# DEPARTMENT OF
# ELECTRICAL & ELECTRONICS ENGINEERING

*MANUAL FOR*

# ELECTRICAL MACHINES LABORATORY -1
## (EE317 -- 3/4 EEE-- I SEMESTER)

## SIR C.R.REDDY COLLEGE OF ENGINEERING
## ELURU - 534007 (A.P)

# LIST OF EXPERIMENTS

**Exp. No : 1**

# O.C.C. OF SEPERATELY EXCITED D.C. GENERATOR

**Aim:-** To plot the open circuit characteristics of a separately excited D.C. generator.

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Voltmeter (M.C) | 0 – 300 V | 1 |
| 2 | Ammeter (M.C) | 0 – 3 A | 1 |
| 3 | Rheostat | 500 Ω, 1.2 A | 2 |
| 4 | Tachometer | 0-5000 R.P.M | 1 |
| 5 | Coupled dc motor-dc generator set | - | - |
| 6 | Connecting wires | - | - |

**Theory:-** The field current $L_f$ is obtained from an external independent DC source. It can be varied from zero upwards by a potentiometer and its value is read by Ammeter connected in the field circuit.

Voltage equation of a DC generator is $E_g = \phi ZNP/60A$

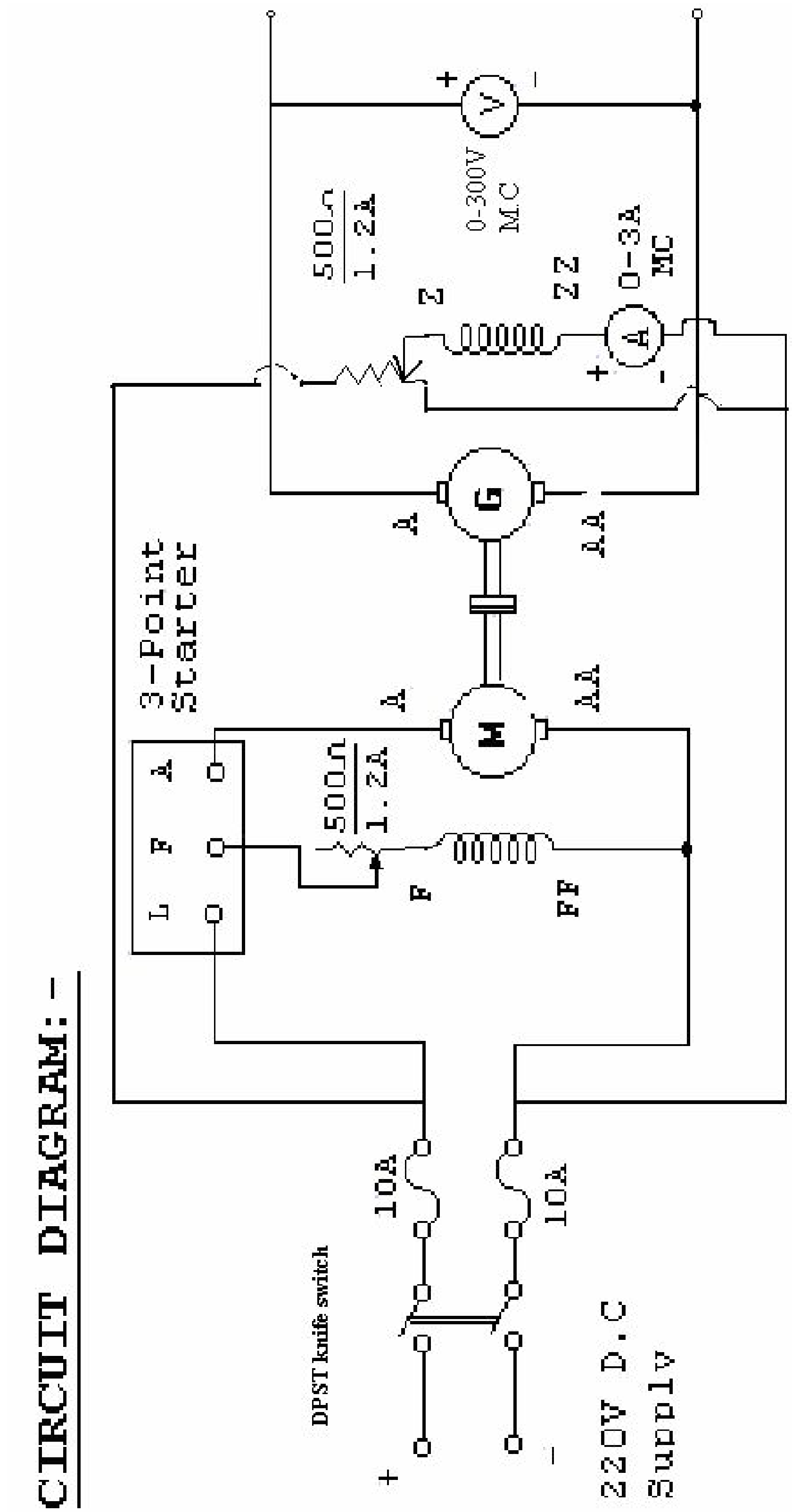
Hence if speed is constant, the above relation becomes $E = K\phi$

It is obvious that when $L_f$ is increased from its initial small value, the flux $\phi$ and hence generated emf increases as current while the poles are unsaturated. But as the flux density increases, the poles become saturated so a generator in $L_f$ is requires to produce a given increase in voltage than as the lower part of the curve.

The curve showing relation between the terminal voltage 'V' and field current $L_f$ when the generator is on no-load

**Procedure:-**

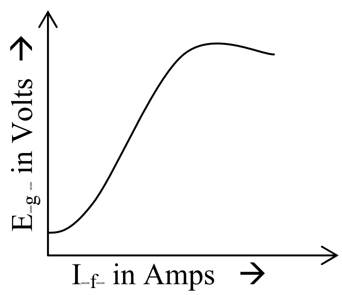
1. The connections are made as shown in the circuit diagram.
2. With the motor field rheostat in CUTOUT position, the generator field rheostat in CUTIN position and the motor 3-point starter handle at its initial position, the DC supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance in the motor armature circuit so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat.
5. The generator field is exited by gradually varying the resistance of the generator field rheostat in steps and for each step the corresponding field current and the no load voltage are noted.
6. Step no. 5 is repeated until the rated voltage of the generator is reached and all the meter readings are noted for each step.
7. The generator field rheostat is brought back to CUTIN position, the motor field rheostat to CUTOUT position and the supply switch is opened.


CIRCUIT DIAGRAM: -
3-Point Starter
L F A
500Ω / 1.2A
F
FF
A
AA
M
G
500Ω / 1.2A
Z
ZZ
0-300V MC
V
0-3A MC
A
10A
10A
DPST knife switch
+
-
220V D.C Supply

**Tabular column:-**

| Sl.No | $I_f$ In Amps | $E_g$ In volts |
|---|---|---|
| | | |

**Nature of graph:-**




**Result:-**

**Viva – Voce Questions:-**

1 What is the principle of a dc generator?

2 What is Fleming's right hand rule?

3 What are the main components of a dc generator?

4 What is the purpose of a commutator in a dc generator?

5 What are the methods to improve commutation/

6 What is the standard direction of rotation of a dc generator?

7 What is the voltage regulation of an ideal dc generator?

8 What is meant by normal neutral plane?

9. What is the function of interpoles?

10 Expand OCC. What is the other name for it?

**Exp. No : 2**

# SWINBURNE'S TEST ON D.C. SHUNT MOTOR

**Aim:-** To conduct the no load test on the DC shunt motor and determine its efficiency at different loads when operating as a) Motor & b) Generator

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Ammeter (M.C) | 0 – 3 A | 1 |
| 2 | Ammeter (M.C) | 0 – 1.5 A | 1 |
| 3 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 4 | Rheostat | 500 Ω, 1.2 A | 2 |
| 5 | Tachometer | 0-5000 R.P.M | 1 |
| 6 | DC shunt motor | - | 1 |
| 7 | Connecting wires | - | - |

**Theory:-** Swinburne's test is a simple indirect method to calculate the efficiency of a constant flux DC machines. In this method constant losses are calculated at no-load and from this efficiency at any desired load can be pre-determined in advance. In this method the machine is run as a motor at no-load. At its rated voltage & rated speed (adjusted by using shunt field rheostat)

Limitations: Applicable to constant flux machines i.e. shunt & compound machines

Advantages:

- It is economical because power required to test the machine is very small i.e. no load input power.
- The efficiency can be pre-determined at any desired load.

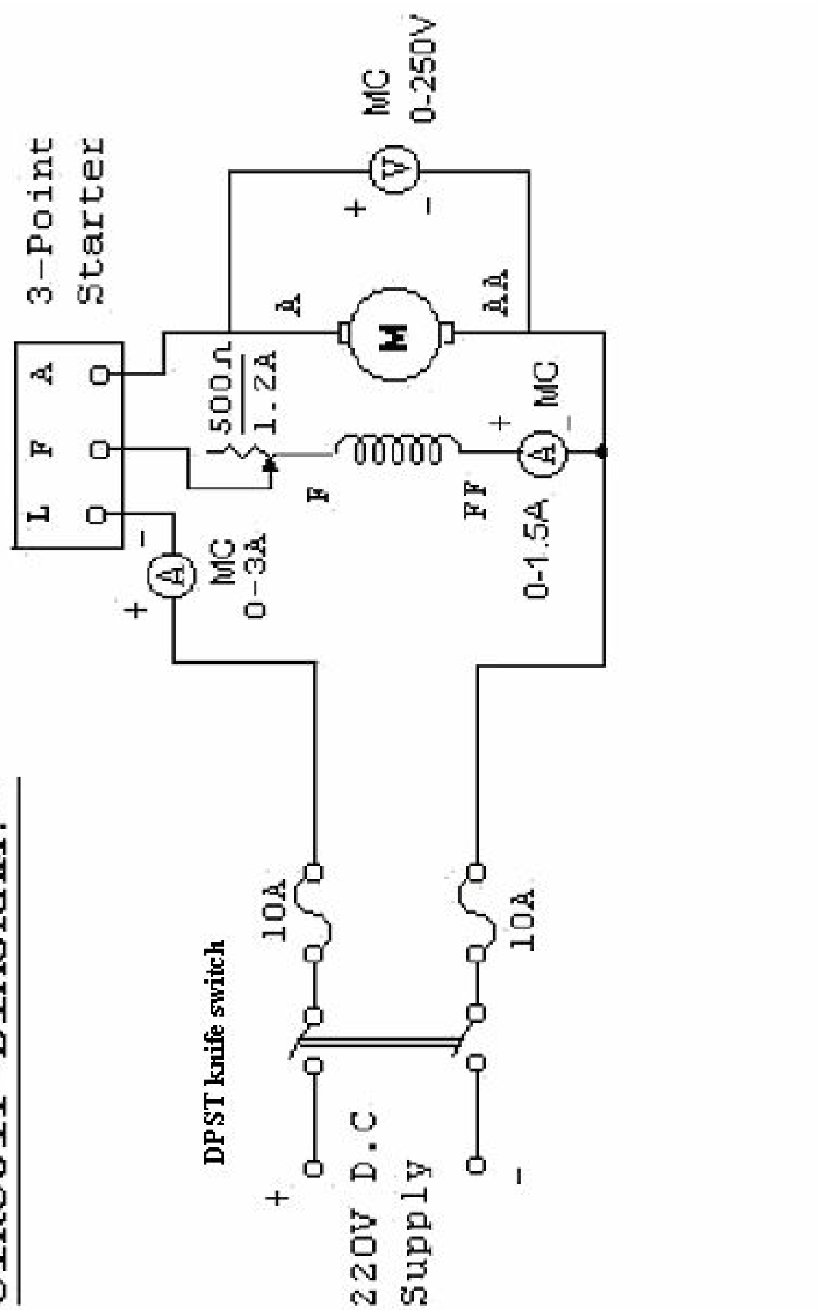
Disadvantages:

- At full load due to armature reaction, flux is destroyed which increases the iron losses. No account is taken for this change in iron losses.
- As the test is on no-load, it is impossible to know whether commutation would be satisfactory at full load and whether the temp. rise would be within the specified limits.

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. With the motor field rheostat in CUTOUT position, 3-point starter handle at its initial position, the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance in the motor armature circuit so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat.
5. All the meter readings are noted into the tabular column.
6. The motor field rheostat is brought back to CUT OUT position and the supply switch is opened.

