Department of Electrical and Electronics Engineering

DC Machines and

Transformers

Laboratory Manual

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Department of Electrical and Electronics Engineering

CERTIFICATE

This is to certify that this book is a bonafide record pratical work done in the DCMT Laboratoryin ....semester of………year duringthe year……......

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S.No	Date	Name of the Experiment	Page No	Sign

Contents

1. Speed Control of a D.C Shunt Motor

Aim:

To obtain the speed characteristics of a D.C shunt motor as a function of armature voltage, field current, and external resistance in the armature circuit.

Name Plate Details:

Power	= 5.0 hp	Speed	=1500 rpm
Armature voltage	= 220 volts	Field voltage	=220 volts
Armature current	= 19.0 amps	Field current	=1.0 amps
Field Winding	= shunt		

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	1 No.
DC Ammeter	0-20A	1 No.
DC Ammeter	0-2A	1 No.
Variable rheostat	0-150Ω	1 No.
Variable rheostat	0-200Ω	1 No.
Speed Indicator	0-2000rpm	1 No.

Theory:

Any D.C. motor can be made to have smooth and effective control of speed over a wide range. The shunt motor runs at a speed defined by the expressions.

$$\text{Eb} = \frac{\Phi ZNP}{60A} \quad \text{and} \quad \text{Eb} = \text{V} - \text{IaRa}$$

$$\text{i.e., N} = \frac{V - I_a R_a}{K\Phi} \quad \text{where} \quad K = \frac{ZP}{60A}$$

Since IaRa drop is negligible N α V and $N \alpha \frac{1}{\Phi}$ or $N \alpha \frac{1}{I_f}$

Where N is the speed, V is applied voltage, Ia is the armature current, and Ra is the armature resistance and Φ is the field flux.

Speed control methods of shunt motor:
1. Applied voltage control.
2. Armature rheostat control.
3. Field flux control.

Applied voltage control:

In the past, Ward-Leonard method is used for Voltage control method. At present, variable voltage is achieved by SCR controlled AC to DC converter unit is used to control the speed of a motor. In this method, speed control is possible from rated speed to low speeds.

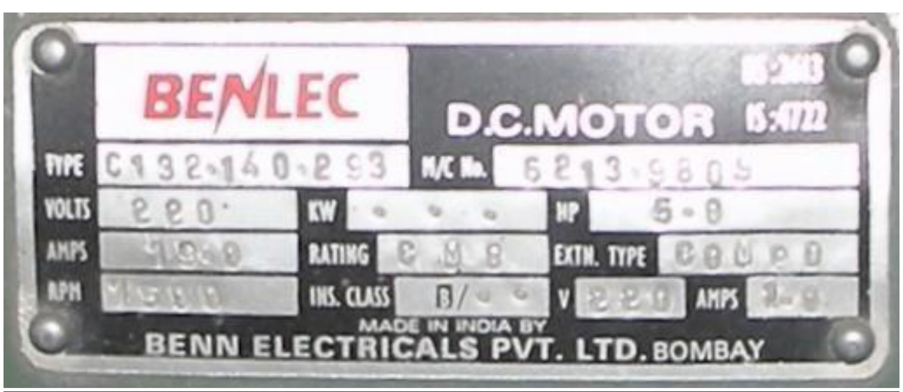
Armature rheostat control:
Speed control is achieved by adding an external resistance in the armature circuit. This method is used where a fixed voltage is available. In this method, a high current rating rheostat is required.

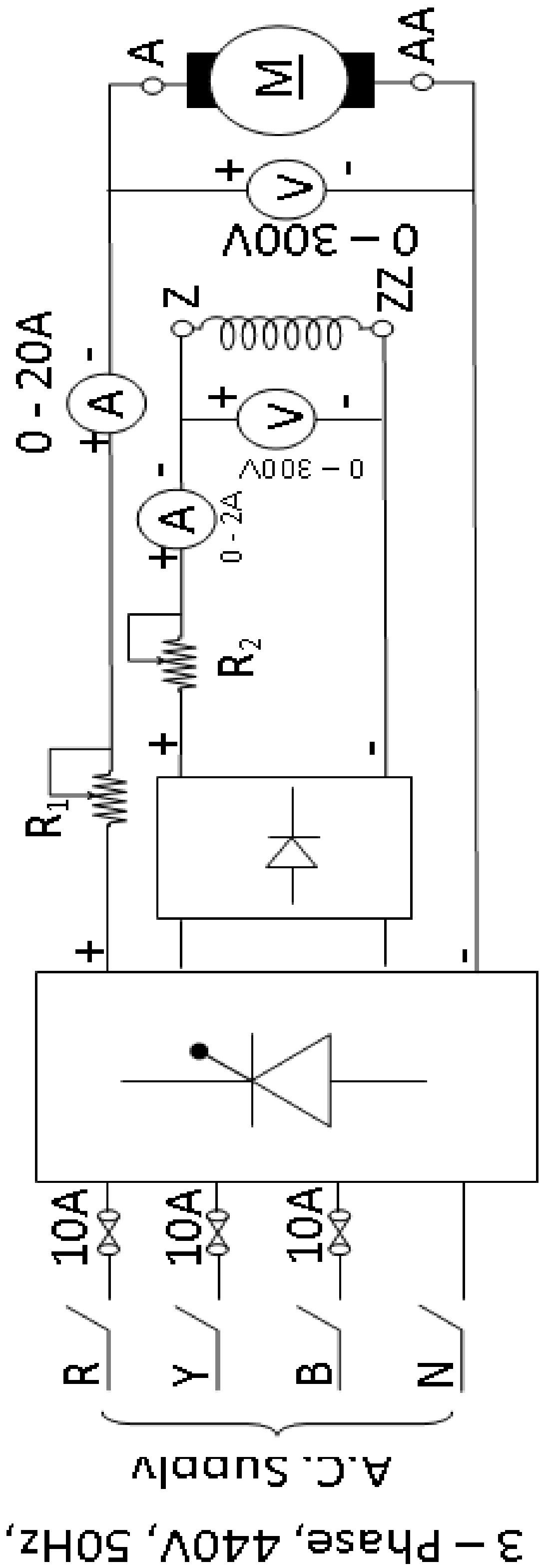
Disadvantages:
(a) Large amount of power is lost as heat in the rheostat. Hence, the efficiency is low.
(b) Speed above the rated speed is not possible. The motor can be run from its rated speed to low speeds.

Field flux control:
Speed control by adjusting the air gap flux is achieved by means of adjusting the field current i.e., by adding an external resistance in the field circuit. The disadvantage of this method is that at low field flux, the armature current will be high for the same load. This method is used to run the motor above its rated speed only.

Panel board:

Name Plate Details:





Circuit Diagram

Procedure:

1. Voltage Control Method:
   - Make the connections as per the given circuit diagram.
   - Keep the External resistances in the Armature and Fields circuits at minimum resistance (zero) position.
   - Switch on the supply and increase the voltage gradually to its rated voltage i.e. 220V.
   - Gradually decrease the voltage and note down the speed at different supply voltages.

2. External Resistance Control in the Armature Circuit:
   - Make the connections as shown in the circuit diagram.
   - Keep the External Resistances in the Armature and field circuit at minimum resistance position.
   - Gradually, increase the voltage till the motor attains the rated voltage.
   - Increase the External resistance in the Armature circuit and record the speed at various armature currents.

3. External Resistance Control in the Field Circuit:
   - Make the connections as shown in the circuit diagram.
   - Keep the External Resistances in the Armature and field circuit at minimum resistance position.
   - Gradually, increase the voltage till the motor attains the rated voltage.
   - Increase the External resistance in the Field circuit and record the speed at various field currents.
   - Do not exceed the speed above 1800rpm.

Observations:

Voltage Control Method:

Field current = A

S.No	Applied Voltage	Armature Current	Speed
1			
2			
3			
4			
5			

Resistance control in the armature circuit:

Applied voltage = V.

Field current = A.

S. No.	Supply Voltage	Armature Voltage	Armature Current	Speed(Rpm)	External Resistance(Ohms)
1					
2					
3					
4					

Flux Control Method:

R_{ext} = Ω,

V_a = V.

S. No.	Field current I_f (amp)	Armature current I_f (amp)	Speed (rpm)
1			
2			
3			
4			
5			

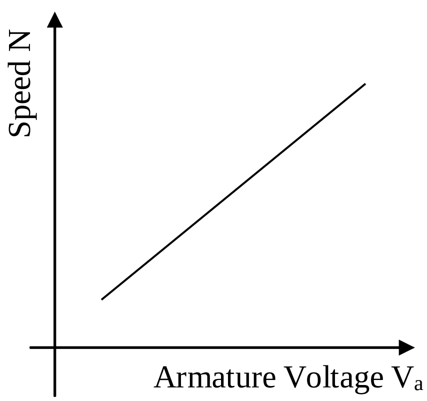
Conclusions:

- Armature Rheostat control method and voltage control methods are useful to obtain the speed less than the rated speed.
- Among the above two methods voltage control method is preferable than Armature Rheostat control since large amount of power is wasted in the external resistance.
- Field control or Flux control method is used to obtain the speed more than the rated speed.

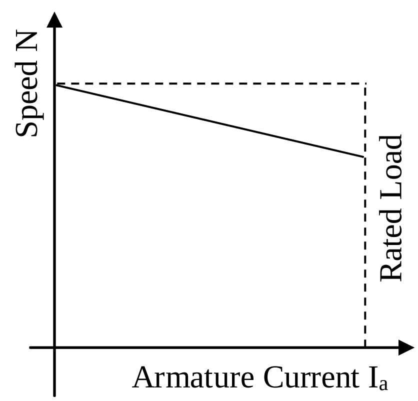
Graphs:

1. For voltage control method, graph between applied voltage ~ speed.
2. For resistance control in the armature circuit method, draw a graph between Armatures ~ Speed.
3. For flux control method, draw a graph between Field current ~ Speed.

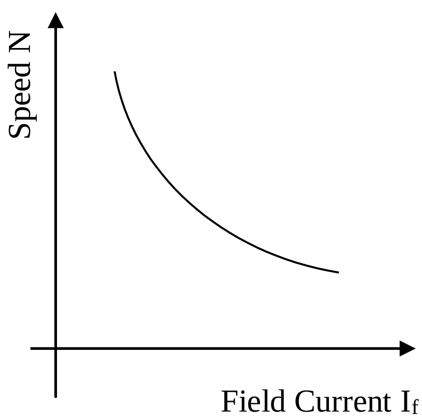
Model Graphs:



Armature Voltage Control method



Armature Rheostatic Control method



Flux Control method

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RESULT:-

2. Brake Test on a DC Shunt Motor

Aim:

To obtain the performance characteristics of a DC shunt motor by load test.

1. Speed ~ Armature current
2. Torque ~ Armature current
3. Induced emf ~ Armature current
4. Torque ~ Speed
5. Output ~ efficiency

Name Plate Details:

Power	= 5.0 hp	Field voltage	= 220 volts
Armature voltage	= 220 volts	Field current	= 1.0 amps
Armature current	= 19.0 amps	Field Winding	= shunt
Speed	= 1500 rpm		

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	1 No.
DC Ammeter	0-20A	1 No.
DC Ammeter	0-2A	1 No.
Variable rheostat	0-200Ω	1 No.
Speed Indicator	0-2000rpm	1 No.
Spring Balance	0-10Kg	2 No.

Theory:

This is a direct method of testing a dc machine. It is a simple method of measuring motor output, speed and efficiency etc., at different load conditions. A rope is wound round the pulley and its two ends are attached to two spring balances S_1 and S_2.The tensions provided by the spring balances S_1 and S_2 are T_1 and T_2. The tension of the rope can be adjusted with the help of swivels.

The force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances in Kg - force.

The induced voltage $E_b = V - I_a R_a$ and $E_b = K\Phi N$, Thus, $K\Phi = \frac{E_b}{N}$

Where V = applied voltage,

I_a = armature current,

R_a = armature resistance.

Total power input to the motor P_{in} = field circuit power + Armature power

$= V_f I_f + V_a I_a$

If „r‟ is the radius of the pulley, then torque at the pulley is given by

$$T_{shaft} = 9.81(T_1 \sim T_2)\ r = 1.5(T_1 \sim T_2)\ \text{N-m}$$

Motor output power $P_{out} = T_{shaft} * \omega = \frac{1.5(T_1 \sim T_2)2\pi N}{60}$.

$$\%\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100$$

A dc shunt motor rotates due to the torque developed in the armature when the armature and field terminals are connected to the dc supply. The direction of rotation can be explained with help of Fleming‟s left hand principle.

A counter emf or back emf (E_b) is induced in the armature conductors while the armature (rotor) rotating in the magnetic field. The direction of the induced emf can be explained with the help of Fleming‟s right hand principle and Lenz‟s law. The direction this induced emf is such that it opposes the applied voltage (V). This induced emf is also called as back emf E_b.

The equation of the motor is $V = E_b + I_a R_a$

Where $E_b = \left(\frac{\Phi Z N}{60}\right)\left(\frac{P}{A}\right)$

$I_a = \frac{(V - E_b)}{R_a}$.

The value of „E_b‟ is zero while starting the motor. Hence, the voltage across the armature has to be increased gradually.

The power developed in the rotor (armature) $= E_b I_a = T\omega$

Where $\omega = \frac{2\pi N}{60}$ is the angular velocity of the pulley, in rad/sec.

In a dc motor $T \alpha \Phi I_a$,

Where Φ= Flux produced by the shunt field per pole

I_a= Armature current

The torque developed in the motor is opposed by the torques due to

(a) Friction and windage

(b) Eddy currents and hysteresis and

(c) Mechanical load connected at the shaft.

The motor runs at a stable speed when the developed torque and resisting torques balance each other.

Let a small load be increased, and then the resisting torque increases and motor speed falls. The back emf reduces due to the fall in the speed. Hence, the armature current increases. ($I_a = \frac{(V - E_b)}{R_a}$).If Φ is assumed constant, (i.e., neglecting the armature reaction) the torque developed by the motor increases and a new stable speed is reached at which the developed torque equals the resisting torque.

Armature current ~ Speed characteristics:

The armature current I_a increases with increase in the load at the shaft. Hence I_aR_a drop increases and counter emf (E_b) decreases.

$$E_b = V - I_aR_a,$$

Where R_a is armature resistance and $E_b \alpha \Phi N$.

If Φ is constant in the shunt motor, by neglecting the armature reaction; the speed falls as E_b falls.

In a dc motor R_a is very small, hence I_aR_a is a small value and fall in E_b with increase in load is small. Thus, the speed falls slightly as I_a increases.

Armature current ~ Torque characteristics:

If Φ is constant, developed torque increases with increase in I_a.

$T = K\Phi I_a$

In actual condition, Φ slightly falls with increase in I_a due to the effect of armature reaction.

Armature current ~ induced emf (back emf):

Induced emf (back emf E_b) falls slightly with increase in I_a as per the equation

$E_b = V - I_aR_a$

Torque ~ Speed:

With increase in load, I_a and T_a increase since the shunt field Φ is constant. The fall in speed is very small as the I_aR_a drop is very small compared to V.

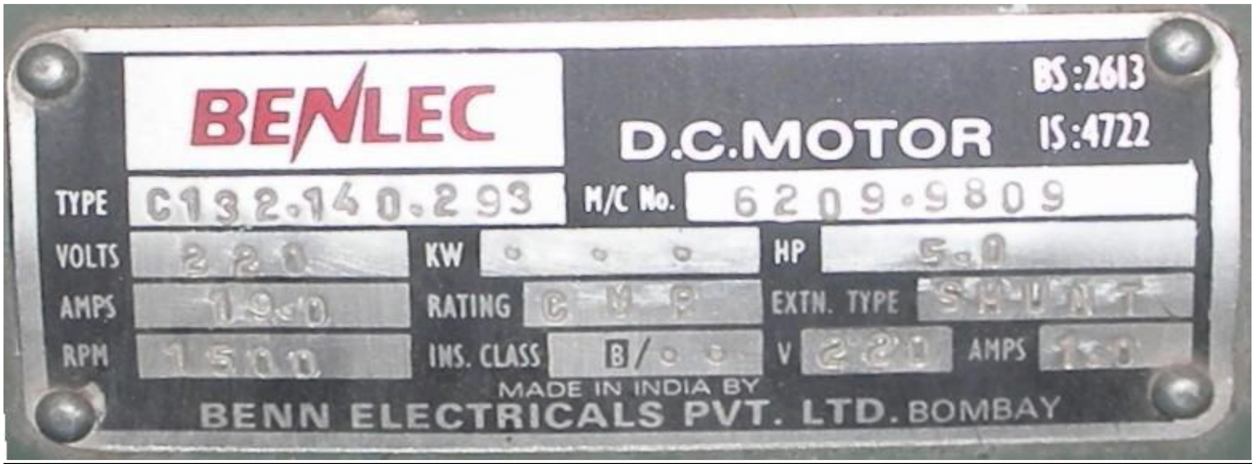
In a dc shunt motor $N \alpha \frac{E_b}{\Phi}$

Output ~ Efficiency:

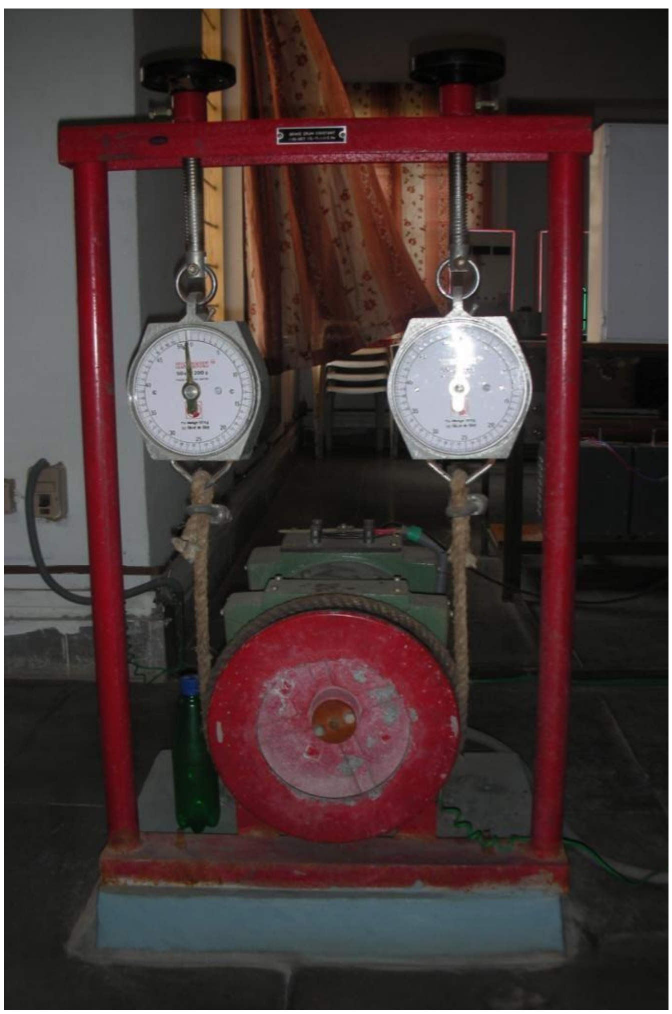
The graph between Output ~ Efficiency indicates that max torque occurs when armature copper losses is equal to the constant losses. (Sum of field copper losses, mechanical losses and Iron losses).

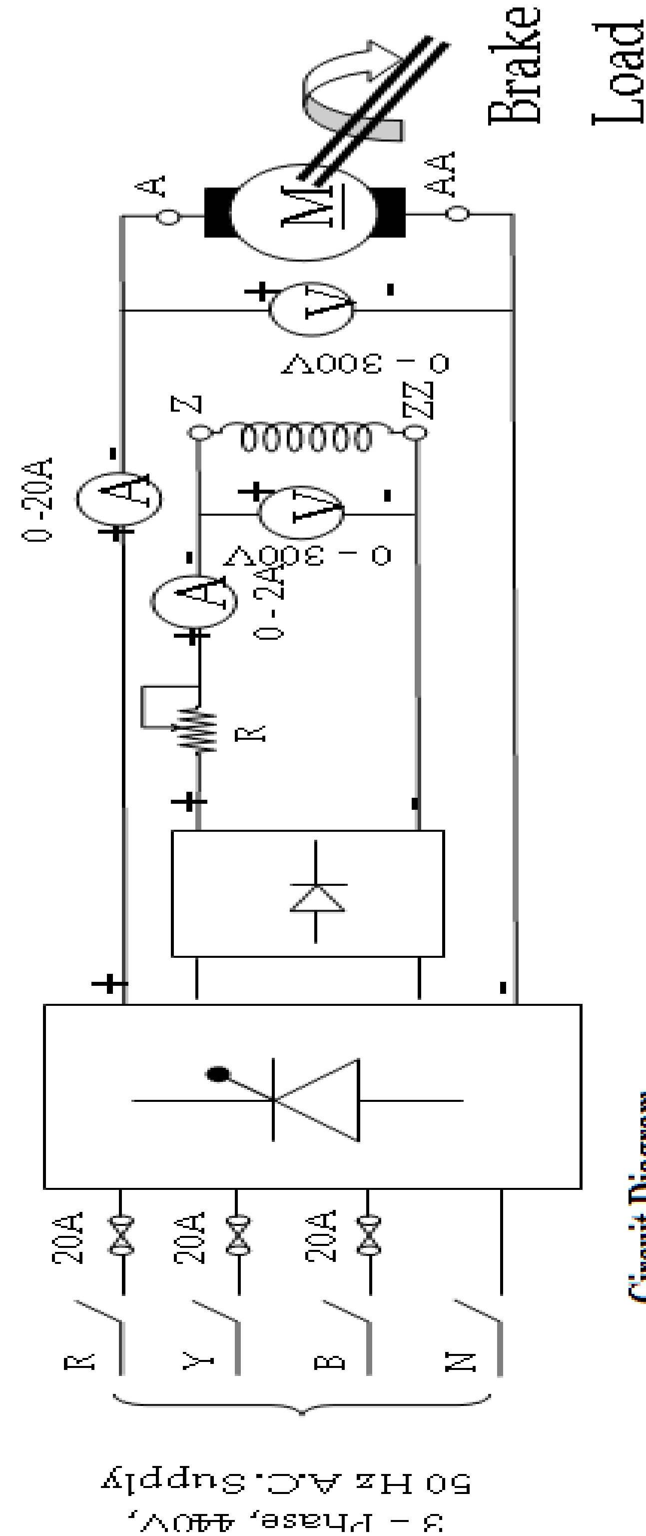
Panel Board:

Name Plate Details:



Brake drum arrangement:





Circuit Diagram

Procedure:

1. Note down the name plate details.
2. Keep the dc drive potentiometers and field control rheostat at minimum resistance position.
3. Loosen the rope on the brake drum and put some water inside the rim of the brake drum.
4. Connect the circuit as shown in the circuit diagram.
5. Switch on the motor and adjust the potentiometers till the armature attains the rated voltage and increase the field rheostat till the motor attains the rated speed.
6. Record the readings of the instruments at no-load condition.
7. Gradually, increase the load on the brake drum and record the readings as per the given table.
8. Do not exceed the armature current more than its rated value.
9. Gradually, reduce the load and switch off the supply.
10. Maintain Constant armature voltage and constant field current during the total experiment.

Observations:

Armature voltage = Volts
Field voltage = Volts
Field current = Amps
No load speed = rpm

S. No.	I_a Amp	N Rpm	T_1 Kg	T_2 Kg	Input (P_{in}) Watts	Shaft Torque (j/rad)	W(rad/sec)	Shaft Output (watts)	%ή	E(volts)	K Vs/r
1											
2											
3											
4											
5											
6											

Sample Calculations:

Armature voltage = 220 volts
Field voltage = 200 volts
No load speed = 1500 rpm
$T_1 \sim T_2$ = 4 kgs.

