Yashoda Shiskshan Prsarak Mandal's
Yashoda Technical Campus
Approved by AICTE Delhi/ Govt. of Maharashtra/ Accredited by NAAC
NH-4, Wadhe, Satara 415011
Email : principalengg_ytc@yes.edu.in Call: 02162-271238/39 Mob. 9172220775
Faculty of Engineering

Department of Electrical Engineering

LABORATORY MANUAL

OF

ELECTRICAL MACHINE-I

FOR

S.Y. Semester – III

Name of Student:- ……………………………………………………..

Class:-…………………….   DIV:-……………

Roll No:-………………..   PRN No:-…………..

SEM:- ODD   Academic Year:-

Vision of the Department
To emerge as a center of excellence in Electrical Engineering education producing knowledgeable, employable, and ethical engineering graduates to serve industry/society

Mission of the Department
We, at Department of Electrical Engineering, are committed to achieve our vision by-
M1: Preparing technically and professionally competent engineers by imparting quality education through effective teaching learning methodologies.
M2: Developing professional skills and right attitude among students that will help them to succeed and progress in their personal and professional career.
M3: Inculcating moral and ethical values in students with concern to society and environment.

SAFTEY INSTRUCTIONS

1. **SAFETY** is of paramount importance in the **Electrical Engineering** Laboratories.
2. Electricity NEVER EXECUSES careless persons. So, exercise enough care and attention in handling **electrical** equipment and follow **safety** practices in the laboratory. (Electricity is a good servant but a bad master).
3. Avoid direct contact with any voltage source and power line voltages. (Otherwise, any such contact may subject you to **electrical** shock)
4. Wear rubber-soled shoes. (To insulate you from earth so that even if you accidentally contact a live point, current will not flow through your body to earth and hence you will be protected from **electrical** shock)
5. Wear laboratory-coat and avoid loose clothing. (Loose clothing may get caught on an equipment/instrument and this may lead to an accident particularly if the equipment happens to be a rotating machine)
6. Girl students should have their hair tucked under their coat or have it in a knot.
7. Do not wear any metallic rings, bangles, bracelets, wristwatches and neck chains. (When you move your hand/body, such conducting items may create a short circuit or may touch a live point and thereby subject you to **electrical** shock)
8. Be certain that your hands are dry and that you are not standing on wet floor. (Wet parts of the body reduce the contact resistance thereby increasing the severity of the shock)
9. Ensure that the power is OFF before you start connecting up the circuit.(Otherwise you will be touching the live parts in the circuit)
10. Get your circuit diagram approved by the staff member and connect up the circuit strictly as per the approved circuit diagram.
11. Check power chords for any sign of damage and be certain that the chords use **safety** plugs and do not defeat the **safety** feature of these plugs by using ungrounded plugs.
12. When using connection leads, check for any insulation damage in the leads and avoid such defective leads.
13. Do not defeat any **safety** devices such as fuse or circuit breaker by shorting across it. **Safety** devices protect YOU and your equipment.
14. Switch on the power to your circuit and equipment only after getting them checked up and approved by the staff member.
15. Take the measurement with one hand in your pocket. (To avoid shock in case you accidentally touch two points at different potentials with your two hands)
16. Do not make any change in the connection without the approval of the staff member.
17. In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up etc), switch off the power to your circuit immediately and inform the staff member.
18. Keep hot soldering iron in the holder when not in use.
19. After completing the experiment show your readings to the staff member and switch off the power to your circuit after getting approval from the staff member.

INDEX

Expt. No.	Title of Experiment	Date of Performance	Date of Submission	Sign of Faculty
1.	To perform the polarity test on single phase transformer			
2.	To perform the transformation ratio test on single phase transformer			
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4.	To perform the indirect loading test on three phase transformers to calculate efficiency			
5.	To draw the speed characteristics of DC shunt motor by- (1) Armature Control method (2) Field Control method			
6.	To perform the load test on DC Shunt motor			
7.	To study the magnetization, internal and External characteristics of a D. C. generator			
8.	To Study DC Machine and Starters for DC Shunt Motor.			

This is certify that …………..………………………………………………. and Roll No………………of S.Y. Electrical has completed all the experiment in the subject Electrical Machine-I during academic Year 2024-25.

Sign of Student **Sign of Faculty** **HOD- Electrical**

Experiment no. 1

Object

Polarity test on single phase transformer

Objectives

To Perform polarity test on single phase transformer

Theory

A polarity test of transformer is a method to ensure correct polarity alignment when connecting transformers in parallel. Current flows from a high voltage point to a low voltage point because of the potential difference. Electrical polarity describes the direction of this current flow. In a DC system, one pole is always positive, and the other is negative, so the current flows in one direction. In an AC system, the terminals change polarity periodically, changing the direction of the current. We use dot convention to identify the voltage polarity of the mutual inductance of two windings.
The two used conventions are:

- If a current enters the dotted terminal of one winding, then the voltage induced on the other winding will be positive at the dotted terminal of the second winding.
- If a current leaves the dotted terminal of one winding, then the polarity of the voltage induced in the other winding will be negative at the dotted terminal of the second winding.

Distribution transformers need to operate continuously and handle high demand during peak times. To manage this, we connect transformers in parallel. Paralleling is done by connecting same polarity terminals of the primary winding together. A similar procedure is done for the secondary winding. Paralleling will increase the power supplying capacity and also the reliability of the system.
We can categorise the polarity of the transformer to two types,

1. Additive Polarity
2. Subtractive Polarity

Additive Polarity
In additive polarity, the voltage (Vc) between the primary side (Va) and the secondary side (Vb) will be the sum of both high voltage and the low voltage, i.e. we will get Vc = Va + Vb

Subtractive Polarity
In subtractive polarity, the voltage (Vc) between the primary side (Va) and the secondary side (Vb) will be the difference of both high voltage and the low voltage, i.e. we will get Vc = Va – Vb

In subtractive polarity, if Vc = Va – Vb, it is a step-down transformer and if Vc = Vb – Va, it is a step-up transformer.

We use additive polarity for small-scale distribution transformers and subtractive polarity for large-scale transformers.

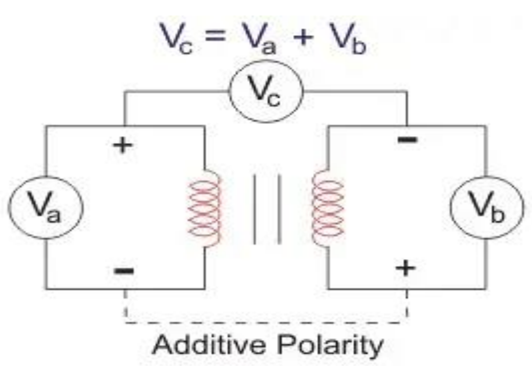
Apparatus

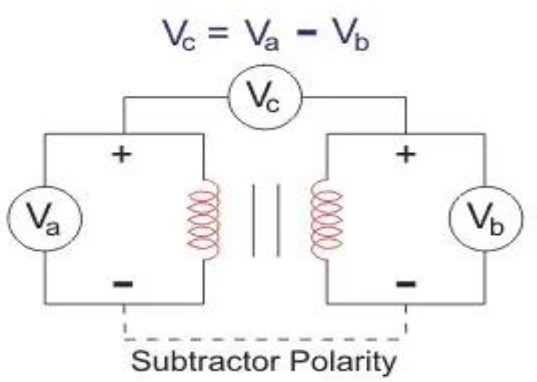
S.No.	Apparatus	Range	Type	Quantity
1	AC Voltmeter	0-300 V	MC	3
2	Transformer	230/230 V, 1KVA	Shell/Core type	1
3	Autotransformer	0-300V, 1KVA	-	1
4	Connecting Wires	2.5sq.mm.	Copper	Few

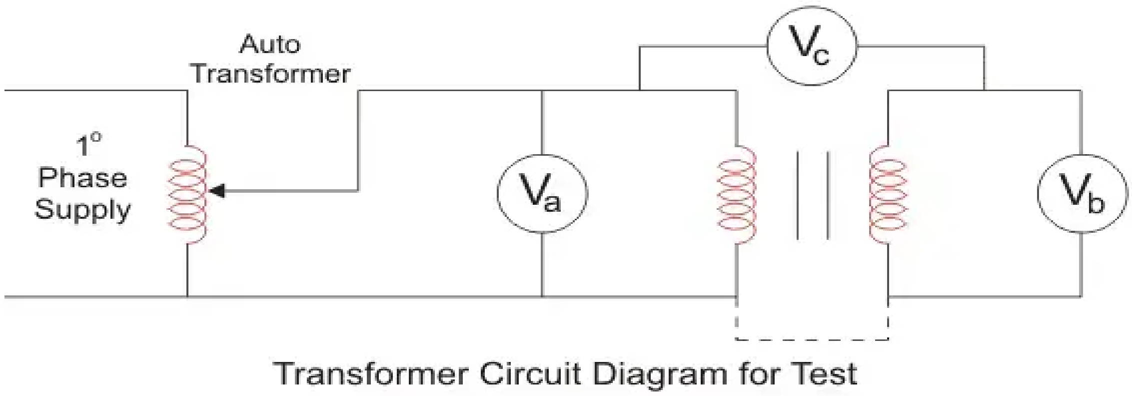
Procedure

1. Connect the circuit as shown above with a voltmeter (Va) across primary winding and another voltmeter (Vb) across the secondary winding.
2. If available, take down the ratings of the transformer and the turn ratio.
3. We connect a voltmeter (Vc) between primary and secondary windings.
4. Apply some voltage to the primary side.
5. By checking the value in the voltmeter (Vc), we can find whether it is additive or subtractive polarity.
6. If additive polarity – Vc should be showing the sum of Va and Vb.
7. If subtractive polarity – Vc should be showing the difference between Va and Vb.