## CIRCUIT DIAGRAM: -



**Tabular column:-**

| Sl.No | $I_0$ In Amps | $I_{sh}$ In Amps | V In volts |
|---|---|---|---|
| | | | |

**Specimen calculations:-**

1. No load armature current = $I_{ao} = I_o - I_{sh}$ amps
   where $I_o$ - is the no-load input current of the D.C motor
   $I_{sh}$ – is the shunt field current
2. Armature copper loss = $I_{ao}^2$ Ra watts
   where $R_a$ – is the armature resistance of the D.C.Machine
   it can be determined by Volt-Amp method.
3. Total input power = $P_i = V I_o$ watts
4. Constant power loss = $P_c = V I_o - I_{ao}^2$ Ra watts
5. Calculation of Efficiency

**when running as motor** : If $I_L$ = Full Load current in amps

| | At full Load | At Half Full Load |
|---|---|---|
| a. Armature current | $= I_a = I_L - I_{sh}$ amps | $I_a = \frac{I_L}{2} - I_{sh}$ amps |
| b. Armature cu. Loss | $= w_c = I_a^2$ Ra watts | $w_c = I_a^2 R_a$ watts |
| c. Motor input | $= P_i = V I_L$ watts | $P_o$ = ½ $VI_L$ watts |
| d. Constant losses | $= P_c$ watts | |
| e. Total losses | $= P_t = P_c + w_c$ watts | |

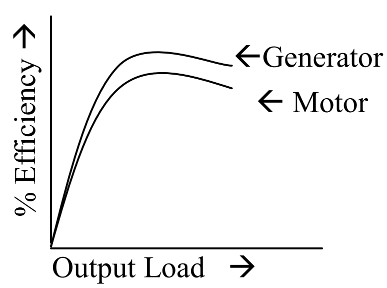
$$\therefore \text{ \% efficiency of motor} = \frac{p_i - p_t}{p_i} \times 100$$

**when running as generator:**

| | At Full Load | At Half Full Load |
|---|---|---|
| a. Armature current | $= I_a = I_L + I_{sh}$ amps | $I_a = \frac{I_L}{2} + I_{sh}$ amps |
| b. Armature cu. Loss | $= w_c = I_a^2 R_a$ watts | $w_c = I_a^2 R_a$ watts |
| c. Generator output | $= P_o = V I_L$ watts | $P_o$ = ½ $VI_L$ watts |
| d. Constant losses | $= P_c$ watts | |
| e. Total losses | $= P_t = P_c + w_c$ watts | |

$$\therefore \text{\% efficiency of generator} = \frac{p_o}{p_o + p_t} \times 100$$

**Nature of Graph :-**



**Result:**

**Viva – Voce Questions:**

1. What can be the reasons, if the motor blows out the fuses at the time of starting?
2. At the time of starting, why should the motor field rheostat be kept in its
3. Minimum position?
4. At the time of starting ,why should be the generator field rheostat is kept to its maximum?
5. Why does the speed fall slightly when the d.c shunt motor is loaded?
6. What will happen if the field current of the d.c shunt motor get interrupted?
7. The wave form of induced emf in the armature conductors of a d.c motor will be in which shape?
8. Explain what happens when a d.c. motor is connected across an a.c. supply?
9. What is the function of interpole?
10. What is the function of commutator?
11. How the interpole windings are connected?
12. What are the advantages of Swinburne's test?
13. What are the disadvantages of Swinburne's test?
14. What are the applications of a dc shunt motor?

**Exp. No : 3**

# LOAD TEST ON D.C. SHUNT MOTOR

**Aim:-** To conduct the brake load test on D.C. shunt motor and determine its performance characteristics.

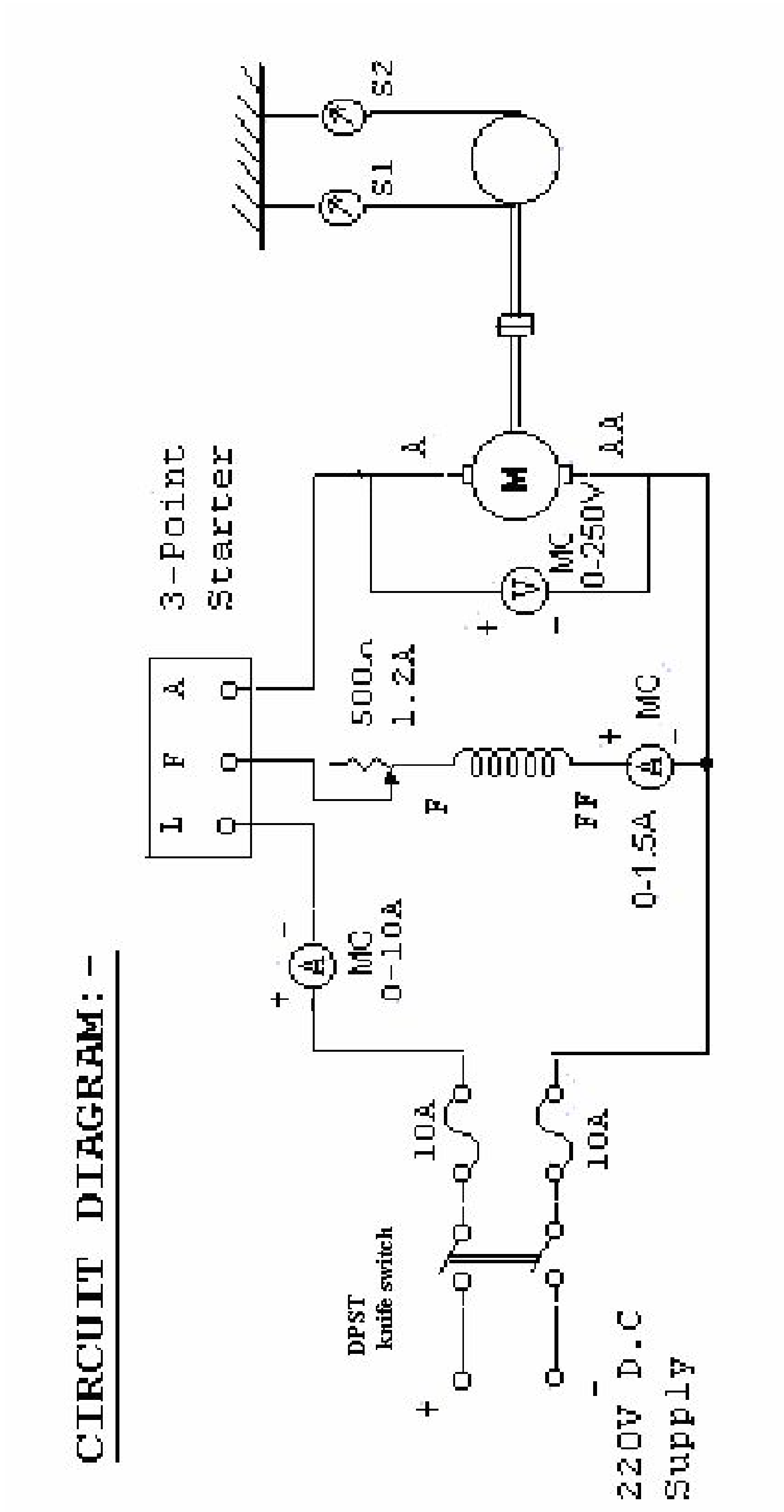
**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Ammeter (M.C) | 0 – 10 A | 1 |
| 2 | Ammeter (M.C) | 0 – 1.5 A | 1 |
| 3 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 4 | Rheostat | 500 Ω, 1.2 A | 1 |
| 5 | Tachometer | 0-5000 rpm | 1 |
| 6 | D.C. shunt motor with loading arrangement | - | 1 |
| 7 | Connecting wires | - | - |

**Theory:-** This is direct method of testing dc machine. This test is conducted on low H.P machines the machine is run as the motor and a brake frictional load is applied to the moving shaft. The moment of the brake drum is restricted with a braking arrangement. The braking arrangement consisting of a) Water cooled brake drum b) belt c) Spring balances to measure the tension on the brake belt and d) tension existing mechanism. The friction between brake drum and belt acts as a mechanical load. By adjusting the tension of the belt the load on the motor can be adjusted. Due to brake friction terrible heat is produced. To keep the brake drum with in the working temperature or to remove the heat due to friction the brake drum is filled with cooled water.

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. With the motor field rheostat in cutout position, the 3 point starter handle in initial position and ensuring that the belt over the brake drum is totally loosened, the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance in the motor armature circuit so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat and all the meter readings as well as speed are noted.
5. The load is applied in steps and for each step all the meter readings, spring balance readings as well as speed are noted.
6. Step no. 5 is repeated until the rated current of the motor is reached.
7. The load is removed in steps, the motor field rheostat is brought back to CUT OUT position and the supply switch is opened.


CIRCUIT DIAGRAM:-
3-Point Starter
L F A
500Ω
1.2A
F
FF
MC
0-1.5A
MC
0-10A
MC
0-250V
M
A
AA
S1
S2
10A
10A
DPST
knife switch
220V D.C
Supply

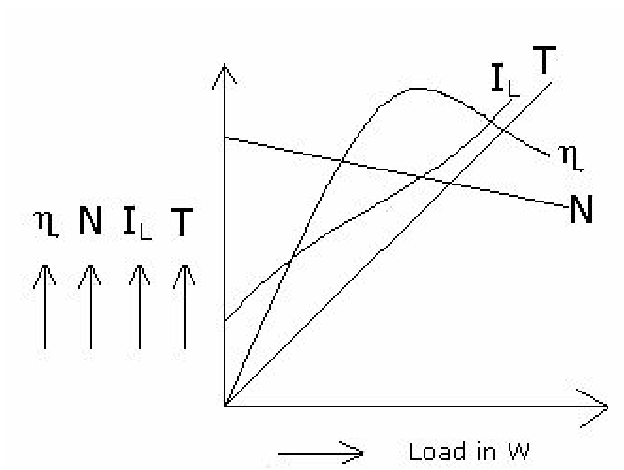
**Tabular column:-**

| Sl. No | V In Volts | $I_L$ In Amps | $I_{sh}$ In Amps | $S_1$ In Kgs | $S_2$ In Kgs | T In N - m | N In rpm | $I_a$ In Amps | Input In Watts | Output In watts | % Efficiency |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | | |

**Specimen calculations:-**

1. Torque $T = (S_1 \sim S_2) \times r \times 9.81$ N – m
2. Armature current $I_a = I_L - I_{sh}$ amps
3. Motor input power $P_i = V \cdot I_L$ watts
4. Motor output power $P_o = \frac{2\pi NT}{60}$ watts
5. % efficiency $\eta = \frac{\text{output power}}{\text{input power}} \times 100$

**Nature of the graph:-**




**Result:-**

**Viva – Voce Questions:-**

1. What is a D.C. motor?
2. What is the working principle of a d.c motor?
3. How the direction of the d.c motor changed?
4. What is back emf?
5. What is the significance of the back emf?
6. What is the formula for back emf?
7. What is the relationship between Eb and V?
8. What is the condition for maximum power?
9. What is the condition for maximum efficiency?
10. What are the main parts of the d.c motor?
11. Write the power equation of the motor?
12. Does the speed have any relationship between the back emf and flux?
13. On what factors the speed of the motor depends?
14. What are the methods for controlling the speed?
15. Why should the d.c motor be not started directly from mains?

**Exp. No : 4**

# SPEED CONTROL OF D.C. SHUNT MOTOR

**Aim:-** To control the speed of a D.C. shunt motor by Armature control method and field control method.

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Ammeter (M.C) | 0 – 1.5/3 A | 1 |
| 2 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 3 | Rheostat | 500 Ω, 1.2 A | 1 |
| 4 | Rheostat | 38 Ω, 10 A | 1 |
| 4 | Tachometer | 0 – 5000 rpm | 1 |
| 6 | D.C. shunt motor | 3HP, 220 V, 12 A | 1 |
| 7 | Connecting wires | - | - |

**Theory:-**

The speed of a dc shunt motor can be mainly controlled by varying

i) Flux/pole (Flux control method)
ii) Resistance of armature circuit (rheostat control method)
iii) Applied control (Voltage control method)

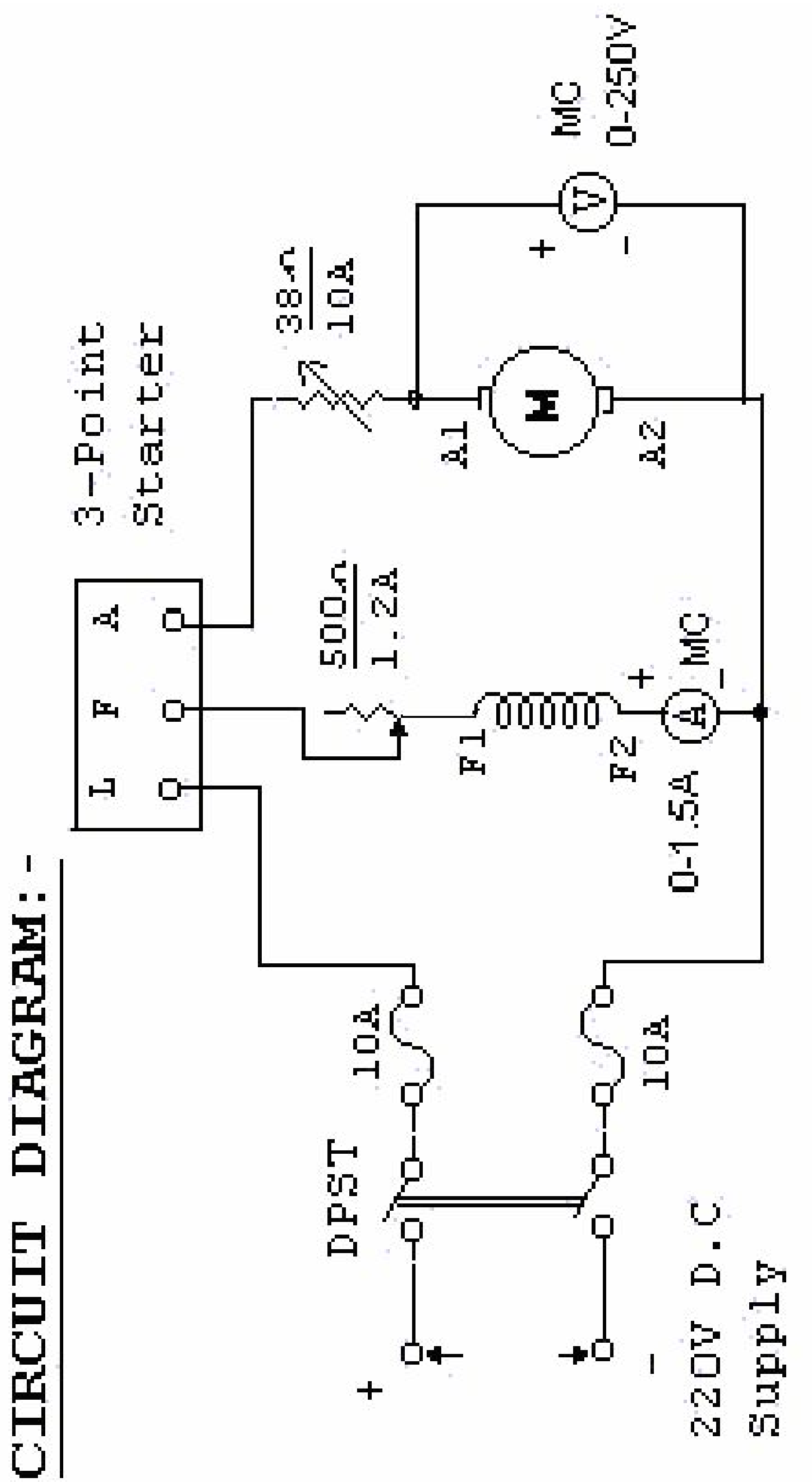
Speed of a motor is given by the relation:

$$N \propto \frac{E_b}{\phi} \quad \text{-- (1)}$$

i) Flux control method:-This method is used when speeds above normal speeds are required. In the above equation (1) by decreasing the flux, the speed can be increased and vice versa. The flux of a dc motor can be changed by changing $I_{sh}$ with the help of a shunt field rheostat. The current in shunt field rheostat is less. $I^2R$ loss is small, so that rheostat is small in size.

ii) Armature or rheostat control method:- This method used when speeds below the no-load speeds are required. In this method the voltage across the armature is varied by increasing a variable rheostat in series with the armature circuit, as resistance is increased, potential difference across the armature & decreased, there by decreasing the armature speed. This method is expensive (Cu loss more) and unsuitable for rapidly changing loads because for a given value of $R_t$, the speed will change with load.

iii) Voltage control method:- In this method the shunt field of the motor is connected across the fixed supply and then by supplying different voltage to the armature different loads are obtained.


