S.J.P.N Trust's

# Hirasugar Institute of Technology, Nidasoshi

*Inculcating Values, Promoting Prosperity*

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**Accredited at 'A' Grade by NAAC**
**Programmes Accredited by NBA: CSE, ECE, EEE & ME**
**Recognized under section 2(f) of UGC Act, 1956**

**Tq: Hukkeri** **Dist: Belagavi**

## DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGG.

# LABORATORY MANUAL

## Name of the Lab: Electrical Machine Laboratory-II

## Semester: IV

## Subject Code: 18EEL47

**Staff Incharge: Prof. S D Hirekodi**

**Technical Staff: Shri. S B Beelur**

**AY 2021-22**

## Overview

| Year / Semester | $2^{nd}$ Year / $4^{th}$ Semester | Academic Year | 2021 - 2022 |
|---|---|---|---|
| Laboratory Title | Electric Machine Lab II | Laboratory Code | 18EEL47 |
| Total Contact Hours | 42 Hours | Duration of SEE | 3 Hours |
| CIE Marks | 40 | SEE Marks | 60 Marks |

## Introduction

This is our core laboratory, in terms of curriculum. The study of electric machines is long established within electrical engineering. The study of electric machinery and electro mechanics offers a wide range of opportunities in such diverse areas as manufacturing process control, control systems, electrical energy generation, electromechanical systems and actuators, electric and hybrid transportation, electrical drives and others. This lab is general enough to hold a number of experiments suitable for giving students enough exposure to enable them to easily adopt experiments in more advanced laboratories in the department.

This is the main lab where experiments like load test on various machines, speed control tests, no load and blocked rotor tests, etc are carried out and also wide variety of practical experiments are performed here with combination of different rotating machines. The laboratory is also used for research activities in machines and to carry out project works on energy conversion.

## General Instructions

1. Make neat and firm circuit connections as per circuit diagram.
2. Do not switch on the supply until the circuit is verified by faculty/instructor.
3. Do not touch any live conductor with your bare hands.
4. Make sure that ground/earth connections of all the equipments are good and firm.
5. Switch off the supply before you leave the laboratory.
6. In case of emergency, switch off the mains.
7. Do not wear loose-fitting clothing or jewelry in the lab.
8. Usage of mobile phone in the laboratory is strictly prohibited.
9. Powered equipment can be hot! Use caution when handling equipment after it has been operated.
10. Use wires of appropriate length & keep your work bench organized and neat.

| Expt. No. | Name of the Experiment |
|---|---|
| 1. | Load test on dc shunt motor to draw speed – torque and horse power – efficiency characteristics. |
| 2. | Speed control of dc shunt motor by armature and field control. |
| 3. | Swinburne's Test on dc motor. |
| 4. | Regenerative test on dc shunt machines. |
| 5. | Load test on three phase induction motor. |
| 6. | No load and Blocked rotor test on three phase induction motor to draw (i) equivalent circuit and (ii) circle diagram. Determination of performance parameters at different load conditions from (i) and (ii). |
| 7. | Load test on single phase induction motor to draw output versus torque, current, power and efficiency characteristics. |
| 8. | Conduct suitable tests to draw the equivalent circuit of single phase induction motor and determine performance parameters. |
| 9. | Retardation test on dc shunt motor. |
| 10. | Conduct an experiment to draw V and Λ curves of synchronous motor at no load and load. |
| 11. | Field Test on dc series machines. |
| 12. | Load test on induction generator. |

## 1.0 **Experiment 01:** Load test on dc shunt motor to draw speed – torque and horse power – efficiency characteristics

## 1.1 Learning Objectives

To perform tests on dc machine to determine their characteristics.

## 1.2 Aim

To Perform load test on DC shunt motor and obtain the following characteristics.
A) Speed Vs. Torque
B) Efficiency Vs. Hp/output power

## 1.3 Material / Equipment Required

| S. no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | DC shunt motor | 3 HP/2.2 KW,1500rpm | 01 |
| 2 | 3-Point starter | - | 01 |
| 3 | Voltmeter | 0-300V (MC) | 01 |
| 4 | Ammeter | 0-10A (MC) | 02 |
| 5 | Rheostat | 200Ω,2.8A | 01 |
| 6 | Rheostat | 25Ω,10A | 01 |
| 7 | Tachometer | - | 01 |
| 8 | Connecting wires | -- | Few |

## 1.4 Theory

It is direct method and consists of applying a load to a pulley mounted on the motor shaft. The brake band is fixed with the help spring balance and is connected to a suspended weight W. The motor runs and the load on the motor is adjusted till it carries full load current.

The net pull on the band due to friction at the pulley is (W1-W2) Kg-Wt or 9.81 (W1-W2) Newton.

