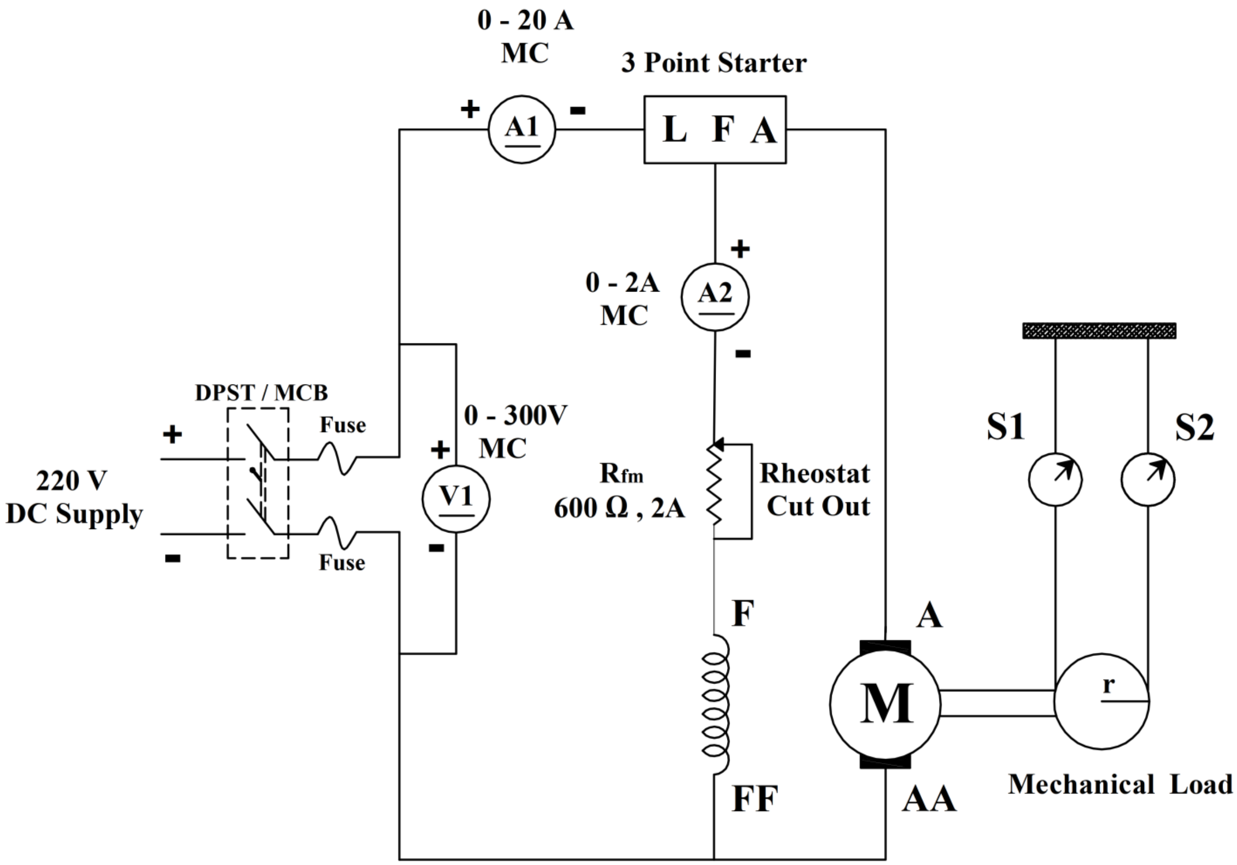
Experiment - 1

Load test on DC shunt motor to draw Speed – Torque and Horsepower – Efficiency characteristics

Learning Objectives:

- To obtain Speed - Torque Characteristics of DC shunt motor.
- To obtain Horse Power - Efficiency Characteristics of DC shunt motor.

Circuit Diagram:



Name Plate Details:

Motor Type: DC Shunt Motor	
Armature	**Field**
Volts :	**Volts:**
Amps :	**Amps:**
Rpm:	

Apparatus Required:

Sl No.	Description	Range	Quantity
1	Moving coil ammeter - A_1	0-20A	1
2	Moving coil ammeter - A_2	0-2A	1
3	Moving coil voltmeter - V_1	0- 300V	1
4	Rheostat - R_{fm}	0 - 600Ω, 2A	1

Procedure:

1. Connections are made as shown in the circuit diagram.
2. The Rheostat R_{fm} is kept in CUT-OUT position. Close the supply switch & start the DC motor using 3-point starter.
3. CUT-IN the motor field rheostat slowly until the motor reaches the rated Speed(N).
4. Note down the initial readings of all the meters.
5. Now load the motor (mechanical loading) in steps nearly to its rated current.
6. For each loading all the meter reading and speed of the motor are tabulated.
7. Release all the loads.
8. Reduce the Speed of motor by making R_{fm} to CUT-OUT position and open the supply switch.
9. Shaft Torque(Tsh), Brake Horse Power (BHP) and Efficiency (η) of the motor are caculated.
10. The graph of %η versus BHP & Speed versus Torque is plotted

Tabular Column:

Sl. No.	V (Volts)	I (Amps)	S_1 kg	S_2 kg	S = (S_1 -S_2) in Kgs	Tsh = 9.81*S* r N-m	N rpm	Motor output= $\frac{T_{sh} \times 2\pi\pi}{60}$ Watts	B.H.P= $\frac{Output}{746}$	%η = $\frac{Output}{Input}$ *100

Calculations:

Motor input = VxI=______ Watts

Motor output = $\frac{T_{sh} \times 2\pi N}{60}$ Watts

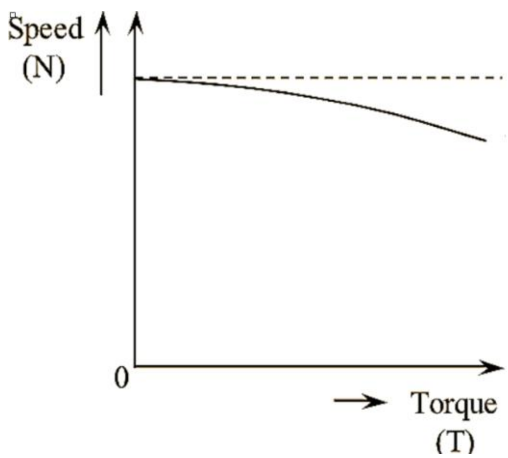
B.H.P= Motor output / 746

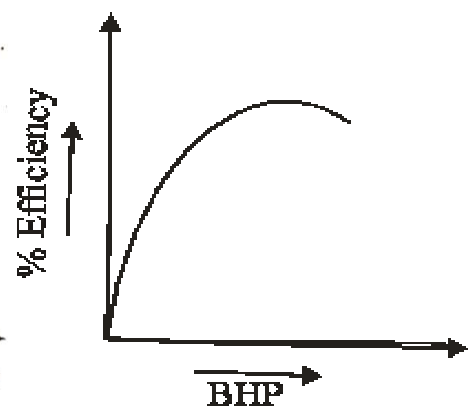
Motor Torque = 9.81*S*r

Where r = Radius of the brake drum

%Efficiency(η) = $\frac{\text{Output}}{\text{Input}} * 100$

Expected Performance Curves:





Inference:

- At No - load the speed and Torque is__________ and _____________respectively
- At Full Load the speed and Torque is__________ and _____________respectively
- At Maximum Efficiency the speed and Torque is__________ and _____________respectively
- The maximum Efficiency is obtained at ______________BHP
- At 50% load the efficiency is ______________
- At full load Efficiency is ____________

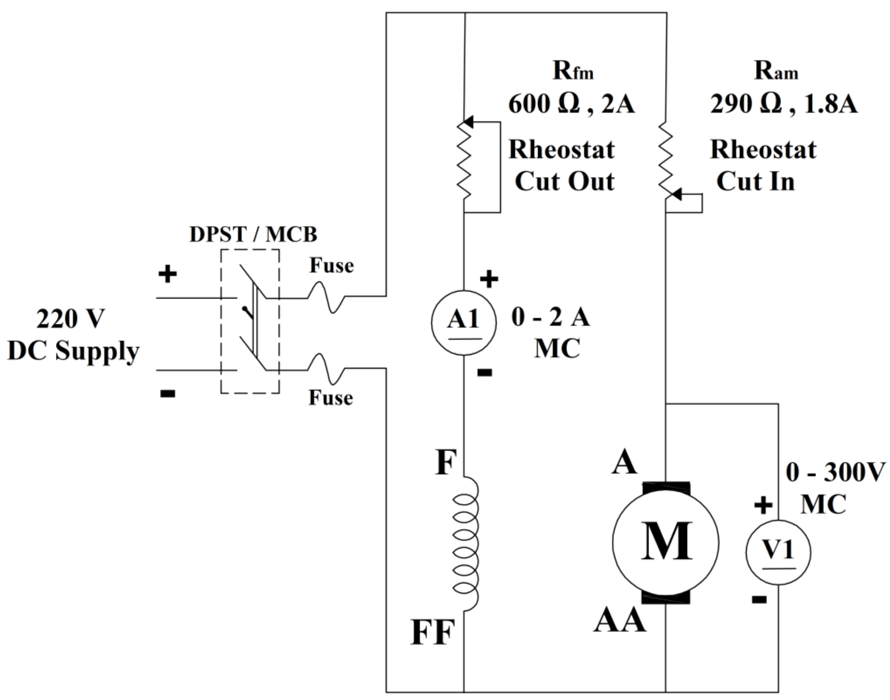
Experiment – 2

Speed control of DC shunt motor by armature and field control

Learning Objectives:

To obtain the characteristic curve and speed control of DC shunt motor by varying armature voltage with field current constant and by varying field current with armature voltage constant.

Circuit Diagram:



Name Plate details of the machines:

Motor Type: DC Shunt Motor	
Armature	**Field**
Volts :	**Volts:**
Amps :	**Amps:**
Rpm:	

Apparatus Required:

Sl No.	Description	Range	Quantity
1	Moving coil ammeter- A_1	0-2A	1
2	Moving coil voltmeter- V_1	0-300V	1
3	Rheostat- R_{fm}	600Ω,2A	1
4	Rheostat- R_{am}	290Ω,1.8A	1

Procedure

Flux control method:

1. Connections are made as shown in the circuit diagram.
2. Keep R_{am} in cut in position and R_{fm}in cut out position.
3. Close the supply switch to start the DC motor.
4. Voltage across the armature of motor is kept constant. The field current is decreased in steps by cutting in $R_{fm}$and at each step, the speed of the motor and corresponding field current are noted and tabulated.
5. Repeat the procedure with another value of armature voltage.
6. Plot a graph of speed v/s field current for each constant armature voltage.

Armature voltage control method:

1. Connections are made as shown in the circuit diagram.
2. Keep R_{am} in cut in position and R_{fm}in cut out position.
3. Close the supply switch to start the DC motor.
4. Adjust the field current to some constant value say (0.5A) by cutting field rheostat.
5. Now by cutting out R_{am} in steps note down corresponding speed and armature voltage and tabulate the same.
6. Experiment is repeated for different constant field current by adjusting the field resistance and step 5 is repeated.
7. A graph of speed v/s armature voltage is plotted for each constant field current

Tabular column:

Flux control :

Armature voltage = ___________

Sl No	I_f Amps	N rpm

Armature voltage = ------------

Sl No	I_f Amps	N rpm

Voltage control:

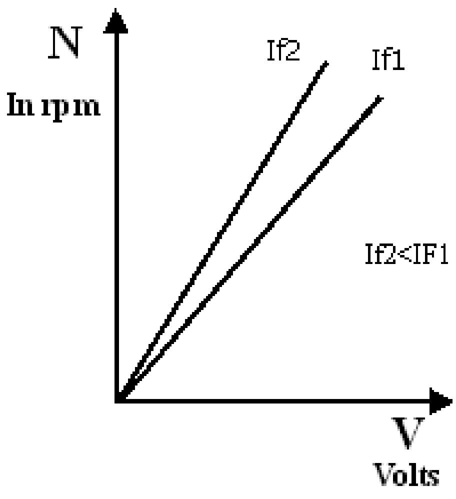
Field current = ___________

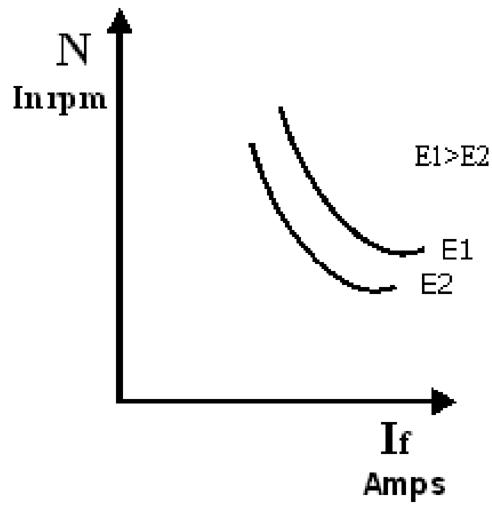
Sl No	V volts	N rpm

Field current = ___________

Sl No	V volts	N rpm

Expected Performance Curves:





Inference:

On completion of the experiment the student will understand how to control the speed of a DC motor by 1) The Armature voltage control method 2) Flux control method.