CIRCUIT DIAGRAM:-
3-Point Starter
L F A
38Ω
10A
MC
0-250V
V
M
A1
A2
500Ω
1.2A
F1
F2
A
MC
0-1.5A
10A
10A
DPST
220V D.C Supply

**Procedure:-**

**a) For Armature voltage control method:-**

1. The connections are made as shown in the circuit diagram.
2. With the armature rheostat is CUTIN position, the field rheostat in CUTOUT position and the 3-point starter handle at its initial position, the D.C. supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the armature resistance so that the motor starts and runs at some speed. Bring the armature rheostat to CUTOUT position to start the experiment.
4. The field current is adjusted to a certain value by varying the field rheostat such that the motor runs at rated speed.
5. The armature rheostat is increased gradually so that the armature voltage is varied in steps and the corresponding speeds are noted in the tabular column.
6. Step no. 5 is repeated until the armature rheostat is completely CUTIN.
7. The field rheostat is brought back to CUTOUT position, the armature rheostat to CUTIN position and the D.C. supply switch is opened.

**b) For field control method:-**

1. Step nos. 1, 2 & 3 of armature voltage control method are repeated.
2. The armature rheostat is varied such that the rated voltage is applied across the armature terminals.
3. The field resistance is gradually cut in steps so that the field current is varied in steps of 0.05A and the corresponding value of speeds is noted.
4. Step no. 3 is repeated until the motor attains 1.4 times rated speed.
5. Step no. 3 and 4 are repeated for an armature voltage of 200V.
6. The field rheostat is brought back to CUT OUT, the armature rheostat to CUT IN position and the supply switch is opened.

**Tabular column:-**

**a) Armature voltage control**

Field current =

| Sl.No | Armature voltage In Volts | Speed In rpm |
|---|---|---|
| | | |

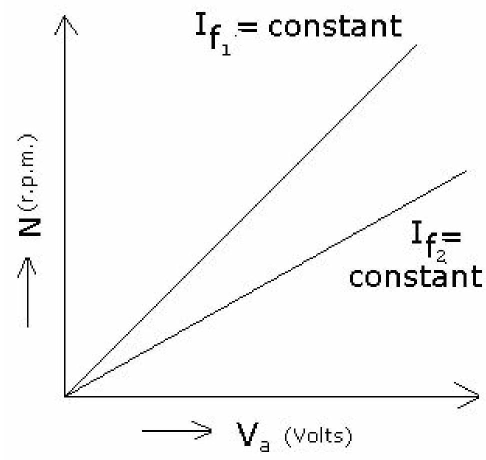
**b) Field control method**

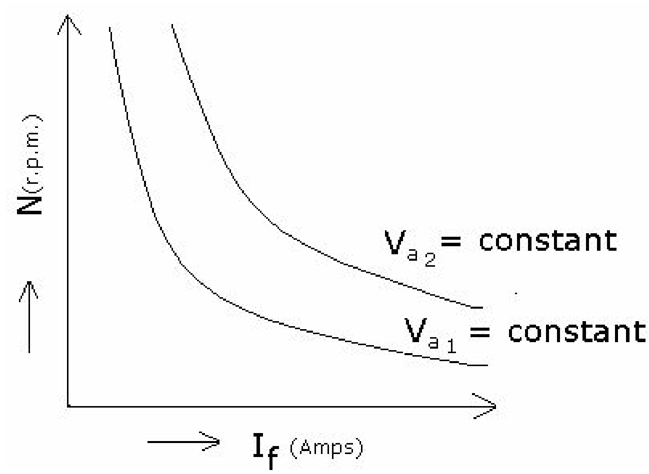
Armature voltage =

| Sl.No | Field current In Volts | Speed In rpm |
|---|---|---|
| | | |

**<u>Nature of graph:</u>**

**a) Armature Voltage Control** **b) Field Control**




**<u>Result:-</u>**

**Viva – Voce Questions:-**

1. Write down an expression, relating speed with the back emf developed in case of D C motors?
2 What is the basic relationship between back emf and applied voltage to the motor?
3 What are the various methods for the speed control of DC motors?
4. In DC machine, the brushes are made of which material?
5. Which material is used to manufacture the commutator segments?
6. Define regulation of a DC motor?
7 What is the condition for maximum power in a DC motor?
8. What are the applications of shunt motors?
9 What are the applications of DC series motors?
10 How the speed of a dc motor is controlled?
11 What is the chief advantage of Ward – Leonard system of DC motor speed control?
12. What is the speed range obtained by series parallel system of speed control of series motors widely used in traction works?
13. In rewinding the armature of a DC motor, progressive connections are changed to retrogressive ones .Will it affect the operation in any way?

**Exp. No : 5**

## HOPKINSON'S TEST ON D.C. MACHINES

**Aim:-** To conduct Hopkinson's test on two identical DC shunt machine and determine the efficiency of each M/C at various loads.

**Apparatus:-**

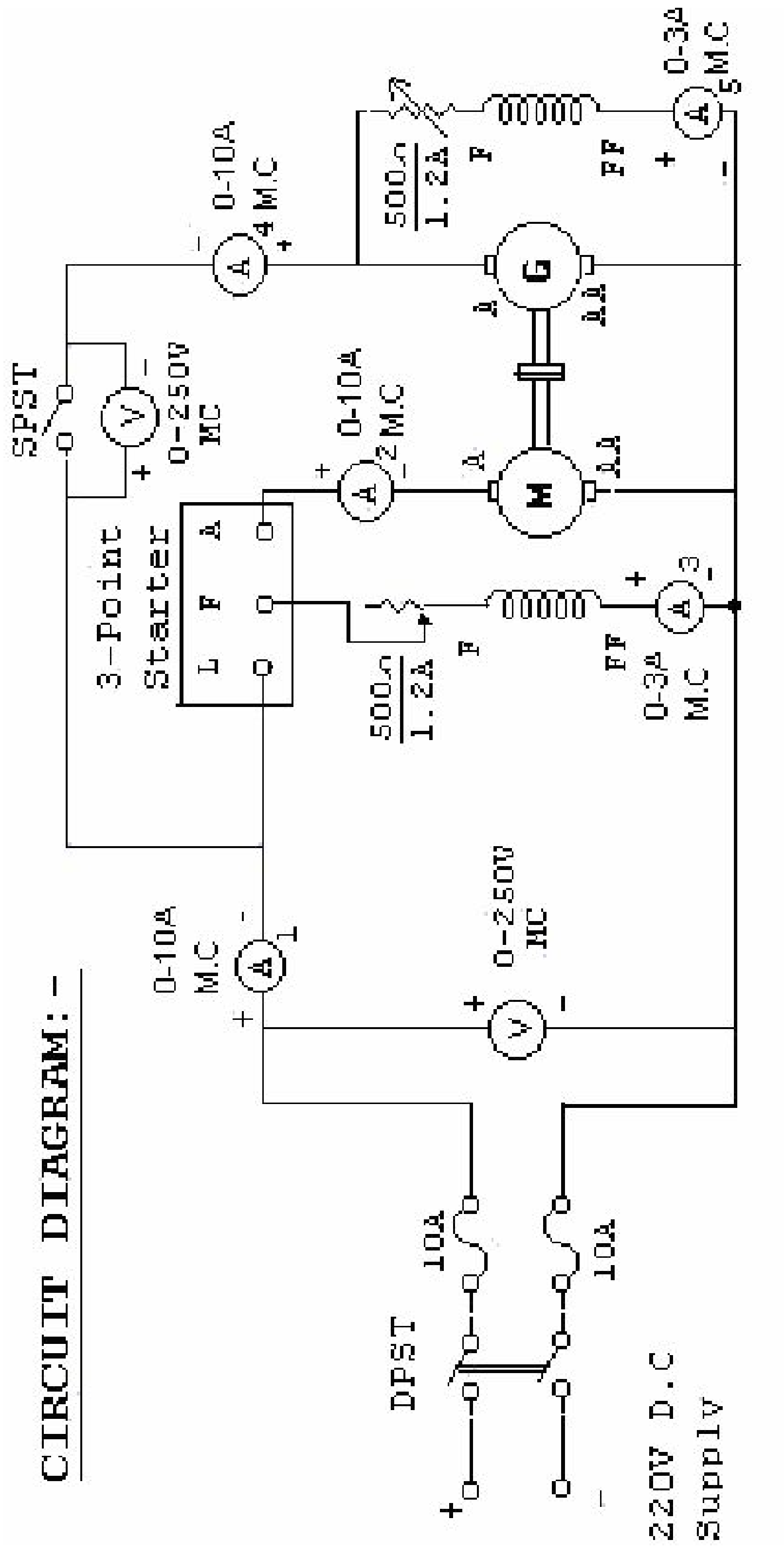
| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Voltmeter (M.C) | 0 – 250 V | 2 |
| 2 | Ammeter (M.C) | 0 – 10 A | 3 |
| 3 | Ammeter (M.C) | 0 – 3 A | 2 |
| 4 | Tachometer | 0 – 5000 rpm | 1 |
| 5 | Rheostat | 500 Ω, 1.2 A | 2 |
| 6 | D.C. shunt motor coupled generator | | |
| 7 | Connecting wires | | |

**Theory:-** By this method full load test can be carried out on two shunt machines, preferably identical ones, without wasting their outputs. The two m/c are mechanically coupled and are adjusted electrically so that one of them runs as a motor and the other as a generator. The mechanical o/p of the motor drives the generator and the electrical o/p of generator is used in supplying the greater part of input to motor. If there were no losses in the m/c s they would have run without any external supply. But due to these losses gen o/p is not sufficient to drive the motor and vice versa. The losses are supplied either by an extra motor which is belt connected to the MG set or as suggested by kapp electrically from the supply mains

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. With motor field rheostat is in cutout position, generator field rheostat is cut in position, ensuring that 3-point starter handle at its initial position and with the S.P.S.T. open, the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance with motor armature circuit, so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat.
5. The generator field rheostat is varied such that the generator terminal voltage is same as supply voltage so that the voltmeter across the SPST switch reads zero value and the SPST switch is closed.
6. The meter readings are noted in the tabular column.
7. The field rheostat of generator is varied in steps such that the armature current is also varied in steps of 1 A and all the meter readings are noted in the tabular column for each step till rated current is reached.
8. The field rheostat of generator is reduced such that armature current of generator reads zero. Open the SPST switch.
9. Motor field rheostat is brought back to CUT OUT, the generator field rheostat to CUT IN position and the supply switch is opened

## CIRCUIT DIAGRAM:-



**Tabular column**:-

| Sl.No | Voltage In Volts | $I_1$ In Amps | $I_2$ In Amps | $I_3$ In Amps | $I_4$ In Amps | $I_5$ In Amps | Generator O/P in watts | Motor O/P in watts | Efficiency of Generator in % | Efficiency of Motor in % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | |

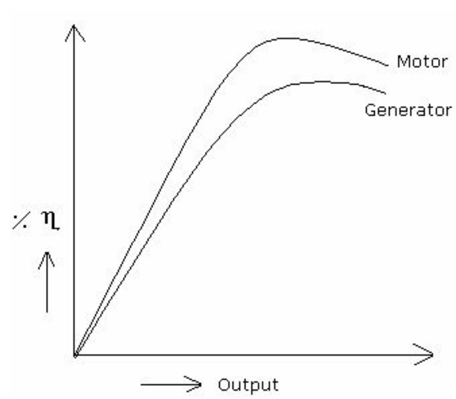
**Specimen calculations:-**

Armature cu losses of generator = $(I_4 + I_5)^2 R_a$
Armature cu losses of motor = $I_2^2 R_a$
Shunt field cu losses in generator = $V I_5$
Shunt field cu losses in motor = $V I_3$
Total stray losses $\rho_s = VI_1 - \left[(I_4 + I_5)^2 R_a + I_2^2 R_a + VI_5 + VI_3\right]$

$\therefore$ Efficiency of Generator $$\eta_g = \frac{VI_4}{VI_4 + \frac{\rho_S}{2} + (I_4 + I_5)^2 R_a + VI_5} \times 100$$

$\therefore$ Efficiency of Motor $$\eta_m = \frac{V(I_1 + I_4) - I_2^2 R_a - VI_3 - \frac{\rho_S}{2}}{V(I_1 + I_4)} \times 100$$

**Nature of graph :-**




**Result:-**

**Viva – Voce Questions:-**

1. What are the methods of testing dc machines and under which test is Hopkinson's test is classified?
2. Why Hopkinson's test is called a regenerative test?
3. What is the formula for efficiency if the machines are identical?
4. What are the advantages of Hopkinson's test?
5. What is the disadvantage of Hopkinson's test?
6. State the reason as to why the voltmeter reading across the switch shows zero value in Hopkinson's test?
7. What is the assumption while calculating efficiency of two machines?
8. How can you overcome the losses in both the machines?
9. Which machine has higher iron loss?
10. Which machine has more armature losses?
11. At which load is the Hopkinson's test is conducted?
12. What is the input to the motor?
13. Compare Swinburne's test and Hopkinson's test?
14. Why is a starter necessary for starting shunt motors?
15. What is the condition of motor-generator set in Hopkinson's test?
16. What is meant by floating?