Armature Current I_a = 4.9 amps
Field current = 0.73 amps
Actual Speed N = 1498 rpm
Armature Resistance Ra = 2.3 ohms

Power input $= V_a I_a + V_f I_f$
$= 220\times4.9 + 200\times.73 = 1224$ watts

Shaft torque $T_{sh} = 1.5\times(T_1 \sim T_2) = 1.5\times4 = 6.0$ N-m

Output $P_{out} = T_{sh} \times \frac{2\pi N}{60} = \frac{6.0\times2\times3.14\times1498}{60} = 940.74W$

% Efficiency $\eta_m = \frac{940.74}{1224}\times100 = 76.85\%$

$E_b = V - I_a R_a = 220 - 4.9 \times 2.3 = 208.7$ volts

$K = \frac{E_b}{\omega} = \frac{208.7}{156.77} = 1.33$ V-s/rad.

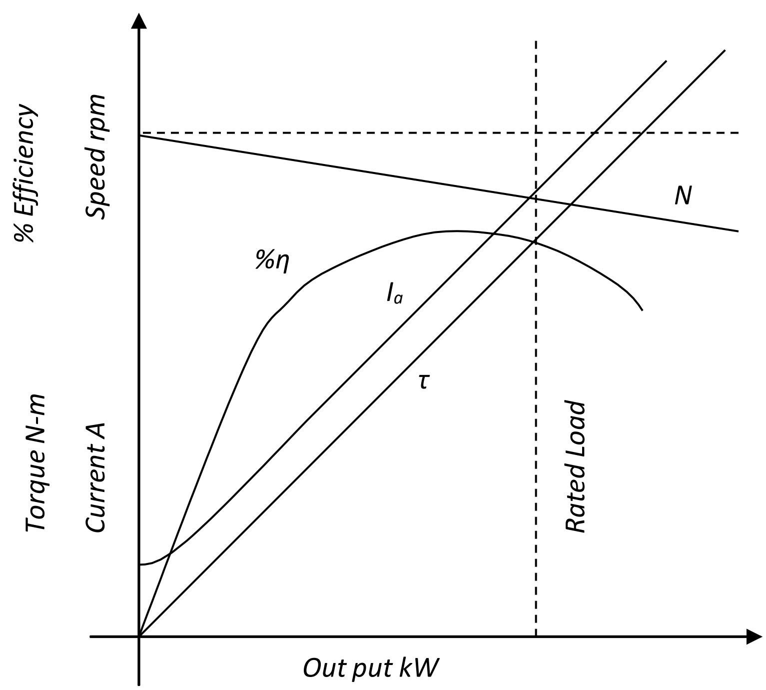
Conclusions:

- The shunt motor speed regulation is small from no load to full load.
- Maximum efficiency occurs at less than its full-load condition.
- Maximum efficiency is between 70 to 85%.
- Speed ~ Torque characteristic is not linear but has some drooping due to demagnetization.

Graphs:

(a) Speed ~ Output (b) Torque ~ Output (c) Induced emf ~ Output (d) Flux per pole ~ Output (f) Efficiency ~ outpute(f) Speed ~ Torque

Model Graphs:



Calculations:-

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RESULT:-

3. Brake Test on a DC Compound Motor

Objective: To obtain the performance characteristics of a DC compound motor.

Name Plate details:

Power = 5.0 hp	Speed = 1500rpm.
Armature voltage = 220 volts	Field voltage = 220 v
Armature current = 19.0 amp	Field current = 1 amp

Apparatus:

Name	Range	Quantity
D.C Voltmeter	0-300V	1No
D.C Ammeter	0-20A	1No
D.C Ammeter	0-2A	1No
Speed Indicator	0-2000 rpm	1No
Spring Balance	0-10Kg	1No

Theory:

This is a direct method of testing a dc compound motor as a cumulative and as a Differential compound motor.

In this method, a rope is wound round the pulley and its two ends attached to two spring balances S1 and S2.The tensions on the rope T1 and T2 can be adjusted with the help of swivels. The force acting tangentially on the pulley is equal to the difference between the readings of the two spring balances.

Power developed in the motor at the shaft = Pout = T $\times\omega$ watts

where $\omega = \frac{2\pi N}{60}$ (N is speed in r.p.m)

T_{shaft} = F× r Newton-metre= $(T_1\text{-}T_2)$ Kg × 9.8× r = $(T_1\text{-}T_2)$ × 1.5

Motor output Pout = $T_{shaft} \times \omega = \frac{1.5(T_1 \sim T_2)2\pi N}{60}$

(R is radius of the pulley in meter and 1kg wt = 9.8 Newton)

Total power input to the motor Pin=Power input to the field

$$P_{in} = V_f I_f + V_a I_a$$

$$\% \text{ Efficiency} = \frac{P_{out}}{P_{in}} \times 100$$

$$E_b = K \Phi \omega \text{ where } \Phi = \Phi_{sh} + \Phi_{se}$$

$$\omega = \{1/K (\Phi_{sh} + \Phi_{se})\} \times [V - I_a (r_a + r_{se})]$$

The induced voltage in the armature $= E_b = V - I_a R_a - I_{se} R_{se}$

WhereV = Applied voltage,

I_a = Armature Current,
I_{se}=Series field current,
R_{se}= Series field resistance,
I_{se}= I_a (for a long shunt compound motor or a separately excited compound motor),
V_f= Voltage to shunt field,
I_f=Shunt field current.

In a separately excited cumulatively compound motor Φ_{sh} is constant. Hence, Φ_{se} increases with increase in the load or armature current. Thus, the speed drops at a faster rate in a cumulative compound motor than in a shunt motor.

$$T_a=K\Phi I_a.$$

Where $\Phi = \Phi_{sh} + \Phi_{se}$; Φ_{sh} is constant. Φ_{se} increases with increase in I_a. Hence T_a increases.

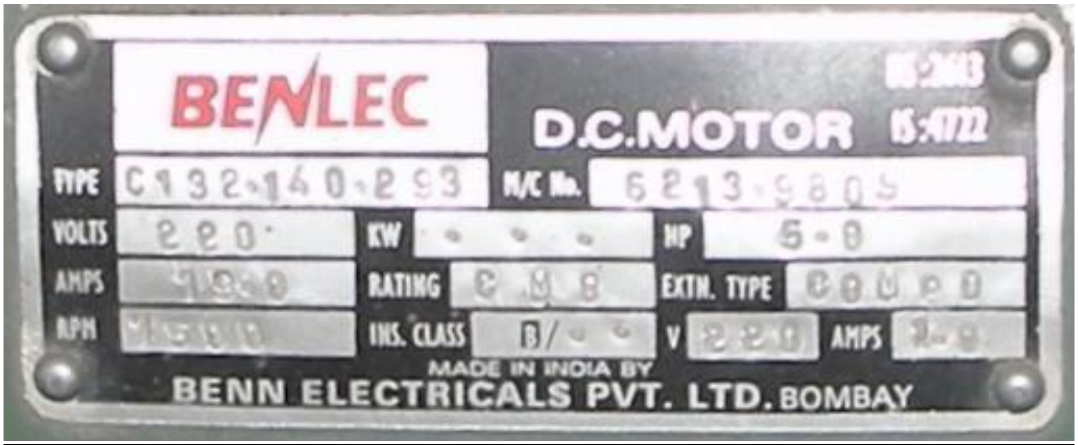
If Φ_{sh} is stronger than Φ_{se}, the $T_a \sim I_a$ characteristic and Speed~Torque characteristic approaches to the shunt motor characteristics. If Φ_{se} is stronger than Φ_{sh}, above characteristics approaches to the series motor characteristics.

In a Differential Compound motor, the series flux opposes the shunt flux. With increase in I_a, the net flux in the air gap deceases. Thus, the motor speed increases slightly with load.

Hence, it can be designed to give a constant speed under all load conditions.

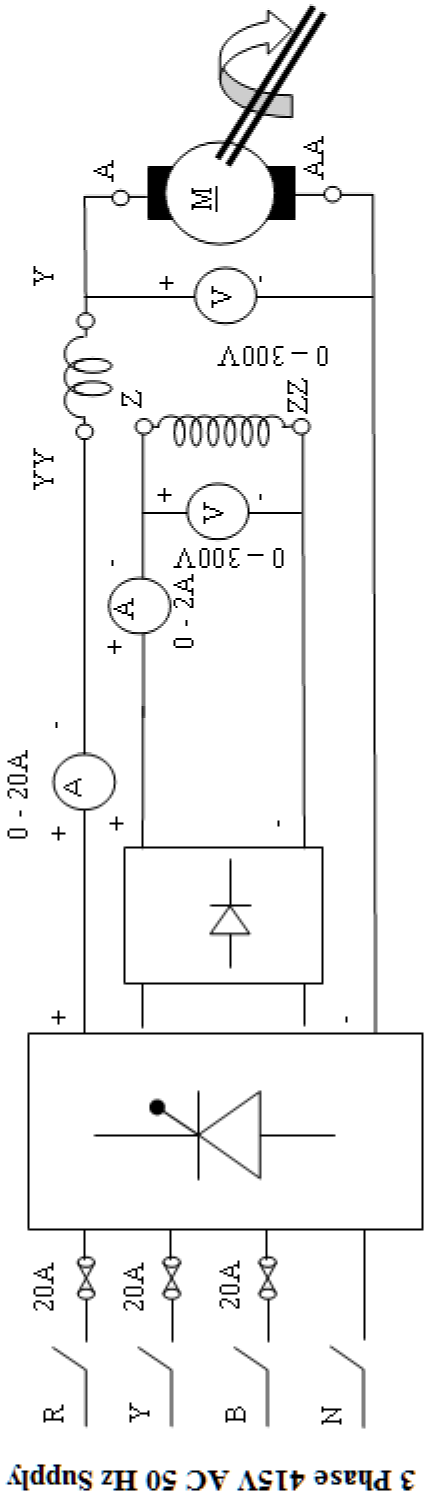
Panel board:

Name Plate Details:

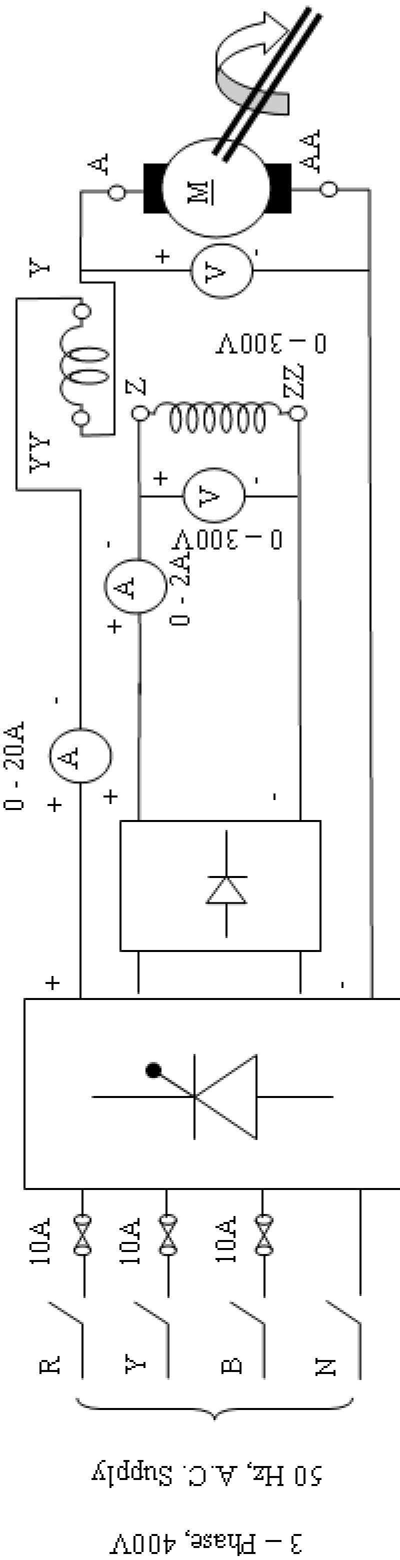


Brake drum arrangement:

Circuit Diagram:



Cumulative Compound DC Motor



Differential Compound DC Motor

Procedure:

1. Note down the name plate details.
2. Keep the DC drive potentiometers at minimum position.
3. Loosen the rope on the brake drum and put some water inside the rim of the brake drum.
4. Connect the circuit as shown in the circuit diagram for cumulative compound motor.
5. Switch ON the motor and adjust the potentiometers until the armature voltage attains the rated voltage.
7. Record the no-load readings as per the given table.
8. Gradually, increase the load on the brake drum and record the readings as per the given table.
9. Do not exceed the armature current more than its rated value.
10. Gradually, reduce the load and switch off the supply.
11. Connect the circuit as shown in the circuit diagram for Differential Compound motor.
12. Repeat the steps from 5 to 10.
13. Maintain constant armature voltage through out the experiment.

Observations:

Cumulative compounding:

Voltage across the armature circuit = V

Voltage across the shunt field circuit = V

Current through the shunt field circuit = A.

SL. No.	I_a (A)	N Rpm	T1 Kg	T2 Kg	Total Input (watts)	shaft Torque (j/r)	ω (r/s)	Shaft Output (watts)	%η	E (volts)	Kφ (vs/r)
1.											
2											
3											

Sample Calculations

Cumulative compounding:

Voltage across the armature circuit = 220 V

Voltage across the shunt field circuit = 221 V

Current through the shunt field circuit = 0.945 A.

Consider

Armature Current I_a = 3.5A

Speed N = 1539 rpm
T_1 = 0 kg; T_2 = 1.8 kg.
Total input =Filed circuit power input + Armature circuit Power input
=221*0.945 + 220 * 3.5 = 978.85 watts
Shaft torque =1.8 * 1.5 = 2.7 j/r
Shaft output =2.7 * 160.012 = 432 watts
Efficiency $= \frac{432}{978.85} = 44.1\ \%$
E =220-3.5 (1.6+0.3) =213.35 V
K_Φ $= \frac{E}{\omega} = 1.333$ v-s/r

Differential Compounding:
Voltage across the armature circuit = 220 V
Voltage across the shunt field circuit = 221 V
Current through the shunt field circuit = 0.9 A.

SL. No.	Ia (A)	N Rpm	T1 Kg	T2 Kg	Total Input (watts)	shaft Torque (j/r)	ω (r/s)	Shaft Output (watts)	%η	E (volts)	Kφ (vs/r)
1.											
2.											
3.											
4.											
5.											

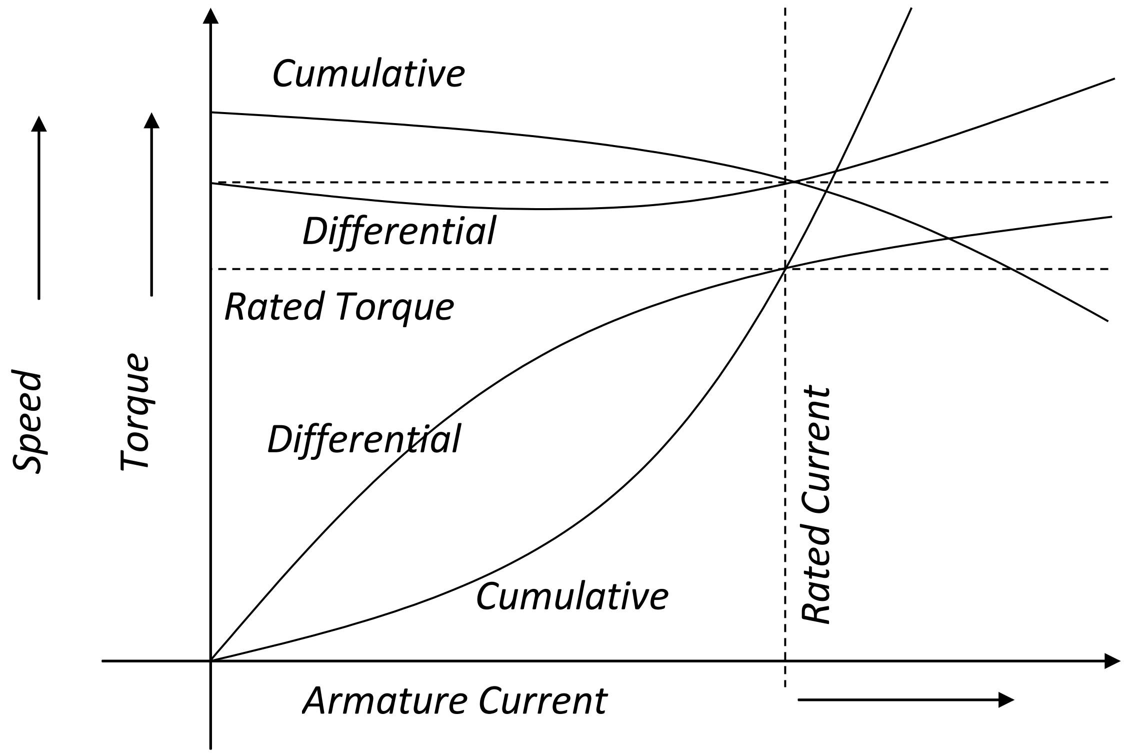
Conclusion:

- The characteristics of Cumulative Compound motor lies between those of the Shunt and Series motor. The Speed~ Torque characteristic is more drooping than a shunt motor.
- In a differential compound motor, flux decreases with increase in armature current and torque. Hence, the Speed ~ Torque characteristic is less drooping and raises at higher torques.

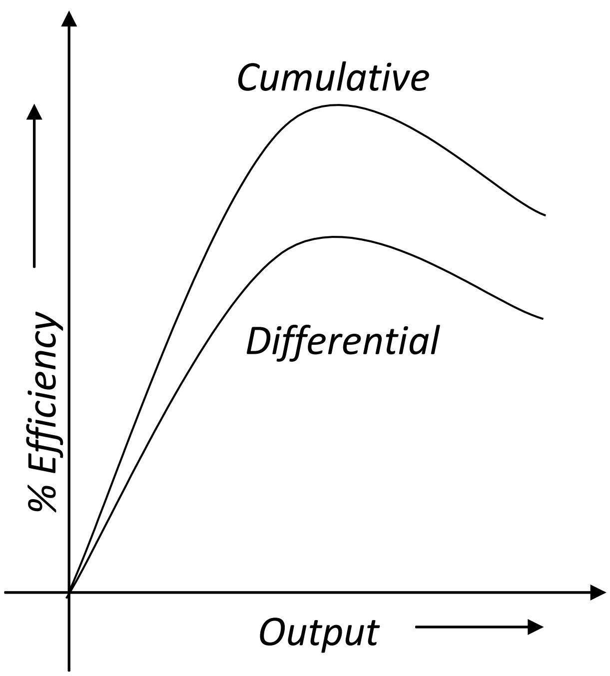
Graphs:

As a cumulative and differential compound motor.
a) Speed ~ Ia b) Torque ~ Ia d) Speed ~ Torque e) Efficiency ~ Output

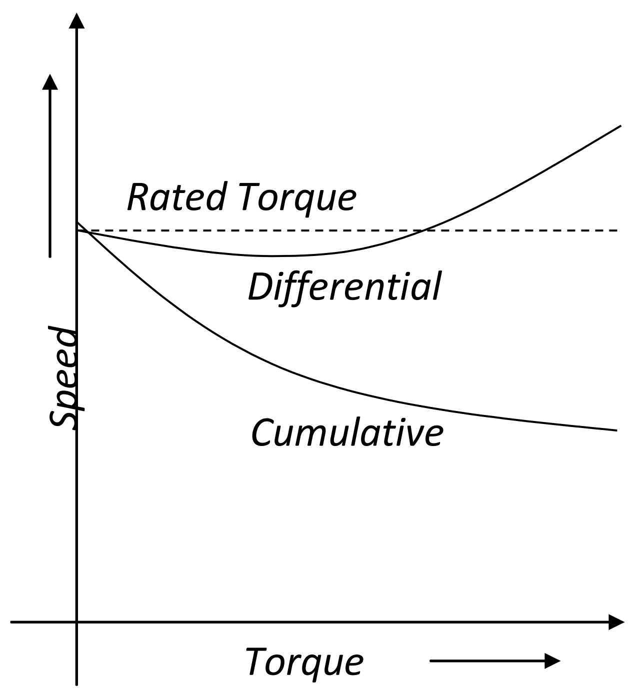
Model Graphs:



Speed, Torque Vs Armature Current Characteristics



% Efficiency Vs Output Characteristics



Speed Vs Torque Characteristics

Calculations:-

INSERT GRAPH SHEETS=3

RESULT:-

4. Open Circuit Characteristics of a D.C. Shunt Generator

Objective:

To find the critical resistance (R_c) and critical speed (N_c) and O.C.C. of a dc shunt generator.

Name Plate details:

Motor		**Generator**	
Power	= 3.0 Kw.	Power	= 3.0 Kw.
Armature	= 220 volts.	Speed	= 1500 rmp.
Armature	= 13.6 amps.	Armature voltage	= 220 Volts.
Field voltage	= 220 volts.	Armature current	= 13.6 amps.
Field current	= 1.0 amps.	Field voltage	= 220 volts.
Speed	= 1500 rmp.	Field current	= 1.0 amps.
Wound	= Shunt.	Wound	= Shunt.

Apparatus:

Name	**Range**	**Quantity**
DC Voltmeter	0-300 V	2 No.
DC Ammeter	0-20A	2 No.
DC Ammeter	0-2A	2 No.
Speed Indicator	0-2000 rpm	1 No.

Theory:

Magnetization Curve:

The graph between the field current and corresponding flux per pole is called the magnetization characteristic of the machine. This is same as B-H curve of the material used for the pole construction.

In a D.C. generator, for any given speed, the induced emf in the armature is directly proportional to the flux per pole.

$$E_g = \frac{\Phi ZNP}{60A} \text{ Volts}$$

Where Φ is the flux per pole in webers,

Z is the no. of conductors in the armature,

N is the speed of the shaft in rpm,
P is the no. of poles and
A is the no. of parallel paths.
A = 2 (wave)
A = p (lap)

As shown in the figure

OA: is the voltage induced due to residual magnetism.
AB: Linear region such that $E_g \alpha I_f$
BC: saturation region.

Open-circuit characteristics:

The armature is driven at a constant speed and the field current increases gradually from zero to its rated value. The terminal voltages (V_1) at no-load condition is measured at different I_f values.

The graph $V_L \sim I_f$ is called open-circuit characteristic. V_L differs from E_g due to (a) Armature reaction (b) Voltage drops in the armature circuit. I_a is very small at no-load condition, these effects are negligible. Hence $V_L = E_g$ at no-load condition. Thus, the open circuit characteristic is same as magnetization curve.

Critical Field Resistance (RC):

Critical Field Resistance is defined as the maximum field circuit resistance at which the shunt generator would just excite at any given speed. At this value the generator will just excites. If the field circuit resistance is increased beyond this value, the generator will fail to excite.

It is the initial slope value of the o.c.c. curve in the linear region (AB) passing through the origin.