Circuit Diagram







Precaution

Be careful that the max. measuring the voltage of voltmeter Vc should be greater than the sum of Va (Primary winding) and Vb (Secondary winding) otherwise during the additive polarity, the sum of Va and Vb comes across it.

Observation Table

Sr. No.	V1	V2	V3=V2+V1
1.			
2.			
3.			
4.			
5.			

Additive Polarity

Sr. No.	V1	V2	V3=V2-V1
1.			
2.			
3.			
4.			
5.			

Subtractive Polarity

Questions

1. What is transformer?
2. What are the different polarities of transformer?
3. What is the condition of additive polarity?
4. What is the condition for subtractive polarity.
5. What are the different types of transformers?
6. What is the use of autotransformer?
7. What is the use of polarity test?

Experiment no. 2

Object

Transformation ratio test on single phase transformer

Objectives

To perform the transformation ratio test on single phase transformer

Theory

The turns ratio of a single-phase transformer can be identified as the ratio of number of turns of the secondary coil (NS) to the number turns of the primary coil (NP).

The turns ratio is defined as k=NS/NP

As the frequency of the alternating current remains the same while flowing through the transformer, then the voltage per unit turn remains the same for both primary and secondary coils,

so that

$$VP/NP=VS/NS$$

$$=NS/NP=VS/VP$$

Thus, the turns ratio k=NS/NP=VS/VP

where, VS and VP are the corresponding voltage across the secondary and primary coils respectively. Further, the power on both sides of the transformer remains the same, then the power across the primary (PP) side will be equal to the power across the secondary (PS) side.

$$\text{i.e., } VP/IP=VS/IS$$

$$=Ip/IS=VS/VP$$

So, the turns ratio can be related as

$$k=VS/VP=IP/IS=NS/NP$$

Where, Ip and IS are the respective currents in the primary and secondary coils.

From the expression of the induced voltage in the transformer $E = 4.44 * f * N * \phi m$, the flux density (Bm) can be determined while the number of turns of primary coil (NP) or secondary coil (NS) and ϕm and cross-sectional area of the core are known. To determine the number of turns of primary and secondary coils an additional 10 turns are wound on the core, which is termed as tertiary coil.

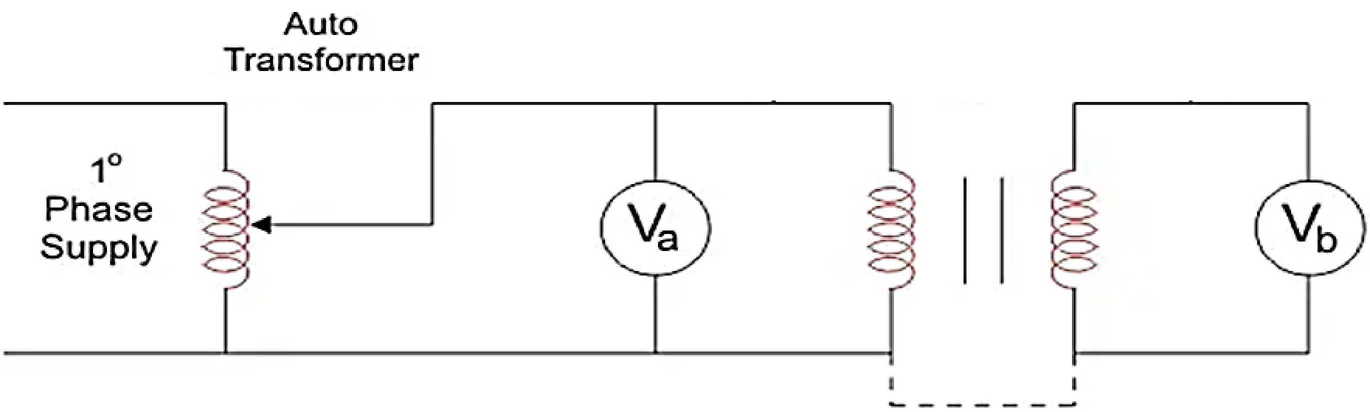
Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	AC Voltmeter	0-300 V	MC	2
2	Transformer	230/230 V, 1KVA	Shell/Core type	1
3	Autotransformer	0-300V, 1KVA	-	1
4	Connecting Wires	2.5sq.mm.	Copper	Few

Procedure

1. Connect all the instruments as per circuit diagram.
2. Now slowly increase the input voltage from the auto-transformer to the circuit and take the readings of voltmeters.
3. Calculate the unknown quantity as per given formulae.

Circuit Diagram



Transformer Circuit Diagram for Test

Precaution

1. Before connecting to the supply check the auto transformer and voltmeter reading/dial is at zero position.
2. Care should be taken for the connections to be tightened properly.

Observation Table

Sr. No.	V1	V2	K=V2/V1	Remark
1.				
2.				
3.				
4.				
5.				

Questions

1. What is the purpose of performing a polarity test on a transformer?
2. Describe the basic procedure for conducting a polarity test on a transformer.
3. What equipment is necessary to carry out a polarity test on a transformer?
4. Explain the significance of ensuring correct polarity in a transformer.
5. What can happen if a transformer is connected with incorrect polarity?

Experiment no. 3

Object

To perform the direct loading test on three phase transformers to calculate efficiency and regulation

Objectives

To conduct load test on three phase transformer and to find efficiency and percentage regulation of both transformers.

Theory

Transformer is a static devise which transfers the AC power from one circuit to another circuit by mutual induction principle. Since there are no rotating parts there are no friction &windage losses. The only losses in transformer are core or iron losses & copper losses. The core losses consists of eddy current loss & hysteresis loss, while copper losses consists of primary winding copper loss & secondary winding copper loss.

This is direct method of testing the transformer in which the transformer is loaded gradually from no load to full load. In this method output of machine is converted into heat in the lamps. The output is wasted, hence only small machines are tested by this method.

Efficiency:

The efficiency of transformer is defined as the ratio of output power to input power. Since the losses in transformer are very less, its efficiency is very high compared to all other types of rotating machines.

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

$$= \frac{\text{Output power}}{\text{Output power + Losses.}} \times 100$$

Regulation:

The change in secondary terminal voltage from no load to full load expressed in percentage of full load is known as Regulation of transformer.

$$\% \text{ Regulation} = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100$$

Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	AC Ammeter	(0-5)A	MI	2
2	Transformer	440/440	Shell/Core	1
3	Auto Transformer	0-440V	-	1
4	AC Voltmeter	(0-600) V	MI	2
5	Wattmeter	(600V, 10A)	Upf	2
5	Resistive Load	5KW, 230V	-	1
6	Connecting Wires	2.5sq.mm	Copper	Few

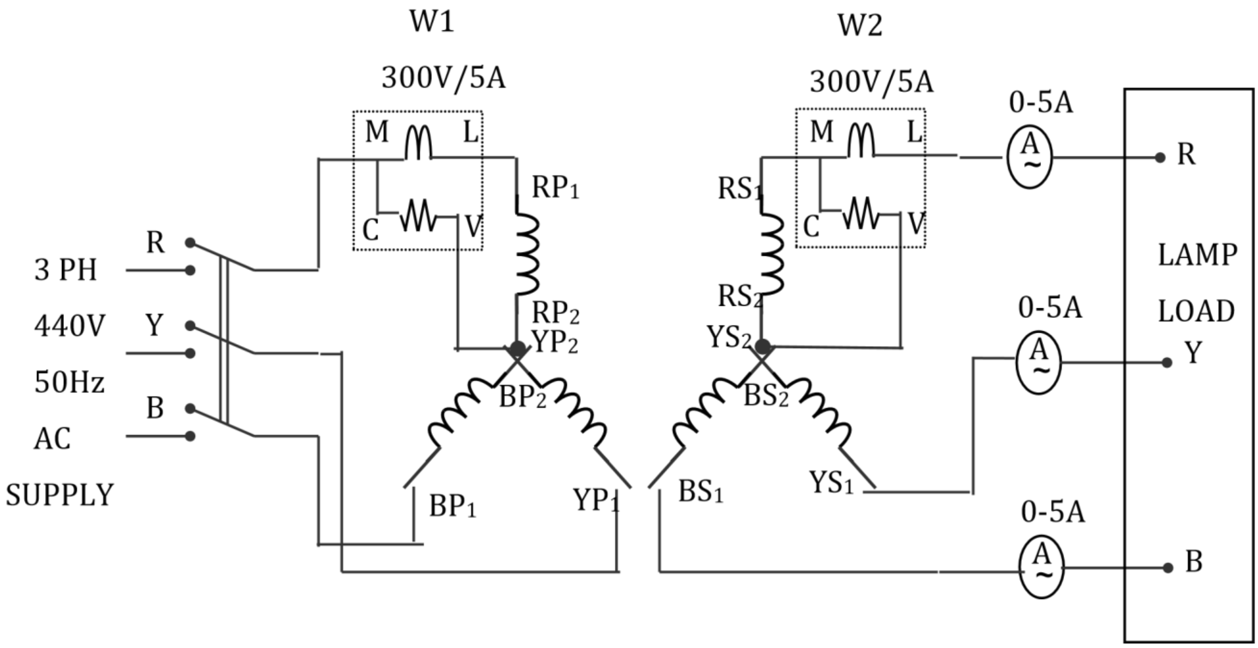
Procedure

1. Make the connections as shown in the circuit diagram.
2. Switch ON the supply.
3. At No load note the readings of Voltmeter, ammeter & wattmeter.
4. Load the transformer in steps by keeping balanced load on each phase.
5. At each step note the readings of all the meters connected.
6. Calculate the Efficiency & Regulation using appropriate formulae.
7. Plot the graph of Efficiency Vs Output Power.