W1=Suspended weight in Kg.
W2= Reading on spring balance in Kg-wt
r = radius of the pulley in meter.
N=motor speed in rpm

The shaft torque $T_{sh}$ developed by the motor= ($W_1$-$W_2$) KgWt =9.81 ($W_1$-$W_2$) Newton.

Output power = $\frac{2\Pi N T_{sh}}{60}$ Watt

Let V = Supply Voltage
I = Current taken by the motor in amperes
Input to motor = VI Watt

Efficiency= $\frac{Output\ \ power}{Input\ \ Power} = \frac{2\Pi N(W_1-W_2)\times r\times 9.81}{60\times VI}$

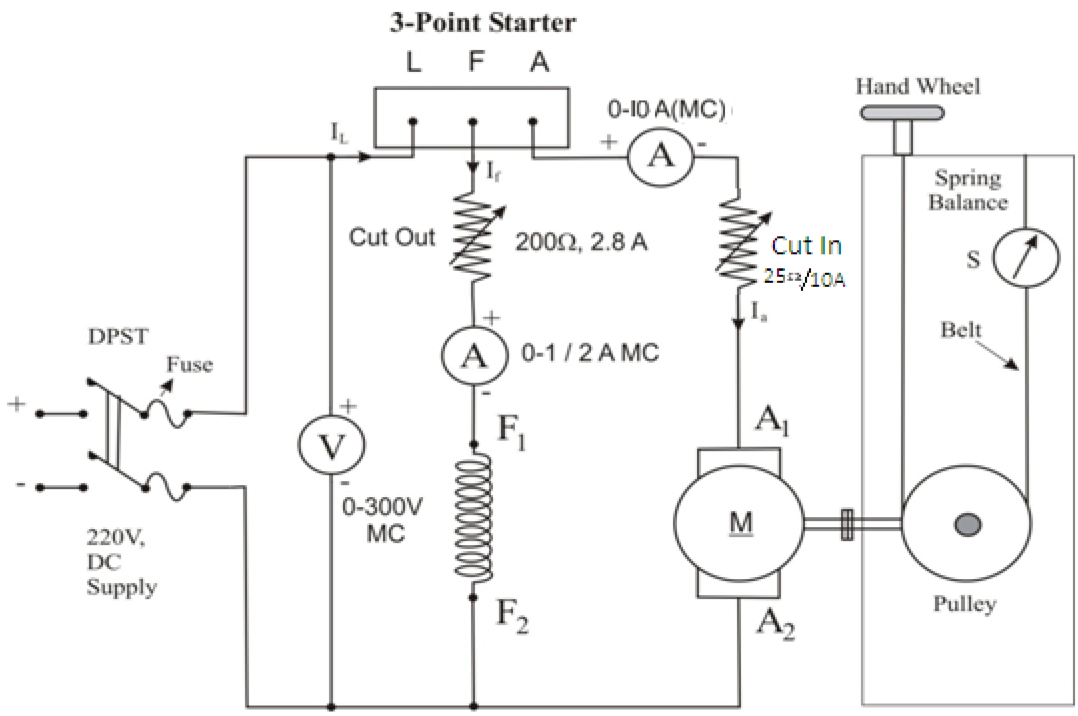
The simple load test described above can be used for small motors only because in the case of

Large motor it is difficult to dissipate the large amount of heat generated.

## 1.5 Procedure

1. Connections are made as per the circuit diagram.
1. Keep the field rheostat (200Ω/ 2.8A) in cut out position & armature rheostat in cut in position.
2. Switch ON the supply by closing the DPST switch.
3. Gradually cut out the armature rheostat & cut in the field rheostat step by step to bring motor to rated speed.
4. Gradually apply mechanical load step by step with the help of break load arrangement and note down the corresponding readings of voltmeter, ammeters, load and speed.
5. Repeat above procedure till the rated current of motor is achieved.
6. Reduce the load to zero.
7. Bring field rheostat and armature rheostat to their original positions and switch OFF the supply.
8. Plot the graph of
9. a) Speed Vs. torque
   b) Efficiency Vs. output power in HP

## 1.6 Circuit Diagram




## 1.7 Specifications & Tabulation

**Specifications:**

1. Power =_____ kw
2. Voltage = _____v
3. Current =_____amp
4. Speed = _____rpm

**TABULATION:**

| Sl. No | Supply Voltage in Volts | Line current in Amps ($I_l=I_a+I_f$) | Input power in HP ($VI_L/746$) | Spring Balance load in Kg (S=S1-S2) | Torque in Nm $T=s\times r\times 9.81$ | Speed N in rpm | Output Power in HP $Po/746$ | Efficiency %η= $\frac{Output\ power}{Input\ power}\times 100$ |
|---|---|---|---|---|---|---|---|---|
| 1 | | | | | | | | |
| 2 | | | | | | | | |
| 3 | | | | | | | | |
| 4 | | | | | | | | |
| 5 | | | | | | | | |
| 6 | | | | | | | | |