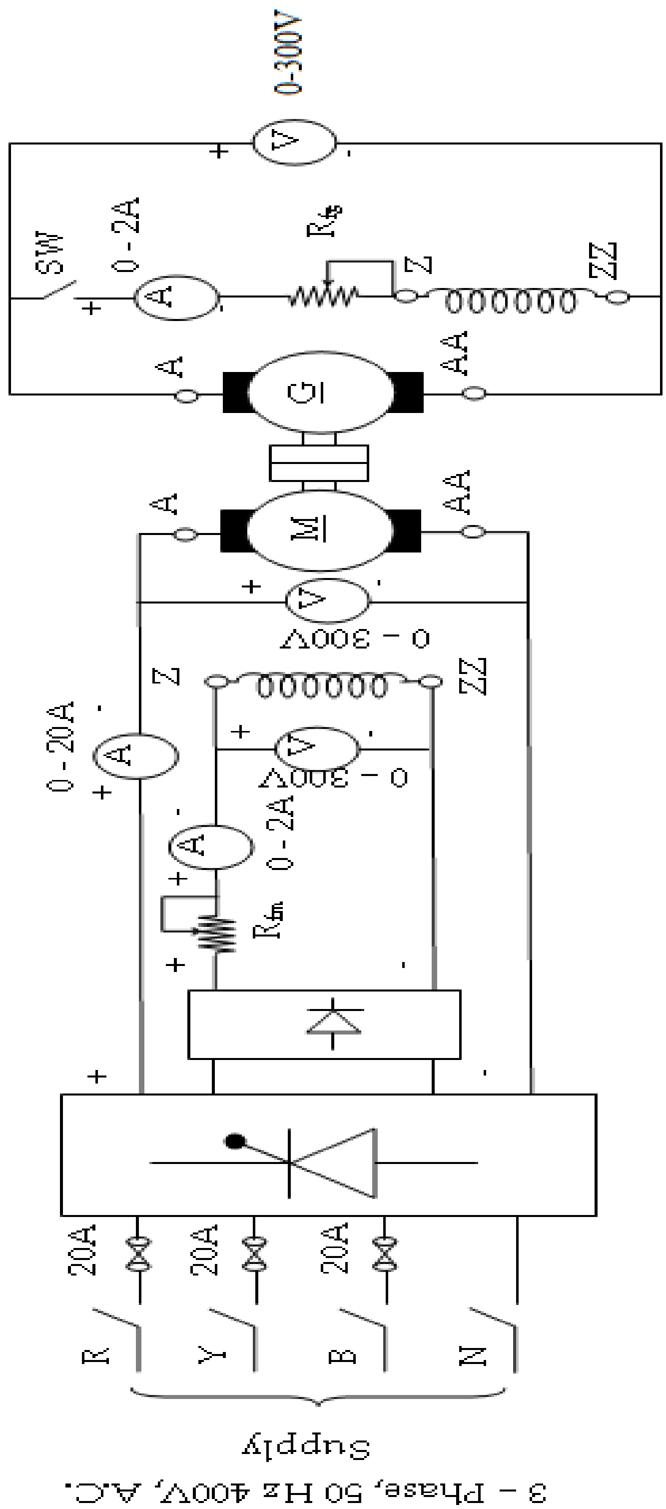
If the field circuit resistance (R_f) is increased to R_C, the machine fail to excite and no e.m.f is induced in the generator. For exciting the generator $R_f < R_c$.

Critical Speed:

For any given field circuit resistance, the speed above which the generator builds up an appreciable voltage is called critical speed.

Panel board:

D.C. Motor – Generator Set:



Circuit Diagram:

Procedure:

1. Note down the ratings of the d.c. shunt motor and the d.c. shunt generator.
2. Connect the circuit as shown in the circuit diagram.
3. Keep the generator field rheostat at maximum resistance position, motor field rheostat at minimum resistance position and open the switch „SW‟.
4. Now start the motor and bring the speed to rated speed of the generator by using motor field rheostat.
5. Note the residual voltage and close the switch „SW‟.
6. Now decrease the field rheostat in the generator field and record the values of I_f and E_g upto the rated voltage of the Generator.
7. Maintain the speed of the motor (Prime Move) at a constant value during the experiment.
8. Plot the magnetization curve and draw a tangent to obtain the critical field resistance.

Procedure for critical speed:

1. Close the switch „SW‟ and keep the generator field rheostat at minimum position.
2. Now increase the speed of the motor gradually, and note down the speed and generated voltage up to the rate voltage of the generator.
3. The speed at which the generator builds up an appreciable voltage is called critical speed.

Observation Table: for R_c andN_c Critical speed calculations critical Resistance

S .No.	I(field) Amp	E (gen)
1		
2		
3		
4		
5		
6		
7		

S.No.	Speed (RPM)	Induced Emf (volts)
1		
2		
3		
4		
5		
6		
7		

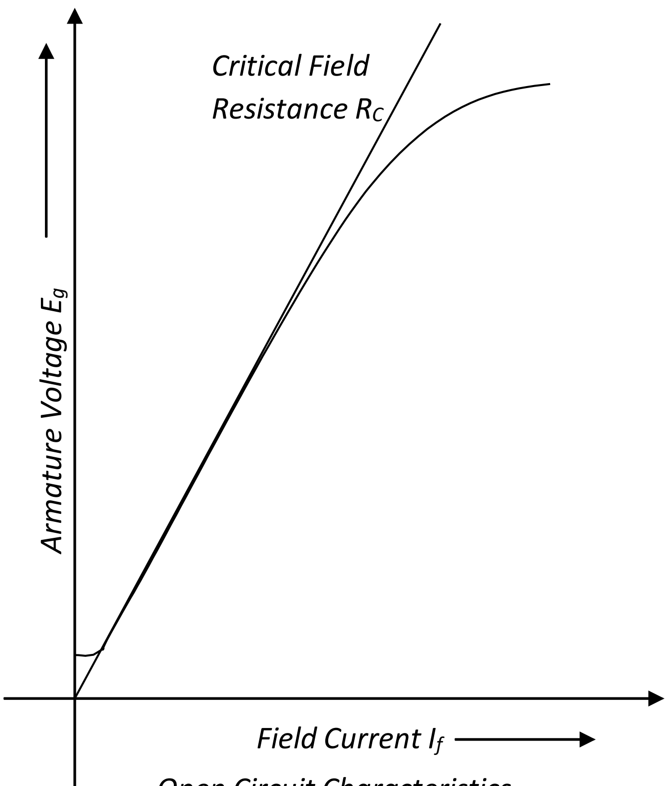
Conclusion:

- The generator emf becomes constant when the field core is saturated.
- The generator builds up the voltage only when the speed is more than critical speed and field circuit resistance is less then the critical field resistance.
- In a self excited generator residual magnetism must present.

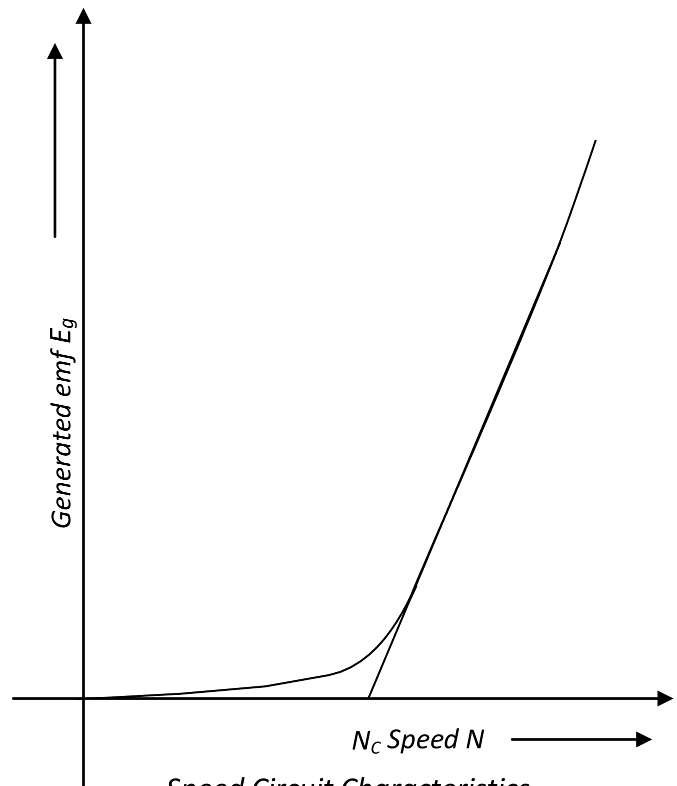
Graphs:

1. Generated Emf E_g Vs Field Current I_f
2. Generated Emf E_g Vs Speed N

Model Graphs:



Open Circuit Characteristics



Speed Circuit Characteristics

Calculations:-

INSERT GRAPH SHEETS=2

RESULT:-

5. Load Test on a D.C. Shunt Generator

Objective:

To conduct a load test on a dc shunt generator and obtain its internal and external characteristics.

Name Plate Details:

Motor		Generator	
Power	= 5.0kW	Power	= 3.0kW
Armature voltage	= 220V	Speed	= 1500rpm
Armature current	= 13.6A	Armature voltage	= 220V
Field voltage	= 220V	Armature current	= 13.6A
Field current	= 1.0A	Field voltage	= 220V
Speed	= 1500rpm	Field current	= 1.0A
Wound	= shunt	Wound	= Shunt

Apparatus:

Name	Range	Quantity
Dc Voltmeter	0-300V	2no.
Dc Ammeter	0-20A	2no
Dc Ammeter	0-2A	2no.
Speed Indicator	0-2000rpm	1no.

Theory:

Performance Characteristics:

a) External Characteristics: This is the relationship between the load voltage and load current for a particular speed of the generator. To understand the nature of this characteristic, the following relationships are useful.

a) $I_f = V_f/R_f$(ohms law)
b) $I = V_L/R_L$(ohms law)
c) $I_a = I_f + I$ (kcl)
d) $E_g = V_L + I_a R_a$ (kvl)

I_f and I_a each produces its own flux in the air gap of the machine and hence there will be a resultant flux in the air gap of the machine. E_g is the induced voltage in the armature due to this resultant flux.

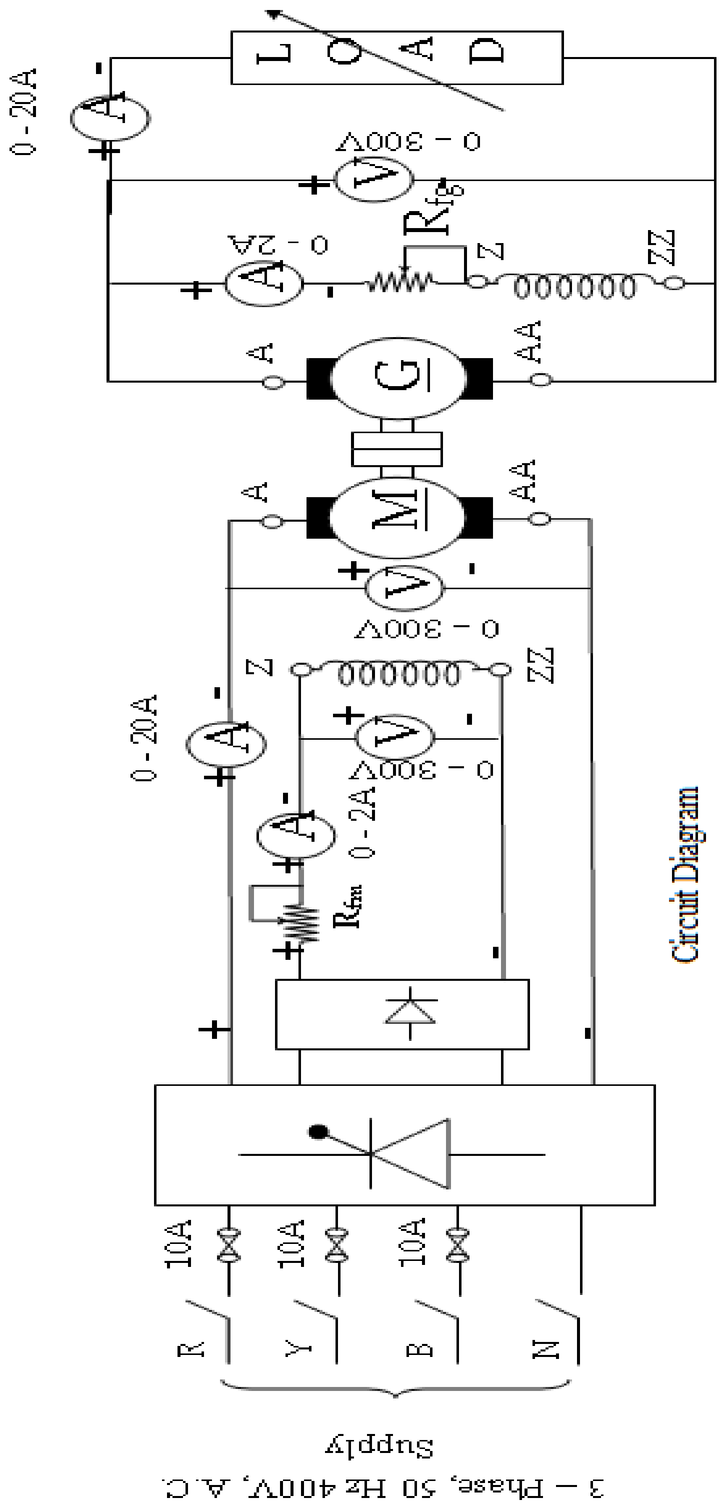
On no load, I_L is zero. The terminal voltage V_L has a value E_0 is given by the point of intersection of the open-circuit characteristics and the field circuit resistance line. As load increases, I_L becomes greater than zero, I_a increases, I_aR_a increases and V_L decreases as per the equation (d).But E_g itself decreases since, i) with an increased I_a, the armature reaction effect increases and the resultant flux reduces. ii) The reduced V_L in turn reduces I_f and the corresponding shunt flux, hence the drop in V_L is large. As load is further increased, I_L reaches a maximum value while V_L keeps falling. Any further increase in load (decrease in load resistance) causes I_L as well as V_L to fall. When V_L has reached a small value, the load is as if it is replaced by short-circuit, V_L=0 and field current is zero. A small I_L however flows through short-circuit which is due to the voltage induced in the armature by the residual flux. The external characteristic is shown in the fig.

b) Internal characteristics: This is the relationship between the net induced voltage in the armature and the armature current.

$$I_a = I_L + I_f; \quad E = V_L + I_a R_a$$

Panel board:

D.C. Motor Generator Set:



Circuit Diagram

Procedure:

1. Note down the ratings of the dc shunt motor and dc shunt generator.
2. Set the dc drive potentiometers at zero position.
3. Set the field rheostat of the generator at maximum resistance position and motor field rheostat in minimum resistance position.
4. Keep all the load switches in the OFF position.
5. Connect the circuit as per the given circuit diagram.
6. Push the START button and adjust the dc drive potentiometer until the motor armature attains the rated voltage.
7. Adjust the field rheostat of the generator until the armature voltage reaches to the rated speed.
8. Note down the voltage and current readings of the motor and generator at no-load.
9. Gradually increase the load on the generator by switching the lamp and heater loads.
10. Record the readings of the measuring instruments at different load conditions.
11. Maintain the motor (prime mover) speed at a constant value during the experiment.
12. Do not exceed the rated current of either the motor or generator.
13. Gradually decrease the load and switch OFF the supply.

Sample Observations and Calculations:

Armature resistance R_a = 3.9 ohms

S.No:	Load voltage V_L (volts)	Load current I (amps)	Field current I_F (amps)	Armature current I_A=I+I_F (amps)	$E_0=V_L+I_AR_A$ (volts)
1					
2					
3					
4					
5					
6					
7					
8					

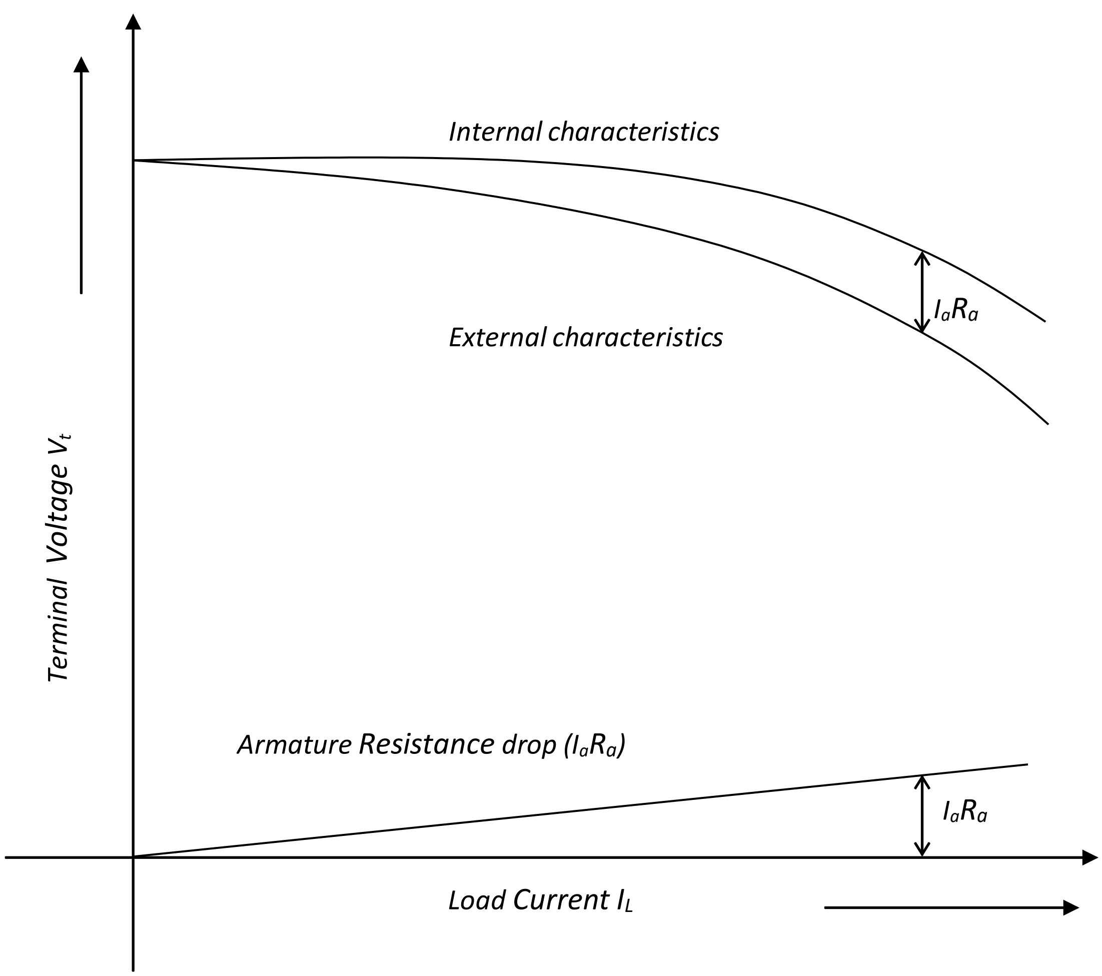
Conclusion:

The Generator terminal voltage drops marginally with the increase in the armature current/load current .If the armature current increased more then its rated value then the terminal voltage fall is very high due to armature reaction .Hence the I_a value also drops .This process continues till the terminal voltage drops to zero. This characteristic is called DROOPING characteristic.

Graphs:

1. Terminal Voltage (V_t) Vs Load Current (I_L)
2. Generated Emf (E_g) Vs Load Current (I_L)
3. Armature drop (I_aR_a) Vs Load Current (I_L)

Model Graph:



Internal and External Characteristics

INSERT GRAPH SHEETS=2

RESULT:-

6. Load Test on a D.C. Series Generator

Objective:

To conduct load test on a dc series generator and to obtain its internal and external characteristics.

Name Plate Details:

Motor		Generator	
Power	= 5.0 hp	Power	= 3.0 hp
Speed	= 1500 rpm	Speed	= 1500 rpm
Armature voltage	= 220 V	Armature voltage	= 220V
Armature current	= 19.0Amps	Armature current	=13.6 Amps
Field voltage	= 220V	Wound	= series
Field current	=1.0 Amps		
Wound	=shunt		

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	2no.
DC Ammeter	0-20A	2no.
DC Ammeter	0-2A	1no.
Speed Indicator	0-2000rpm	1no.

Theory:

In a series generator, the field winding and armature are connected in series. The load is also connected in series with the armature and series field. Thus, $I_L=I_a=I_{se}$

Performance Characteristics:

No-load characteristic (Magnetization Characteristic, E_g~I_f): This is the graph between the generated emf E_g and the field current I_f at no-load and constant speed. This curve is obtained by separately exciting the field from a separate voltage source.

Internal Characteristic (E~I_a): The graph between the E and I_a is called the Internal Characteristic. $E=V_L+I_a(R_a+R_{se})$

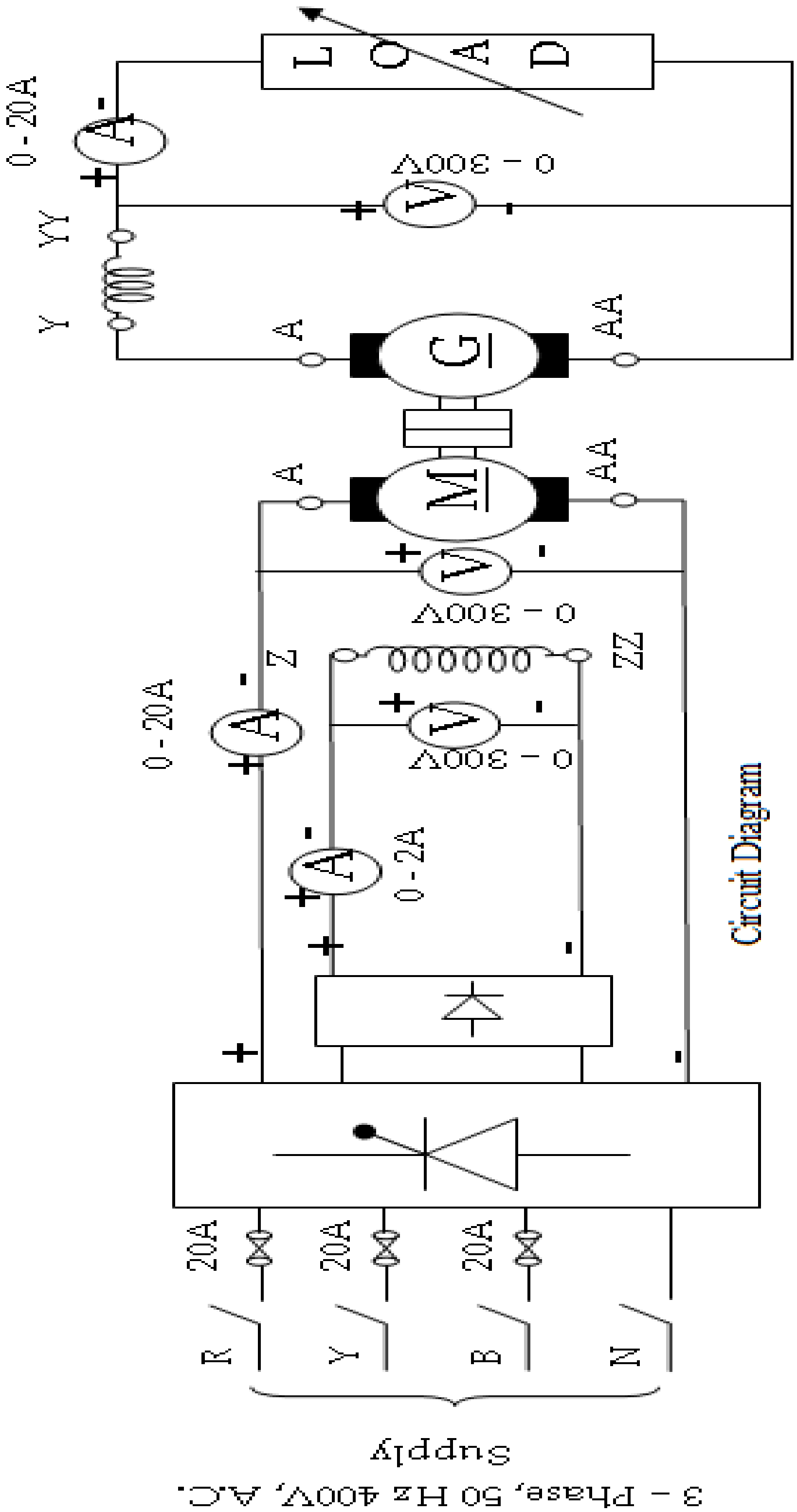
When operating as series generator, there are two fluxes in the machine air gap. One due to the field and another due to the armature. The induced emf in the armature is due to the net flux in the air gap. Thus, the relationship between the induced emf, the armature current is called the internal characteristic. (after considering the armature reaction)

External Characteristics (V_L~I_L): The graph between V_L and I_L is called External Characteristic. This is a raising characteristic. In a series generator, if the total resistance of the circuit (sum of armature, field and load resistance) is more than the critical field resistance, then the emf build up process shall not begin.

