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Jawaharlal Nehru New College of Engineering, Shivamogga.
Department of Electrical and Electronics Engineering

Electric Motors Lab (BEEL404)

Name of the Student: ______________________________

USN: ______________________________

Laboratory Course Manual for IV Semester BE (EEE)
(CBCS - 22 Scheme)
VTU-Belagavi

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BE Electrical and Electronics Engineering (EEE)
Chaise Based Credit System
Semester- IV
Electric Motors Lab (BEEL404)

List of Experiments

Experiment No.1

Load Test on DC Shunt Motor to draw Speed-Torque and Horse Power - Efficiency Characteristics.

Aim: To draw the performance characteristics of the given DC shunt Motor by direct Loading.

Objectives:

1. To determine the efficiency of the given DC shunt Motor by conducting Load test.
2. To find the various parameters such as torque, input power, output power etc.
3. To obtain the electrical and mechanical characteristics for the given DC shunt Motor.

Apparatus Required:

Sl. No	NAME	RANGE	TYPE	QUANTITY In No
1	Voltmeter	0 - 300V	MC	1
2	Ammeter	0 – 10/20 A	MC	1
3	Rheostat	118 Ω & 32 Ω	Variable	1
4	Tachometer	0 to 2000 rpm	Contact	1
5	Connecting Wires	*****	*****	Required

Machine Ratings	
Excitation	
Voltage	
Current	
Speed(RPM)	

THEORY:

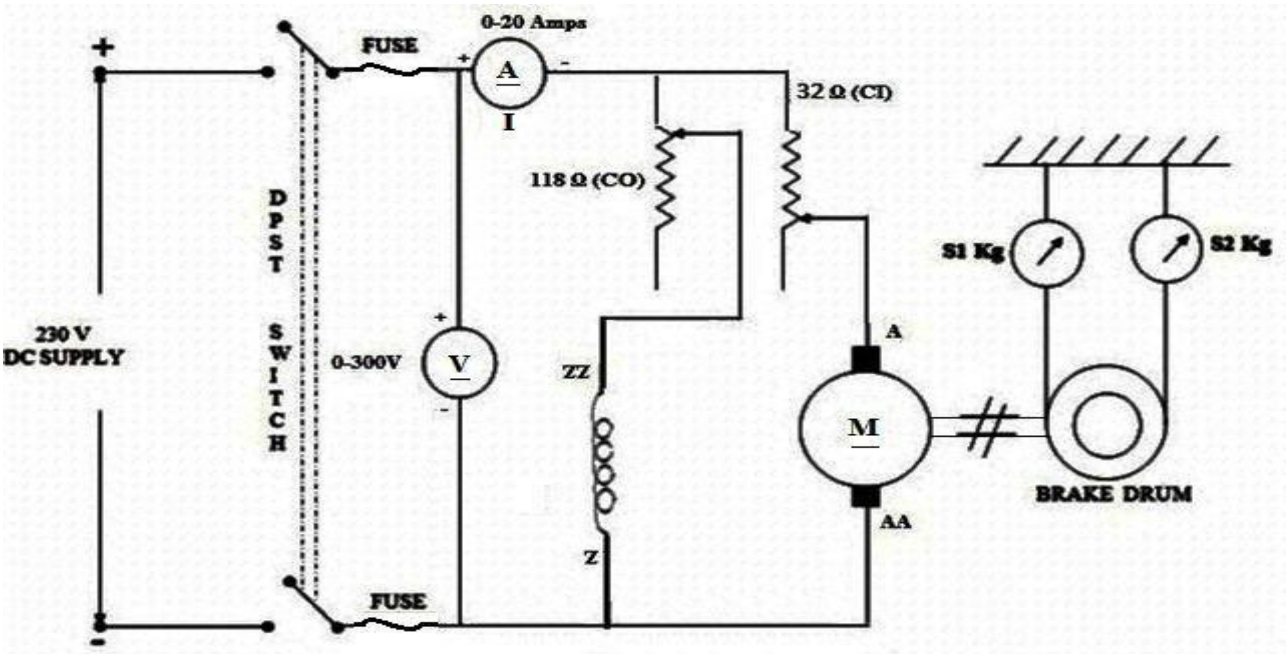


Figure 1.1Circuit diagram of D.C shunt Motor

Procedure:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. The supply is given by closing DPST switch.
3. The Motor is started by keeping Armature Rheostat in cut in position, Field Rheostat in cut out position and drum belt is kept loose.
4. The Motor is brought to its rated speed by first cutting out (32 Ω**) Armature Rheostat** and then if necessary by Cutting in Field Rheostat (118 Ω)
5. The No Load readings are tabulated.
6. The Load is applied in steps and note down all the meter readings, spring balance readings & speed for various Load currents.
7. The above procedure is repeated till Motor draws its rated current
8. Performance characteristics are drawn from the tabulated readings & calculated values.

Tabulation

Sl. No	Motor voltage V	Motor Current I	Speed N in rpm	S_1 In Kg	S_2 In Kg	Torque $T=(S_1 - S_2)\times r\times 9.81$ N-m	Input to Motor V×I Watts	Output of Motor $\frac{2\pi NT}{60}$ Watts	$\%\eta=\frac{output}{input}\times 100$	Output in $HP=\frac{output}{735.5}$

Calculations:

The circumference of the break drum is measured using thread and scale.

Circumference of break drum, C = 2 π r = 100 Cm.

Radius of break drum, $r = \frac{C}{2\pi} \times \frac{100\times10^{-2}}{2\pi} = 0.16m$

Input to Motor = VI= …………… =...........Watts

Output of Motor = $\frac{2\pi N T}{60}$ = ……………. = ...Watts

Torque T= $(S_1 \sim S_2) \times r \times 9.81$=…………… =...............N-m

Efficiency of Motor (%η) = $\frac{output}{input}\times100$= …………… =............%

Output of Motor in HP = $\frac{output\ in\ watts}{735.5}$ = ………… …..= ....HP

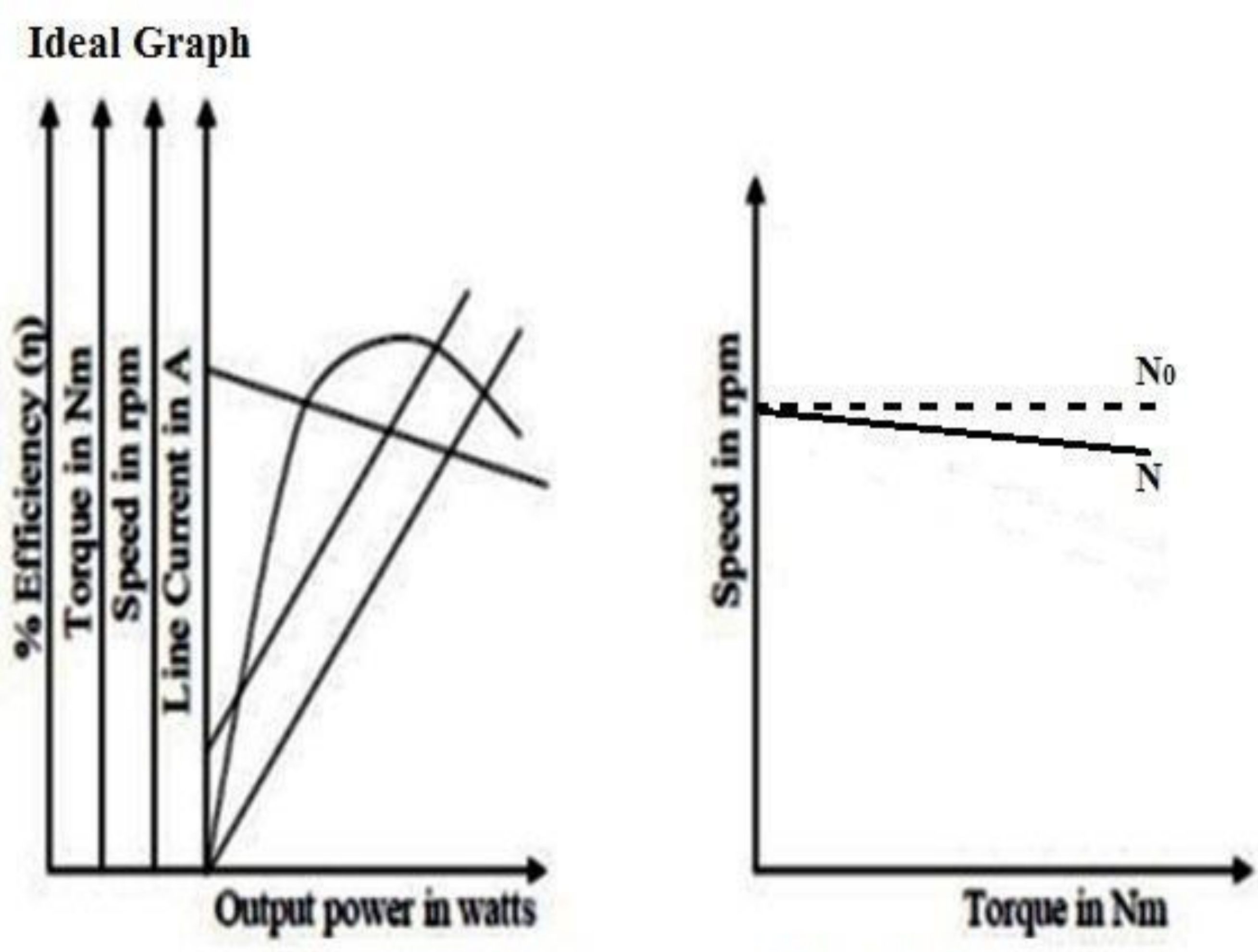
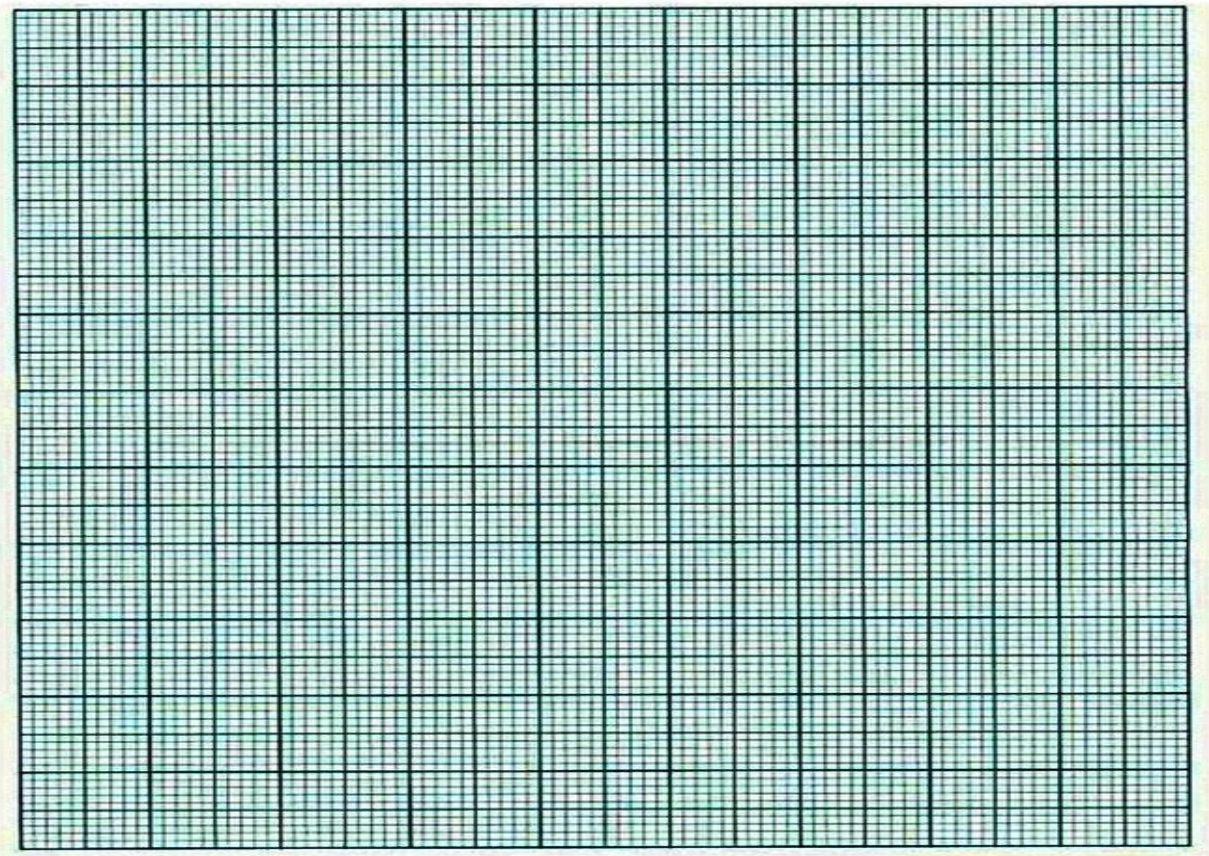
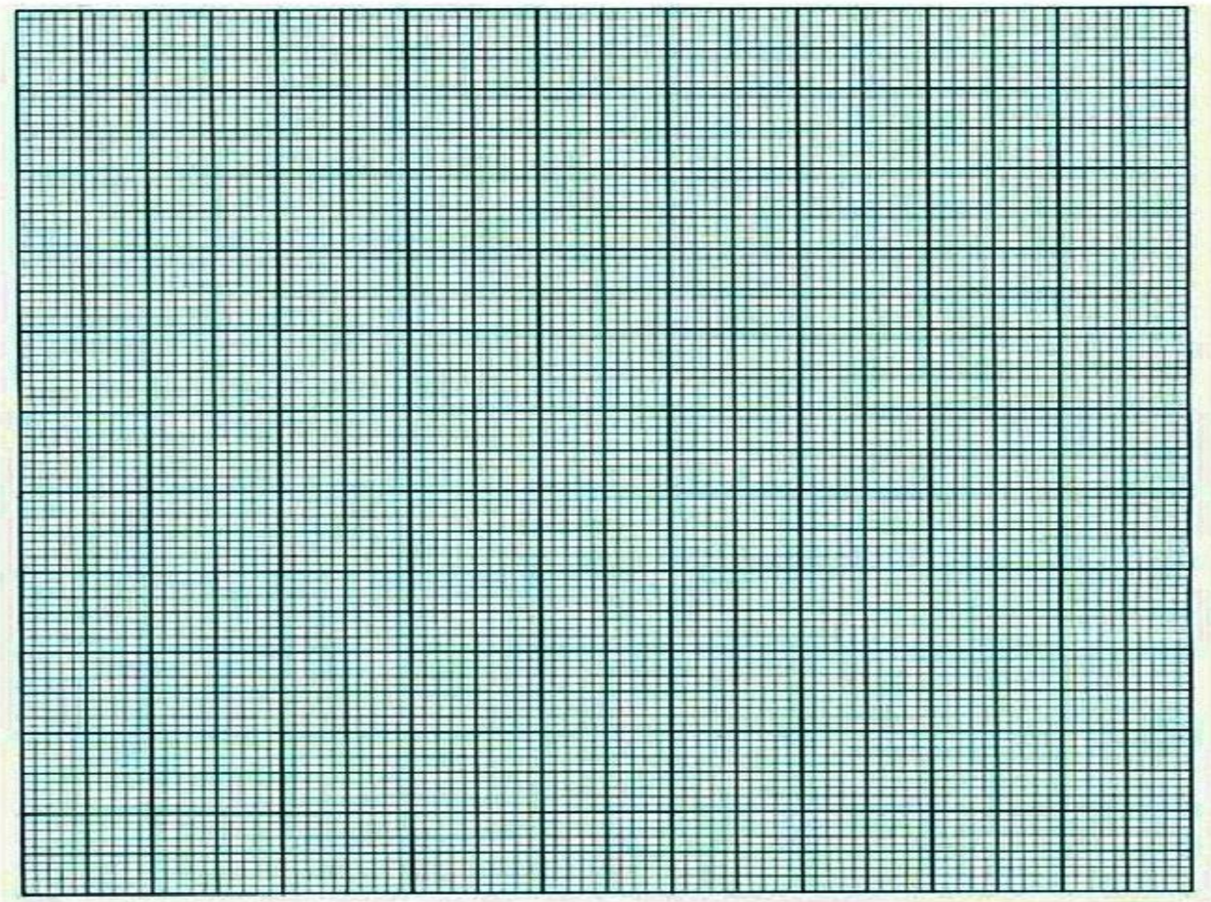
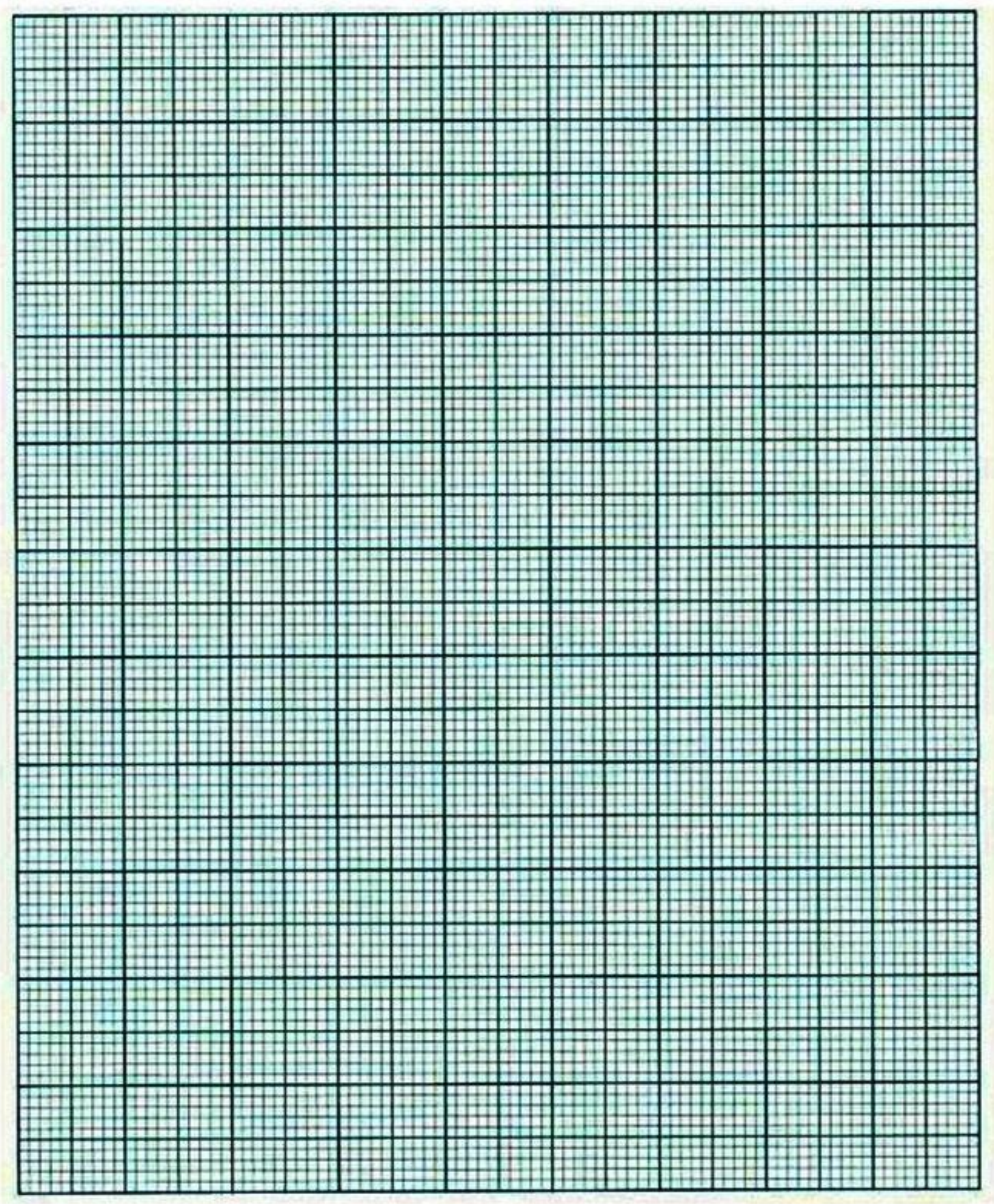


Figure 1.2 Performance Characteristic







Expected Result: The performance characteristics of D C Shunt Motor are to be plotted

RESULT:

Signature of the Staff in-charge

Experiment No. 2

Fields Test on DC Series Machines

Aim: Determination of the efficiency of DC Machine by Field's method.