**Exp. No : 6**

# DC SHUNT GENERATOR CHARACTERISTICS

**Aim:-** To conduct the no-load and load test on a D.C. shunt generator and draw its O.C.C, internal and external characteristics.

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 2 | Ammeter (M.C) | 0 – 10 A | 1 |
| 3 | Ammeter (M.C) | 0 – 2 A | 1 |
| 4 | Rheostat | 500 Ω, 1.2 A | 2 |
| 5 | Tachometer | 0 – 5000 rpm | 1 |
| 6 | Rheostatic load box | 230 V/ 10 A | 1 |
| 7 | D.C. shunt generator coupled D.C. motor | - | - |
| 8 | Connecting wires | - | - |

**Theory:-**

External characteristic curve (ECC):- This is drawn under load condition.
It is the curve drawn between load current or line current and load voltage or terminal voltage taking current on X axis induced emf on Y axis.

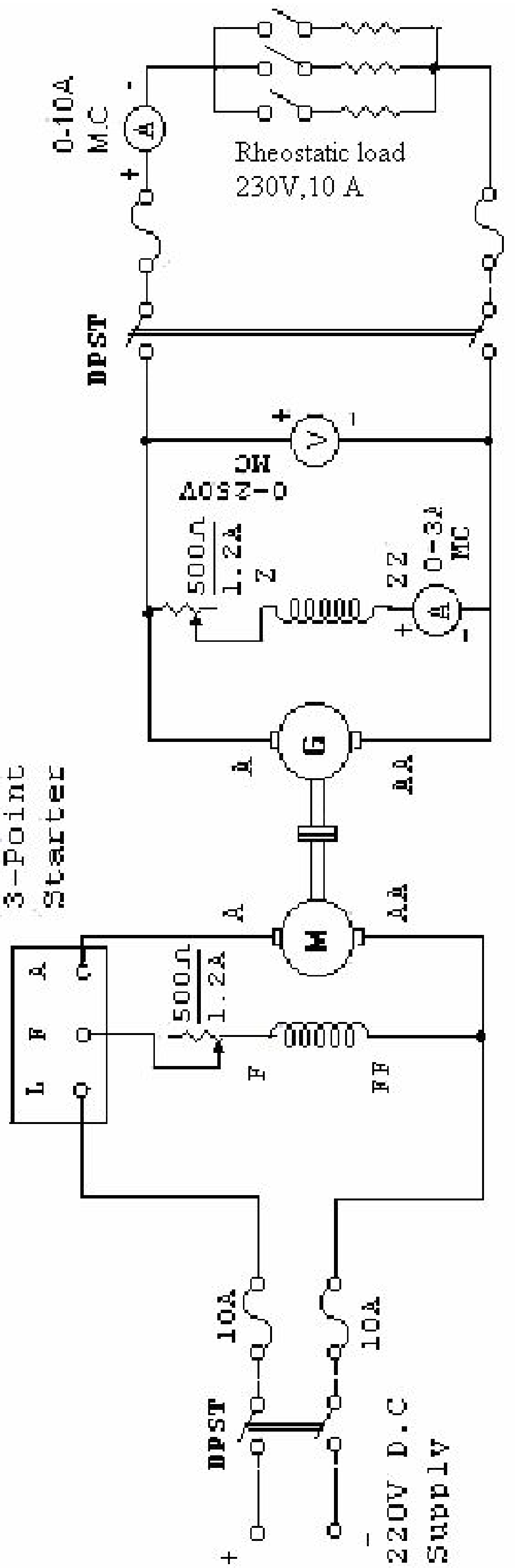
Internal characteristic curve (ICC). It is also called as total characteristic curve. It is drawn between armature current and generated voltage. Taking armature current on X axis, induced emf on Y axis

Relation between terminal voltage and induced emf:-The voltage given to the terminal is known as terminal voltage and induced in the generator is known as induced emf it is represented by E.

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. Ensuring that the motor field rheostat is in CUTOUT position, generator field rheostat is in CUTIN position, 3-point starter handle is in initial position and the load switch is in off position and the supply switch (DPST) is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance with motor armature circuit, so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat.
5. The generator field rheostat is varied in steps and the readings of field current and terminal voltage are noted.
6. Step No 5 is repeated until the generator voltage reaches to its rated value.
7. The load switch (DPST) is closed to connect the load to the generator and all the meter readings are noted in the tabular column.
8. The load is varied in steps and all the meter readings are noted in the tabular column.
9. Step no.8 is repeated until the rated current of the generator is reached.
10. The load is reduced in steps, the load switch is opened, the generator field rheostat is brought back to CUTIN position, the motor filed rheostat to CUTOUT position and the supply switch is opened.

## CIRCUIT DIAGRAM:-



**Tabular Column:-**

**Open circuit characteristic**

| Sl.no | $I_f$ In Amps | E In Volts |
|---|---|---|
| | | |

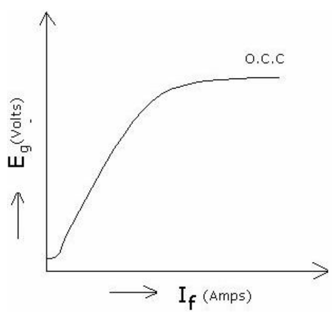
**Internal and external characteristic**

| Sl.no | $I_f$ In Amps | $I_L$ In Amps | V In volts | $I_a$ In Amps | $I_a R_a$ In Volts | E In volts |
|---|---|---|---|---|---|---|
| | | | | | | |

**Specimen calculations:-**

Induced voltage under load = $E = V + I_a R_a$

**Nature of graph:-**




*Fig(a)* : Open Circuit Characteristic

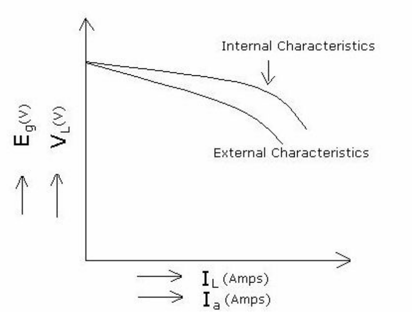



*Fig (b)* : Internal ($E_g$ Vs $I_a$) and External ($V_L$ Vs $I_L$) Characteristics

**Result:-**

**Viva – Voce Questions:-**

1. What is the principle of a dc generator?
2. What is Fleming's right hand rule?
3. What are the main components of a dc generator?
4. What is the purpose of a commutator in a dc generator?
5. Name the e various characteristics of a dc generator
6. Define critical resistance.
7. Define critical speed of a shunt generator?
8. How is critical resistance determined?
9. What are the conditions for build of voltage in a shunt generator?
10. What happens if a dc machine is operated at a speed below rated speed?
11. What is the type of voltage induced in the armature of a dc generator?
12. What is meant by build-up of voltage?
13. What is the standard direction of rotation of a dc generator?
14. What is the voltage regulation of an ideal dc generator?
15. What is meant by normal neutral plane?

**Exp. No : 7**

# D.C SERIES GENERATOR CHARACTERISTICS

**Aim:-** To draw the internal and external characteristics of DC series generator by conducting load test.

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 2 | Ammeter (M.C) | 0 – 10 A | 1 |
| 3 | Rheostat | 500 Ω, 1.2 A | 1 |
| 4 | Tachometer | 0 – 5000 rpm | 1 |
| 5 | Load box | 230 V/ 10 A | 1 |
| 6 | D.C. series generator coupled to DC motor | - | - |
| 7 | Connecting wires | - | - |

**Theory:-** In series generator the field winding is connected in series with the armature winding.

ECC: External characteristic curve. It is the curve drawn between the load current and terminal voltage. Taking load current ($I_L$) on X axis and terminal voltage on Y-axis

ICC: Internal characteristic curve. It is the curve drawn between armature current and generated voltage. Taking armature current $I_a$ on X axis and generated voltage on Y axis

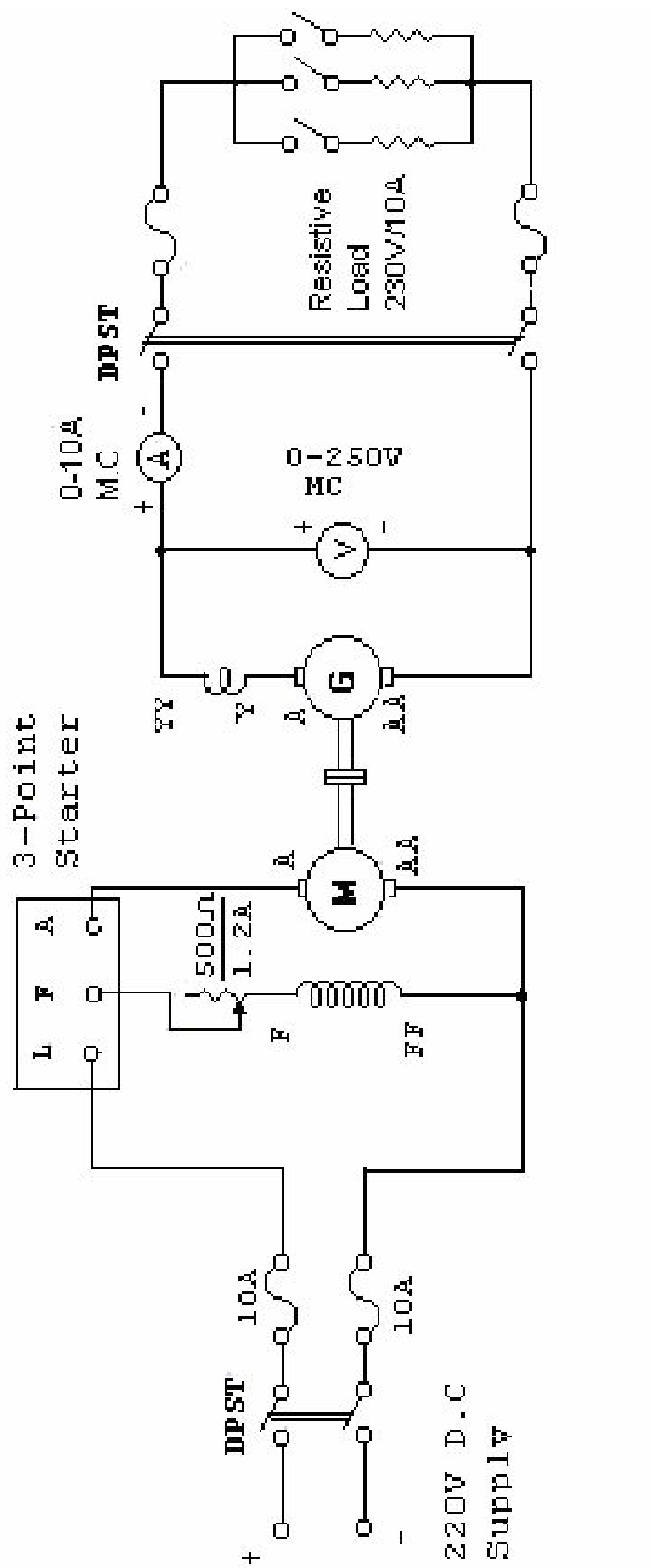
In series generator

Armature current = field current = load current

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. Ensuring that the motor field rheostat is in CUTOUT position, the 3-point starter handle is in initial position, the generator load switch in open position the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the motor armature circuit resistance, so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat. And the voltmeter reading is noted (indicates residual voltage)
5. The load switch of the generator is closed.
6. The load is varied in steps and all the meter readings are noted in the tabular column.
7. Step No 6 is repeated until the rated current of the generator is reached.
8. The load is removed in steps, the load switch of the generator is opened the motor field rheostat is brought back to CUTOUT position and the supply switch is opened.

## CIRCUIT DIAGRAM: -



**Tabular Column :-**

| Sl. no | $L_L$ In Amps | $V_L$ In volts | $I_a R_a$ Drop In Volts | Induced E.M.F In volts |
|---|---|---|---|---|
| | | | | |

**Specimen calculations :-**

Induced E.M.F = E = V + $L_a$ ($R_a$+$R_{sc}$)

**Nature of graph :-**

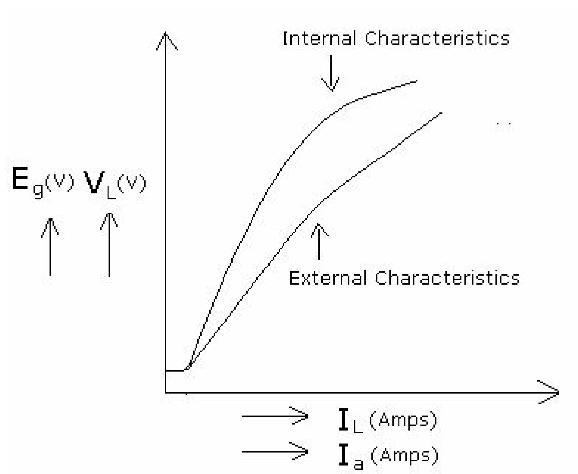



*Fig:* Internal ($E_g$ Vs $L_a$) and External ($V_L$ Vs $I_L$) Characteristics

**Result:-**

**Viva – Voce Questions:-**

1. At high loads, how does the series generator behave?
2. How is the series generator started?
3. What are the indications of an overload?
4. How can we say that field and armature connections are correct?
5. How can loss of residual magnetism be corrected?
6. Give some applications of series generator.
7. What happens if series resistance is more than critical field resistance?
8. Define critical resistance.
9. What are the different type's generators?
10. What is the function of commutator?