The net induced emf in the armature, supplies the voltage drop across the armature and fields resistances and also the load. So, the actual generated emf can be written as

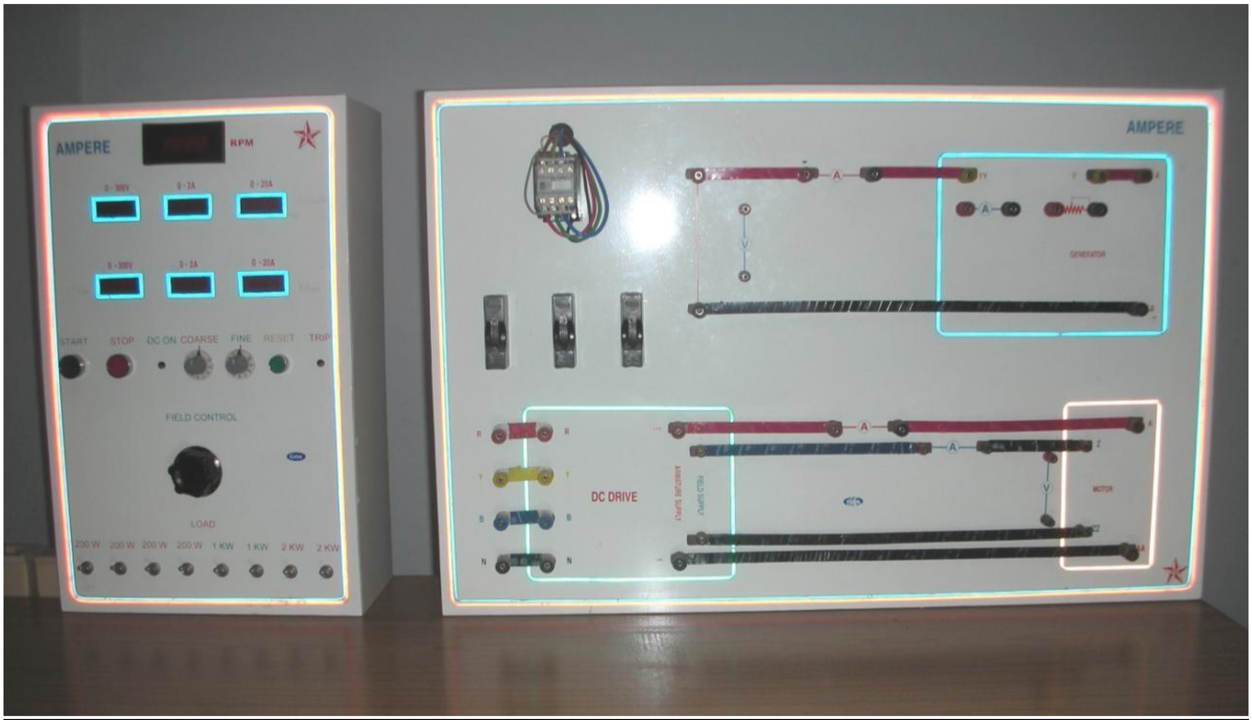
E_g=voltage drop across the armature and field+ voltage across the external load.

$$E_g=I_a(R_a+R_{se})+V_L$$

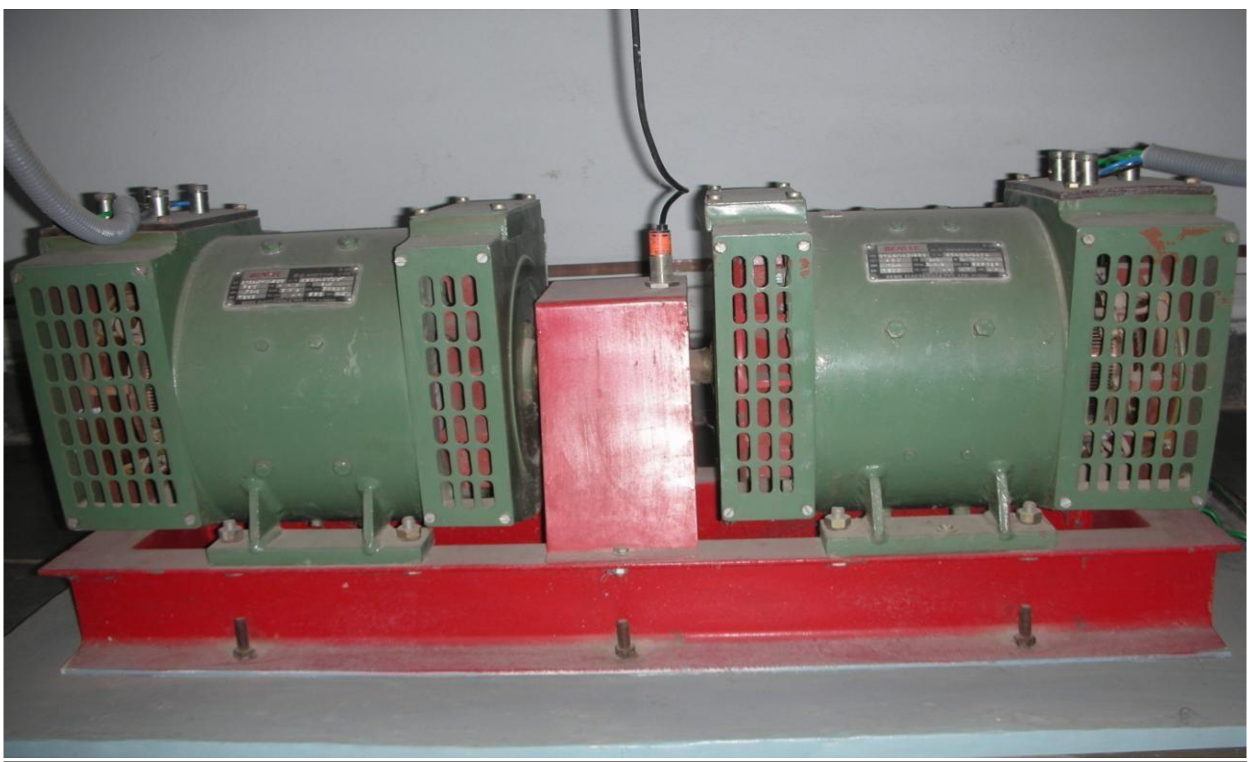


Circuit Diagram

Panel board:



Motor-Generator Set:



Procedure:

1. Note down the ratings of the dc shunt motor and dc generator.
2. Set the dc drive potentiometers at zero position.
3. Connect the circuit as shown in the circuit diagram.
4. Keep all the loads in OFF position.
5. Push the START button and adjust the dc drive potentiometer till the motor armature attains the rated voltage.
6. Record the readings of the instruments at no-load condition.
7. Gradually, add the loads and record the values as per the given table.
8. Do not exceed the armature current more than the rated value of the motor or generator.
9. Remove the loads gradually and Switch OFF the power supply.
10. Maintain the motor (Prime Mover) RPM at a constant value during the experiment.

Armature Resistance of the Generator = 2.2 ohms
Field Resistance of the Generator = 1.1 ohms
Rated Speed of the Generator = 1500 RPM

Observations:

Prime motor (DC motor) Speed=1500 rpm

Sl.No.	Drive motor				Series Generator	
	Armature Voltage	Armature Current	Field Voltage	Field Current	Load Voltage	Load Current
1						
2						
3						
4						
5						
6						
7						
8						

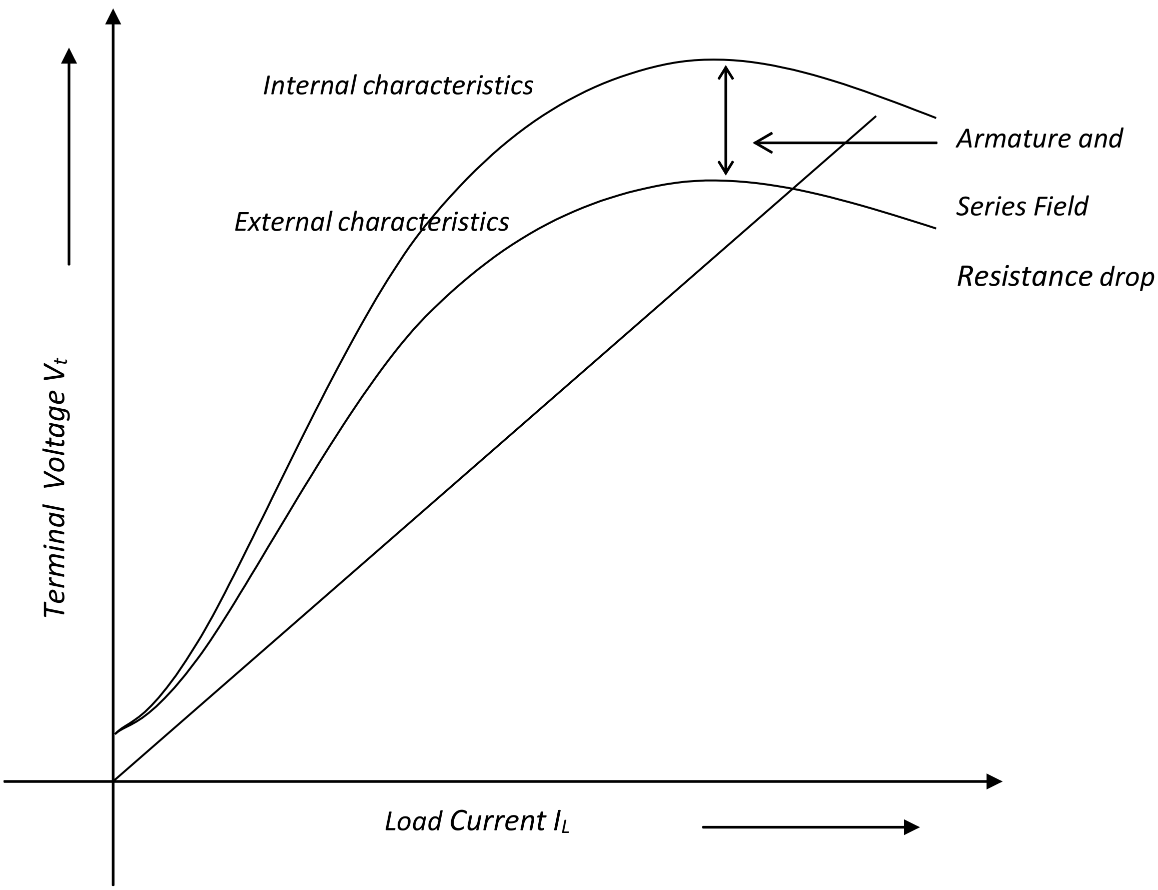
Conclusion:

In a Series Generator, the generated voltage increases with the load. Hence, its characteristics are called as "Raising Characteristics".

Graphs:

1. Armature Voltage (V_a) Vs Armature Current (I_a)
2. Terminal Voltage (V_t) Vs Load Current (I_L)

Model Graphs:



Internal and External Characteristics

INSERT GRAPH SHEETS=1

RESULT:-

7. Load Test on a D.C. Compound Generator

Objective:

To conduct a load test on a dc compound generator,(a) As Cumulatively Compounded, (b) As a differentially compounded and draw its internal and external characteristics.

Name Plate Details:

Motor		Generator	
Power	= 5.0 hp	Power	=3.0 kW
Speed	=1500 rpm	Speed	=1500 rpm
Armature voltage	=220 volts	Armature voltage	=220 volts
Armature current	=19.0 amps	Armature current	=13.6 amps
Field voltage	=220 volts	Field voltage	=220 volts
Field current	=1.0 amps	Field current	=1.0 amps
Wound	= shunt	Wound	= shunt

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	2 No.
DC Ammeter	0-20 A	2 No.
DC Ammeter	0-2 A	2 No.
Speed Indicator	0-2000 rpm	1 No.

Theory:

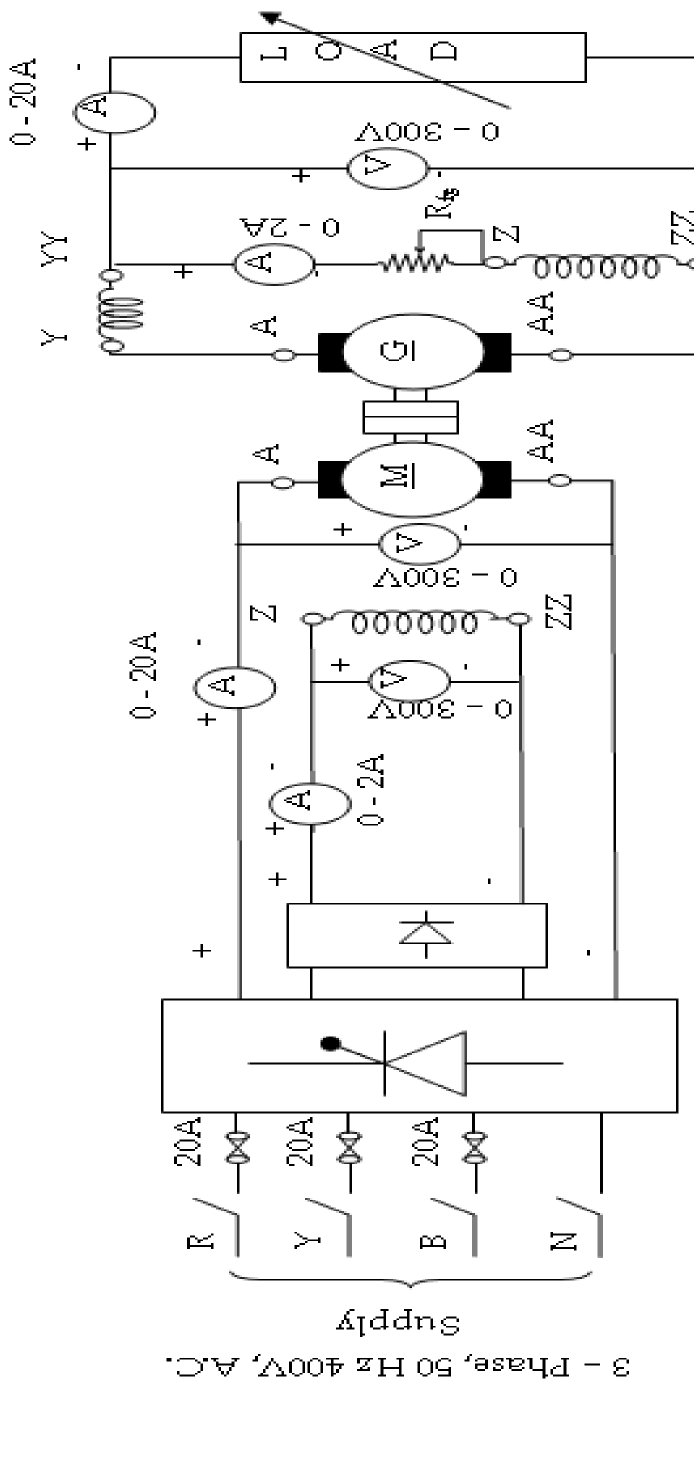
A Compound generator consists of a series field winding and a shunt Field winding. It is further categorized into (a) cumulatively compound generator (b) Differentially Compounded generator.

Cumulatively Compound generator: In this generator, the flux produced by both field Windings adds up together. Hence, the net flux will be increased as the load on the Generator increases. The emf generated and hence, the terminal voltage increases with load till the series field is saturated. The terminal voltage decreases further Increase in the load current due to the armature reaction. Thus, the cumulatively Compounded Generator is categorized as (a) Flat-Compounded (b) Over Compounded and (c) Under Compounded based on the emf generated from No load to rated-load.

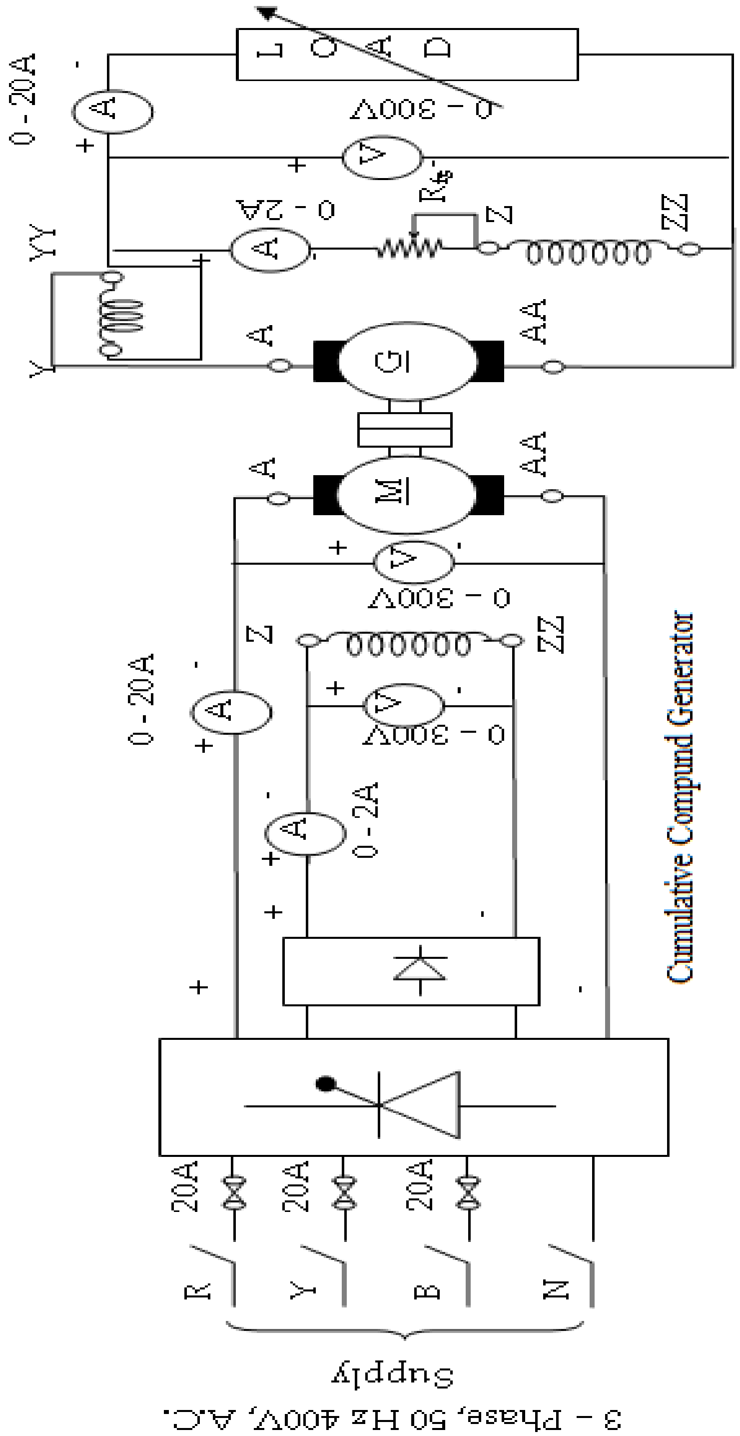
Differentially Compounded Generator: In this generator, the flux produced by both Field windings opposes each other. Hence, the net flux in the air gap decreases and the generated emf decreases with the increase in the load.

The graph between V_L and I_L is the External characteristic of the motor.

The graph between E and I_a is the Internal characteristic of the motor.



Differential Compound Generator


Cumulative Compund Generator
3 – Phase, 50 Hz 400V, A.C.
Supply
R
Y
B
N
20A
20A
20A
0 - 20A
0 - 2A
0 – 300V
M
G
A
AA
Z
ZZ
Y
YY
LOAD

Procedure:

1. Note down the ratings of the dc shunt motor and dc compound generator.
2. Set the dc drive potentiometers at zero positions.
3. Keep field rheostat of the generator at maximum resistance position.
4. Keep all the load switches in OFF position.
5. Connect the circuit as per the circuit diagram.
6. Push the START button and adjust the dc drive potentiometers until armature winding of the motor attains the rated voltage.
7. Now adjust the field rheostat of the generator to bring the terminal voltage of the generator to its rated value.
8. Gradually increase the load. (i.e. switch on the electrical load).
9. Record the readings of the measuring instruments at different load conditions.
10. Do not exceed the rated values of the armature current in the motor and in the generator.
11. Gradually decrease the loads and switch OFF the supply.
12. Maintain the motor (prime mover) speed at a constant value through out the experiment.
13. Conduct the experiment (a) As a cumulatively compounded (b) As a Differential compounded.

Rating of the compounded Generator under test:

Armature resistance of the drive motor = 2.0 ohms

Field resistance of the drive motor = 223.1 ohms

Armature resistance of the generator = 3.9 ohms

Shunt field resistance of the generator = 254.7 ohms

Series field resistance of the generator = 0.6 ohms

Rated speed of the motor = 1500 rpm

Observation & Calculations:

Cumulatively Compounded Generator:

Sl. No.	Drive motor			Generator			$I_a = I_L+I_F$	$E= V+I_aR_a$
	Armature Voltage (volts)	Armature Current (amps)	Field Current (amps)	Load Voltage (volts)	Load Current (amps)	Shunt Field current	Armature Current (amps)	Armature Voltage (volts)
1.								
2.								
3.								
4.								
5.								
6.								

Differentially Compounded Generator:

Sl. No.	Drive motor			Generator			$I_a= I_L+I_F$	$E= V+I_aR_a$
	Armature Voltage (volts)	Armature Current (amps)	Field Current (amps)	Load Voltage (volts)	Load Current (amps)	Shunt Field current	Armature Current (amps)	Armature Voltage (volts)
1.								
2.								
3.								
4.								
5.								
6.								

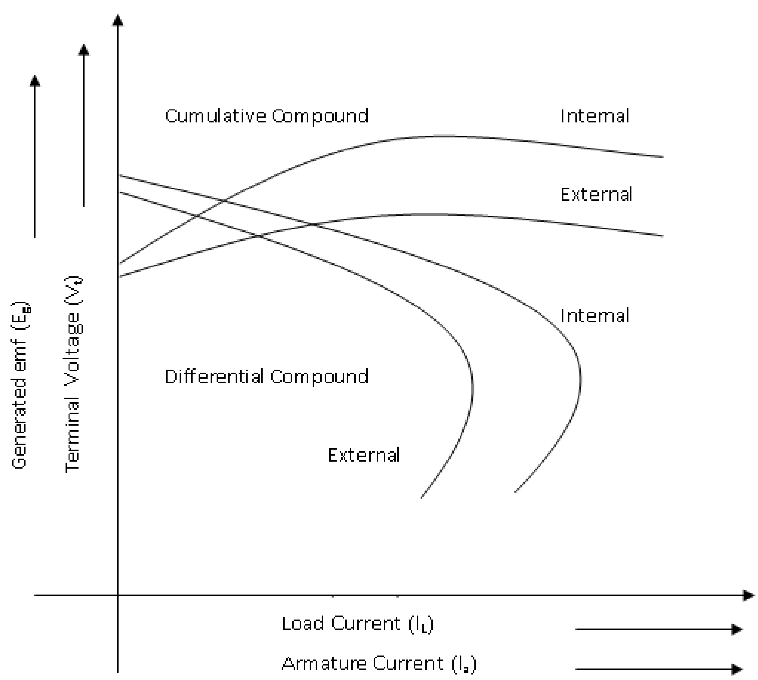
Conclusion:

- The terminal voltage of a cumulative compound generator increases with the load current and also it depends upon the degree of compounding or strength of the series field.
- Flat compound generators are used for maintaining constant voltage at load terminals.
- The short- circuit current in a differential compound generator is considerably less. Hence, these generators are used for wielding.