OBJECTIVE: To determine the efficiency of the given DC Shunt Motor by conducting Load test.

APPARATUS REQUIRED:

Sl. No	NAME	RANGE	TYPE	QUANTITY
01	Voltmeter	0 - 300V, 0 -30V	MC	1
02	Ammeter	0 – 10/20 A, 0 – 1/2 A	MC	1
03	Rheostat	28 Ω	Variable	1
04	Tachometer	0 – 2000 rpm	Contact	1
05	Connecting Wires	*****	*****	Required

Machine Ratings			
Excitation: Generator		Excitation: Motor	
Voltage		Voltage	
Current		Current	
Speed(RPM)		Speed(RPM)	

THEORY:

Circuit Diagram:

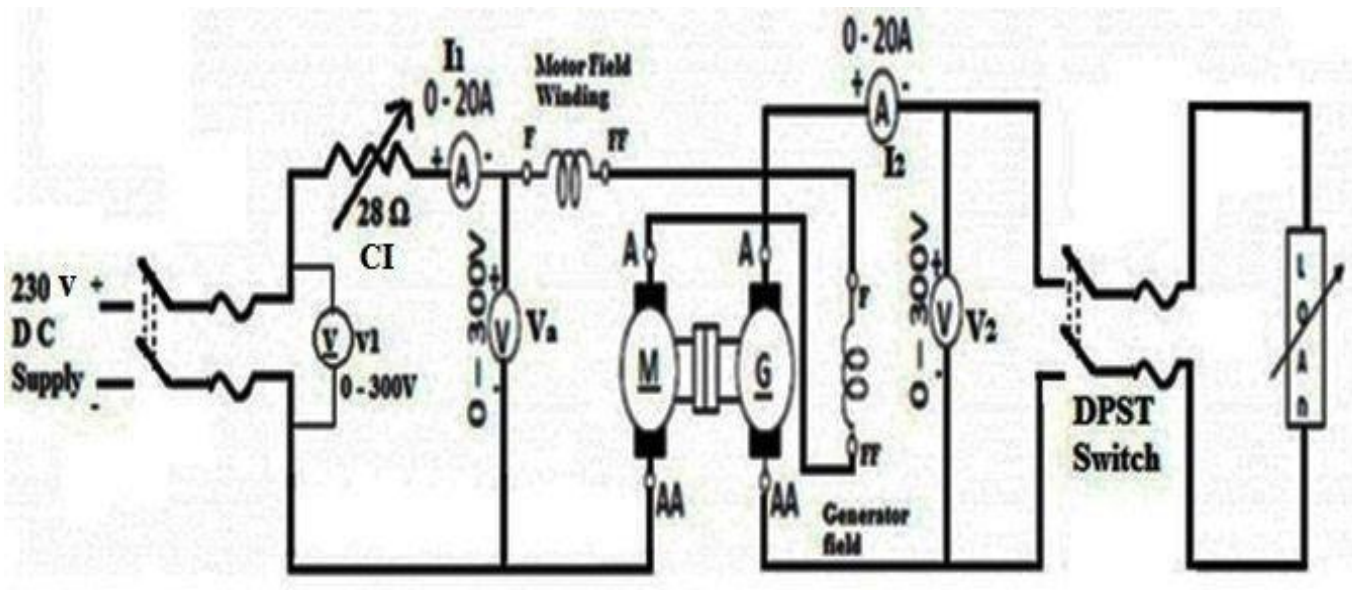


Figure 2.1 DC Series Motor and DC series Generator

PROCEDURE:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Initially the Load switch is kept closed. There should be sufficient Load on the Generator. Rheostat connected on Motor side should be kept in cut-in position.
3. Close the supply switch and bring the Motor to its rated speed by varying the rheostat.
4. Adjust the Load such that the voltage across the armature should be of its rated value and speed of the set is within the permissible limit.
5. Note down all the meter readings along with speed.
6. Apply Load in steps and note down all meter readings. If possible maintain voltage across the Motor constant.
7. Measure the Armature and Field winding Resistances of Motor and Generator.

Circuit Diagram for measuring winding resistance:

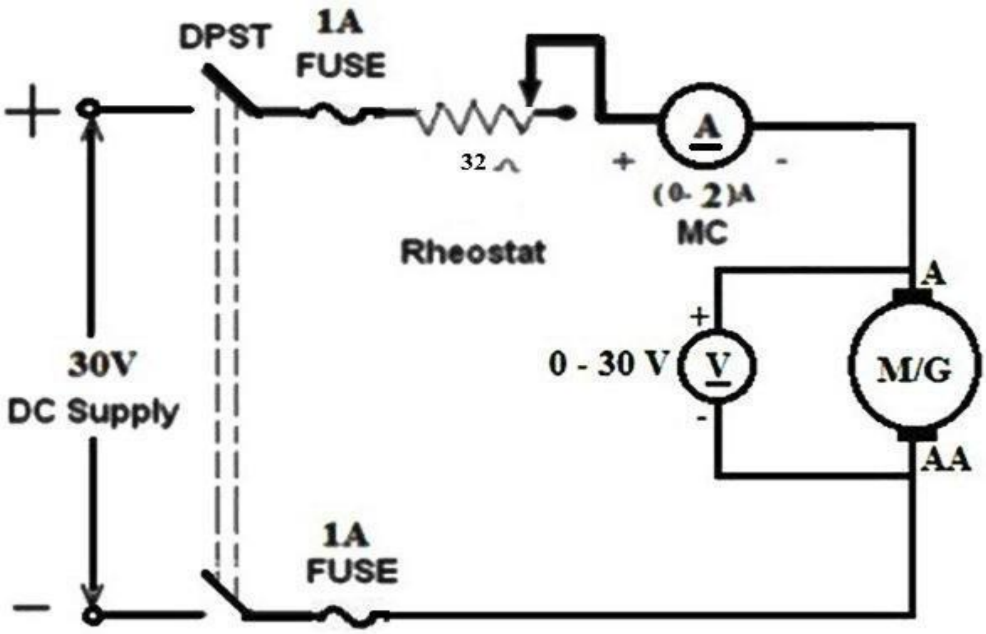


Figure 2.2 Measuring winding resistanceCircuit.

PROCEDURE FOR MEASURING WINDING RESISTANCE:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Initially rheostat is set at maximum resistance position.
3. Switch ON the supply, and vary the rheostat gradually and note down the readings of ammeter and voltmeter
4. For the corresponding values, average of R is taken.

Sl. No	V_1 In Volts	I_1 in Amps	V_a in Volts	V_2 in Volts	I_2 In Amps	N In rpm	Input to Motor in Watts	Output of Motor In Watts	Motor %η	Torque in Nm	Generator input In Watts	Generator output in Watts	Generator Efficiency %η

To find Armature/Field Resistance of M/G:

Sl. No	I(A)	V (Volts)	$R_{am} = \frac{V}{I} =$ Ω
Armature Resistance of Motor:			

Sl. No	I(A)	V (Volts)	$R_{fm} = \frac{V}{I} =$ Ω
Field Resistance of Motor:			

Sl. No	I(A)	V (Volts)	$R_{ag} = \frac{V}{I} =$ Ω
Armature Resistance of Generator:			

Sl. No	I(A)	V (Volts)	$R_{fg} = \frac{V}{I} =$ Ω
Armature Resistance of Generator:			

Calculations:

Torque $T = \frac{output \times 60}{2\pi N} = \ldots\ldots\ldots\ldots$ **Nm**

Power input to whole set= $V_1 \times I_1 = \ldots\ldots\ldots\ldots$ **Watts**

Generator output= $V_2 \times I_2 = \ldots\ldots\ldots\ldots$ **Watts**

Total losses on the whole set $(W_t) = (V_1 \times I_1) - (V_2 \times I_2) = \ldots\ldots\ldots\ldots$ **Watts**

Armature and field copper losses $(W_c) = I_1^2(R_{am}+R_{fm}+R_{fg})+I_2^2R_{ag} = \ldots\ldots\ldots\ldots$ **Watts**

Rotational losses, stray losses $= W_t - W_c = \ldots\ldots\ldots\ldots$ **Watts**

Stray losses per Machine $(W_s) = \frac{W_t - W_c}{2} = \ldots\ldots\ldots\ldots$ **Watts**

Motor

Input $= V_a I_1 = \ldots\ldots\ldots$ **Watts**

Motor losses =
$I_1^2(R_{am}+R_{fm})+W_s = \ldots\ldots\ldots$ **Watts**

Efficiency of Motor

$$(\%\eta) = \frac{o/p}{i/p} \times 100 = \frac{input - losses}{i/p} 100 = \ldots\ldots\ldots\%$$

Generator

Output $= V_2 \times I_2 = \ldots\ldots\ldots\ldots$ **Watts**

Field copper losses $= I_1^2R_{fg} = \ldots\ldots\ldots\ldots$ **Watts**

Armature copper losses $I_2^2R_{ag} = \ldots\ldots\ldots\ldots$ **Watts**

Stray losses $(W_s) = \frac{W_t - W_c}{2} = \ldots\ldots\ldots\ldots$ **Watts**

Total losses= $I_1^2R_{fg} + I_2^2R_{ag} + W_s = \ldots\ldots\ldots$ **Watts**

Efficiency of Generator

$$(\%\eta) = \frac{o/p}{i/p} \times 100 = \frac{output}{output+losses} \times 100 = \ldots\ldots\ldots\%$$