Precaution

1. Connect the wattmeter strips at desired range of voltage & current.
2. Ensure all switches of lamp load are OFF before starting the experiment.
3. If wattmeter reading is in reverse direction then replace the connection of current coil of wattmeter.
4. Consider the multiplying factor of each wattmeter for calculation.

Circuit Diagram



Observation Table

No load secondary voltage V_{NL} = Volts.

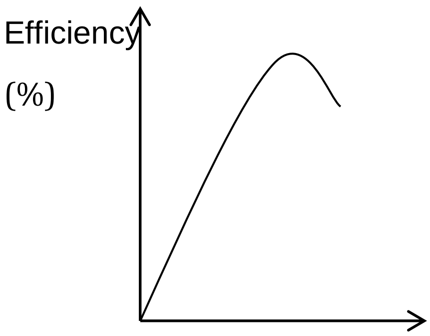
Sr. No	Load	Primary			Secondary			Input Power W1(watt)	Output Power W1(watt)	Efficiency η%	% Regulation
		V1 (Volt)	I1 A	W1 (Watts)	V2 (Volt)	I2 A	W2 (Watts)				

Sample Calculations

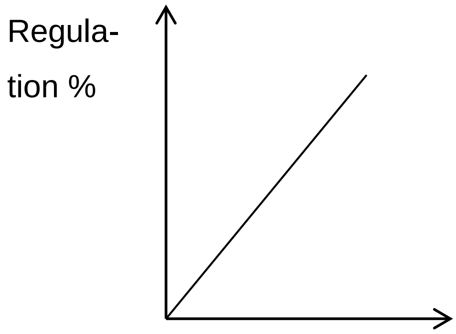
Output Power = W_2 x Multiplication factor
Input Power = W_1 x Multiplication factor

Efficiency η % = (Output Power/ Input Power)* 100%
Regulation R % = (V_{NL} - V_{FL} (Secondary)/ V_{NL} *100%

Sample graph



Output Power (W)



Load Current (A)

Result

The load test on single phase and three phase transformer is conducted.
a)Percentage Efficiency (% η) of Three phase transformer = ……………..%
b)Percentage Regulation (% R) of Three phase transformer = ……………..%

Questions

1. What are the causes of voltage drop in transformer?
2. How much is the voltage regulation for ideal transformer?
3. What are the various losses taking place in transformer?
4. State limitations of direct loading test?
5. What are the factors on which iron losses depends?
6. How will you minimize iron losses?
7. If transformer A & B has 3% & 4% voltage regulation respectively, then which one is better why?
8. What measure will you suggest to improve the efficiency of transformer?
9. What is the condition for maximum efficiency of a transformer?
10. Why is the efficiency of a transformer higher than that of motors?

Experiment no. 4

Object

To perform the indirect loading test on three phase transformers to calculate efficiency

Objectives

i) To predetermine the efficiency and regulation of a transformer by conducting open circuit test and short circuit test.

ii) To understand the basic working principle of a transformer.

iii) To obtain the equivalent circuit parameters from OC and SC tests, and to estimate efficiency & regulation at various loads.

Theory

Open circuit (OC) test:

The purpose of this test is to determine no load loss (core loss) and no load current I_0 which is helpful in finding X_0 and R_0. Since, the core loss and the magnetizing current depend on applied voltage, this test is performed by applying the rated voltage to one of the windings keeping the other winding open (generally HV winding is kept open and rated voltage is applied to LV winding). The ammeter, voltmeter and wattmeter are connected in low voltage winding (primary winding). Therefore normal flux will be set up in the core, hence normal iron loss will occur which are recorded by the wattmeter. As the primary no load current I_0 is small usually 2 to 10% of rated current copper loss is negligible in primary and nil in secondary. Hence the wattmeter reading represents practically the core loss under no load condition.

Since, the secondary terminals are open (no load is connected across the secondary), current drawn from the source is called as no load current. Under no-load condition the power input to the transformer is equal to the sum of losses in the primary winding resistance R_1 and core loss. Since, no load current is very small, the loss in winding resistance is neglected. Hence, on no load the power drawn from the source is dissipated as heat in the core. Here I_0 and P_i are the current and input power drawn by the transformer at rated voltage V_0 respectively. Sometimes a high resistance voltmeter is connected across the secondary it gives the induced emf in the secondary.

Short circuit (SC) test

In this test one winding usually the low voltage winding is short circuited by a thick conductor or by an ammeter. A low voltage usually 5 to 10% of normal primary voltage is applied to the primary and is gradually increased till full load currents are flowing in both primary and secondary. Since in this test the applied voltage is small percentage of normal voltage, the mutual flux produced is also a small percentage of its normal value. Hence core losses are very small with the result that the wattmeter reading represent the full load copper loss for both winding. Hence, the power input on short circuit is dissipated as heat in the winding.

Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	AC Ammeter	(0-5)A	MI	32
2	Transformer	440/440	Shell/Core	1
3	Auto Transformer	0-440V	-	1
4	AC Voltmeter	(0-600) V	MI	1
5	Wattmeter	(600V, 10A)	Upf	2
6	Connecting Wires	2.5sq.mm	Copper	Few

Procedure

OPEN CIRCUIT TEST:

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

SHORT CIRCUIT TEST:

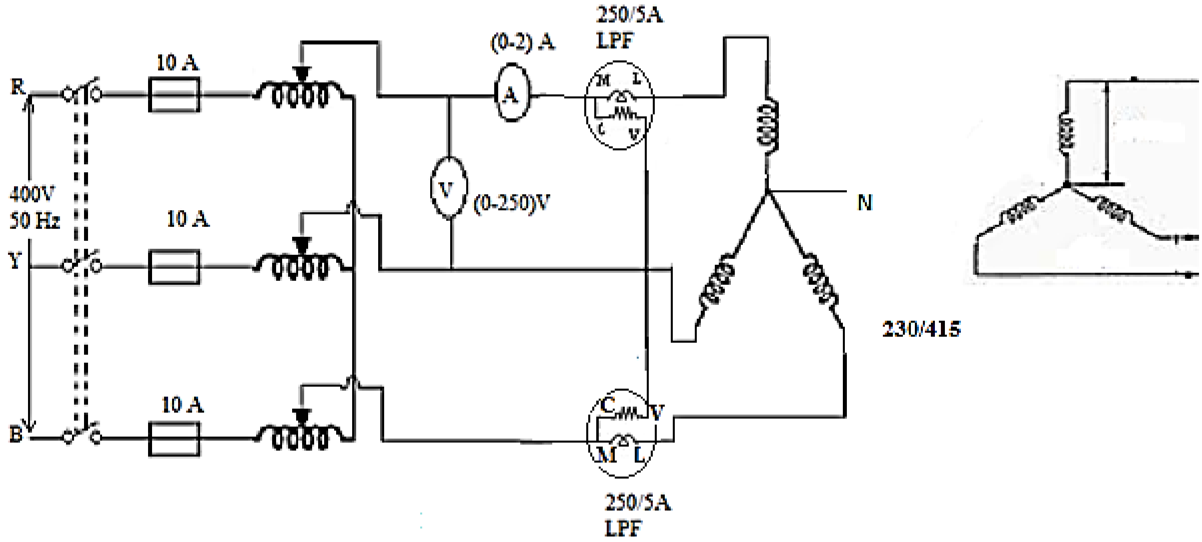
1. Connections are made as per the circuit diagram.
2. After checking the minimum position of Autotransformer, DPST switch is closed.
3. Auto transformer variac is adjusted get the rated primary current.
4. Voltmeter, Ammeter and Wattmeter readings on primary side are noted.
5. Auto transformer is again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

Precaution

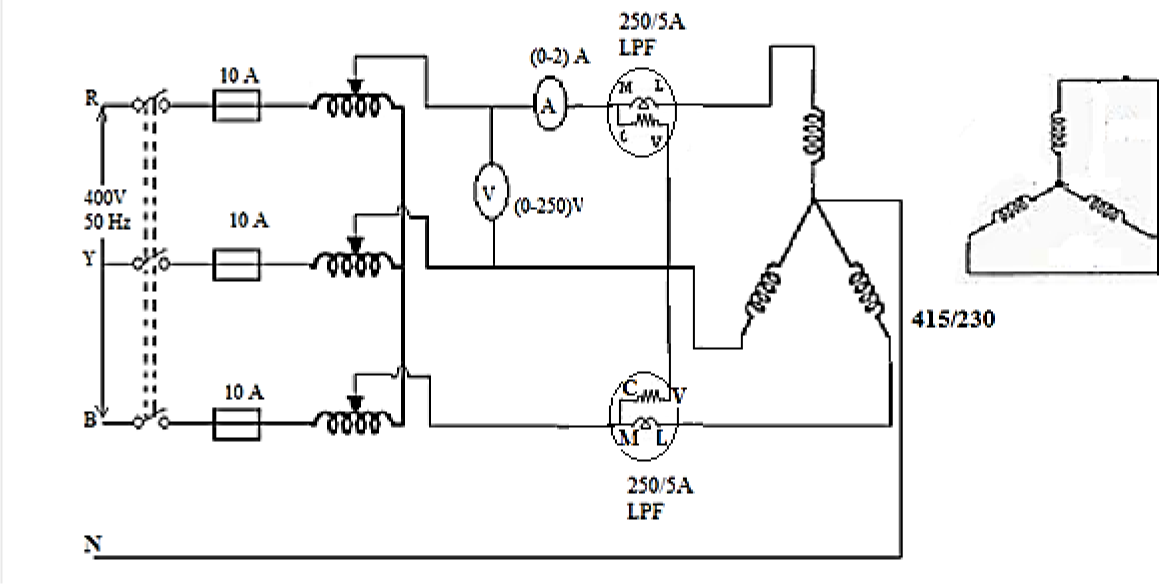
1. Auto Transformer should be in minimum voltage position at the time of c losing& opening DPST Switch.

Circuit Diagram

OC TEST



SC TEST



Observation Table

1. **Open Circuit Test**

Sr. No.	Open Circuit Voltage Voc	Ope Circuit Current Ioc	Open Circuit Power Woc

2. Short Circuit Test

Sr. No.	Short Circuit Voltage Vsc	Short Circuit Current Isc	Short Circuit Power Wsc

Calculations

Core loss:

$W_0 = V_0 I_0 \cos\Phi_0$

$\cos\Phi_0 = (W_0)/V_0 I_0$ $\Phi_0 = \cos^{-1}(W_0/V_0 I_0)$

$Z_{02} = (V_{sc}/I_{sc})\Omega$ $R_{02} = W_{sc}/(I_{sc})^2\ \Omega$

$X_{02} = (Z_{02}^2 - R_{02}^2)^{1/2}\ \Omega$ $K = V_2/V_1 = 2$

$R_{02} = W_{sc}/I_{sc}^2\Omega$ $R_{01} = R_{02}/K^2\ \Omega$

$R_0 = V_0/I_w\ \Omega$ $X_0 = V_0/I_\mu\ \Omega$

Percentage Efficiency: for all loads and p.f.

$$\%\text{Efficiency } \eta = \frac{\text{Output Power}}{\text{Input Power}} * 100 = \frac{(X) \times \text{KVA rating} \times 1000 \times \cos\Phi}{\text{Output power + losses}} * 100$$

$$= \frac{(X) \times \text{KVA rating} \times 1000 \times \cos\Phi}{(X) \times \text{KVA rating} \times 1000 \times \cos\Phi + W_o + X^2 W_{sc}} * 100$$

Percentage Regulation:

+ = lagging

- = leading

$$R\% = \frac{(X) \times I_{sc} (R_{o2} \cos\phi \pm X_{o2} \sin\Phi) \times 100}{V_2}$$

Where X is the load and it is 1 for full load, ½ for half load, ¾ load, ¼ load etc.. and the power factor is, unity p.f, o.8 p.f lag and 0.8 p.f lead

Result

Thus the efficiency and regulation of a transformer is predetermined by conducting open circuit test and short circuit test

% Efficiency =……….%

% Regulation= ……….%

Questions

1) Which winding (LV or HV) should be kept open while conducting OC test? Justify your answer.
2) What is the purpose of OC and SC tests?
3) Why is the core of a transformer laminated?
4) What is meant by regulation?
5) Define the term transformation ratio?
6) What are the components of no load current?
7) What are the parameters of the equivalent circuit?

Experiment no. 5

Object

Speed control of DC Shunt motor

Objectives

To draw the speed characteristics of DC shunt motor by- (1) Armature Control method (2) Field Control method

Theory

From the voltage equation of dc shunt motor,

We have,

$$V = E_b + I_a R_a$$

$$E_b = V - I_a R_a \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Also,

$$E_b = \frac{P\text{Ø}ZN}{60A}$$

$$N = \frac{E_b\, 60\, A}{\text{Ø}PZ} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

$$N \,\alpha\, \frac{E_b}{\text{Ø}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$ [Since all other terms are constant.]

Putting eqn (1) in (3).

$$N \,\alpha\, \frac{V - Ia\, Ra}{\text{Ø}}$$

Thus, from this equation it is seen that speed of dc shunt motor can be changed by,

a. Changing the flux Ø. i.e. by adding resistance in field circuit.
b. Changing $I_a R_a$ or armature voltage. i.e. by adding resistance in armature circuit.

A) Speed Control by Changing Armature Voltage.

This method is also called as Rheostatic control method or Armature Voltage control method. In this method a variable resistor is connected in the armature circuit with the help of which the armature voltage can be changed (From normal to lesser values). This causes decrease in armature voltage & thus decrease in speed. This method is used to get the speed below normal speed. The waste of power due to resistance in armature circuit is very high. Therefore in this method the efficiency of motor is affected. So this method is used for speed control of short duration.

B) Speed Control by Changing Flux.

This method is also called as flux control method or field current control method. In this method a variable resistor is connected in the field circuit with the help of which the field current can be decreased. This causes decrease in flux & thus increase in speed.

This method is used to get the speed above normal speed. The waste of power due to resistance in field circuit is very small. Therefore in this method the efficiency of motor is not affected much.

Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	DC Ammeter	(0-5A)	MC	1
2	DC Shunt Motor	220V, 1500 RPM, 1HP	Shunt	1
3	DC Voltmeter	(0-300)V	MC	1
4	Rheostat	100Ω/5A, and 290Ω/2.8A	Wire Wound	1
5	Tachometer	(0-3000) rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

Procedure

A) Armature Voltage Control

- Make the Connections as shown in the circuit diagram.
- Switch ON the supply & start the motor with the help of starter
- Keep field current (I_f) at a constant value by varying the rheostat in field circuit.
- Change the armature voltage (V_a) in steps by varying the rheostat in armature circuit.
- Note down the corresponding values of Speed.
- Plot the graph of Speed (N) Vs Armature voltage (Va).

B) Flux Control Method

- Make the connections as shown in the circuit diagram.
- Switch ON the supply & start the motor with the help of starter
- Keep armature voltage V_a at a constant value by varying the rheostat in armature circuit.
- Change the field current in steps by varying rheostat in field circuit.
- N

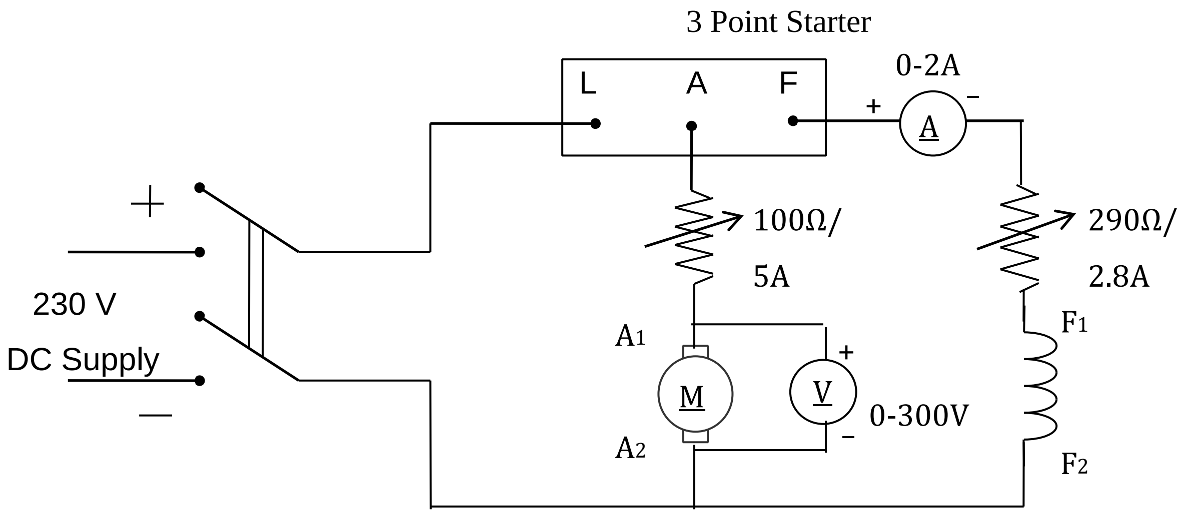
ote down the corresponding values of Speed at each step.

- Plot the graph of Speed (N) Vs Field current (I_f).

Precaution

- Keep the rheostat in armature circuit at its maximum position.
- Keep the rheostat in field circuit at its minimum position.

Circuit Diagram



Observation Table

A) Speed Control by Changing Armature Voltage

Field Current (constant) =………. amp.

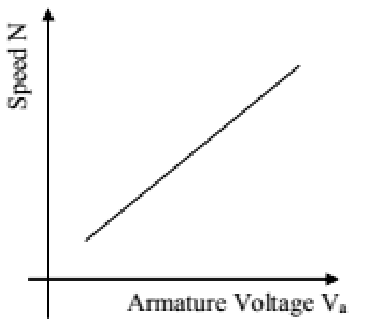
Sr No	Armature Voltage V_a(Volt)	Speed N (rpm)
1		
2		
3		
4		
5		

B) Speed Control by Changing Flux.

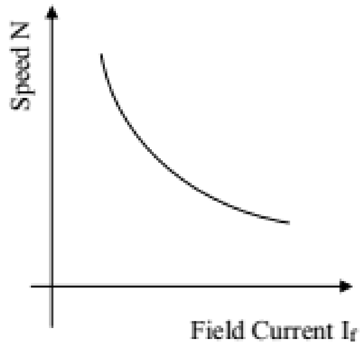
Armature Voltage (constant) =……… Volts.

Sr No	Field Current (I_f) amp	Speed(N) rpm
1		
2		
3		
4		
5		

Nature of graph for Flux control method



Armature Voltage Control method



Flux Control method

Questions Speed Control by Changing Flux

1. Can you get fine speed control with this method?
2. What are the applications of variable speed motor?
3. State the factors on which Speed of DC Motor depends.
4. What will happen, if the field circuit rheostat is kept maximum while starting the motor?
5. What will happen, if the field circuit gets open during the running condition?
6. What is the effect of saturation on motor speed?
7. Why the speed of dc shunt motor is considered practically constant?
8. State the factors on which Speed of DC Motor depends
9. What will happen if resistance in armature circuit is very high at starting?
10. What are the advantages & disadvantages of this method?

Experiment no. 6

Object

Load test on DC Shunt motor.

Objectives

To perform the load test on DC Shunt motor

Theory

This is direct method of testing the motor in which the motor is loaded gradually from no load to full load. The pulley is fitted on the shaft of a motor. A rope or leather belt is wound round the pulley & its two ends are attached to two spring balances F_1& F_2. The tension of the belt can be adjusted with the help of the wheel.

The force acting tangentially on the pulley is equal to the difference between two spring balance readings.

i.e. $F = (F_1 - F_2)$

If r = radius of pulley in meters,

N = speed in rpm,

Advantages of Break load test.

1. It is direct method of testing.
2. Temperature rise of machine can be noted.
3. Results are accurate.
4. Any type of motor Shunt, Series or Compound can be tested.

Disadvantages of Break load test.

1. Not suitable for large machines.
2. Limitations due to brake friction, burning of belt etc.
3. Energy is wasted in testing.
4. Requires large time for testing.

Precaution

1. Keep the rheostat in armature circuit at its maximum position.
2. Keep the rheostat in field circuit at its minimum position.

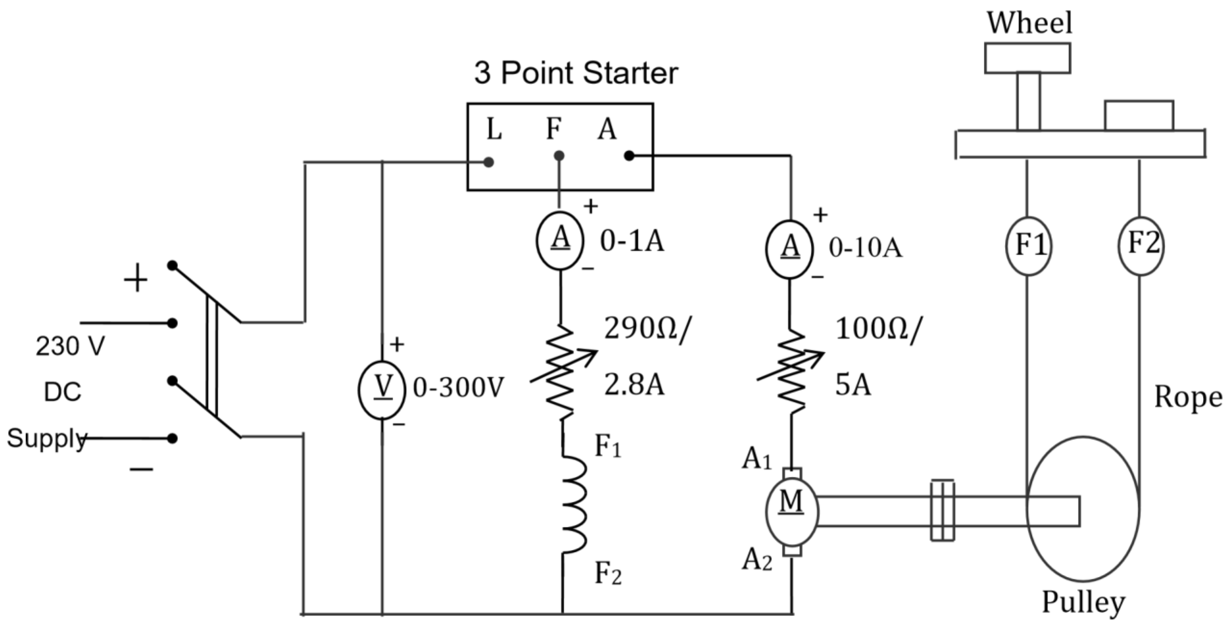
Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	DC Ammeter	(0-10)A	MC	1
2	DC Shunt Motor	220V, 1500 RPM, 1HP	Shunt	1
3	DC Voltmeter	(0-300)V	MC	1
4	Rheostat	100Ω/5A	Wire Wound	1
5	Tachometer	(0-3000) rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

Procedure

1. Make the connections as shown in the circuit diagram.
2. Switch ON the supply & start the motor with the help of starter
3. Adjust the rheostat in armature circuit & set the motor speed at its rated value.
4. At No load note the readings of Voltmeter, ammeter & tachometer.
5. Load the motor in steps by moving the wheel on rope-pulley arrangement.
6. At each step note the readings of all the meters & spring balance readings F_1 & F_2.
7. Calculate the Torque, Output Power, Input Power & Efficiency using appropriate formulae.
8. Plot the graph of Efficiency Vs O/P power Torque Vs O/P power Speed Vs O/P power & Speed Vs Torque.

Circuit diagram



Observation Table

Circumference of the Brake drum = cm.

Sr. No	Voltage V(Volts)	Current I(Amp)	Spring Balance Reading		(F_1-F_2) Kg	Speed N(rpm)
			F_1(Kg)	F_2(Kg)		

Sample Calculations

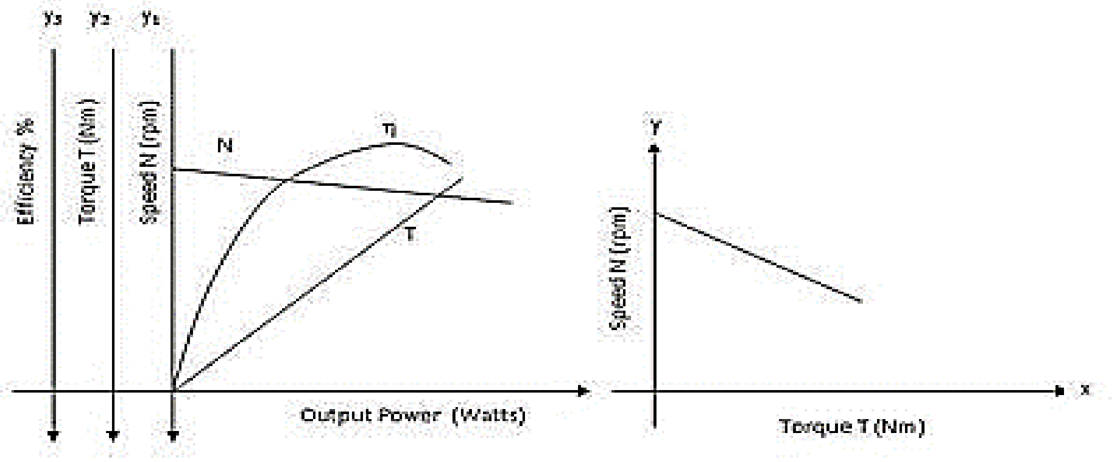
Torque $T = (S_1 \sim S_2) \times r \times 9.81$ Nm Where **r** is the radius of drum in meter

Input Power $P_i = VI$ Watts

$$\text{Output Power } P_m = \frac{2\pi N * T}{60} \text{ Watts}$$

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

Nature of graph



Result

Average efficiency of shunt motor is, η % =………..%

Conclusion

From this experiment we studied the direct loading test of dc shunt motor by using pulley and rope arrangement and calculate the percentage efficiency of dc motor.

Questions

1. What is the purpose of brake test on dc shunt motor?
2. What are the limitations of brake load test?
3. Why cooling is necessary for brake drum?
4. Why brake test is used only for small capacity of dc motor?
5. Comment on the nature of efficiency curve?
6. State the importance of performing a load test on dc shunt motor?
7. When does the efficiency of motor become maximum?

Experiment no. 7

Object

Open Circuit Characteristics of a D.C. Shunt Generator

Objectives

To study the magnetization, internal and External characteristics of a D. C. generator

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.

$$Eg = \frac{PZNP}{60\,A} \text{ Volts}$$

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)

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.

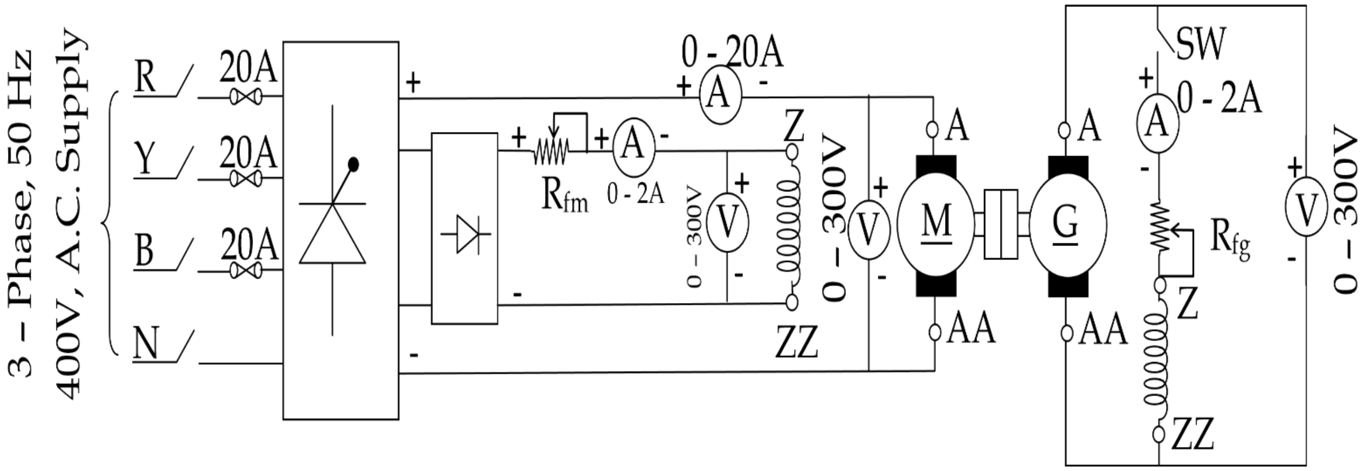
Apparatus

S.No.	Apparatus	Range	Type	Quantity
1	DC Motor-Shunt Generator set	220V, 1500 RPM,3HP	Shunt	1
2	DC Voltmeter	0-300 V	MC	2
3	DC Ammeter	0-10A	MC	2
4	DC Ammeter	0-2A	MC	2
5	Tachometer	(0-3000) rpm	Digital	1
6	Connecting Wires	2.5sq.mm.	Copper	Few

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.

Circuit Diagram



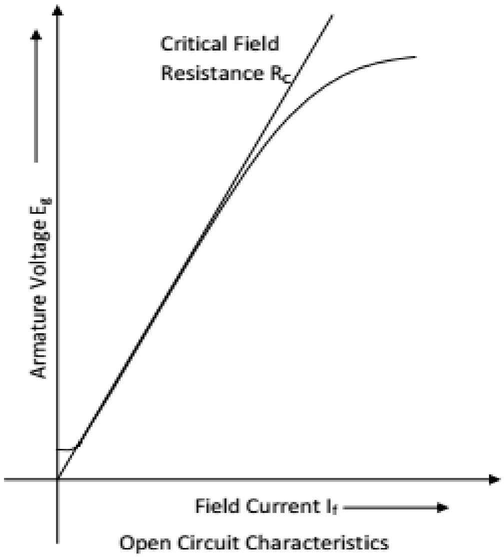
Precaution

Keep the rheostat in armature circuit at its maximum position.
Keep the rheostat in field circuit at its minimum position.

Observation Table

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

Nature of graph



Questions

1. List the parts of DC generator.
2. How DC generator works?
3. What are the different types of windings in DC generator?
4. Define Pole pitch, coil pitch, pitch factor, distribution factor
5. What are types of DC generator?
6. What are the applications of DC Generator?

Experiment no. 8

Object

To Study DC Machine and Starters for DC Motor.

Objectives

1. To Study DC Machine its construction and working
2. To study different types of starters for DC Motor.

Theory

Construction of DC Machine

The d.c. generators and d.c. motors have the same general construction. In fact, when the machine is being assembled, the workmen usually do not know whether it is a d.c. generator or motor. Any d.c. generator can be run as a d.c. motor and vice-versa. All d.c. machines have five principal components viz., (i) field system (ii) armature core (iii) armature winding (iv) commutator brushes [See Fig. 1.7].

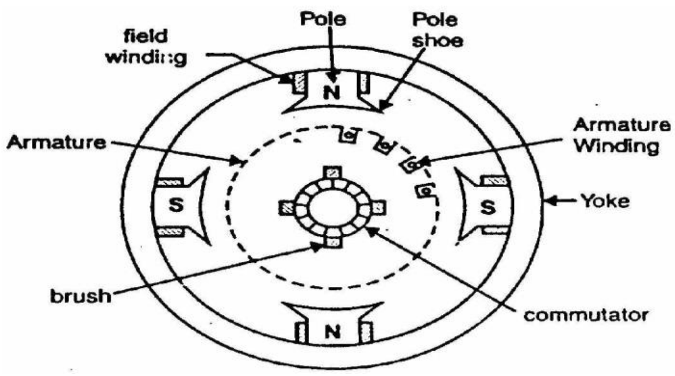


Fig. (1.7)

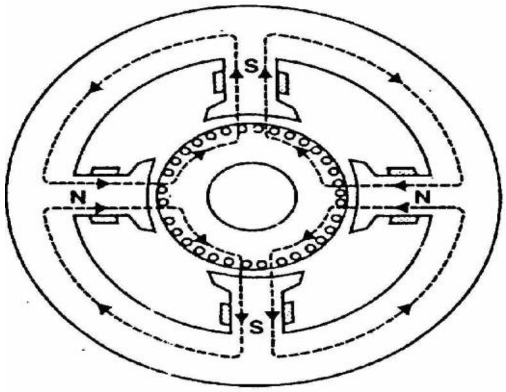


Fig. (1.8)

(i) Field system

The function of the field system is to produce uniform magnetic field within which the armature rotates. It consists of a number of salient poles (of course, even number) bolted to the inside of circular frame (generally called yoke). The yoke is usually made of solid cast steel whereas the pole pieces are composed of stacked laminations. Field coils are mounted on the poles and carry the d.c. exciting current. The field coils are connected in such a way that adjacent poles have opposite polarity.

The m.m.f. developed by the field coils produces a magnetic flux that passes through the pole pieces, the air gap, the armature and the frame (See Fig. 1.8). Practical d.c. machines have air gaps ranging from 0.5 mm to 1.5 mm. Since armature and field systems are composed of materials that have high permeability, most of the m.m.f. of field coils is required to set up flux in the air gap. By reducing the length of air gap, we can reduce the size of field coils (i.e. number of turns).

(ii) Armature core

The armature core is keyed to the machine shaft and rotates between the field poles. It consists of s lotted soft-iron laminations (about 0.4 to 0.6 mm thick) that are stacked to form a cylindrical core as shown in Fig (1.9). The laminations (See Fig. 1.10) are individually coated with a thin insulating film so that they do not come in electrical contact with each other. The purpose of laminating the core is to reduce the eddy current loss. The laminations are slotted to accommodate and provide mechanical security to the armature winding and to give shorter air gap for the flux to cross between the pole face and the armature

“teeth”.

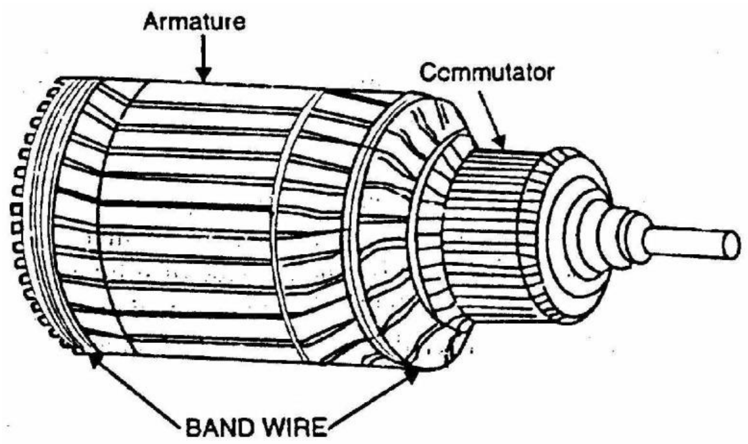


Fig. (1.9)

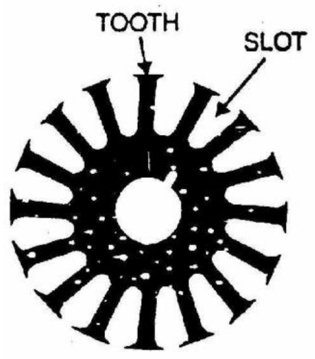


Fig. (1.10)

(iii) Armature winding

The slots of the armature core hold insulated conductors that are connected in a suitable manner. This is known as armature winding. This is the winding in which “working” e.m.f. is induced. The armature conductors are connected in series-parallel; the conductors being connected in series so as to increase the voltage and in parallel paths so as to increase the current. The armature winding of a d.c. machine is a closed-circuit winding; the conductors being connected in a symmetrical manner forming a closed loop or series of closed loops.

(iv) Commutator

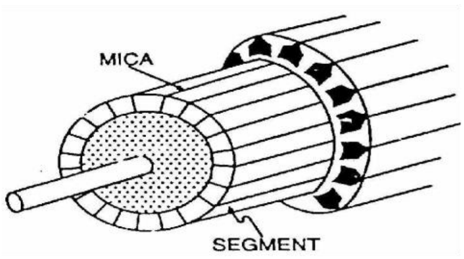
A commutator is a mechanical rectifier which converts the alternating voltage generated in the armature winding into direct voltage across the brushes. The commutator is made of copper segments insulated from each other by mica sheets and mounted on the shaft of the machine (See Fig 1.11). The armature conductors are soldered to the commutator segments in a suitable manner to give rise to the armature winding. Depending upon the manner in which the armature conductors are connected to the commutator segments, there are two types of armature winding in a d.c. machine viz., (a) lap winding (b) wave winding.

Great care is taken in building the commutator because any eccentricity will cause the brushes to bounce, producing unacceptable sparking. The sparks may bum the brushes and overheat and carbonise the commutator.

(v) Brushes

The purpose of brushes is to ensure electrical connections between the rotating commutator and stationary external load circuit. The brushes are made of carbon and rest on the commutator. The b

rush pressure is adjusted by means of adjustable springs (See Fig. 1.12). If the brush pressure is very large, the friction produces heating of the commutator and the brushes. On the other hand, if it is
too weak, the imperfect contact with the commutator may produce sparking.



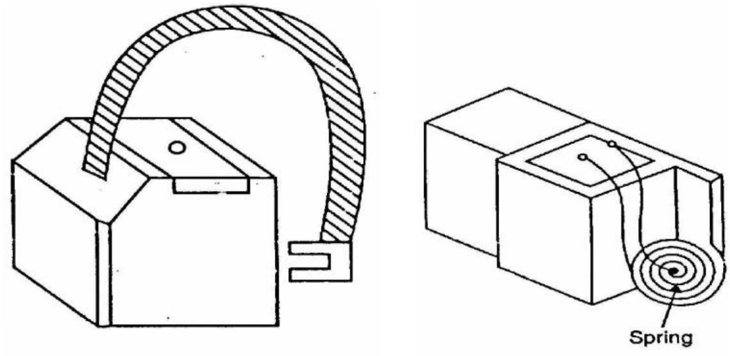


Fig. (1.11) **Fig. (1.12)**

Multipole machines have as many brushes as they have poles. For example, a 4pole machine has 4 brushes. As we go round the commutator, the successive brushes have positive and negative polarities. Brushes having the same polarity are connected together so that we have two terminals viz., the +ve terminal and the −ve terminal.

1.5 General Features OF D.C. Armature Windings

(i) A d.c. machine (generator or motor) generally employs windings distributed in slots over the circumference of the armature core. Each conductor lies at right angles to the magnetic flux and to the direction of its movement Therefore, the induced e.m.f. in the conductor is given by; e = B□v volts

where B = magnetic flux density in Wb/m^2 □ = length of the conductor in metres v = velocity (in m/s) of the conductor

(ii) The armature conductors are connected to form coils. The basic component of all types of armature windings is the armature coil. Fig. (1.13) (i) shows a single-turn coil. It has two conductors or coil sides connected at the back of the armature. Fig. 1.13 (ii) shows a 4-turn coil which has 8 conductors or coil sides.

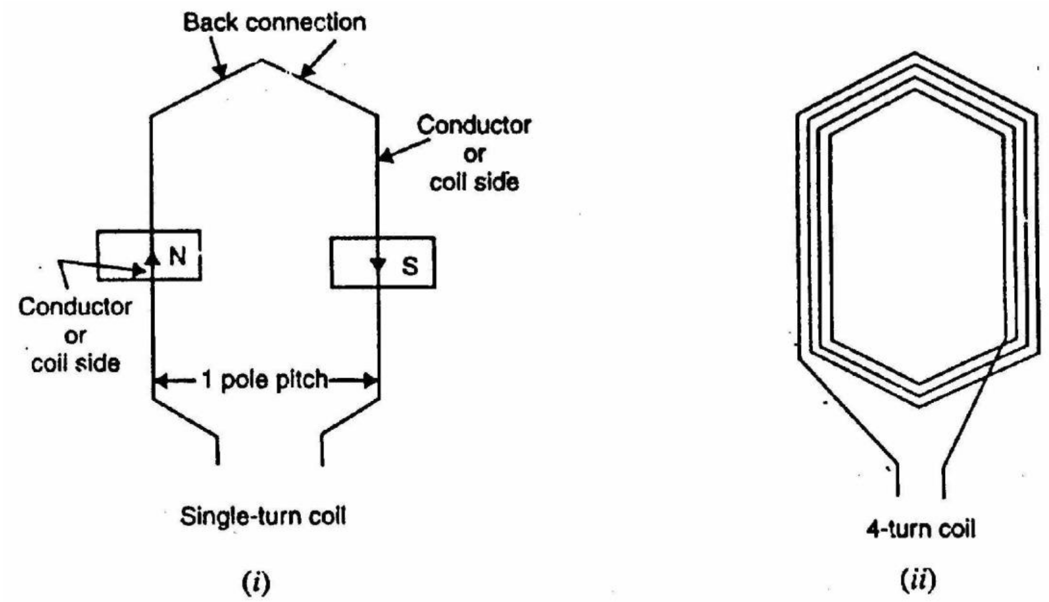


Fig. (1.13)

The coil sides of a coil are placed a pole span apart i.e., one coil side of the coil is under N-pole and the other coil side is under the next S-pole at the corresponding position as shown in Fig. 1.13 (i). Consequently the e.m.f.s of the coil sides add together. If the e.m.f. induced in one conductor is 2.5 volts, then the e.m.f. of a single-turn coil will be = 2 × 2.5 = 5 volts. For the same flux and speed, the e.m.f. of a 4-turn coil will be = 8 × 2.5 = 20 V.

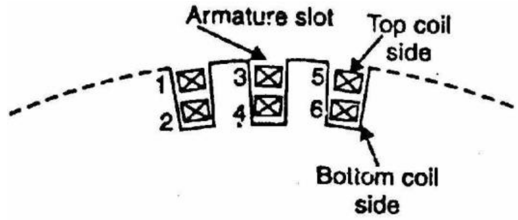
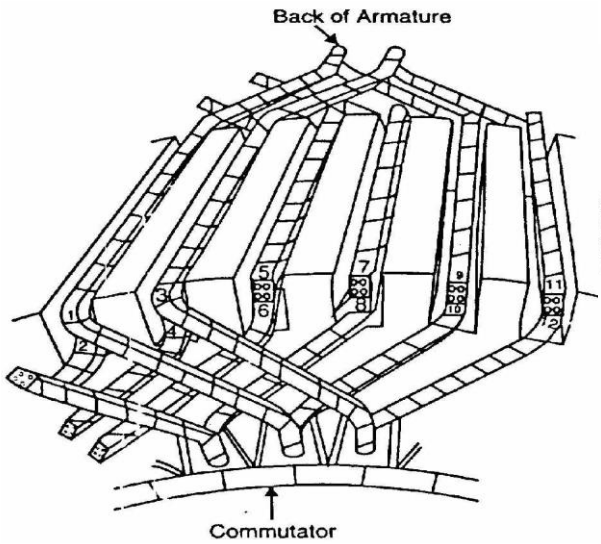


Fig. (1.14)

(iii) Most of d.c. armature windings are double layer windings i.e., there are two coil sides per slot as shown in Fig. (1.14). One coil side of a coil lies at the top of a slot and the other coil side lies at the bottom of some other slot. The coil ends will then lie side by side. In two-layer winding, it is desirable to number the coil sides rather than the slots. The coil sides are numbered as indicated in Fig. (1.14) . The coil sides at the top of slots are given odd numbers and those at the bottom are given even numbers. The coil sides are numbered in order round the armature.

As discussed above, each coil has one side at the top of a slot and the other side at the bottom of another slot; the coil sides are nearly a pole pitch apart. In connecting the coils, it is ensured that top coil side is joined to the bottom coil side and vice-versa. This is illustrated in Fig. (1.15). The coil side 1 at the top of a slot is joined to coil side 10 at the bottom of another slot about a pole pitch apart. The coil side 12 at the bottom of a slot is joined to coil side 3 at the top of another slot. How coils are connected at the back of the armature and at the front (commutator end) will be discussed in later sections. It may be noted that as far as connecting the coils is concerned, the number of turns per coil is immaterial. For simplicity, then, the coils in winding diagrams will be represented as having only one turn (i.e., two conductors).



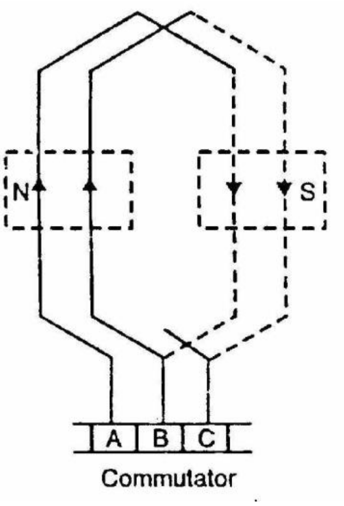


Fig. (1.15) **Fig. (1.16)**

(iv) The coil sides are connected through commutator segments in such a manner as to form a series-parallel system; a number of conductors are connected in series so as to increase the voltage and two or more such series-connected paths in parallel to share the current. Fig. (1.16) shows how the two coils connected through commutator segments (A, R, C etc) have their e.m.f.s added together. If voltage induced in each conductor is 25 V, then voltage between segments A and C = 4 × 2.5 = 10 V. It may be noted here that in the conventional way of representing a developed armature winding, full lines represent top coil sides (i.e., coil sides lying at the top of a slot) and dotted lines represent the bottom coil sides (i.e., coil sides lying at the bottom of a slot).

(v) The d.c. armature winding is a closed circuit winding. In such a winding, if one starts at some point in the winding and traces through the winding, one will come back to the starting point without passing through any external connection. D.C. armature windings must be of the closed type in order to provide for the commutation of the coils.

1.6 Commutator Pitch (Y_C)

The commutator pitch is the number of commutator segments spanned by each coil of the winding. It is denoted by Y_C.

In Fig. (1.17), one side of the coil is connected to commutator segment 1 and the other side connected to commutator segment 2. Therefore, the number of commutator segments spanned by the coil is 1 i.e., $Y_C = 1$. In Fig. (1.18), one side of the coil is connected to commutator segment 1 and the other side to commutator segment 8. Therefore, the number of commutator segments spanned by the coil = 8 − 1 = 7 segments i.e., $Y_C = 7$. The commutator pitch of a winding is always a whole number. Since each coil has two ends and as two coil connections are joined at each commutator segment,

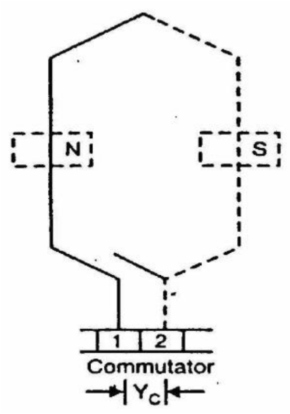


Fig. (1.17)

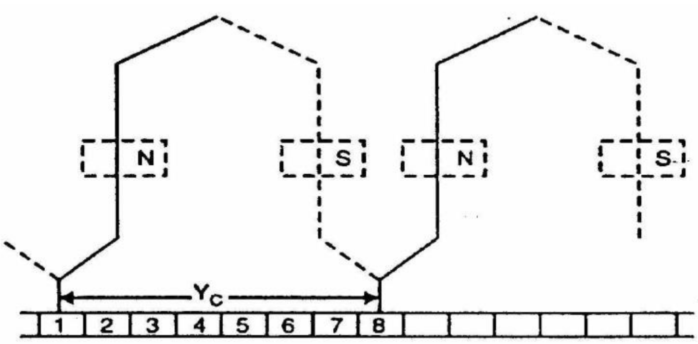


Fig. (1.18)

∴ Number of coils = Number of commutator segments

For example, if an armature has 30 conductors, the number of coils will be 30/2 = 15. Therefore, number of commutator segments is also 15. Note that commutator pitch is the most important factor in determining the type of d.c. armature winding.

1.7 Pole-Pitch

It is the distance measured in terms of number of armature slots (or armature conductors) per pole. Thus if a 4-pole generator has 16 coils, then number of slots = 16.

$$\therefore \quad \text{Pole pitch} = \frac{16}{4} = 4 \text{ slots}$$

Also $\text{Pole pitch} = \frac{\text{No.of conductors}}{\text{No.of poles}} = \frac{16 \times 2}{4} = 8 \text{ conductors}$

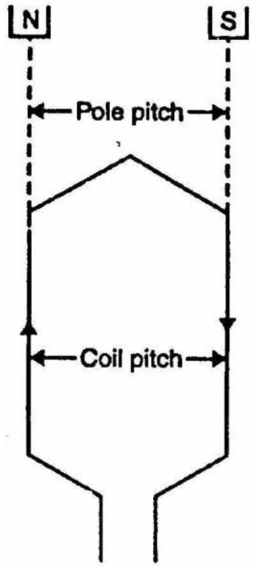
1.8 Coil Span or Coil Pitch (Y_S)

It is the distance measured in terms of the number of armature slots (or armature conductors) spanned by a coil. Thus if the coil span is 9 slots, it means one side of the coil is in slot 1 and the other side in slot 10.

1.9 Full-Pitched Coil

If the coil-span or coil pitch is equal to pole pitch, it is called full-pitched coil (See Fig. 1.19). In this case, the e.m.f.s in the coil sides are additive and have a phase difference of 0°. Therefore, e.m.f. induced in the coil is maximum. If e.m.f. induced in one coil side is 2-5 V, then e.m.f. across the coil terminals = 2 × 2.5 = 5 V. Therefore, coil span should always be one pole pitch unless there is a good reason for making it shorter.

Fractional pitched coil. If the coil span or coil pitch is less than the pole pitch, then it is called fractional pitched coil (See Fig. 1.20). In this case, the phase difference between the e.m.f.s in the two coil sides will not be zero so that the e.m.f. of the coil will be less compared to full-pitched coil. Fractional pitch winding requires less copper but if the pitch is too small, an appreciable reduction in the generated e.m.f. results.



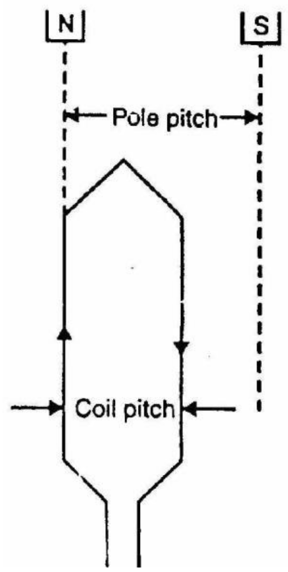


Fig. (1.19) **Fig. (1.20)**

DC Motor Starters

Necessity of D.C. Motor Starter

At starting, when the motor is stationary, there is no back e.m.f. in the armature. Consequently, if the motor is directly switched on to the mains, the armature will draw a heavy current ($I_a = V/R_a$) because of small armature resistance. As an example, 5 H.P., 220 V shunt motor has a full-load current of 20 A and an armature resistance of about 0.5 W. If this motor is directly switched on to supply, it would take an armature current of 220/0.5 = 440 A which is 22 times the full-load current. This high starting current may result in:

1. burning of armature due to excessive heating effect,
2. damaging the commutator and brushes due to heavy sparking,
3. excessive voltage drop in the line to which the motor is connected. The result is that the operation of other appliances connected to the line may be impaired and in particular cases, they may refuse to work.

In order to avoid excessive current at starting, a variable resistance (known as starting resistance) is inserted in series with the armature circuit. This resistance is gradually reduced as the motor gains speed (and hence E_b increases) and eventually it is cut out completely when the motor has attained full speed. The value of starting resistance is generally such that starting current is limited to 1.25 to 2 times the full-load current.

Types of D.C. Motor Starters

The stalling operation of a d.c. motor consists in the insertion of external resistance into the armature circuit to limit the starting current taken by the motor and the removal of this resistance in steps as the motor accelerates. When the motor attains the normal speed, this resistance is totally cut out of the armature circuit. It is very important and desirable to provide the starter with protective devices to enable the starter arm to return to OFF position

1. when the supply fails, thus preventing the armature being directly across the mains when this voltage is

restored. For this purpose, we use no-volt release coil.

2. when the motor becomes overloaded or develops a fault causing the motor to take an excessive current. For this purpose, we use overload release coil.

There are two principal types of d.c. motor starters viz., three-point starter and four-point starter. As we shall see, the two types of starters differ only in the manner in which the no-volt release coil is connected.

Three-Point Starter

This type of starter is widely used for starting shunt and compound motors.

Schematic diagram

Fig. shows the schematic diagram of a three-point starter for a shunt motor with protective devices. It is so called because it has three terminals L, Z and A. The starter consists of starting resistance divided into several sections and connected in series with the armature. The tapping points of the starting resistance are brought out to a number of studs. The three terminals L, Z and A of the starter are connected respectively to the positive line terminal, shunt field terminal and armature terminal. The other terminals of the armature and shunt field windings are connected to the negative terminal of the supply. The no-volt release coil is connected in the shunt field circuit. One end of the handle is connected to the terminal L through the over-load release coil. The other end of the handle moves against a spiral spring and makes contact with each stud during starting operation, cutting out more and more starting resistance as it passes over each stud in clockwise direction.

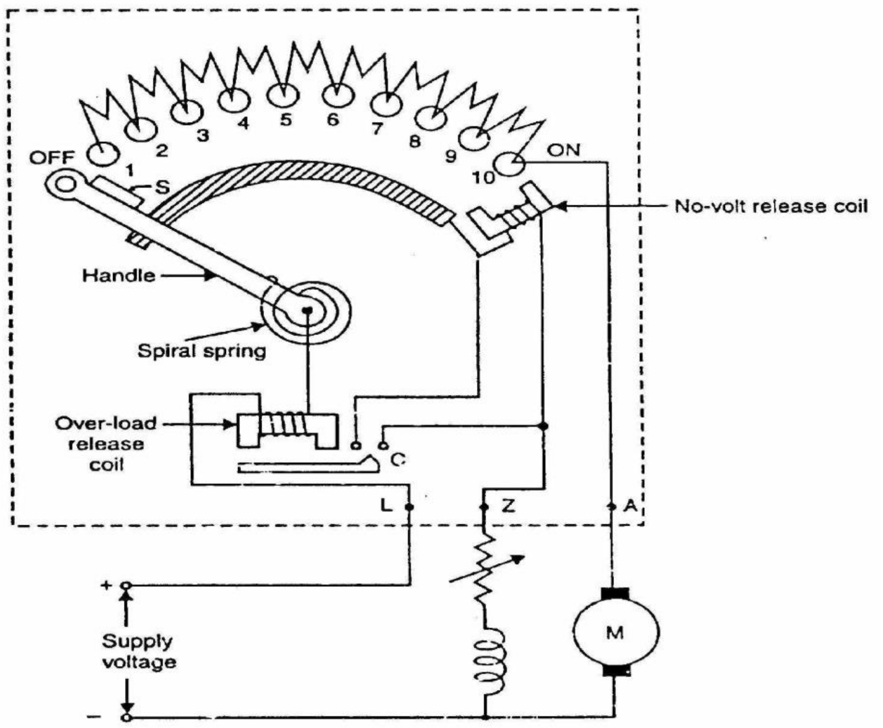
Operation

To start with, the d.c. supply is switched on with handle in the OFF position.

The handle is now moved clockwise to the first stud. As soon as it comes in contact with the first stud, the shunt field winding is directly connected across the supply, while the whole starting resistance is inserted in series with the armature circuit.

As the handle is gradually moved over to the final stud, the starting resistance is cut out of the armature circuit in steps. The handle is now held magnetically by the no-volt release coil which is energized by shunt field current.

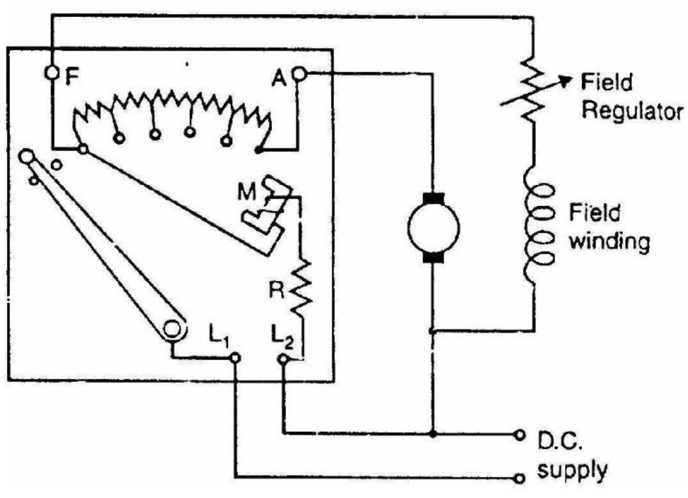
If the supply voltage is suddenly interrupted or if the field excitation is accidentally cut, the no-volt release coil is demagnetized and the handle goes back to the OFF position under the pull of the spring. If no-volt release coil were not used, then in case of failure of supply, the handle would remain on the final stud. If then supply is restored, the motor will be directly connected across the supply, resulting in an excessive armature current. If the motor is over-loaded (or a fault occurs), it will draw excessive current from the supply. This current will increase the ampere-turns of the over-load release coil and pull the armature C, thus short-circuiting the no-volt release coil. The no-volt coil is demagnetized and the handle is pulled to the OFF position by the spring. Thus, the motor is automatically disconnected from the supply.



Drawback

In a three-point starter, the no-volt release coil is connected in series with the shunt field circuit so that it carries the shunt field current. While exercising speed control through field regulator, the field current may be weakened to such an extent that the no-volt release coil may not be able to keep the starter arm in the ON position. This may disconnect the motor from the supply when it is not desired. This drawback is overcome in the four point starter.

Four-Point Starter



In a four-point starter, the no-volt release coil is connected directly across the supply line through a protective resistance R. Fig. shows the schematic diagram of a 4-point starter for a shunt motor (over-load release coil omitted for clarity of the figure). Now the no-volt release coil circuit is independent of the shunt field circuit. Therefore, proper speed control can be exercised without affecting the operation of no-volt release coil.