Graphs:

1. Terminal Voltage (V_t)Vs Load Current (I_L)
2. Generated emf (E_g) Vs Armature Current (I_a)

Model Graphs:



Internal and External Characteristics

INSERT GRAPH SHEETS=2

RESULT:-

8. Hopkinson's Test on D.C. Shunt Machines

Objective:

To perform Hopkinson‟s test on two similar DC shunt machines and hence obtain their efficiencies at various loads.

Name Plate Details:

Motor		Generator	
Power	= 3.0 kW	Power	= 3.0 kW
Speed	= 1500 rpm	Speed	= 1500 rpm
Armature voltage	= 220 volts	Armature voltage	= 220 volts
Armature current	= 13.6 amps	Armature current	= 13.6 amps
Field voltage	= 220 volts	Field voltage	= 220 volts
Field current	= 1.0 amps	Field current	= 1.0 amps

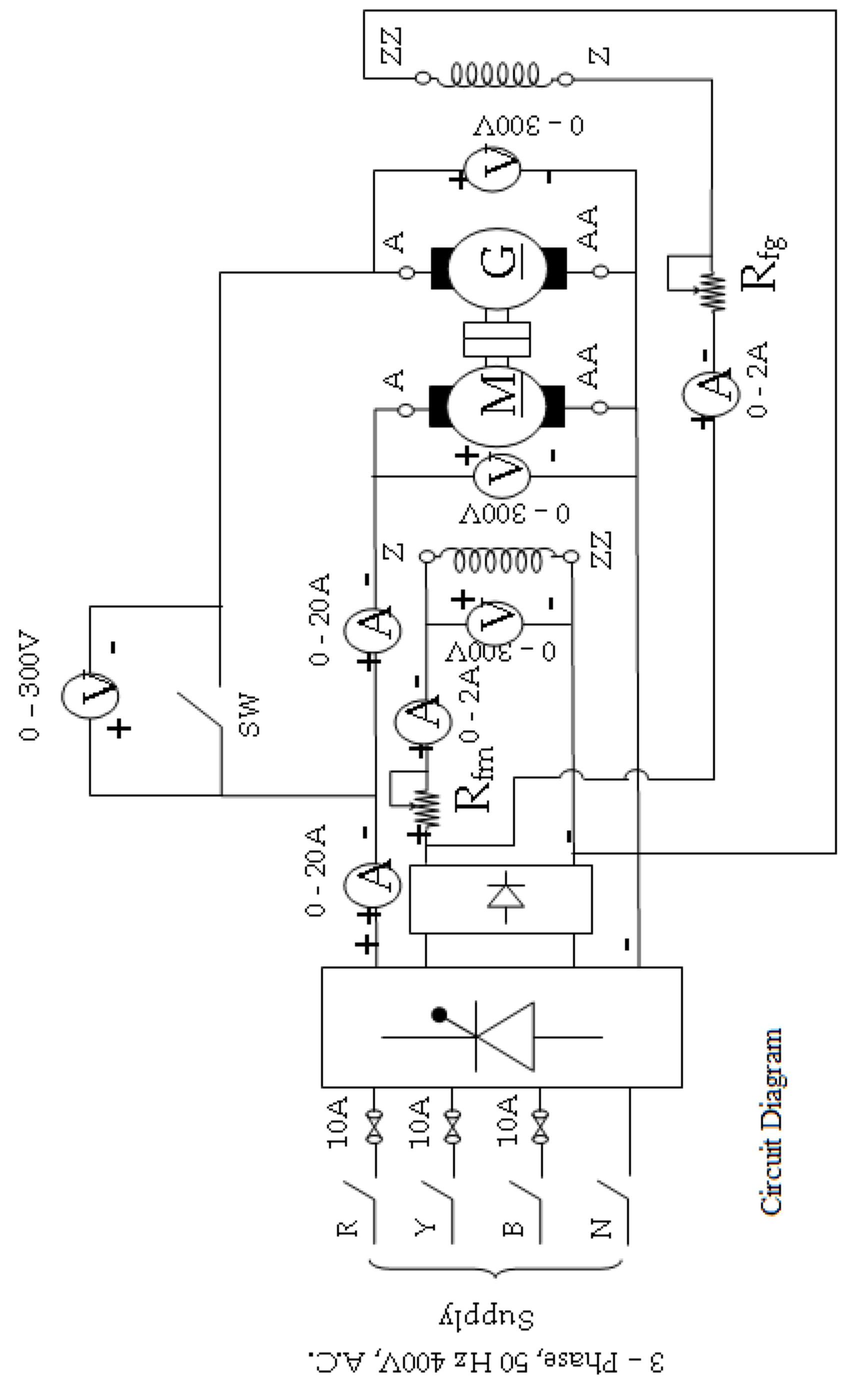
Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300 V	2 No
DC Ammeter	0-20A	2 No
DC Ammeter	0-2 A	2 No
DC Speed Indicator	0-2000 rpm	1 No

Theory:

To find efficiency of a dc shunt machine, the best method is to directly load it and measure its output and input. For large rating machines the direct load test method is difficult to conduct due to a) It is costly to obtain a suitable load and b) The amount of energy to be spent for testing is too large. For, these reasons, electrical engineers use indirect methods like Swinburne‟s test, Separation of losses, and the Retardation test etc, are used to determine the efficiency. These tests are simple to carry out but they offer no information about how the machine performs under actual load conditions. Also, because of assumptions the results obtained are not so accurate.

Hopkinson‟s test (also called Regenerative or Back-to-Back test) offers the advantages of load test without its disadvantages. By this method, full-load test can be carried out on two identical shunt machines without wasting theirs outputs. The two machines are mechanically coupled and are so adjusted that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator. The generator emf value is brought to the bus bar voltage and then paralleled it to bus bars. The electrical output of the generator is used in supplying the greater part of input to the motor. If there were no losses in the machines, then they would have run without any external power supply. But due to losses, generator output is not sufficient to drive the motor and vice versa. Thus, these losses in the machines are supplied electrically from the supply mains.


ZZ
Z
0 - 300V
A
AA
G
M
Rfg
0 - 2A
0 - 20A
SW
Rfm
3 - Phase, 50 Hz 400V, A.C.
Supply
R
Y
B
N
10A
Circuit Diagram

Procedure:

1. Note down the ratings of the two dc machines.
2. Set the potentiometers to zero position.
3. Connect the circuit as per the circuit diagram.
4. Keep the switch SW in open position.
5. Keep the Motor field rheostat R1 at minimum resistance position and Generator field rheostat R2 at maximum resistance position.
6. Push the START button and adjust the dc drive potentiometer till armature Voltage of the motor attains the rated value and adjust the rheostat R1 till the motor reaches the rated speed.
7. Adjust the field current (by Adjusting the field rheostat R2) of the generator so that the voltmeter reads zero.
8. Now close the switch SW (Machine-2 is now floating).
9. Decrease the excitation of the Machine-1 or increase the excitation of Machine-2 so as to load the machines.
10. For various positions of these field settings, note all meter readings and the Speed.
11. Decrease the current gradually to a minimum value and switch OFF the supply.

Note: The currents of the machines should not exceed their rated values. (Care must be taken in these adjustments since small changes in the field currents can cause large changes in the armature currents and over load the machines.)

Calculation of Efficiencies:

I_1 = Current drawn from the mains.
I_2 = Current supplied by the generator to the motor.
I_{f1} = Field current of motor.
I_{f2} = Field current of generator.
$I = I_1 + I_2$ = Input to the motor.
V = Supply voltage.
V_f = Voltage across the field.

The electrical output of the generator plus the small power taken from the supply, equal to the power drawn by the motor as a mechanical power after supplying the motor losses.

$I = I_1 + I_2$
Motor input $= V(I_1 + I_2)$
Generator output $= VI_1$
Let R_a = Hot armature resistance of each machine.(=1.2 * armature resistance at room temperature)
Armature copper losses in a generator $= I_2^2 * R_{a2}$
Armature copper losses in a motor $= (I_1 + I_2)^2 * R_{a1}$
Shunt copper losses in a generator $= V_f * I_{f2}$
Shunt copper losses in a motor $= V_f * I_{f1}$
Motor and Generator losses are equal to the power supplies by the mains.
Power drawn from supply $= VI_1$

Stray losses of both the machines = $VI_1 - [I_2^2 R_{a2} + (I_1 + I_2) R_{a1}] = W_{TS}$
Therefore, total stray losses for the set Ws = $W_{TS} / 2$
The stray losses are approximately equal in two machines.
Stray losses per machine = W_s

For Generator:
Total losses W_g = $I_2^2 R_{a2} + I_{f2} V_f + W_s$
Output = VI_2
Therefore % efficiency N_g (neta) = $(VI_2 / (VI_2 + W_g))*100$.

For Motor:
Total losses W_m = $(I_1 + I_2)^2 R_{a1} + V_f I_{f1}$
Input P_{in} = $V(I_1 + I_2) + V_f I_{f1}$
Output P_o = $P_{in} - W_m$
Therefore % efficiency N_m(neta) = $(P_o / P_{in})*100$

Observations:

Armature resistance of motor and generator $R_{a1} = R_{a2} = 2.3$ ohms (1.2 *1.9 ohms)
Supply voltage V = 227 volts
Field supply voltage V_f =210 volts

Sl. No.	Description of the Variable	Values of the variables				
		1	2	3	4	5
1.	Speed(rpm)					
2.	Current drawn from the supply I_1(amps)					
3.	Armature current of the Motor $I_1 + I_2$ (amps)					
4.	Armature current of the Generator I_2 (amps)					
5.	Field current of the Motor I_{f1} (amps)					
6.	Field current of the Generator I_{f2}					

Sample Calculations:

Power drawn from the supply VI_1 = 227 * 2.85 = 646.9 Watts
Armature copper losses of the motor = $(I_1 + I_2)^2 * R_{a1}$
= $(10.52)^2 * 2.3$ = 254.5 Watts
Armature copper losses of the generator = $I_2^2 * R_{a2}$
= $(7.77)^2 * 2.3$ = 138.8 Watts
Total stray losses of the two machines = $W_{TS} = P_{in}$ -(motor + generator copper losses)

= 646.9 – (254.5 + 138.8) = 253.6 watts

Stray losses per machine W_s = W_{TS} / 2 = 126.8 Watts

Field Cu. Losses in a motor =$V_f I_{f1}$ = 210 * 0.732 = 153.72 watts

Field Cu. Losses in a generator =$V_f I_{f2}$ = 210 * 0748 = 157.08 Watts

Efficiency Calculations:

For Generator:

Total losses W_g = $I_2^2 R_{a2} + I_{f2} V_f + W_s$

= 138.8 + 157.08 + 126.8 = 422.68 Watts

Output = V I_2 = 227 * 7.77 = 1763.8 watts

Input = Output + Total losses

= 1763.8 + 422.7 = 2186.5 Watts

% Efficiency $\eta_m = \frac{P_{out}}{P_{in}}$ x 100 = $\frac{2006.75}{2541.75}$ x 100 = 80.6%

For Motor:

Total losses W_m = $(I_1 + I_2)^2 * R_{a1} + I_{f1} V_f + W_s$

= 254.5 + 153.7 + 126.8 = 535 Watts

Input P_{in} = $V (I_1 + I_2) + V_f I_{f1}$

= 227 * 10.52 + 153.7 = 2541.75Watts

% Efficiency $\eta_m = \frac{P_{out}}{P_{in}}$ x 100 = $\frac{2006.75}{2541.75}$ x 100 = 78.95%

Conclusions:

- This test is useful to determine the efficiency of any higher capacity dc machine accurately at all load conditions with less input power. The sparking at the brushes for all load conditions can also be observed.
- The disadvantage of this test is that two similar dc machines are required.

Calculations:-

VIVA QUESTIONS:

1.what are advantages of Hopkinson‟s test over Swinburne‟s test ?what are limitations?

2.What will happen if the armature rheostat is set to zero (i.e., maximum V_a) and field circuit resistance kept at high (i.e., minimum I_f) at the time of starting?

3.What are the essential connections needed for test?

4.What are other names of Hopkinson‟s test?

5.Why,the retardation test is more appropriate for large machines?

9. Field's Test

Objective:

To determine the efficiency of the two given dc series machines which are mechanically coupled.

Name Plate Details:

Motor		Generator	
Power	= 3.0kW	Power	=3.0kW
Speed	= 1500rpm	Speed	= 1500rpm
Voltage	= 220Volts	Voltage	= 220Volts
Current	= 13.6 Amps	Current	= 13.6 Amps

Apparatus:

Name	Range	Quantity
DC Voltmeter	0 – 300V	1 No.
DC Ammeter	0 – 20A	1 No.
Speed Indicator	0 – 2000rpm	1 No.

Theory:

Testing of series motors in the laboratory is rather more difficult compared to testing of shunt motors. This is because:

(a) The field current varies over a wide range during normal working conditions of a series motor. Therefore, tests made at a constant excitation are no value.

(b) On no- load, the series motor attains dangerously high speed. So no – load test is not possible.

Field‟s Test is conducted on series machines to obtain its efficiency.

In this test,

- Two similar rating series machines are mechanically coupled.
- One series machine runs as a motor and drives another series machine, which runs as a generator.
- The series field winding of the generator is connected in series with the motor series field winding as shown in the figure.
- This test is not a regenerative test.

Calculations:

Let I_1 = Current drawn from the supply
V_1 = Voltage across the motor or supply
I_2 = Current flows into the load
V_2 = Voltage across the load

Power drawn from the supply (P_{in}) = $V_1 I_1$ Watts
Power consumed in the load (P_{out}) = $V_2 I_2$ Watts
Total losses in the two machines (W_L) = $(V_1 I_1 - V_2 I_2)$ Watts
Total copper losses in the two machines (W_{Cu})= $I_1^2 (R_{a1} + R_{Se1} + R_{Se2}) + I_2^2 R_{a2}$

Stray losses in two machines (Iron losses + Mechanical losses) = $W_L - W_{Cu}$

Stray losses of each machine = $W_{Stray} = \dfrac{W_L - W_{Cu}}{2}$

Both machines are mechanically coupled. Hence, the mechanical losses are same. Both series field windings are connected in series and carry the same current. Whereas, the armature currents are slightly different. Thus, the armature reaction is different in both the machines. So their iron losses are approximately same. Hence, the stray losses are same in both the machines.

For motor:

Power input to the motor $P_{in} = V_1 I_1 - I_1^2 R_{Se2}$

Total losses in the motor $W_{ml} = W_S + I_1^2(R_{a1} + R_{Se2})$

Motor output $= P_{in} - W_{ml}$

% Efficiency of the motor $\eta_m = \dfrac{P_{in} - W_{ml}}{P_{in}} \times 100$

For Generator:

Power input of the Generator $P_{out} = V_2 I_2$

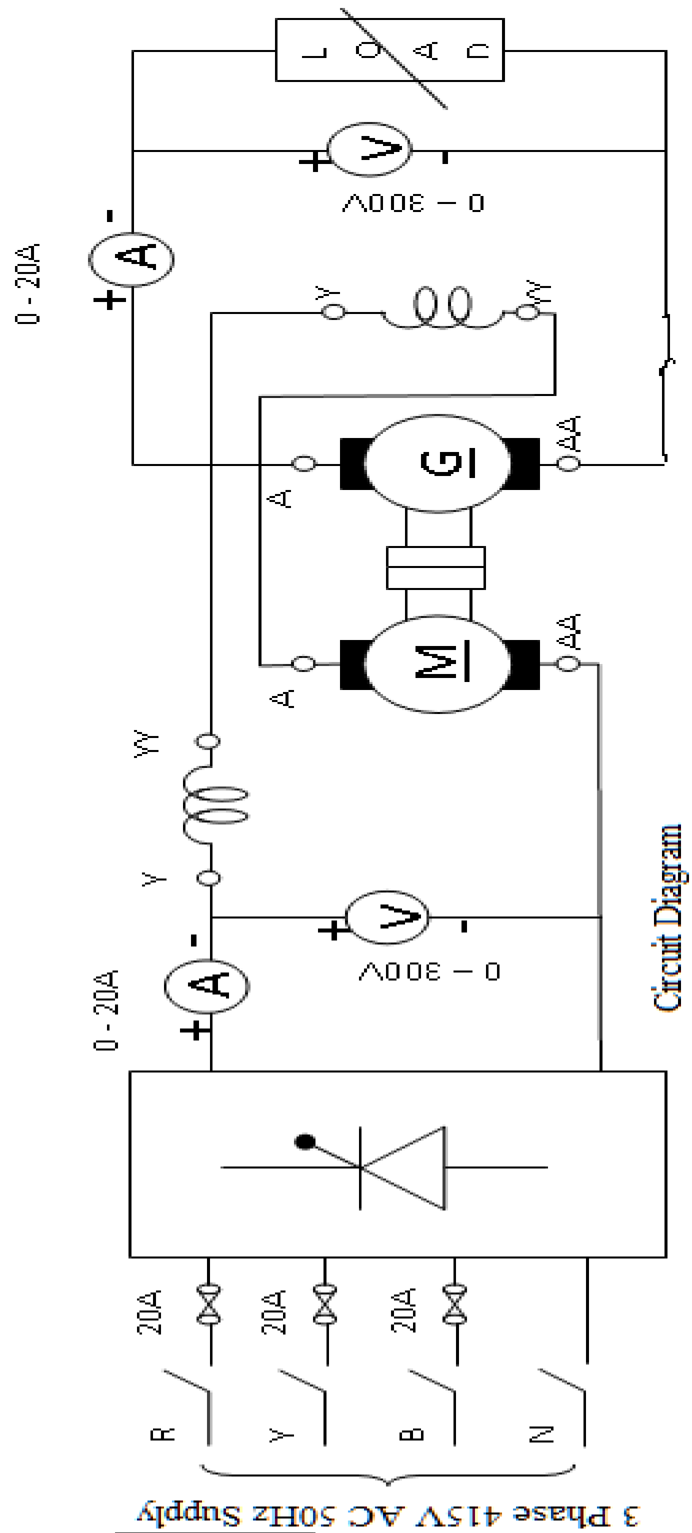
Total losses in the Generator $W_{gl} = W_S + I_1^2 R_{Se2} + I_2^2 R_{a2})$

Input to the Generator $P_{in} = P_{out} + W_{gl}$

% Efficiency of the generator $\eta_g = \dfrac{P_{out}}{P_{in}} \times 100$

$$\% \eta_g = \frac{V_2 I_2}{V_2 I_2 + W_{gl}} \times 100$$

Panel board:



Circuit Diagram

Procedure:

1. Note down the ratings of the dc series motor and dc series generator.
2. Set the dc drive potentiometers at zero positions.
3. Put a minimum load of 400W on the generator.
4. Connect the circuit as shown in the circuit diagram.
5. Push the START button and gradually increase the armature voltage and simultaneously add the loads till the armature current I_a or I_f reaches the rated value.
6. Reduce the loads one by one till the motor speed does not exceed 1800rpm.
7. Note down the readings at different loads.
8. Gradually, reduce the armature voltage of the prime mover.
9. Keep a minimum load of 400W and then switch off the supply.

Observations:

Armature resistance of the motor (R_{a1}) = 2.0Ω
Series field resistance of the motor (R_{Se1}) = 0.8Ω
Armature resistance of the generator (R_{a2}) = 2.0Ω
Series field resistance of the generator (R_{Se2}) = 0.8Ω

Observation table:

Supply Voltage V_1 volts						
Current drawn from the supply I_1 amps						
Load Voltage V_L volts						
Load Current I_L amps						
Speed N rpm						

Sample calculations:

V_1 = 200V
I_1 = 11 A
V_L = 161V
I_L = 9.1A
Power input $P_{in} = V_1 I_1$ = 2100Watts
Power output $P_{out} = V_L I_L$ = 1465Watts
Total Losses in two machines $W_L = P_{in} - P_{out}$ = 2100 – 1465 = 635Watts
Field copper losses in the motor = $I_1^2 R_{Se1} = 11^2 \times 0.8$ = 96.8 Watts
Field copper losses in the generator = $I_1^2 R_{Se2} = 11^2 \times 0.8$ = 96.8 Watts
Armature copper losses in the motor = $I_1^2 R_{a1} = 11^2 \times 2.0$ = 242 Watts
Armature copper losses in the generator = $I_L^2 R_{a2} = 9.1^2 \times 2.0$ = 165.6 Watts

Total copper losses in the field and armature of the generator and motor is P_{Cu} = 96.8 + 96.8 + 242 + 165.6 = 601.2Watts

Stray losses in each machine = $W_S = \frac{P_L - P_{Cu}}{2} = \frac{634.9 - 601.2}{2} = 16.85$ Watts

Motor efficiency calculations:

Power input to the motor $P_{in} = V_1 I_1 - I_1^2 R_{Se2}$ = 2100 – 96.8 = 2003.2 Watts
Total losses in the motor $W_{ml} = I_1^2 R_{Se1} + I_1^2 R_{a1} + W_S$ = 96.8+242+16.85 = 355.65W
Motor Output = $P_{in} - W_{ml}$ = 2003.2 – 355.65 = 1647.5 Watts

$$\%\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100 = \frac{1647.5}{2003.2} \times 100 = 82.2\%$$

Generator Efficiency Calculations:

Generator output $P_{out} = V_L I_L = 1465$Watts

Total Losses in the Generator $W_{gl} = W_S + I_1^2 R_{Se2} + I_L^2 R_{a2}$

$= 16.85 + 96.5 + 165.6 = 279.25$ Watts

Power input to the generator $P_{in} = P_{out(g)} + W_{gl} = 1465 + 279.25 = 1744.25$ Watts

%Efficiency of the generator = $\frac{P_{out}}{P_{in}} \times 100 = \frac{1465}{1774.25} \times 100 = 83.9\%$

Conclusions:

- Both the identical series machines are coupled mechanically and electrically.
- It is not a regenerative test.
- The main disadvantage is that a relatively small error in the measurement of the motor input or generator output may result in a relatively large error in the calculated efficiency.
- The efficiency can be calculated on the series motor at light loads otherwise for a series motor the motor goes to dangerously high speeds at light loads.

Calculations:-

RESULT:

VIVA QUESTIONS

1. Why there should be a minimum load to switch off the supply?
2. List out the applications of series generator?
3. Why, a series generator characteristics is called a rising characteristics?

10. Separation of Losses in a D.C. Shunt Motor

Objective:

To obtain separately the hysterisis, eddy current, function and Windage losses of the given motor.

Name Plate Details:

Power	= 5.0 hp	Speed	= 1500 rpm
Armature voltage	= 220 volts	Field voltage	= 220 volts
Armature current	= 19.0 amps	Filed current	= 1.0 amps

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	1 No.
DC Ammeter	0-20A	1 No.
DC Ammeter	0-2A	1 No.
Speed Indicator	0-2000rpm	1 No.
Auto Transformer	2A, 1-ph	1 No.
Variable Rheostat	0-200Ω, 500W	1 No.

Theory:

At a given excitation, friction losses and hysterisis are proportional to speed. Windage losses and eddy current losses on the other hand are both proportional to square of speed. Hence, for a given excitation (field current) we have,
Friction losses = AN Watts, Windage losses = BN^2 Watts
Hysterisis losses = CN Watts, Eddy current losses = DN^2 Watts; Where N = speed.
For a motor on no load, power input to the armature is the sum of the armature copper losses and the above losses.