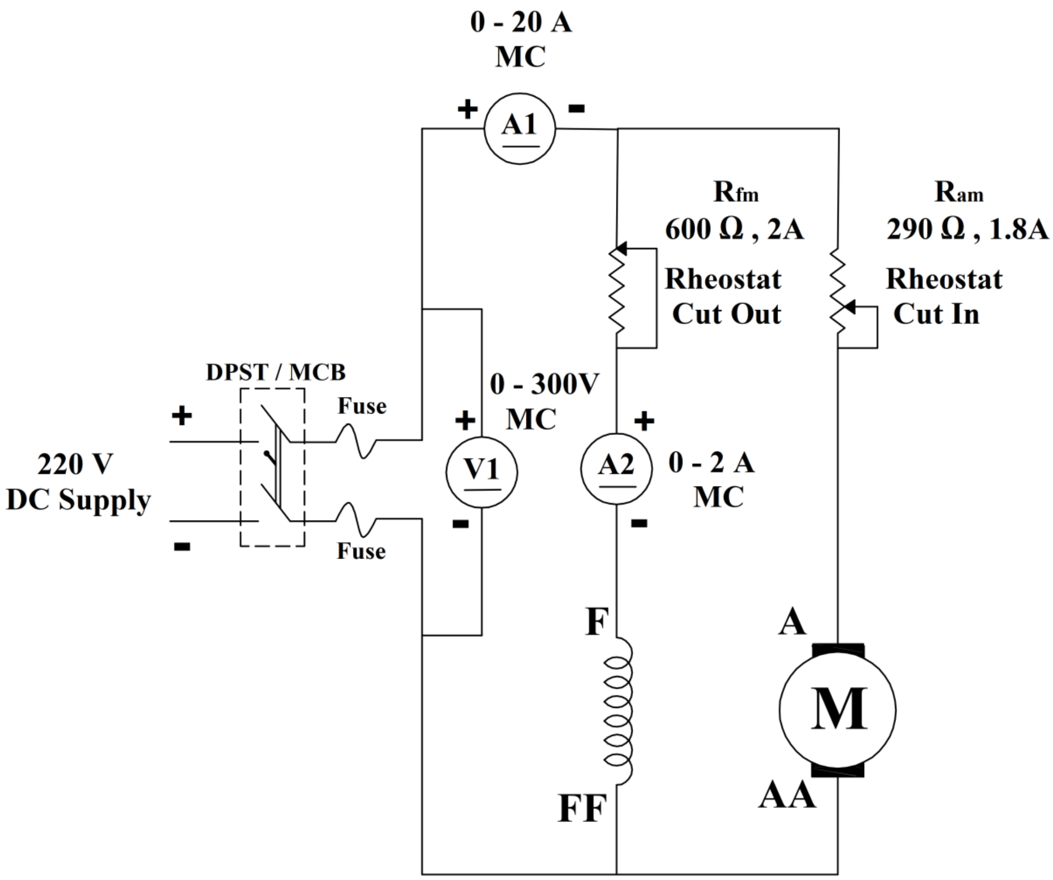
Experiment - 3

Swinburne's Test on DC motor

Learning Objectives:

To predetermine the efficiency of the machine at any load by the indirect method of testing a DC machine.

Circuit Diagram:



Name Plate details of the machines:

Motor Type: DC Shunt Motor	
Armature	**Field**
Volts :	**Volts:**
Amps :	**Amps:**
Rpm:	

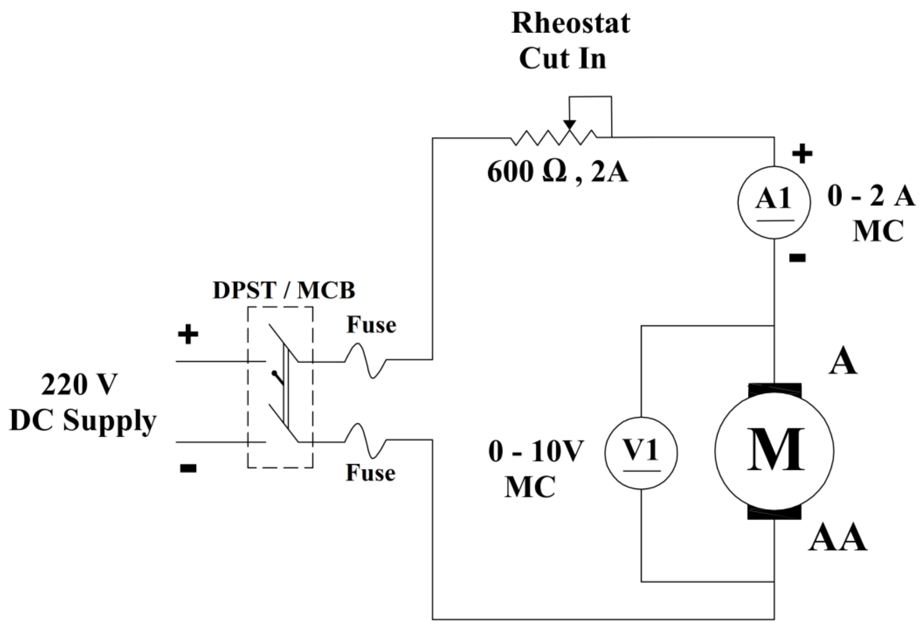
Apparatus Required:

Sl No.	Description	Range	Quantity
1	Moving coil ammeter - A_1	0-10A	1
2	Moving coil ammeter- A_2	0-2A	1
3	Moving coil voltmeter - V_1	0-300V	1
4	Rheostat - R_{fm}	600Ω, 2A	1
5	Rheostat - R_{am}	18Ω, 12A	1

Procedure:

1. Connections are made as shown in the circuit diagram.
2. Keep R_{am} in cut in position and R_{fm}in cut out position.
3. Close the supply switch to start the DC motor bring the motor to the rated speed by Cutting-out $R_{am}$and cutting in R_{fm}.
4. Note down all the meter readings and are tabulated.
5. Armature resistance is found out by VA method and calculations are carried out to obtain efficiency of DC machines when running as a motor and as a generator.
6. A graph of efficiency v/s different loading is plotted for motor and generator.

Measurement of armature resistance:



Resistance of the armature:

V (Volts)	I (Amps)	R_a = V/I Ohms

Armature resistance =______Ω

NO –Load readings:

V = ________ I_L = _______ I_f= _________ N=_________

Calculation:

Specimen calculation to calculate efficiency of machine when running as

Motor:

- No Load armature copper loss = $I^2_a R_a = (I_L - I_f)^2 R_a$ = ________Watts
- No Load Input power = VI_L = _________Watts
- Constant Losses = $W_C = VI_L - (I_L - I_f)^2 R_a$ = ______Watts

The η of the machine when running as a motor for different % of loading is given by,

$$\%\ \eta m = \frac{output}{Input} = \frac{Input - Losses}{Input}\ X\ 100$$

$$= 1 - \left[\frac{Losses}{Input}\right]\ X\ 100 = 1 - \left[\frac{Constant\ losses\ + Armature\ w_{cu}}{XI_rV}\right] * 100$$

$$= 1 - \left[\frac{Losses}{Input}\right]\ X100 = 1 - \left[\frac{Constant\ losses\ + Armature\ w_{cu}}{XI_rV}\right] * 100$$

$$= 1 - \left[\frac{Wc + (XI_r - If)^2 R_a}{XI_rV}\right]\ X\ 100$$

= ___________%

Where X is fraction of load and I_r is rated current of the machine

Fraction of load X	**% η_m**

Specimen calculation to calculate efficiency of machine when running as **GENERATOR:**

- No Load armature copper loss = $I^2_a R_a = (I_L + I_f)^2 R_a$ = ______Watts
- No Load Input power = VI_L = ______ Watts
- Constant Losses = $W_C = VI_L - (I_L + I_f)^2 R_a$ = _____________Watts

Total losses = constant losses + armature copper loss=________________ Watts.

The η of the machine when running as a generator for different % of loading is given by,

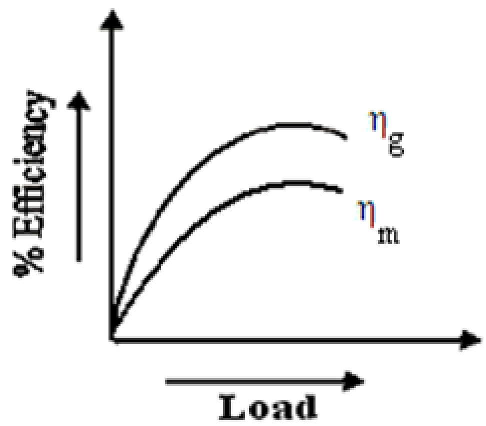
$$\%\,\eta g = \frac{output}{output + losses} * 100$$

$$\%\,\eta g = \frac{XIrV}{XIrV + W_C + (XI_r + If)^2 R_a} * 100$$

=_______%

Fraction of load X	**% η_g**

Expected Performance Curve:



Inference

On completion of the experiment, the student will determine the Losses of the machine without loading.

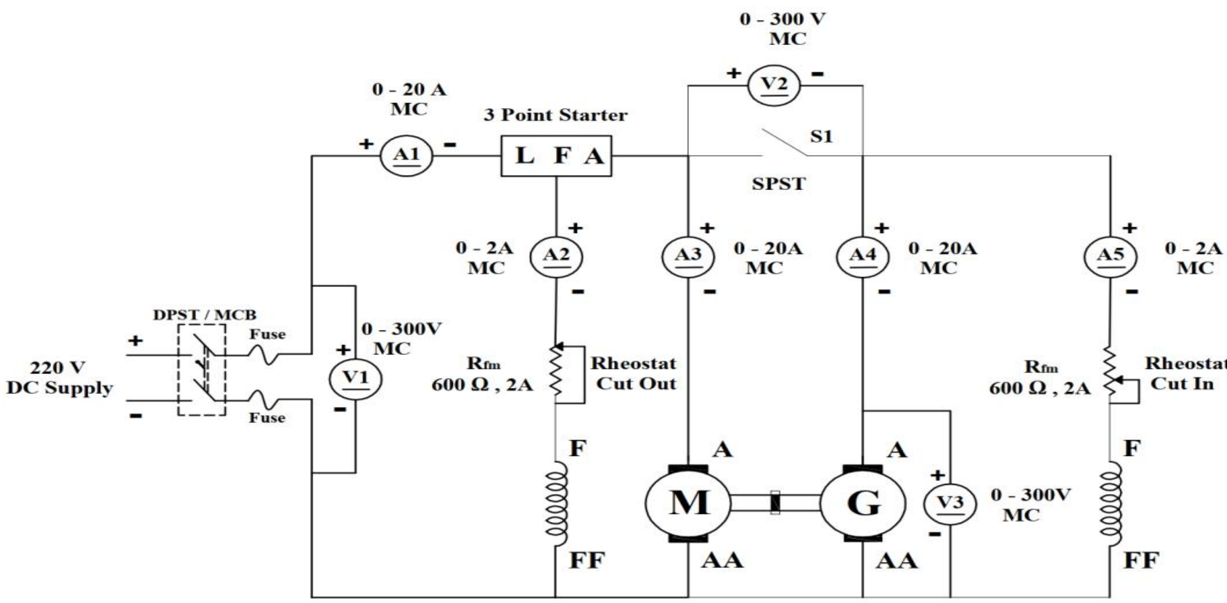
Experiment - 4

Regenerative test on DC shunt machines

Learning Objectives:

To perform Hopkinson's test on two similar DC shunt machines.

Circuit Diagram :



Name plate details:

Motor Type: DC Shunt Motor		Motor Type: DC Shunt Generator	
Armature	**Field**	**Armature**	**Field**
Volts :	**Volts:**	**Volts :**	**Volts:**
Amps :	**Amps:**	**Amps :**	**Amps:**
Rpm:		**Rpm:**	

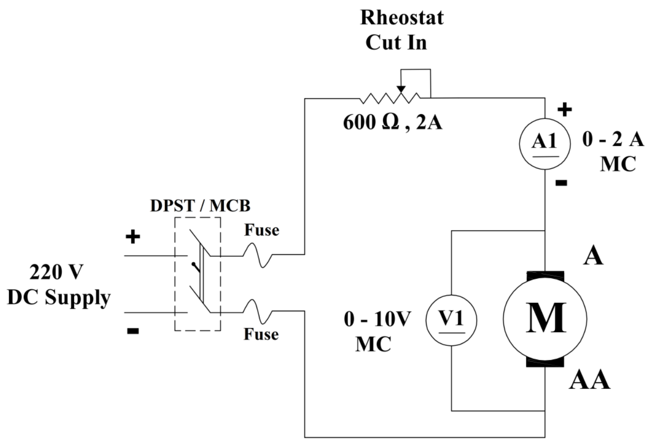
Apparatus Required:

Circuit Ref.	Equipment	Rating	Quantity
A_1,A_3,A_4	Moving coil ammeter	0-20A	3
A_2,A_5	Moving coil ammeter	0-2A	2
V_1,V_2	Moving coil voltmeter	0-250V	2
V_3	Moving coil voltmeter	0-600V	1
R_{fm} , R_{fg}	Rheostat	300Ω, 1.5A	2
S_1	SPST Switch	220V, 16A	1

Procedure :

1. Connections are made as shown in the circuit diagram.
2. Keep the motor field rheostat cut out and generator field rheostat cut in and the switch 'S' open.
3. Close the supply switch.
4. Cut in the motor field rheostat until the rated speed is reached.
5. Now cut out the field rheostat of the generator slowly and observe the reading of the voltmeter across the switch. If it decreases, continue cutting out the resistance until the voltmeter reads zero and close the SPST switch. If the voltmeter reading increases when the resistance is cut out, then interchange the armature terminals, cut out the resistance and bring the voltmeter to zero before closing the switch. Now the generator voltage is equal to the supply voltage.
6. Note down the no-load readings.
7. Now over-excite the generator (increase the field current) and under-excite the motor and maintain the constant speed (decrease its field current). Note down all the meter readings.
8. Continue until rated current flows through the motor armatures by maintaining rate speed of the motor.
9. Slowly bring back field rheostat R_{fg} to cut in position by maintaining rated speed & adjust motor field rheostat R_{fm} until the generator armature current shows zero (A_4) then open SPST switch. Reduce the speed and open the main supply switch.
10. Measure the armature resistance of the motor and generator by the VA method.
11. The efficiency of the machines is calculated. The graph of efficiency versus output of both the machines are plotted.