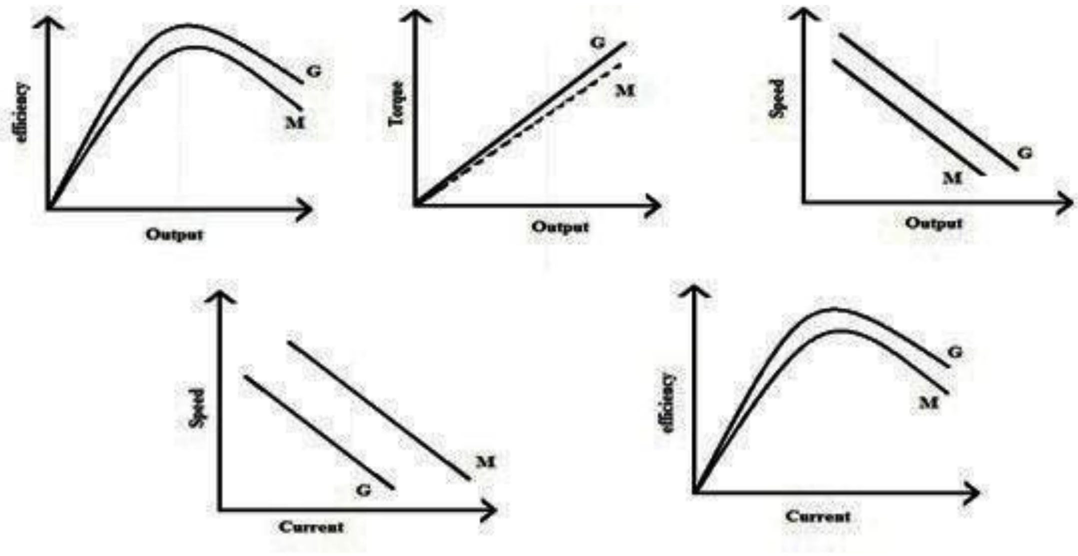
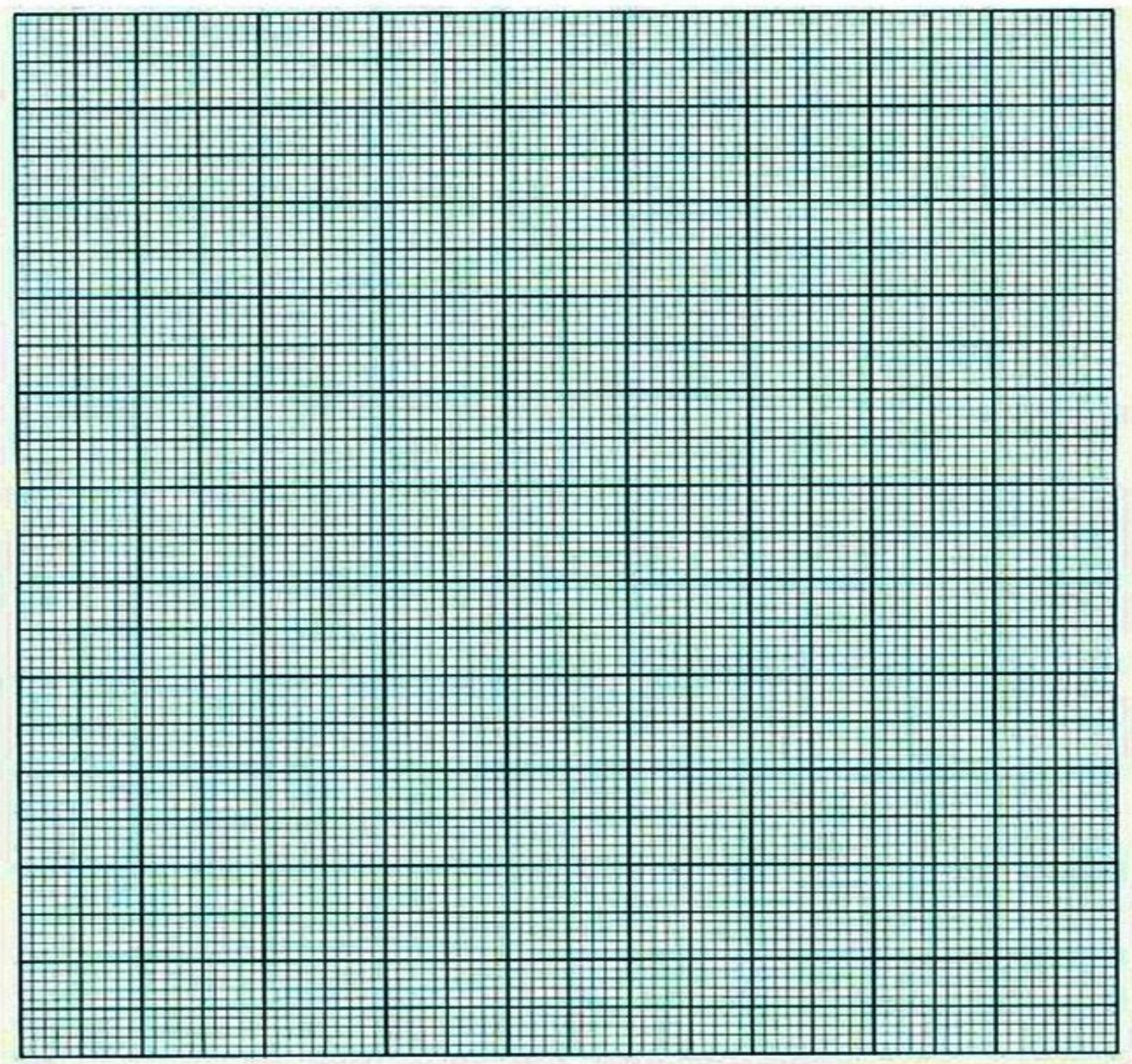
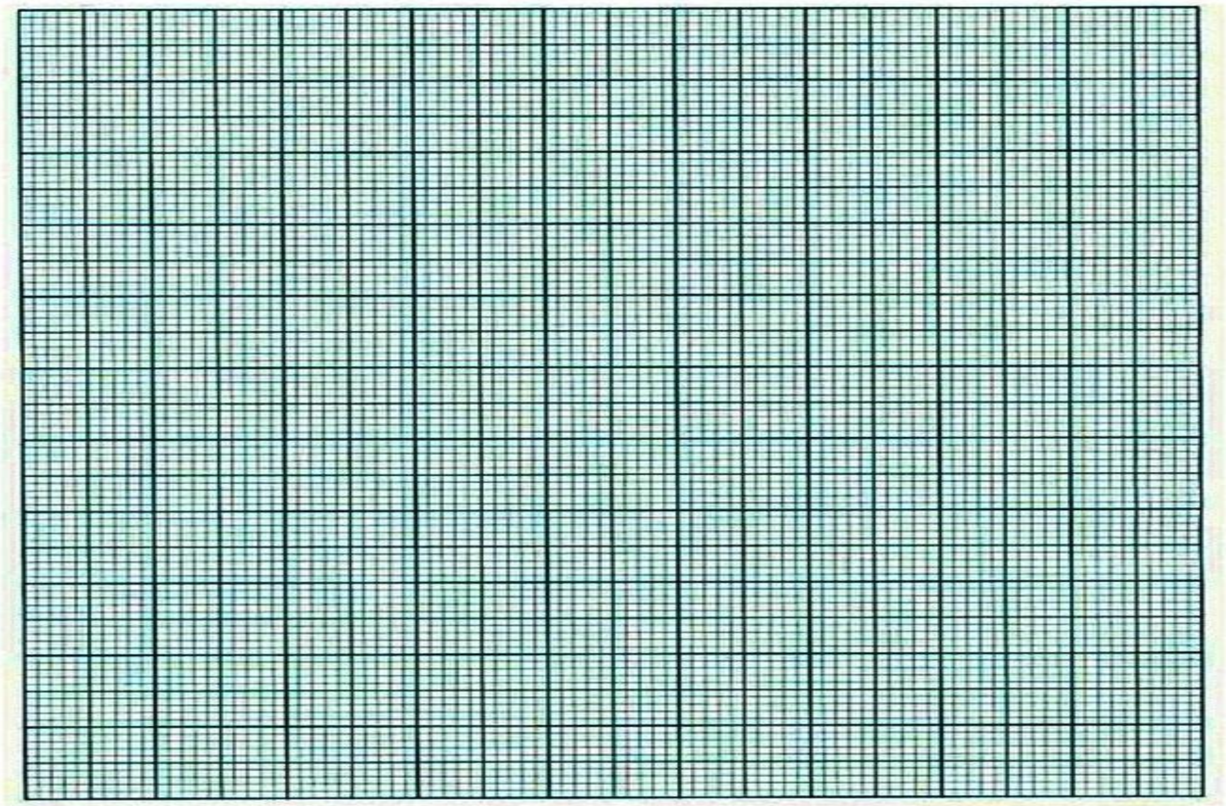
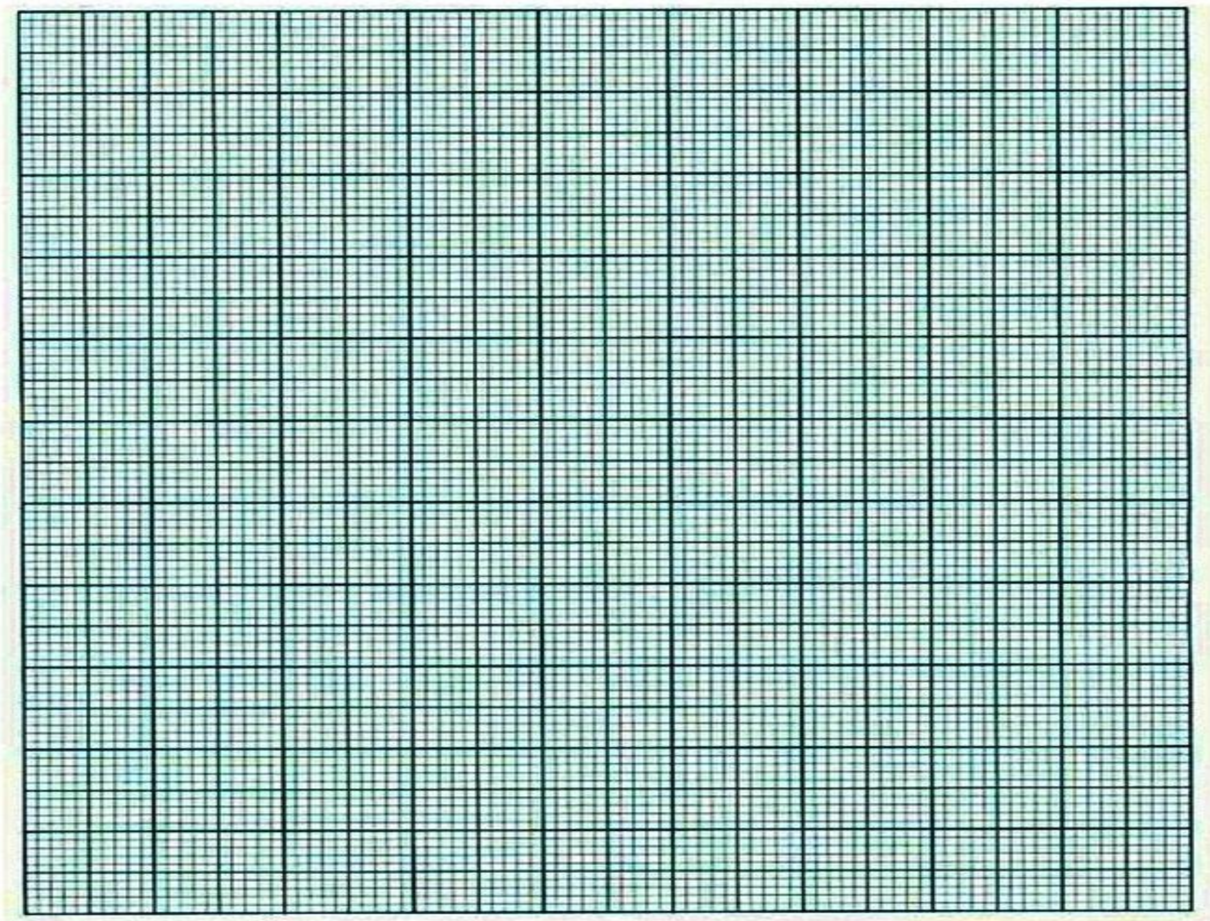
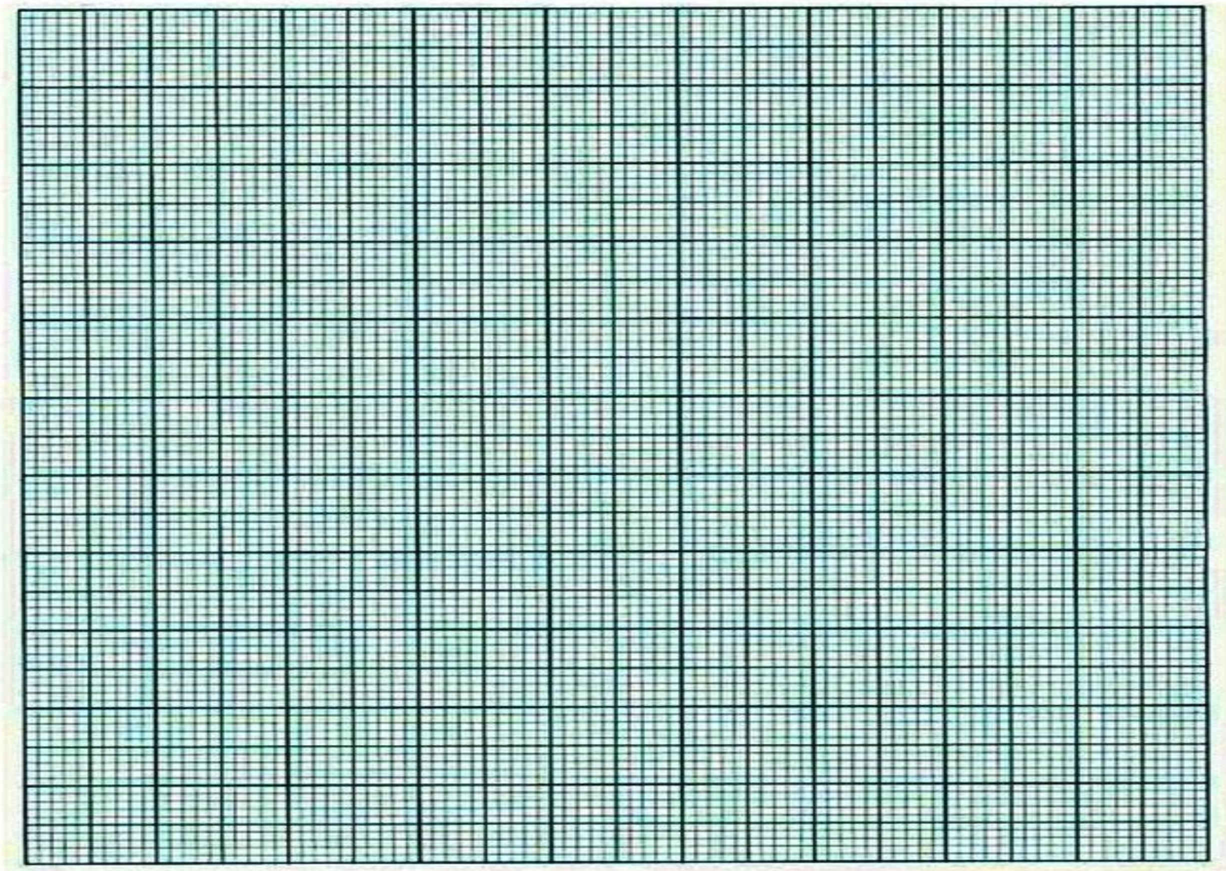


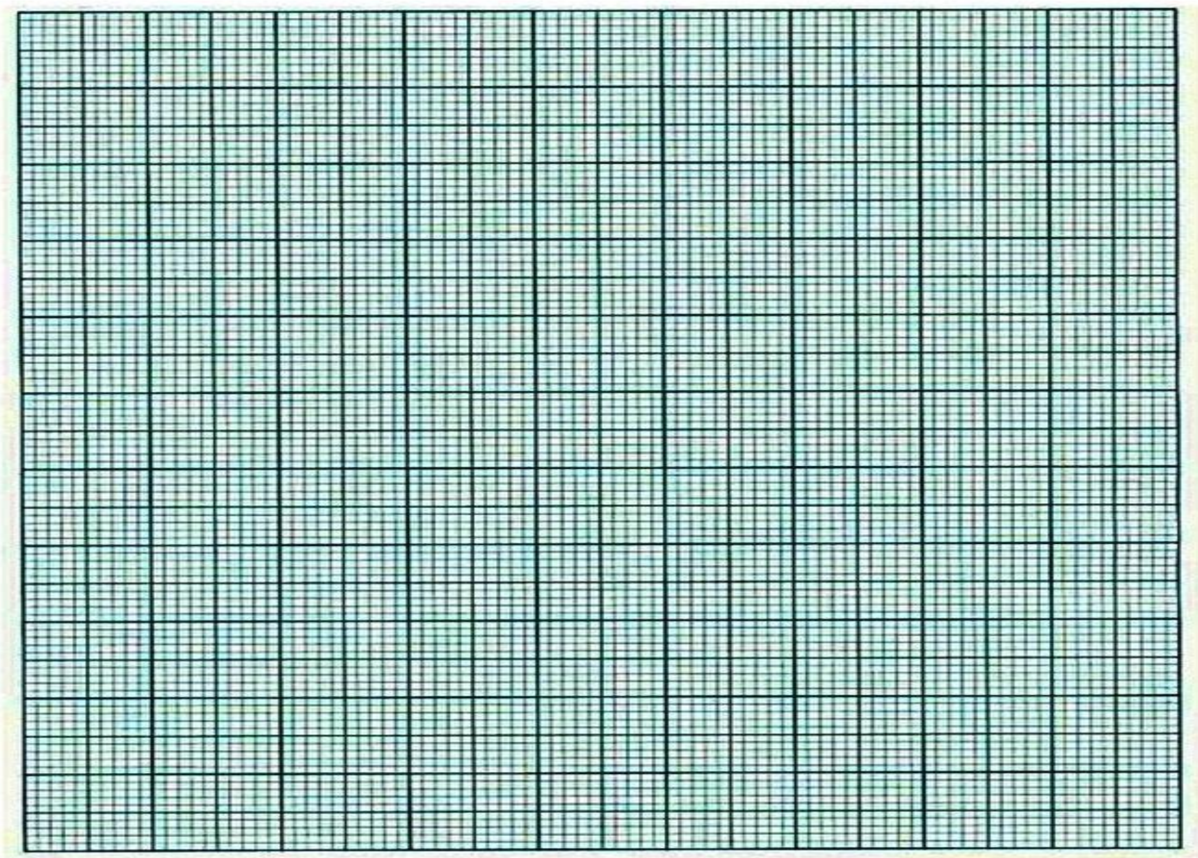
Figure 2.3 Ideal Graphs











Expected Result: Efficiency of Motor and Generator is to be determined by Field test and characteristics are to be drawn.

RESULT:

Signature of the Staff in-charge

Experiment No. 3

Speed Control of a D.C Shunt Motor by Armature control and field control.

Aim: To obtain the speed characteristics of a D.C shunt Motor as a function of armature Voltage, field current.

Apparatus:

Sl. No	Name	Range	Type	Quantity In No
1	Voltmeter	0-300V	MC	2
2	Ammeter	0-1/2A	MC	1
3	Rheostat	0-118Ω & 0-32 Ω	Variable	1
4	Tachometer	0 – 2000 rpm	Contact	1
5	Connecting Wires	*****	*****	Required

Machine Ratings	
Excitation	
Voltage	
Current	
Speed(RPM)	

Circuit diagram:

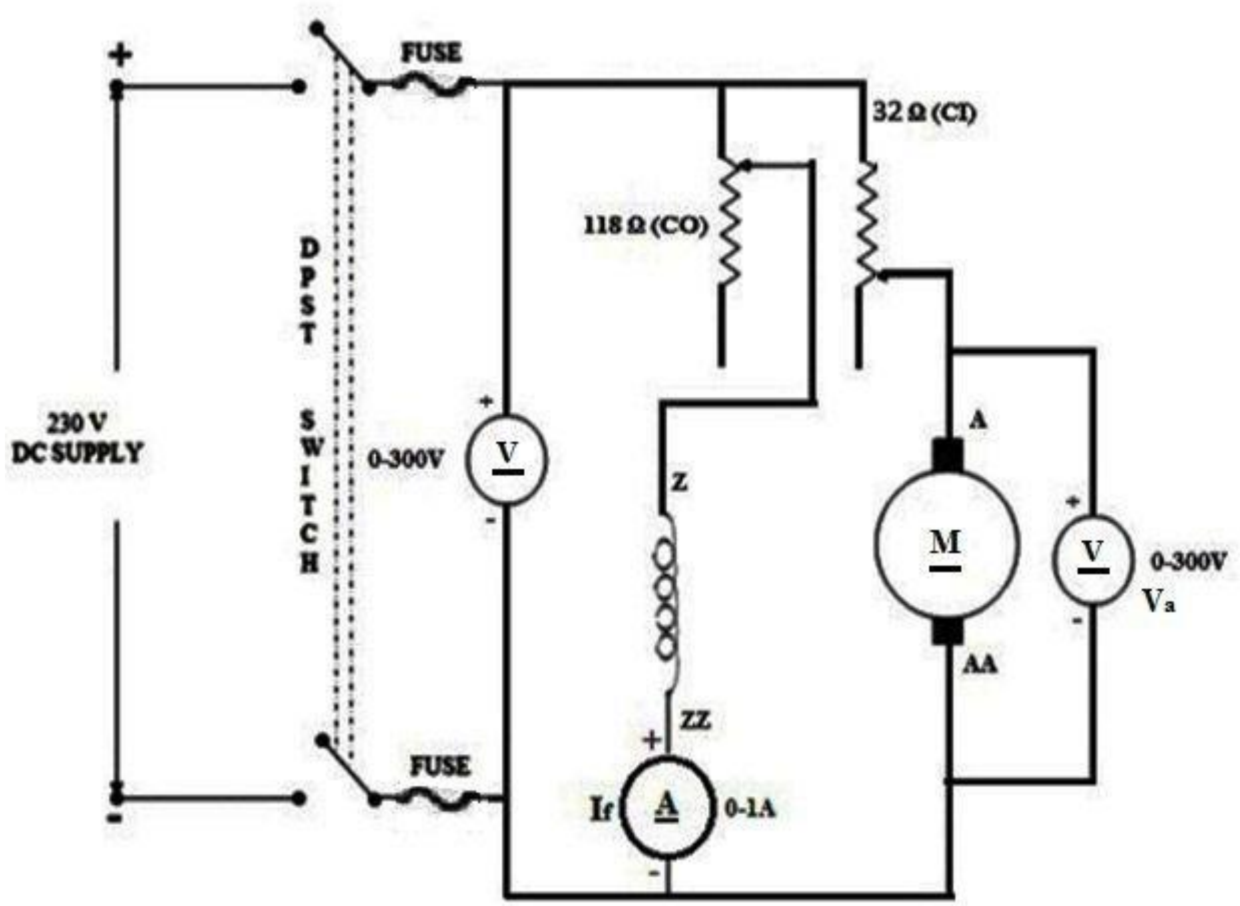


Figure 3.1 DC Shunt Motor

Procedure:

- **Armature Voltage Control Method:**

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Keep the Armature Resistance in Cut in position and Field Rheostat in cut-out position.
3. Supply switch is closed.
4. In this case the field current I_f kept constant at a particular value say 0.8 Amps by varying Field Rheostat.
5. Increase the voltage gradually to its rated voltage i.e. 220V by varying armature resistance.
6. Gradually decrease the voltage by varying armature resistance and note down the speed at different supply voltages.
7. The above procedure is repeated for two more values of the field current (say 0.6 & 0.7 A).

- **Field Control or Flux Control Method:**

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Keep the Armature Resistance in Cut in position and Field Rheostat in cut-out position.
3. Supply switch is closed.
4. In this method voltage across the armature is kept constant say 160V by varying Armature Rheostat
5. Now field current (I_f) is varied in steps by varying Field Rheostat and record the speed at various field currents.
6. Run the Machine beyond the ratedspeed.

Observations:

Voltage Control Method:

Field current (I_f) =0.8 A

Sl.No	Applied Voltage V_a in Volts	Speed N in Rpm

Field current (I_f) = 0.7 A

Sl.No	Applied Voltage in Volts	Speed N in Rpm

Flux Control Method:

V_a= 160 V.

Sl.No	Field current(I_f) (amp)	Speed N in Rpm

V_a= 150 V.

Sl.No	Field current(I_f) (amp)	Speed N in Rpm

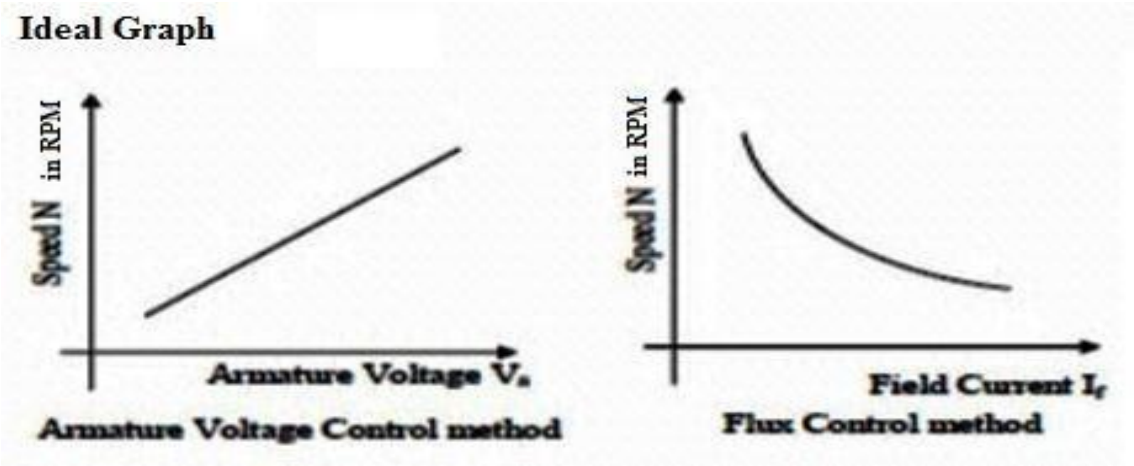
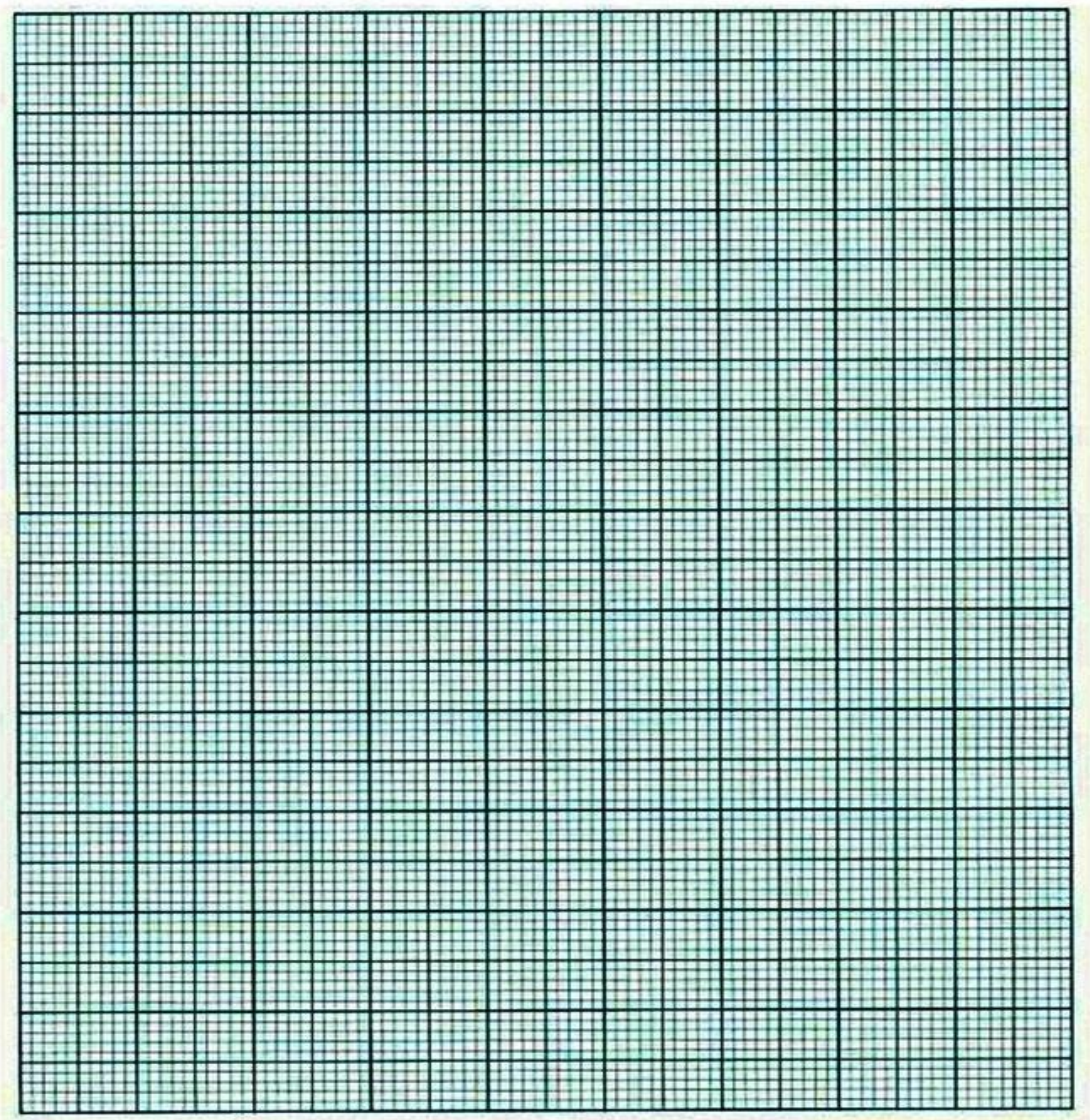
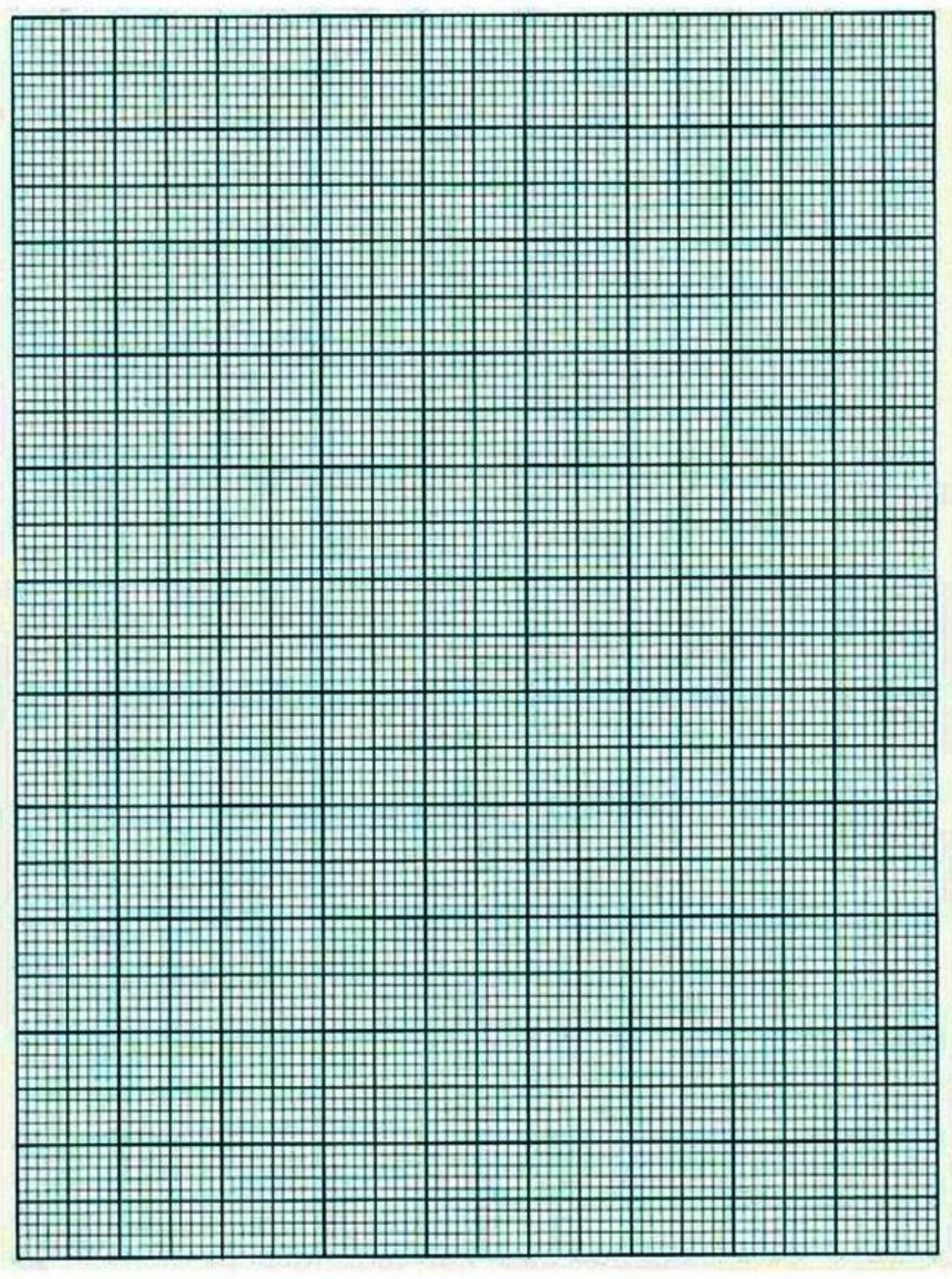

Ideal Graph
Speed N in RPM
Armature Voltage V_a
Armature Voltage Control method
Speed N in RPM
Field Current I_f
Flux Control method

Figure 3.2





Expected Result: The graphs are to be plotted according to ideal graphs.

Result:

Signature of the Staff in-charge

Experiment No. 4

Swinburne's Test on DC Motor

Aim: To perform no Load test on DC Shunt Motor

Apparatus Required:

Sl. No	Name	Range	Type	Quantity In No
1	Voltmeter	0-300V 0-30V	MC	2 1
2	Ammeter	0-1/2A 0-10A	MC	1 1
3	Rheostat	0-118Ω & 0-32 Ω	Variable	1 1
4	Tachometer	0 – 2000 rpm	Contact	1
5	Connecting Wires	*****	*****	Required

Machine Ratings	
Excitation	
Voltage	
Current	
Speed(RPM)	

Circuit diagram:

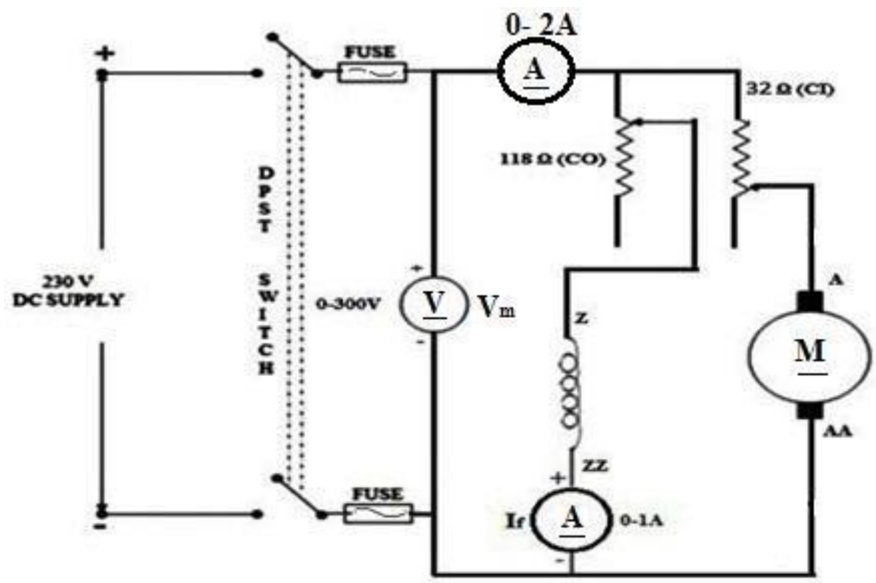


Figure 4.1 DC Shunt Motor

Procedure:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. The supply is given by closing DPST switch.
3. The Motor is started by keeping Armature Rheostat in cut in position and Field Rheostat in cut out position
4. The Motor is brought to rated speed by first cutting out (32 Ω**)** Armature Rheostat and then if necessary by Cutting in Field Rheostat (118 Ω)
5. The no Load readings are Tabulated.

Tabular Column:

Sl No.	Motor Voltage (V_m)	Motor current(I_{mo})	Motor field current(I_f)

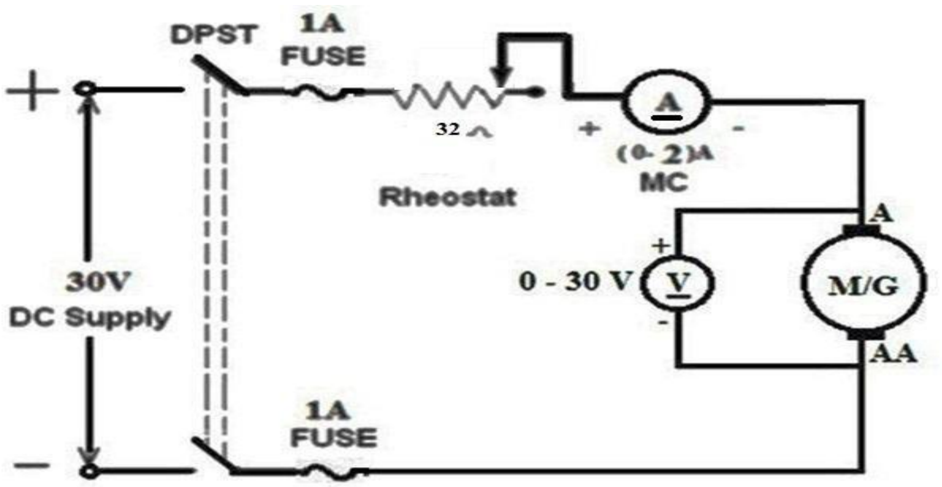


Figure 4.2 Circuit diagram to measure Armature Resistance (Ra)

Procedure to measure to measure Armature of DC Motor:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Now close the DC Supply switch and low voltage is applied by varying 32 Ω Rheostat, note down the readings of all meters.
3. An armature and field resistance of DC Motor is to be calculated.

To find Armature Resistance of Motor:

Sl. No	I(A)	V (Volts)	$R_{am} = \frac{V}{I} = \Omega$
Armature Resistance of Motor			

Calculations: (a): When running as a Motor:

No Load input = V_m I_{mo} = ------------------ =------------- Watts

No Load armature copper losses = $I_{ao}^2R_a$= ------------------ =-------------Watts

Constant Loss (W_c) = No Load input-no Load armature copper loss

W_c = (V_m I_{mo})-($I_{ao}^2R_a$)= ------------------------------------ = - - - - - - Watts

To find efficiency of Machine when running as Motor at full Load:

Full Load input = V_m I_{fl} = -------------------------------- =----------Watts

Output = input- losses

I_a=I_{fl}- I_f

Output = V_m× I_{fl}- [W_c- $I_a^2R_a$] = -------------------------------- =---------- Watts

$\%\boldsymbol{\eta} = \frac{o/p}{i/p} \times 100$ = - = - - - - - - **%**

Repeat the procedure to Predetermine efficiency at 3/4th, 1/2th, 1/4thof full Load

To find efficiency of Machine when running as Generator at full Load:

Output = V_L× I_{FL}

Full Load input = Output+Losses= V_L× I_{FL} +[W_c + (I_{FL}+ I_F)^2R_a] = --------------------------- = --------- Watts

Output = input- losses

$\%\boldsymbol{\eta} = \frac{o/p}{i/p} \times 100$ = **……….%**

Repeat the procedure to Predetermine efficiency at x = 3/4th, 1/2th, 1/4thof full Load

Expected Result: Predetermination of efficiency of a DC Shunt Motor is to be calculated and tabulated.

Result:

Loadings (%x)	$\%\boldsymbol{\eta}\ of\ Motor$	$\%\boldsymbol{\eta}\ of\ Generator$
1		
1/2		
3/4		
1/4		

Signature of the Staff in-charge

Experiment No. 5

Retardation Test on D.C. Shunt Motor

Aim: To determine the Moment of inertia and Stray losses of the shunt wound DC Machine.

OBJECTIVES: Obtain the Electrical and Mechanical Characteristics for the given DC shunt Motor.