In the circuit diagram, power input to the armature = V.Ia watts.
Armature copper losses = $Ia^2.Ra$ watts
$V.Ia - Ia^2.Ra = (A + C)N + (B + D)N^2$
W/N = (A+C) + (B+D)N.

The graph between W/N & N is a straight line, from which (A+C) and (B+D) can be found. In order to find A, B, C and D seperately, let the field current be changed to a reduced value I^I_f, and kept constant at that value.

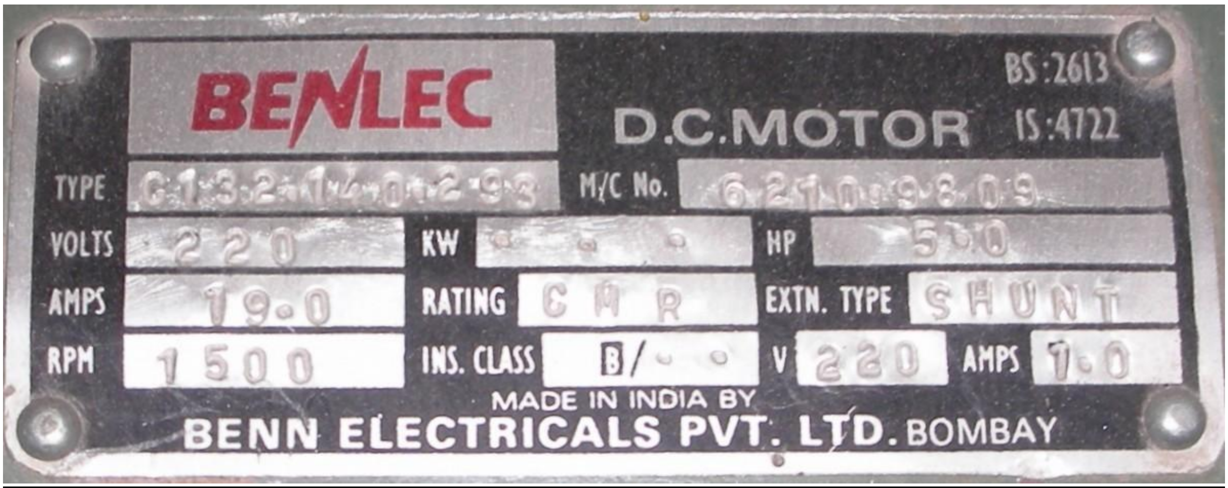
If, voltage is applied to the armature as before, we now have $W/N = (A+C^I)\ N + (B+D^{''})\ N^2$ (at the reduced excitation, function and windage losses are still are AN and BN^2, but hysterisis losses become C^IN and eddy current losses become $D^I\ N^2$). We can now obtain (A+C) and (B+D) as before.

Now, C/C^I = (flux at normal excitation/flux at reduced excitation), and
D/D^I = (flux at normal excitation/flux at reduced excitation)

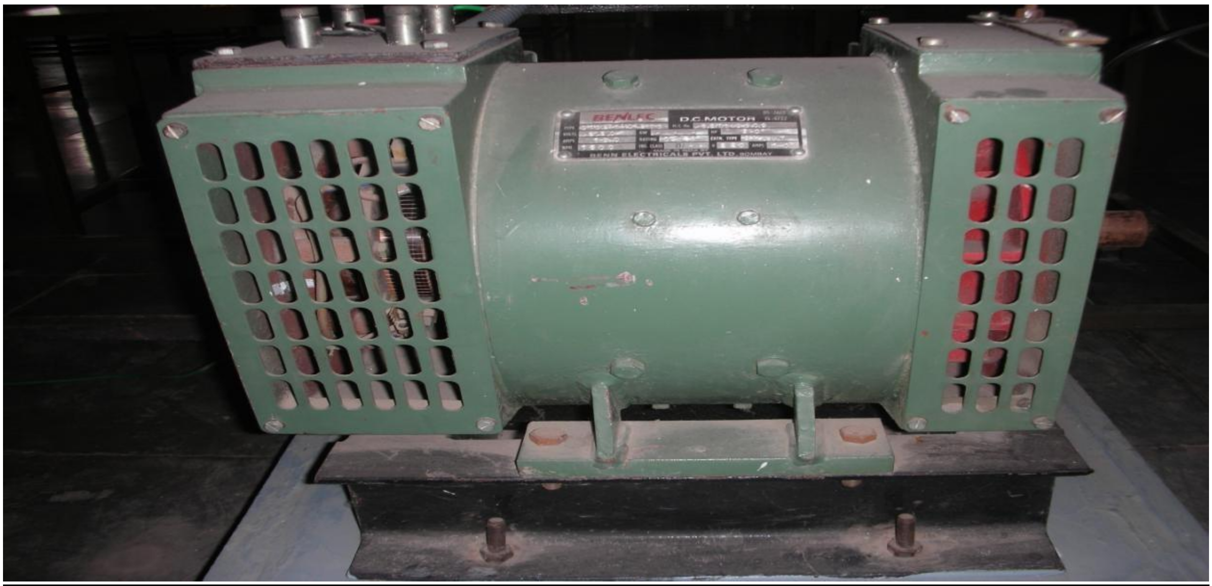
So, if we determine the ratio (flux at normal excitation/flux at reduced excitation) we can find A, B, C, D, C^I, & D^I.

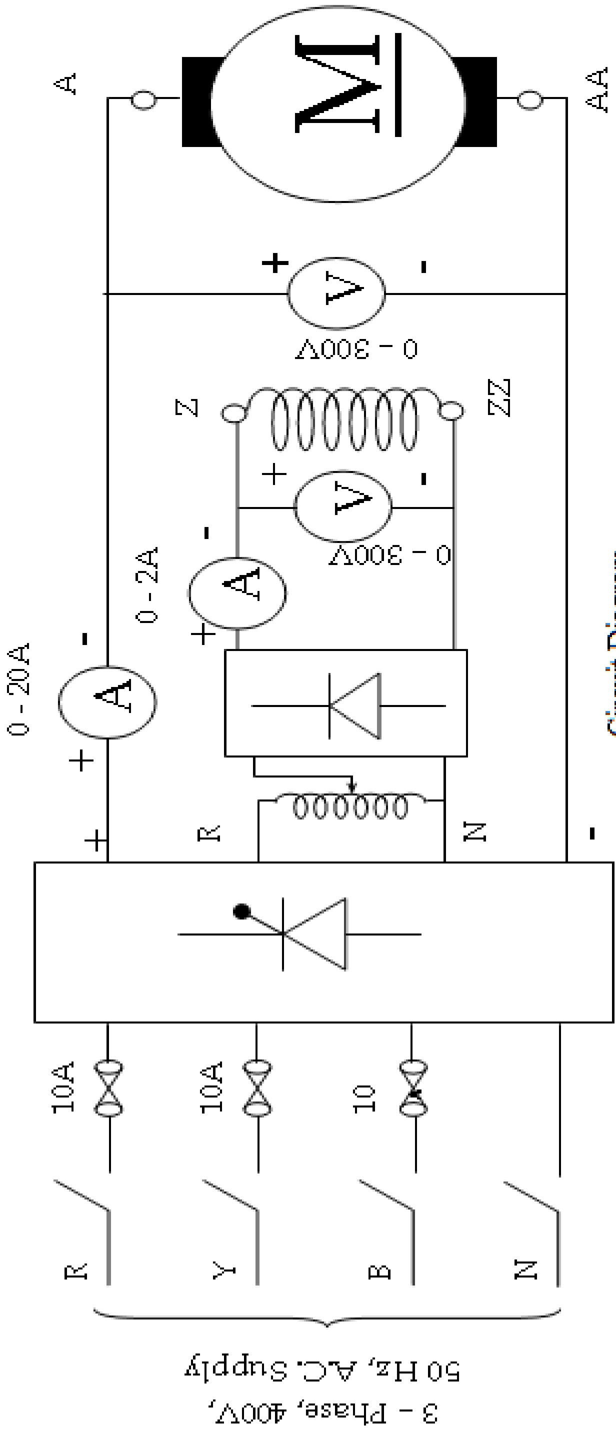
Panel board:

Name Plate:



Test Machine





Circuit Diagram

Procedure:

1. Start the motor on no load with filed auto transformer in maximum voltage position.
2. Increase the armature voltage till the speed is about 200rpm more than the rated value.
3. Now, gradually decrease the armature voltage, and note down the values of armature voltage, armature current and speed.
4. Repeat the experiment at some other field current.
5. Measure the armature resistance separately, after disconnecting the circuit.

Sample data, calculations and results:

Ratings of the machine under test:
Armature resistance = 1.7Ω (Ra)

Full exciation: Field current = 0.9Amps

Armatur voltage, volts(V)				
Armature current, amps(Ia)				
Speed , N (rpm)				
$W = V.Ia – I^2_a.R_a$, watts				
W/N (watts/rpm)				
k ϕ				

Reduced excitaion: Field current = 0.6Amps.

Armatur voltage, volts(V)				
Armature current, amps(Ia)				
Speed , N (rpm)				
$W = V.Ia – I^2_a.R_a$, watts				
W/N (watts/rpm)				
k ϕ				

At full excitaion, average value of K1ϕ = 0.14847.
At reduced excitation, value of K1ϕ = 0.126097.
Φ/ϕ1 = 1.77426902
$C/C^I = (\phi/\phi 1)^{1.6} = 1.2986$
$D/D^I = (\phi/\phi 1)^2 = 1.3863$
From graph, (A+C) = 0.0564 Watts/rpm (B+D) = 246 x 10 Watts/rpm

(A+C) = 0.0558 Watts/rpm (B+D) = 212 x 10 Watts/rpm
Hence, A = 0.0538 Watts/rpm B = 124.8 x 10 Watts/rpm
C = 0.00261 Watts/rpm D = 121.2 x 10 Watts/rpm
At rates speed (1500rpm),
Friction losses = 80.7 Watts.
Windage (air friction) losses = 28.1 Watts.
Hysterisis losses = 4 Watts.
Eddy current losses = 27.3 Watts.
Total mechanical + iron losses (stray losses) = 140 Watts.
(This agrees fairly well with the value of 136 Watts in the table.)
Calculations:-

INSERT GRAPH SHEETS=1

RESULT:-

VIVA QUESTIONS

1. What are different types of losses that are can be separated in the experiment?

2. Explain hysteresis phenomenon?

11. Swinburne's Test

Objective

To pre-determine the efficiency of a D.C shunt machine considering it as a motor by performing Swinburne‟s test on it.

Name Plate Details:

Power = 5.0 hp	Speed = 1500 rpm
Armature voltage = 220 volts	Field voltage = 220 volts
Armature current = 19.0 amps	Filed current = 1.0 amps

Apparatus:

Name	Range	Quantity
DC Voltmeter	0-300V	1 No.
DC Ammeter	0-20A	1 No.
DC Ammeter	0-2A	1 No.
Speed Indicator	0-2000rpm	1 No.
Auto Transformer	2A, 1-ph	1 No.
Variable Rheostat	0-200Ω, 500W	1 No.

Theory:

Testing of D.C. machines can be divided into three methods: (a) direct, (b) regenerative, and (c) indirect. Swinburne‟s Test is an indirect method of testing a D.C. machine. In this method, the constant losses of the D.C. machine are calculated at no-load. Hence, its efficiency either as a motor or as a generator can be pre-determined. In this method, the power requirement is very small. Hence, this method can be used to pre-determine the efficiency of higher capacity D.C. machines as a motor and as a generator.

Disadvantages:

(1) Efficiency at actual load is not accurately known.
(2) Temperature rise on load is not known.
(3) Sparking at commutator on load is not known.

Power input at No-load = Constant losses + Armature copper losses
Power input at No-load = Constant losses
Power input = Va Ia + Vf If

Losses in a D.C. Machine:

The losses in a D.C. machine can be divided as 1) Constant losses, 2) Variable losses, which changes with the load.

Constant losses:

Mechanical Losses: Friction and Windage losses are called mechanical losses. They depend upon the speed. A D.C. shunt machine is basically a constant speed machine both as a generator and as a motor. Thus, the mechanical losses are constant.

Iron Losses: For a D.C. shunt machine, the field current hence the flux. Hence, hysteresis and eddy current losses (which are also called as iron losses) remain constant.

Field Copper Losses: Under normal operating conditions of a D.C. shunt machine, the field current remains constant. Thus, power received by the field circuit (which is consumed as field copper losses) is constant.

Constant losses in a D.C. shunt machine = Mechanical losses + Iron Losses + Filed copper losses

Variable Losses:

The power lost in the armature circuit of s D.C. machine increases with the increase in load. Thus, the armature copper losses are called as variable losses.

Efficiency of a D.C. machine:

% Efficiency = (Output Power/ Input Power)x100

As a generator Input power, P in = (P out) + (constant losses) + (armature copper losses at a given load Ia^2Ra

P_{out} = VL . IL

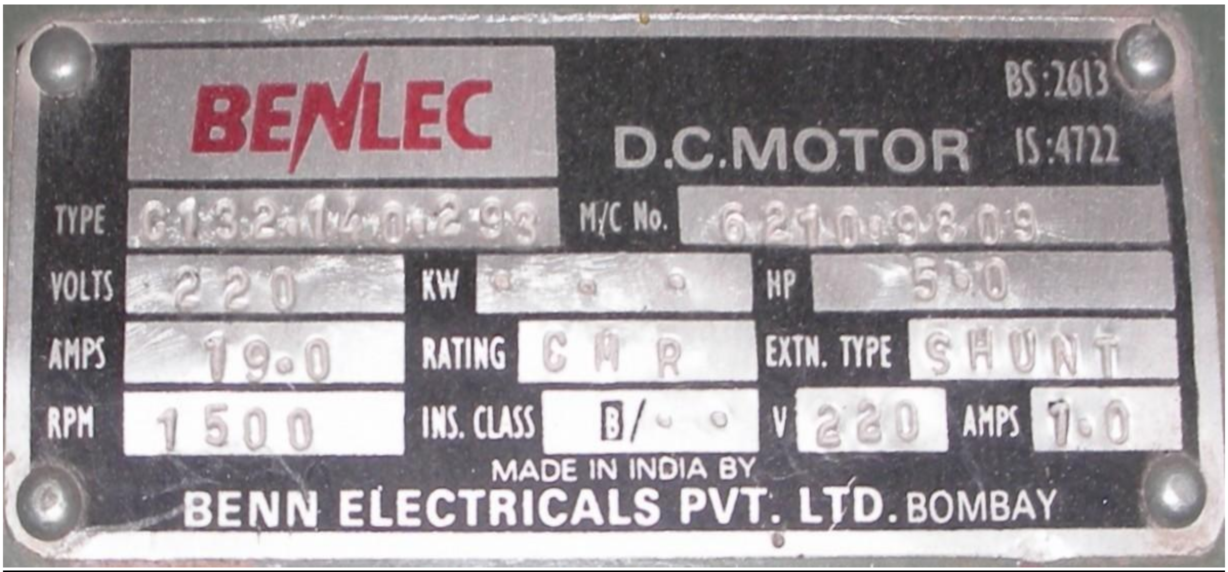
where, Ia = IL + If → self excited generator(Vf.If is not encountered for Pin)

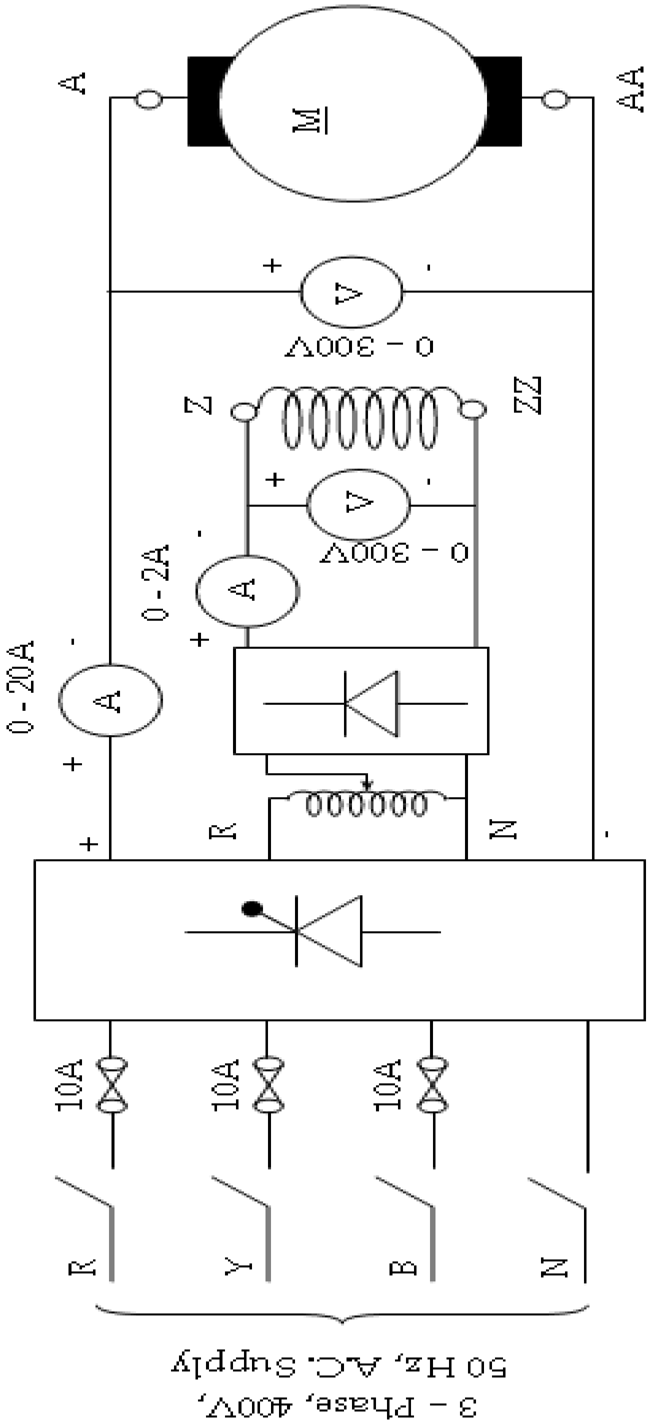
Ia = IL → seperately excited motor

Note: While calculating the armature copper losses on load condition, the hot resistance of the armature = 1.2Ra (normal temperature) is considered.

Panel board:

Name Plate




A
AA
M
0 - 300V
Z
ZZ
0 - 300V
0 - 2A
0 - 20A
R
N
10A
10A
10A
R
Y
B
N
3 – Phase, 400V,
50 Hz, A.C. Supply

Procedure:

1. Keep the field voltage control auto transformer at maximum position.
2. Keep the D.C. drive potentiometers at zero position.
3. Connect the circuit as shown in the circuit diagram.
4. Run the machine as a motor at no-load.
5. Adjust the voltage applied to the armature to get rated voltage.
6. Adjust the field auto transformer till the motor attains the rated speed.
7. Measure the field voltage and current.
8. Measure the field resistance and armature resistance.

Observations:

At no-load (separately excited D.C. motor):
Speed = 1500rpm
Armature voltage = 237 V
Field voltage = 208V
Armature current = 0.65A
Field current = 1.0A
Armature resistance = 1.6Ω
Field resistance = 210 Ω

Sample Calculations:

Armature copper loss = 0.65 x 1.6 = 0.676 watts
Field copper loss = 1.0 x 210 = 210 watts
Mechanical loss + iron losses =armature input – armature copper loss
Total constant losses = Mechanical loss + iron loss + field copper loss
= 153.4 + 210 = 363.4 watts

Efficiency as a motor:

Let us assume that the current drawn by the armature = 5A
Input to the motor = input to the armature + input to the field
= (237 x 5) + (210 x 1) = 1395 watts
Total losses = constant losses + armature copper losses
= 363.4 + (5^2 x 1.2 x .6) = 411.4 wtts
Output = Input – total losses = 1395 – 411.4 = 983.6 watts
Efficiency, η_m = output/input = (983.6/1395) x 100 = 70.5%

Efficiency as a generator:

Let us assume that the current delivered by the armature = 5A
Output = 237 x 5 = 1185 watts
Total losses = constant losses + armature copper losses
= 363.4 + (5^2 x 1.2 x 1.6) = 411.4 watts
Efficiency, η_g = output/input = (1185/1596.4) x 100 = 74.2%

As a motor:

Sl. No.	Load Current I_L	Power Input	Copper Loss	Total Loss	Power Output	Efficiency
1.						
2.						
3.						
4.						
5.						

As a motor:

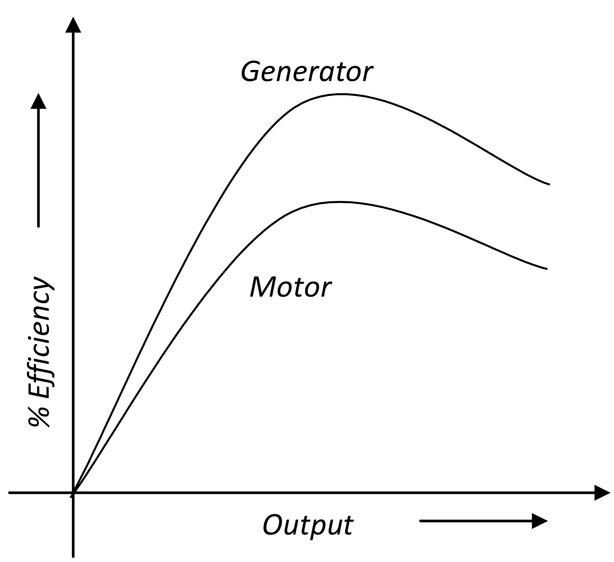
Sl. No.	Load Current I_L	Power Input	Copper Loss	Total Loss	Power Output	Efficiency
1.						
2.						
3.						
4.						
5.						

Conclusion:

- The power required to conduct the test is very less as compared to the direct loading test.
- Constant losses are calculated from this method are used to compute the efficiency of a D.C. machine as a generator and as a motor wihtout actually loading it.
- Hence this is an economic method.

Graph:

Draw the graph between Efficiency and IL of the machine as a motor and as a generator on the same graph sheet.



% Efficiency Vs Output Characteristics

Model Graph:

Calculations:-

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RESULT:-

VIVA QUESTIONS

1. What is difference between determine and pre determine?
2. Why efficiency of generator is more compared to generator?
3. What are various losses which are under consideration for calculation Efficiency? Why do losses occur?

12.O.C. Test, S.C. Test & Load Test on a single phase transformer.

Objective:

To determine the iron losses, copper losses and efficiency of a transformer at any load.

Apparatus:

0-2 Amps Ammeter	01
0-20 Amps Ammeter	01
0-300 Volts Voltmeter	01
0-200 Watts L.P.F. type Wattmeter	01
0-3.0 KW U.P.F. type Wattmeter	01

Transformer Ratings :

Power:2 KVA, Primary/Secondary :230/415Volts.
:8.69/4.82 Amps.

