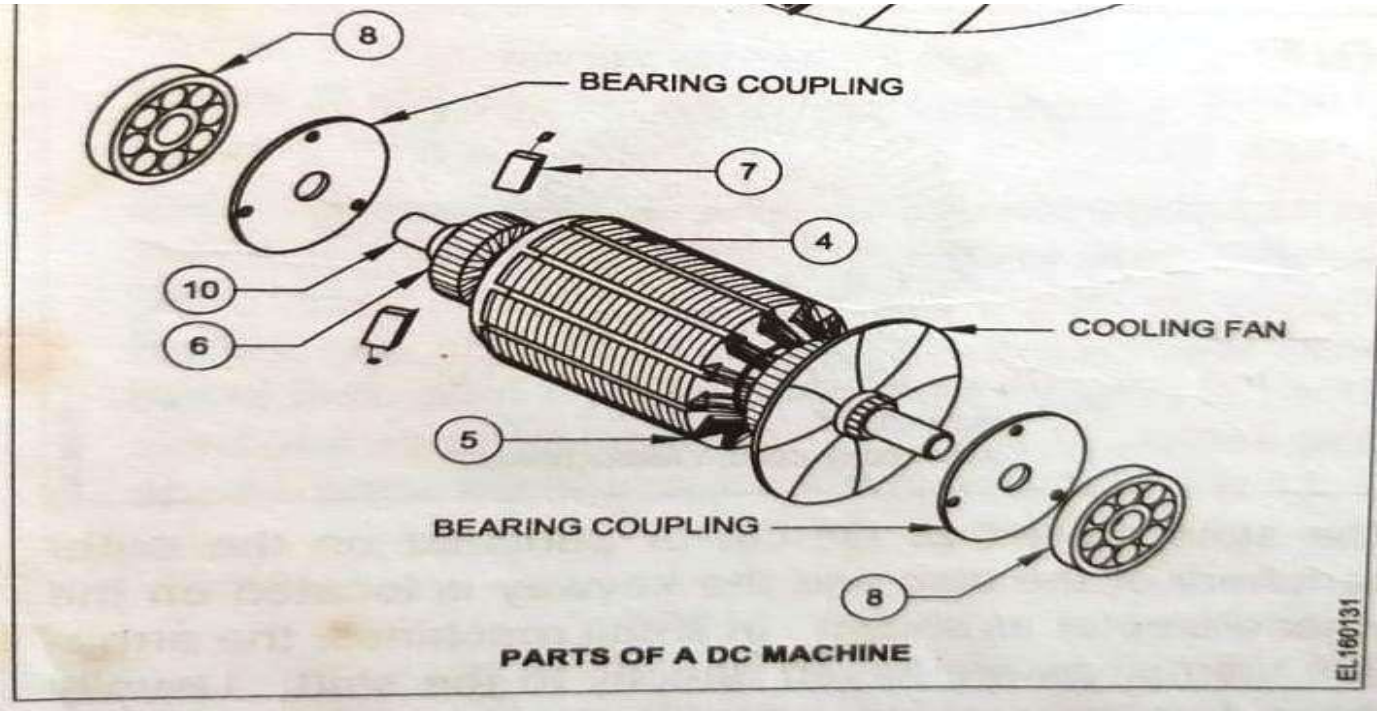
Bearing and End plate:- A bearing is a machine element which are used to reduce friction between moving parts. In DC machines ball and roller bearing are generally used which are filled with grease or lubricating oils. The bearings are housed in these end plates and they are fixed to the yoke. They help the armature for frictionless rotation and to position the armature in the air gap of the field poles.





Cooling Fan:- Cooling fan are placed on the shaft of Dc machine which mainly used for cooling purpose.

Shaft:- A shaft is a mechanical component for transmitting torque and rotation. It is Cylindrical in shape and made of cold rolled or hot rolled steel.



Terminal Box:- Terminal box in dc machines are placed on the yoke. It is used for connection of machine winding terminal and supply terminal.

Name Plate:- It is placed on the yoke which indicates the machine in formations like capacity, rpm, wattage, insulation class etc.

Conclusion:- From this experiment, we learnt about the various parts of Dc machine.

Experiment – 3

AIM: To obtain the open circuit characteristics of DC shunt generator and find its critical resistance.

APPARATUS REQUIRED:

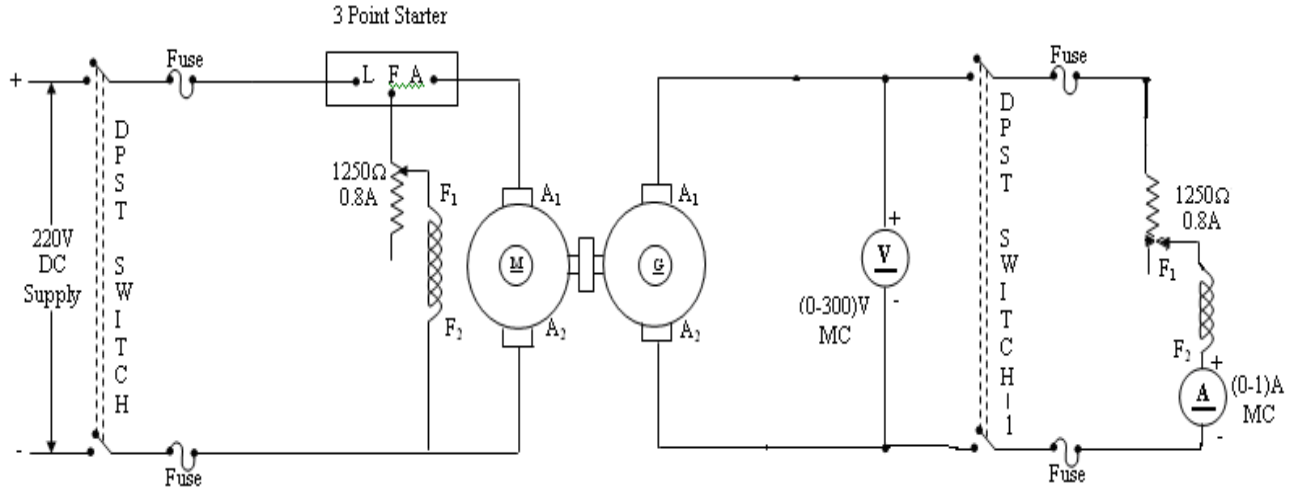
S.No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-1)A	MC	1
2	Voltmeter	(0-300)V	MC	1
3	Rheostats	1250□, 0.8A	Wire Wound	2
4	SPST Switch	-	-	1
5	Tachometer	(0-1500)rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	As per required

PRECAUTIONS:

1. The field rheostat of motor should be in minimum resistance position at the time of starting and stopping of the machine.
2. The field rheostat of generator should be in maximum resistance position at the time of starting and stopping of the machine.
3. DPST-1 should be kept open during starting and stopping of the machine

CIRCUIT DIAGRAM:

OPEN CIRCUIT CHARACTERISTICS OF DC SHUNT GENERATOR



FUSE RATING:

DC Motor

125% of rated current

DC Shunt Generator

10% of rated current

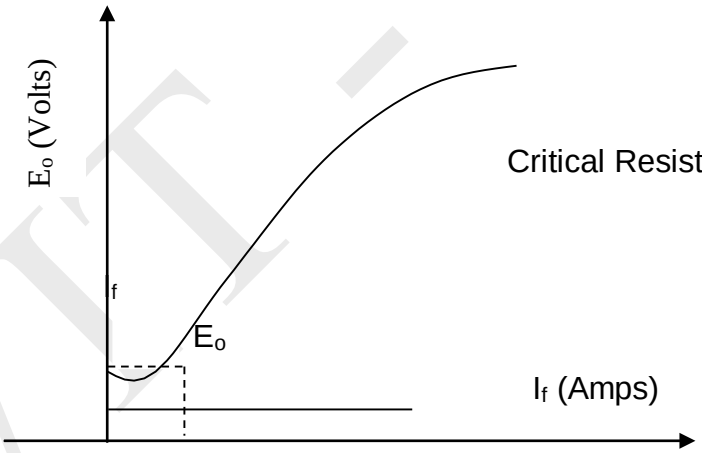
NAME PLATE DETAILS:

	Motor	**Generator**
Rated Voltage	:	
Rated Current	:	
Rated Power	:	
Rated Speed	:	

TABULAR COLUMN:

Sl. No	**Field Current I_f (Amps)**	**Armature Voltage E_o (Volts)**

MODEL GRAPH:



Critical Resistance = E_o / I_f Ohms

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking minimum position of motor field rheostat, maximum position of generator field rheostat, DPST switch is closed and starting resistance is gradually removed.
3. By adjusting the field rheostat, the motor is brought to its rated speed.
4. Voltmeter and ammeter readings are taken when the SPST switch is kept open.
5. After closing the DSPST switch, by varying the generator field rheostat, voltmeter and ammeter readings are taken.
6. After bringing the generator rheostat to maximum position, field rheostat of motor to minimum position, both DPST-1 and DPST switch is opened.