APPARATUS REQUIRED:

Sl. No	NAME	RANGE	TYPE	QUANTITY	Machine Ratings	
01	Voltmeter	0 - 300V	MC	1	Excitation	
02	Ammeter	0 – 10/20A 0-1/2A	MC	2 1	Voltage	
03	Rheostat	118 Ω , 32 Ω & 100 Ω	Variable	1	Current	
04	DPDT Switch		Knife	1	Speed(RPM)	
05	Tachometer	0 – 2000 rpm	Contact	1		
06	Connecting Wires	*****	*****	Required		

THEORY

Circuit Diagram:

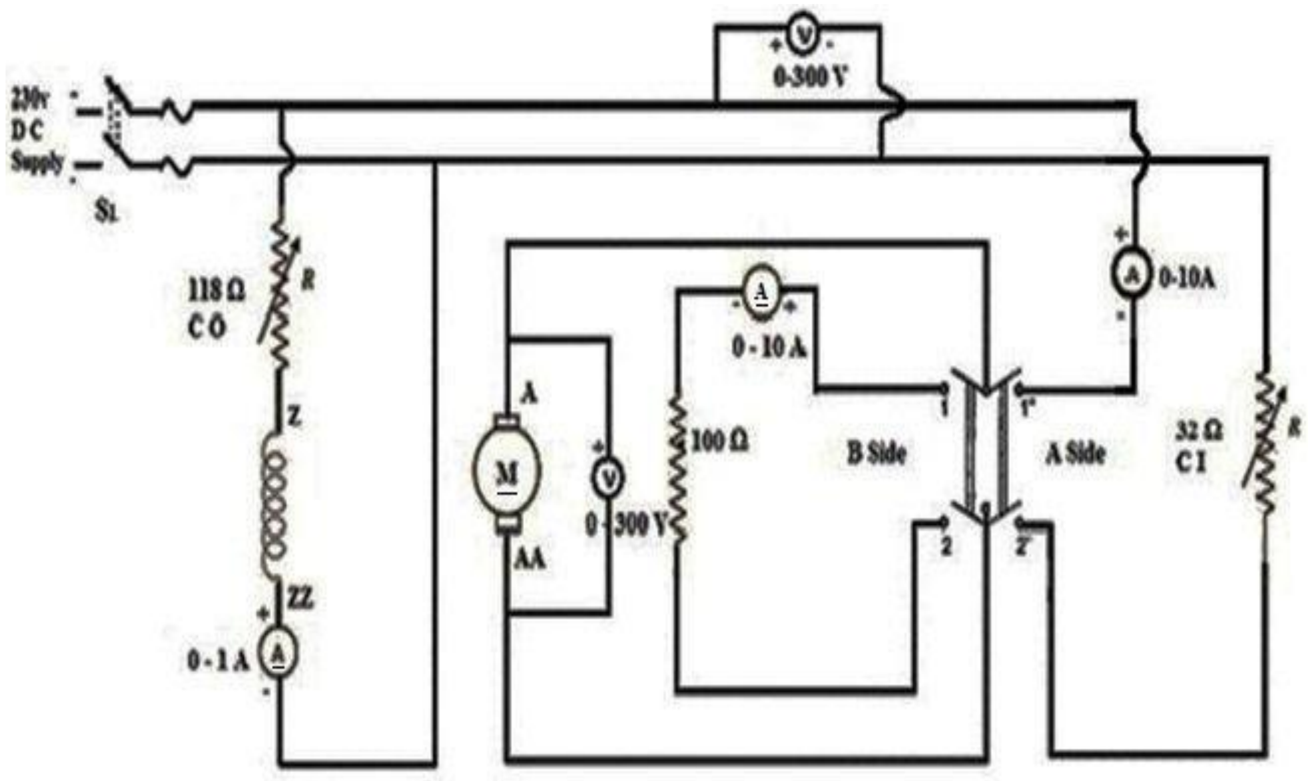


Figure 5.1 D.C. Shunt Motor

Procedure:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Initially all the Rheostats are kept at their respective positions & both the switches (S_1& DPDT) are kept open.
3. Now close S_1 and DPDT towards A-side.
4. Bring Motor to rated speed by varying Armature Rheostat and if necessary by varying Field Rheostat.
5. Note down all meter readings.
6. Now open the DPDT switch by simultaneously switching ON the stop watch.
7. Note down the time T1 taken to retard the speed of the Machine from rated speed to any suitable speed (say 1500 – 1000 rpm) this is the run-down of the Machine with excitation.
8. Now bring the Rheostats to their original position and close DPDT towards A side. Bring Motor to rated speed by varying Armature Rheostat and if necessary by varying Field Rheostat.
9. Throw the DPDT switch to B-Side by simultaneously switching on the stop watch. Note down reading of ammeter voltmeter at 1500rpm & at 1000rpm also note down the time T2 taken to retard the speed of the Machine from rated speed to any suitable speed (say 1500 – 1000 rmp) this is the run-down of the Machine with excitation.
10. Bring the Rheostats to their original position and close DPDT towards A side. Bring Motor to rated speed by varying Armature Rheostat and if necessary by varying Field Rheostat.
11. Now switch off the supply mains S1 and open the DPDT. Note down the time taken T3 to retard its speed from 1500 – 1000 rpm. This is the run-down without excitation.

Note:

- Maintain constant field current at all the three readings also it should be noted that when armature slow down with no excitation its kinetic energy is used to overcome mechanical losses only because due to the absence of flux there is no iron loss.
  With excitation, kinetic energy is used to supply mechanical and iron losses known as stray losses. If moment of inertia I is taken in Kg-m^2 then rate of loss of energy is in Watts.

Sl. No	Conditions	Speed in rpm	Time in sec	V in Volts	I in Amps
1	With Excitation	1500 1000	T1	V_1= V_2= V_{avg}=	I_1= I_2= I_{avg}=
2	With Excitation and Load	1500 1000	T2	V_1= V_2= V_{avg}=	I_1= I_2= I_{avg}=
3	Without Excitation	1500 1000	T3	V_1= V_2= V_{avg}=	I_1= I_2= I_{avg}=

Calculation:

- Time T1 is taken when full excitation.
- Time T2 is taken when full excitation with Load.
- Time T3 is taken with No excitation.

We have to calculate

- Moment of inertia of armature in Kg – m^2.
- Iron loss.
- Mechanical loss at a mean speed.

Average speed = $\frac{1500+1000}{2} = 1250\ rpm$

Mechanical loss $W_m = (\frac{2\pi}{60})^2\ IN\ \frac{dN}{dt}$ = ------------------------------- = ---------

Where dN = Speed drop from 1500 to 1000 rpm = 500 rpm.

dt= T3= --------seconds

N= average speed=1250 rpm

I= moment of inertia.

Stray loss $W_s = (\frac{2\pi}{60})^2\ IN\ \frac{dN}{dt}$ = ---------------------- = ------

Where dt= T2= Sec

N= average speed=Rpm

dN = Speed drop=in Rpm

I= moment of inertia.

Also Ws= $W'\{\frac{T2}{T1-T2}\}$ = ---------------------- = ------ Watts

Where

W′ = VI Watts.

V= Load voltage.

I= Load current.

Iron loss (W_i)= W_s - W_m= ---------------------- = ------ Watts

Expected Result:

Moment of inertia, stray loss, iron loss and mechanical loss of dc shunt Machine is to be determined.

Result:

Signature of the Staff in-charge

Experiment No. 6

Regenerative Test on DC Shunt Machine (Hopkinson's test)

Aim: To conduct full Load test on two Identical DC shunt Machines and draw the Performance characteristics of the same Machine.

OBJECTIVE:
1. To determine the stray losses of the Machines.
2. To obtain efficiency curves for the Motor and Generator and draw the curves.

Apparatus Required:

Sl. No	APPARATUS NAME	RANGE	TYPE	QUANTITY In No
01	Voltmeter	0 - 300V 0-30V	MC	1
02	Ammeter	0 – 10/20 A 0-1/2A	MC	2 1
03	Rheostat	118 Ω , 32 Ω , 100 Ω & 750 Ω	Variable	1
04	SPDT Switch		Knife	1
05	Tachometer	0 – 2000 rpm	Contact	1
06	Connecting Wires	*****	*****	Required

Machine Ratings			
Excitation: Generator		Excitation: Motor	
Voltage		Voltage	
Current		Current	
Speed(RPM)		Speed(RPM)	

Circuit diagram:

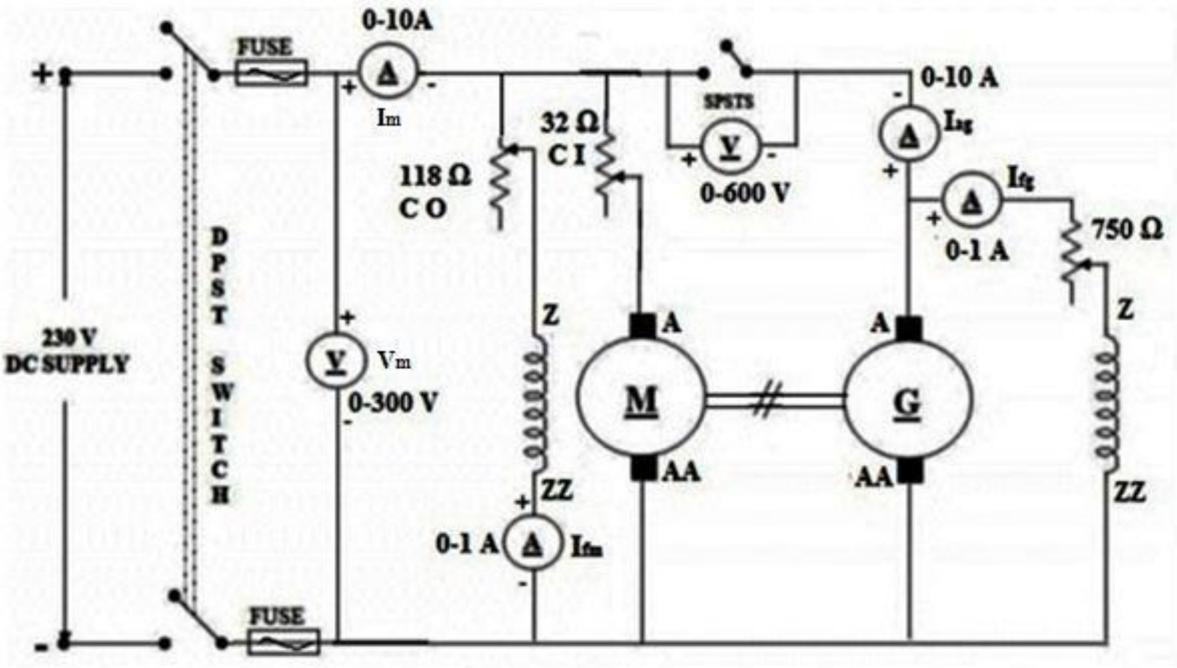


Figure 6.1D.C. Shunt Motor

PRECAUTION

1. The Field Rheostat of the Machine marked M should be kept at minimum position at the time of starting.
2. The Field Rheostat of the Machine marked G should be kept at maximum position at the time of starting.
3. SPST switch should be open at the time of starting.

PROCEDURE:

1. The Circuit Connections is made as per the Circuit diagram shown in the figure.
2. Initially all the Rheostats are kept in their respective positions and SPST switch is kept open.
3. Bring the Motor its rated speed and note down all meter readings.
4. Now the 750Ω rheostat is cutting out gradually such that the voltmeter connected across SPST switch reads zero and note down all the meter readings with speed.
5. Now Generator and Motor are at same potential.
6. Now close SPST switch and over excite the Generator by cutting out 750Ω rheostat and note down all meter readings.
7. Under excite the Motor field by cutting in 118Ω rheostat and note down all meter readings.

Tabular column:

SL No	V_m in Volts	I_m in Amps	I_{fm} in Amps	I_{fg} in Amps	I_{ag} in Amps	N in rpm	
1							**Without developing E.M.F of Generator**
2							**When both Machines are at same potential**
3							**Loading condition**
4							**X=1 X=0.75 X=0.5 X=0.25**
5							
6							
7							
8							

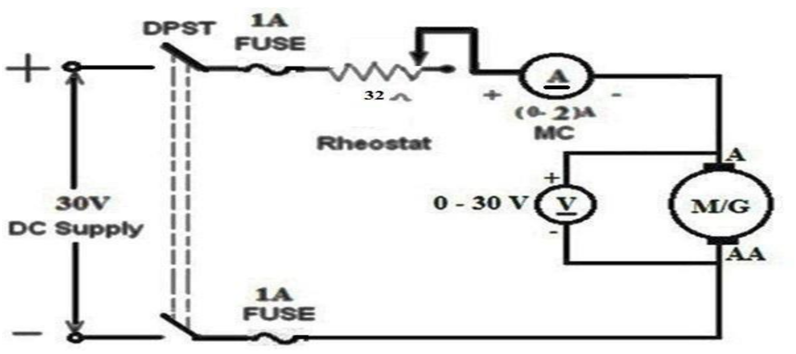


Figure 6.2 Circuit diagram to find Armature Resistance

Procedure to measure to measure Armature/Field Resistance of Machine:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Now close the DC Supply switch and low voltage is applied by varying 32 Ω Rheostat, note down the readings of all meters.
3. Armature and field resistances of DC Machines are to be calculated.

To find Armature/Field Resistance of Machine

Sl. No	I(A)	V (Volts)	$R_{am} = \frac{V}{I} = \quad \Omega$	Sl. No	I(A)	V (Volts)	$R_{fm} = \frac{V}{I} = \quad \Omega$
Armature Resistance of Motor:				**Field Resistance of Motor:**			
Sl. No	**I(A)**	**V (Volts)**	$R_{ag} = \frac{V}{I} = \quad \Omega$	**Sl. No**	**I(A)**	**V (Volts)**	$R_{fg} = \frac{V}{I} = \Omega$
Armature Resistance of Generator:				**Armature Resistance of Generator:**			

Calculations:

Supply voltage = V_m = ---------Volts

Motor input = $V_m(I_1+I_2)$= --------- Watts

Where $I_1 = (Ia+I_{fg})$ =..............A

$I_2 = (I_m+I_{fg})$ =.............. A

Generator output = $V_m \times I_1$…Watts

Let

R_{am} = Armature Resistance of Motor in **Ω**

R_{ag}= Armature Resistance of Generator in **Ω**

R_{fm}= Field Resistance of Motor in **Ω**

R_{fg}= Armature Resistance of Generator in **Ω**

Generator armature copper loss= $I_a^2 R_{ag}$= -------------Watts

Motor armature copper losses = $(I_1+I_2)^2 R_{am}$= ---- ------- Watts

Shunt field copper loss of Motor=$I_{fm}^2 R_{fm}$= ------------- Watts

Shunt field copper loss of Generator= Ifg2Rfg= ------------- Watts

Stray losses of both the Machines=Total power drawn by the supply- copper losses of both Machines

$W=V_mI_m-[Ia^2Rag+ (I_1+I_2^{2)})R_{am}+ I_{fg}^2R_{fg}+ I_{fm}^2R_{fm}]=$ ------------------- Watts

Since both Machines are identical stray losses are equally divided.

$\therefore$ stray losses of each Machine = $\frac{W}{2}$ =..........Watts

<u>For Generator</u>

Total losses in Generator = $Wg= Ia^2Rag+ I_{fg}^2R_{fg}+\frac{W}{2}$=----------Watts

Output of Generator= $V_m\ I_1$= ……W

$(\%\boldsymbol{\eta}\ )=\frac{o/p}{output+losses} \times 100 =$ **……….%**

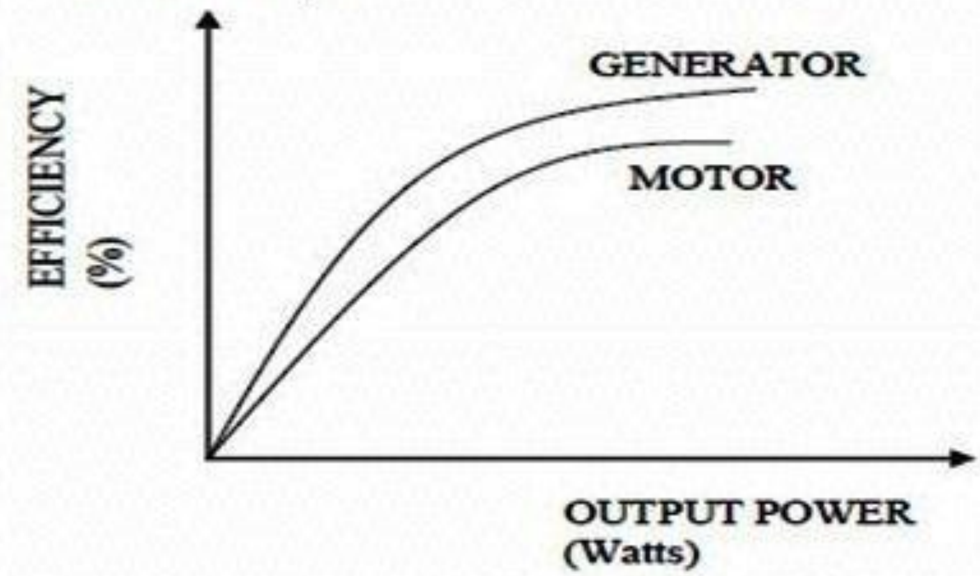
<u>For Motor</u>

Input to Motor = $V_m\times (I_1+I_2)$= ………Watts

Total losses in Motor = $Wm= (I_1+I_2)^2\ Rag+ I_{fm}^2R_{fm}+\frac{W}{2}$= ---------Watts

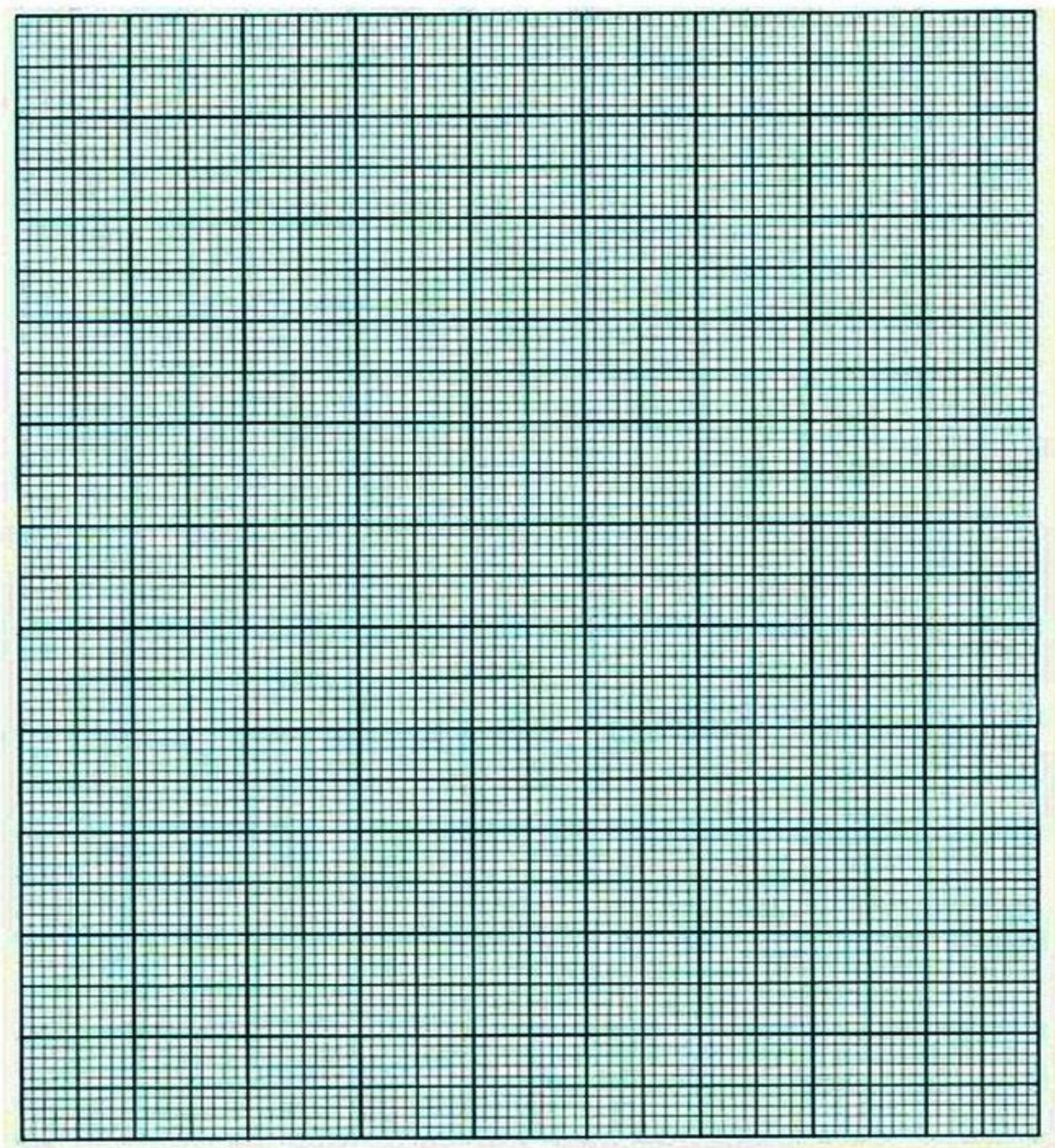
$\%\boldsymbol{\eta} =\frac{input-losses}{i/p} \times 100 =$ **……….%**

Ideal Graph



Performance Characteristics

Figure 6.3



Expected Result: Efficiency of Motor and Generator at various Loads are to be determined.

Result:

Loadings ($\%x$)	$\%\boldsymbol{\eta}\ of\ Motor$	$\%\boldsymbol{\eta}\ of\ Generator$
1		
1/2		
3/4		
1/4		

Signature of the Staff in-charge

Experiment No. 7

Load test on 3 Phase induction Motor

Aim: To obtain the performance characteristics of an induction Generator by conducting Load test on it.

Apparatus Required:

Sl. No	NAME	RANGE	TYPE	QUANTITY In No	Machine Ratings	
01	Voltmeter	0 - 600V	MI	1	Power rating	
		0-300V	MC	2	Voltage	
02	Ammeter	0 – 10/20 A	MI	2	Current	
		0 – 10/20 A	MC	1	Speed(RPM)	
03	Rheostat	750 Ω	Variable	1	Frequency	
04	SPDT Switch		Knife	1	PF	
05.	Tachometer	0 – 2000 rpm	Contact	1	Connecting wires as per requirement	

Theory

Circuit Diagram:

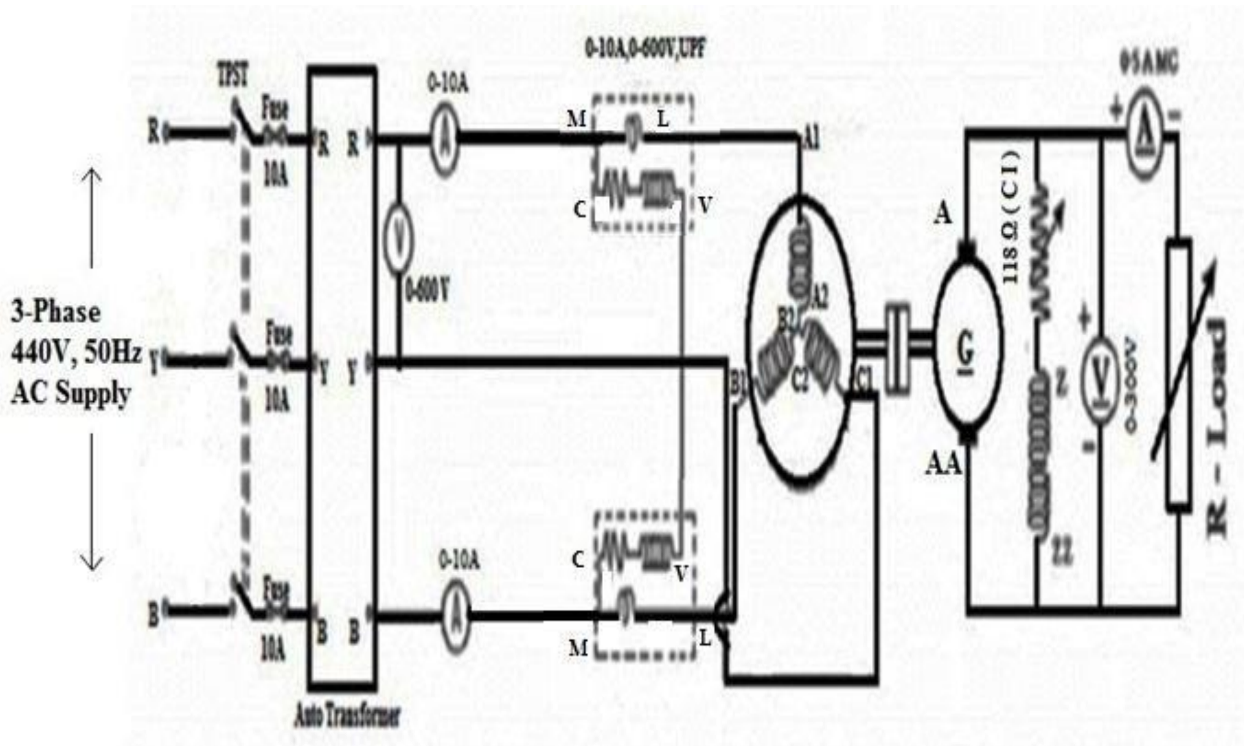


Figure 7.13-PhaseInduction Motor

PROCEDUCE:

- Circuit connections are made as per the Circuit diagram shown in figure.
- Initially Load switch is kept open, filed rheostat is kept in cut in position and auto transformer knob is in Zero position.
- Now the AC supply switch is closed, the induction Motor is brought to its rated speed by gradually applying voltage using Auto transformer.
- Build up the Generator voltage by cutting out of 750 ohm rheostat and note down the no Load readings.
- Now close the Load switch the Motor is Loaded in steps at each step the voltage of Generator is maintained constant, at each step note down all meter readings along with speed.
- Above procedure is repeated till the Motor draws its rated current.

Note:

- **If one of the wattmeter kicks back, then connection of C & V is interchanged the reading is taken as negative.**

Sl. No	V_1 in Volts	I_1 in A	I_2 in A	$I = I_1 + I_2$ in Amps	W1 In Watts	W2 In Watts	V_L in Volts	I_L current In Amps	Speed N In Rpm	Input to induction Motor W1+W2	Output of DC Generator or $V_L I_L$	Output of Motor =inputto Generator	%η	Cosϕ	Torque T In Nm	%Slip

Calculation:

Watt meter constant K=$\frac{VI\ Cos\emptyset}{Full\ scale\ reading}$**=**

Output of DC Generator=$V_L \times I_L$ **= ----------- =------- Watts**

Input to DC Generator =$\frac{Output\ of\ DC\ Generator}{\eta}$**= ----------- =--------Watts (assume η** $_{\text{of DC Gen}}$**=0.85)**

But Output of 3Ø induction Motor = Input to Dc Generator =----------------- Watts

Input to 3Ø induction Motor = $W_1 \pm W_2$ **=**

$\%\boldsymbol{\eta}=\frac{output\ of\ 3ph\ Induction\ motor}{input\ to\ 3ph\ Induction\ motor}\times 100$ **=**

B.H.P =$\frac{\text{Output of Induction motor}}{735.5} =$

Power factor Cosϕ= Cos$\{\tan^{-1}\sqrt{3}\,(\frac{W1-W2}{W1+W2})\}$=

Expected result: Performance characteristics of three phase induction Motor are to be plotted. The curves plotted should match with the ideal curves.

<u>Result:</u>

Signature of the Staff in-charge

Experiment No. 8

No Load and Blocked rotor test on 3 Phase induction Motor to draw (i) Equivalent Circuit and (ii) Circle diagram. Determine the performance parameters at different Load conditions from (i) and (ii).

Aim: To determine the equivalent Circuit of a 3- ϕ induction Motor and calculate various parameters of induction Motor with the help of circle diagram.

Sl. No.	Name	Type	Range	Quantity	Machine Rating	
1	Voltmeter	MI	(0-600)V	1	Power rating	
2	Ammeter	MI	(0-10)A	1	Voltage	
3	Wattmeter	Electro dynamo meter type	10A/600V UPF 10A/600V UPF	1 1	Current	
4	Tachometer	Digital/Analog	*****	1	Speed(RPM)	
5	Connecting Wires	*****	*****	Required	Frequency	
					PF	

Circuit diagram:

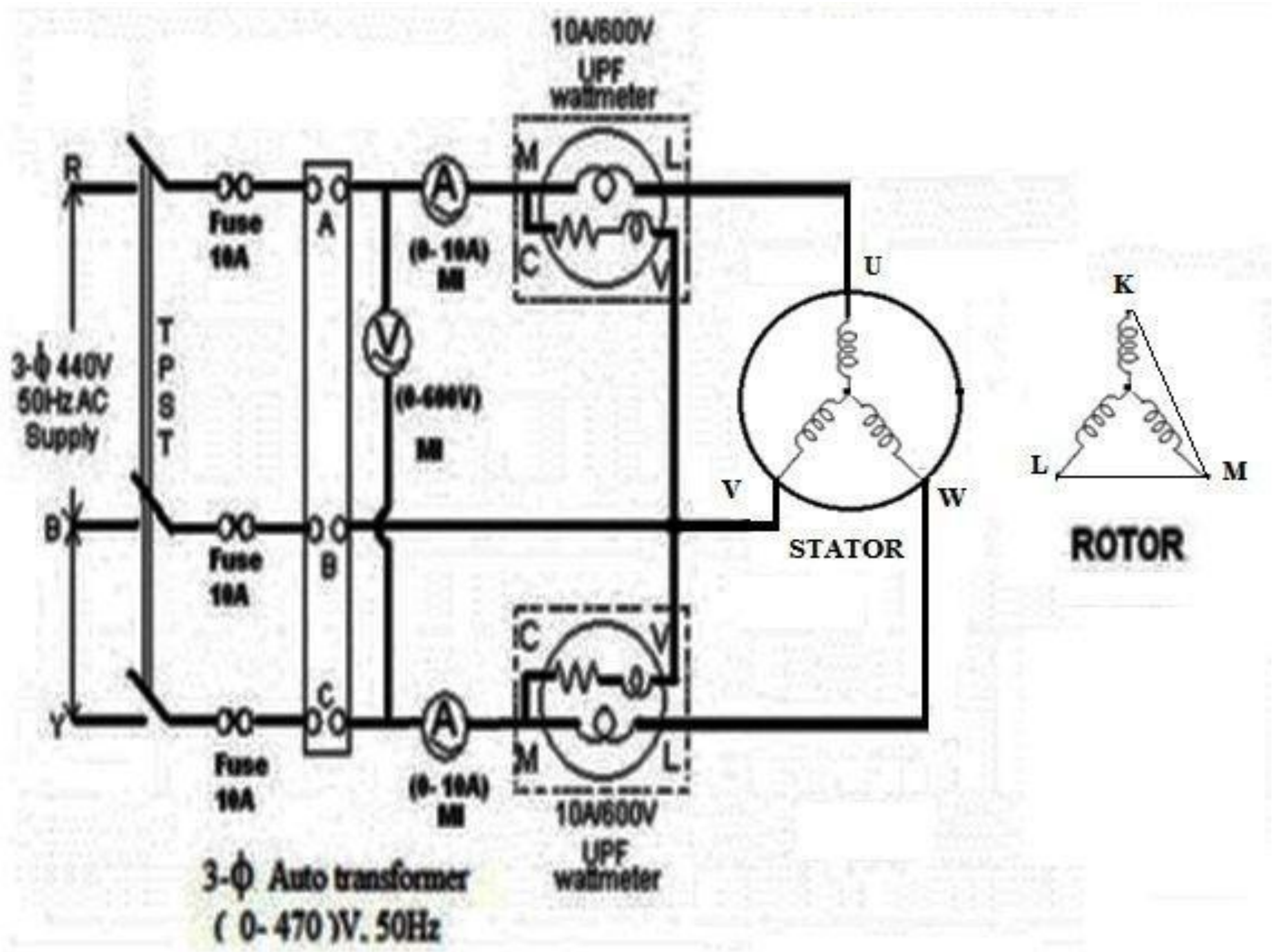


Figure 8.13-Phase Induction Motor

PROCEDURE:

NO LOAD TEST:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Ensure that the 3- ϕ Auto transformer is kept at Zero position and belt is freely suspended.
3. Switch ON the supply. Increase the 3- ϕ Auto transformer output voltage gradually until rated voltage is observed in voltmeter. Note that the induction Motor takes large current initially, so; keep an eye on the ammeter such that the starting current should not exceed 7 Amp.
4. By the time speed gains rated value, note down the readings of voltmeter, ammeter, and wattmeter.
5. Bring back the variac to zero output voltage position and switch OFF the supply.

BLOCKED ROTOR TEST:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. The rotor is blocked by tightening the belt.
3. A small voltage is applied using 3- ϕ Auto transformer to the stator so that rated current flows in the induction Motor.
4. Note down the readings of Voltmeter, Ammeter and Wattmeter in a tabular column.
5. Bring back the 3- ϕ Auto transformer tozero position and switch OFF the supply.

OBSERVATIONS:

No Load Test:

Sl No	Voltmeter reading V in Volts	Ammeter reading I in Amps	Wattmeter Reading		Total power W1+W2
			W_1	W_2	

Blocked Rotor Test

Sl No	Volt meter reading V in Volts	Ammeter reading I in Amps	Wattmeter Reading		Total power W1+W2
			W_1	W_2	

Measurement of stator winding resistance (r1):

Circuit diagram:

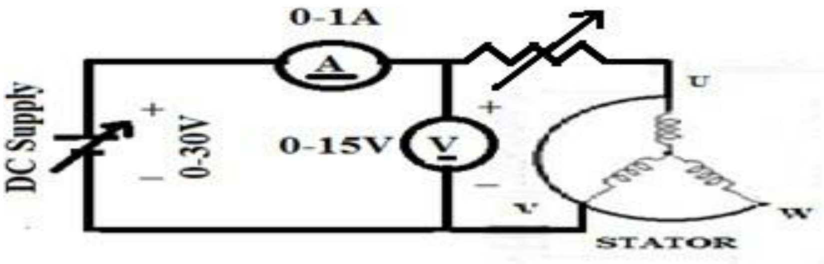


Figure 8.2Measurement of stator winding resistance.

Measurement of Stator resistance:

1. Connect the Circuit as per the Circuit diagram shown in figure.

2. Keeping Rheostat in maximum resistance position switch on the 30 V Dc supply.

3. Using Volt-Ammeter method measure the Resistance of the Stator winding.

4. After finding the stator resistance, R_{dc} must be multiplied with 1.6 so as to account for skin effect i.e. R_{ac} = 1.6 R_{dc}.

TABULAR COLUMN:

S no.	Voltage (v)	Ammeter(I)	Stator Resistance $R_{dc} = \frac{V}{I}\ \Omega$	$R_{ac} = \frac{1.6Rdc}{2}\ \Omega$
1				
2				
3				
Average Stator Resistance/Phase =-----------Ω				

No Load test:

Wattmeter constant $W_C = \frac{VI\ Cos\ \emptyset}{Maximum\ Deflection}$

$I_0 = (I_1+I_2)/2$= ----Amps

$W_0 = w_1+w_2$= ------- Watts

$Cos\emptyset_0 = P0/(\sqrt{3}\ V_0 I_0)$=-------

$\emptyset_0$ = ----------degrees

I_{SN} = Isc V_0/Vsc= ----- Amps

$W_{SN} = W_{sc} (I_{SN}/I_{SC})$^2 A=--------Watts

Blocked Rotor test

Wattmeter constant $W_C = \frac{VI\ Cos\ \emptyset}{Maximum\ Deflection}$

$I_0 = (I_1+I_2)/2$= ----Amps

$W_0 = w_1+w_2$= ------- Watts

$Cos\emptyset sc$ ==P0/($\sqrt{3}\ V_0 I_0$)=-------

$\emptyset_0$ = ----------degrees

I_{SN} = Isc V_0/Vsc= ----- Amps

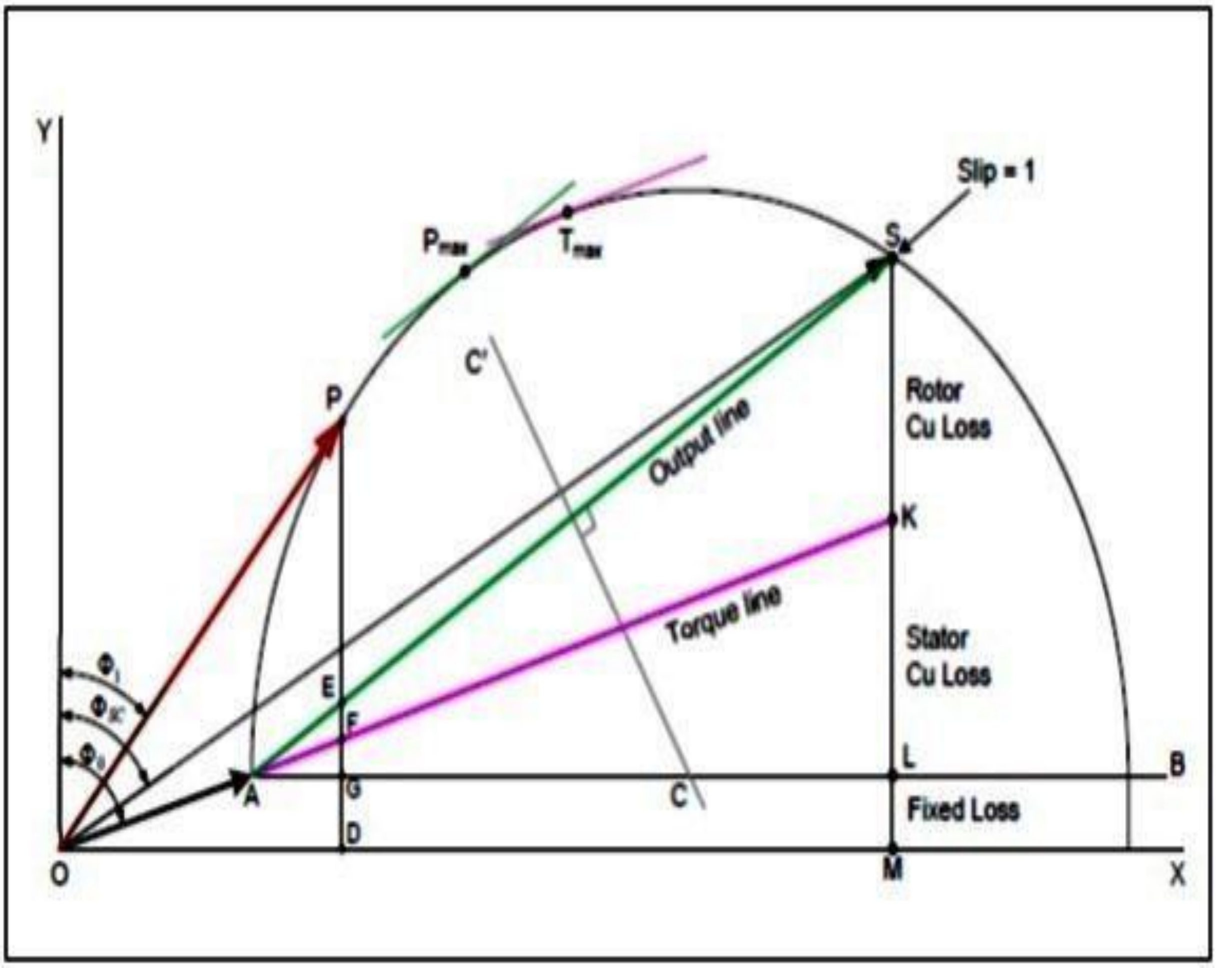
$W_{SN} = W_{sc} (I_{SN}/I_{SC})^2$ A= ------- Watts

Construction of Circle Diagram

1. Draw horizontal axis OX and vertical axis OY. Here the vertical axis represents the voltage reference.
2. With suitable scale, draw phasor OA with length corresponding to I0 at an angle Φ0 from the vertical axis. Draw a horizontal line AB.
3. Draw OS equal to I_{SN} at an angle Φ_{SC} and join AS.
4. Draw the perpendicular bisector to AS to meet the horizontal line AB at C.
5. With C as centre, draw a semi-circle passing through A and S. This forms the circle diagram which is the locus of the input current. From point S, draw a vertical line SL to meet the line AB. Fix the point K as below.
   For wound rotor machines where equivalent rotor resistance R2′ can be found out:

Divide SL at point K so that SK: KL = equivalent rotor resistance: stator resistance.
For squirrel cage rotor machines:

6. Find Stator copper loss using I_{SN} and stator winding resistance R1.
   Rotor copper loss = total copper loss – stator copper loss.
7. Divide SL at point K so that SK : KL = rotor copper loss : stator copper loss
   Note: If data for separating stator copper loss and rotor copper loss is not available then assume that stator copper loss is equal to rotor copper loss. So divide SL at point K so that SK= KL
8. For a given operating point P, draw a vertical line PEFGD as shown.
   Then, PD = input power, PE = output power, EF = rotor copper loss, FG = stator copper loss, GD = constant loss (iron loss + mechanical loss)
9. Efficiency of the machine at the operating point P, $\eta = \frac{PE}{PD}$
10. Power factor of the machine at operating point P = $\cos\Phi_1$
11. Slip of the machine at the operating point P, $s = \frac{EF}{PF}$
12. Starting torque at rated voltage (in syn. watts) = SK
13. To find the operating points corresponding to maximum power and maximum torque, draw tangents to the circle diagram parallel to the output line and torque line respectively. The points at which these tangents touch the circle are respectively the maximum power point (Tmax) and maximum torque point (Pmax)



Calculations

Expected Result: Performance of 3-Ph Induction Motor is to be determined by constructing circle diagram.

Result:

Signature of the Staff in-charge

Experiment No.9

Load test on Induction Generator

Aim: To determine the efficiency of Generator at different Loads and to show that an AC Machine can be run as both Motor as well as Generator.

Apparatus Required:

Sl. No.	Name	Type	Range	Quantity In No	Machines Rating	
1	Voltmeter	MI MC	(0-600)V (0-300)V	1 2	Power rating	
2	Ammeter	MI MC	(0-10/20)A (0-10/20)A	2 1	Voltage	
3	Wattmeter	Electro dynamo meter type	0-600V UPF 0-10A	2	Current	
4	Rheostat	Variable	750 Ω	1	Speed(RPM)	
5	Tachometer	Digital/Analog	*****	1	Frequency	
6	Connecting Wires	*****	*****	Required	PF	

Circuit diagram:

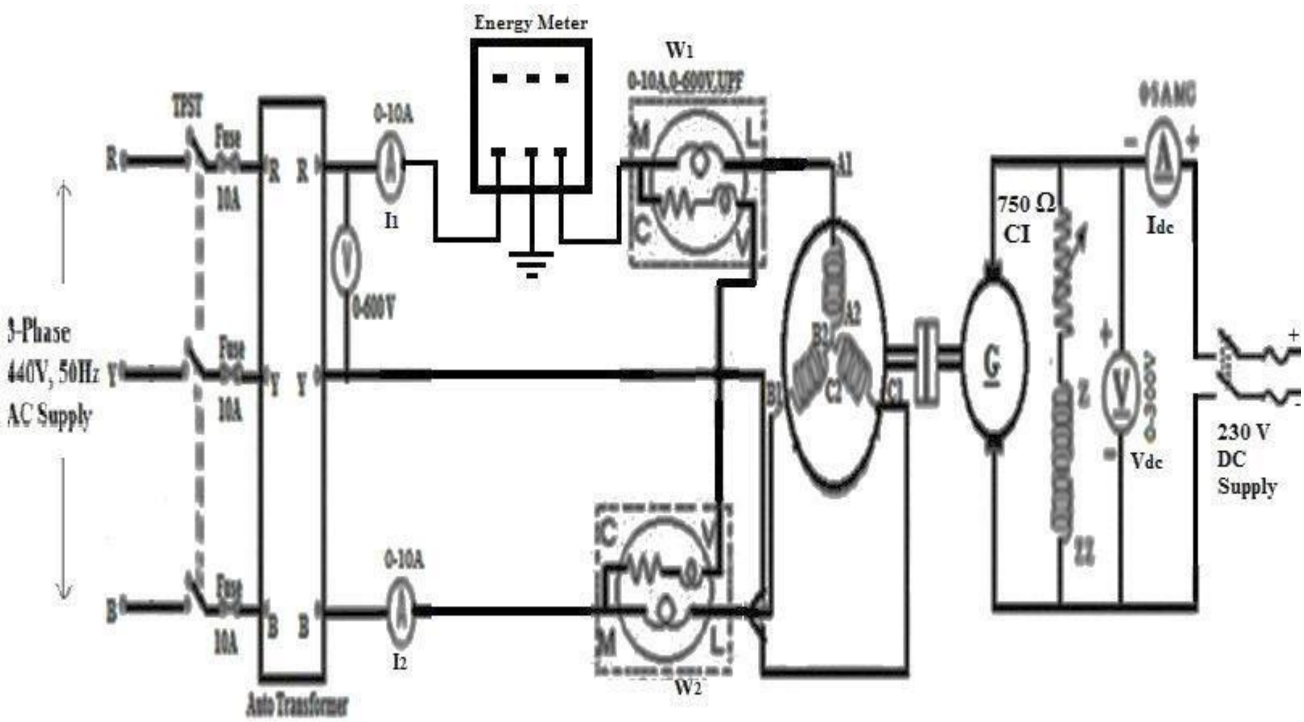


Figure 9.1 Induction Generator

Procedure: LOAD TEST:

- Circuit connections are made as per the Circuit diagram shown in figure.
- Ensure that the 3- ϕ Auto transformer is kept at 0 positions and belt is freely suspended.
- Switch ON the supply. Increase the 3- ϕ Auto transformer output voltage gradually until rated voltage is observed in voltmeter. Note that the induction Motor takes large current initially, so; keep an eye on the ammeter such that the starting current should not exceed 8 Amp.
- A 750Ω rheostat is in cut in position and 230V DC supply switch is open.
- Now close the AC supply switch and apply the voltage gradually by varying the auto transformer
- Now build the Generator voltage to its rated value by varying 750Ω rheostat and note down all the meter readings.
- Now observe the voltage across the DC supply (230V DC supply) and adjust Generator output voltage equal to that of DC supply switch.
- At synchronous speed, note down the readings of all the meters, ensure that some of wattmeter's readings are equal to zero.
- Speed of the Machine is varied by varying Armature Rheostat and all the meter readings are noted down.

SL No	I_1 in Amps	I_2 in Amps	W1 in Watts	W2 in Watts	V in Volts	voltage V_{DC} in Volts	I_{DC} current in Amps	Speed N In rpm	Cos ϕ	Input to induction Generator	Output of induction Generator	$\%\eta$

Calculation:

Wattmeter constant (k) $= \dfrac{VI \ \cos\phi}{Maximum\, deflection} =$

Input to DC Motor $= V_{DC} \times I_{DC} =$---------------- Watts

Output of DC Motor = Input $\times\ \eta$

$= V_{DC} \times I_{DC} \times\ \eta$ (assume 85% η)

$=$- - - - - - - - - - Watts

Input to induction Generator=output 0f DC Motor

Out of Induction Generator$= W_1 \pm W_2$

$\%\ \eta\ of\ Induction\ Generator = \dfrac{o/p}{Input} \times 100 =$ ……….%

Calculations

Expected Result: Performance characteristic of 3-ph induction Generator is to be calculated.

Result:

Signature of the Staff in-charge

Experiment No. 10

Load Test on single phase Induction Motor to draw out put V/s Torque, current, power and efficiency characteristics.

Aim: Obtain performance characteristics of the given single phase Induction Motor

Apparatus Required:

Sl. No.	Equipment	Type	Range	Quantity In No	Machines Rating	
1	Voltmeter	MI	(0-300)V	1	Power rating	
2	Ammeter	MI	(0-10)A	1	Voltage	
3	Wattmeter	Dynamo-type	(0-300)V LPF (0-10)A	1	Current	
4	Tachometer	Analog/Digital Contact type	0-2000rpm	1	Frequency	
5	Connecting Wires	*****	*****	Required	PF	

Circuit Diagram:

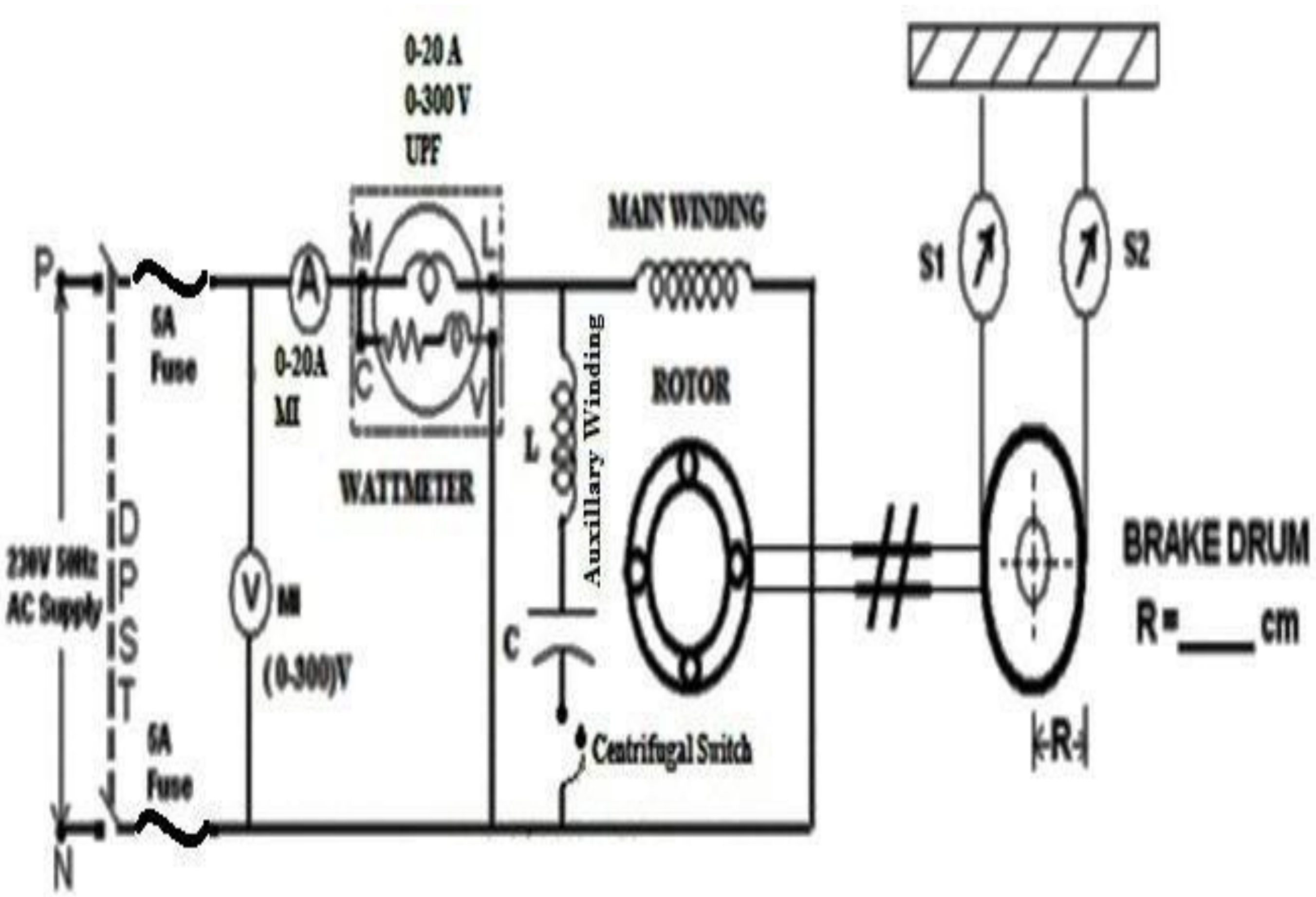


Figure 10.1single phase Induction Motor

PROCEDURE:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. DPST switch is closed and Machine M is by keeping Armature Rheostat in cut in position and Field Rheostat in Cut out position
3. Now Close the supply switch Bring the Motor to its rated speed by varying Armature Rheostat if necessary by varying Field Rheostat.
4. Apply Load in Steps and corresponding meter readings are noted down and tabulated
5. Loading process is done till the Motor draws rated current
6. %η and other parameters are calculated graphs are plotted.

Calculations:

Wattmeter constant (k) $=\frac{\text{VI Cos}\phi}{Maximum\ deflection} =$

Radius of Break drum ®= -------- meters

(F_1 and F_2 is Load in kgs)

Shaft Torque T_{sh} (F1≅F2) r------------- kgm

%Slip $=\frac{Ns-N}{N}\times 100$

$Ns=\frac{120f}{P}=\frac{120x50}{4}=1500$rpm

Input to induction Motor= ---------- Watts

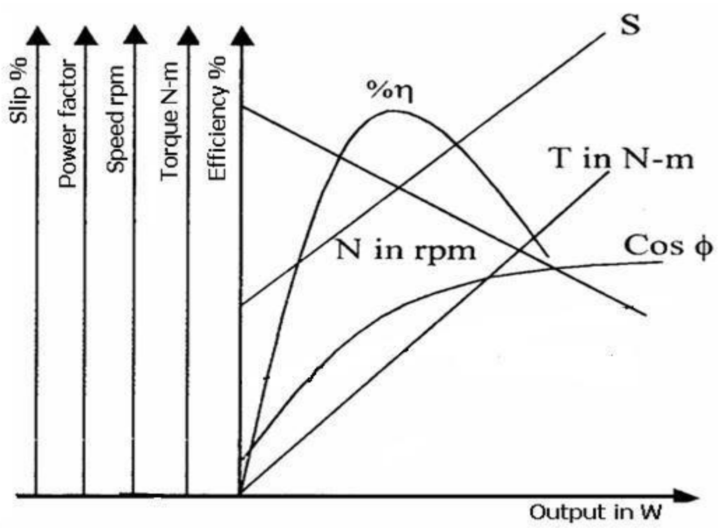
Output in BHP $= \frac{2\pi NT}{4500} = ----$

Output in Watts = BHP×735.5= ------------ Watts

$\%\eta=\frac{Output}{Input}\times 100 =$----------

$Cos\phi=\frac{W}{VI}=$ -------

Ideal Graph:



Expected Result:

Performance characteristic of single phase induction Motor by direct Loading is to be plotted.