Circuit Diagram :

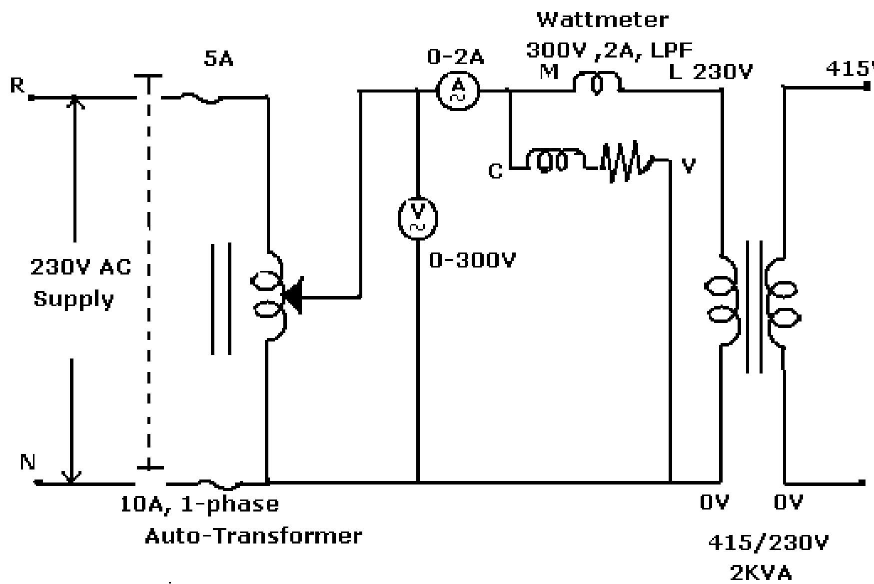

Fig.1.1: Open Circuit Test

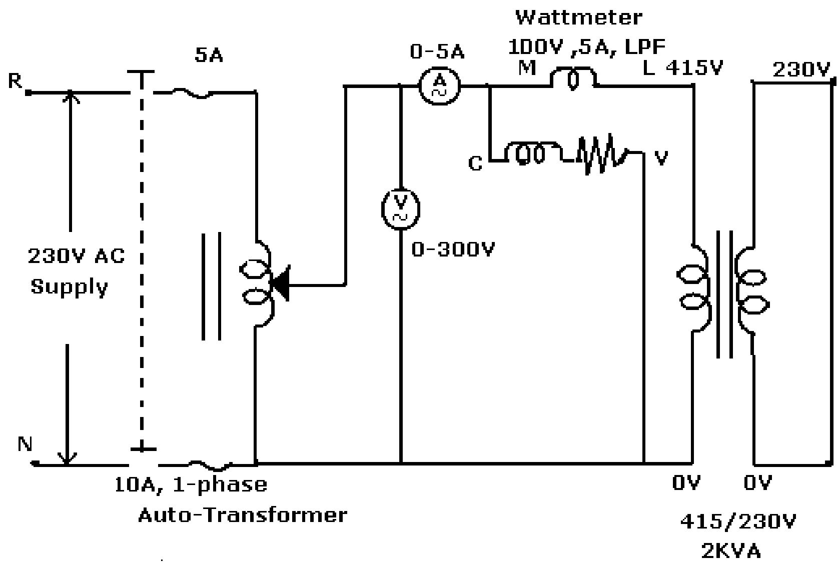

Fig.1. 2:Short Circuit Test

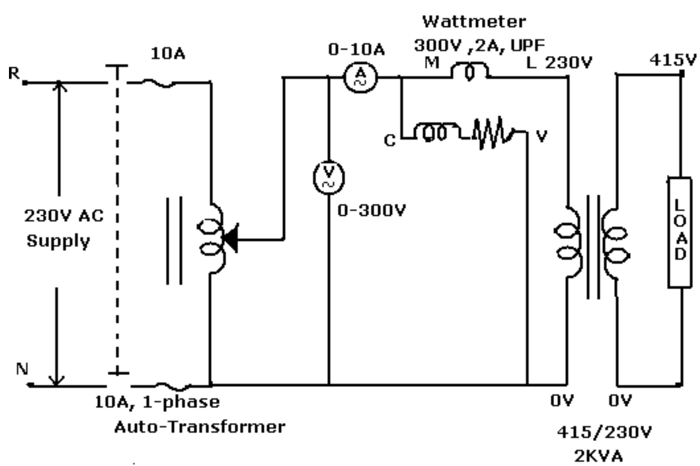

Fig.1.3: Load Test

Theory:

A transformer is a static device which transfers the electrical energy from one circuit to another circuit without any change in the frequency. The transformer works on the principle of electromagnetic induction between two windings placed on a common magnetic circuit. These two windings are electrically insulated from each other and also from the core.

The losses in a transformer are (i) magnetic losses or core losses (ii) ohmic losses or copper losses. The losses of a transformer, magnetic losses and ohmic losses can be determined by performing (a) open circuit test and (b) short circuit test. From the above tests, the efficiency and regulation of a given transformer can be predetermined at any given load. The power consumed during these tests is very less as compared to the load test. ln this experiment LV side parameters are denoted by suffix 1 and FIV side parameters by suffix2.

Open Circuit Test:

In open circuit test, usually HV side is kept open and meters are connected on LV side as shown in the fig.1.1. When rated voltage is applied to the LV side, the ammeter reads the no-load current Io and watt meter reads the power input . The no load current I_{NL} is 2 to 5% of full load current. Hence, the copper losses at no-load are negligible. We represent the iron or core losses. Iron losses are the sum of hysteresis and eddy current losses.

$$W_o = V_{LV} I_O \cos\phi_0$$

Short Circuit Test:

This test is performed to determine the equivalent resistance and leakage reactance of the transformer and copper losses at full – load condition.

In this test usually LV side is shorted and meters are connected on HV side. A variable low voltage is applied to the HV winding with the help of an auto-transformer. This voltage is varied till the rated current flows in the HV side or LV side. The voltage applied is 5 to 10 percent of rated voltage, while the rated current flows in the windings. The wattmeter indicates the full load copper losses and core losses at V_{SC} But the iron, losses at this low voltage are negligible as compared to the iron losses at the rated voltage

Load Test:

This test is performed to determine the efficiency and regulation of a transformer at different load conditions. Usually, this test is performed for low, power, rating of transformers. This test gives accurate results as compared to the above tests. In this test, measurements are taken on HV side and LV side at different load conditions. W indicates the input power at LV side and W indicates the output power connected on secondary side (HV).

Procedure:

(a) O.C Test:

* Connect the circuit diagram as shown in the figure 1.1
* Gradually increase the voltage using the auto-transformer till the voltmeter reads 230V
* Record the voltmeter, ammeter and L.P.F. wattmeter readings.
* The ammeter indicates the no-load current and wattmeter indicates the iron losses
* Switch off the supply and set the auto-transformer at zero position.

(b) S.C Test:

* Connect the circuit diagram as shown in the figure I .2
* Gradually increase the voltage using the auto-transformer till the ammeter reads 4.82 amps, (the rated current of the transformer on HV side)
* Record the voltmeter, ammeter and U.PF. wattmeter readings.
* The ammeter indicates Isc, voltmeter indicates Vsc and wattmeter indicates Wsc copper losses of the transformer at full load condition.
* Switch off the supply and set the auto-transformer at zero position.

(c) Load Test:

* Connect the circuit diagram such that the supply on LV side and load on HV side as shown in the fig. 1.3.
* Gradually increase the voltage using auto transformer till the voltmeter reads the rated voltage, 230v on LV side and also record the voltage on HV side.
* Maintain the voltage V to be constant for all loads.
* Switch on the load switches one by one and record the ammeter, voltmeter and wattmeter readings. (The load current should not be exceed the rated current,4.82A.)
* Switch off the supply and set the auto-transformer at zero position.

Calculations :

* Determine the R_{02} , X_{02}, Z_{02} ,R_{01} , X_{01} , Z_{01} , and R_0 , X_0 values on both sides of the transformer from O.C. test and S.C test.
* Tabulate the efficiency and regulation of the transformer at different load conditions by assuming load with different power factors.
* Draw the equivalent circuit diagram on both sides.

Observations:

O.C Test: Voc =230V; Ioc = 0.48A, Woc = 50w. (LV data)
S.C Test : Vsc = 25V; Isc =4.824, Wsc = 90W (HV data)

Equivalent Circuit Diagram of transformer:

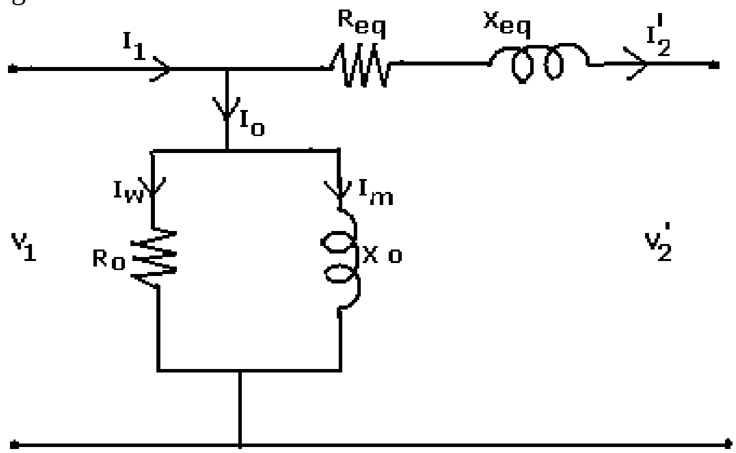

Fig.1.4: Equivalent Circuit

Sample Calculation

Calculation of Ro and Xo of equivalent circuit from o.c test

V_0 = 230V I_0 = 0.48A W_0 = 0.05

Iron losses = Wo = $V_1 I_0 \cos\phi_0$

$$\text{Coso } \phi 0 = \frac{W0}{V1I0} = \frac{50}{230x0.48}$$

$\phi_0 = 63.06^0$, $\sin \phi_0 = 0.8915$

$I = I_0 \cos \phi_0$ = 0.48x0.8915 = 0.43A

$I_w = I_0 \cos \phi_0$ = 0.48 x 0.453 = 0.2174A

LVside

$$Ro = \frac{V1}{Iw} = \frac{230}{0.217} = 1058\ \Omega$$

$$Xo = \frac{V1}{I} = \frac{230}{0.45} = 534.88\ \Omega$$

HV side R_0 : LVside R_0 x K^2 = 3444.5Ω

HV side X_0 : HV side X_0 x K^2 = 1740.7Ω

$$\text{Where } K = \frac{V_{HV}}{V_{LV}} = \frac{415}{230} = 1.804$$

SC TEST:

Calculation of R_{01} and X_{01} for equivalent circuit

I_{sc} = 4.824 A V_{SC} = 25V W_{sc} = 0.09KW

Full load copper losses or variable losses = Wsc = $I^2_{sc} R_{02}$

$$R02 = \frac{WSC}{ISC^2} = \frac{90}{(4.82)^2} = 3.874\ \Omega$$

$$Z02 = \frac{VSC}{ISC} = \frac{25}{4.82} = 5.187\ \Omega$$

$$X02 = \sqrt{(Z02^2 - R02^2)} = 3.45\ \Omega$$

$$R01 = \frac{R02}{K^2} = 1.19\ \Omega$$

$$X01 = \frac{X02}{K^2} = 1.06\Omega$$

Calculation of percent regulation from sc test

At full load current, I_2 = 4.82 A, V_2 = 4 I 5V, p.f = 0. 8 lag
Percent regulation

$$= \frac{I2\ (R02\ Cos\emptyset + X02\ Sin\emptyset)}{V2} = 6\%$$

Efficiency Calculation from O.C and S.C tests

$$\%\eta = \frac{\text{Out put in KVA}*\text{p.f}*100}{\text{Output in KVA}*\text{p.f}+\text{Iron losses}+x^2\text{Full loadcopperlosses}}$$

At full load 0.8 power factor

$$\%\eta = \frac{2000 \times 0.8 \times 100}{2000 \times 0.8 + 50 + 90} = 92\%$$

where x

$$= \frac{\text{Actual load in KVA}}{\text{Rated load KVA}}$$

Sample Observations for Load Test:

V_1 = 230V **Load Test**

Primary		Secondary				
I_1(A)	W_1(kw)	V_2(V)	I_2(A)	W_2(kw)	$\%\eta = \frac{W_2}{W_1}$	$\% reg = \frac{V_{2NL} - V_2}{V_{2NL}}$
0.54	0.05	412	0.02	0	0	0
1.61	0.35	409	0.72	0.31	88.6	0.78
2.86	0.64	405	1.44	0.59	92	1.7
4.14	0.94	402	2.16	0.88	93.6	1.428
5.42	1.22	398	2.87	1.16	95.1	2
6.68	1.52	395	3.56	1.41	92.8	2.43

Observations:

Primary		Secondary			
I_1 (A)	W_1 (kw)	V_2 (V)	I_2 (A)	%η	%reg.

Calculations:

13. Sumpner's Test

Objective:

To predetermine the efficiency, regulation and equivalent circuit of a given pair of identical single - phase transformers by conducting Sumpner's test.

Name plate details of the two identical transformers:

Primary voltage	: 230 Volts	Secondary voltage:	415 Volts
Primary current	: 69Amps .	Secondary current	4.82 Amps
Power (Burden)	: 2KVA	Frequency:	50 Hz.

Apparatus:

Digital voltmeter,0 to 1000Volts	02
Digital ammeter, 0 to l0 Amps	02
Digital wattmeter, 0 to 300 Watts	02
Digital temperature indicator, 0 to 100 Degrees	01

Theory:

The efficiency of a transformer can be predetermined by conducting o.c. and s.c. tests. But the rise in temperature can be found only by conducting the actual load test. It is difficult io conduct the actual load test for large transformers. [n case of Sumpner‟s test the efficiency, regulation and rise in temperature can be obtained with small amount of power consumption.

In Sumpner's test, the two primary windings of the identical transformers are connected in parallel across the supply and the two secondary‟s are connected in series with their polarities in opposition. One digital wattmeter (L.P.F. type), one voltmeter and one ammeter are connected at primary side. One digital wattmeter (U.P.F: type), one voltmeter and one ammeter are connected at secondary side. If primaries are energized then the voltage across the two secondaries will be zero since both the transformers are identical transformers.

The power input to the transformers at no-load is indicated by the wattmeter on the primary side. This power is, equal-to the iron losses of the two transformers. An auto-transformer is connected in series with the two secondary‟s. A small voltage is injected in the secondary circuit from a separate ac source. It will circulate a current in the secondary side since the secondary‟s are in opposition, the secondary current will cause primary current in opposite directions so that the reading of wattmeter on primary is not affected and it will indicate the iron losses of the two transformers. The auto-transformer is adjusted till the full load current flows in the secondary side of the transformer. At full load current the wattmeter on the secondary side indicates the full load copper losses of the two transformers.

Procedure:

* Make all the connections as per the circuit diagram shown in fig .Z.Z.
* Keep the switch 's' open on the secondary side of the transformer.
* Keep the auto-transformer at zero position and disconnect the supply to the auto transformer.
* Apply the normal voltage of 230Volts to the primary side.
* Check the voltmeter reading across the switch. If it reads zero, it means the secondary‟s are connected in opposition. If the voltmeter reads twice the secondary rated voltage then the connections should be reversed on the secondary side.
* lf voltmeter reads zero close the switch .S'.
* Connect the supply to the auto-transformer and energize the secondary circuit and adjust the auto transformer till the ammeter on the secondary side reads the rated current (4.82A).
* Record the readings of the meters on both the primary and secondary sides.
* Calculate R_{eq} , x_{eq} , regulation and efficiency of the transformer 0.8 pf lag, 0.8pf lead and upf for full load and half load conditions.

Observations:

$V_1 = 220$ V	$I_1 = 0.86$ A	$W_1 = 94.3$ W
$V_2 = 50$ V	$I_2 = 4.65$ A	$W_2 = 185$ W

Formulas for Calculations:

Core loss for each transformer = $W_0 = \frac{W1}{2} = \frac{94.3}{2} = 47.15$ W

Full load copper loss for each transformer = $W_0 = \frac{W2}{2} = \frac{185}{2} = 92.5$ W

$$\%\eta = \frac{\text{Out put in KVA} * \text{p.f} * 100}{\text{Output in KVA} * \text{p.f} + \text{Iron losses} + x^2 \text{Full load copper losses}}$$

Where

$$x = \frac{\text{Actual load in KVA}}{\text{Rated load KVA}}$$

% Regulation of the transformer = $\frac{I2(Req\ Cos\emptyset + Xeq\ Sin\emptyset)}{V2}$

Where V_2 = Secondary voltage at no-load.

Calculations for R_{eq}, X_{eq}:

$I^2_{sc} R_{eq} = \frac{Wsc}{2}$ $\quad$ $Z_{eq} = \frac{Vsc}{Isc}$ $\quad$ $X_{eq} = \sqrt{(Zeq^2 - Req^2)}$

Diagram of Equivalent circuit of the transformer:

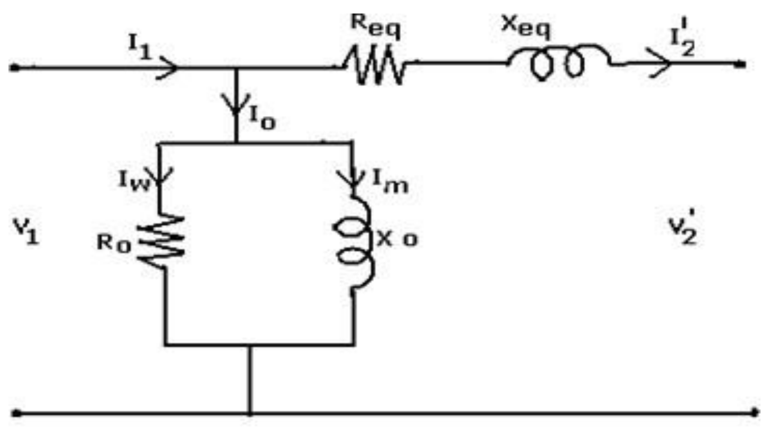

Fig 2.1 : Equivalent Circuit

Calculation for equivalent circuit of transformer:

$I_w = I_0 \cos\phi$ $\quad$ $I_\mu = I_0 \sin\phi$

I_0 is the no load current on primary side

$$R_0 = \frac{V_1}{I_w} \qquad X_0 = \frac{V_1}{I_\mu}$$

Graphs: Plot the graph for output in KW Vs percent for 0.8p.f and u.p.f. at full and half loads.

Circuit Diagram:

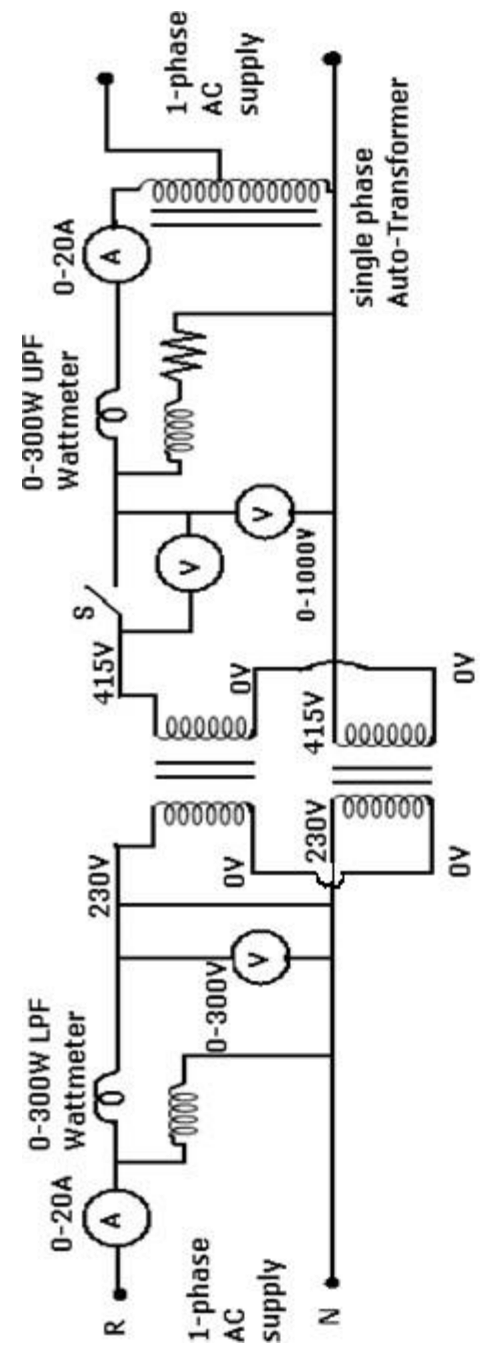

Fig. 2.2: Sumpner's test

Calculation for R_0 and X_0

$V_1 = 220$ V $I_1 = 0.86$ A $W_1 = 94.3$ W

$W_0 = \frac{94.3}{2} = 47.15W$ $I_0 = \frac{0.86}{2} A$

$\text{Cos}\phi_0 = \frac{W0}{V0\ I0} = \frac{47.15}{220 \times 0.43} = 0.498$

$I_w = I_0\ \text{Cos}\phi = 0.43 \times 0.498 = 0.214A$

$I_\mu = I_0\ \text{Sin}\phi = 0.43 \times 0.866 = 0.372A$

$R_0 = \frac{V1}{Iw} = 1028\Omega,\ X_0 = \frac{V1}{I\mu} = 591.4\ \Omega$

$W_{sc} = \frac{185}{2} = 92.5W,\ V_{sc} = \frac{50}{2} = 25V,\ I_{sc} = 4.65A$

HV $R_{02} = \frac{Wsc}{Isc^2} = 4.278\ \Omega,\ Z_{02} = \frac{Vsc}{Isc} = \frac{25}{4.65} = 5.376\ \Omega.$

$HVX_{02} = \sqrt{(5.376)^2 - (4.278)^2} = 3.26\Omega$

$K = \frac{415}{230} = 1.804$

$LVZ_{01} = \frac{Z02}{K^2} = \frac{5.376}{1.804^2} = 1.652\ \Omega$

LV $R_{01} = \frac{4.27}{1.804^2} = 1.314\Omega$

$LVX_{01} = \frac{X02}{K^2} = 1.0\ \Omega$

Total losses = $W_i + W_{cu} = 92.5 + 47.15 = 139.3W$

Output = Rated power = 2KVA.

Calculation of efficiency at full load with 0.8 p.f. lag

$\%\eta = \frac{2000X0.8X100}{2000X0.8 + 139.3} = 92\%$

Calculation of regulation at full load with 0.8 p.f. lag

$\%\ reg = \frac{4.65}{415}[4.27X0.8 \pm 3.26X0.6]$

Where „+‟ is for lagging and „-„ is leading loads

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Result:

14. SCOTT CONNECTION

Objective:-

To study the Scott Connection of transformers and to verify different types of connections of Three-Phase Transformers.

Apparatus:-

Name Plate Details:-

P=2KVA V_{HV}= 415V V_{LV}= 230V

I_{HV}=4.82A I_{LV} = 8.696A

Theory:

Scott Connection:-

Three Phases: Consider three lines R, Y and B. let ac voltages V_{RY}, V_{YB} and V_{BR} exist between these lines. These three voltages constitute a set of three-phase line voltages. If the magnitudes of three voltage phasor are the same, and if there is a phase angle of 120^0 between any pair of voltages, then the set of voltages constitute a three-phase balanced set.

Two-phases: consider 4 lines I,2,3 and4 as in the fig.10. Let ac voltages V_{12} and V_{34} exist between lines I and 2, and lines 3 and 4 respectively. V_{12} and V_{34} constitute a set of two phase voltages.

If the magnitudes of the two voltage phasor are the same, and if there is a phase difference of 90^0 between them they constitute a two-phase balanced set. Suppose lines 2 and3 are joined. Then the Voltage between I and 4 is the sum of the voltages V_{12}, & V_{34}. If the two-phase supply is balanced, these voltages are equal in magnitude and 90^0 out of phase. So their sum has a magnitude 1.414 times the magnitude of the individual voltages. This is one means of checking a two-phase balanced supply. Another way is to observe the wave forms in the CRO.

Conversion:

We can convert three-Phase to two phase and vice-versa using two transformers .We can show two-phase voltages between lines I and 2 , and lines 3 and 4, we will get balanced three phase voltages between R,Y and B.