**Exp. No : 8**

# D.C COMPOUND GENERATOR CHARACTERISTICS

**Aim:-** To draw the internal and external characteristics of DC short shunt compound generator by conducting load test (Both cumulative & differential)

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 2 | Ammeter (M.C) | 0 – 10 A | 1 |
| 3 | Ammeter (M.C) | 0 – 3 A | 1 |
| 4 | Rheostat | 500 Ω, 1.2 A | 2 |
| 5 | Tachometer | 0 – 5000 rpm | 1 |
| 6 | Load box | 230 V/ 10 A | 1 |
| 7 | D.C. compound generator coupled to DC shunt motor | - | - |
| 8 | Connecting wires | - | - |

**Theory:-**The method of adding the series field flux with the shunt field flux is known as compounding. According to method of compounding the compound generators are classified into two categories.

i) Cumulatively compounding generator.
ii) Differential compounding generator.

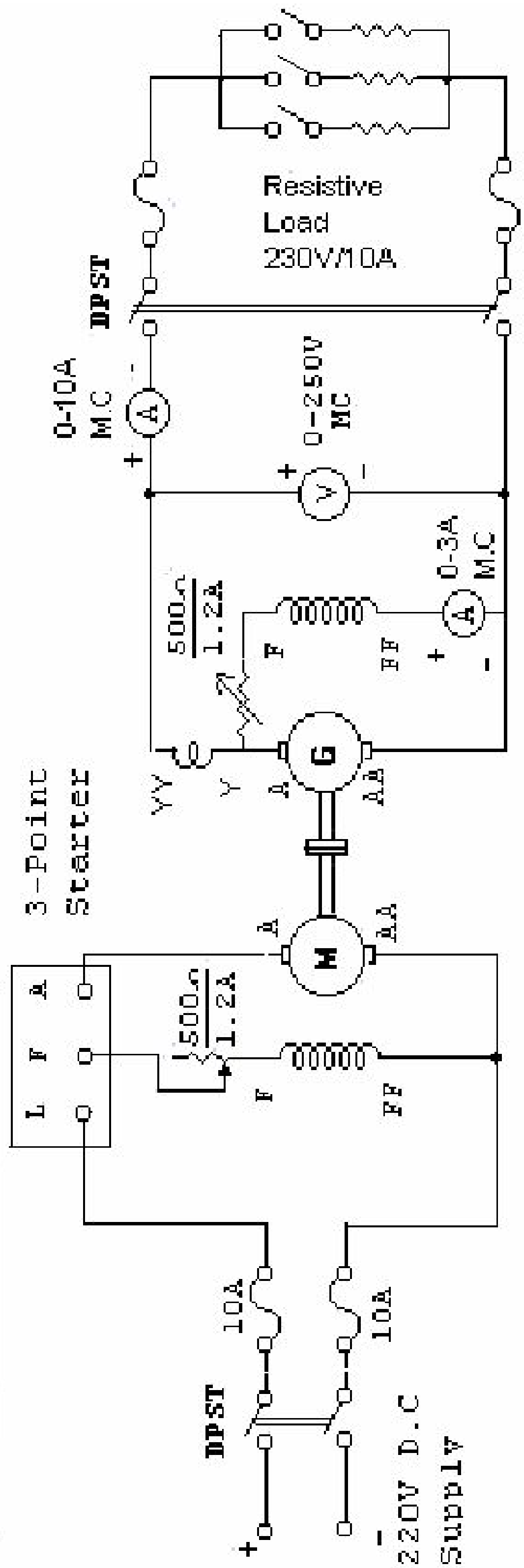
In cumulative compounding generator the flux produced by the series field winding must be right direction with the shunt field flux. i.e. the series field flux in phase with the shunt field flux. but in the case of differential compounding generator the flux produced by the series field winding is in such a direction that it should opposes the shunt field flux there by the resultant flux decreases.

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. With motor field rheostat is in CUTOUT position, generator field rheostat in CUTIN position, ensuring that the 3-point starter handle is in initial position, and load switch in off position the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually, so that the motor starts.
4. The motor is brought to its rated speed by varying the motor field rheostat.
5. The generator field rheostat is varied gradually so that the generator voltage is built up to its rated value.
6. The load switch of the generator is closed
7. The load is applied in steps and for each step all the meter readings are noted.
8. Step No.(7) is repeated until the rated current of the generator is reached
9. The load is removed in steps, the load switch of the generator is opened the generator field rheostat is brought back to CUTIN position the motor field rheostat to CUTOUT position and the supply switch is opened.
10. The series field winding terminals of the generator are interchanged and the above procedure is repeated to get another type of compounding.

*Note: If the first one is cumulative compound, second one will be differential compounding.*

## CIRCUIT DIAGRAM: -



**Tabular Column:-**

a) Cumulative Compounding:

| Sl.no | $L_L$ In Amps | $V_L$ In volts | $L_f$ In Amps | $L_a$ In Amps | $E_g$ In volts |
|---|---|---|---|---|---|
| | | | | | |

b) Differential Compounding:

| Sl.no | $L_L$ In Amps | $V_L$ In volts | $L_f$ In Amps | $L_a$ In Amps | $E_g$ In volts |
|---|---|---|---|---|---|
| | | | | | |

**Specimen calculations:-**

The Induced E.M.F $E_g = V_L + I_a R_a + I_L R_{sc}$

**Nature of graph:-**

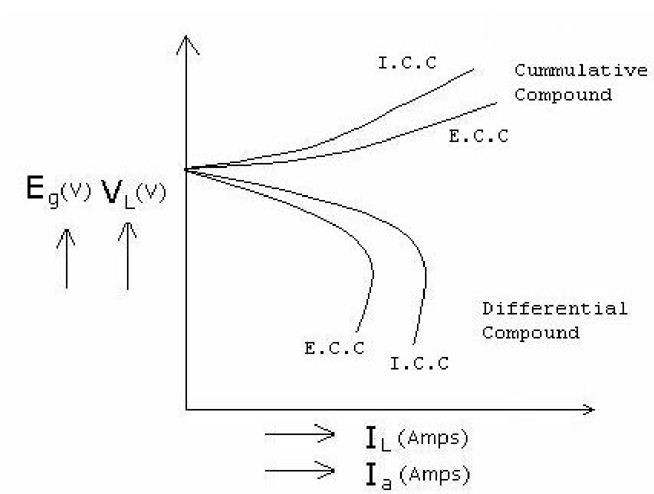



*Fig:* Internal ($E_g$ Vs $I_a$) and External ($V_L$ Vs $I_L$) Characteristics

**Result:-**

**Viva – Voce Questions:-**

1. What is the classification of different types of generators?
2. What is the need for a compound generator?
3. What is meant by the cumulatively compounded generator?
4. What is meant by differential compounded generator?
5. What is meant by a flat compounding?
6. What is meant by over- compounding?
7 What is meant by under compound?
8 What are the indications of an overload?
9. How is a shunt generator converted to a compound generator?
10 What are the different types's of generators?

**Exp. No : 9**

# LOAD TEST ON D.C. SERIES MOTOR

**Aim:-** To conduct the load test on D.C. Series motor and draw its performance characteristics.

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Ammeter (M.C) | 0 – 30 A | 1 |
| 2 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 3 | Tachometer | 0-5000 rpm | 1 |
| 4 | D.C. Series motor with loading arrangement | - | 1 |
| 5 | Connecting wires | - | - |

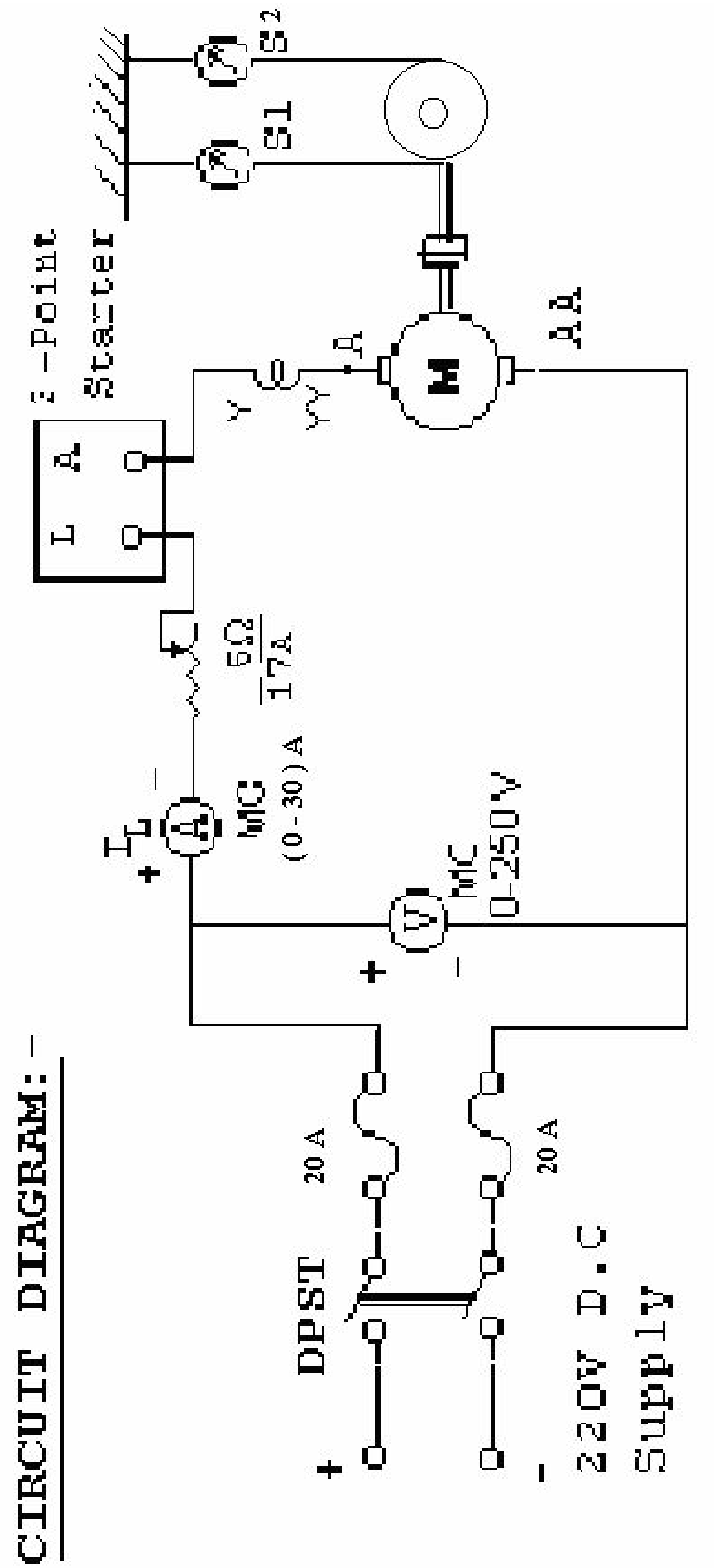
**Theory:-** The nature of graph shows the speed characteristic curve of a dc series motor. The shape of the speed curve is similar to rectangular hyperbola. At no load the motor running at very high speed and at full loads the motor running at very low speeds. The speed is changing very rapidly from low speed to high speed when the load is decreases from full to no loads therefore the series motor is called variable speed motor. In the speed torque curve of a series motor, the curve starts from just above zero and the torque increasing rapidly as the load current increases. This shows the motor is not having constant speed nor constant torque. This variable characteristic curve is very suitable for electric traction.

**Procedure:-**

1. The connections are made as shown in the circuit diagram.
2. Ensuring that the belt over the brake drum is tightened and the 2-point starter handle at initial position and armature rheostat in CUTIN position, the supply switch is closed.
3. The 2-point starter handle is moved clock wise gradually to cut out the resistance in the motor armature circuit so that the motor starts. Then , armature rheostat is brought to CUTOUT position.
4. All the meter readings, spring balance readings as well as speed are noted.
5. The load is applied in steps and for each step all the meter readings, spring balance readings as well as speed are noted.
6. Step no. 5 is repeated until the rated current of the motor is reached.
7. The supply switch is opened with minimum load on the motor.

