LABORATORY INSTRUCTION MANUAL

JIS College of Engineering

(NAAC and NBA Accredited Institution)

Approved by AICTE, New Delhi & Affiliated to WBUT

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Electrical Machine Laboratory Manual

Mechanical Engineering

2nd Year

3rd Semester

Department of Electrical Engineering

2016

GENERAL SAFETY INSTRUCTIONS FOR THE STUDENTS

Read this section carefully before you perform any experiment in the Electrical Machine Laboratory

1. While performing experiments in the Electrical Machine Laboratory, you must follow stringent safety rules and precautionary measures for your own safety as well as for safety of your co-workers. Always remember that you are working at voltage levels much higher compared to normal working voltage.

2. Don't attempt to enter the lab floor except when asked for and accompanied by concerned teachers / instructors.

3. Do not attempt to operate any equipment yourself without permission of the concerned teachers / instructors. You should never be in casual while in the lab floor. Be careful that you don't operate any button etc. by mistake: it may lead to serious mal operation and hazards.

4. Always maintain sufficient distance from the live objects to avoid electrical shock due to induction.

5. Before taking entry in the lab floor, always double check that all the apparatus and equipment are disconnected from supply and are properly grounded.

6. Use the ground rod to earth all apparatus before putting hands on them.

LIST OF EXPERIMENT

1. Study of the characteristics of a separately excited DC generator.
2. Study of the characteristics of a DC motor
3. Study of the characteristics of a compound DC generator (short shunt).
4. Measurement of speed of DC series motor as a function of load torque.
5. Speed control of 3 phase Induction motor by different methods & their comparison.
6. Determination of regulation of Alternator by Synchronous Impedance method.
7. Determination of equivalent circuit parameters of a single phase motor.
8. Load test of single phase Induction motor to obtain the performance characteristics.
9. Study of equivalent circuit of three phase induction motor by no load and blocked rotor test.
10. Study of performance of three phase squirrel- cage Induction motor – determination of Iron-loss, friction & windage loss.

EXPERIMENT NO : ME – 1

TITLE **STUDY THE CHARACTERISTICS OF SEPARATELY EXCITED D.C. GENERATOR**

OBJECTIVE : To plot the following characteristics of a separately excited D.C. generator

I. No load characteristics or magnetizing curve.
II. Load characteristics.
III. External characteristics.

APPARATUS:

Sl No	Apparatus Name	Apparatus Type	Range	Makers Name	Serial No
1	Motor				
2	Generator				
3	Ammeter 1				
4	Ammeter 2				
5	Voltmeter				
6	Rheostat				
7	Load Box				
8	Tachometer				

THEORY :

1. **NO-LOAD CHARACTERISTICS OR MAGNETIZING CURVE**

The expression for generated e.m.f. E_g in d.c. generator armature winding can be written as

$$E_g = \frac{\varphi Z N}{60} \times \frac{P}{A}$$

Where φ is flux per pole in Wb, *Z* is total no. of armature conductor, *N* is speed of generator in r.p.m., *P* is no. of pole and *A* is no. of parallel paths. So, with the constant speed, $E_g = K\varphi$. The variation of armature generated e.m.f. E_g with field current I_f for zero armature current is known as magnetization or no-load or open circuit characteristic (O.C.C). The typical O.C.C is shown in Fig 1. For low values of I_f O.C.C is a straight line, but with increased values of I_f and above, saturation sets in. The value of E_g at zero field current is called *residual voltage*. If speed is reduced, O.C.C. shifts bodily downwards.

2. **LOAD CHARACTERISTICS**

In separately excited d.c. generator terminal voltage $V_t = E_g - I_a R_a$ and also the generated e.m.f. $E_g \propto I_f N$. So, for a constant speed and load current I_a, terminal voltage V_t changes with the change of field current I_f. This characteristic, drawn between terminal voltage V_t and field current I_f known as load characteristic which is shown in Fig 2. The load characteristic is obtained by just shifting the no-load characteristic bodily downward by armature voltage drop $I_a R_a$.

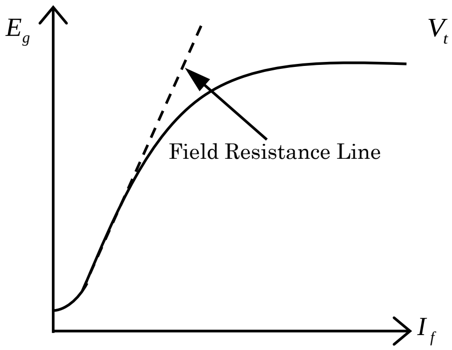


FIG. 1. NO-LOAD CHARACTERISTIC

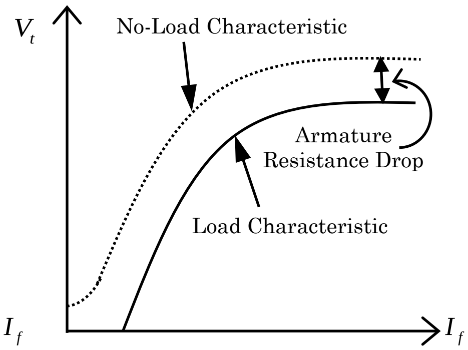


FIG. 2. LOAD CHARACTERISTIC

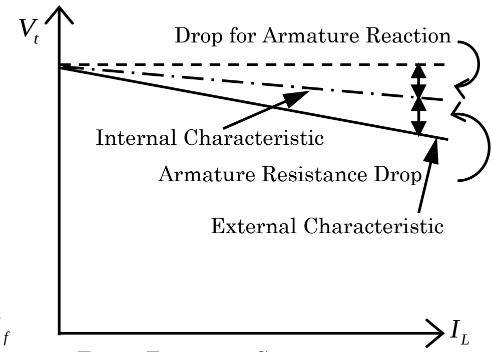
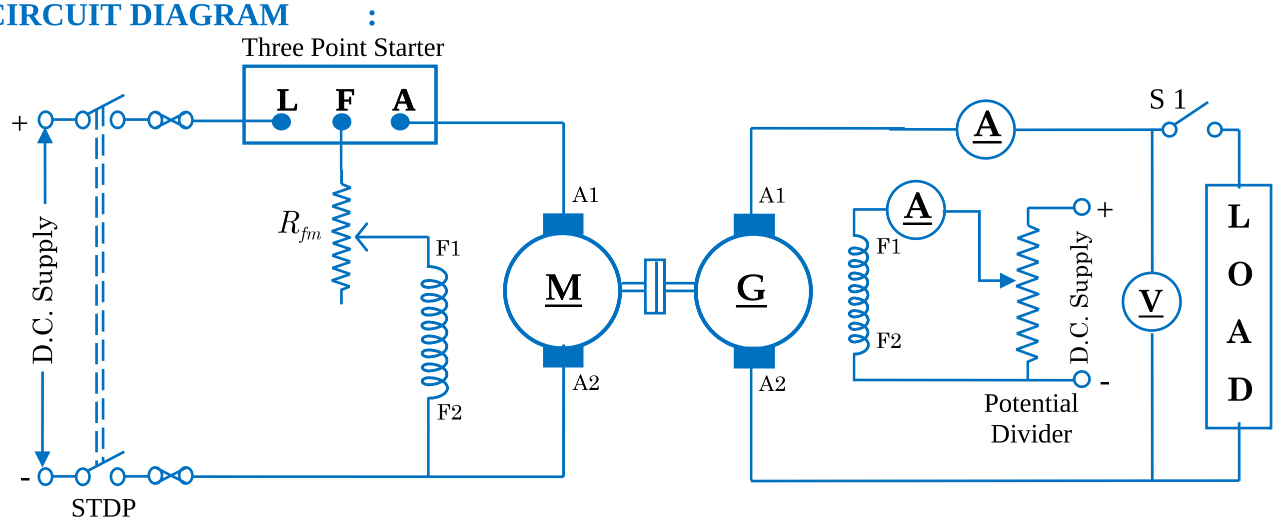


FIG. 3. EXTERNAL CHARACTERISTIC

3. EXTERNAL CHARACTERISTICS

External characteristic gives variation of generator terminal voltage V_t with load current I_L for constant speed and fixed field current. A typical external characteristic which is shown in Fig 3. The decrease in terminal voltage from generated e.m.f. with increase in load is due to voltage drop caused by armature reaction and armature circuit resistance.

CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit as shown in Fig.
2) Keep the switch S1 in OFF position.
3) Set motor field rheostat R_{fm} to its minimum and potential divider to zero output.
4) Switch ON d.c. supply and start the motor with the help of three point starter.
5) Adjust the speed of the d.c. motor at its rated value with help of R_{fm}.
6) Excite the generator field from same d.c. source by changing the setting of the potential divider.
7) Note the generated e.m.f. E_g and field current I_f. Increase the generator field current I_f in steps and note the corresponding voltage. Take the reading up to 120 % of generator rated voltage.
8) Now make the switch S1 ON to connect the load.

9) Excite the generator field by changing the setting of the potential divider in steps.
10) Note down the voltmeter readings V_t and corresponding generator field current I_f.
11) Again make the switch S1 OFF.
12) Now adjust the generator field current I_f by changing the setting of the potential divider to obtain the rated induced e.m.f. on generator.
13) Now make the switch S1 ON and vary the load current I_L in steps. For each step adjust the motor field rheostat R_{fm} to keep the speed constant.
14) Note down the voltmeter readings V_t and corresponding load current I_L.
15) Disconnect the circuit from the supply.
16) Draw the three characteristics of separately excited d.c. generator.

OBSERVATION TABLE :

1. NO-LOAD CHARACTERISTICS :

Sl No	Field Current I_f (amps)	Generated e.m.f. E_g (volts)	Speed N (r.p.m.)
1	0		
2			
3			
:			
:			
:			
8			
9			
10			

2. LOAD CHARACTERISRICS :

Load = A

Sl No	Field Current I_f (amps)	Terminal Voltage V_t (volts)	Speed N (r.p.m.)
1		0	
2			
3			
:			
:			
:			
8			
9			
10			

3. EXTERNAL CHARACTERISTICS :

Sl No	Load	Load Current I_L (amps)	Terminal Voltage V_t (volts)	Speed N (r.p.m.)
1	1 A			
2	2 A			
3	3 A			
4	4 A			
5	5 A			

RESULT : Draw the no-load characteristic, load characteristic and external characteristic of separately excited d.c. generator.

DISCUSSION :

1. What is residual magnetism?
2. What is the effect of variation of speed on no-load characteristic?
3. What is the purpose of plotting the magnetization curve?
4. What are the factors which affect the shape of the magnetization curve?
5. Why load characteristics have similar nature with no-load characteristics?
6. What should be done if generator fails to build up?
7. What are the reasons of fall of terminal voltage?
8. What is the shape of external characteristic of d.c. shunt and series generator?
9. In external characteristics, what are the armature resistance drop and armature reactance drop?

EXPERIMENT NO : ME – 2

TILLE **STUDY THE CHARACTERISTICS OF D.C. SHUNT MOTOR**

OBJECTIVE : To draw the following characteristics of a D.C. shunt motor

I. Speed vs. Armature Current
II. Torque vs. Armature Current
III. Speed vs. Torque

APPARATUS:

Sl No	Apparatus Name	Apparatus Type	Range	Makers Name	Serial No
1	Motor				
2	Ammeter				
3	Voltmeter				
4	Tachometer				

THEORY :

1. SPEED – CURRENT CHARACTERISTIC

When a d.c. shunt motor has attained its final temperature, the exciting current is constant and quite independent of changes in the value of load current in armature. The flux, however, thus not retain its no-load value, owing to the effect of armature reaction. If the effect of armature reaction is neglected, flux φ will remains constant. The motor speed being given by

$$N \propto \frac{V - I_a R_a}{\Phi}\left(= \frac{E_b}{K\Phi}\right)$$

Considering φ remains constant, the speed can be written as $N \propto V - I_a R_a$. The typical speed-current characteristic is shown in Fig. 1. In d.c. shunt motor, flux automatically becomes slightly weaker as load increases, and this may partially or entirely compensate the effete of armature resistance and speed of the motor may remain sensibly constant at all loads or it may even increases slightly when the load increases. Thus speed-current curve will be almost a horizontal line drooping slightly at heavy load. Due this nearly constant speed nature d.c. shunt motor used as constant speed drive.

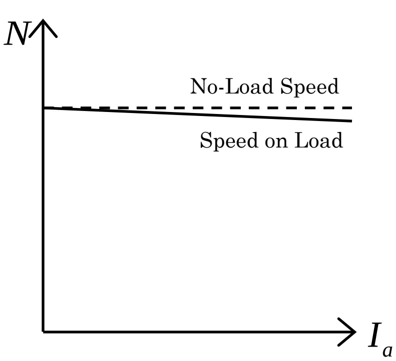


FIG. 1. SPEED – CURRENT CHARACTERISTIC

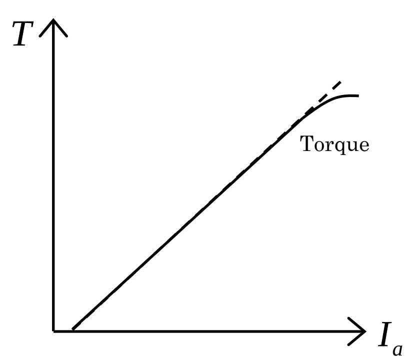


FIG. 2. TORQUE – CURRENT CHARACTERISTIC

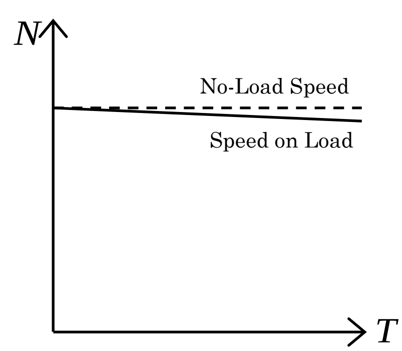


FIG. 3. TORQUE – SPEED CHARACTERISTIC

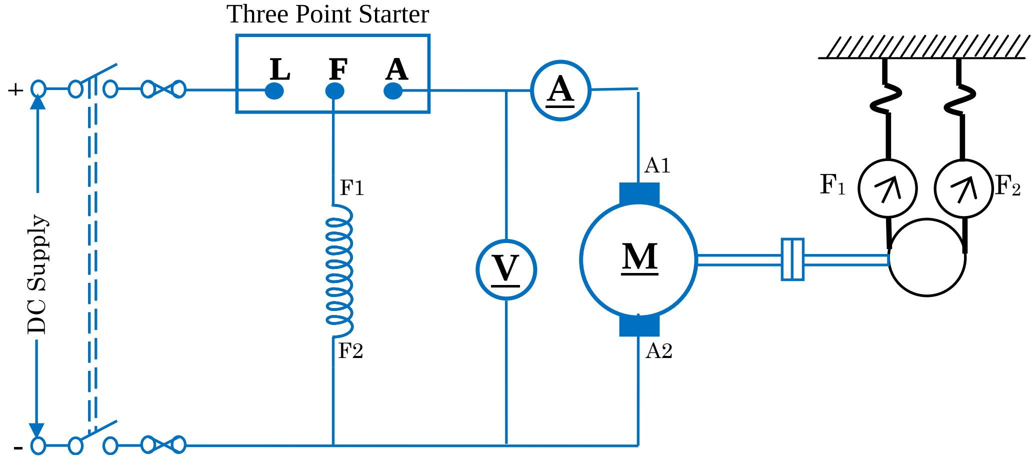
2. TORQUE – CURRENT CHARACTERISTIC

For a d.c. motor torque $T \propto \varphi I_a$. Neglecting the effect of armature reaction, φ is nearly constant in d.c. shunt motor and thus $T \propto I_a$. The torque-current curve would be a straight line passing through origin if flux were constant and friction losses were negligible. The typical torque-current characteristic is shown in Fig. 2.

3. SPEED – TORQUE CHARACTERISTIC

Since the torque is proportional to armature current in a d.c. shunt motor the speed torque characteristic of such a motor will be identical to speed-current characteristic. The speed-torque characteristic of d.c. shunt motor is shown in Fig. 3.

CIRCUIT DIAGRAM :



PROCEDURE .

1) Connect the circuit diagram as shown in Fig.
2) Set the two load F_1 and F_2 at zero value.
3) Switch ON the d.c. power supply and start the motor with help of three point starter.
4) Increase load gradually (mechanical or break load) in steps.
5) Note down the voltage, current, force F_1 and F_2, speed N for every step.
6) Disconnect the motor from power supply.
7) Calculate the efficiency of motor and draw the above mention curves.

OBSERVATION TABLE :

Sl No	Voltage V (volts)	Current I (amps)	Force (Kg)			Speed N (r.p.m.)
			F_1	F_2	$F = F_1 - F_2$	
1						
2						
3						
4						
5						

Diameter of pulley, d = m.

CLCULATION :

Input to the motor $= VI$

Output of the motor $= Torque \times \omega$

Where torque $= F \times \frac{d}{2} \times 9.81$ and $\omega = 2\pi f, f = \frac{N}{60}$

Efficiency $= \frac{\text{Output}}{\text{Input}}$

SL NO	Input Power P_{in} (watts)	Total Force F (Kg)	Angular Speed ω (rad/sec)	Output Torque T (Nw-m)	Output Power P_o (watts)	Efficiency (%)
1						
2						
3						
4						
5						

RESULT : Draw the torque-current, speed-current and speed torque characteristic of d.c. shunt motor.