Stare-Star Connection: This test is most economical for small high voltage transformer because the no of turns per phase and the amount of insulation required is minimum. The ratio of line voltages on the primary and secondary sides is same as the transformation ratio of each transformer. Angular displacement between primary and secondary voltages is zero. By stabilizing primary neutral we can avoid distortion in the secondary phase voltages. This connection works satisfactorily only if the load is balanced. As the frequency of this component is thrice the frequency of the circuit, at any given it tends to flow either towards or away from the neutral point in all the three transformers. The advantage of this connection is that insulation is stressed only to the extent of line to neutral voltage i.e 58% of the line voltage.

Delta-Delta connection: This connection is economical for large, low-voltage transformer in which insulation problem is not so urgent, because it increases the number of turns/phase. The ratio of transformation between primary and secondary line voltage is exactly the same as that of each transformer. No difficulty is experienced from unbalanced load as the case ofY-Y connection. The three phase voltages remain practically constant regard less of load imbalance. An advantage of this connection is that one transformer becomes disabled; the system can continue to operate in open-delta or in V-V although with reduced available capacity. The reduced capacity is 58% and not 66.7% of the normal value.

Star-Delta Connection: The main use of this connection is at the sub-station end of the transmission line where the voltage is star connected with grounded neutral. The ratio between the secondary and primary line voltage is 1/3 times the, transformation ratio of each transformer. There is 30^0 shift between the primary and secondary line voltages which means that a Y-Y transformer bank cannot be paralleled with either Y-Y or a Delta-Delta bank. Also, third harmonic currents flow in the Delta to provide a sinusoidal flux.

Delta - Star connection : This connection is generally employed where it is necessary to step up the voltages. The neutral of the secondary is grounded for providing 3-phase 4-wire service. In recent years, this connection has gained considerable popularity because it can be used to serve both the 3-phase power equipment and single phase lightening circuits. The ratio of primary of secondary is 1/3 times the transformation ratio of each transformer.

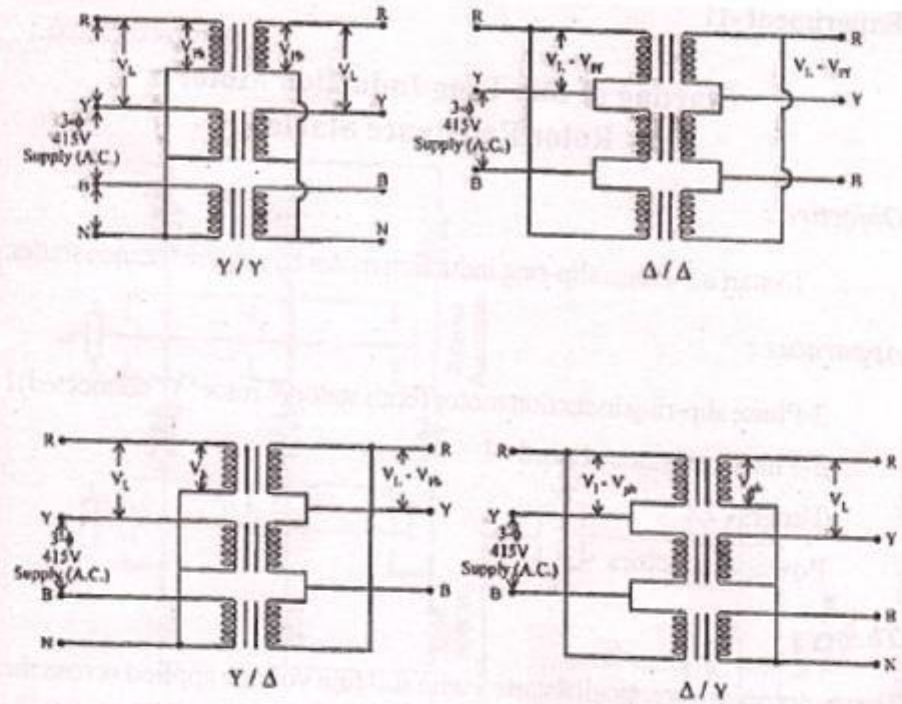
Procedure:

- Make the connections as shown in the circuit diagram.
- Measure the following voltages; V_{RY}, V_{YB}, V_{BR}, V_{12} and V_{34} .
- Instead of connecting the line R at the 86-6% point on the transformer T_1, connect it at the 415V point, the rest of the connections being the same V_{12} and V_{34} are unequal.

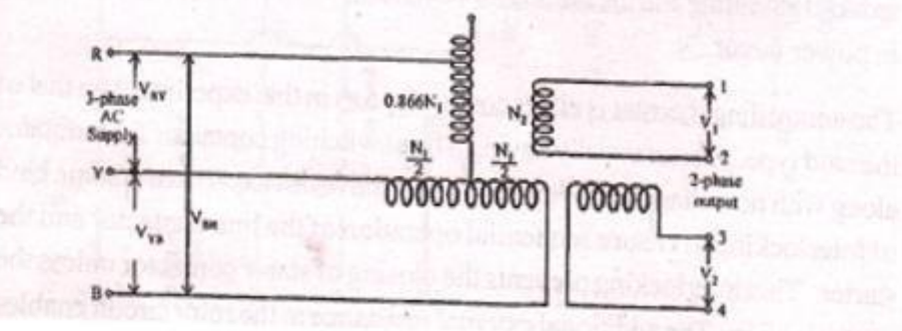
Star-star connection

Primary side	**secondary side**
V_{RY} =374V	V_{RY}= V_{YB}= V_{BR} =203V
V_{YB} = 374V	
V_{BR}= 374V	
Delta to Delta	**Star to Delta**
V_{RY}= V_{YB}= V_{BR} =368V	V_{RY}= V_{YB}= V_{BR} =368V
V_{RY}= V_{YB}= V_{BR} =203V	V_{RY}= V_{YB}= V_{BR} =117V
Delta to Star	**Scott Connection**
V_{RY}= V_{YB}= V_{BR} =368V	V_{RY}= V_{YB}= V_{BR} =368V
V_{RY}= V_{YB}= V_{BR} =356V	V_1= V_2=210V

Circuit Diagram:



Circuit Diagram for Scott Connection



Conclusion:

The voltages for different types of three phase transformers and scott connection are verified.

15. Heat Run Test

Objective: To measure the rise in temperature inside the winding of a 3- phase transformer using Heat-Run test.

Apparatus:

Name of the Apparatus	
2KVA, 415/230V transformers	01
0-4 Amps auto-transformer	01
0-300W L.P.F. Wattmeter	01
0-3 KW U.P.F. Wattmeter	01
0-20Amps Ammeters	01
0-750V Voltmeters	01
0-300^0 C Temperature Indicator	01

Procedure:

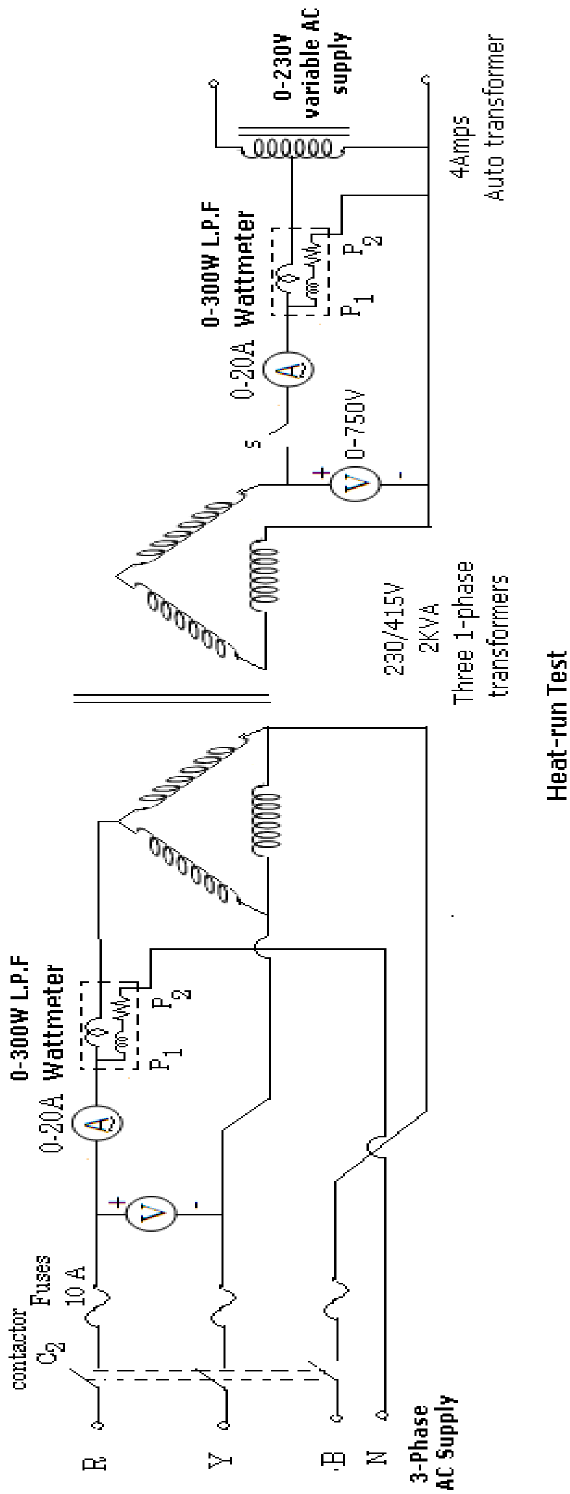
1. Connect the circuit as shown in the figure
2. Connect the voltmeter across R_1 & B_2 on LV Side
3. Keep the switch in the off position.
4. Switch on the 3-phase power supply.
5 . Record the Ammeter, Voltmeter readings on the primary side and observe the reading on the secondary side, which is connected between R_1 & B_2.
6. If the voltmeter indicates high value then conduct the polarity test and connect them as per the dot convention.
7. If this voltmeter indicates zero, then switch ON S_{w1} and slowly increase the auto transformer till the ammeter indicates the rated current of the secondary winding 8.2 Amps.

Theory:

Heat-Run test on a 3-phase transformer is similar to the sumpner's test conducted on two single phase transformers. ln this test the LV Winding is excited at normal voltage and frequency. The wattmeter indicates the core losses in one limb. (Since only one wattmeter is used for power measurement. If 2-wattmeter method is used then the total core loss is W_1+W_2. The total core loss is obtained by multiplying the above reading with 3. If the voltmeter connected on open-delta side indicates zero if the windings are connected in delta as per the dot convention. Under this condition, voltage is injected on the secondary side using auto transformer till the rated current is reached. The wattmeter reading on the primary side is unaffected.

The rise in temperature is measured periodically to obtain the thermal equilibrium.

Circuit Diagram:



Observation Table (1):

S.No.	Current(A)	Wattmeter Reading(W)	Total corelosses(3xW)
1	8.08	280	840
2	7.0	210	630
3	6.1	160	480

Practical Observations:

S.No.	Current(A)	Wattmeter Reading(W)	Total corelosses(3xW)

Observation Table (2):

S.No.	Time(min)	Temparature(^{0}C)
1	0-15	29.9
2	15-30	38.6
3	30-45	47.6
4	45-60	55.4

Practical Observations:

S.No.	Time(min)	Temparature(^{0}C)

Graph:

Draw the graph between temperatures Vs. Time.

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Conclusions: Heat run test is performed on 3-Phase transformers.

16. Hysteresis loss determination

1. Objective

To record the hysteresis loop of the core of an iron cored transformer and to find the hysteresis losses (the power converted to heat due to hysteresis) in the iron core of the transformer.

2. Hysteresis loop of the core of an iron cored transformer:

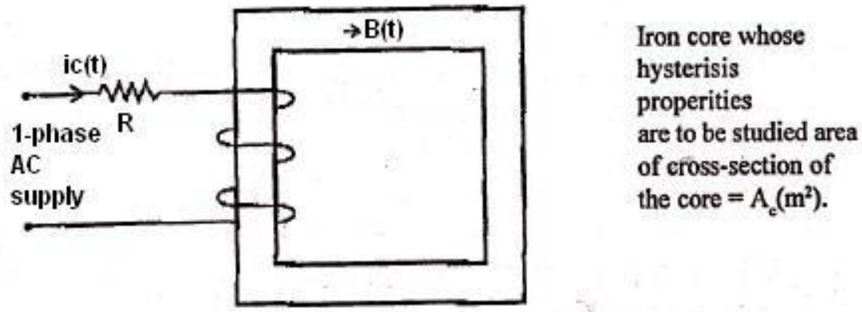

Fig. 9.1

In fig.9.1, the voltage v(t) applied to winding 1 of the transformer equals the induced emf e(t) in the winding (neglecting the winding resistance). But from Faraday's law, e(f)=[N,A_c] $\frac{dB(t)}{dt}$ where B(t) is the flux density in the core. (N_1 is the number of turns of the winding, and Ac the area of cross-section of the core are constants). Hence v(t) = [N,A_c] $\frac{dB(t)}{dt}$ Assuming the flux density to vary sinusoidally with time, let B(t)=B_{max} sin wt. Then v(t) = N_1 A_c B_{max} sin (Ct+TM/2). We see that v(t) is also sinusoidal, at the same frequency as B(t), but leading B(t) by 90^0. If we can correct this phase shift, we can use v(t) as a signal representing B(t).

The current io (t) flowing through the winding 1 produces an mmf of N_i I_0 (t) amp-turns. The corresponding H is N_1 and I_c is the circumferential length of the core. N_i and I_c are constants and so H is proportional to I_0 (t). We can use I_0 (t) as a signal representing H(t).

A plot of B-H where both B and H vary between a positive maximum and a, negative maximum is called the hysteresis loop of the core. We can use v (after correcting the phase shift) to represent B i_0 to represent H. If we give these two signals to a CRO, we can observe the hysteresis loop of the transformer on the screen.

9.2 Obtaining a signal corresponding to B(t) (which lags v(t) by90^0):

$$V = V\angle 0^0$$

$$I = \frac{V}{R} = \frac{V}{R}\angle 0^0$$

$$V_c = I(-jx_c) = \frac{V}{R}X_c\angle -\frac{\Pi}{2}$$

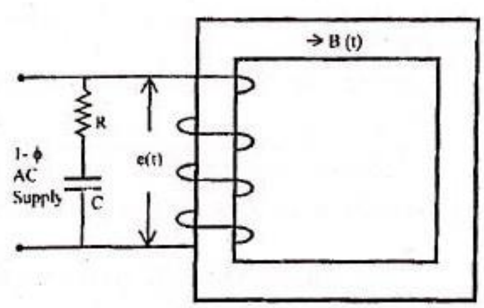

Fig. 9.2

Voltage v(t), which is applied to the winding, is also applied to the resistance R in series with the capacitance c. If the resistance is large compared to the capacitive reactance, the current I through the R-C branch is nearly in phase with the voltage V. V_c, the voltage across the capacitance lags this current, and hence the voltage v, by 90^0. V and V_c are the phasor representations of the instantaneous quantities v(t) and $v_c(t)$, Since V_c lags V by 90^0, $V_c(t)$ also lags v(t) by same amount. Thus, $v_c(t)$, as well as B(t) lag v(t) by 90^0, and so they both are in phaase. We can use $v_c(t)$ to represent B(t).

obtaining a signal corresponding to H(t) which is proportional to $I_0(t)$:

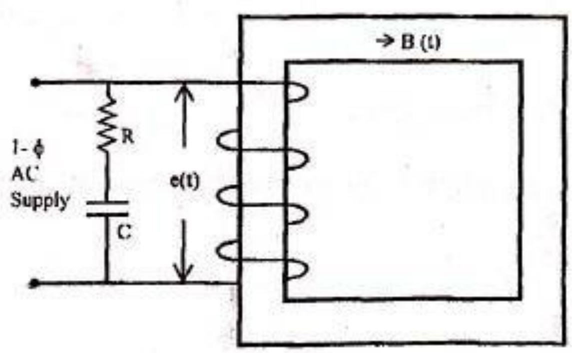

Fig. 9.3

From fig. 9.3, we see that the current $i_0(t)$ flows through R_0. Hence the voltage across R_0 is $i_0(t)R_0$ which is proportional to, and which represents H(t). Note that R_0 is in series with the transformer reduces the voltage across the transformer. Hence, the current $i_0(t)$ reduces. For this change to be small, R_0 must be chosen small-as possible.

Obtaining the hysteresis losses from the hysteresis loop seen on the CRO:

Consider the circuit of fig-9.4. mmf=$N_1 i_0$ (t).

$$H(t) = \frac{\text{mmf}}{\text{circumfential length of the core}} = N_1 \frac{i_0\,(t).}{I_c}$$

Signal applied to the X-deflection plates of the CRO = $i_0(t)\,R_0$ volts =H(t) $I_c \frac{R_0}{N_1}$ volts, which is proportional to H(t). With an X-deflection scale of x volts/cm, a given value H_1 of H, corresponds to ($H_1\, I_c \frac{R_0}{N_1}$x) cms on the screen.

Let B(t), the flux density through the core (assumed sinusoidal), be B(t) – B_m sin wt N/A-m. The signal applied to the Y-deflection plates of the, CRO = $v_c(t)\phi$ volts. The relation between B(t) and $v_c(t)$, can be derived as follows:

$V(t)= N_1 \frac{d}{dt} = N_1\, t \frac{d\{B(t)A_c}{dt}$, { (t) the flux through the core, equals the flux density B(t) multiplied by the area of cross-section of the core A_c}

$\frac{dB(t)}{dt} = B_m$ cost. So, v(t) = $N_1\, A_c\, B_m$cost,

And V=($N_1\, A_c B_m$c/2)<0^0.

I is in phase with V (approximately) since R is selected to be much larger than X_c.

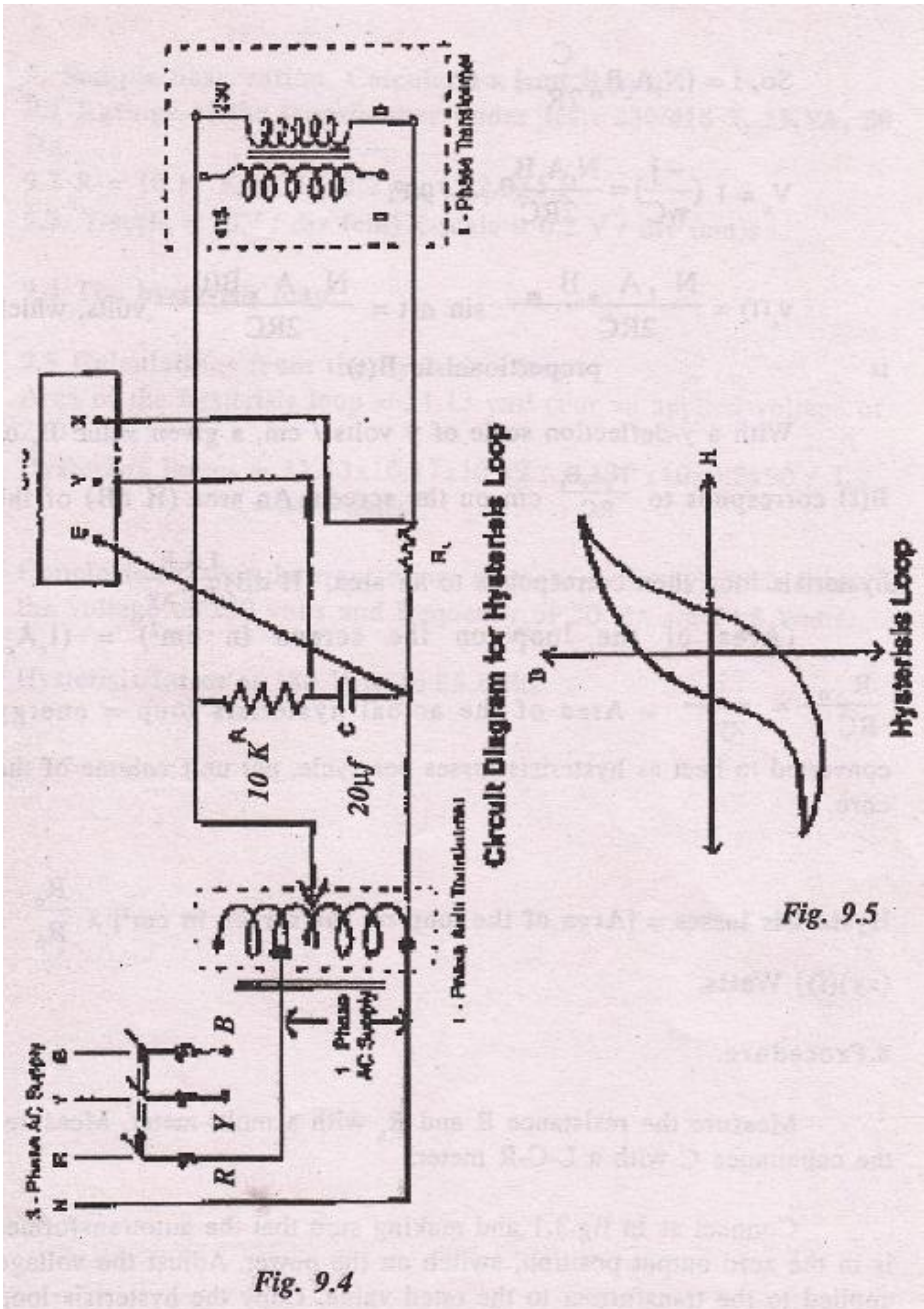
Circuit Diagram for Hysterisis Loop
Hysterisis Loop
1 - Phase Transformer
230
415
10 K
R
20μf
C
E
Y
X
H
B
1 - Phase Auto Transformer
1 Phase AC Supply
3 - Phase AC Supply
N
R
Y
B

Fig. 9.4

Fig. 9.5

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So, I= $(N_1 A_c B_m \frac{c}{2R}) < 0^0$,

$V_c = i(\frac{-j}{wc}) = \frac{N1\ AcBm}{2RC} < -90^{0.}$

$V_c(t) = \frac{N1\ AcBm}{2RC} \sin\omega t = \frac{N1\ AcBm}{2RC}$ Volts, which is proportional to B(t).

With a y-deflection scale of y volts I cm, a given value B, of $\frac{N1\ AcB1}{RCy}$ cm on the screen. An area (H dB) of the hysteresis loop then corresponds to an area, (H dB) $\frac{Ic\ AcR0}{RCxy}$

(Area of the loop on the screen in cm^2) = $(I_c A_c) \frac{Ro}{RC} X \frac{i}{xy} =$ Area of actual hysteresis loop = energy converted to heat as hysteresis losses per cycle, per unit volume of the core.

.

Hysteresis losses = [Area of the loop on the screen in cm²] x$\frac{RC}{Ro}$ (xy) (f)] Watts.

4. Procedure.

Measure the resistance R and Ro with a multi-meter. Measure the capacitance C with a L-C-R meter.

Connect as in fig.3.1 and making sure that the autotransformer is in the zero output position, switch on the power. Adjust the voltage applied to the transformer to the rated value. copy the hysteresis loop on the screen on a graph sheet. Also note the x-deflection scale and they y-deflection scale.

9. Sample observation, Calculation and Results:

Ratings of the transformer under test: 230/415 V,2KVA, 50Hz.9.2 R = 10.17 KΩ, R_0=1.2Ω, C=2.635µF

9.3.Y-scale=10V/div(cm) X-scale=0.2 V/div(cm)s.

The hysteresis loop:

Calculations from the hysteresis loop:

Area of the hysteresis loop = 11.13 cm², (For an applied voltage of 230 volts).

Hysteresis losses = $11.13x10.I7x10^3x2.63x10^{-6}$ x10x0.2x50 / 1.2

= 24.8 watts.

Conclusions: For the transformer under test, the hysteresis losses at the voltage of 230 volts and frequency of 50 Hz are 24.8 Watts.

Hysteresis losses at 180 V are 16.85 watts.

Result: