

Aim: Familiarisation of the electrical machine laboratory apparatus

Theory:

Resistor: It is the opposition to current. Equal to voltage divided by current. SI unit is Ω

$$R = V/I$$

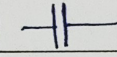
Symbol



Capacitor: Passive, two terminal component that stores energy electrostatically in electric field. Consists of two plates separated by dielectric material, which increases charge capacity. Capacitors are used in various electrical circuits.

$$C = Q/V$$

Symbol

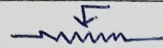


Inductor: An inductor, or choke is a passive component made of wire coil that induces a magnetic field when current flows through it. It has a stronger magnetic field than a simple coil wrapped around a magnetic solid core.

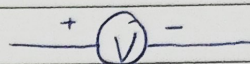
Symbol:

Rheostat: Adjustable resistor used to vary current or resistance in a circuit. It can be generator characteristics, dim lights and control motor speed.

Symbol:



Voltmeter : Potential difference between two points is measured using this. Can be designed for both DC & AC. Typically consists of a galvanometer with a series resistance to avoid drawing too much current.

Symbol 

Ammeter : Measures current in amperes. Has negligible internal resistance. Galvanometer can be converted into ammeter using a shunt resistance.

Symbol :

Relay : Opens

Relay : Opens or closes contacts to control other electrical devices. Operates on electromagnetic attraction, moving an armature to open or close connections.

Circuit Breaker : A circuit breaker interrupts or faults current and functions as a switch. It protects electrical systems from damage by opening or closing circuits.

Auto

Auto transformer : Has single winding on a laminated core, with part of winding shared between primary & secondary sides. It acts as a voltage regulator, supplying part of

Experiment :

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load current directly from the supply and
the rest through transformer action

MCB



1 2 3

Voltmeter



4 5

Ammeter

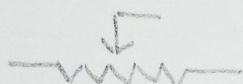


6 7

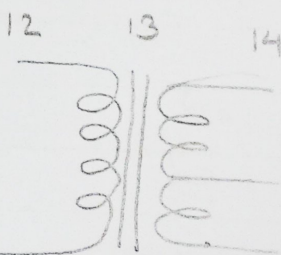
Wattmeter



8 9 10 11

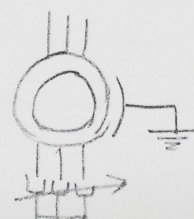


18 19 20



12 13 14
21 22 23

15 16 17



24 25 26

Aim : Speed control of slip ring induction motor

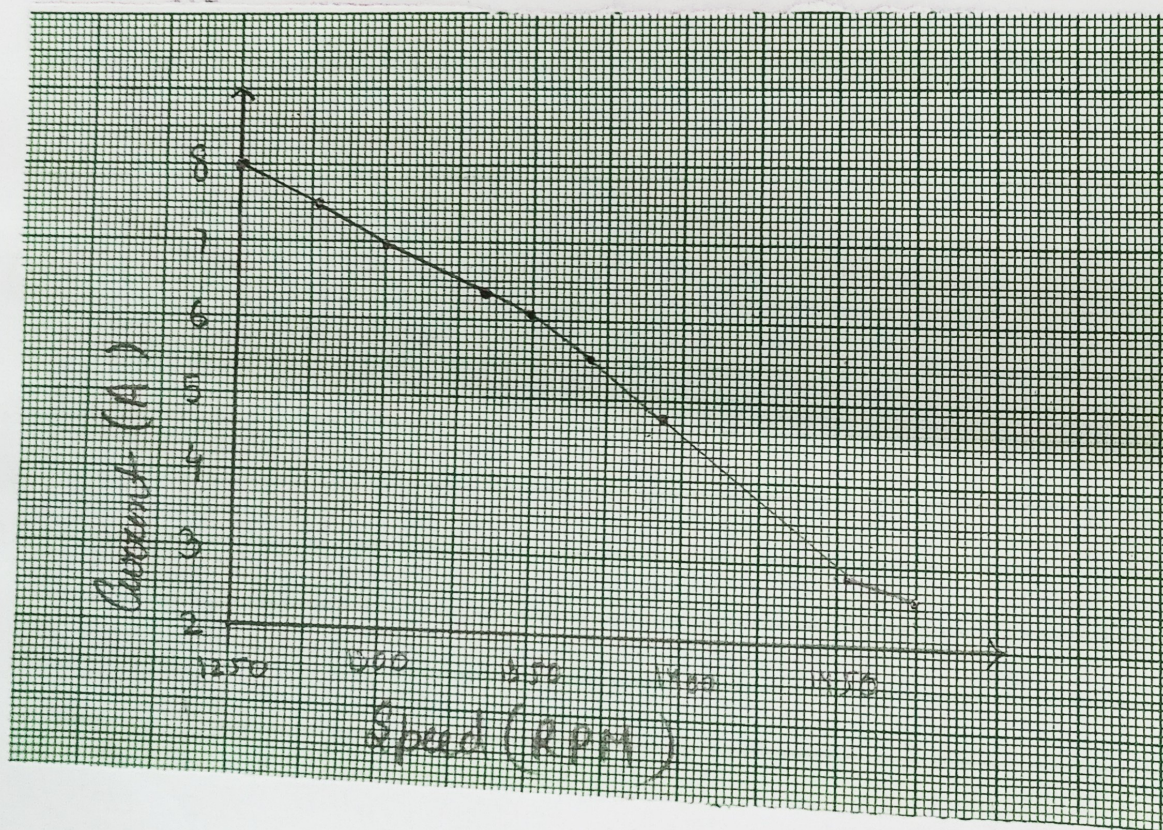
Apparatus : MCB, Voltmeter, Ammeter, Wattmeter, rheostat, Autotransformer, 3 ϕ induction motor, connecting wires.

Theory : A wound induction motor, or slip ring induction motor, features stator similar to squirrel cage motor but has insulated rotor windings connected via slip rings and brushes. These ~~extra~~ slip rings do not carry power; instead, they allow for resistance to be added in series with the rotor windings during startup.

Slip ring Characteristics :

Can be started with full line voltage applied to its stator. The rotor winding terminals connect to three slip rings insulated from the shaft, with brushes leading to external resistance. At startup, the external resistance is added to limit starting current as rotor accelerates, the resistance is gradually reduced to maintain maximum torque. Eventually external resistance is fully removed, allowing the motor to develop full torque at a low slip. Notably, the slip ~~is~~ required for max torque is directly proportional to rotor resistance, meaning inc resistance inc slip.

SNo	Current (A)	Power (W)	Speed (RPM)
1	2.6	40	1474
2	2.9	140	1454
3	4.8	680	1388
4	5.5	820	1363
5	6.1	940	1352
6	6.4	1040	1334
7	6.9	1100	1300
8	7.5	1160	1278
9	8	1200	1250



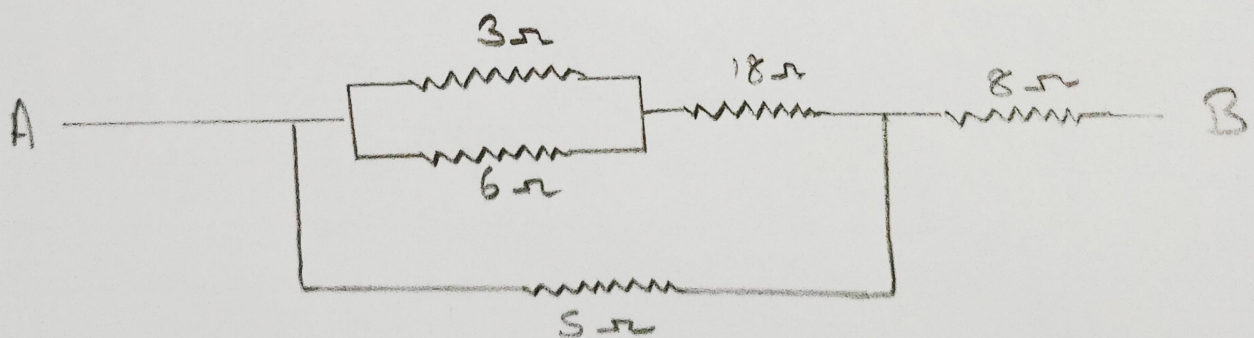
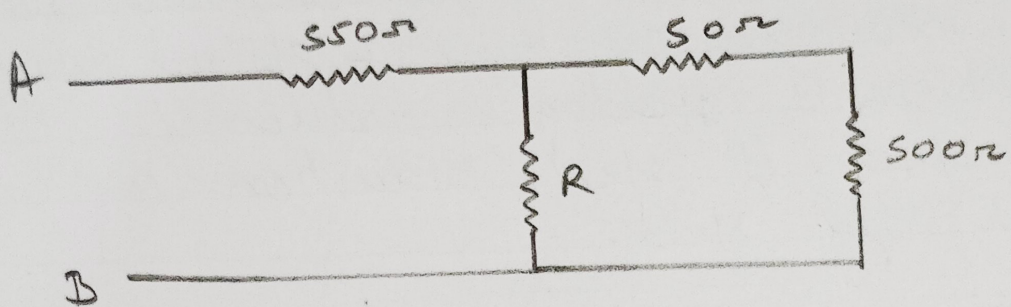
⇒ Methods of speed control (Rotor-Rheostat)

External rheostat used for starting can also control speed, provided it is rated for continuous operation. Initially, maximum resistance is applied during startup which is gradually reduced to increase speed. If speed reduction is needed at full speed.

$$\boxed{\text{Torque}(T) = \frac{S U_p (S)}{\text{Rotor resistance}(R)}}$$

⇒ Disadvantage:

- Increased $I^2 R$ ~~losses~~ as rotor resistance rises.
- Decreased motor efficiency
- Losses directly proportional ~~in~~ to the reduction in speed



Questions

Q1 Value of unknown resistor R if the voltage drop across the 500Ω resistor is $2.5V$

$$R = 550 \Omega$$

$$\text{Current in } 500 \Omega \text{ resistor} = \frac{2.5}{500} = 0.005$$

~~Ans~~

50Ω resistor has the same current

$$50 \times 0.005 = 0.25 V \text{ across } 50 \Omega \text{ resistor}$$

$$\text{Across } R = 0.25 + 2.5 = 2.75 V$$

Q-2 Calculate the effective resistance of the following combination of resistors and voltage drop across each resistor if voltage of $60V$ is applied between A & B

Resistance

$$\frac{1}{R} = \frac{1}{3} + \frac{1}{6} = \frac{3}{6} \Rightarrow R = 2 \Omega$$

$$2 \Omega + 18 \Omega = 20 \Omega$$

$$\frac{1}{R} = \frac{1}{20} + \frac{1}{5} = \frac{5}{20} \Rightarrow R = 4 \Omega$$

$$\text{Total} \Rightarrow 4 \Omega + 8 \Omega = 12 \Omega$$

$$\text{Total current} = \frac{60}{12} = 5 A \text{ at start}$$

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$$20\Omega \text{ section} \Rightarrow 5\left(\frac{5}{5+20}\right) \Rightarrow 1A$$

$$5\Omega \text{ ^{resistor} section} \Rightarrow 5\left(\frac{20}{5+20}\right) = 4A$$

$$3\Omega \Rightarrow 1\left(\frac{6}{6+3}\right) = \frac{2}{3}A$$

$$6\Omega \Rightarrow 1\left(\frac{3}{6+3}\right) = \frac{1}{3}A$$

$$18\Omega \Rightarrow 1A$$

$$8\Omega \Rightarrow 5A$$

Voltage

$$8\Omega \text{ resistor} \Rightarrow 8 \times 5 \Rightarrow 40V$$

$$18\Omega \text{ resistor} \Rightarrow 18 \times 1 \Rightarrow 18V$$

$$6\Omega \text{ resistor} \Rightarrow \frac{1}{3} \times 6 \Rightarrow 2V$$

$$3\Omega \text{ resistor} \Rightarrow \frac{2}{3} \times 3 \Rightarrow 2V$$

$$5\Omega \text{ resistor} \Rightarrow 4 \times 5 \Rightarrow 20V$$

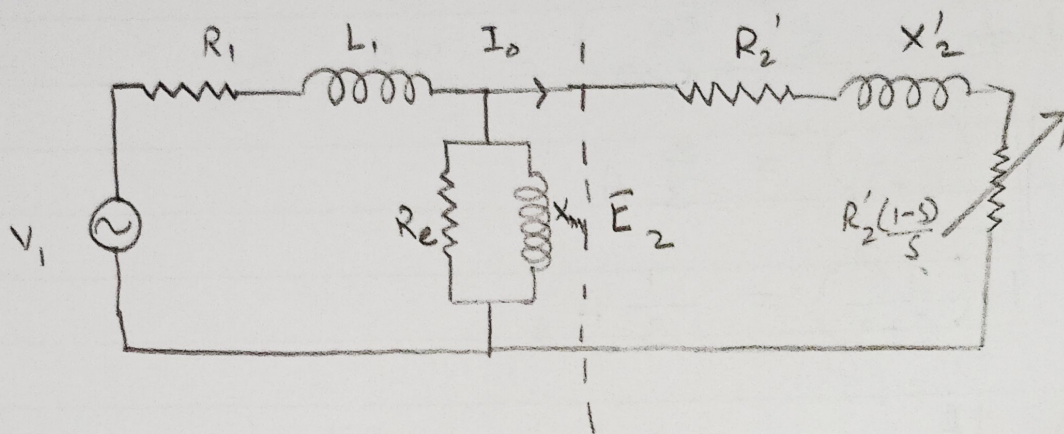


Fig: Phase equivalent circuit of poly phase induction motor

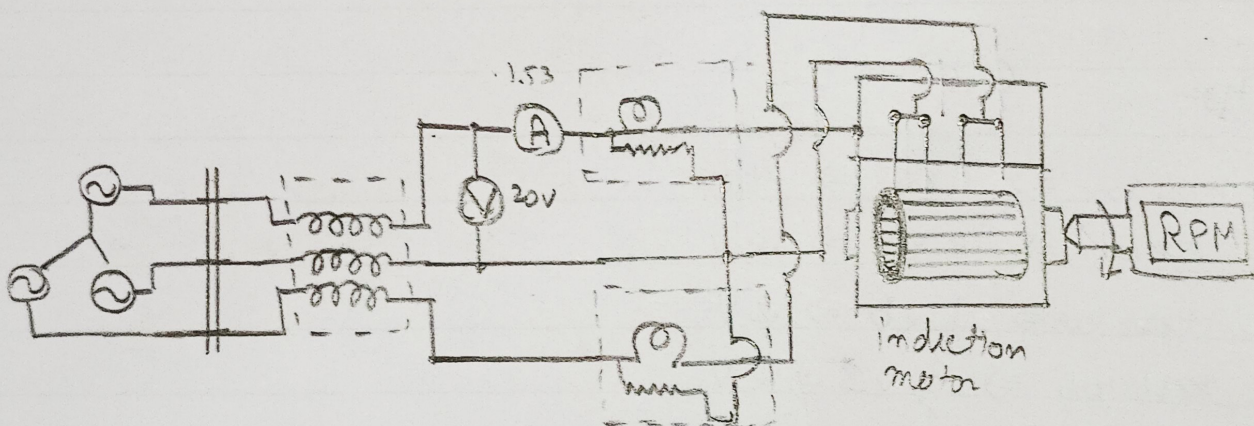


Fig: No load test of induction motor

A

Aim : To Study no load test on three phase induction motor

Apparatus :

- 3-phase induction motor
- TPST Switch
- Three phase Variac
- Voltmeter
- Ammeter
- Wattmeter
- Digital tachometer
- Connecting wires

Theory :

Induction motors are a major consumers of global electrical power. Their steady state performance can be studied using a per phase equivalent circuit with parameters such as:

V_1 : input voltage per phase

R_1, X_1 : Stator resistance & leakage reactance per phase

R_2, X_2 : Rotor resistance & leakage reactance per phase

X_m : Magnetising reactance

R_e : Core loss

I_1, I_2 : Stator and rotor current (referred to stator) per phase

Developed Torque is given by :

$$T = \frac{3(I_2)^2 R_2}{s \omega_s} , \text{ N-m}$$

where,

ω_s = Synchronous Speed

ω_r = Rotor speed

s = Slip

V_s (volt)	I_L (Amp)	W_1 (watt)	W_2 (watt)	Speed	Total Copper Loss	Rotor Angle	I/P Power
2	0.15	0.15	0.19	0.00	0.62	29.3	0.45
4	0.31	0.63	0.80	0.00	2.57	29.3	1.87
6	0.46	1.41	1.77	0.00	5.74	29.3	4.17
8	0.61	2.49	3.14	0.00	10.15	29.3	7.37
10	0.76	3.88	4.89	0.00	15.82	29.3	11.48
12	0.92	5.64	7.10	0.00	22.93	29.3	16.68
14	1.07	7.65	9.63	0.00	31.13	29.3	22.63
16	1.22	9.97	12.55	0.00	40.59	29.3	29.48
18	1.38	12.68	15.97	0.00	51.61	29.3	37.52
20	1.53	15.62	19.67	0.00	63.60	29.3	46.22

To predict motor performance, Engineers conduct :

1. No load test : Determine R_e & X_m
2. Blocked rotor test : Finds R_1, R_2, R_e, X_1, X_2

Conclusions

We have successfully conducted the no-load test on a three phase induction motor and analysed ~~that~~ its characteristics. Hence we can conclude

Aim: Study Blocked rotor test on induction motor

Apparatus:

3-phase induction motor

Digital tachometer

TPST Switch

Connecting wires

Three phase variac

Voltmeter

Ammeter

Theory

Blocked Rotor test determines the key equivalent circuit parameters, including stator and rotor resistance R_1 , R_2 and leakage reactance (X_1 , X_2)

$$\text{Torque (T)} = \frac{3(I_2)^2 R_2}{s \omega_s}$$

$$\text{Slip (s)} = \frac{\omega_s - \omega_m}{\omega_s}$$

$$\text{Input power } P_{in} = 3 V_L I_L \cos \phi$$

$$\text{Output Power } P_{out} = (1-s) \omega_s$$

Rotor is not allowed to rotate so that the speed of motor rotor is zero RPM slip corresponding to zero speed is unity

V_s	I_L	W_1	W_2	Speed	Total Copper Loss	Rotation Angle	I/P Power
5	0.3	0.77	1.50	0	2.89	29.31	2.27
10	0.7	3.61	7.00	0	12.97	29.31	10.57
15	1.2	9.27	18.00	0	39.06	29.31	27.19
25	1.9	16.48	47.50	0	97.03	29.31	71.74
30	2.3	24.46	68.99	0	138.20	29.31	104.21
35	2.6	35.54	90.99	0	180.94	29.31	137.44
40	3.1	46.87	123.99	0	259.21	29.31	187.28
45	3.5	63.86	157.49	0	324.18	29.31	237.88

Conclusion

We have successfully conducted the blocked rotor test on a three phase induction motor to determine parameters such as stator & rotor resistance and leakage reactance

Precautions

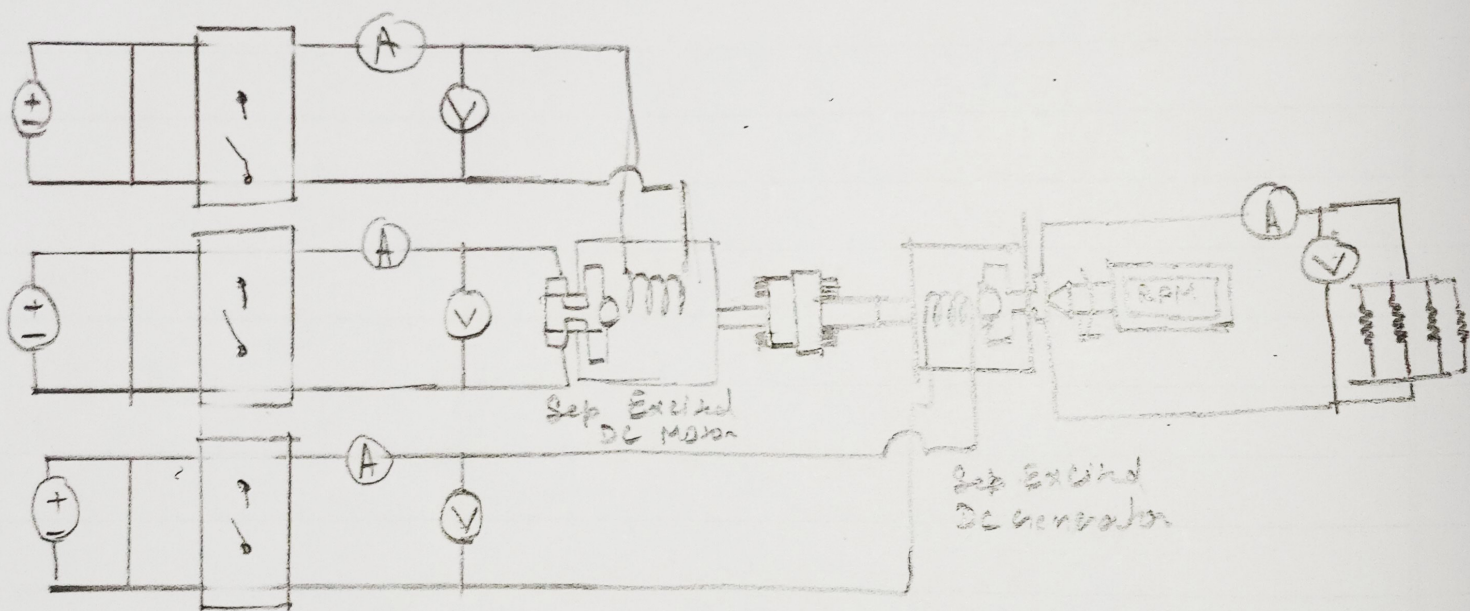
Ensure rotor is securely blocked

Apply low voltage initially

Monitor temperature rise

Use properly rated instruments

Gradually inc voltage



Aim: To study load Test on separately excited DC motor.

Apparatus:

- Separately Excited DC motor
- DPST Switch
- Variable Voltage device
- Voltmeter
- Ammeter
- Wattmeter
- Digital tachometer
- Separately excited DC generator
- Load Bank
- Connecting wires

Theory

Separately excited DC motors are widely used in industrial applications due to their high speed, moderate torque, and low construction cost. They are preferred over AC motors for their simpler control and lower manufacturing ~~system~~ costs.

Construction & working

Main Parts: Field winding, Armature winding, Yoke, Commutator and brushes

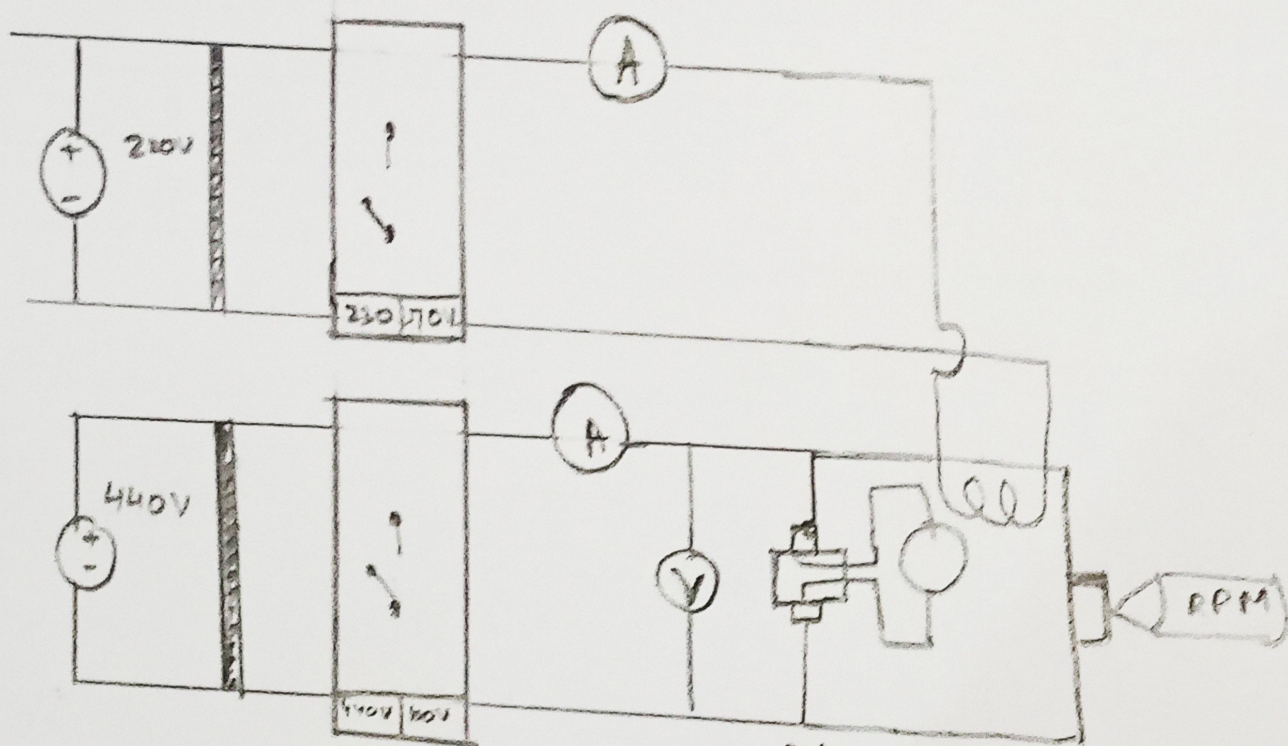
Operation: DC supply is given to both field and armature windings.

Torque Generation: Current in armature reacts with

field flux, producing rotational force

Commutation & Brushes: Ensure continuous and unidirectional torque

Induced EMF: Generated as the armature rotates, ~~opposing~~ opposing the applied voltage



Separately
Excited
DC Motor

Aim : Study the Speed control of Separately excited DC Motor

Apparatus

Separately Excited DC Motor • Load Resistor or Rheostat
DPST Switch • Generator
Tachometer • Connecting wires
Variable Voltage Source
Rectifier

Theory :

DC motors are highly adaptable to speed adjustment making them competitive in industrial drives. Their speed can be controlled using the following methods

⇒ Varying Field Excitation (Φ)

- Adjusting shunt field resistance changes motor speed
- lower field rheostat resistance results in low speed & vice-versa
- This method maintains constant horsepower and suits applications involving reduced torque at high speeds

⇒ Varying Armature Terminal Voltage

- Speed changes with varying armature voltage

while keeping excitation constant.

A rectifier is often required to control armature voltage in ac constant

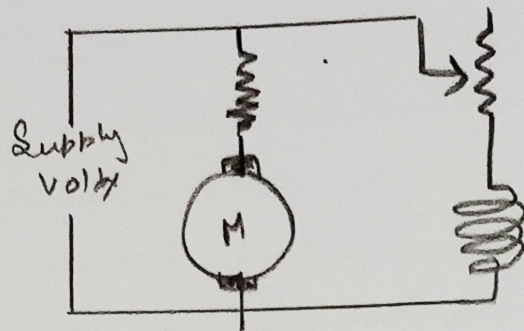
Motor operates in constant torque mode, maintaining rated torque across speeds

$$\text{Torque} \Rightarrow T = K \phi I_a$$

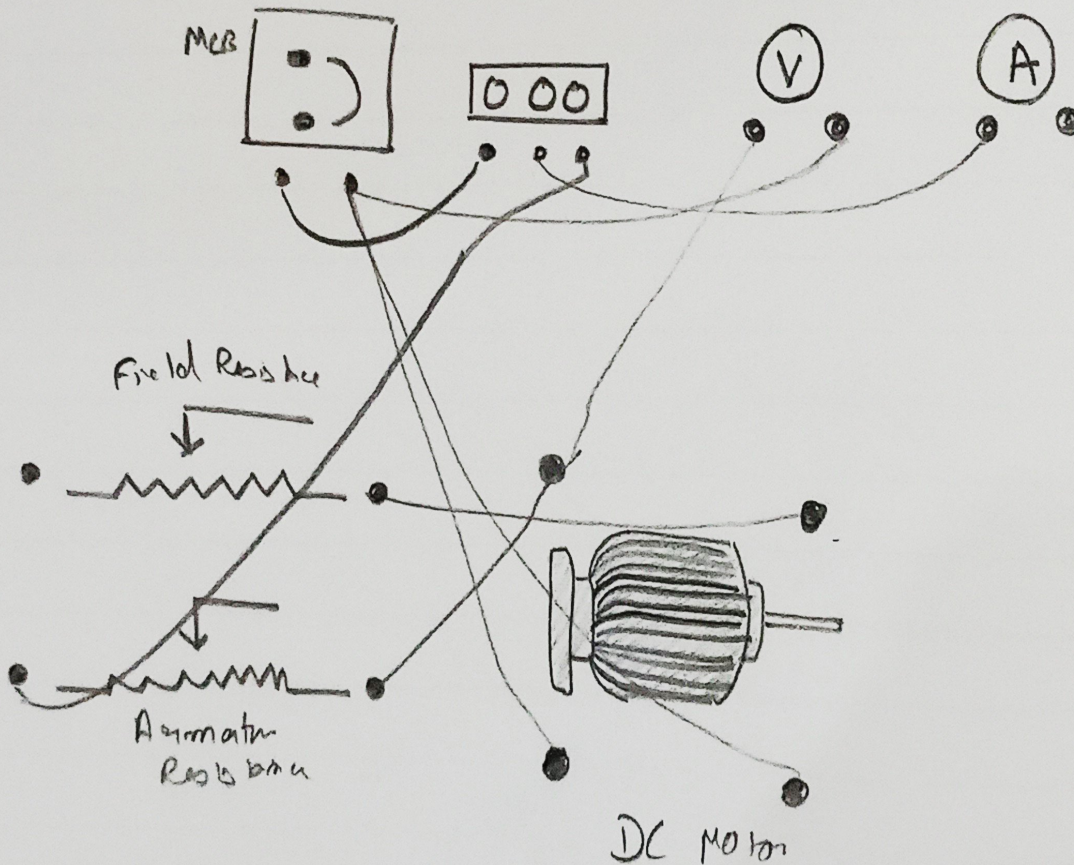
Speed

Conclusion

Inverse relationship between field voltage and speed, along with the proportionality of armature voltage to speed, make DC motors suitable industrial applications requiring a variable speed drive



Equivalent Circuit for field controlled DC Motor



Aim: Speed control of DC motor by field resistance control. Draw the graph between the armature current and motor speed by varying the field resistance.

Apparatus:

DC Shunt Motor

• Connecting wires

• Variable resistance x 2

Voltmeter

Ammeter

Theory:

Speed of DC shunt motor is given by:

$$N = \frac{V_a - I_a R_a}{K \phi}$$

Where V_a is the armature voltage ϕ is the flux proportional to field current ~~determined~~ by the ~~me~~ I_f . And I_a is the armature current determined by the mechanical load. Speed control is achieved by varying V_a and I_f using the external resistance either in series with the armature or the field circuit.

Methods of speed control

Current (A)	Speed (RPM)
0.1	2500
0.3	2100
0.4	1930
0.5	1700
0.6	1575
0.7	1480
0.8	1400

- Armature Resistance Control
- Field Resistance Control

In Field resistance control Method, speed is controlled by varying the field current I_f . Which ~~directly~~ directly the flux Φ . A shunt field regulator an external resistance in series with field windings. It is used for the adjustment. Increasing resistance reduces I_f lowering the flux Φ and increasing motor speed. This allows speed control above the base speed but does not permit operation below the rated speed.

Conclusion

We have seen that speed control of a DC Shunt motor can be effectively achieved by varying field resistance. Increasing the resistance decreases the field ~~resistance~~ current I_f , reducing flux Φ and inc the speed above the base level. However This method does not allow speed reduction below the rated value.

Precautions : Avoid excessive speed

Check for coil temperature

Ensure stable operation

Use proper regulations

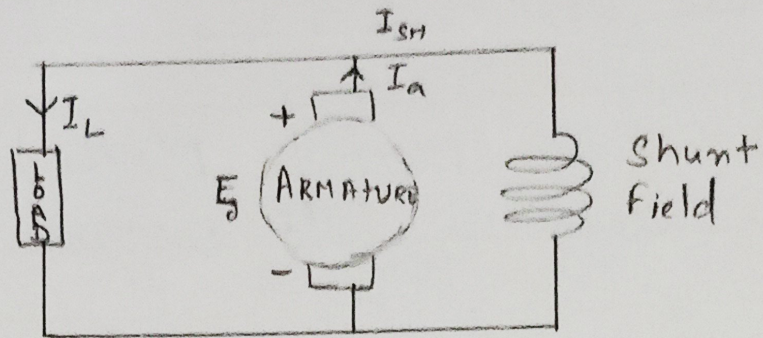
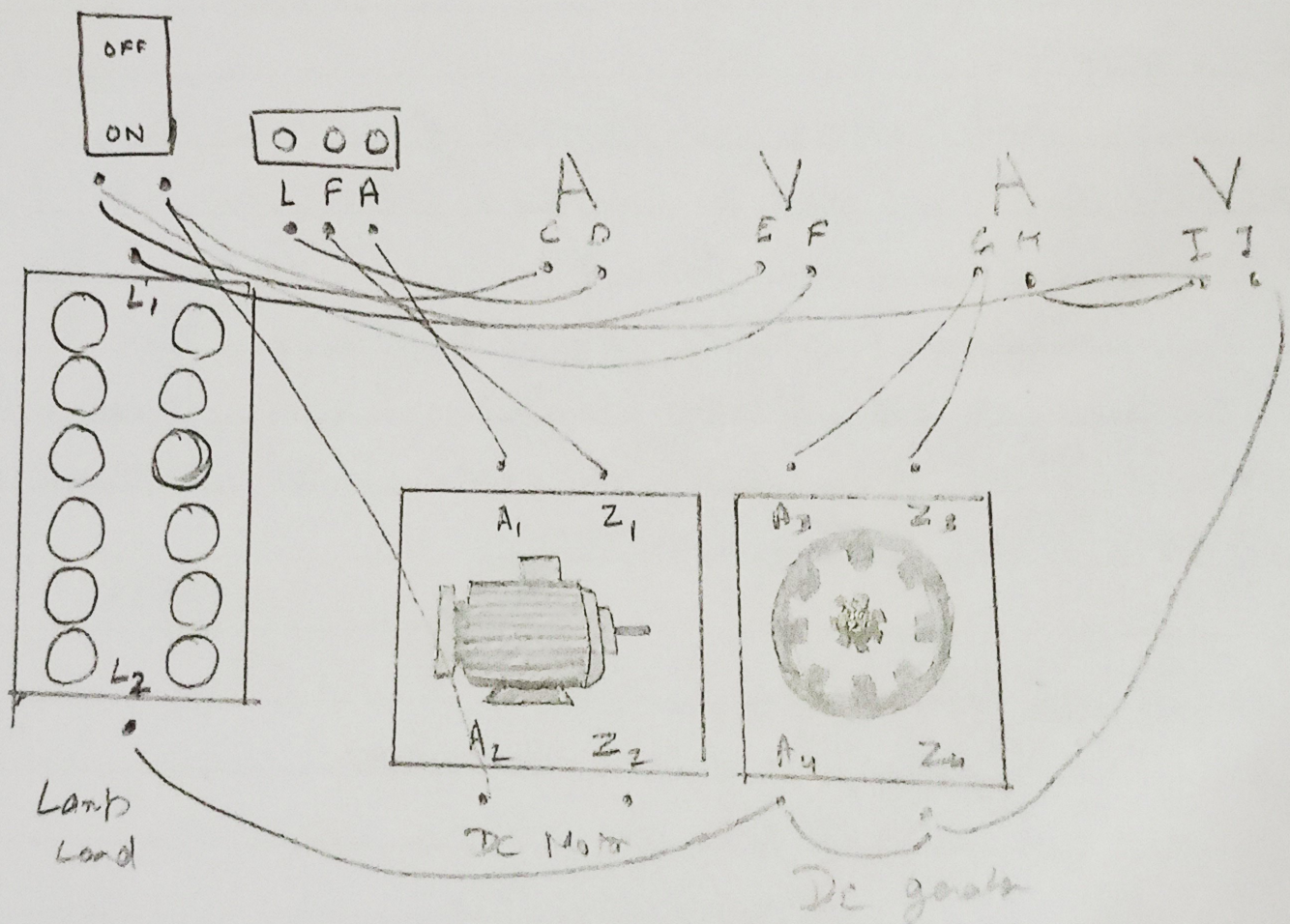


fig 1: Eq circuit of
DC shunt generator



Aim : To study the load characteristics of DC shunt generator. Draw the internal characteristics and external characteristics under diff loading conditions

Apparatus :

- DC motor
- DC generator
- Lamp load
- Ammeter
- Voltmeter
- Connecting wires

Theory :

A shunt generator has its field winding connected in parallel to the armature winding so the terminal voltage applies to it. The winding consists of many turns of the fine wire with high resistance. Only a small fraction of the armature current I_a flows through the field winding I_{sh} while I_L supplies the load.

Internal characteristics

This curve relates to the generated voltage E_g and load current I_L . Due to armature reaction. E_g decreases when the generator is loaded. The no-load voltage curve (AD) is

Current A	Voltage V
1.2	220
2.8	212
3.2	208
3.6	205
5.5	200
7	195
8.1	189
10.2	184
11	179
12.7	176

higher than the internal characteristics.

External on Load characteristics

This curve shows ~~that~~ how ~~max~~ terminal voltage varies with load current. Due to armature resistance, terminal voltage is lower than generated voltage.

$$V = E_g - (I_L + I_{sh}) R_a$$

As load ~~current~~ resistance decreases, load current inc up to a certain limit, after which further resistance reduction results in decline of current. Eventually, terminal voltage drops to zero, though residual magnetism may retain some voltage.

Aim: V curves and inverted V curves Three phase Synchronous Motor

Apparatus:

Salient Pole Synchronous Motor

TPST Switch

Three-phase Auto Transformer

DPST Switch

- DC generator

- Resistive load bank

- Rheostat arrangement

- Voltmeter & Ammeter

Theory

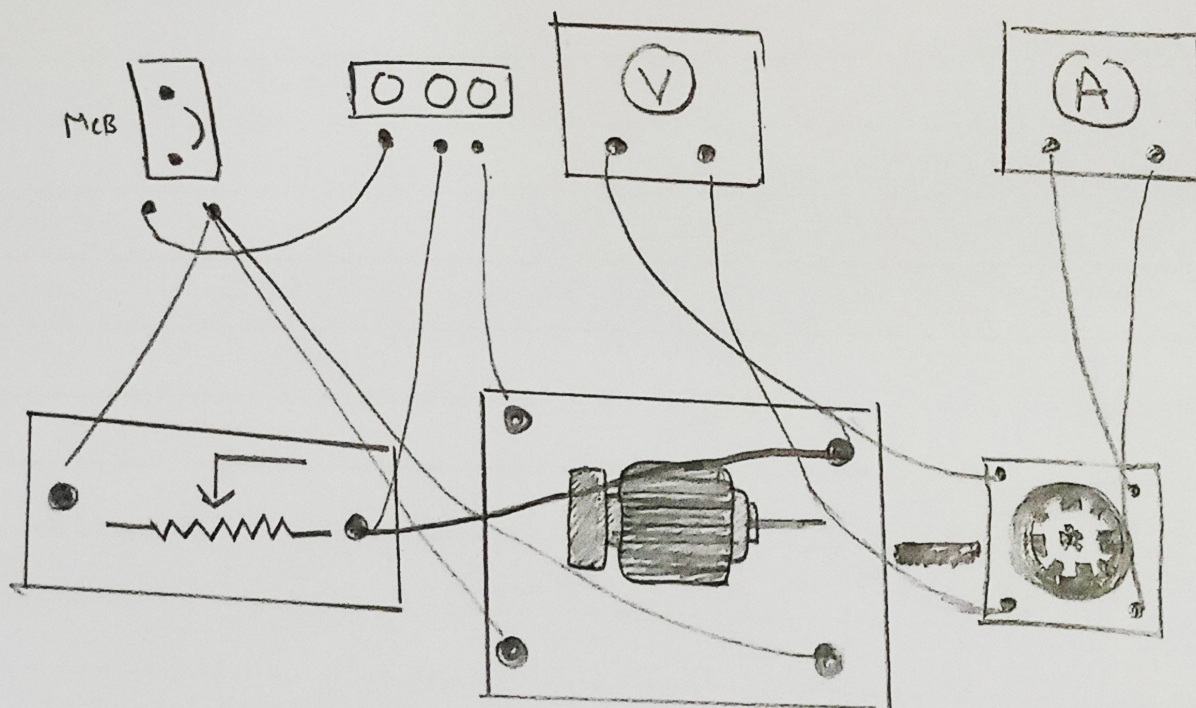
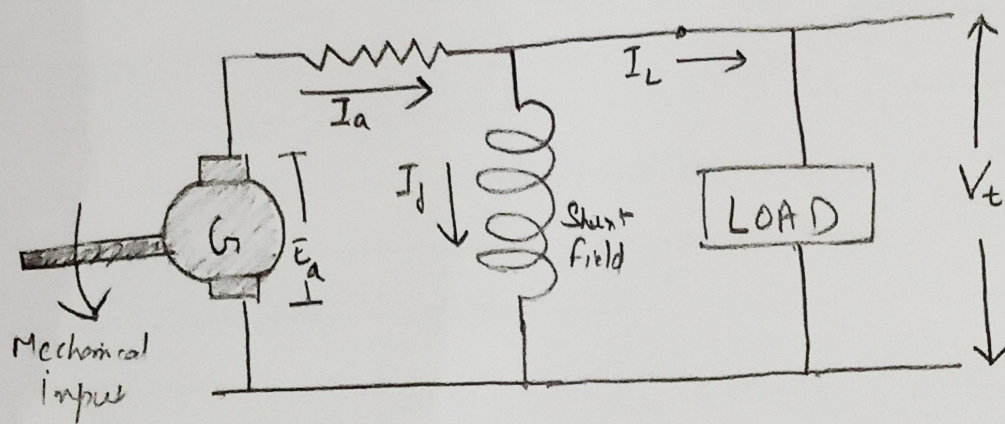
Electromagnetic Devices require a magnetising current, which lags applied voltage by nearly 90° . A Synchronous motor is a double-excited machine, where the armature receives AC Supply AC Supply while the field winding is fed By DC.

At constant voltage, the resultant air gap flux remains unchanged and is established by both armature and field winding. If field current is just sufficient to maintain flux, the motor operates at unity power factor - this condition - this condition is called normal excitation

- Under-Excitation - Lagging power factor

- Over Excitation - Leading power factor

The V-curve represents how armature current varies with field current. The inverted V-curve shows the power factor's behaviour with changing excitation.



Aim: To study the magnetization characteristics of DC shunt generator. Draw the graph between the armature voltage & field current

Apparatus:

Rheostat

Voltmeter

Ammeter

Motor

Rotor

MCB

Theory:

DC shunt generator converts mechanical energy into electrical energy. It ~~is~~ is self-exciting using induced EMF E_a to generate field current I_f . Which establishes the magnetic flux ϕ . The induced EMF is given by:

$$E = \frac{N P \phi Z}{60 A}$$

Where ϕ is flux, N is speed, Z is conductors, P is poles and A is parallel paths

Critical Field Resistance

Minimum resistance at which the generator fails to excite. It is found by plotting the OCC

Vol tage(V)	Current(A)
0	0
115	0.16
120	0.18
126	0.20
129	0.21
132	0.23
135	0.24
138	0.28
142	0.30

Curve and determining the tangent ~~at~~ slope from origin. Due to residual magnetism. A small EMF is generated even when $I_f = 0$

Initially EMF is proportional to ~~flux~~ Excitation current

At higher flux density, iron path reluctance increases.

Residual magnetism initiates small EMF strengthening pole flux and stabilizing generation.