**Tabular column:-**

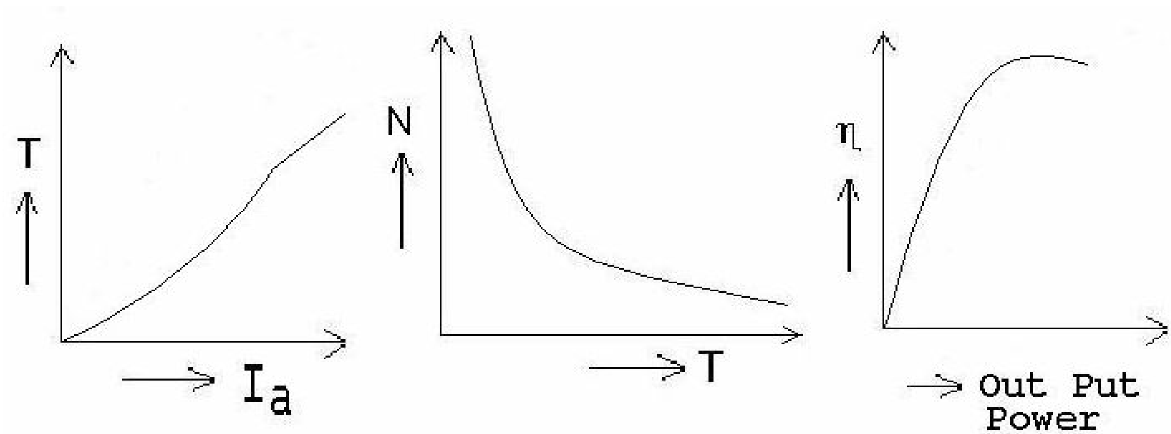
| Sl. No | $V_L$ In Volts | $I_L$ In Amps | $S_1$ In Kgs | $S_2$ In Kgs | N In rpm | T In N - m | Input In watts | Output In watts | % Efficiency |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |


CIRCUIT DIAGRAM:-
3-Point Starter
L
A
S1
S2
Y
YY
A
AA
M
5Ω
17A
+
I
L
−
MC
(0-30)A
+
−
V
MC
0-250V
20 A
20 A
DPST
+
−
220V D.C
Supply

**Specimen calculations:-**

1. Torque $T = (S_1 \sim S_2) \times r \times 9.81$ N – m
2. Motor input power $P_i = V_L \cdot I_L$ watts
3. Motor output power $P_o = \dfrac{2\pi NT}{60}$ watts
4. % efficiency $\eta = \dfrac{\text{output power}}{\text{input power}} \times 100$

**Nature of the graph:-**




**Result:-**

**Viva – Voce Questions:-**

1. What is the principle of a motor?
2. What is the condition for maximum power in a DC motor?
3. Define Torque?
4. Write the torque equation of a DC motor?
5. What is the shaft torque equation of a DC motor?
6. Shaft torque $T_{sh}$ =(9.55 output power)/N, N-m
7. What are different compound motors?
8. What are the characteristics of series motors?
9. Give some application of DC series motors?
10. What type of starter is used for DC series motor?
11. What is the range of speed obtained by series parallel system of speed control of series motors?
12. What happen if the direction of current at the terminals of a series motor is reversed?

**Exp. No : 10**

## RETARDATION TEST ON D.C. SHUNT MOTOR

Aim:- To conduct retardation test on a given DC shunt motor and predict the efficiency of m/c when it is operated as a) Motor and b) Generator.

Apparatus:-

| S.No | Apparatus | Range | Type | Qty |
|---|---|---|---|---|
| 1 | Ammeter | 0-10A | MC | 2 |
| 2 | Voltmeter | 0-250V | MC | 1 |
| 3 | Rheostat | 230Ω/1.7A<br>38Ω/8.5A<br>500Ω/1.2A | | 1<br>1<br>1 |
| 4 | Single pole double through switch | | | 1 |

**Theory:-**

This method is applicable to shunt motors and generators to find stray losses. Thus knowing armature and shunt cu losses at a given load current efficiency can be evaluated.

The m/c under test is speeded up beyond its normal speed and then supply is cutoff from the armature while keeping the field excited consequently the armature slows down and its kinetic energy is used to meet rotational losses i.e friction and windage losses.

Kinetic energy of armature K.E = $\frac{1}{2}I\omega^2$

Where I - Moment of inertia of armature

ω - angular velocity

∴ Rotational Losses = Rate of losses of K.E

$$W = \frac{d}{dt}\left(\frac{1}{2}I\omega^2\right) = I\omega\frac{d\omega}{dt}$$

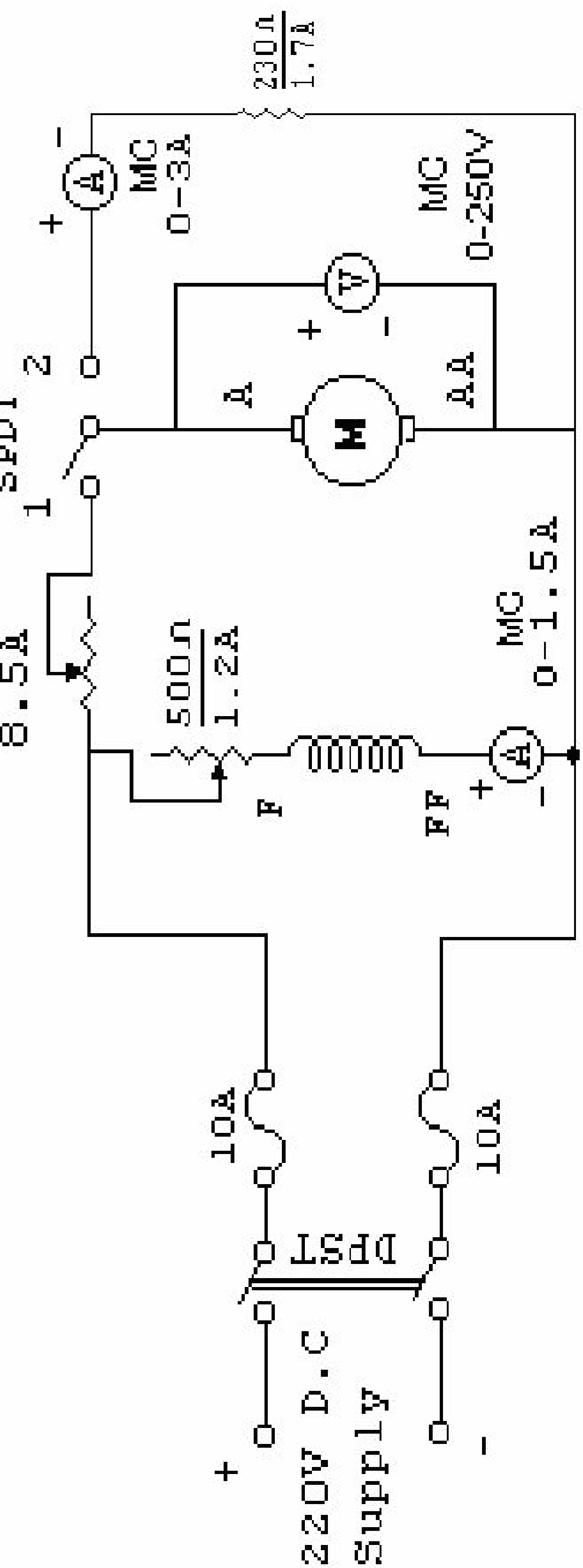
but $\omega = \frac{2\pi N}{60}$

$$\therefore \quad W = I\left(\frac{2\pi N}{60}\right)\left(\frac{2\pi}{60}\right)\frac{dN}{dt} \quad = I\left(\frac{2\pi}{60}\right)^2 N\frac{dN}{dt}$$

$$W+W^1 = I\left(\frac{2\pi}{60}\right)^2 N\frac{dN}{dt_2}$$

$$W = W^1\frac{t_2}{t_1 - t_2}$$

**CIRCUIT DIAGRAM:-**



## Procedure:

1. All the connections are made as shown in circuit.
2. The DPST switch is closed with the armature rheostat in maximum position and switch SPDT in position
3. As the motor starts rotating the rheostat must be brought to its initial position.
4. Now by varying field rheostat the speed of motor is brought just above rated speed.
5. Now voltage across armature is measured.
6. Now SPST switch is opened and the time taken by the motor terminal voltage to pull from 220V to 100V is noted.
7. Up to $6^{th}$ step is repeated and the switch is moved from position 1 to 2 and time taken by the motor terminal to fall from 220V to 180V is noted.
8. From the above data stray losses can be calculated.
9. Armature and shunt field Cu losses can be calculated. Hence efficiency can be obtained.

**Tabular column:-**

| Sl.No | Vmax In volts | Vmin In volts | $t_1$ in Seconds | $t_2$ in Seconds |
|---|---|---|---|---|
| | | | | |

**Specimen calculations:-**

The power absorbed by resistance Ra is

$$\text{Power (P)} = \left(\frac{V\max + V\min}{2}\right)^2 \Big/ R_L + R_a$$

$$\text{Stray losses } Ws = \frac{P * t_2}{t_1 - t_2}$$

Shunt field copper losses Wsh = VIsh

Calculation of Efficiency

**when running as motor :**

If $I_L$ = Full Load current in amps

| | At full Load | At Half Full Load |
|---|---|---|
| a. Armature current | $= I_a = I_L - I_{sh}$ amps | $I_a = \frac{I_L}{2} - I_{sh}$ amps |
| b. Armature cu. Loss | $= w_a = I_a^2$ Ra watts | $w_c = I_a^2 R_a$ watts |
| c. Motor input | $= P_i = V I_L$ watts | $P_o = ½ VI_L$ watts |
| d. Total losses | $= P_t =$ Ws+ Wa+ Wsh watts | |

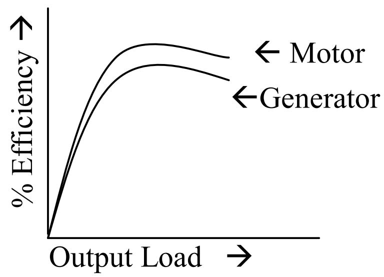
$$\therefore \text{ \% efficiency of motor} = \frac{p_i - p_t}{p_i} \times 100$$

**when running as generator:**

| | At Full Load | At Half Full Load |
|---|---|---|
| a. Armature current | $= I_a = I_L + I_{sh}$ amps | $I_a = \frac{I_L}{2} + I_{sh}$ amps |
| b. Armature cu. Loss | $= w_a = I_a^2 R_a$ watts | $w_a = I_a^2 R_a$ watts |
| c. Generator output | $= P_o = V I_L$ watts | $P_o = \frac{1}{2} V I_L$ watts |
| d. Constant losses | $= P_c$ watts | |
| e. Total losses | $= P_t = W_s + Wsh + w_a$ watts | |

$$\therefore \text{\% efficiency of generator} = \frac{p_o}{p_o + p_t} \times 100$$

**Nature of Graph :-**




**Result:-**

**Viva – Voce Questions:**

1. Do you require a starter for a dc motor under the running condition, why?
2. Can you use the dc motor as a dc generator? If so, what is to be done?
3. What are the losses taking place in a dc machine.
4. What are the stray losses?
5. What is the principle of operation of dc motor?
6. What happens to dc shunt motor if source polarity reversed?
7. A dc shunt motor refuses to start when switched on what could be the possible reasons and remedies?
8. What happens to motor if field circuit is suddenly opened?
9. What are the advantages and disadvantages of Retardation test over the other tests?
10. When will you get the maximum efficiency for a dc machine?

**Exp No: 11**

# SEPERATION OF LOSSES IN A DC MACHINE

**Aim: -** To separate the constant losses of a single dc machine in to their respective components

**Apparatus:-**

| S.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1 | Ammeter (M.C) | 0 – 3 A | 1 |
| 2 | Ammeter (M.C) | 0 – 1.5 A | 1 |
| 3 | Voltmeter (M.C) | 0 – 250 V | 1 |
| 4 | Rheostat | 500 Ω, 1.2 A | 1<br>1 |
| 5 | Tachometer | 0-5000 R.P.M | 1 |
| 6 | DC shunt motor | - | 1 |
| 7 | Connecting wires | - | - |

**Theory:-**

Various components of constant losses in a dc machine are iron losses viz. hysteresis loss and eddy current loss, and mechanical losses viz. friction and windage loss. they can be approximated as follows:

mechanical losses = $AN+BN^2$ (approximately)
iron losses = $CN+DN^2$ (with excitation kept constant)

To separate these components, the dc machine is run as a motor at no-load.

Input power to armature circuit at no-load = Constant losses + $I_{a0}^2 R_a$

Then,

Total constant losses = input power at no load - $I_{a0}^2 R_a$
= W

Hence, $W = (AN + BN^2) + (CN + DN^2)$

Or

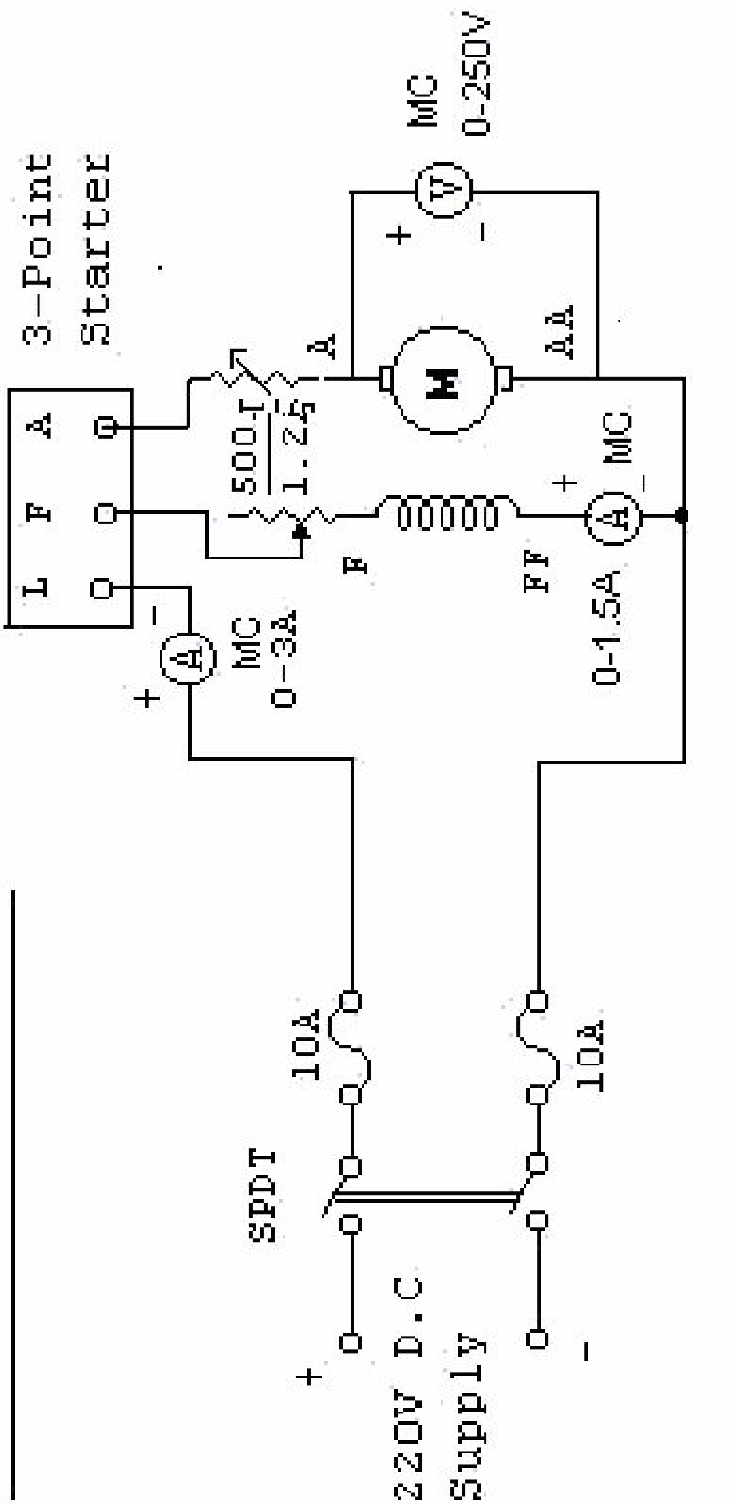
$W/N = (A+C)+(B+D)N$

Plotting W/N against speed, a straight line is obtained from where (A+C) and (B+D) can be calculated. The procedure repeated for reduced excitation changes only iron losses and not mechanical losses and hence losses can be separated.