DISCUSSION :

1. Why does the speed fall slightly when d.c. shunt motor is loaded?
2. With the increased load, how does d.c. shunt motor current adjust itself automatically to meet the new condition?
3. How armature reaction affect the two characteristics of dc shunt motor?
4. What are the application of d.c. shunt motor?
5. How to reverse the direction of rotation of d.c. shunt motor?
6. How three point starter limit the starting current?
7. Explain the nature of efficiency vs. load curve?
8. If the supply voltage is dropped by half, what is the effect on three characteristics?
9. What will happen if the field current of d.c. shunt motor gets interrupted?
10. What will happen if suddenly load is removed from the motor?

EXPERIMENT NO : ME – 4

TITLE **MEASUREMENT OF SPEED OF A D.C. SERIES MOTOR AS A FUNCTION OF LOAD TORQUE**

OBJECTIVE : To draw the following characteristics of series motor

i. Speed vs. current.
ii. Torque vs. current.
iii. Speed vs. torque.

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Range	Makers Name	Serial No
1	D.C. Series Motor				
2	Ammeter				
3	Voltmeter				
4	Tachometer				

THEORY :

1. **SPEED – CURRENT CHARACTERISTIC :**

In d.c. series motor, exciting coil current increases in direct proportion to the load current or armature current I_a, so neglecting armature reaction effects, value of the field flux will vary with load current. The motor speed *N* for a series motor is given by

$$N \propto \frac{V - I_a(R_a + R_{se})}{\varphi}\left(= \frac{E_b}{K\varphi}\right)$$

At the low value of I_a the voltage drop $[I_a(R_a + R_{se})]$ is negligibly small in comparison with V.

$$\therefore N \propto \frac{V}{\varphi}$$

Since applied voltage V is constant, speed *N* is inversely proportional with field flux *φ*. In series motor the field flux φ is produced by the armature current, thus $\varphi \propto I_a$. Hence the series motor is variable flux machine. So, $N \propto 1/I_a$. Thus, for series motor, the speed is inversely proportional to the armature (load) current. The typical speed-current characteristic is shown in fig. 1. Neglecting the slight effect due to armature resistance, initial portion of speed-current curve will be rectangular hyperbola as initial portion of magnetization curve is a straight line. The final portion of the graph will merge into a straight line and speed is zero when value of the current is the normal short circuit current of the motor *i.e.* equal to applied voltage divided by motor resistance. Normally this current is very many times full-load current.

2. **TORQUE – CURRENT CHARACTERISTIC :**

For a d.c. motor torque $T \propto \varphi I_a$. Neglecting saturation effect, in d.c. series motor, $\varphi \propto I_a$ and hence at rated load $T \propto I_a^2$. The typical torque-current characteristic is shown in fig. 2. The initial potion of total torque in d.c. series motor will be parabolic in nature, until magnetization curve ceases to be straight line, but ultimately will merge into a straight line when magnetic circuit (iron core) is virtually saturated. The useful torque is, of course, less than the total torque due to mechanical losses.

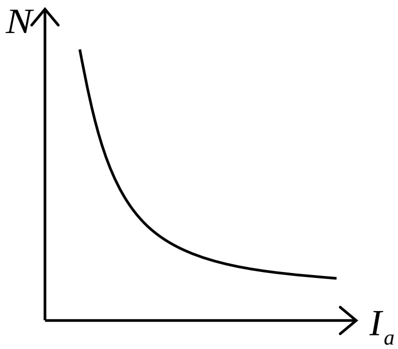


FIG. 1. SPEED – CURRENT CHARACTERISTIC

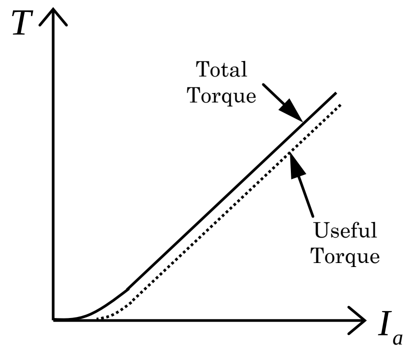


FIG. 2. TORQUE – CURRENT CHARACTERISTIC

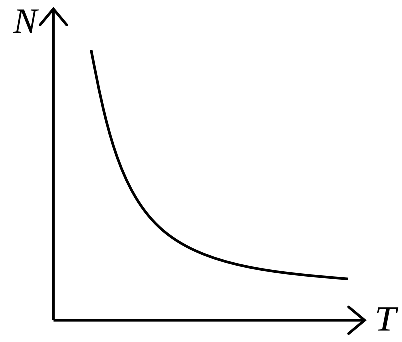


FIG. 3. TORQUE – SPEED CHARACTERISTIC

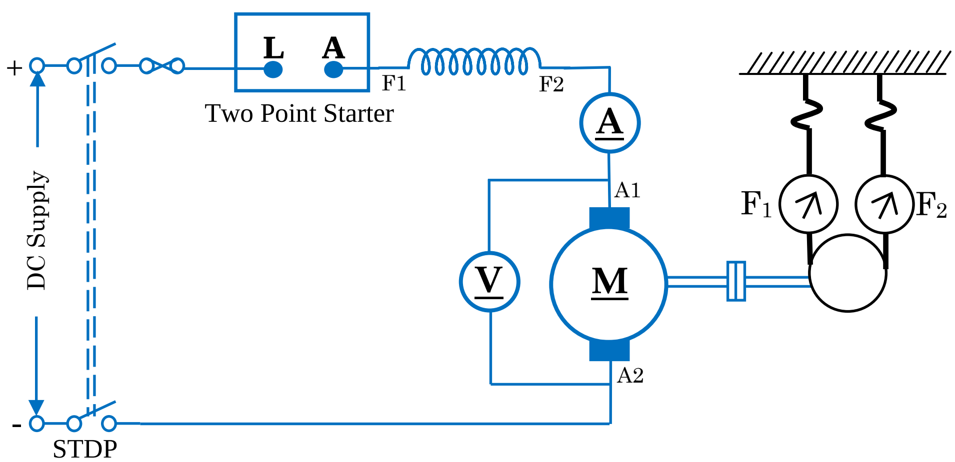
3. SPEED – TORQUE CHARACTERISTIC :

For a d.c. series motor, speed N is given by

$$N \propto \frac{V - [I_a(R_a + R_{se})]}{\varphi}$$

The torque is $T \propto I_a^2$ and field flux $\varphi \propto I_a$. So $N \propto \frac{V}{\sqrt{T}}$. Thus speed-torque characteristic of d.c. motor is a rectangular hyperbola as shown in Fig. 3.

CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit diagram as shown in Fig.
2) Set the two load F_1 and F_2 at some value so that initial speed of the motor is within limit.
3) Switch ON the d.c. power supply and start the motor with help of two point starter.
4) Increase load gradually (mechanical or break load) in steps.
5) Note down the voltage, current, force F_1 and F_2, speed N for every step.
6) Disconnect the motor from power supply.
7) Calculate the efficiency of motor and draw the above mention curves.

OBSERVATION TABLE :

Sl No	Voltage V (volts)	Current I (amps)	Force (Kg)			Speed N (r.p.m.)
			F_1	F_2	$F = F_1 - F_2$	
1						
2						
3						
4						
5						

Diameter of pulley, d = m.

CLCULATION :

Input to the motor $= VI$

Output of the motor $= Torque \times \omega$

Where torque $= F \times \frac{d}{2} \times 9.81$ and $\omega = 2\pi f, f = \frac{N}{60}$

Efficiency = Output/Input

SL NO	Input Power P_{in} (watts)	Total Force F (Kg)	Angular Speed ω (rad/sec)	Output Torque T (Nw-m)	Output Power P_o (watts)	Efficiency (%)
1						
2						
3						
4						
5						

RESULT

: Draw the torque-current, speed-current and speed torque characteristic of d.c. series motor.

DISCUSSION :

1. How armature reaction affect the two characteristics of d.c. series motor?
2. Why should the d.c. series motor not be operated at no load and light load?
3. What are the advantage of d.c. series motor?
4. What are the application of d.c. series motor?
5. How can the speed of d.c. series motor be increased?
6. How can the speed of d.c. series motor be increased?
7. How to reverse the direction of rotation of d.c. series motor?
8. If the supply voltage is dropped by half, what is the effect on three characteristics?
9. What happen if suddenly load is removed from the motor?
10. Explain the nature of efficiency vs. load curve?
11. What is the effect of saturation on speed and torque?

EXPERIMENT NO : ME – 6

TITLE **DETERMINATION OF REGULATION OF AN ALTERNATOR BY SYNCHRONOUS IMPEDANCE METHOD**

OBJECTIVE : To determine the voltage regulation of a three phase alternator by synchronous impedance method

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Specification / Range	Makers Name	Serial No
1	Motor				
2	Alternator				
3	Voltmeter				
4	Ammeter 1				
5	Ammeter 2				
6	Rheostat				

THEORY : The synchronous impedance of a given three phase alternator can be determined from the following two experiments.

1. **OPEN CIRCUIT TEST :**

In this test, the alternator is run with the prime mover i.e. d.c. motor. The output terminals of the alternator are kept open i.e. alternator run on no-load. The induce emf per phase corresponding to various values of field current is measured. The curve is drawn between the induced emf per phase and the field current as shown in Fig (Curve I). This curve is known as open circuit characteristics (O.C.C.).

2. **SHORT CIRCUIT TEST :**

In this test, the output terminals of the alternator are short circuited through low resistance ammeter. The short circuit current is measured corresponding to various values of field current while speed is kept constant with the help of field rheostat. The curve is drawn between short circuit current and field current as shown in Fig. (Curve II). This curve is known as short circuit current (S.C.C.).

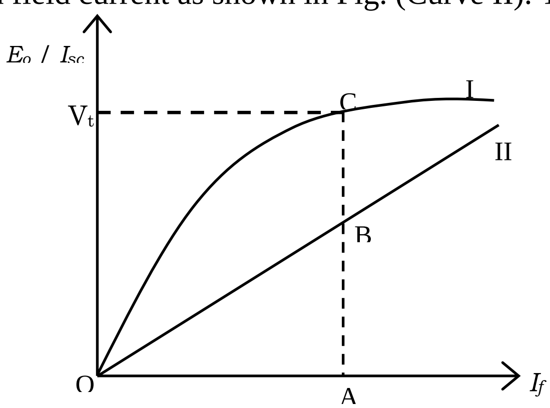


FIG. 1. O.C.C. AND S.C.C. CHARACTERISTIC OF ALTERNATOR

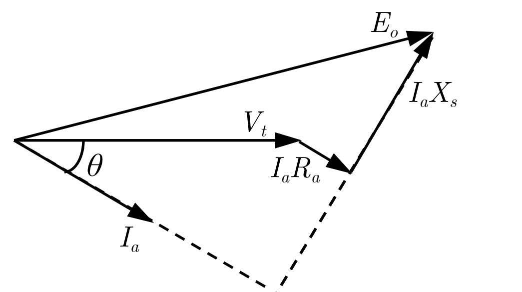


FIG. 2. PHASOR DIAGRAM OF ALTERNATOR AT LAGGING LOAD

Let OA represent the field current corresponding to rated terminal voltage. Then AB represents the rated short circuited current and AC represents the induced e.m.f. per phase. Under the short circuit condition whole of the e.m.f. AC is used to create the short circuit current AB. Now, we can write

$$\text{Synchronous impedance, } Z_s = \frac{AC(in \quad volts)}{AB(in \quad amperes)}$$

The value of armature resistance per phase R_a can be determined by an accurate ohmmeter. Effective value of armature resistance can be determined by increasing the measured value by 20 % to account for the skin effect and effect of temperature rise. Then, synchronous reactance X_s can be calculated as $X_s = \sqrt{Z_s^2 - R_a^2}$. The regulation of a synchronous generator is the rise of terminal voltage of an isolated machine when full load at given power factor is removed from the machine considering the field excitation and speed remaining constant. If I_a be rated current, from phasor diagram of alternator at lagging load (Fig 2.) induced e.m.f. per phase $E_o = \sqrt{(V\cos\varphi + I_a R_a)^2 + (V\sin\varphi + I_a X_s)^2}$. If V_t be normal rated terminal voltage and the terminal voltage rises to E_o when full load is thrown off, then $percentage\ regulation = \frac{E_o - V}{V} \times 100\%$. For lagging power factor value of sinφ should be taken as positive and for leading power factor value of sinφ taken as negative.

CIRCUIT DIAGRAM :

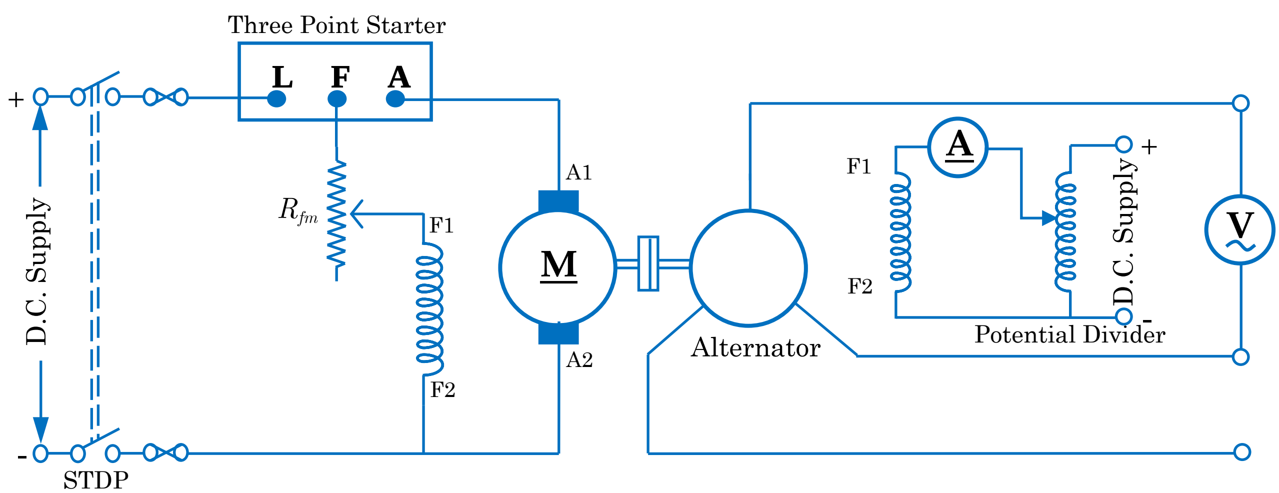


FIG 1 : EXPERIMENTAL SET-UP FOR PERFORMING OPEN CIRCUIT TEST

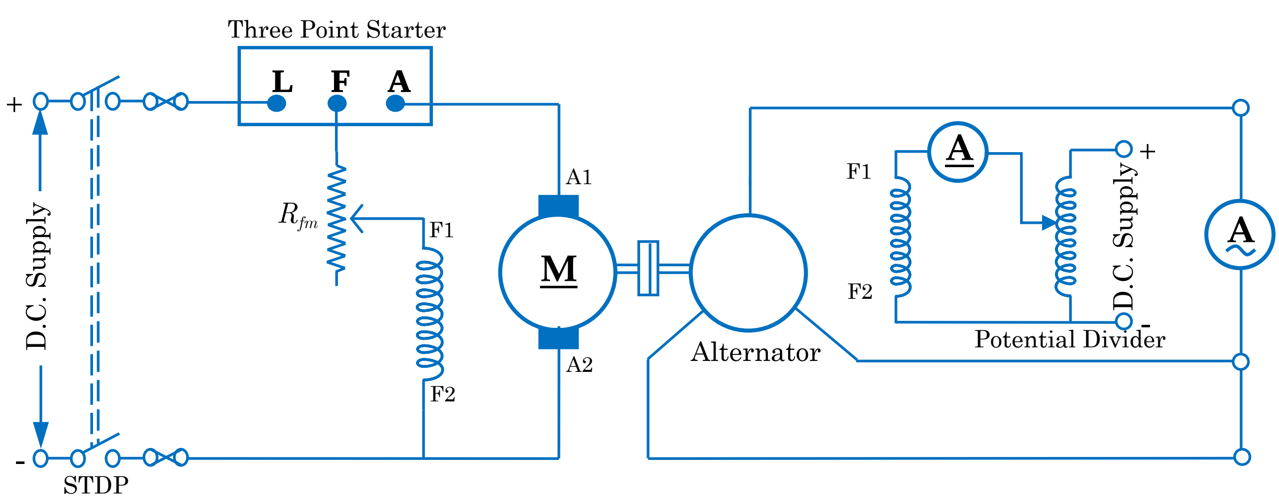


FIG 2 : EXPERIMENTAL SET-UP FOR PERFORMING SHORT CIRCUIT TEST

PROCEDURE :

1) Connect the circuit as shown in Fig. 1.
2) Set motor field rheostat R_{fm} to its minimum and potential divider to zero output.
3) Switch ON the d.c. power supply and start the motor with the help of three point starter.
4) Adjust the speed of motor equal to the synchronous speed of alternator with the help of field rheostat. Maintain this synchronous speed throughout the experiment.
5) Increase alternator field current by varying the field voltage gradually. Note down the voltmeter reading connected across the alternator terminals for various values of alternator field current. Go up to 10 % above the rated voltage of alternator.
6) Switch OFF the d.c. supply.
7) Short the alternator output through ammeter as shown in Fig. 2 and repeat steps 3 & 4 above.
8) Increase alternator field current by varying field voltage gradually. Note ammeter readings connected across the alternator terminals for various values of alternator field current.
9) Switch OFF the d.c. supply and disconnect all connection.
10) Measure per phase armature resistance and field resistance with the help of multi-meter.
11) Plot the O.C.C. and S.C.C. curves.
12) Calculated the value of synchronous reactance and regulation of alternator.

OBSERVATION TABLE :

SL NO	Open-circuit Test		Short-circuit Test	
	Field Current I_f (amps)	Terminal Voltage V_t (volts)	Field Current I_f (amps)	Short-circuit Current I_{sc} (amps)
1				
2				
3				
4				
5				

Armature resistance per phase = Ω
Effective value of armature resistance = Ω

RESULT :

Synchronous Impedance per phase = Ω
Voltage regulation at 0.8 power factor lagging = %
Voltage regulation at 0.8 power factor leading = %
Voltage regulation at zero power factor = %

DISCUSSION :

1. What are the advantages of this method over direct loading method?
2. Why is the open circuit characteristic non-linear?
3. Why is the short circuit characteristic linear?
4. What are the different components of synchronous impedance?
5. What happen if the speed of d.c. motor is not constant throughout the experiment?
6. Why regulation is positive for lagging load and negative for leading load?
7. What are the other methods for regulation calculation?

EXPERIMENT NO : ME – 7

TITLE DETERMINATION OF EQUIVALENT CIRCUIT PARAMETER OF A SINGLE PHASE INDUCTION MOTOR

OBJECTIVE : Determine the equivalent circuit of a single phase induction motor by No load test and blocked-rotor test.

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Specification / Range	Makers Name	Serial No
1	Induction Motor				
2	Ammeter				
3	Voltmeter				
4	Wattmeter				
5	Variac				
6	Tachometer				

THEORY :

The equivalent circuit of single phase induction motor is determined by the no-load test and block rotor test. The equivalent circuit of single phase induction motor is shown in Fig. 1.

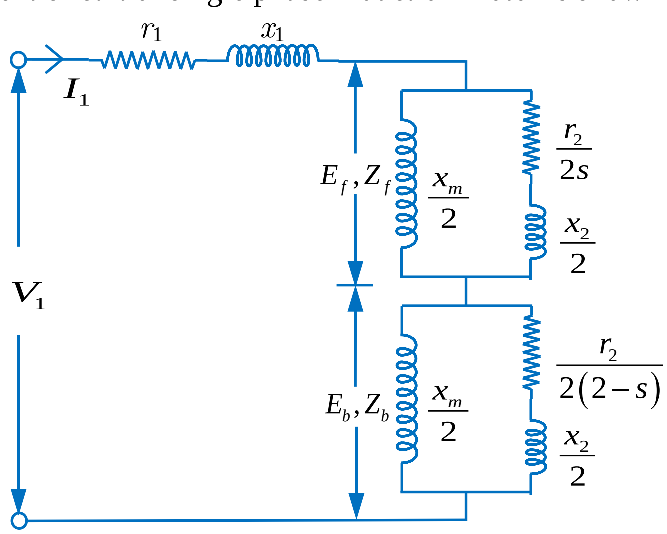


FIG 1 : EQUIVALENT CIRCUIT OF SINGLE PHASE IM

1. **BLOCKED-ROTOR TEST :**

With the rotor at rest, single-phase voltage, applied to stator main winding, is increased gradually from zero so that rated current flow in main winding. Under these condition i.e. with rotor stationary, the slip $s = 1$ and the voltage required to circulate full-load current is very low. Therefore, flux is small and the magnetizing current flowing to X_m is also very low. In view of this, magnetizing reactance can be neglected and that gives the equivalent circuit as shown in Fig. 2.

Let consider V_{sc} = Applied short circuit voltage on stator side.

I_{sc} = Short circuit current.

W_{sc} = Total ohmic loss.

Then the total equivalent resistance $R_{sc} = r_1 + 2\left(\frac{r_2}{2}\right) = \frac{W_{sc}}{I_{sc}^2}$

Since resistance of main winding r_1 is already measured, effective rotor resistance $r_2 = R_{sc} - r_1$

The total equivalent per phase impedance $Z_{sc} = \frac{V_{sc}}{I_{sc}}$

Therefore total equivalent per phase reactance $X_{sc} = x_1 + 2\left(\frac{x_2}{2}\right) = \sqrt{Z_{sc}^2 - R_{sc}^2}$

Since the leakage reactance x_1 and x_2 can't be separated out, it is assumed that $x_1 = x_2 = \frac{1}{2}X_{sc}$

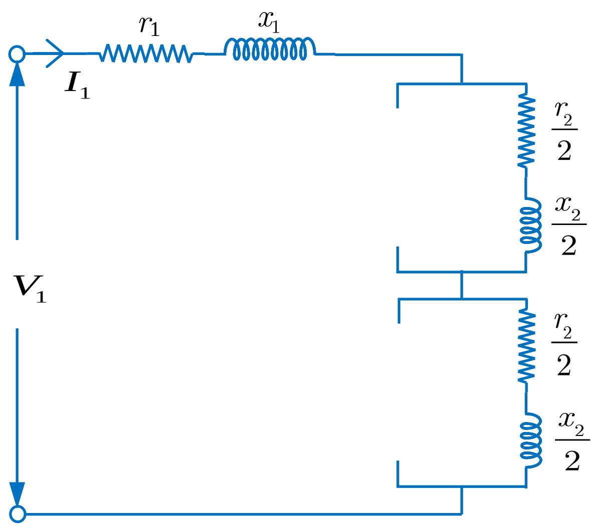


FIG 2 : EQUIVALENT CIRCUIT FOR BLOCK ROTOR TEST

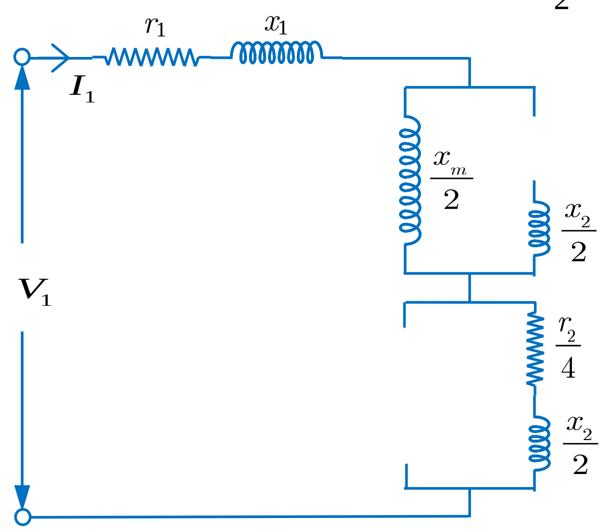


FIG 3 : EQUIVALENT CIRCUIT FOR NO LOAD TEST

2. NO-LOAD TEST :

This test is similar to open circuit test on a transformer. The motor is runs at no load. The power input is measured by wattmeter. With the motor running at no load, the slip is very close to zero. It may be therefore be assumed that $s \cong 0$. Under these conditions $\frac{r_2}{2s}$ become infinity and $\frac{r_2}{2(2-s)} = \frac{r_2}{4}$ in series with $\frac{x_2}{2}$ become several times smaller than $\frac{x_m}{2}$. Incorporating these approximation gives the equivalent circuit as shown in Fig 3.

Let consider V_o = No-load applied voltage.

I_o = Exciting current or No-load current

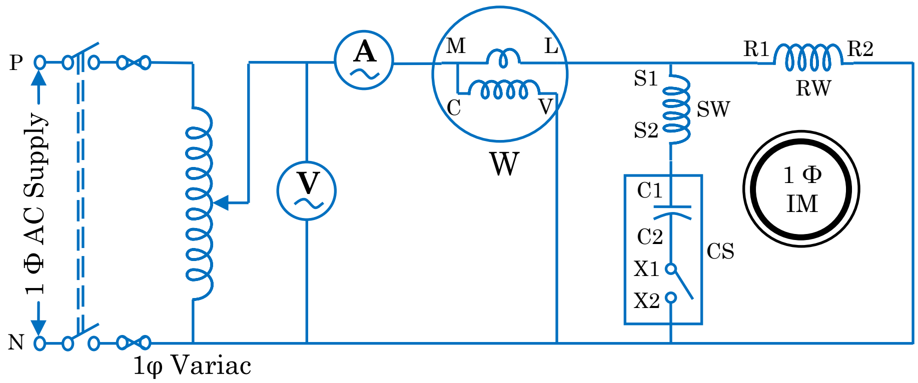
W_o = Core loss and Mechanical loss.

Therefore no load power factor $\cos\varphi_o = \frac{W_o}{V_o I_o}$

So, the impedance is $Z_o = \frac{V_o}{I_o}$ and the reactance is $X_o = Z_o \sin\varphi_o$

From the circuit shown in above, we can write that $R_o = r_1 + \frac{r_2}{4}$ and $X_o = x_1 + \frac{1}{2}(x_2 + X_m)$

CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit as shown in Fig.
2) Set the variac at zero output voltage and switch ON the power supply.
3) Block the rotor with the help of clamp as such a way that it cannot rotate. Rotor can be blocked by disconnecting auxiliary or starting winding (SW) from main or running winding (RW).
4) Adjust the applied voltage at a very low voltage with the help of single phase variac such that ammeter indicates the full load current.
5) Note down the ammeter, voltmeter and wattmeter reading.
6) Disconnect the power supply.
7) Calculate R_{sc} and X_{sc} from these readings.
8) Measure d.c. main winding resistance by multimeter and calculate equivalent a.c. resistance r_1 by multiplying 1.2 with d.c. resistance value on account to incorporate skin effect
9) Calculate rotor resistance r_2.
10) Connect the circuit as shown in Fig.
11) Set the variac at zero output voltage and switch ON the supply.
12) Adjust the applied voltage at rated voltage with the help of single-phase variac.
13) Note down the voltmeter, ammeter and wattmeter reading.
14) Switch OFF the power supply.
15) Calculate the R_o and X_o from these readings. Calculate the X_m.
16) Draw the equivalent circuit of single-phase induction motor.

OBSERVATION TABLE :

No-load Test			Blocked-rotor Test		
Voltage V_o (volts)	Current I_o (amps)	Power Input W_o (watts)	Voltage V_{sc} (volts)	Current I_{sc} (amps)	Power Input W_{sc} (watts)

Main winding resistance = Ω

Auxiliary winding resistance = Ω

CALCULATION :

The total series impedance $Z = Z_1 + Z_f + Z_b$

So, the input current $I_m = \frac{V}{Z}$

Now, the core, friction and windage loss $P_r = W_o - I_o^2 R_o$

Therefore, output power $P_{out} = P_{mech} - P_r = \left[I_m^2 \left(R_f - R_b \right)(1-s) \right] - P_r$

And, input power $P_{in} = VI_m \cos\varphi$

So, efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

RESULT :

Stator resistance	=	Ω
Rotor resistance	=	Ω
Magnetizing reactance	=	Ω
Leakage reactance	=	Ω
Efficiency of induction motor	=	%

Draw the equivalent circuit of single phase induction motor.

DISCUSSION :

1. Why single phase induction motor is not a self-starting motor?
2. Why rotor will blocked when auxiliary or starting winding is disconnecting from main winding?
3. What is the function of clutch switch (CS)?
4. Among the starting winding and running winding, which one has high resistance and why?

EXPERIMENT NO : ME – 8

TITLE **LOAD TEST ON SINGLE PHASE INDUCTION MOTOR TO OBTAIN THE PERFORMANCE CHARACTERISTICS**

OBJECTIVE : To determine the torque, output power, efficiency, input power factor and slip of single-phase Induction motor for various load and plot the following curve.

i. Efficiency vs. output power.
ii. Torque vs. output power.
iii. Line current vs. output power.
iv. Power factor vs. output power.
v. Slip vs. output power
vi. Torque vs. slip.

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Specification / Range	Makers Name	Serial No
1	Induction Motor				
2	Ammeter				
3	Voltmeter				
4	Wattmeter				
4	Variac				
7	Tachometer				

THEORY : The load test on induction motor helps us to compute the complete performance of induction motor means to calculate the various quantities i.e. torque, slip, efficiency, power factor etc at different loading. In this test supply voltage is applied to motor and variable mechanical load is applied to the shaft of motor. Mechanical load can be provided by brake and pulley arrangement. The input current, input voltage, input power and speed of motor are observed from the experiment and various performance quantities are calculated as explain below.

SLIP

Due to the three-phase supply given to stator of an induction motor, a rotating magnetic field of constant magnitude is set up in the stator of the motor. The speed with which this rotating magnetic field rotates is known as synchronous speed and is given by

$$N_s = \frac{120f}{P}$$

Where f =supply frequency.
P =no of poles on the stator of the rotor.

The actual speed of the rotor N_r is always less than the synchronous speed. So the slip of the motor is given by

$$s = \frac{N_s - N_r}{N_s} \times 100\%$$

This value of slip at full load lies between 2 to 5%.

TORQUE

Mechanical loading is applied on induction motor by means of brake and pulley arrangement. The belt can be tightened or loosened by means of threaded rods with handles fixed on frame. Two spring balances are provided at the end of belt. The net force exerted at the brake drum can be obtained from the readings of the two spring balance i.e. F_1 and F_2

Net force exerted on drum, $F = (F_1 - F_2)$ Kg

And Torque $T = F \times \frac{d}{2} \times 9.81$ Nw-m

Where d = effective diameter of brake drum in meter.

OUTPUT POWER

The output power of induction motor can be calculated as $P_o = \frac{2\pi N_r T}{60}$

Where N_r = speed of induction motor in r.p.m.

INPUT POWER

The input power can be calculated from the readings of wattmeter connected in the circuit

$$P_{in} = W$$

POWER FACTOR

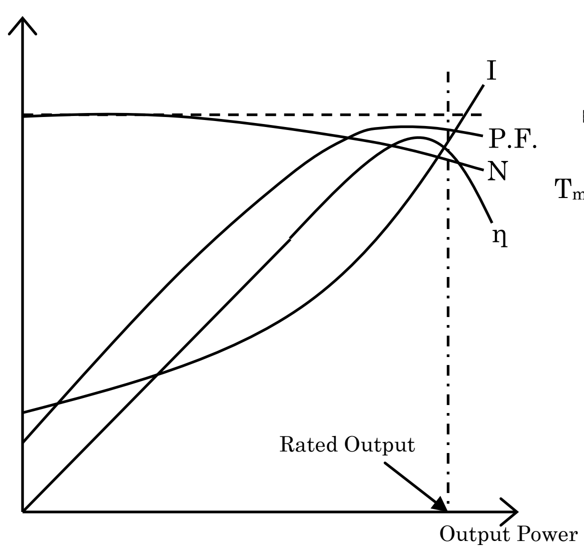
The power factor can be calculated from the following relation

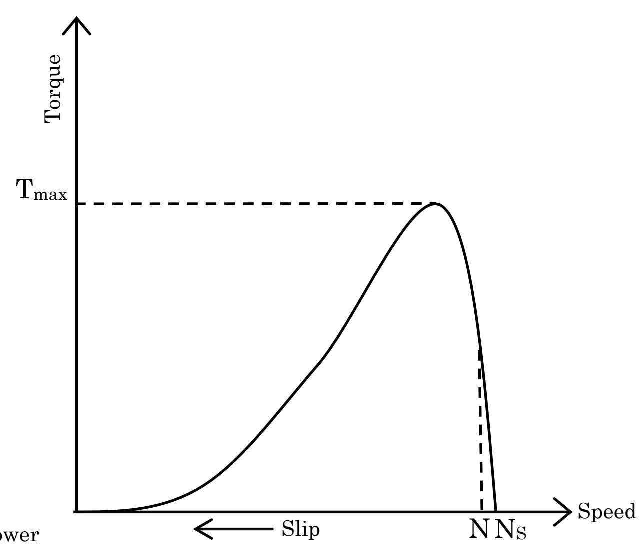
$$\cos\ \varphi = \frac{P_{in}}{VI}$$

EFFICIENCY

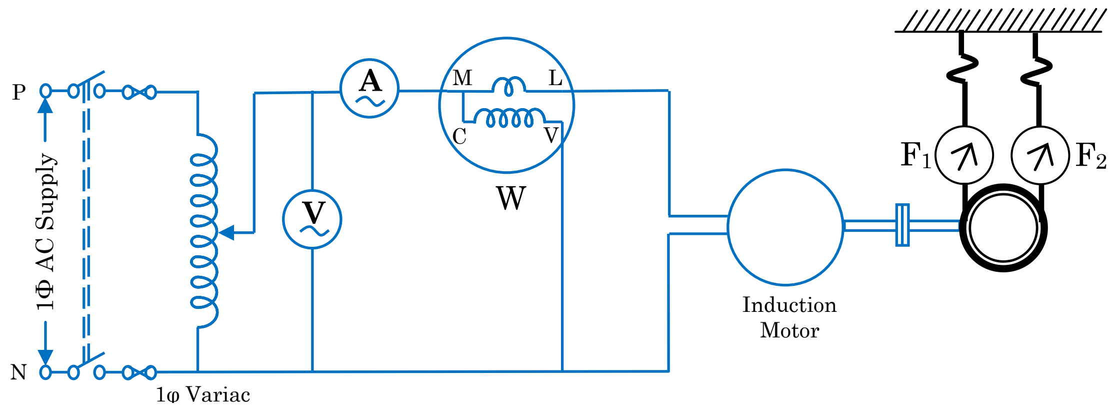
The efficiency of induction motor can be calculated using the relation

$$\eta = \frac{\text{output power}}{\text{input power}} \times 100\%$$





CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit as shown in Fig.
2) Set the single-phase variac at minimum voltage and brake pulley arrangement at no load.
3) Switch ON the power supply and start the induction motor.
4) Now gradually increase the applied voltage by varying the variac very slowly up to the rated voltage.
5) Increase the mechanical load on motor in steps and note down the various reading for each load.
6) Switch OFF the supply and disconnect the motor.
7) Calculate the various quantities and plot the various curves.

OBSERVATION TABLE :

SL NO	Input Voltage V (volts)	Input Current I (amps)	Input Power W (watts)	Force (Kg)			Speed N_r (r.p.m.)
				F_1	F_2	$F = F_1 - F_2$	
1							
2							
3							
4							
5							

Diameter of pulley, d = m.

CALCULATION :

SL NO	Input Power P_{in} (watts)	Total Force F (Kg)	Output Torque T (Nw-m)	Output Power P_o (watts)	Slip (%)	Power Factor	Efficiency (%)
1							
2							
3							
4							
5							

RESULT **:** Draw the following curve of single-phase slip ring induction motor

i. Efficiency vs. output power.
ii. Torque vs. output power.
iii. Line current vs. output power.
iv. Power factor vs. output power.
v. Slip vs. output power
vi. Torque vs. slip.

DISCUSSION **:**

1. Why at the time of starting of single phase induction motor ammeter reading fast increase rapidly and then reduce to zero and again increase slowly with the increase of load?
2. Why single phase induction motor has no starting torque?
3. How single phase induction motor is become a self starting motor?
4. Why single phase induction motor cannot run at synchronous speed?
5. Why no-load power factor of single phase induction motor is very low?
6. Why efficiency of single phase induction motor falls near the rated output?
7. What are the applications of single phase induction motor?
8. How starting torque of single phase induction motor can be increased?
9. Do you reverse the direction of rotation of single phase induction motor?

EXPERIMENT NO : ME – 9

TITLE STUDY OF EQUIVALENT CIRCUIT OF THREE-PHASE INDUCTION MOTOR BY NO-LOAD TEST AND BLOCKED-ROTOR TEST

OBJECTIVE : To determine the parameter of equivalent circuit of three phase induction motor.

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Range	Makers Name	Serial No
1	Induction Motor				
2	Voltmeter				
3	Ammeter				
4	Wattmeter 1				
5	Wattmeter 2				
6	Variac				

THEORY :

1. **NO-LOAD TEST :**

This test is similar to open circuit test on a transformer. A three-phase auto-transformer is used to supply rated voltage at the rated frequency. The motor is runs at no load. The power input is measured by two wattmeter method. The power factor under no-load condition is generally less than 0.5. Therefore one of the wattmeter will show negative reading. It is therefore necessary to reverse the direction of current coil terminal to take the reading.

Let consider V_o = Applied per phase voltage on stator side

I_o = Exciting per phase current or No-load current

W_o = Core loss and Mechanical loss.

Therefore no load power factor $\cos\varphi_o = \dfrac{W_o}{\sqrt{3}V_o I_o}$

And per phase impedance $Z_o = \dfrac{V_o}{\sqrt{3}I_o}$

And per phase resistance $R_o = \dfrac{W_o}{3I_0^2}$

Therefore the per phase reactance $X_o = \sqrt{Z_0^2 - R_0^2}$

2. **BLOCK ROTOR TEST :**

In this test motion of the rotor is blocked by a brake or belt. This test is analogous to the short-circuit test of a transformer because the rotor winding is short-circuited. Only a reduced voltage needs to be applied to the stator at rated frequency. This voltage should be such that the ammeter reads rated current of motor. The total power input W_{sc} is equal to the algebraic sum of the two wattmeter reading i.e equal to copper loss of stator and rotor.

Let consider V_{sc} = Applied per phase SC voltage on stator side.

I_{sc} = Short circuit per phase current.

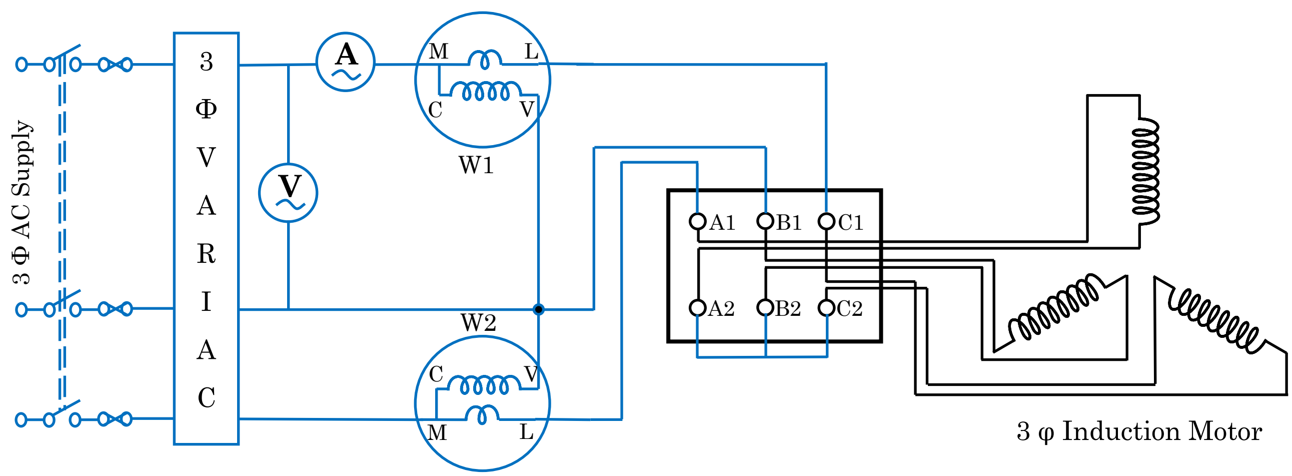
W_{sc} = Total ohmic loss.

Then the total equivalent per phase resistance $R_{eq} = \frac{W_{sc}}{3I_{sc}^2}$

The total equivalent per phase impedance $Z_{eq} = \frac{V_{sc}}{\sqrt{3}I_{sc}}$

Therefore total equivalent per phase reactance $X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$

CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit as shown in Fig.
2) Set the three phase variac to zero and switch ON the power supply.
3) Apply the voltage gradually in stator with the help of three-phase variac and start the motor.
4) Apply a voltage little bit higher than the rated voltage and run at its rated speed.
5) Watch the wattmeter reading. Due to low power factor one of wattmeter indicates negative reading. In case of that, set the three phase variac to zero, disconnect the power supply, reverse the current coil direction, apply the voltage again and then take the voltmeter, ammeter and wattmeter reading. Which wattmeter indicates negative reading put negative sign in that case.
6) Disconnect the power supply and set the three phase variac to zero.
7) Calculate R_o and X_o from the observed reading.
8) Block the rotor with the help of clamp as such a way that it cannot rotate.
9) Select low range for voltmeter and again reverse the current coil direction which wattmeter indicates negative reading.
10) Apply very low voltage by gradually increase the setting of three-phase variac and watch the ammeter. Increase the voltage until the ammeter reads rated full load current. Note that current should not exceed the rated value.
11) Note down the voltmeter, ammeter and wattmeter reading.
12) Disconnect the circuit from the supplies and set the three phase variac to zero..
13) Calculate R_{eq} and X_{eq} from the observed reading.

14) Measure stator resistance by multimeter. Calculate equivalent a.c. resistance r_1 by multiplying 1.2 with d.c. resistance value on account to incorporate skin effect
15) Calculate rotor resistance r_2 and rotor self-reactance X_2.
16) Draw the equivalent circuit of three phase induction motor

OBSERVATION TABLE :

No Load Test					Blocked Rotor Test				
Voltage V_o (volts)	Current I_o (amps)	Wattmeter Reading			Voltage V_{SC} (volts)	Current I_{SC} (amps)	Wattmeter Reading		
		W_1 (watts)	W_2 (watts)	$W = W_1 + W_2$ (watts)			W_1 (watts)	W_2 (watts)	$W = W_1 + W_2$ (watt)

Stator resistance per phase, $r_1 =$ Ω

CALCULATION : Let

x_1 = Per phase leakage reactance of stator winding.

x_2 = Per phase leakage reactance of rotor winding.

r_1 = Per phase stator resistance.

Per phase leakage reactance, $x_1 = x_2 = \frac{1}{2} X_{eq}$

Therefore per phase magnetizing reactance $X_m = X_o - x_1$

And per phase rotor self-reactance $X_2 = X_m + x_2$

Per phase rotor resistance $r_2 = (R_{eq} - r_1) \times \left(\frac{X_2}{X_m} \right)^2$

RESULT :

Stator resistance	=	Ω
Rotor resistance	=	Ω
Magnetic leakage reactance	=	Ω
Stator and rotor leakage reactance	=	Ω

Draw the equivalent circuit of three phase Induction Motor.

DISCUSSION:

1. How the mechanical load is incorporate in equivalent circuit?
2. What is the difference between the no-load test on an induction motor and open circuit test on transformer?
3. In no-load test why wattmeter indicates negative reading?
4. How you will get the positive wattmeter reading?
5. In no-load test wattmeter reads which losses?
6. If the blocked rotor test is to be performed on wound rotor motor and if rotor winding is kept open, will you be able to perform the test?
7. How direction of rotation of three phase induction motor can be reversed?

EXPERIMENT NO : ME – 10

TITLE :**STUDY OF THE PERFORMANCE OF THREE PHASE SQUIRREL-CAGE INDUCTION MOTOR - DETERMINATION OF IRON-LOSS, FRICTION & WINDAGE LOSSES**

OBJECTIVE : To determine the effect of varying applied voltage on speed, power factor, input power and current etc. and determine the Iron-Loss, Friction & Windage Losses of three-phase squirrel-cage induction motor.

APPRATUS :

Sl No	Apparatus Name	Apparatus Type	Range	Makers Name	Serial No
1	Induction Motor				
2	Voltmeter				
3	Ammeter				
4	Wattmeter 1				
5	Wattmeter 2				
6	Variac				

THEORY : This test is basically open circuit test or no load test which gives the core loss, friction and windage loss, magnetizing current and no-load power factor. The stator connections are made to a supply of normal frequency and variable voltage and instruments are included to measure the voltage, input power and current. After having been started, the motor is run with its rotor in normal condition i.e. short-circuited but decoupled from load. The slip is very small and cannot be accurately found from the difference between running and synchronous speed. At normal voltage, no-load current is one-quarter to one-third of normal full load current. The power factor is very low since two components of no-load current magnetizing current and core-loss current differ considerably in magnitude.

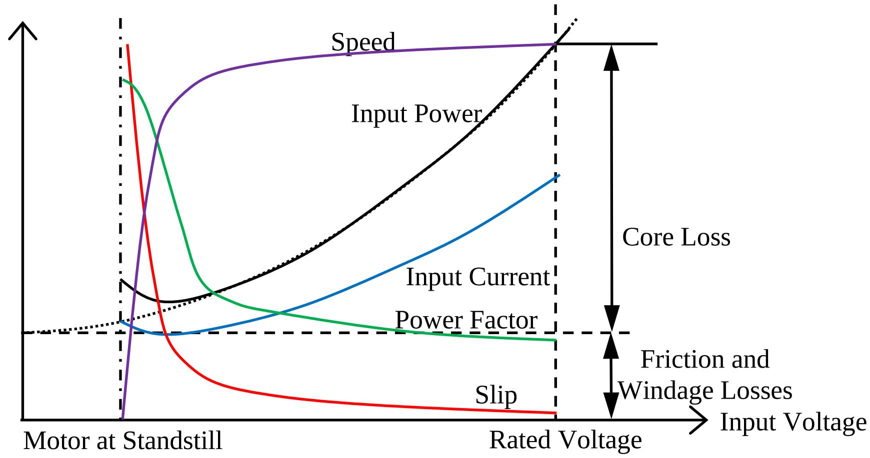


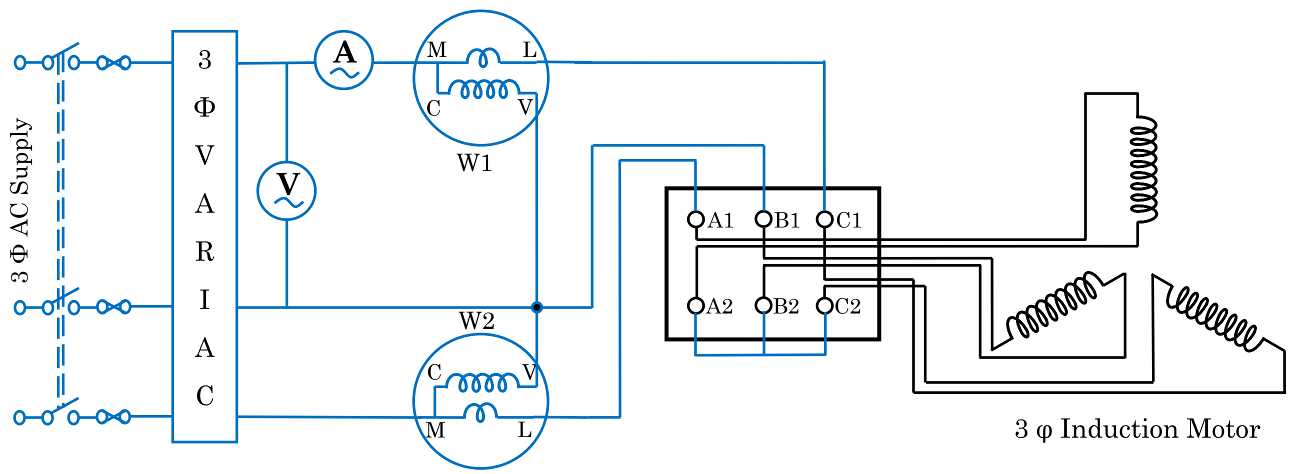
FIG. 1. TYPICAL CURVES DRAWN FROM NO-LOAD TEST DATA

As the voltage is reduced, power and current fall because the main flux (which is roughly proportional to applied voltage at fast) reduces simultaneously. The power curve is nearly parabolic near normal rated voltage since core losses are proportional to square of flux density and therefore of voltage. The power factor rises since magnetizing current falls faster than core-loss current.

When voltage has been reduced to, say 20% of normal rated voltage, the magnetizing current is small and so is the core loss. The speed has fallen only by a few percent, however, friction and windage loss is still maintained. Which in turn draw considerable active current to counterbalance the corresponding. The power factor thus rises and slip must be greater to permit the rotor e.m.f. to increase and circulate a large torque current. The power is now almost entirely for the mechanical losses and if the curve be extrapolated to zero voltage, the intercept represents the mechanical losses i.e. friction and windage loss.

If the voltage is reduced still further, the torque is maintained only by increases in slip and current. Eventually conditions become unstable and motor stops. The power curve actually includes a small copper loss but if no-load current at normal voltage is about one-third of full load current, copper loss due to it will be only one-ninth of normal and may generally be neglected.

CIRCUIT DIAGRAM :



PROCEDURE :

1) Connect the circuit as shown.
2) Set the three phase variac to zero and switch ON the power supply.
3) Apply the voltage gradually in stator with the help of three-phase variac and start the motor.
4) Apply a voltage little bit higher than the rated voltage and run at its rated speed.
5) Watch the wattmeter reading. Due to low power factor one of wattmeter indicates negative reading. In case of that, set the three phase variac to zero, disconnect the power supply, reverse the current coil direction, apply the voltage again and then take the voltmeter, ammeter and wattmeter reading. Which wattmeter indicates negative reading put negative sign in that case.
6) Note down the voltmeter, ammeter and wattmeter reading.
7) Decrease the supply voltage in steps till motor stops and take the meter readings in every step. As soon as speed falls rapidly to zero ammeter and wattmeter reading also increase fast.
8) Disconnect the power supply and set the three phase variac to zero.
9) Plot the input power vs. voltage curve. The power at normal rated voltage is the total no-load loss. From the extrapolated graph, the intercept of power curve with y-axis gives friction and windage loss. Subtracting friction and windage loss from no-load loss gives the core loss of the motor.
10) Plot the speed, input power, current, power factor and slip vs. stator voltage.

OBSERVATION TABLE :

Sl No	Voltage V_L (volts)	Current I_L (Amps)	Power Input			Speed N_r (r.p.m.)
			W_1 (watts)	W_2 (watts)	$W = W_1 + W_2$ (watts)	
1						
2						
3						
4						
5						
:						
:						
:						
:						
15						
16						
17						
18						
19						
20						

RESULT :

Sl No	Input Voltage (volts)	Slip $s = \frac{N_s - N_r}{N_s} \times 100\%$	Power Factor $\cos\phi = \frac{W}{\sqrt{3} V_L I_L}$
1			
2			
3			
4			
5			
:			
:			
:			
:			
15			
16			
17			
18			
19			
20			

Core Loss or Iron Loss	=	watts
Friction and Windage Loss	=	watts

Draw the speed vs. stator voltage, input power vs. stator voltage, current vs. stator voltage, power factor vs. stator voltage and slip vs. stator voltage.

DISCUSSION:

1. Why power curve is parabolic in nature near normal rated voltage?
2. When voltage is been reduced, why no-load current is increased at very low voltage?
3. When voltage is been reduced, why input power is increased at very low voltage?
4. When voltage is been reduced, why power factor is very high at very low voltage but it is low near normal rated voltage?
5. Why copper loss is not been considered at no-load?