Measurement of armature resistance :



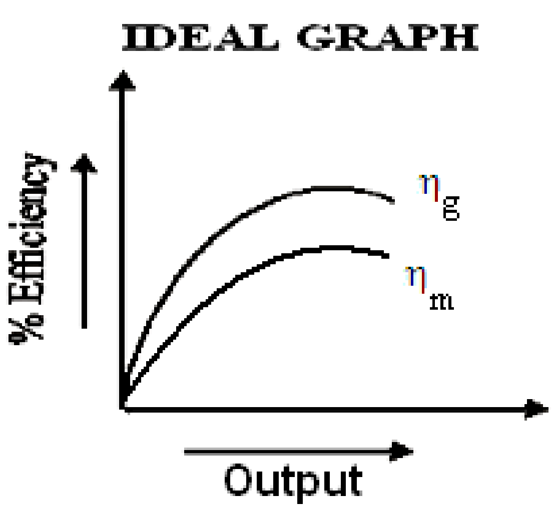
Resistance of the armature:

V(Volts)	I (Amps)	R_a = V/I Ohms

Motor Armature resistance (R_{arm})=______Ohms

<u>Note:</u>- Similarly found Generator armature resistance

GeneratorArmature resistance (R_{arg})=______Ohms



Hopkinson's test :

N = __________rpm

Sl. No.	I_L Amps	I_{fm} Amps	I_{am} Amps	I_{fg} Amps	I_{ag} Amps	V_1 volts	V_2 volts

Efficiency of generator :

Output (Watts)	Losses (watts)	Input = output + losses	% η_g

Efficiency of Motor :

Input (Watts)	Losses (watts)	output = Input - losses	% η_m

Calculations:

Power drawn by supply = $V_1 * I_L$ =____________Watts

Motor armature copper losses = $I_{am}^2 * R_{arm}$=____________Watts

Motor field copper losses = $V_1 * I_{fm}$=____________Watts

Total motor loss = $I_{am}^2 * R_{arm} + V_1 * I_{fm} + W/2$ =____________Watts

Generator armature copper losses = $I_{ag}^2 * R_{arg}$=____________Watts

Generator field copper losses = $V_2 * I_{fg}$=____________Watts

Total generator loss = $I_{ag}^2 * R_{arg} + V_2 * I_{fg} + W/2$=____________Watts

Total stray losses of the two machines (W) = $V_1 * I_L - [(V_1 * I_{fm} + I_{am}^2 * R_{arm}) + (V_2 * I_{fg} + I_{ag}^2 * R_{arg})]$ =____________Watts

Assuming stray losses to be equally distributed in both the machines, stray losses in each machines = $\frac{W}{2}$ =____________Watts

%Efficiency of the motor = $\frac{(\text{Motor input} - \text{losses})}{\text{Motor input}} * 100 = \frac{[V_1(I_{fm}+I_{am}) - \text{Total loss of motor}]}{V_1(I_{fm}+I_{am})} * 100$

% Efficiency of the generator = $\frac{\text{Generator output}}{(\text{Generator output} + \text{losses})} * 100 = \frac{V_2(I_{ag} - I_{fg})}{V_2(I_{ag} - I_{fg}) + \text{Total loss of generator}} * 100$

Inference :

On completion of the experiment, the student will determine Efficiency at different loads.

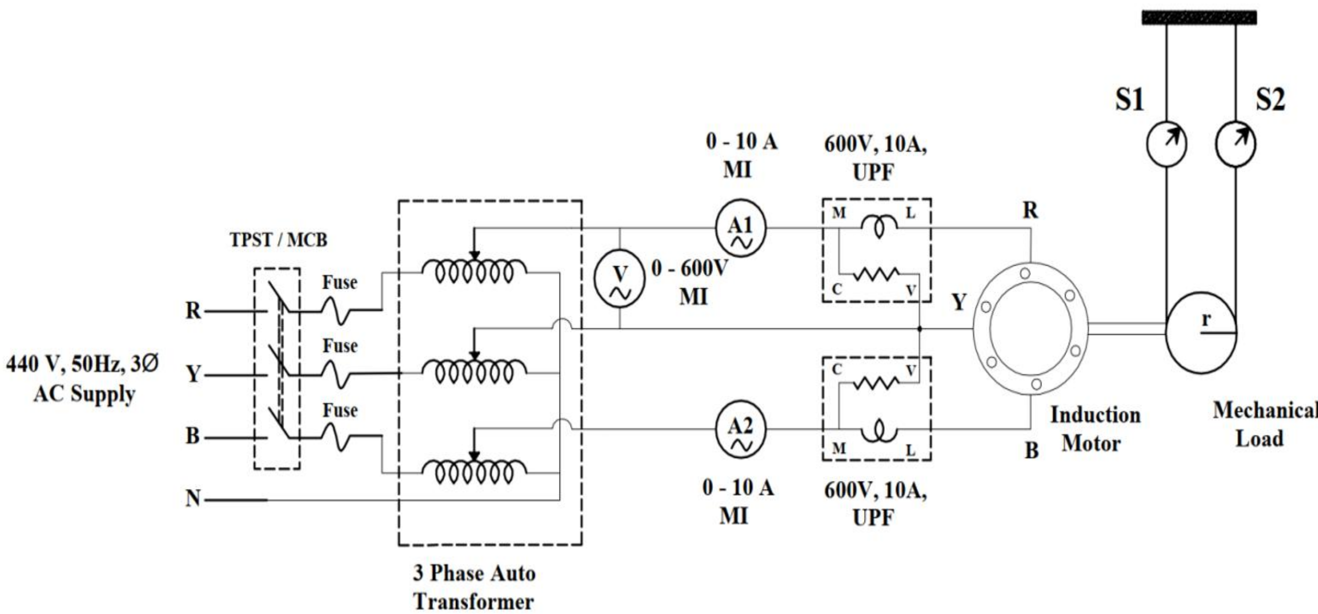
Experiment - 5

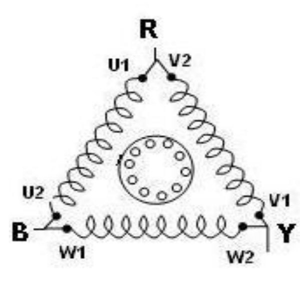
Load test on three phase Induction Motor

Learning Objectives:

To Conduct Load test on three phase induction motor to obtain performance curves by Indirect Loading (Mechanical Loading) BHP v/s η, BHP v/s slip, BHP v/s power factor and torque v/s speed.

Circuit Diagram:





Apparatus Required :

Sl No	Equipment	Rating	Quantity
1.	3Φ Auto transformer	0 – 470V	1 Nos.
2.	AC Ammeter	0 – 10A	2 Nos.
3.	AC Voltmeter	0 – 600V	1 No.
4.	UPF wattmeter	10/20A, 600V	2 No.

Procedure :

1. Make the connections as shown in the circuit diagram.
2. Keeping the Brake drum free, the supply switch is closed (pour water into the brake drum before closing the switch).
3. With the 3ϕ auto-transformer at minimum position, the supply switch is closed. Using the 3ϕ auto-transformer apply the rated voltage.
4. The Induction motor current is increased by tightening the brake drum till the rated current. At each current, all the meter readings are noted, including the speed of the Induction motor.
5. The brake drum is made free and then the 3ϕ auto-transformer voltage is reduced to zero and supply switch is opened.

Tabular Column:

Sl. No.	I_1 Amps	I_2 Amps	$I=\frac{(I_1+I_2)}{2}$	Wattmeter reading in Watts W1+W2	Spring balance Reading		S=S1-S2	Torque (N-m)	BHP	%η	Slip	N rpm
					S1	S2						

Calculations :

Torque= 9.81*S*R =

R is the radius of the brake drum in meters.

$$output = \frac{2\pi NT}{60}$$

$$BHP = \frac{2\pi NT}{4500}$$

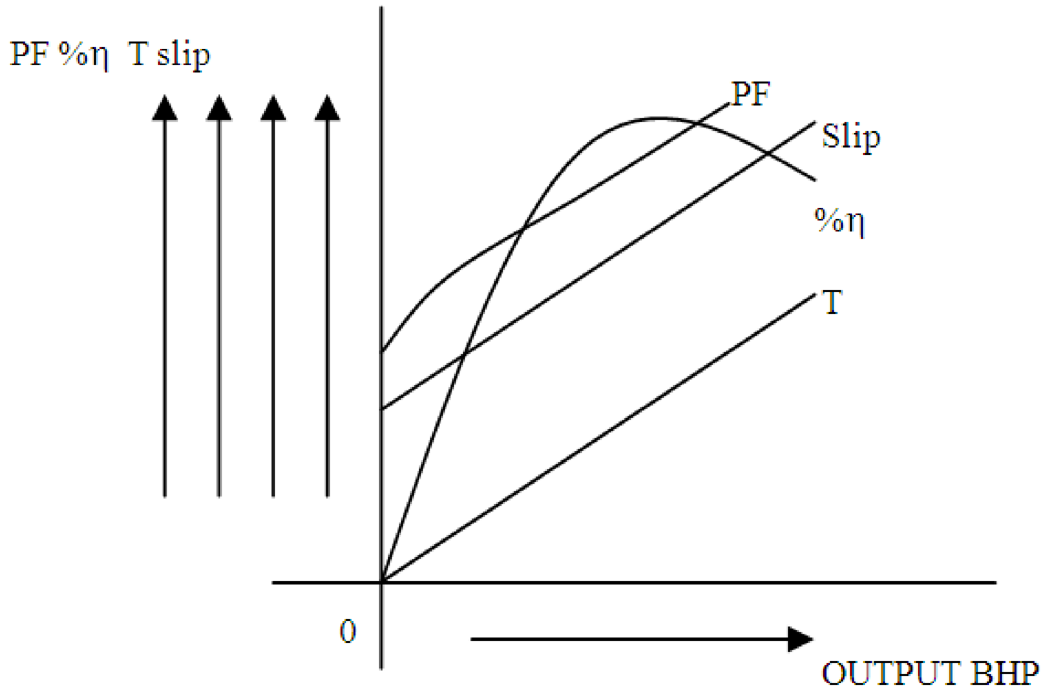
$$\therefore \text{\% Efficiency of the motor} = \frac{\text{Output in Watts}}{\text{Input in Watts (wattmeter reading)}} \times 100$$

$$\text{power factor} = \frac{W}{\sqrt{3} V I}$$

$$\% slip = \frac{N_S - N}{N_S} \times 100$$

$$N_S = \frac{120 \times f}{P}$$

Expected Performance Curves :



Inference :

On completion of the experiment, the student will understand the characteristics of a three-phase induction motor.

Experiment – 6 (A)

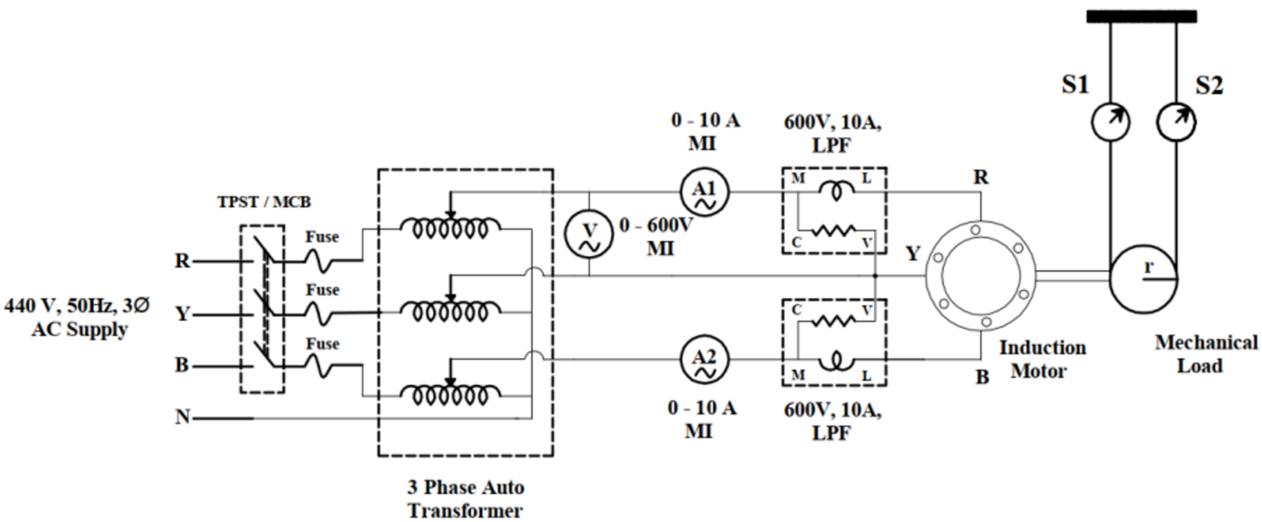
Blocked and no-load test on three phase induction motor to draw equivalent circuit and Determination of performance parameters at different load conditions

Learning Objectives:

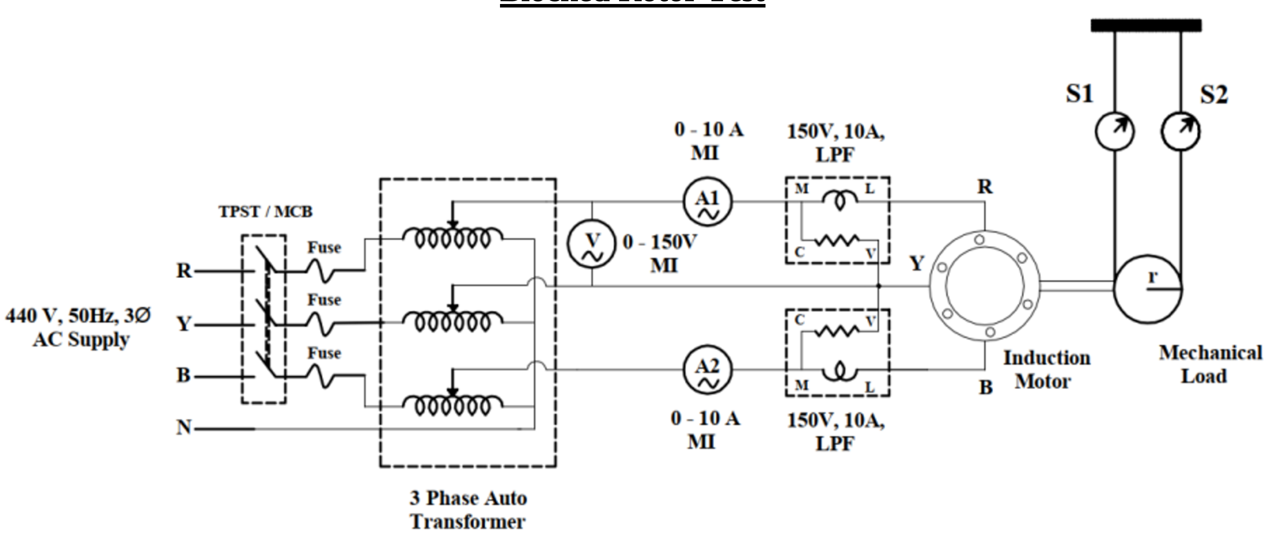
To obtain the equivalent circuit parameters of three phase Induction motor and determination of performance parameters at different load conditions.

Circuit Diagram:

No Load Test



Blocked Rotor Test



Apparatus Required:

Sl No	Apparatus	Range	Quantity
1.	3ϕ Auto transformer	0 – 470V	1 No.
2.	AC Ammeter	0 – 10A	2 Nos.
3.	AC Voltmeter	0 – 600V	1 No.
4.	DC Ammeter	0 – 2A	1 No.
5.	DC Voltmeter	0 – 300V	1 No.
6.	UPF wattmeter	10/20A, 600V	2 No.
7.	Connecting wires		

Procedure:

Open Circuit test:

1. Make connections as shown in the circuit diagram (a).
2. Keeping the brake drum free & the 3phase autotransformer in minimum position, Supply Switch is closed.
3. The rated voltage of the Induction Motor is applied by varying the 3-phase autotransformer.
4. The readings of all the meters are noted.
5. 3-phase autotransformer voltage is reduced to minimum position. The supply switch is opened.

Blocked Rotor test:

1. Make connections as shown in circuit diagram (b).
2. Keeping the brake drum of Induction Motor tight & 3-phase autotransformer in minimum position, supply switch is closed.
3. The 3-phase autotransformer voltage is increased slowly to get the ammeter reading less than the stator current. All the meter readings are noted.
4. 3-phase autotransformer voltage is reduced to minimum position & the brake drum of the Induction motor is made free. The supply switch is opened.

Tabular Column:

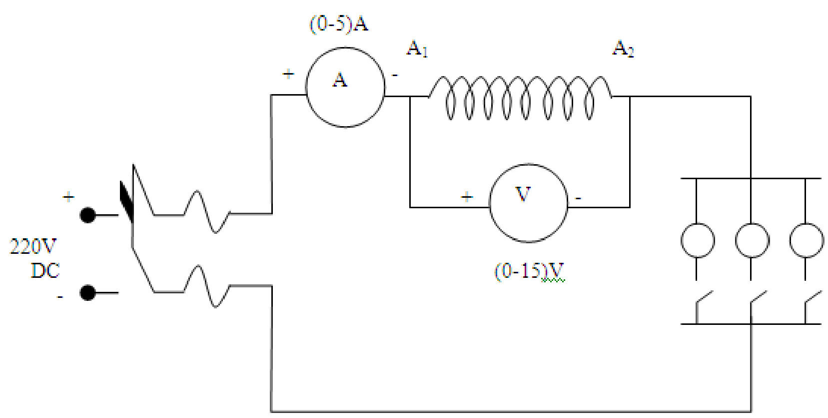
From Open circuit test:

Sl No.	V_0 **Open Circuit Voltage (volts)**	I_1 **Ammeter reading (amps)**	I_2 **Ammeter reading (amps)**	$I_0 = \frac{I_1 + I_2}{2}$	W_1 **Wattmeter Reading (watts)**	W_2 **Wattmeter Reading (watts)**	$W_0 = W_1 + W_2$ **(watts)**

From Blocked Rotor test:

Sl No.	V_{SC} **Short Circuit Voltage (volts)**	I_1 **Ammeter reading (amps)**	I_2 **Ammeter reading (amps)**	$I_0 = \frac{I_1 + I_2}{2}$	W_1 **Wattmeter Reading (watts)**	W_2 **Wattmeter Reading (watts)**	$W_0 = W_1 + W_2$ **(watts)**

Measurement Of Resistance:



Procedure for Measurement of Resistance:

1. Connect the circuit as shown in the above circuit diagram.
2. With regulated Power Supply in minimum position, Switch ON the supply.
3. Vary the Regulated power supply rheostat, note down ammeter & voltmeter readings.
4. Reduce the RPS to zero position & rheostat to cut in position the supply switch is opened.

Tabular Column:

Sl. No.	I_{DC}	V_{DC}	R_{DC}

Calculations:

From No Load Test:

1. I_L (Loss Component) $= \frac{I_0 \cos\phi_0}{\sqrt{3}}$
2. I_μ (Magnetizing Component) $= \frac{I_0 \sin\phi_0}{\sqrt{3}}$
3. $R_0 = \frac{V_0}{I_L}$; $X_0 = \frac{V_0}{\mu}$

From blocked rotor test:

1. $R_{01}/Ph = \frac{W_{SC}}{\sqrt{3}\left(\frac{I_{SC}}{Ph}\right)^2}$; $Z_{01}/Ph = \frac{V_{SC}}{\left(\frac{I_{SC}}{\sqrt{3}}\right)}$; $X_{01}/Ph = \sqrt{Z_{01}^2 - R_{01}^2}$
2. Starter Winding Resistance: $R_{DC} =$ ________ $R_{AC} = 1.3R_{DC}$
3. $R_L^| = R_2^|\left(\frac{1}{S} - 1\right)$; Where $R_2^| = R_{01} - R_1$
4. $I_2^| = \frac{V_{Ph}}{R_{01} + R_L^| + JX_{01}}$

5. $Output = 3 \times \left|I_2^{|}\right|^2 \times R_L^{|}$
6. Input = Output + losses at R_{01} + losses at R_{01} (i.e., W_0)
7. $\%\eta = \frac{output}{input} \times 100$

Inference :

On completion of the experiment, the student will understand the motor characteristics in all the operating conditions and the equivalent circuit parameters of 3Φ Induction motor and performance parameters at different load conditions.

Experiment - 6(B)

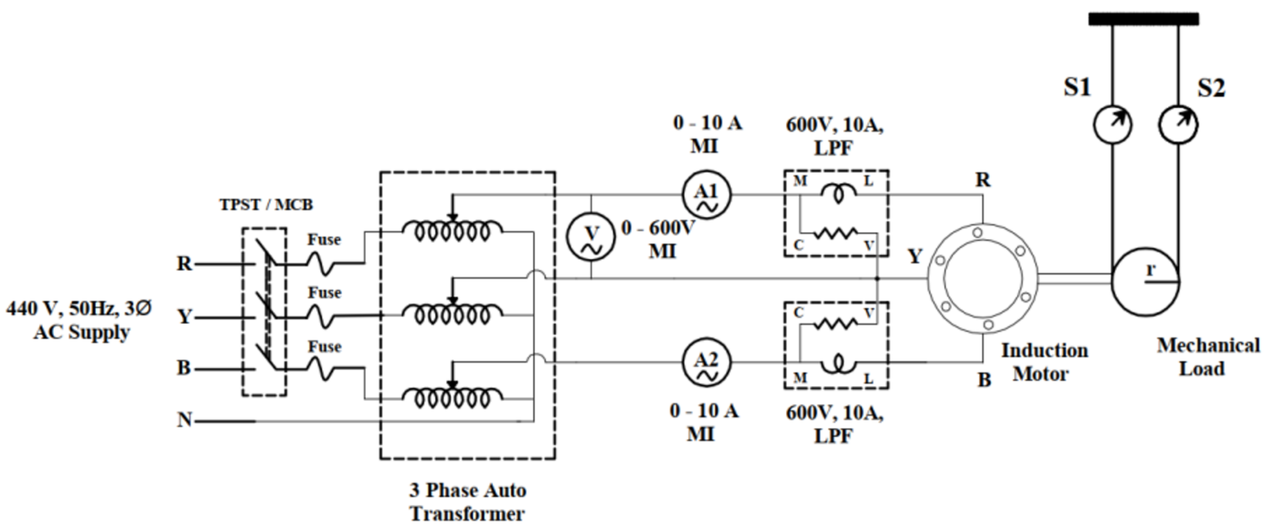
Blocked and no - load test on three phase induction motor to draw circle diagram and Determination of performance parameters at different load conditions

Learning Objectives:

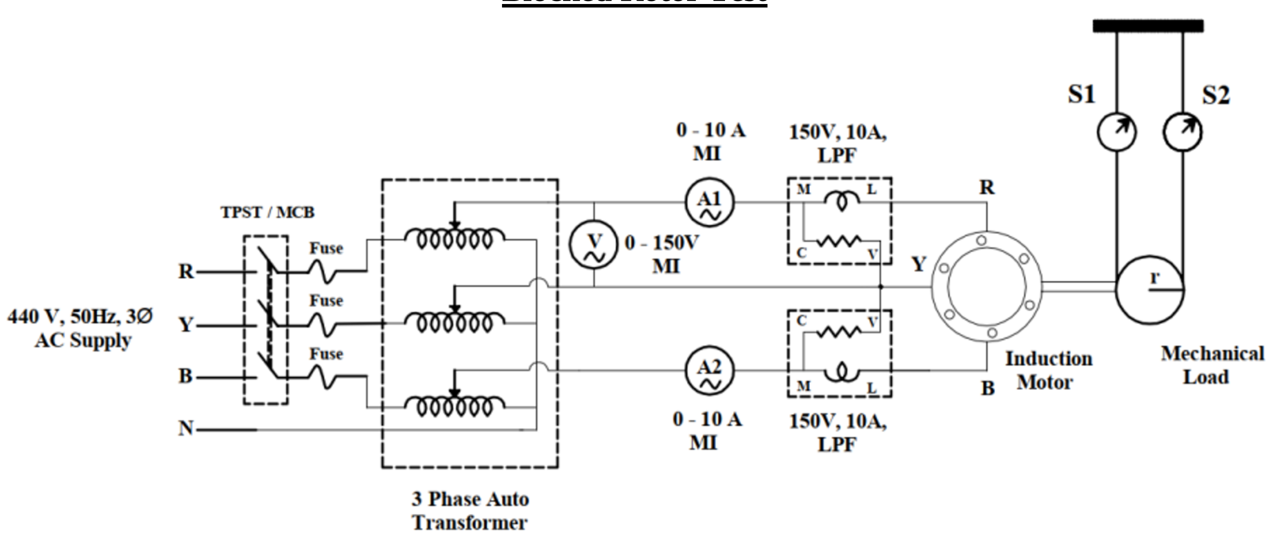
To draw Circle Diagram of Three phase Induction motor and determination of performance parameters at different load conditions.

Circuit Diagram:

No Load Test



Blocked Rotor Test



Apparatus Required:

Sl No	Apparatus	Range	Quantity
1.	3ϕ Auto transformer	0 – 470V	1 Nos.
2.	AC Ammeter	0 – 10A	2 Nos.
3.	AC Voltmeter	0 – 600V	1 No.
4.	DC Ammeter	0 – 2A	1 No.
5.	DC Voltmeter	0 – 300V	1 No.
6.	UPF wattmeter	10/20A, 600V	2 No.

Procedure:

Open Circuit test:

1. Make connections as shown in circuit diagram (a).
2. Keeping the brake drum free & the 3phase autotransformer in minimum position, Supply Switch is closed.
3. The rated voltage of the Induction Motor is applied by varying the 3-phase autotransformer.
4. The readings of all the meters are noted.
5. 3-phase autotransformer voltage is reduced to minimum position. The supply switch is opened.

Blocked Rotor test:

1. Make connections as shown in circuit diagram (b).
2. Keeping the brake drum of Induction Motor tight & 3-phase autotransformer in minimum position, supply switch is closed.
3. The 3-phase autotransformer voltage is increased slowly to get the ammeter reading less than the stator current. All the meter readings are noted.
4. 3-phase autotransformer voltage is reduced to minimum position & the brake drum of the Induction motor is made free. The supply switch is opened.