**Procedure:-**

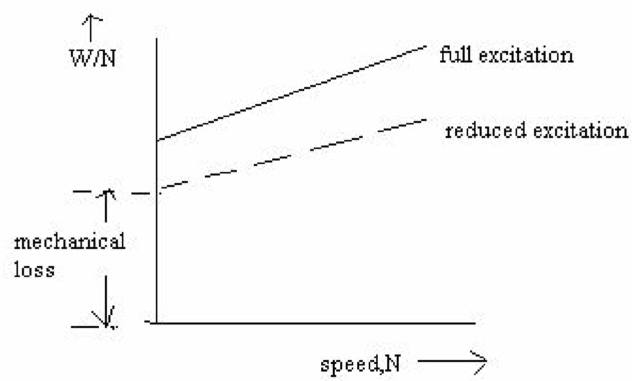
1. The connections are made as shown in the circuit diagram.
2. With the motor field rheostat in CUTOUT position, armature rheostat in CUTIN position and3-point starter handle at its initial position, the supply switch is closed.
3. The 3-point starter handle is moved clock wise gradually to cut out the resistance in the motor armature circuit so that the motor starts and runs at reduced speed. Cutout fully the external resistance in the armature circuit.
4. Adjust the field current to rated value and keep it constant.
5. Vary the motor speed by varying armature resistance and note all the meter readings in the tabular column up to rated speed.
6. Adjust the field current to a reduced value (app.70 percent of rated value) and repeat step 5.
7. The rheostats are brought back to CUT OUT position and the supply switch is opened.
8. Measure the armature resistance by volt-amp method.

## CIRCUIT DIAGRAM:-



**Observations & Calculations**:

| S. no. | If | I | V | $I_{a0}^2 R_a$ | W | W/N |
|---|---|---|---|---|---|---|
| | | | | | | |




Constant losses = input power at no load - $I_{a0}^2 R_a$

i.e. W = $V I - I_{a0}^2 R_a$

= mechanical losses + iron losses

Now,

mechanical losses from graph =

therefore, iron losses =

**Result**:

The constant losses of the given dc motor are:

mechanical losses =

iron losses =

## Viva-voce questions

1 Identify the locations of field and armature windings for different machines.
2. What do you mean by rated values of a machine
.3 Write down the EMF equation of a dc generator?
4 To find OCC of a self excited shunt generator it has to be connected as a separately excited generator when it is (true or false)
5. Expand OCC what is the other name for it?
6. Commutator works as a _____________ in dc generator and as a ___________ in a dc motor.
7. Interpoles will be placed between ____________ in a dc generator.
8. A dc shunt motor can be started using 4 point starter (True or False) ?
9 What is the function of generator?
10. What is the basic working principle of a d.c generator?
11 What are the total losses takes place in a d.c generator (or d.c machine)?
12 What is hysteresis loss?
13. What are eddy current losses?
14. What is commutator?
15 . How you collect the d.c from the commutator?
16. Why brushes are used?

**Exp. No.12**

# OPEN CIRCUIT AND SHORT CIRCUIT TESTS ON 1-ϕ TRANSFORMER

**Aim: -**Conduct the open circuit and short circuit test on 1-ϕ transformer and determine the efficiency and regulation at different loads.

Apparatus: -

| Sl.No | Apparatus | Range | Qty |
|---|---|---|---|
| 1. | Ammeter (M.I) | 0 - 3A | 1 |
| 2. | Ammeter (M.I) | 0 – 10A | 1 |
| 3. | Voltmeter (M.I) | 0 – 30V | 1 |
| 4. | Voltmeter (M.I) | 0 – 150V | 1 |
| 5. | Wattmeter L.P.F | 2.5A/150V | 1 |
| 6. | Wattmeter U.P.F. | 10A/75V | 1 |
| 7. | Variac | 230V/0-270V, 8A | 1 |
| 8. | 1-ϕ Transformer | 230V/115V 2kVA | 1 |
| 9. | Connecting wires | - | - |

**Theory:-**

By conducting O.C. and S.C. tests on a given transformers we can predict the efficiency, regulation and equivalent circuit without actually loading it. The purpose of this test is to determine no-load loss (or) core loss and no-load current, which is helpful in finding $x_0$ and $R_0$.

In O.C test one winding of the transformer usually high voltage winding is left open and the other is connected to its supply of normal voltage and frequency. A wattmeter w, voltmeter V, and an ammeter A are connected in L.V. winding, with the normal voltage is applied to the primary, normal flux will be setup in the core hence normal iron losses will occur which are recorded by the wattmeter. The no-load current is small so copper loss is negligibly small. Hence the wattmeter reading represents practically the core loss.

In S.C. test one winding, normally L.V. winding is short-circuited and meters are connected in H.V. side. Very low voltage is applied on H.V. side and it is increased slowly until full load current is flowing in the winding. Under these conditions wattmeter reading represents the full load copper loss. There is also a small amount of core loss, which is negligible compared to the copper loss.

Procedure:-

For O.C Test:-

1) The connections are made as shown in the circuit diagram.
2) With the dimmerstat at zero output position, the supply switch (DPST) is closed.
3) The output of the dimmer stat is adjusted such that the voltmeter reads the rated voltage at the L.V winding of the transformer and all the meter readings are noted in the tabular column.
4) The dimmer stat is brought back to zero output and the supply switch (DPST) is opened

For S.C Test:-

1) The connections are made as shown in the circuit diagram.
2) With the dimmer stat at zero output, the supply switch is closed.
3) The output of the dimmer stat is adjusted such that the ammeter reads the rated current at the H.V winding of the transformer and all the meter readings are noted in the tabular column.
4) The dimmer stat is brought back to zero output and the supply switch is opened

Tabular Column:-

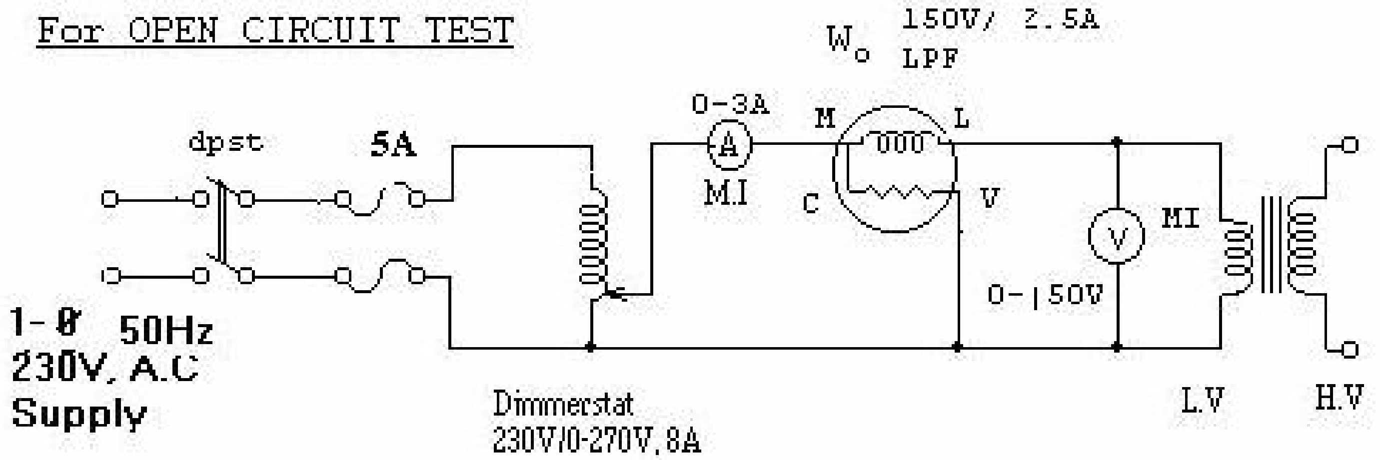
| | Open circuit test | | | Short circuit Test | | |
|---|---|---|---|---|---|---|
| S.l No | $V_o$ in volts | $I_o$ in Amps | $W_o$ in Watts | $V_{SC}$ in volts | $I_{SC}$ in Amps | $W_{SC}$ In Watts |
| | | | | | | |

Equivalent Circuit Parameters

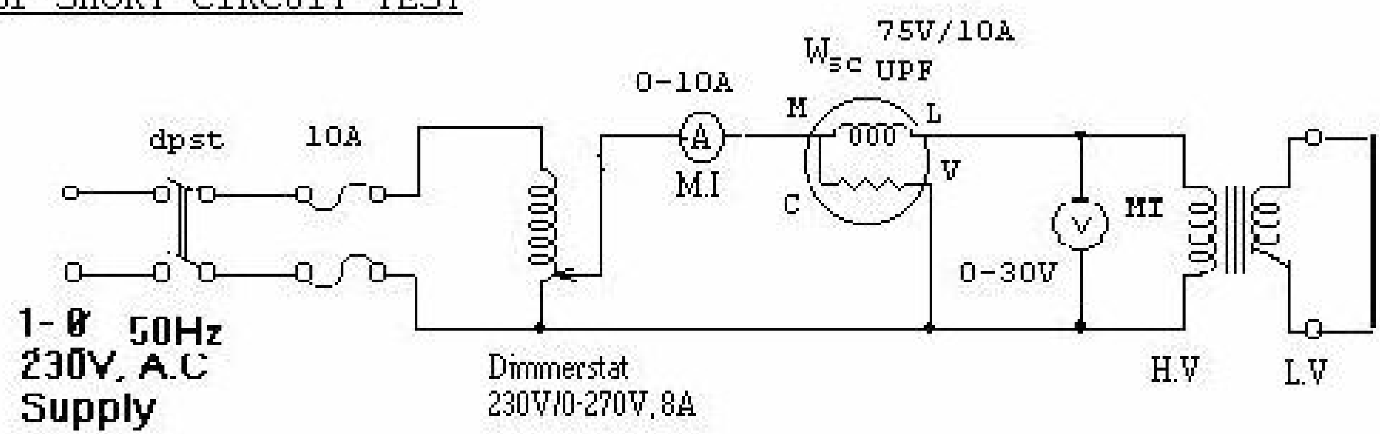
| S.l No | COS $\phi_o$ | $I_w$ in Amps | $I_m$ in Amps | $R_o$ in Ω | $X_m$ in Ω | Cos $\phi_{sc}$ | $R_{eq}$ in Ω | $X_{eq}$ in Ω | $W_{SC}$ In Watts |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | |

## Circuit Diagram:-

For OPEN CIRCUIT TEST




For SHORT CIRCUIT TEST



**Specimen calculations:-**

$$\text{Rated current of transformer} = \frac{\text{KVA rating of transformer}}{\text{Supply voltage}}$$

$$\text{Wattmeter Multiplication factor} = \frac{\text{Voltage Range X Current Range}}{\text{Maximum wattmeter scale reading}} \times \text{Power factor}$$

Input Power = Wattmeter reading X Wattmeter Multiplication factor

1. $Cos\phi_0 = \frac{w_0}{v_0 i_0}$  2. $I_W = I_0 \text{Cos}\phi_o$  3. $I_m = I_0 \text{Sin}\phi_o$  4. $R_o = \frac{V_o}{I_w}$

5. $X_m = \frac{V_o}{I_m}$  6. $R_{eq} = \frac{W_{sc}}{I_{sc}^2}$  7. $Z_{eq} = \frac{V_{sc}}{I_{sc}}$  8. $X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$

$$\%\text{ Efficiency at full load} = \frac{FullloadVA \times Cos\phi}{FullloadVA \times Cos\phi + W_o + W_{sc}} \times 100$$

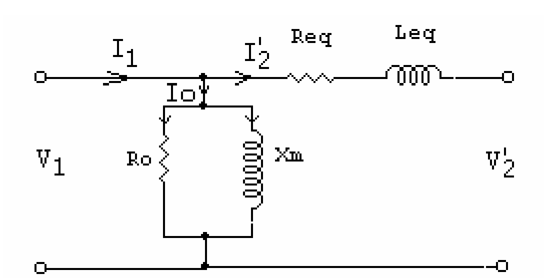
Efficiency at any load X*F.L, where X = ¼ or X= ½ or X = ¾

$$\%\text{ Efficiency at X.* F.L} = \frac{X \cdot FullloadVA \times Cos\phi}{X \cdot FullloadVA \times Cos\phi + W_o + X^2 W_{sc}} \times 100$$

$$\%\text{ Regulation} = \frac{R_{eq} COS\phi \pm X_{eq} SIN\phi}{V_{rated}} \text{ X } 100$$