Conclusion:

From the above experiment we know the, open circuit characteristics of DC shunt generator are obtained and its critical resistance.

Experiment No: 04

AIM: Plot External characteristics of a DC shunt generator at constant speed.

Apparatus required:

S.NO	Name of the apparatus	Type	Range	Quantity
1	Ammeter	MC	0-20A	1
2	Ammeter	MC	0-2A	1
3	Voltmeter	MC	0-300V	1
4	Tachometer	Digital	0-9999rpm	1
5	Connecting Wires	2.5sq.mm.	Copper	As per required

Fuse rating: For Open Circuit test 10% of rated full load current

Theory :

Load characteristics are study of voltage when the load on a generator is increased from no load or decreased from full load.

There are two types of characteristics

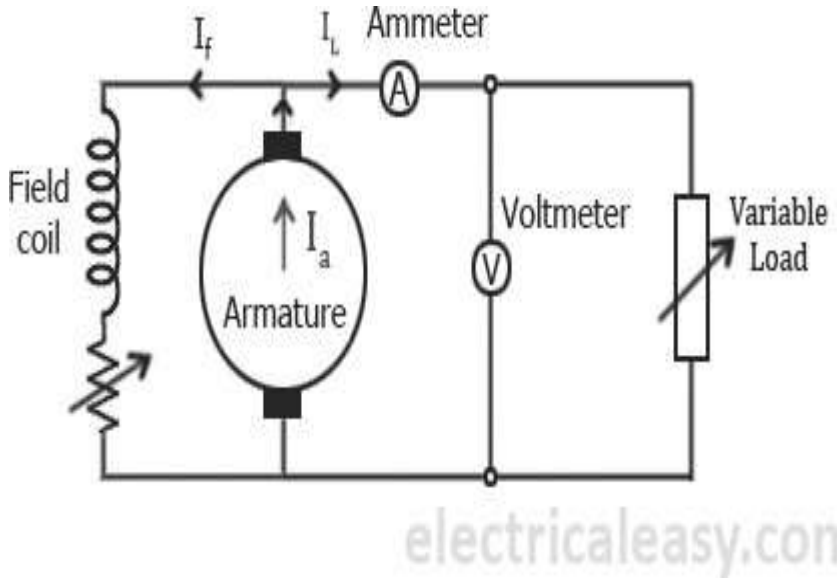
(i) External characteristics

(ii) Internal characteristics

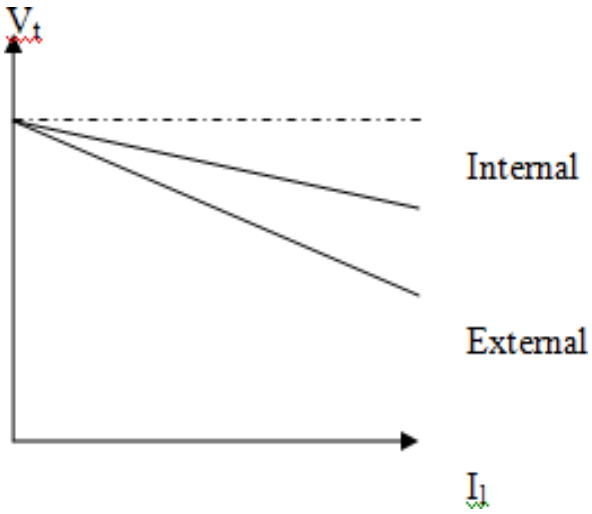
External characteristics

A plot of the terminal voltage V_T and load current I_L with preset values of field current and speed gives External characteristics curve. The drop in terminal voltage V_T is due to armature reaction and further reduction is due reduction in field current $I_{f,}$ since the terminal voltage fallen because of the above two reasons.

Circuit Diagram:-



Model graph:



Tabulation:-

Sl. No	Load Current (I_L) in ampere	Terminal Voltage (V_T) in Volt
1		
2		
3		
4		

Procedure:

i. Connections are made as shown in fig-1.
ii. Ensuring the field resistance of motor in minimum position and generator field resistance in maximum position. Motor is switched ON by dragging the starters handle slowly still it attains ON position Adjust the field of motor to run the generator with rated speed
iii. by adjusting the field of generator keep the terminal voltage V_L around 220V (rated voltage)
iv. Load the generator by keeping the speed of generator constant and note the values of VL, IL, and If.
v. Repeat step 4 till the rated load current is attained.
vi. Reduce the load and switch off the supply
vii. Plot the load characteristics as external and internal characteristics

Conclusion: - From this experiment, we learnt about the external characteristic of DC shunt generator.

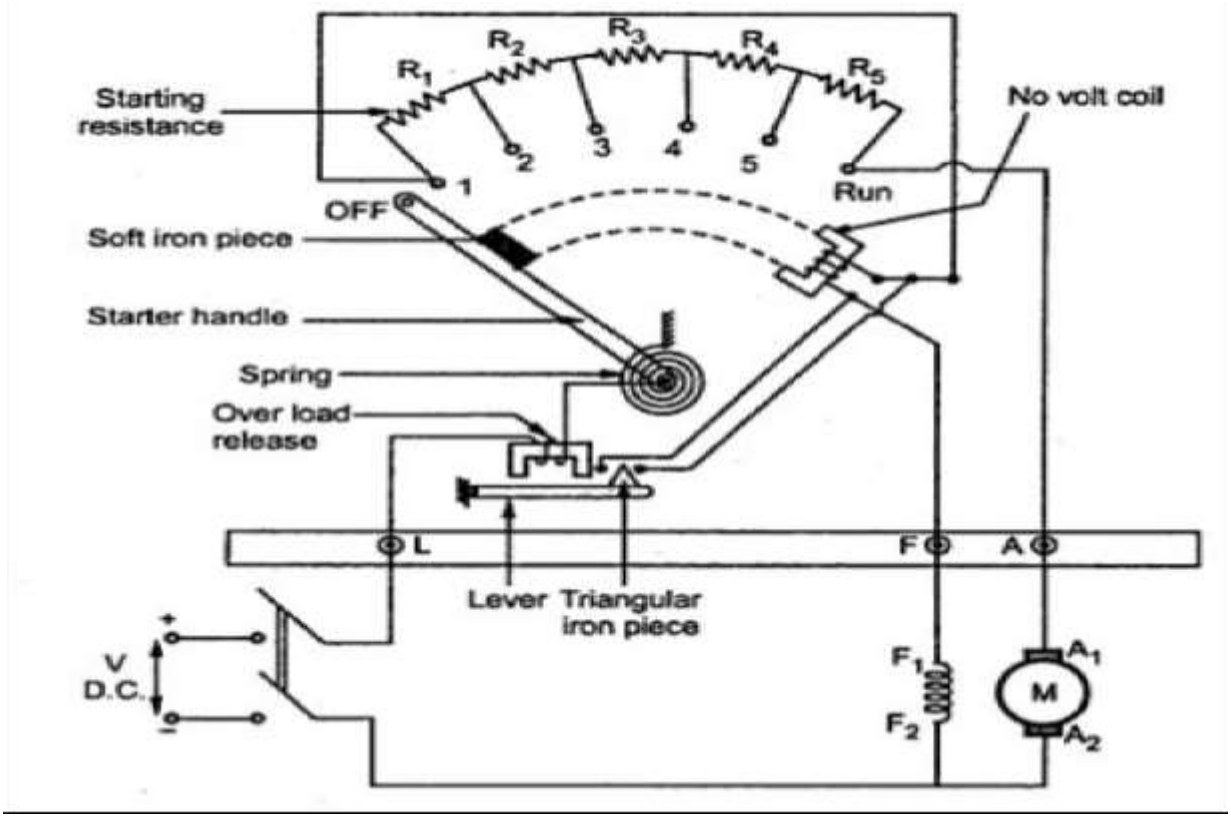
Experiment – 5

Aim:- Study of Four Point Starter, connect and run a DC compound motor & measure no load current.

APPARATUS REQUIRED:-

Sl. No	Name of the Equipment	Specification	Quantity
1	DC Compound Motor	220v, 1500 RPM	1no
2	Four Pont starter	220v,10A	1no
3	DC Ammeter	(0-5)A	1no
4	DC Voltmeter	(0-300)V	1no
5	Connecting Wires	2.5 sq mm	As Per Required

Circuit Diagram:-



Theory:-

Necessity of Starter:-

(i) Starter is used to protect Dc motor from damage which can be caused by very high current and torque during starting.

(ii) Starting of DC motor, the armature is stationary, thus the back emf is also zero which is proportional to speed.

(iii) As armature resistance is very small, if the voltage is applied to it, it will drew many times of full load current.

(iv) This can cause heavy damage to the armature, so the starting current should be limited to a safe value.

(v) This can be done by inserting a resistance in series with the armature at the time of starting for a period of 5 to 10 sec.

Three- Point Starter:-

1. It is used to start the dc shunt motor.
2. The series resistance is connected to the armature
3. The shunt field in series with the holding coil.
4. It has also overload coil, which is connected series with the supply which is used to protect the motor from over load current
5. The starter has insulated handle or knob for the operator's use.

Procedure:-

I. We should take all the tools & instrument for this experiment.

II. Connect the Starter as per circuit diagram with DC compound Motor.

III. Check all the connection.

IV. Switch on the D.C. Supply start the motor with the help of starter.

V. Gradually increase the starter handle to the holding coil.

VI. Measure the starting No load current.

Tabulation:-

Sl. No	No- load current (I_0) in Ampere

Conclusion:- From this experiment we learnt about the four point starter.

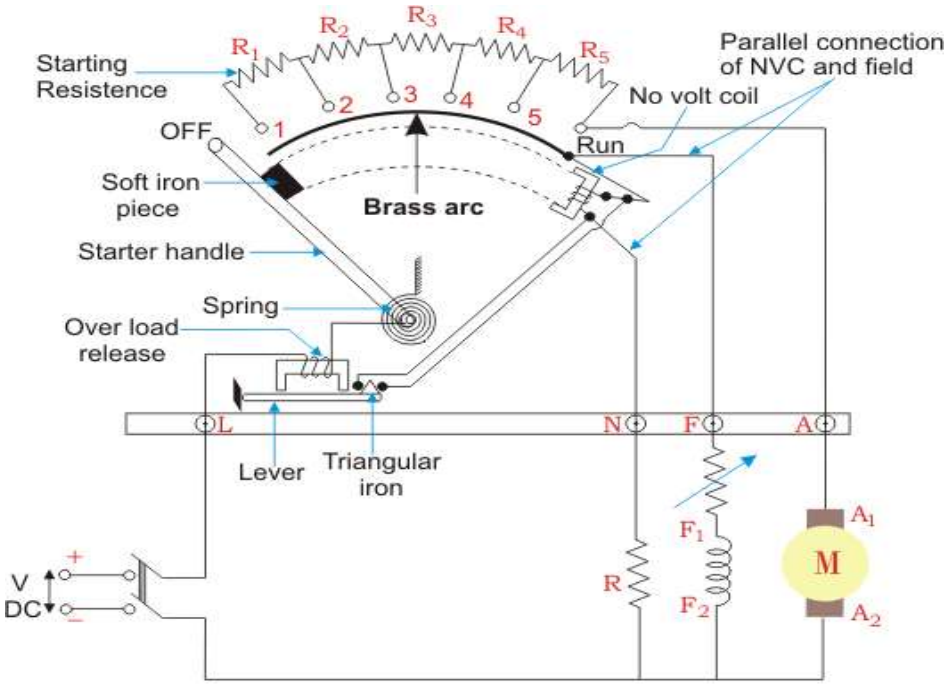
Experiment – 6

Aim:- Study of Four Point Starter, connect and run a DC compound motor & measure no load current.

APPARATUS REQUIRED:-

Sl. No	Name of the Equipment	Specification	Quantity
1	DC Compound Motor	220v, 1500 RPM	1no
2	Four Pont starter	220v,10A	1no
3	DC Ammeter	(0-5)A	1no
4	DC Voltmeter	(0-300)V	1no
5	Connecting Wires	2.5 sq mm	As Per Required

Circuit Diagram:-



Four Point Starter

Theory:-

Necessity of Starter:-

(i) Starter is used to protect Dc motor from damage which can be caused by very high current and torque during starting.
(ii) Starting of DC motor, the armature is stationary, thus the back emf is also zero which is proportional to speed.
(iii) As armature resistance is very small, if the voltage is applied to it, it will drew many times of full load current.
(iv) This can cause heavy damage to the armature, so the starting current should be limited to a safe value.
(v) This can be done by inserting a resistance in series with the armature at the time of starting for a period of 5 to 10 secs.

Four- Point Starter:-

(i) It is used to start the dc compound motor.
(ii) It is similar to 3-point starter but here the holding coil is not connected in series with the shunt field.
(iii) It is connected across the supply in series with a resistor. This resistor limits the current in the holding coil to the desired value.
(iv) If the line voltage drops below the desired value, the magnetic attraction of the holding coil is decreased and then the spring pulls the starter handle back to the 'off' position.

Procedure:-

a. We should take all the tools & instrument for this experiment.
b. Connect the Starter as per circuit diagram with DC compound Motor.
c. Check all the connection.
d. Switch on the D.C. Supply start the motor with the help of starter.
e. Gradually increase the starter handle to the holding coil.
f. Measure the starting No load current.

Tabulation:-

Sl. No	No- load current (I_0) in Ampere

Conclusion:- From this experiment we learnt about the four point starter.

Experiment-7

Aim: – Control the speed of a Dc shunt motor by field flux control method & armature voltage control method.

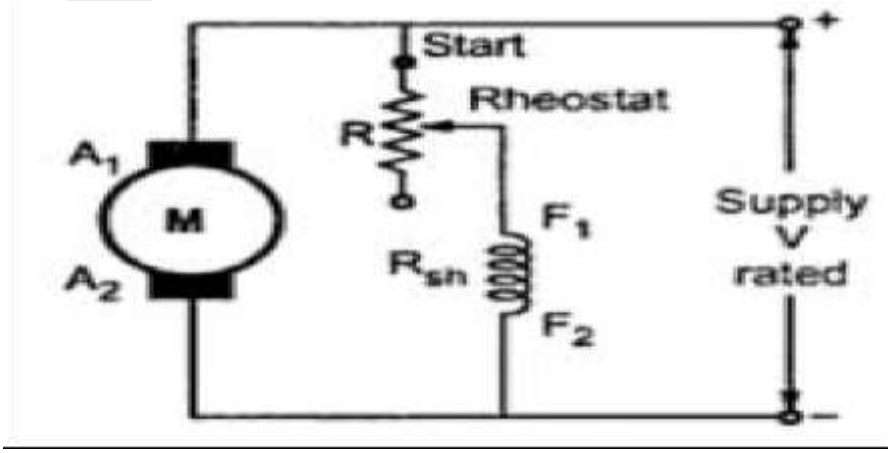
APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-20) A	MC	1
2	Voltmeter	(0-300) V	MC	1
3	Rheostats	1250Ω , 0.8A 50Ω , 3.5A	Wire Wound	Each 1
4	Tachometer	(0-3000) rpm	Digital	1
5	Connecting Wires	2.5sq.mm.	Copper	Few

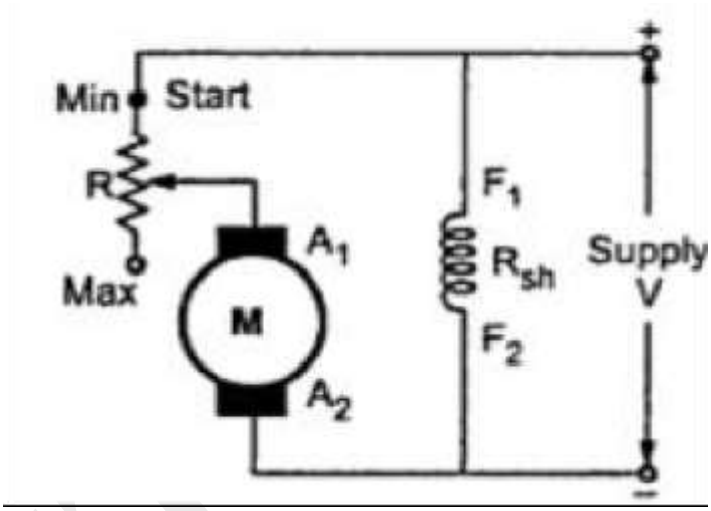
PRECAUTIONS:

1. Field Rheostat should be kept in the minimum resistance position at the time of starting and stopping the motor.
2. Armature Rheostat should be kept in the maximum resistance position at the time of starting and stopping the motor.

Circuit Diagram:-

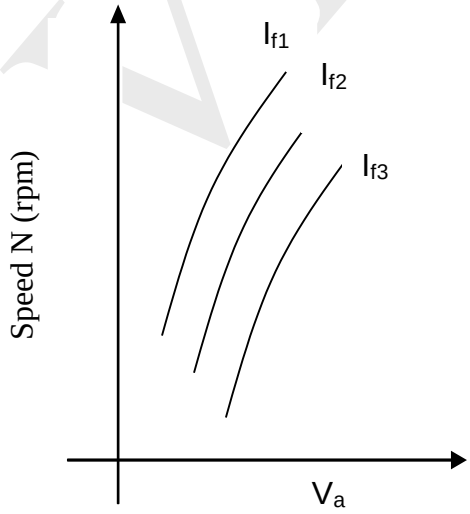


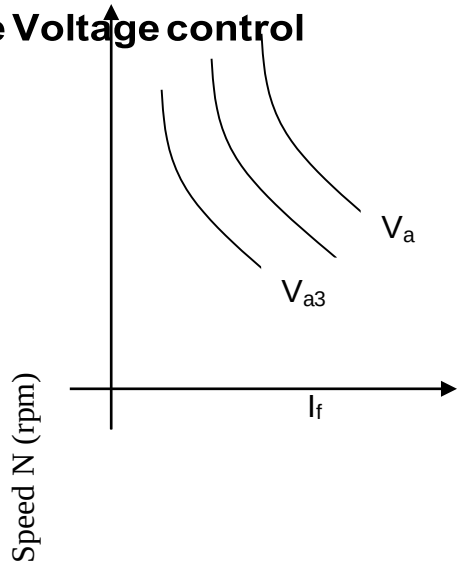
[Circuit Diagram of Field Flux control Method]



[Circuit Diagram of Armature Voltage control

MODEL





TABULAR COLUMN:

(i) Armature Voltage Control:

S.No.	I_{f1} =		I_{f2} =		I_{f3} =	
	Armature Voltage V_a (Volts)	Speed N (rpm)	Armature Voltage V_a (Volts)	Speed N (rpm)	Armature Voltage V_a (Volts)	Speed N (rpm)

(ii) Field Flux Control:

S.No.	V_{a1} =		V_{a2} =		V_{a3} =	
	Field Current I_f (A)	Speed N (rpm)	Field Current I_f (A)	Speed N (rpm)	Field Current I_f (A)	Speed N (rpm)

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking the maximum position of armature rheostat and minimum position of field rheostat, DPST switch is closed

(i) Armature Control:

1. Field current is fixed to various values and for each fixed value, by varying the armature rheostat, speed is noted for various voltages across the armature.

(ii) Field Control:

1. Armature voltage is fixed to various values and for each fixed value, by adjusting the field rheostat, speed is noted for various field currents.
2. Bringing field rheostat to minimum position and armature rheostat to maximum position DPST switch is opened.

Conclusion: From the above experiment, we have been obtained the speed control characteristic curve of DC Shunt motor.

Experiment-08

Aim: – Determine the armature current vs. speed characteristic of a DC motor.

Sl. No	Name of the Equipment	Specification	Quantity
1	Dc Series Motor	220v, 1500 RPM, 3KW	1no
2	DC Shunt Motor	220v, 1500 RPM, 3KW	1no
3	DC Compound Motor	220v, 1500 RPM, 3KW	1no
4	Tachometer	Digital Type, (0-9999) rpm	1no
5	DC Ammeter	(0-5)A	1no
6	DC Voltmeter	(0-300)V	1no
7	Connecting Wires	2.5 sq. mm	As Per Required

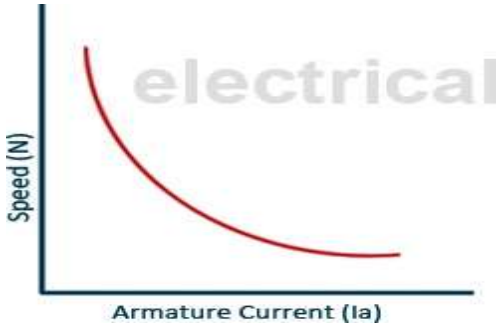
Theory:-

Dc Series Motor:-

We know the relation, $N \propto E_b/\phi$

For small load current (and hence for small armature current) change in back emf Eb is small and it may be neglected. Hence, for small currents speed is inversely proportional to ϕ. As we know, flux is directly proportional to Ia, speed is inversely proportional to Ia. Therefore, when armature current is very small the speed becomes dangerously high. That is why a series motor should never be started without some mechanical load.

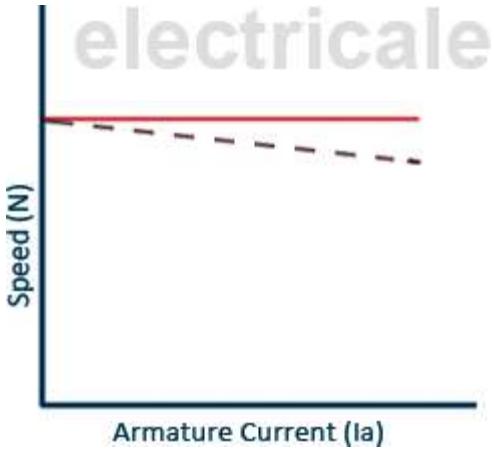
But, at heavy loads, armature current I_a is large. And hence, speed is low which results in decreased back emf E_b. Due to decreased E_b, more armature current is allowed.



[Characteristic of DC Series Motor]

DC Shunt Motor:-

As flux ϕ is assumed to be constant, we can say N ∝ Eb. But, as back emf is also almost constant, the speed should remain constant. But practically, ϕ as well as Eb decreases with increase in load. Back emf Eb decreases slightly more than ϕ, therefore, the speed decreases slightly. Generally, the speed decreases only by 5 to 15% of full load speed. Therefore, a shunt motor can be assumed as a constant speed motor. In speed vs. armature current characteristic in the following figure, the straight horizontal line represents the ideal characteristic and the actual characteristic is shown by the dotted line



[Characteristic of DC Shunt Motor]

Dc Compound Motor:-

DC compound motors have both series as well as shunt winding. In a compound motor, if series and shunt windings are connected such that series flux is in direction as that of the shunt flux then the motor is said to be cumulatively compounded. And if the series flux is opposite to the direction of the shunt flux, then the motor is said to be differentially compounded. Characteristics of both these compound motors are explained below.

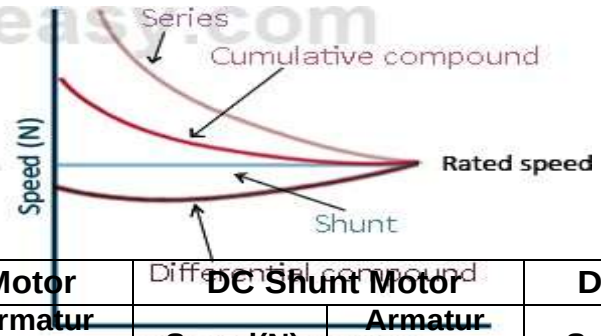
(a) Cumulative compound motor

Cumulative compound motors are used where series characteristics are required but the load is likely to be removed completely. Series winding takes care of the heavy load, whereas the shunt winding prevents the motor from running at dangerously high speed when the load is suddenly removed. These motors have generally employed a flywheel, where sudden and temporary loads are applied like in rolling mills.

(b) Differential compound motor

Since in differential field motors, series flux opposes shunt flux, the total flux decreases with increase in load. Due to this, the speed remains almost constant or even it may increase slightly with increase in load ($N \propto E_b/\phi$). Differential compound motors are not commonly used, but they find limited applications in experimental and research work.

Tabulation :-



[Characteristic of DC Compound Motor]

Sl No	DC Series Motor		DC Shunt Motor		DC Compound Motor	
	Speed(N)	Armature Current (I_a)	Speed(N)	Armature Current (I_a)	Speed(N)	Armature Current (I_a)
1						
2						
3						
4						
5						

Procedure:-

I. We should take all the tools & instrument for this experiment.
II. Connect all the motors as per circuit diagram.
III. Check all the connection.
IV. Switch on the D.C. Supply start the motor with the help of starter.
V. Gradually increase the starter handle to the holding coil.
VI. Measure the starting No load current and full load current of all motors.
VII. Measure the speed of all motors with the help of tachometer.

Conclusion:- From the above experiment, we learnt the characteristics of all the DC motors.

Experiment No- 09

AIM : Determine the efficiency of a DC machine by break test method.

–

Apparatus Required:

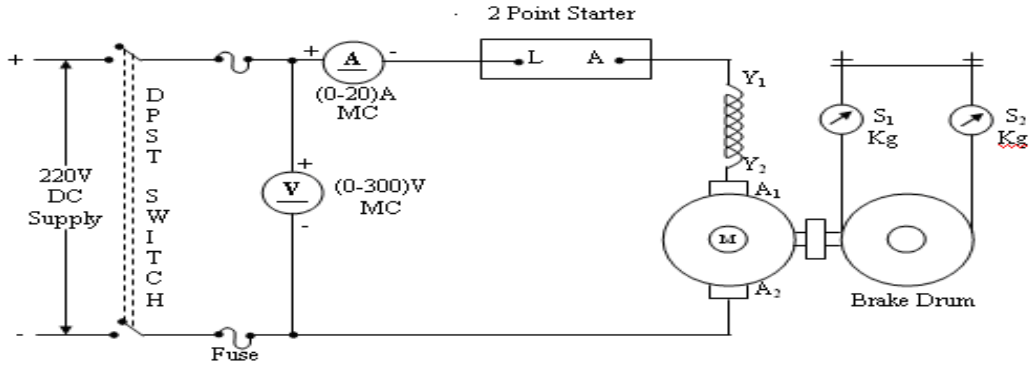
S. No	Equipment	Rating	Type	Quantity
1	Ammeter	(0-25A)	MC	1No
2	Voltmeter	(0-300V)	MC	1No
3	Tachometer	0-9999rpm	Digital	1No
4	Connecting wires	2.5 sq mm	Coppew	As per required

Theory:

There are several tests that are conducted upon a DC machine (Motor or Generator) to judge its performance. One important test is performed to measure the efficiency of the DC machine. Efficiency depends on its losses. The smaller the losses the greater is its efficiency and vice versa. The consideration of losses in a DC machine is important because they determine the efficiency of the machine and appreciably influences its operating cost. And also they determine heating of the machine and hence the power output that may be obtained without undue deterioration of the insulation.

In this method a brake drum is connected in the shaft of the motor with spring balances to measure the load. The mechanical output of the motor is calculated with the help of spring balances readings and speed of the machine.

Circuit Diagram:- LOAD TEST ON DC SERIES MOTOR



FUSE RATING:

125% of rated current

NAME PLATE DETAILS:

Rated Voltage :
Rated Current :
Rated Power :
Rated Speed :

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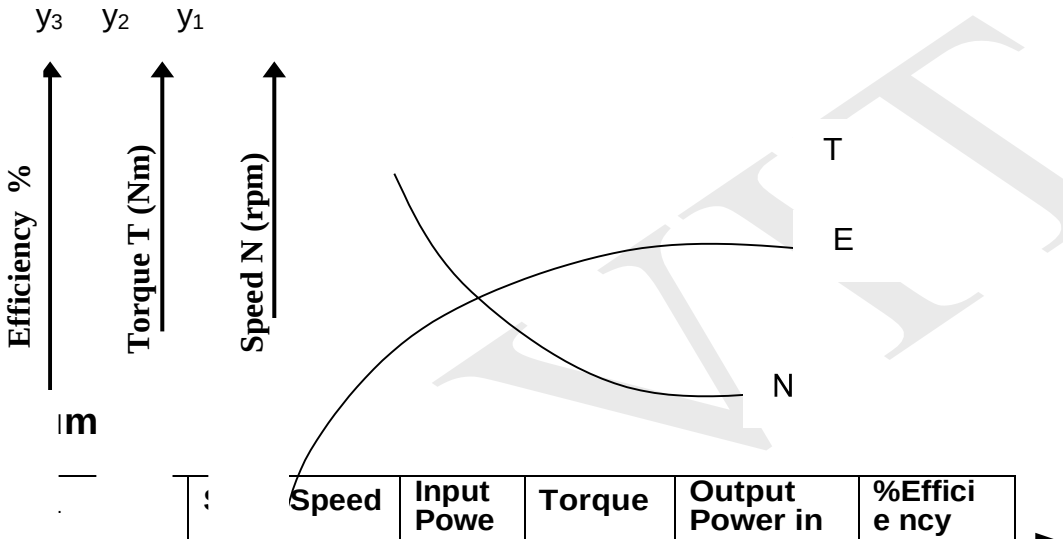
Model Graph



Tabular form

SL No	V_L (V)				Speed 'N' in RPM	Input Power (w)	Torque (T) in 'Newton meter's	Output Power in		%Efficiency
								Watts	BHP	

Calculations:

Radius of the Brake drum r =..... Mtrs Torque

(T) = $(F_1 - F_2)$ r.g N.mtr

Power Output = (2 **π** NT / 60) watts

%Efficiency = (Output / Input) X 100.

Procedure:

I. Make the connections as per circuit diagram.

II. Keep the field regulator of the Motor at minimum Resistance position.

III. At the time of starting check that the belt on the pulley is free, so that there is no load on the pulley.

IV. Start the motor slowly by using stator

V. Adjust the field regulator so that motor runs at its rated speed.

VI. Apply load on the pulley gradually in steps by adjusting of tension of spring Balance.

VII. Take the readings of the Ammeter and Voltmeter and two spring balance readings and the speed for each step.

VIII. Cool the pulley throughout the loading period by pouring water.

IX. Continue the experiment till full load of the motor is reached.

Conclusion:- From the above experiment, we learnt the load test on the given D.C series motor was conducted and its performance characteristics were drawn and the following conclusion can be given based on the performance curves.

Experiment-10

Aim: – Identification of terminals, determination of voltage transformation ratio of a single phase transformer.

APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	3 -ϕ Transformer	3-ϕ, (0- 440)V	-	1
2	Transformer Turn Ratio Tester	3-ϕ, (0- 440)V	-	1
3	Connecting Wires	2.5sq.mm	Copper	As per required

Theory:-

Transformation Ratio (K) is defined as the ratio of the EMF in the secondary coil to that in the primary coil.

$K = E2/E1 = (4.44(\Phi m)fN2)/(4.44(\Phi m)fN1)$

Therefore,

$K = E2/E1 = N2/N1$….(1)

Now,

V1 = E1 + voltage

drop E2 = V2 +

voltage drop

Due to the resistance in the windings and some leakage flux, there is some loss in voltage. This is called as Voltage Drop.

But, in ideal case, voltage drop can be neglected.

Hence,

V1 =

E1 E2

= V2

Hence,

E2/E1 = V2/V1…..(2)

Also, in a transformer, the power across the primary as well as the secondary winding is same. Hence,

V1.I1 = V2.I2

V1/V2 = I2/I1 ..... (3)

Now, combining (1), (2) & (3), we get,

K = E2/E1 = N2/N1 = V2/V1 = I2/I1

Where,

1 represents the primary coil

2 represent the secondary coil

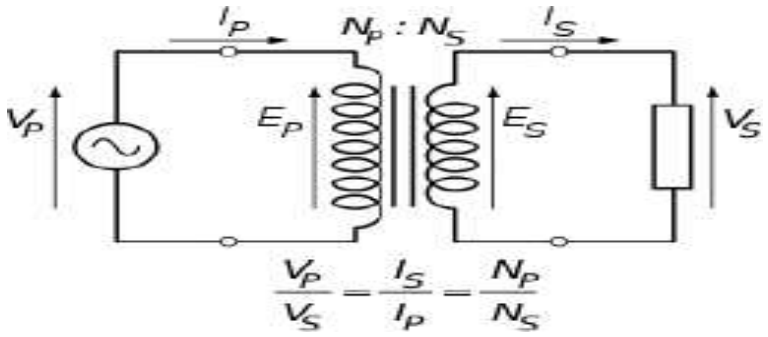
E is emf in the respective coil

V is the voltage in the respective coil

I is the current in the respective coil

N is number of turns of the respective coils

Φm is the mutual flux in the core.



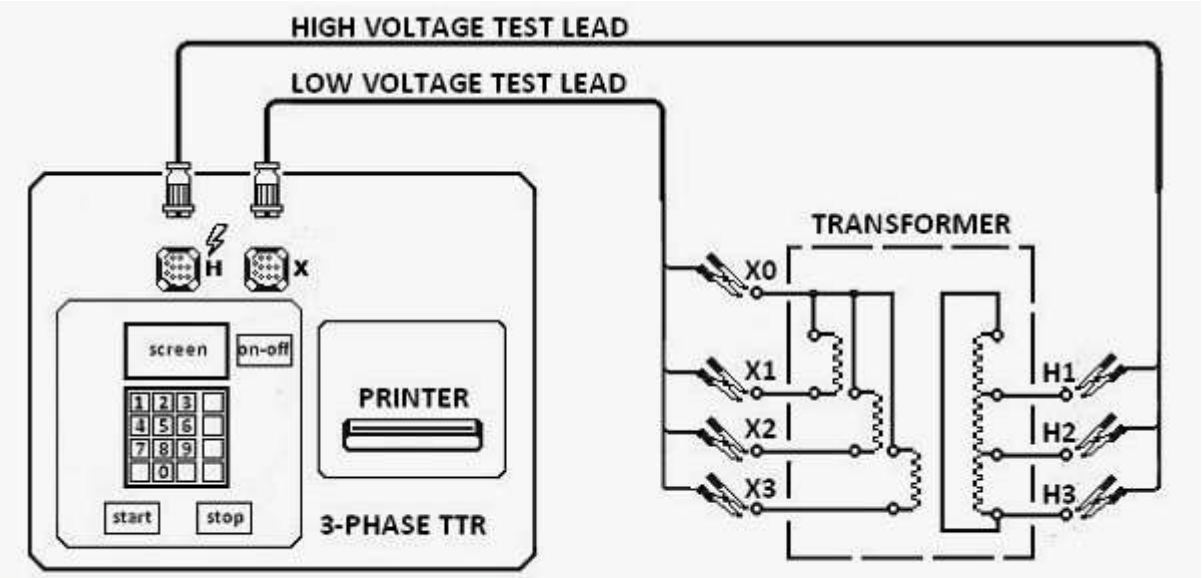


Figure 1 – Three-phase Transformer Turns Rati (TTR) Connection diagram.

Tabulation:-

Sl.No	V_1 in Volt	V_2 in Volt	E_1 in Volt	E_2 in Volt	I_1 in Ampere	I_2 in Ampere	N_1 in Turn	N_2 in Turn

Procedure:-

1) Isolate the equipment, apply working grounds to all incoming and outgoing cables
2) Disconnected cables should have sufficient clearance from the switchgear terminals greater that the phase spacing distance. Use nylon rope to hold cable away from incoming and outgoing terminals as required.
3) Connect the H designated three-phase test lead with the military style connector at one end to the mating connection on the test set marked with an H. Ensure that the connector's index notch lines up properly
4) Connect the X designated three-phase test of lead military style connector at one end to the mating connection on the test set marked with an X. Ensure that the connector's index notch lines up properly.

5) Connect the H1, H2, H3 designated test lead to the corresponding H1, H2, H3 transformer terminal / bushing. Connect the H0 test lead if H0 terminal/bushing is present.
6) Connect the X1, X2, X3 designated test leads to the corresponding X1, X2 X3 transformer terminals / bushings. Connect the X0 test lead if X0 terminal/bushing is present.
7) Perform turns ratio measurements for all tap positions.
8) Confirm that the measured ratios is within 0.5% of the calculated ratios

Conclusion:- From the above experiment, we learnt about the transformation ratio of transformer.

Experiment-11

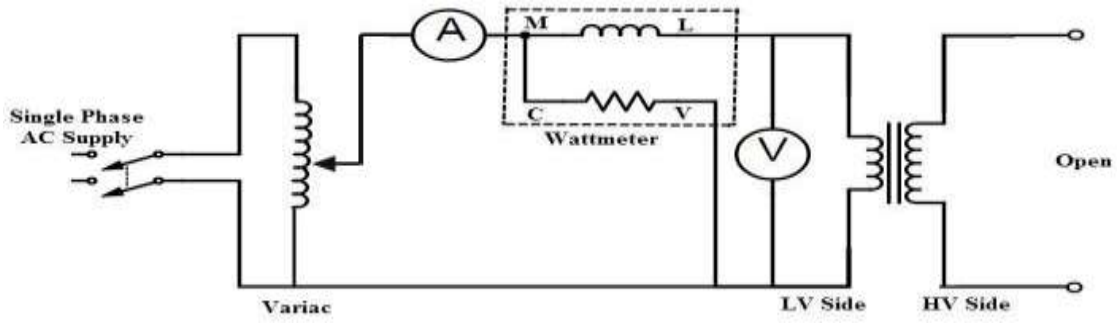
Aim:- Perform OC test and SC test of a single phase transformer.

APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	Single Phase Transformer	1kw, 220v/110v	Shell	1
2	Ammeter	(0-2)A (0-5) A	MI MI	1 1
3	Voltmeter	(0-150)V	MI	2
4	Wattmeter	(150V, 5A) (150V, 5A)	LPF UPF	1 1
5	Connecting Wires	2.5sq.mm	Copper	Few

Theory:-

Open Circuit Test: - The purpose of the open circuit test is to determine the no-load current and losses of the transformer because of which their no-load parameter are determined. This test is performed on the primary winding of the transformer. The wattmeter, ammeter and the voltage are connected to their primary winding. The nominal rated voltage is supplied to their primary winding with the help of the ac source. The secondary winding of the transformer is kept open and the voltmeter is connected to their terminal. This voltmeter measures the secondary induced voltage. As the secondary of the transformer is open the no-load current flows through the primary winding. The value of no-load current is very small as compared to the full rated current. The copper loss occurs only on the primary winding of the transformer because the secondary winding is open. The reading of the wattmeter only represents the core and iron losses. The core loss of the transformer is same for all types of loads.



[Open Circuit Test]

Short Circuit Test: – The short circuit test is performed for determining the below mention parameter of the transformer.

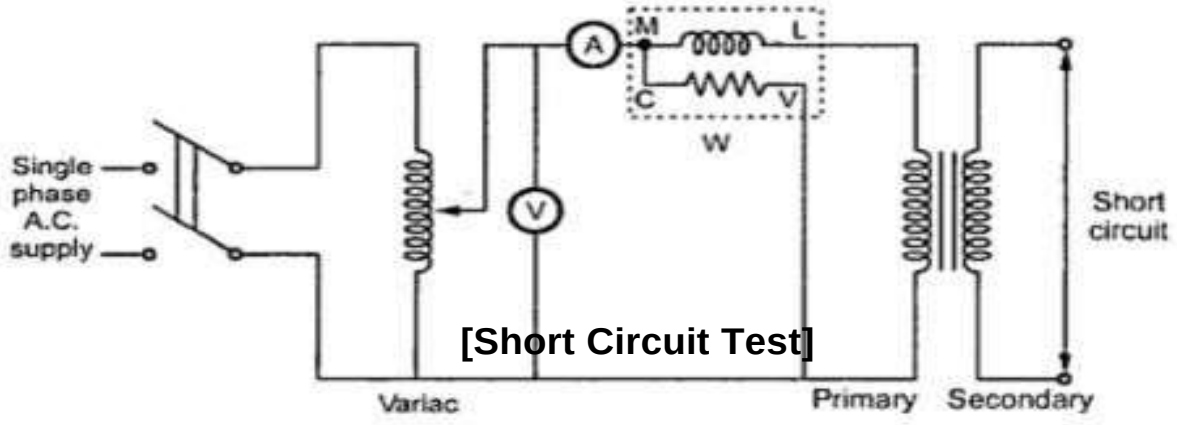
- It determines the copper loss occur on the full load. The copper loss is used for finding the efficiency of the transformer.
- The equivalent resistance, impedance, and leakage reactance are known by the short circuit test.

The short circuit test is performed on the secondary or high voltage winding of the transformer. The measuring instrument like wattmeter, voltmeter and ammeter are connected to the High voltage winding of the transformer. Their primary winding is shortcircuited by the help of thick strip or ammeter which is connected to their terminal.

The low voltage source is connected across the secondary winding because of which the full load current flows from both the secondary and the primary winding of the transformer. The full load current is measured by the ammeter connected across their secondary winding.

The low voltage source is applied across the secondary winding which is approximately 5 to 10% of the normal rated voltage. The flux is set up in the core of the transformer. The magnitude of the flux is small as compared to the normal flux.

The iron loss of the transformer depends on the flux. It is less occur in the short circuit test because of the low value of flux. The reading of the wattmeter only determines the copper loss occur on their windings. The voltmeter measures the voltage applied to their high voltage winding. The secondary current induces in the transformer because of the applied voltage.



[Short Circuit Test]

TABULAR COLUMN:

OPEN CIRCUIT TEST:

V_{sc} (Volts)	I_{sc} (Amps)	W_{sc} (Watts)

SHORT CIRCUIT TEST:

V_o (Volts)	I_o (Amps)	W_o (Watts)

PROCEDURE:

OPEN CIRCUIT TEST:

1. Connections are made as per the circuit diagram.
2. After checking the minimum position of Autotransformer, DPST switch is closed.
3. Auto transformer (variac) is adjusted get the rated primary voltage.
4. Voltmeter, Ammeter and Wattmeter readings on primary side are noted.
5. Auto transformer is again brought to minimum position and DPST switch is opened.

SHORT CIRCUIT TEST:

1. Connections are made as per the circuit diagram.
2. After checking the minimum position of Autotransformer, DPST switch is closed.
3. Auto transformer (variac) is adjusted get the rated primary current.
4. Voltmeter, Ammeter and Wattmeter readings on primary side are noted.
5. Auto transformer is again brought to minimum position and DPST switch is opened.

Conclusion:- From the above experiment, we leant the OC test and SC test of a single phase transformer.

Experiment-12

Aim:- Determine the voltage regulation of a single phase transformer at different loads.

APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-10)A (0-5) A	MI MI	1 1
2	Voltmeter	(0-150)V (0-300) V	MI MI	1 1
3	Wattmeter	(300V, 5A) (150V, 5A)	UPF UPF	1 1
4	Auto Transformer	1□ , (0-260)V	-	1
5	Resistive Load	5KW, 230V	-	1
6	Connecting Wires	2.5sq.mm	Copper	As per required

FORMULA:

Output Power = W_2 x Multiplication factor Input Power = W_1 x Multiplication factor

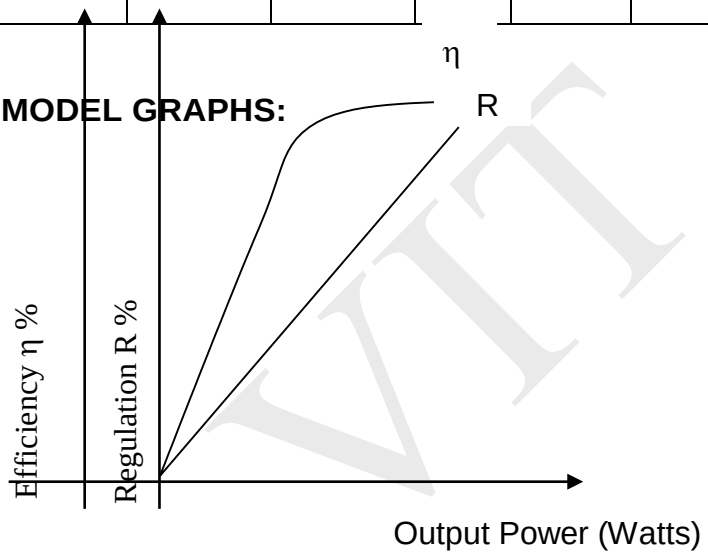
$$\% = \frac{\text{Output Power}}{\text{Input Power}} \text{ Efficiency } \square \times 100\%$$

$$= \frac{V_{NL} - V_{FL}}{V_{NL}} \text{ (Secondary) Regulation R \%} \times 100\%$$

TABULAR COLUMN:

Sl. No.	Load	Primary			Secondary			Input Power W_1 x MF	Output Power W_2 x MF	Efficiency %	% Regulation
		V_1 (Volts)	I_1 (Amps)	W_1 (Watts)	V_2 (Volts)	I_2 (Amps)	W_2 (Watts)				

MODEL GRAPHS:



PRECAUTIONS:

1. Auto Transformer should be in minimum position.
2. The AC supply is given and removed from the transformer under no load condition.

PROCEDURE:

1. Connections are made as per the circuit diagram.
2. After checking the no load condition, minimum position of auto transformer and DPST switch is closed.
3. Ammeter, Voltmeter and Wattmeter readings on both primary side and secondary side are noted.
4. The load is increased and for each load, Voltmeter, Ammeter and Wattmeter readings on both primary and secondary sides are noted.
5. Again no load condition is obtained and DPST switch is opened.

Conclusion:- From The above experiment, we learnt the voltage regulation of a single phase transformer at different loads.

Experiment-13

Aim- Polarity test of single phase transformer and parallel operation of two single phase transformer.

APPARATUS REQUIRED:

S.No.	Apparatus	Range	Type	Quantity
1	Ammeter	(0-10)A (0-5) A	MI MI	1 1
2	Voltmeter	(0-150)V (0-300) V	MI MI	1 1
3	Auto Transformer	1□ , (0-260)V	-	2
4	Connecting Wires	2.5sq.mm	Copper	As per required

Theory:-

Polarity Test of Transformer :- Polarity means the direction of the induced voltages in the primary and the secondary winding of the transformer. If the two transformers are connected in parallel, then the polarity should be known for the proper connection of the transformer.There are two types of polarity one is **Additive**, and another is **Subtractive**.