Tabular Column:

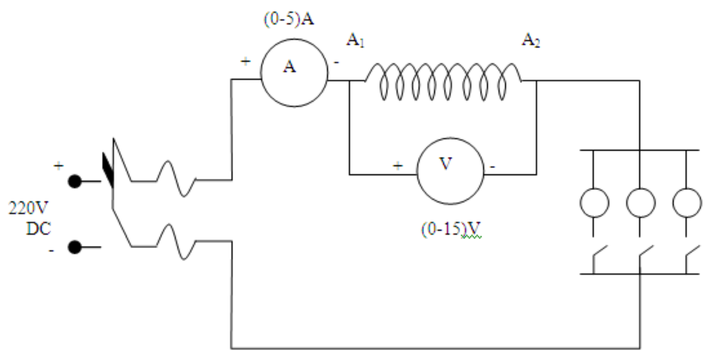
From Open circuit test:

Sl No.	V_0 Open Circuit Voltage (volts)	I_1 Ammeter reading (amps)	I_2 Ammeter reading (amps)	$I_0 = \frac{I_1 + I_2}{2}$	W_1 Wattmeter Reading (watts)	W_2 Wattmeter Reading (watts)	$W_0 = W_1 + W_2$ (watts)

From Blocked Rotor test:

Sl No.	V_{SC} Short Circuit Voltage (volts)	I_1 Ammeter reading (amps)	I_2 Ammeter reading (amps)	$I_0 = \frac{I_1 + I_2}{2}$	W_1 Wattmeter Reading (watts)	W_2 Wattmeter Reading (watts)	$W_0 = W_1 + W_2$ (watts)

Measurement Of Resistance:



Procedure for Measurement of Resistance:

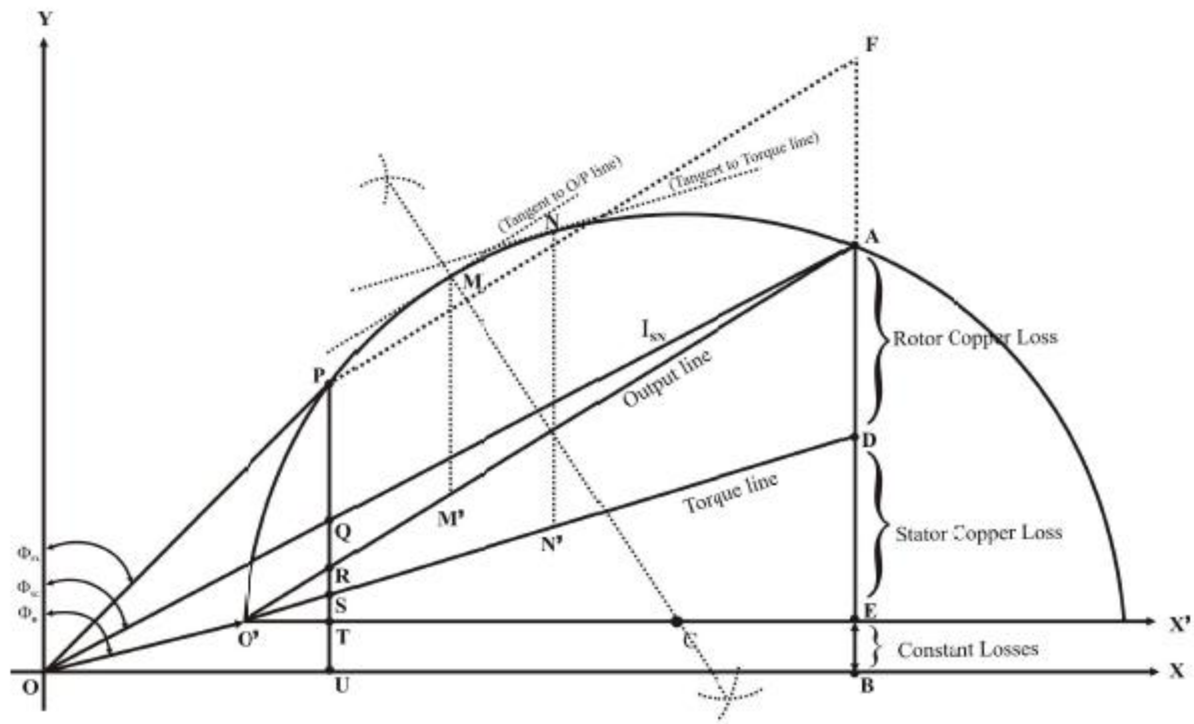
1. Connect the circuit as shown in the above circuit diagram.
2. With regulated Power Supply in minimum position, Switch ON the supply.
3. Vary the Regulated power supply rheostat, note down ammeter & voltmeter readings.
4. Reduce the RPS to zero position & rheostat to cut in position the supply switch is opened.

Tabular Column:

Sl. No.	I_{DC}	V_{DC}	R_{DC}

Expected Performance Curves :

Construction of Circle Diagram for an Induction Motor:



Procedure:

NOTE: I_0 and I_{SC} are line currents obtained from Open Circuit and Short Circuit Tests respectively.

1. The angle between No-Load voltage Vo and No-Load current Io is,

$$\cos\phi_0 = \frac{W_0}{\sqrt{3V_0 I_0}}$$

Where, W_0 is sum of wattmeter readings $W_1 \& W_2$ (obtained from No-Load Test).

I_0 is represented as OO' placed at an angle of lagging with respect to voltage vector, V.

2. The angle between Short circuit voltage Vsc and Short circuit current Isc is

$$\cos\phi_0 = \frac{W_{SC}}{\sqrt{3V_{SC} I_{SC}}}$$

Where, W_{SC} is sum of wattmeter readings $W_1 \& W_2$ (obtained from Blocked Rotor Test).

$$I_{SN} = I_{SC} \times \left[\frac{V_{rated}}{V_{SC}}\right]^2$$

Where, I_{SN} is the short circuit current for a rated voltage of $V_{rated,}$ I_{SN} is represented as OA,placed at an angle of ϕ_0 lagging with respect to voltage vector, V.

3. The points O'A are joined & the line is bisected at right angles. Let the bisector cut the horizontal at point C.
4. With C as center and O'C as radius, a semicircle is drawn such that it passes through A.O'A represents the **output line.**
5. AG represents short circuit input per phase with rated voltage $V_{rated,}$ which is given as,

$$W_{SN} = W_{SC}\left(\frac{V_{rated}}{V_{SC}}\right)^2$$

6. $Power\ Scale = \frac{W_{SN}}{AG} watts/cm$
7. Using the power scale the point E is obtained by taking EF equal to stator copper loss, i.e.,

$$EF = \frac{3I_{SN}^{2}R_{AC}}{Power\ Scale}$$

Where, $R_{AC} = 1.4 \times R_{DC}$ is obtained from Measurement of resistance of the winding of the motor.(Assume $R_{AC} = 1.5\ to\ 2\Omega$)

The line O'E is represented as the **Torque Line**.

8. The line GA is extended to H,such that:

$$AH = \frac{Output/Phase}{Power\ Scale}$$

9. From H drawn a line parallel to Output line O'A,such that the line cuts the semicircle at point O.From P draw a line perpendicular to OG.
10. Efficiency at full load is,

$$\%\eta = \frac{PQ}{PT} \times 100$$

11. $Slip\ at\ Full\ Load = \frac{Rotor\ Cu\ Loss}{Rotor\ input} = \frac{QR}{PR} \times 100$
12. Power factor at Full Load, $p.f = \frac{PT}{PO}$
13. Full Load Line Current $= \sqrt{3} \times OP \times current\ scale$
14. Full load Torque $= 3 \times PR \times power\ scale\ sync.\ watts$
15. Draw a line parallel to Output line O'a such that it cuts the semicircle tangentially at point M. From M draw line MN perpendicular to OA to cut the output Line at N.
16. Maximum Power Output $= 3 \times \left(MN \times power\ scale\right)\ sync.\ watts$
17. Draw a line parallel to Torque line O'E such that it cuts the semicircle tangentially at point K. From K draw line KL perpendicular to OE to cut the output Line at L.
18. Maximum Torque Output $= 3 \times \left(KL \times power\ scale\right)\ sync.\ watts$
19. Starting Torque $T_{ST} = AE \times power\ scale.$
20. Starting Torque with respect to Full load Torque, $T_{ST} = \frac{AE}{PR} \times T_{FL}$

Inference :

On completion of the experiment, the student will understand the motor characteristics in all the operating conditions the Circle Diagram of the 3Φ Induction motor is obtained and performance parameters at different load conditions are determined

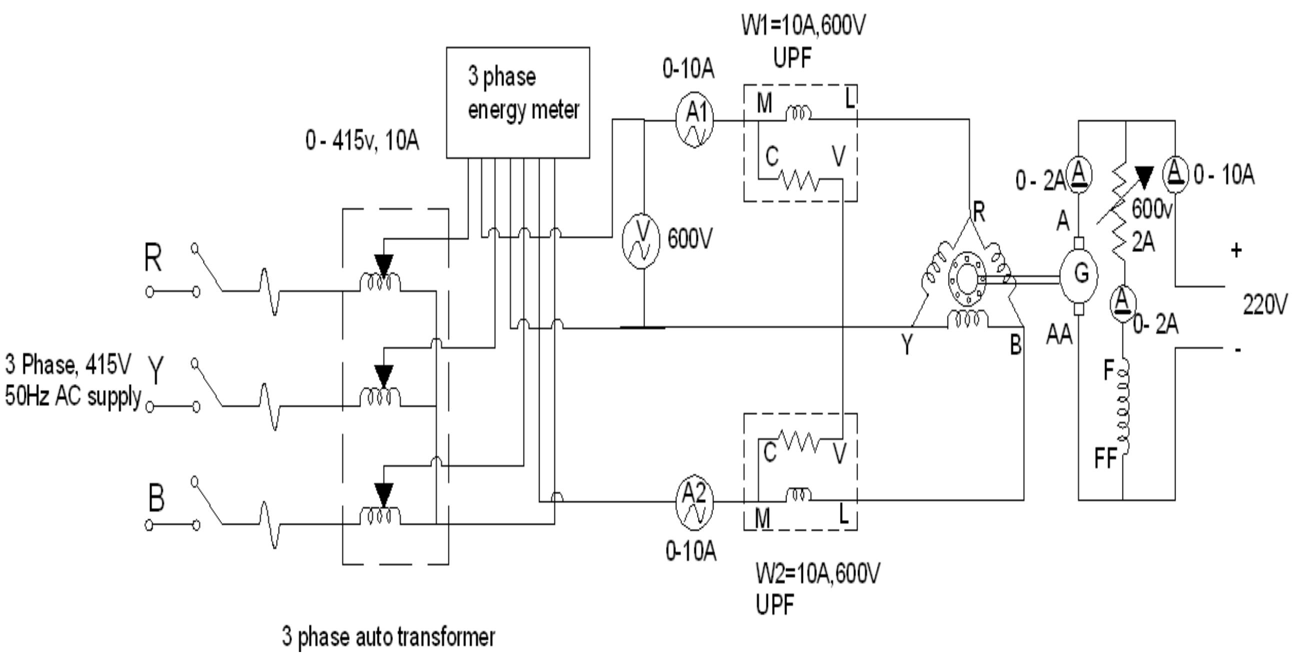
Experiment - 7

Load test on induction generator

Learning Objectives:

To run the induction machine as an induction generator and obtain the Performance characteristic of an induction machine and measure the real and reactive powers.

Circuit Diagram:



Apparatus Required:

Sl No	Apparatus	Range	Quantity
1.	AC Ammeter	0 – 10A	2 Nos.
2.	AC Voltmeter	0 – 600V	1 No.
3.	DC Ammeter	0 – 2A	1 No.
4.	DC Voltmeter	0 – 300V	1 No.
5.	UPF wattmeter	10/20A, 600V	2 Nos.
6.	3 phase Autotransformer	0 to 470V	1 No.
7.	Rheostat	600 ohms	1

Procedure:

1. Make the connections as shown in the circuit diagram. The field resistance is kept maximum, S_1 is kept open. DC supply is kept open.
2. The AC Supply switch is closed.
3. The Field resistance of the generator is gradually reduced till rated voltage of generator is built-up, which can be read on voltmeter.
4. The DC supply switch is closed. The reading of voltmeter across the single pole switch S1 is noted. If it reads zero, the polarity of the generator voltage is same as that of the DC supply. On the hand, if voltmeter across S_1 reads double the rated voltage, then polarities are opposite and in this case armature terminals of DC generator are interchanged.
5. The voltage across S_1 is made by slightly adjusting the field resistance and then S1 is closed.
6. Now, the field resistance is gradually increased in steps above synchronous speed and at each step, reading of all the meters is noted and tabulated. Speed is also measured at each step. (The DC generator runs as a DC motor and drives the induction motor as an induction generator.)
7. This continues till the rated current of the induction machine is reached.
8. Now the field resistance is cut out until both ammeters reads zero. The switch S1 is opened and resistance is completely cut in until the generator voltage reduces to zero. The DC supply switch and the AC supply are opened.