RESULT:

Signature of the Staff in-charge

Experiment No. 11

Conduct a suitable experiment to draw the equivalent Circuit of 1 phase induction Motor and determine performance parameters

Aim: To determine the equivalent Circuit parameters of a single phase induction Motor by Performing the no-Load and blocked rotor tests.

APPARATUS REQUIRED:

Sl. No.	Equipment	Type	Range	Quantity In No	Machine Rating	
1	Voltmeter	MI	(0-300)V	1	Power rating	
2	Ammeter	MI	(0-10)A	1	Voltage	
3	Wattmeter	Dynamo-type	(0-300)V LPF (0-10)A	1	Current	
4	Wattmeter	Dynamo-type	(0-150)V UPF (0-10)A	1	Speed(RPM)	
5	Connecting Wires	*****	*****	Required	Frequency	
					PF	

Circuit diagram:

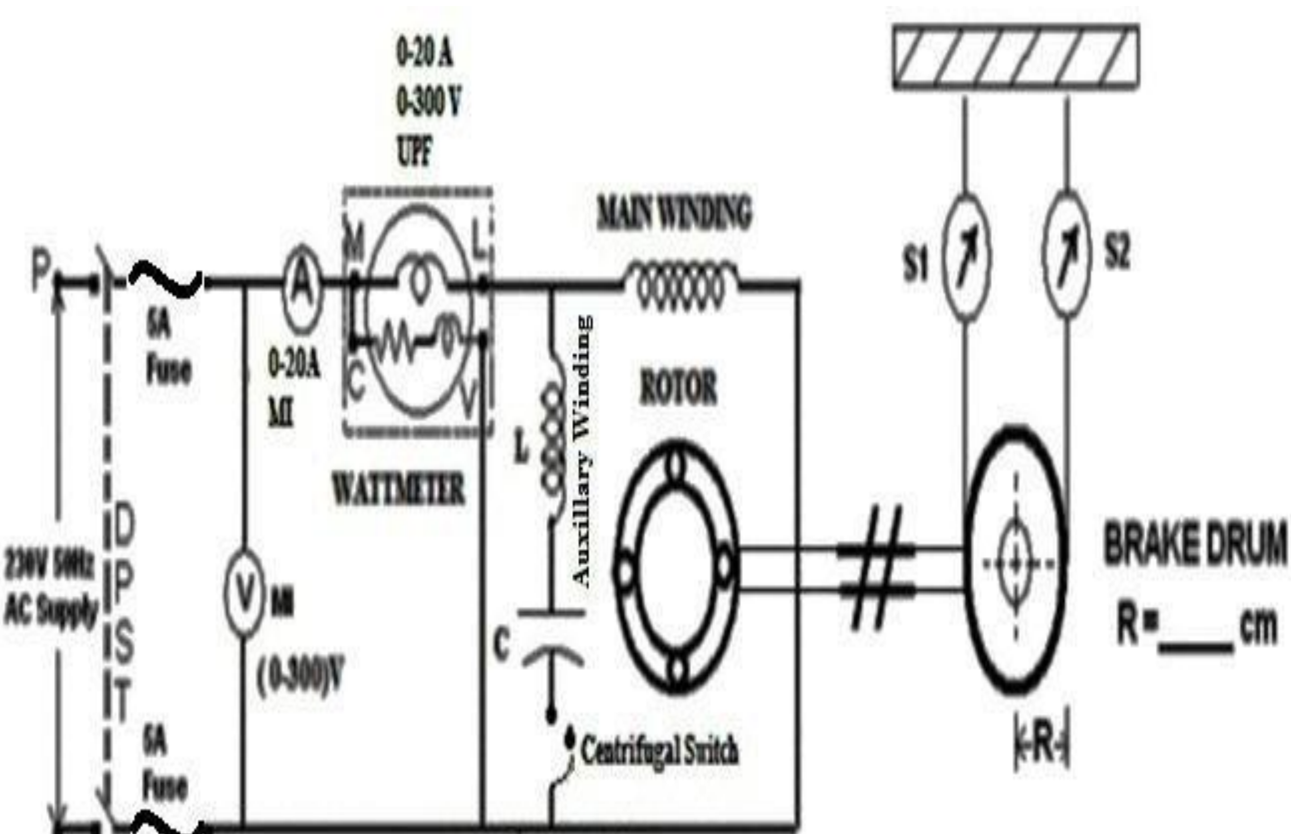


Figure 11.1 single phase Induction Motor

PROCEDURE:
No Load Test:

1. Circuit connections are made as per the Circuit diagram shown in figure.
2. Be sure that variac (auto transformer) is set to zero output voltage position before starting the experiment.
3. Now switch ON the supply and close the DPST switch.
4. The variac is varied slowly, until rated voltage is applied to Motor and rated speed is obtained.
5. Take the readings of Ammeter, Voltmeter and wattmeter in a tabular column.
6. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.

Blocked Rotor Test:

1. To conduct blocked rotor test, necessary meters are connected to suit the full Load conditions of the Motor.
2. Connections are made as per the Circuit diagram.
3. Before starting the experiment auto transformer is set to zero output voltage position.
4. The rotor shaft of the Motor is held tight with the rope around the brake drum.
5. Switch ON the supply, and variac is gradually varied till the rated current flows in the induction Motor.
6. Readings of Voltmeter, Ammeter, and wattmeter are noted in a tabular column.
7. The variac is brought to zero output voltage position after the experiment is done, and switch OFF the supply.
8. Loosen the rope after the experiment is done.

Circuit diagram to measure Stator and Rotor winding Resistance:

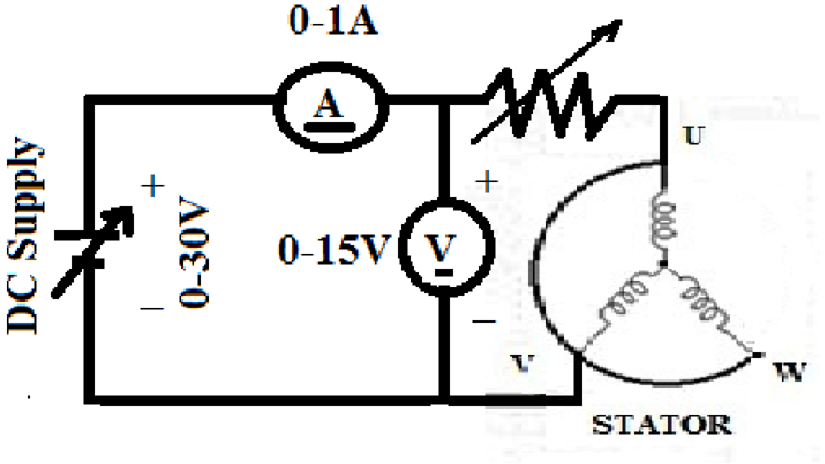


Figure 11.2**Circuit diagram for measurement resistance r1.**

Measurement of Stator resistance:

1. Connect the Circuit as per the Circuit diagram shown in figure.

2. Keeping Rheostat in maximum resistance position switch on the 30 V Dc supply.

3. Using Volt-Ammeter method measure the Resistance of the Stator winding.

4. After finding the stator resistance, R_{dc} must be multiplied with 1.6 so as to account for skin effect i.e. $R_{ac} = 1.6\ R_{dc}$.

TABULAR COLUMN:

S no.	Voltage (v)	Ammeter(I)	Stator Resistance $R_{dc} = \frac{V}{I}\ \Omega$	$R_{ac} = \frac{1.6 Rdc}{2}\ \Omega$
1				
2				
3				
Average Stator Resistance/Phase =-----------Ω				

Calculation for No-Load Test:

$$V_o I_o \cos \Phi_o = W_o$$

$$\cos \Phi_o = \frac{W_o}{V_o I_o}$$

$$Z_o = \frac{V_o}{I_o}$$

$$X_o = Z_o \sin \Phi_o$$

$$X_o = X_1 + \frac{1}{2}(X_2 + X_m)$$

$$X_m = 2(X_o - X_1) - X_2$$

Calculation for Blocked Rotor Test:

$$Z_{sc} = \frac{V_{sc}}{I_{sc}}$$

$$R_{sc} = \frac{W_{sc}}{I_{sc}^2}$$

r_1 is the DC resistance of stator of motor

$$r_2 = R_{sc} - r_1$$

$$x_1 + x_2 = X_{sc}$$

since leakage reactance can't be seperated out , it is common practice to to assume $x_1 = x_2$

$$x_1 = x_2 = \frac{X_{sc}}{2} = X_{sc} = \frac{1}{2}\sqrt{Z_{sc}^2 - R_{sc}^2}$$

OBSERVATIONS:

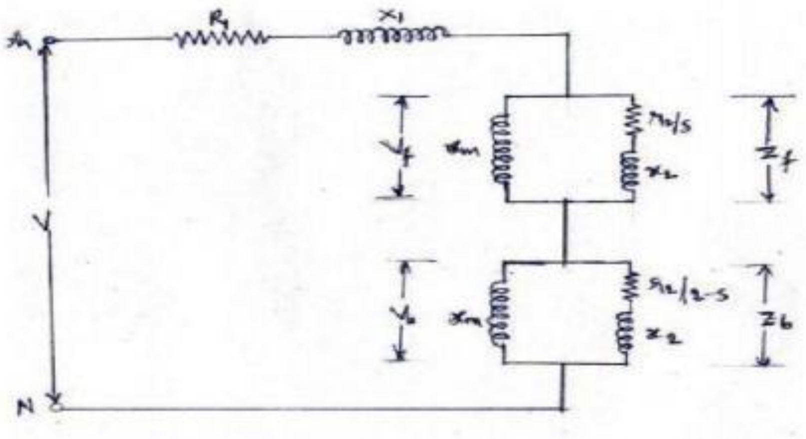
For NO-Load Test:

Sl no.	Voltmeter reading Vo	Ammeter reading Io	Wattmeter reading Wo

For Blocked Rotor Test:

Sl no.	Voltmeter reading Vo	Ammeter reading Io	Wattmeter reading Wo

Expected Result: Equivalent Circuit parameters of 1-Ph Induction Motor are to be calculated and Equivalent Circuit is to be drawn.



Result:

Signature of the Staff in-charge

Experiment No. 12

Conduct an experiment to draw V and inverted V curves of synchronous Motor at no Load and Load conditions

Aim: To plot the ‘v’ and ‘inverted v’ curves of Synchronous Motor.

APPARATUS REQUIRED:

Sl. No.	Name	Type	Range	Quantity In No	Machine Rating	
1	Voltmeter	MI	(0-600)V (0-300)V	1 1	Power rating	
2	Ammeter	MC MI	(0-10)A (0-10)A	1 1	Voltage	
3	Rheostat	Wire-wound	400 Ω /1.7A	1	Current	
4	Tachometer	Digital	*****	1	Speed(RPM)	
5	Wattmeter	Electrodynamometer	10A, 600V UPF 10A , 600V LPF	1 1	Frequency	
6	Connecting Wires	*****	*****	Required	PF	

Circuit diagram:

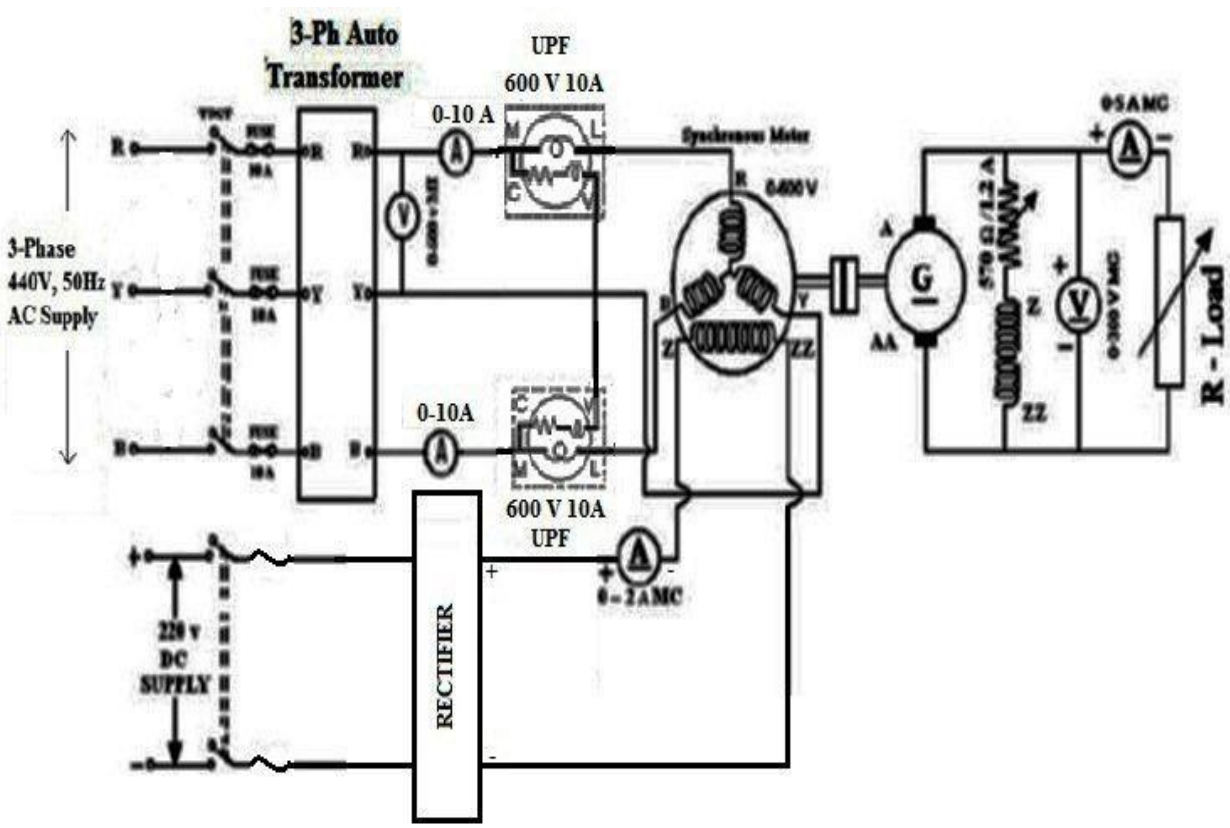


Figure 12.1synchronous Motor

PROCEDURE:

1. Connections are made as per the Circuit diagram.
2. Initially auto transformers knob is kept at zero position. Load switch and excitation switch is kept open and 750 Ω Rheostat is kept in cut in position.
3. Now close the 3- Ø *A*C Supply Switch and now gradually apply the 90%of the rated voltage of synchronous Motor by using 3-Ø Auto transformer.
4. Observe the direction of rotation of the Motor. If it rotates in opposite direction, then interchange any two terminals of the supply and then synchronous Motor rotates in same direction as indicated.
5. Now close the excitation switch and apply voltage such that rated excitation current flows through the field winding.
6. Apply remaining 10% supply voltage and then check the speed, now synchronous Motor rotates at synchronous speed i.e. 1500rpm.
7. Build up the generated voltage to its rated value by varying 750 Ω Rheostat.
8. Now close the Load switch and apply the Load at some value.
9. Vary the excitation by using rectifier such that current drawn by the Motor should be minimum at the time note down readings of all meters. That excitation is taken as normal excitation.
10. Now under excite the field in steps and note down all the meter readings.
11. Now over excite the field in steps and note down all the meter readings.

OBSERVATION TABLE:

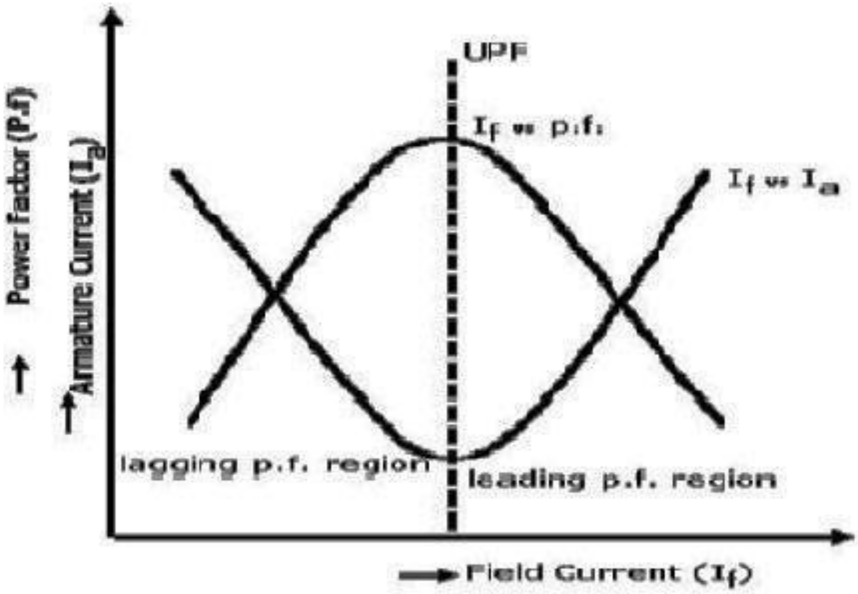
SL No	V_1 in Volts	I_1 in Amps	I_2 in Amps	I_{avg} in Amps	W1 in Watts	W2 In Watts	Load voltage V_L in Volts	Load current I_L in Amps	Speed N in rpm	Field current I_F in Amps	Power factor Cosϕ	Excitation status
												Under excitation
												Normal Excitation
												Over excitation

Caculations:

Wattmeter constant= $\frac{VI\ \cos\phi}{Full\ scale\ reading}$

Cos**ϕ=Cos**$\{Tan^{-1}\ \sqrt{3}(\frac{w1-w2}{w1+w2})\}$

MODEL GRAPHS:



Expected Result: v and inverted v curves for synchronous machine are to be drawn. The plotted characteristic curves should match the given ideal curves.

RESULT:

Signature of the Staff in-charge