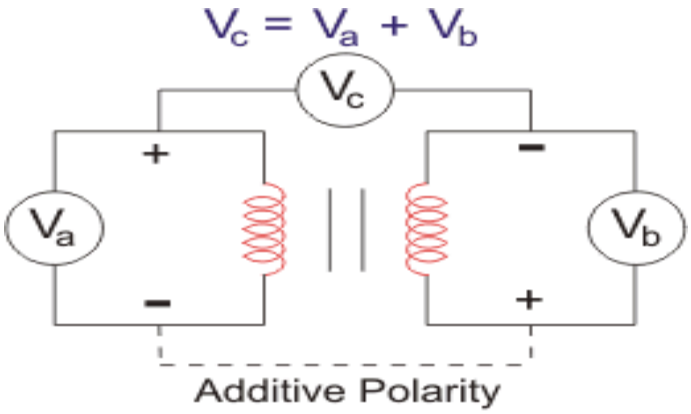
Additive Polarity: In additive polarity the same terminals of the primary and the secondary windings of the transformer are connected

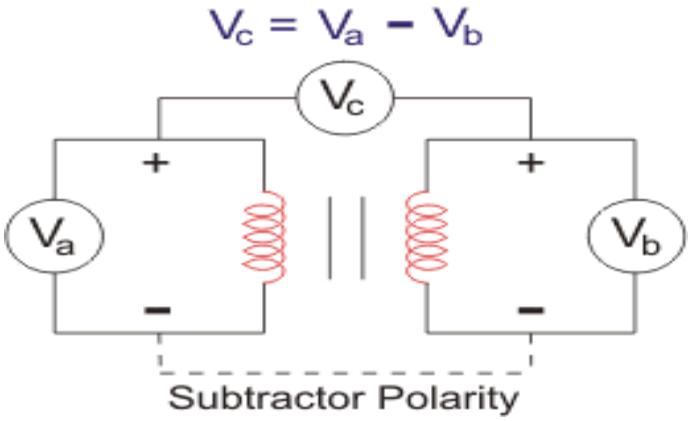
Subtractive Polarity: In subtractive polarity different terminals of the primary and secondary side of the transformer is connected.

Each of the terminals of the primary as well as the secondary winding of a transformer is alternatively positive and negative with respect to each other as shown in the figure below.

Let A_1 and A_2 be the positive and negative terminal respectively of the transformer primary and a_1, a_2 are the positive and negative terminal of the secondary side of the transformer.

If A_1 is connected to a_1 and A_2 is connected to a_2 that means similar terminals of the transformer are connected, then the polarity is said to be additive. If A_1 is connected to a_2 and A_2 to a_1, that means the opposite terminals are connected to each other, and thus the voltmeter will read the subtractive polarity.





It is essential to know the relative polarities at any instant of the primary and the secondary terminals for making the correct connections if the transformers are to be connected in parallel or they are used in a three phase circuit.

In the primary side, the terminals are marked as A_1 and A_2 and from the secondary side the terminals are named as a_1 and a_2. The terminal A_1 is connected to one end of the secondary winding, and a voltmeter is connected between A_2 and the other end of the secondary winding.

When the voltmeter reads the difference that is $(V_1 - V_2)$, the transformer is said to be connected with opposite polarity know as Subtractive polarity and when the voltmeter reads $(V_1 + V_2)$, the transformer is said to have additive polarity.

Parallel Operation of Two Single Phase Transformers:-

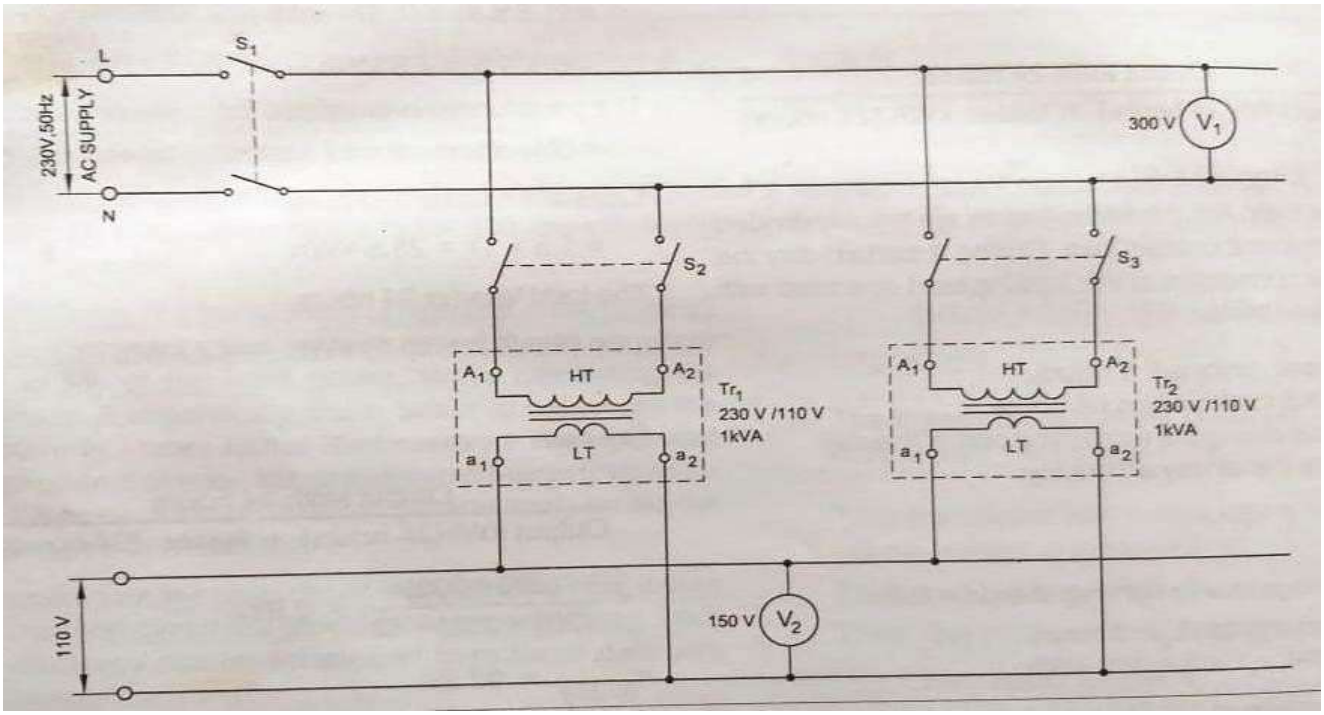
Parallel operation of two or more Transformers means that all the Transformers Primary is connected with the common supply and their Secondary are feeding to a common bus through which load is connected. Parallel operation of Transformers requires that their Primaries as well as Secondaries are connected in parallel.

Parallel operation of two or more Transformers has many advantages when compared with a single large Transformer. Though using single large Transformer instead of two or more Transformers connected in parallel are cheap but still due to the following advantages, parallel operation of Transformers are preferred where required

With two or Transformers, the Power System becomes more reliable. Let one Transformer develops a fault, then the faulty Transformer can be removed from the circuit while maintaining the power supply at a reduced level through healthy Transformers. Thus in this way, Power System becomes more reliable.

Depending upon the load, Transformers can be switched ON / OFF. In this way, Transformer losses are reduced and the system becomes more efficient and economical.

If the power demand increases with time then extra spare Transformer can be taken into service to meet the power demand.



[Parallel Operation of Single Phase Transformer]

Condition for Parallel Operation of Transformers:-

When operating two or more transformers in parallel satisfactory performance conditions should be met.

A) The same voltage ration
B) The same per unit (or percentage) impedance
C) The same polarity
D) The same phase sequence and zero relative phase displacement

Procedure:-

Polarity

Test:-

- Connect the circuit as shown in the above circuit diagram figure and set the autotransformer to zero position.
- Switch on the single phase supply
- Records the values of the voltages as shown by the voltmeter V_1, V_2 and V_3.
- If the reading of the V_3 shows the addition of the value of V_1 and V_2 that is $V_2 = V_1+V_2$ the transformer is said to be connected in additive polarity.
- If the reading of the V_3 is the subtraction of the readings of V_1 and V_2, then the transformer is said to be connected in subtractive or negative polarity.

Parallel Operation:-

a. First, perform the polarity test on each of the units and label or note down terminals with the same polarity
b. Also, confirm that no-load secondary voltages of both transformers match in magnitude. If possible, also check the respective instantaneous phase angles. Note: It is important to perform both these tests before attempting the parallel operation.
c. Perform the SC test to find out leakage impedance parameters of the two transformers. Attempt to calculate the power sharing analytically using equivalent circuit of transformer.
d. With the primaries in unenergized state, connect a common load across the transformer secondaries, with the load KVA rating not exceeding the total KVA rating of the two units.

e. Slowly increase the autotransformer voltage until rated voltage appears across the primaries of each transformer.

Conclusion: – From this experiment, we learnt the polarity test and parallel operation of single phase transformer.