Tabular Column:

Sl. No.	I_L **Amps**	W_1 **Watts**	W_2 **Watts**	V_{DC} **volts**	**Speed RPM**	**Output watts**	**Input watts**	**Efficiency** $\%\eta$	$p.f = \cos\phi$

Calculations:

Power Input = $V_{DC} I_{DC} \times 0.8$ watts assuming 80% efficiency for DC motor

Power Output = $(W_1 + W_2)$ watts

$$\%\eta = \frac{(W_1 + W_2)}{V_{DC} I_{DC} \times 0.8} \times 100$$

Power factor $(\tan\phi) = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$ (for Induction generator)

$\therefore \cos\phi =$ ________________ (leading)

$$\%slip = \frac{N_S - N}{N_S} \times 100$$

Where N_S is Synchronous speed given by

$$N_S = \frac{120 \times f}{P}$$

Inference :

On completion of the experiment, the student will understand the characteristics of an induction machine working as a generator

Experiment - 8

Load test on single phase induction motor to draw output versus torque, current, power and efficiency characteristics.

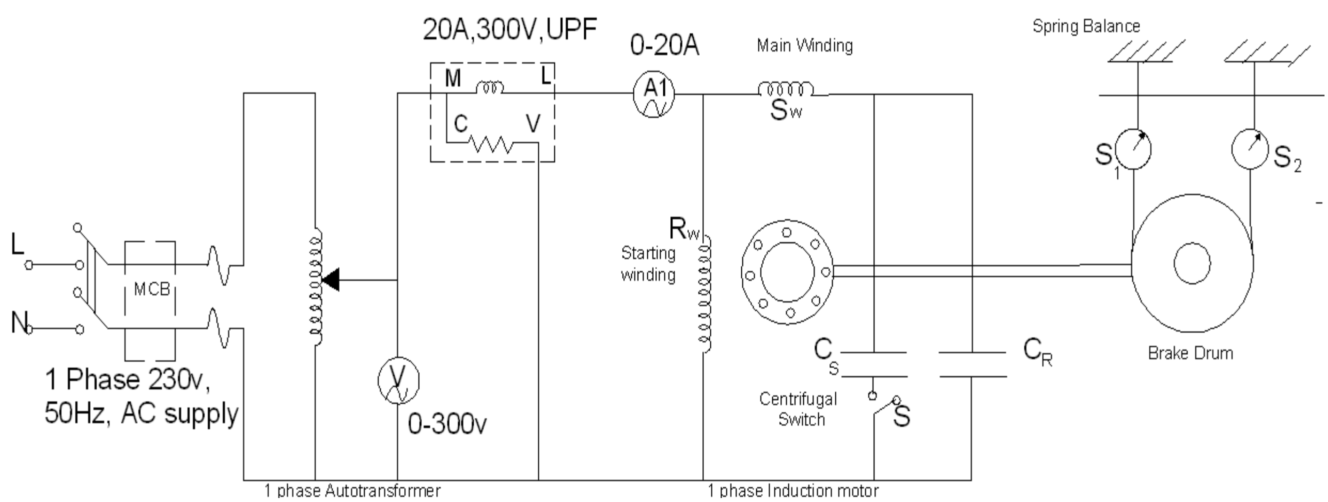
Learning Objectives:

To draw output versus torque, current, power and efficiency characteristics of single-phase induction motor.

Apparatus Required:

Sl No	Apparatus	Range	Quantity
1.	A Capacitor Start, 1ϕ Induction Motor		
2.	1ϕ Auto transformer	0 – 300V	1 Nos.
3.	AC Ammeter	0 – 10A	1 Nos.
4.	AC Voltmeter	0 – 300V	1 Nos.
5.	UPF wattmeter	5/10A, 300V	1 Nos.
6.	Connecting wires		

CIRCUIT DIAGRAM:



PROCEDURE:

1. Make the connections as shown in circuit diagram.
2. Keeping the 1Φ auto-transformer in minimum position &brake drum of the induction machine free, the supply switch is closed (pour water in the brake drum before closing the switch).
3. Apply the rated voltage by gradually varying the 1Φ auto-transformer.
4. The no load reading of ammeter, voltmeter and wattmeter with speed are noted down.
5. The induction motor current is increased by tightening the brake drum till the rated current is attained. At each current, all the meter readings are noted, including the speed of the induction motor.
6. The brake drum is made free and the 1Φ auto-transformer is brought to minimum position & the supply switch is opened.

TABULAR COLUMN:

Sl. No.	I Amps	W Watts	V Volts	N rpm	Spring balance Reading		S1~S2	Torque (Kg-m).	BHP	%η	Slip	PF
					S1	S2						

CALCULATIONS :

If S_1 and S_2 are the spring balance readings and 'r' is the radius of the brake drum in 'meters', then the shaft torque is given by

$$Torque = (S_1 - S_2)\, r\ Kg - meters.$$

$\therefore B.H.P = \frac{2\pi NT}{4500}$ Where N is the speed of the motor at that load.

The output of the motor in watts is then given by,

$$output = B.H.P \times 735.5 watts.$$

But, the input to the motor = W (wattmeter reading) watts.

$$\therefore \text{\% Efficiency of the motor} = \frac{\text{Output in Watts}}{\text{Input in Watts (wattmeter reading)}} \times 100$$

If N_S is the synchronous speed of the motor given by

$$N_S = \frac{120 \times f}{P} = \frac{120 \times 50}{4} = 1500 RPM$$

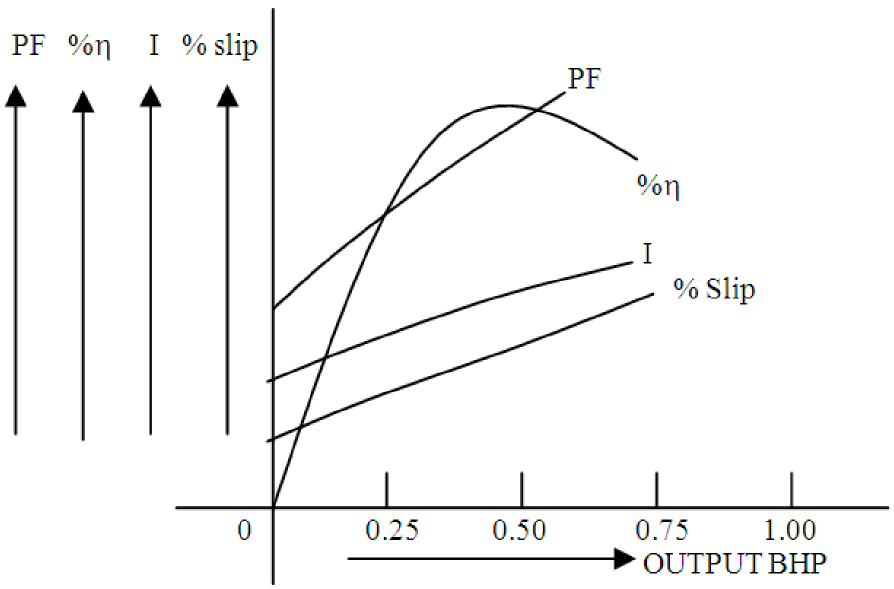
Where $f =$ frequency of the supply and $P =$ number of poles of the motor and N is the actual speed, then the % slip can be calculated using the equation,

$$\%slip = \frac{N_S - N}{N_S} \times 100$$

The p.f of the motor can be calculated using the equation $\text{power factor} = \frac{W}{V \times 1}$

<u>GRAPHS</u>:

The graph of % slip, % efficiency, power factor and the line current V/s output in B.H.P is drawn as shown below.



Inference :

On completion of the experiment, the student will understand the characteristics of a single-phase induction motor.

Experiment No: 9

Conduct suitable tests to draw the equivalent circuit of single phase induction motor and determine performance parameters.

Learning Objectives:

To conduct a test on the induction motor to determine the performance characteristics and to obtain an Equivalent circuit of a single-phase Induction motor.

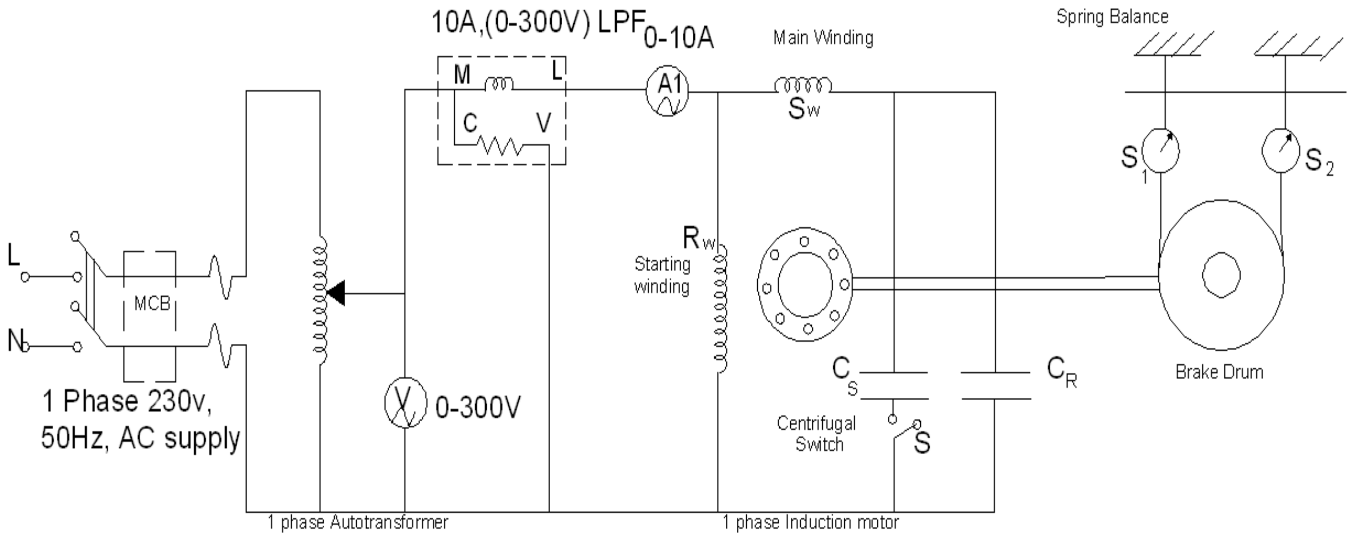
Nameplate details:
Induction Motor:

APPARATUS REQUIRED:

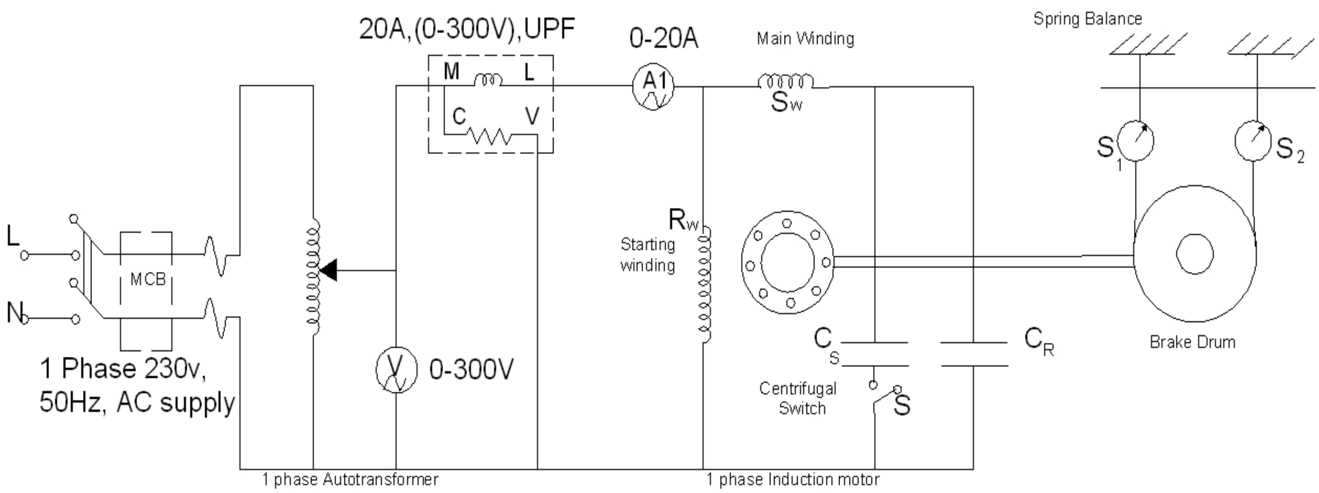
S. No	Name of Apparatus	Range	Type	Qty.
1	A Capacitor Start, single phase Induction motor			
2	AC Voltmeter	0-300V	Moving iron	1
3	AC Ammeter	0-10A	Moving iron	1
4	AC Ammeter	0-20A	Moving iron	1
5	Wattmeter	0-300V, 20A	UPF	1
6	Wattmeter	0-300V, 10A	LPF	1
7	1 Φ Auto-transformer	0 – 300V		
6	Connecting wires			

CIRCUIT DIAGRAM:

No Load Test on Single phase induction motor



Block Rotor Test on Single phase induction motor



PROCEDURE:

No Load Test:

1) Connections are given as per the circuit diagram.
2) Precautions are observed and the motor is started at no load.
3) The autotransformer is varied to have a rated voltage applied.
4) Meter readings are noted.

Blocked Rotor Test

1) Connections are given as per the circuit diagram.
2) Precautions are observed and the motor is started at full load or blocked rotor position.
3) The autotransformer is varied to have a rated current flowing in the motor.
4) Meter readings are noted.

PRECAUTIONS

NO LOAD TEST

1) Initially DPST Switch is kept open.
2) Autotransformers are kept at a minimum potential position.
3) The machines must be started on no load.