Where + is for Lagging P.F
- is for Leading P.F

**Equivalent Circuit:-**




$R_o$, $X_m$ – are referred to L.V Side

$R_{eq}^1$. $X_{eq}^1$ – Referred to H.V Side

These values referred L.V Side are

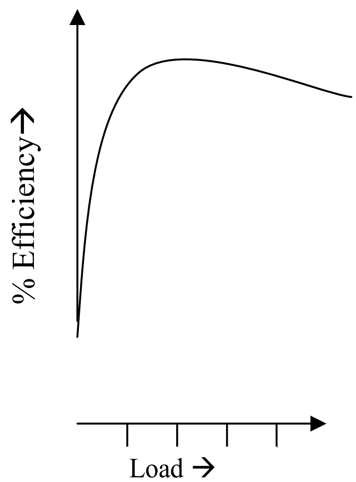
$$R_{eq} = a^2 R_{eq}^1$$

$$X_{eq} = a^2 X_{eq}^1$$

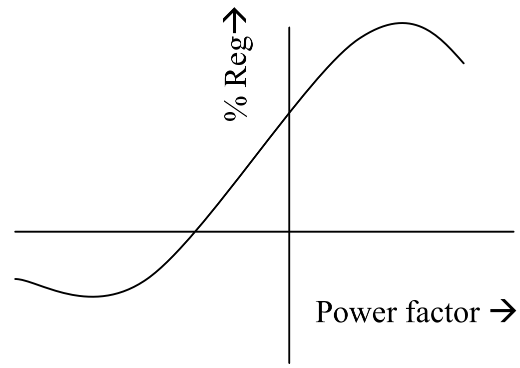
where $a = \frac{N_1}{N_2} = \frac{L.V}{H.V}$

Nature of graph:-

a) % Efficiency Vs Load




b) % Regulation Vs Power Factor




**Result:-**

**Viva – Voce Questions**

1 What is the purpose of OC & SC test?
2. Why are transformers rated in KVA?
3. Why is the OC test conducted on LV side?
4. Why is the SC test conducted on HV side?
5. Why is an L.P.F wattmeter is used in OC test?
6. Why is a UPF wattmeter is used in SC test
7. What are the advantages of transformer tests?
8. What is the applied voltage $V_{Sc}$ under sc test?
9. Why iron loss are neglected in SC test
10 What is the value of primary current in OC test and why copper losses are neglected?
11 What are the readings of wattmeter obtain practically in OC & SC test
12. What is the output of transformer in SC test and what indicates the input power
13 What are the components of core loss?
14 What is the condition for maximum efficiency?
15 Name the various types of transformers
16. Under what condition is DC supply applied to the primary of transformers?
17 Why are iron core transformers not used for high frequency applications?
18. What are the components of equivalent circuit of a transformer?

**Exp. No.13**

## PARALLEL OPERATION OF 1-ϕ TRANSFORMERS

**Aim:-** To operate two transformers in parallel and studies the load sharing of each transformer

Apparatus:-

| Sl.No | Apparatus | Type | Range | Qty |
|---|---|---|---|---|
| 1 | Voltmeter | M.I | 0 – 300 V | 1 |
| 2 | Voltmeter | M.I | 0 – 250 V | 1 |
| 3 | Voltmeter | M.I | 0 – 150 V | 1 |
| 4 | Ammeter | M.I | 0 – 20 A | 2 |
| 5 | Ammeter | M.I | 0 – 30 A | 1 |
| 6 | Connecting wires | - | -- | -- |

Theory:-

The various conditions which must be fulfilled for the satisfactory parallel operation of two or more single-phase transformers are as follows:

a) The transformers must have the same voltage ratios, i.e, with the primaries connected to the same voltage source; the secondary voltages of all transformers should be equal in magnitude.
b) The equivalent leakage impedances in ohms should be inversely proportional to their respective KVA ratings. In other words, the per unit leakage impedances of the transformers based on their own KVA ratings must be equal.
c) The ratio of equivalent leakage reactance to equivalent resistance, i.e $X_e / R_e$ should be same for all the transformers.
d) The transformers must be connected properly, so far as their polarities are concerned.

If the secondary terminals are connected with wrong polarities large circulating currents will flow and the transformer may get damaged. Therefore, condition (d) must be strictly fulfilled.

Figure shows two single phase transformers in parallel, connected to the same voltage source on the primary side. A further check on the polarities can be applied by connecting a voltmeter V in series with the two secondaries. Zero voltmeter reading indicates proper polarities. If the voltmeter reads the sum of two secondary voltages, the polarities are improper and can be connected by reversing the secondary terminals of any one transformer.

No – load Operation**:**

If the no-load secondary voltage $E_a$ and $E_b$ for transformers A and B are equal in magnitude and are in line phase, then $\bar{E}_a - \bar{E}_b = 0$ and no current can circulate in the transformer windings of $\bar{E}_a$ and $E_b$ are unequal on out of phase, then the resultant voltage $\bar{E}_a - \bar{E}_b$ will calculate a current $I_C$ given by the expression,

$$\bar{I}_C = \frac{\bar{E}_a - \bar{E}_b}{\bar{Z}_{ea} - \bar{Z}_{eb}}$$

where $Z_{ea}$ and $Z_{eb}$ are equivalent leakage impedances in ohms.

On-load operation:

(a) Equal voltage ratios: When the transformers have equal voltage ratios, the magnitudes of the secondary no-load voltages are equal. Further if the primary leakage impedance drops due to exciting currents are also equal, then $\bar{E}_a = \bar{E}_b$ and the circulating current at no-load is zero.

(b) Unequal voltage ratios:Unequal secondary emfs give rise to circulating current on no-load. When the load is connected, the transformers share the load current in proportion to their KVA ratings which further depends upon their leakage impedances. The resultant current in any transformer is equal to the phasor sum of the circulating current and load current shared by it.

**Procedure:-**

Polarity test:

1. The connections are made as shown in the circuit diagram
2. The supply switch is closed and observe the voltmeter reading
3. Interchange the secondary winding terminals of the transformer and once again observe the voltmeter reading.
4. The supply switch is opened.

   Note:

   i. If the voltmeter reads the sum of the voltages of two windings then the transformer which are in additive polarity.
   ii. If the voltmeter reads the difference of the voltage of this working then transformer winding are in subtractive polarity.

Parallel operation:-

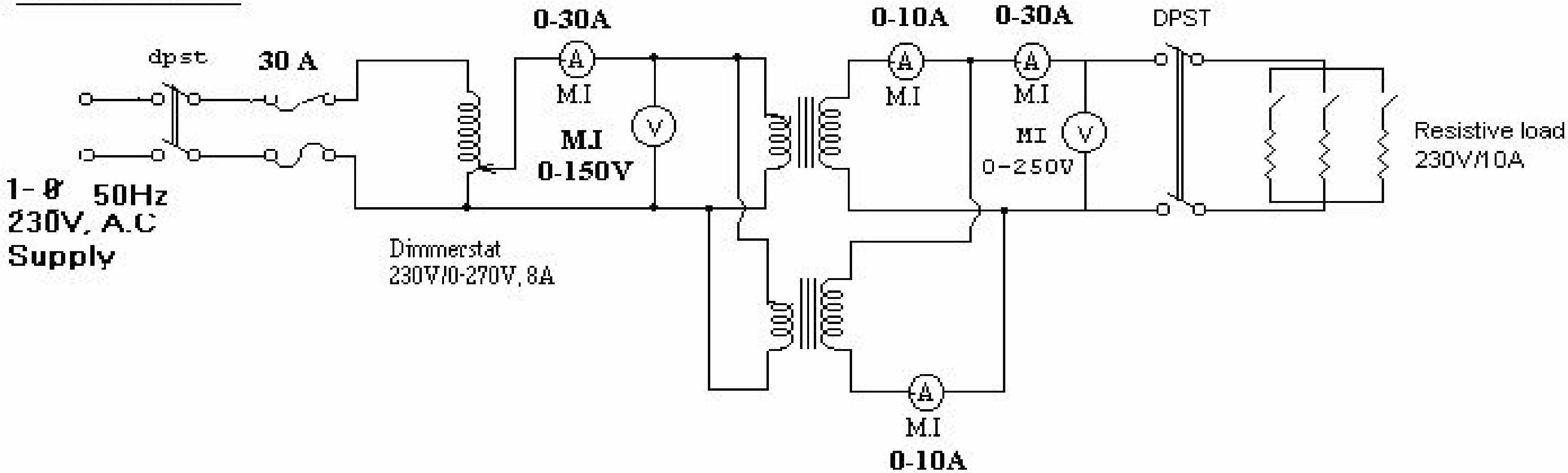
1. The connections are made as shown in the circuit diagram.

2. Consider that the dimmer stat at zero out put position, the load switch is off position the supply switch (DPST) is closed.
3. The dimmer stat out put is gradually adjusted such the voltmeter reads rated voltage of the primary winding.
4. The load on the transformer is applied by in steps load switch all the meter readings are noted in the tabular column.
5. Increase the load in steps and for each step the meter readings are noted in the tabular form.
6. The step no 5 is repeated until the transformers reaches the rated current.
7. Remove the load in steps and switch off the load switch and bring back to zero out put position.
8. The supply switch is opened.

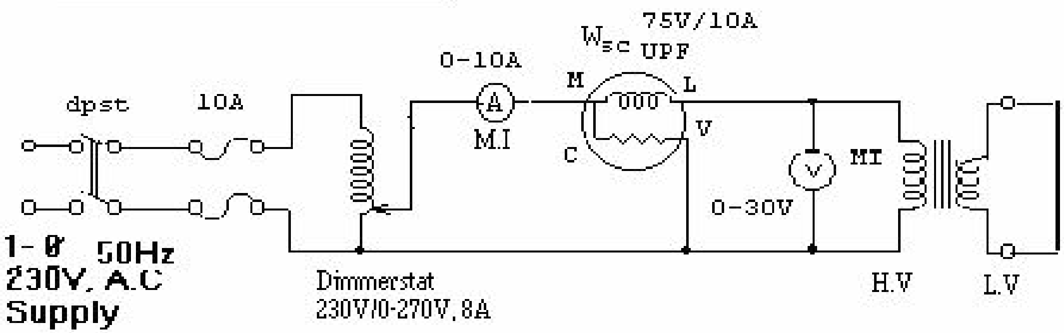
Impedance test (Transformer A & B):

1. The connections are made as shown in circuit diagram.
2. With the dimmer stat at zero out put position, the supply switch is closed.
3. The dimmer stat out put is gradually varied so that the transformer draws rated current all the other meter readings are noted in the tabular form.
4 The dimmerstat is brought back to zero out put position and the supply switch is opened

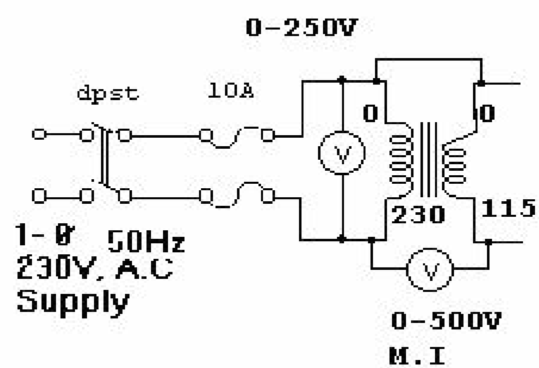
**LOAD TEST:**




**SHORT CIRCUIT TEST:**




**POLARITY TEST:**



Tabular Column:-

**Impedance Test :**

| Sl No | $V_{sc}$ in Volts | $I_{sc}$ in Amps | $W_{sc}$ in watts | $\cos\phi_{sc}$ | $Z_{sc}$ in Ω | $R_{sc}$ in Ω | $X_{sc}$ in Ω |
|---|---|---|---|---|---|---|---|
| Transformer A | | | | | | | |
| Transformer B | | | | | | | |

**Load Test:**

| Sl No | $I_1$ in Amps | $I_2$ in Amps | $I_T$ in Amps |
|---|---|---|---|
| | | | |

Specimen Calculations:-

The current shared by each transformer can be calculated as

$$I_A = I_T \frac{\overline{Z}_B}{\overline{Z}_A + \overline{Z}_B}$$

$$I_B = I_T \frac{\overline{Z}_A}{\overline{Z}_A + \overline{Z}_B}$$

Where ZA & $Z_B$ are the impedances of Transformer A & B

**Result:-**

**Viva – Voce Questions**

1. Why is parallel operation of transformers necessary?
2. What are the conditions to be satisfied for parallel operation of transformers?
3. If the two secondaries of the transformers in parallel are not connected with proper polarity and a voltmeter is connected in series with the winding then the reading will be?
4. Why is the rating of the transformer expressed in KVA?
5. If a 100KVA transformer has $Z_{eq}$=2Ω, then the other transformer of 500KVA in parallel must have $Z_{eq}$ of?
6. Can two transformers of different sizes be operated in parallel?
7. At no-load if $E_a$ and $E_b$ are the secondary voltages of transformers A nd B and their equivalent impedances are $Z_a$ and $Z_b$ then circulating current is ?
8. When is the circulating current produced in the parallel operation of two transformers?
9. What is the effect of circulating currents when two transformers are connected in parallel?
10. What is the permissible value of the circulating current?
11. How do we eliminate circulating currents?
12. What is the KVA carried by each transformer in case of equal voltage ratios?
13. Among transformers and rotating machines, which one has higher efficiency?