BLOCKED ROTOR TEST

1) Initially the DPST Switch is kept open.
2) Autotransformers are kept at a minimum potential position.
3) The machine must be started at full load (blocked rotor)

$R_{eff}=1.5*R_{DC}$

FORMULA:

NO LOAD TEST:

- $\cos \Phi = Wo/VoIo$
- $I_w = I_o \cos\Phi$
- $I_m = I_o \sin \Phi$
- $R_o = V_o/Iw$
- $X_o = V_o/Im$

Blocked Rotor Test

- $Z_{sc} = V_{sc}/I_{sc}\ \Omega$
- $R_{sc} = W_{sc}/I_{sc2}\ \Omega$
- $X_{sc} = \sqrt{(Z_{sc2} - R_{sc2})}\ \Omega$

Tabular Columns:

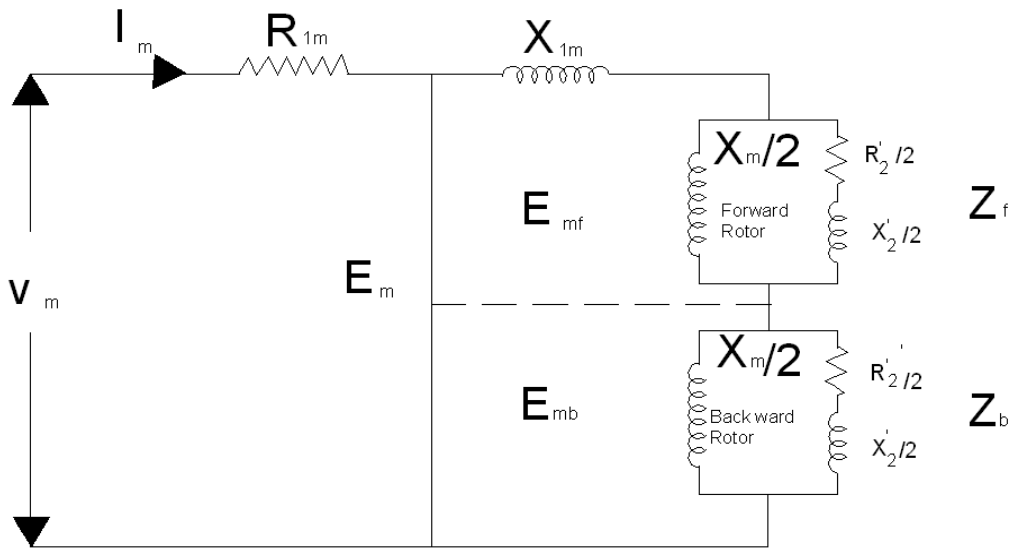
NO LOAD TEST:

Sl.No.	Vo(volts	Io(amps)	Wo (watts)
1.			

BLOCKED ROTOR TEST

Sl.No.	Vsc (volts)	Isc (amps)	Wsc(watts)
1.			

Equivalent Circuit:



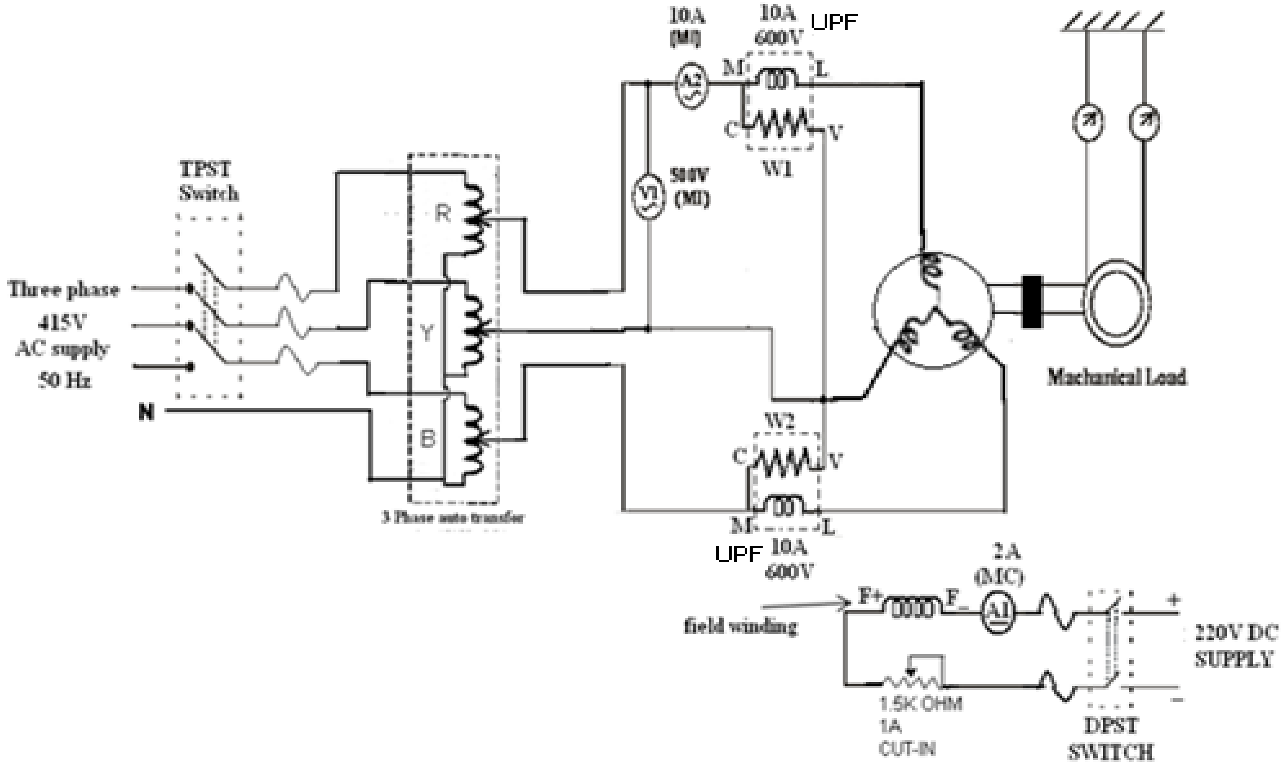
Inference: On completion of the experiment, the student will understand the performance characteristics single phase induction motor.

Experiment No: 10

Conduct an experiment to draw V and Λ curves of the synchronous motor at no load and load conditions

Learning Objectives:

To obtain V and Λ curves of synchronous motor.



Name plate details:

Synchronous Motor:

Apparatus:

Circuit reference	Description	Rating	Quantity
A_1	Moving coil Ammeter	0-2 A	1
A_2	Moving iron Ammeter	0 -10 A	1
V_1	Moving iron voltmeter	0 -500 V	1
W_1,W_2	Watt meters	10 A, 600 V	2
R_{fm}	Rheostat	1.5KΩ, 1 A	1
Auto-transformer	3Φ Auto-transformer	415V	1

Procedure:

1. Connections are made as shown circuit diagram.
2. Now close the AC supply switch and apply 415V by varying 3Φ auto-transformer and ensure proper direction of rotation of the motor.
3. Close the DC supply switch with the field rheostat completely cut-in, thus exciting the field of the synchronous motor. Let the motor run on no-load.(The line current should decrease slightly when DC supply switch is closed, if line current is increased interchange the field terminals)
4. Synchronous motor runs at synchronous speed.
5. Now vary the excitation of the synchronous motor in steps by varying the field rheostat.
6. Note down the corresponding reading.
7. Further variation of field excitation cause line current to reach to its minimum and increases from minimum to higher values of load current.
8. Care has to be taken to see that excitation should not be increase further beyond the rated value.
9. Reduce the excitation to a minimum. Open the DC supply switch and bring auto-transformer to minimum position and open AC supply switch.

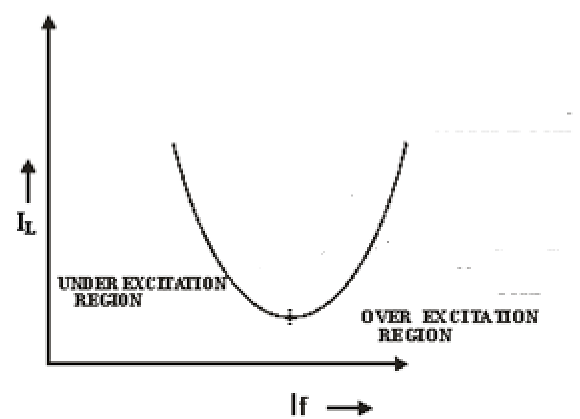
Tabular Column

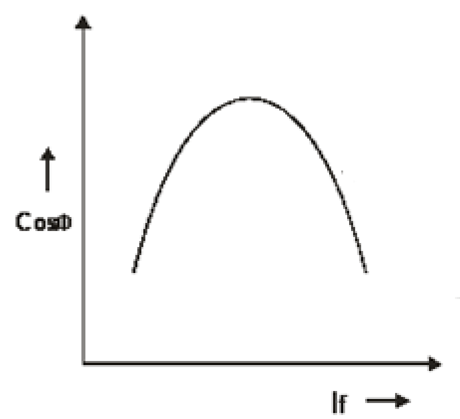
I_f in Amps	I_L in Amps	W_1 in watts	W_2 in watts	Cos Φ

Without Load

Cos Φ = $(W1 + W2)\ /\ (\sqrt{3}\ V_L I_L)$

<u>Ideal graph:</u>





<u>Outcome</u>

On completion of the experiment, the student will draw the performance curves and understand performance characteristics of synchronous motor.

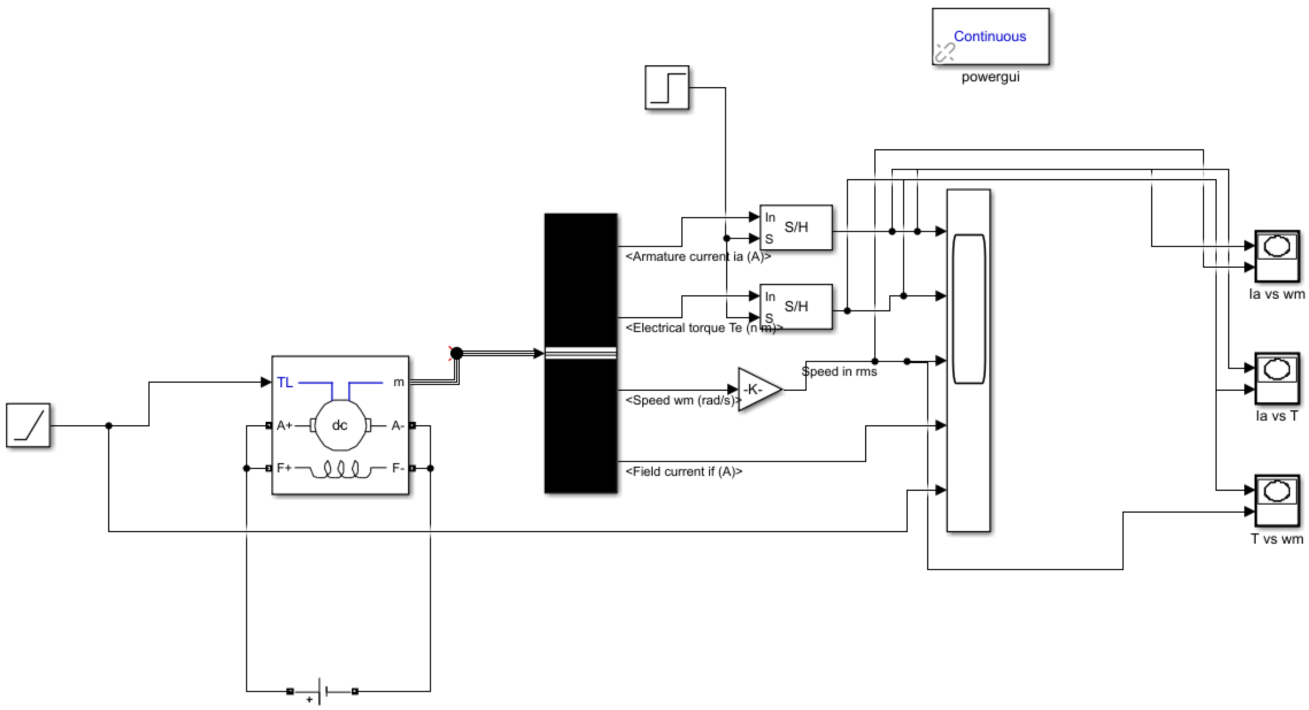
Experiment No: 11

Conduct an experiment to analyze the current and load torque of the DC Shunt Motor using Simscape.

Objective

To simulate and analyze the armature current, field current, and load torque of a DC shunt motor using Simscape in MATLAB/Simulink.

Circuit Diagram



Procedure:

Step 1: Open MATLAB and Create a New Simulink Model

1. Open MATLAB and type simulink in the command window.
2. Create a new Simulink model.

Step 2: Add and Configure the DC Shunt Motor

1. Drag a DC Machine (Shunt) block from the Simscape → Electrical → Specialized Power Systems → Machines library.
2. Double-click the motor block and set:
   - Rated Voltage: As per the chosen motor specification.
   - Armature Resistance and Inductance: Based on standard values.
   - Field Resistance and Inductance: Based on standard values.

Step 3: Provide Power Supply to the Motor

1. Add a DC Voltage Source from Simscape → Electrical → Specialized Power Systems → Sources.

2. Connect a Controlled Voltage Source in series to regulate armature voltage.
3. Add a Resistor and Inductor in series with the field winding to complete the circuit.

Step 4: Implement Load Torque

1. Drag a Mechanical Rotational Reference from Simscape → Foundation Library → Mechanical.
2. Add a Torque Source to simulate the load torque effect.
3. Connect the torque source to the motor shaft.

Step 5: Measurement Setup

1. Add Current Sensor and Voltage Sensor blocks to measure:
   - Armature current
   - Field current
   - Applied voltage
2. Use Scope blocks to visualize results.

Step 6: Configure Simulation Settings

1. Drag and add the PowerGUI block for simulation.
2. Set the simulation mode to Discrete or Continuous (as needed).
3. Choose an appropriate simulation time (e.g., 5 seconds).

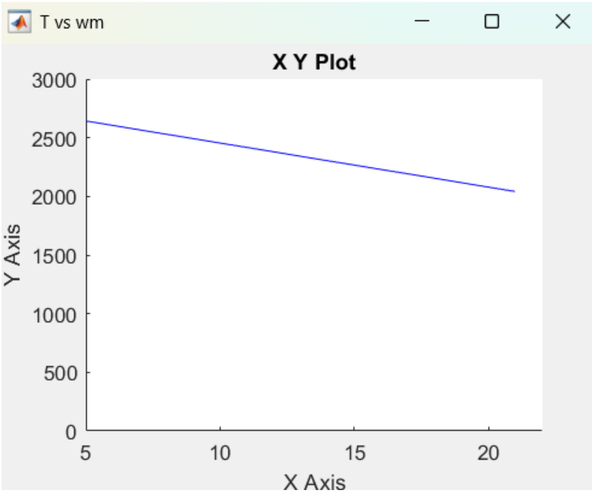
Step 7: Run the Simulation

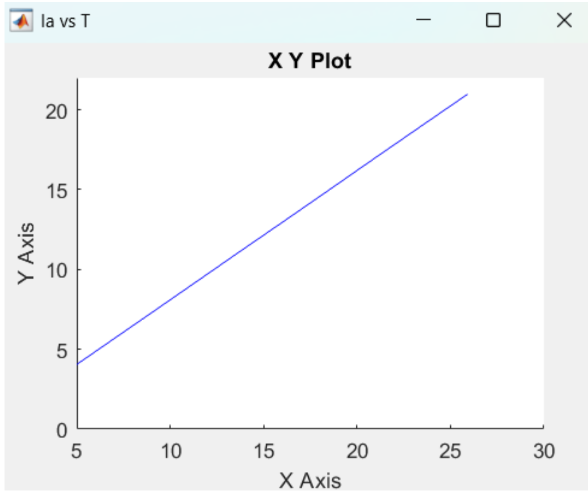
1. Click Run to start the simulation.
2. Observe the following parameters on scopes:
   - Armature Current (I_A)
   - Field Current (I_F)
   - Load Torque effect on speed

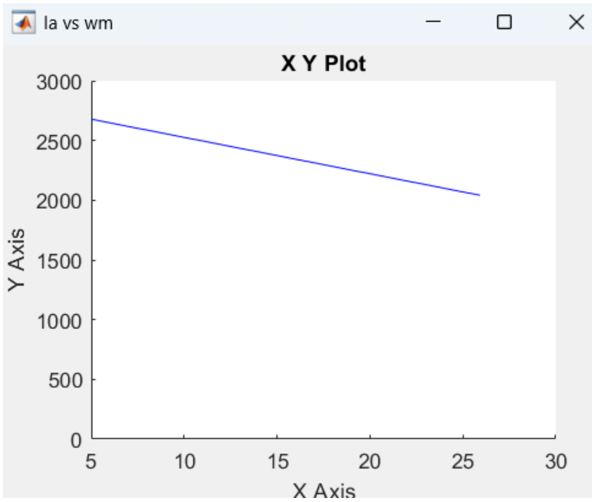
Step 8: Analyze the Results

1. Check the current and torque waveforms.
2. Observe how armature current changes with load variations.
3. Analyze the relationship between load torque and speed.

Expected Output Curves







Outcome

- The simulation provides insights into the current flow in the armature and field windings.
- Load torque directly affects the speed and armature current.
- The results help in understanding the working of a DC Shunt Motor under different loads.

For More details click on the link

https://www.youtube.com/watch?v=aicNiN4VzF4

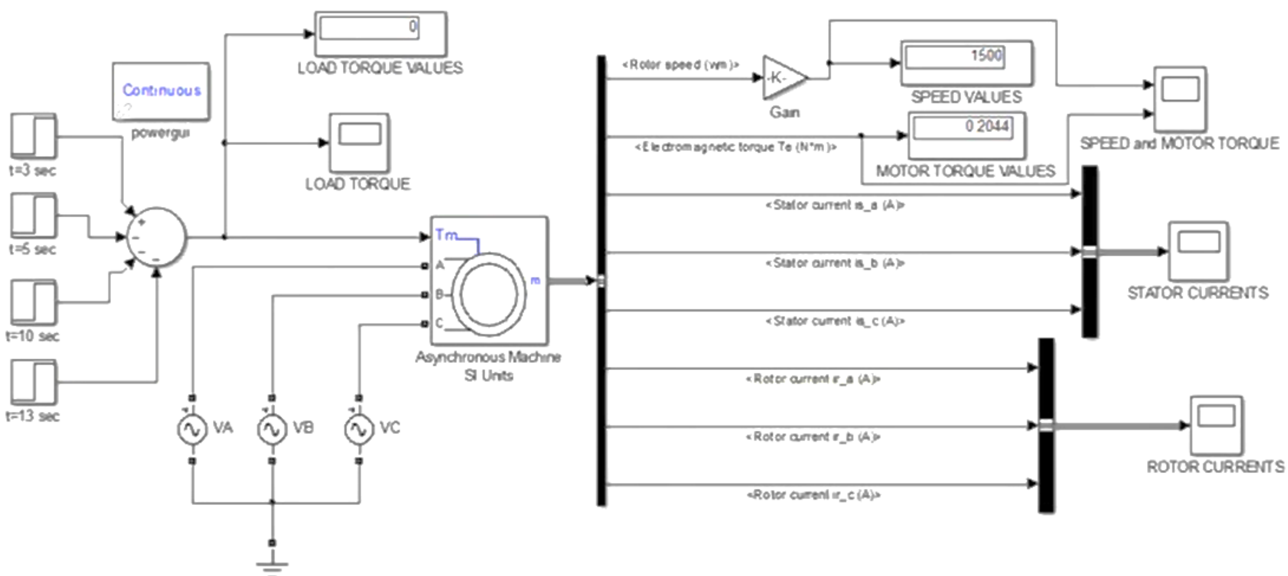
Experiment No: 12

Design and simulation of three phase induction motor at different load conditions in MATLAB/Simulink

Objective

To design and simulate a three-phase induction motor in MATLAB/Simulink and analyze its performance under different load conditions.

Simulink Model



$$V_{max} = \frac{\sqrt{2} * V_{rms}}{\sqrt{3}}$$

$$= \frac{\sqrt{2} * 400}{\sqrt{3}} = 326.54 \text{ V}$$

Procedure

Step 1: Open MATLAB and Create a New Simulink Model

1. Open MATLAB and type simulink in the command window.
2. Create a new Simulink model.

Step 2: Add the Three-Phase Induction Motor

1. Drag and drop the Three-Phase Induction Motor block from:
   - *Simscape → Electrical → Specialized Power Systems → Machines*.
2. Configure motor parameters:
   - Rated Power
   - Voltage
   - Frequency

- Stator & Rotor Resistance and Inductance

Step 3: Provide Power Supply

1. Add a Three-Phase Voltage Source from:
   - *Simscape → Electrical → Specialized Power Systems → Sources*.
2. Set the voltage, frequency, and source parameters according to the motor rating.

Step 4: Apply Load Torque

1. Add a Mechanical Rotational Load block to simulate different loading conditions.
2. Connect it to the motor shaft.
3. Vary the torque to analyze different load conditions (e.g., No Load, Light Load, Full Load, Overload).

Step 5: Measurement Setup

1. Add Current, Voltage, Speed, and Torque Sensors:
   - Measure stator current, rotor current, speed, and torque.
2. Connect these sensors to Scope blocks for visualization.

Step 6: Configure the Simulation

1. Add the PowerGUI block and set it to Discrete or Continuous Mode.
2. Set the simulation time (e.g., 5-10 seconds).

Step 7: Run the Simulation

1. Click Run to start the simulation.
2. Observe the motor behavior at different loads:
   - Speed Variation
   - Torque Response
   - Current Draw
   - Power Consumption

Step 8: Analyze the Results

1. Compare motor speed and torque at various load conditions.
2. Observe stator and rotor current variations.
3. Evaluate the effect of increased load on motor efficiency.

Table-1: speed and motor torque values for different load conditions

Load torque (TL) in N-M		Motor torque(T) in N-M	Speed(N) in rpm
T_L at 3sec.	T_L		
T_L at 5 sec.	$\frac{TL}{2}$		
T_L at 10sec.	$\frac{TL}{4}$		
T_L at 13sec	0		

T_{lost} = loss torque due to friction, windage and iron losses.

T_{sh} (or) T_L = load torque

$T_a = T_{lost} + T_{sh}$

Power (P_{out}) = $T_{sh} * \omega$

$$T_{sh} = \frac{Pout}{\omega}$$

P_{out}=4000 watts

$$\omega = \frac{2\Pi N}{60}$$

$$\omega = \frac{2\Pi * 1430}{60}$$

$$= 149.67 \text{rad/sec.}$$

$$T_{sh} = \frac{4000}{149.67}$$

T_{sh} (or) T_L = 26.72 N-M , $\frac{TL}{2} = 13.36\, N - M$, $\frac{TL}{4} = 6.68 N - M$

Outcome

- The speed of the induction motor decreases with increasing load.
- Rotor current increases under higher load conditions.
- The simulation helps understand the performance and efficiency of the three-phase induction motor.

For More details click on the link

https://www.youtube.com/watch?v=EGbOgQr4Lnk

VIVA – VOCE QUESTIONS

1. How can the direction of rotation of a DC shunt motor be reversed?
2. What are the mechanical and electrical characteristics of a DC shunt motor?
3. What are the applications of a DC shunt motor?
4. What is meant by armature reaction?
5. How should a generator be started?
6. When a generator loses its residual flux due to short circuit, how can it be made to build up?
7. What causes heating of armature?
8. What will happen if both the currents are reversed?
9. What will happen if the field of a d.c shunt motor is opened?
10. What happens if the direction of current at the terminals of series motor is reversed?
11. Explain what happens when a d.c motor is connected across an a.c supply?
12. Why does a d.c motor sometimes spark on light load?
13. A d.c motor fails to start when switched on. What could be the possible reasons and remedies?
14. What is meant by back e.m.f?
15. Discuss different methods of speed control of a d.c motor.
16. Why a d.c series motor should not be started at No load?
17. What are the losses that occur in d.c machines?
18. State some present day uses of d.c machines.
19. Why a DC series motor should never be stared without load?
20. Why a DC series motor has a high starting torque?
21. Compare the resistances of the field windings of DC shunt and series motor?
22. What are the applications of DC series motor?
23. Comment on the Speed – Torque characteristics of a DC series motor.
24. How does the torque vary with the armature current in a DC series motor?
25. How does the speed of a DC shunt motor vary with armature voltage and field current?
26. Compare the resistance of the armature and field winding.
27. What is the importance of speed control of DC motor in industrial applications?
28. Which is of the two methods of speed control is better and why?
29. Why is the speed of DC shunt motor practically constant under normal load condition?

30. What are the factors affecting the speed of a DC shunt motor?
31. What is meant by residual magnetism?
32. What is critical field resistance?
33. What is meant by saturation?
34. What is the difference between external and internal characteristics?
35. What is the purpose of Swinburne's test?
36. What are the constant losses in a DC machine?
37. What are the assumptions made in Swinburne's test?
38. Why is the indirect method preferred to the direct loading test?
39. The efficiency of DC machine is generally higher when it works as a generator than motor. Is this statement true or false? Justify your answer with proper reasons
40. What is the purpose of Hopkinson's test?
41. What are the precautions to be observed in this test?
42. What are the advantages of Hopkinson's test?
43. What are the conditions for conducting the test?
44. Why the adjustments are done in the field rheostat of generator and motor?
45. If the voltmeter across the SPST switch reads zero what does it indicate? If it does not read zero value what does it indicate?
46. What are the other names for Hopkinson's test?
47. Why is armature resistance less than field resistance of DC shunt machine?
48. Why is armature resistance more than field resistance of DC series machine?
49. Write the e.m.f equation of DC and AC machine.
50. Write the torque equation of DC motor.
51. Why a synchronous motor is a constant speed motor
52. At what load angle is power developed in a synchronous motor becomes its maximum value?
53. What happens when the field current of a synchronous motor is increased beyond the normal value at constant input?
54. Name any two methods of starting a synchronous motors
55. Why synchronous generators are used for the production of electricity?
56. What is the difference between synchronous generator & asynchronous generator?
57. Difference between a four point starter and three point starter?
58. What is the basic difference between Synchronous motor and an Induction Motor

59. What is the SLIP?
60. What is a Synchronous Speed?
61. What is the general working principle of Induction motor
62. What is the function of centrifugal starting switch in a single-phase induction motor?
63. Why do we use capacitor-start induction motors in applications requiring high starting torque in preference to repulsion induction motors?
64. Why is the power factor of a single-phase induction motor low?
65. What is the working principle of 3 – phase induction motor?
66. What are the different types of 3 – phase induction motor?
67. Why 3 – phase induction motor is widely used for industrial applications?
68. What are the various losses in induction motors?
69. Why induction motor is called as rotating transformer?
70. What is the torque line in the Circle Diagram?
71. What are the advantages of circle diagram?
72. What is advantage of plotting the V &Inverse Λ Curves

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