## 1.8 Formula / Calculations

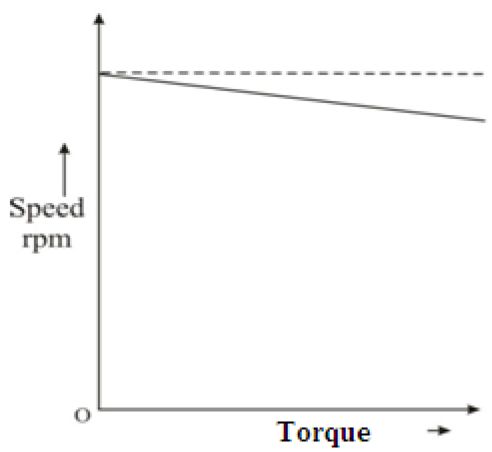
Circumference of a pulley= 2Πr  $r = \frac{\text{Circumference of a pulley}}{2\Pi}$

Output power, $P_o = \frac{2\Pi N T_{sh}}{60}$ Watt

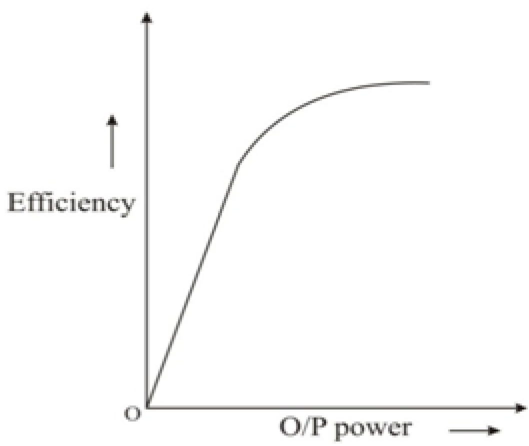
Efficiency= $\frac{Output\ \ power}{Input\ \ Power}$

## 1.9 Nature of Graph

A) Speed V/s Output power




B) Efficiency V/s Output power



## 1.10 Results

## 1.11 Conclusion

## 1.12 Remarks

**Faculty Signature**

## 2.0 **Experiment 02:** Speed control of dc shunt motor by armature and field control.

## 2.1 Learning Objectives

To control the speed of dc motor

## 2.2 Aim

Speed control of DC motor by 1) Armature control

2) Flux control or Field control method

## 2.3 Materials / Equipments Required

| S. no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | DC shunt motor | 5 HP/3.7 KW,1500rpm | 01 |
| 2 | 3-Point starter | - | 01 |
| 3 | Voltmeter | 0-300V (MC) | 01 |
| 4 | Ammeter | 0-10A (MC) | 01 |
| 5 | Rheostat | 200Ω,2.8A | 01 |
| 6 | Rheostat | 50Ω,5A | 01 |
| 7 | Tachometer | - | 01 |
| 8 | Connecting wires | -- | Few |

## 2.4 Theory

1) **Armature control method:**

In this method, shunt-field current is maintained constant, while the voltage applied to the armature is varied. DC motor speed is proportional to the counter emf ($N \propto Eb$). This is equal to the applied voltage minus the armature circuit IR drop. At rated current, the torque remains constant regardless of the dc motor speed (since the magnetic flux is constant) and, therefore, the dc motor has constant torque capability over its speed range.

This method is used when speed below the rated speed required. As the supply voltage is normally constant, the voltage across the armature is varied by adding a variable resistance in series with the armature.

The shunt field winding is excited by the normal voltage hence $I_{sh}$ is constant (rated) in this method. Initially the armature rheostat position is set minimum and rated voltage gets applied across the armature. So, speed is rated for a given load, armature current is fixed. So when extra resistance is added in armature circuit, $I_a$ remains same and there is a voltage drop across the resistance added ($I_aR$). Hence voltage across the armature decreases, decreasing the speed below the normal value. By varying this extra resistance various speeds below the rated value can be obtained. So for a constant load torque the speed is directly proportional to the voltage across the armature.

2) **Flux control or Field control method:**

Speed is inversely proportional to the flux. The flux is dependent on the current through the shunt field winding. The flux can be controlled by adding a rheostat in series with the shunt field winding. At the beginning Rheostat kept at minimum position. The supply voltage is at its rated value so current through the shunt field winding is also at its rated value. Hence the speed is also rated normal speed the rheostat is increased due to which shunt field current $I_{sh}$ decreases decreasing the flux produced as $N \propto \frac{1}{\varphi}$ . The speed of the motor increases beyond its rated value.It is recommended that rated values of electrical parameters should not be exceeded but the speed which is mechanical parameter can be increased up to twice its rated value. As field winding resistance is high, the field current is small hence power loss ($I_{sh}^2 R$) in the external resistance is very small. This makes the method more economical and efficient. As the field current is small size of the rheostat required is small

## 2.5 Procedure

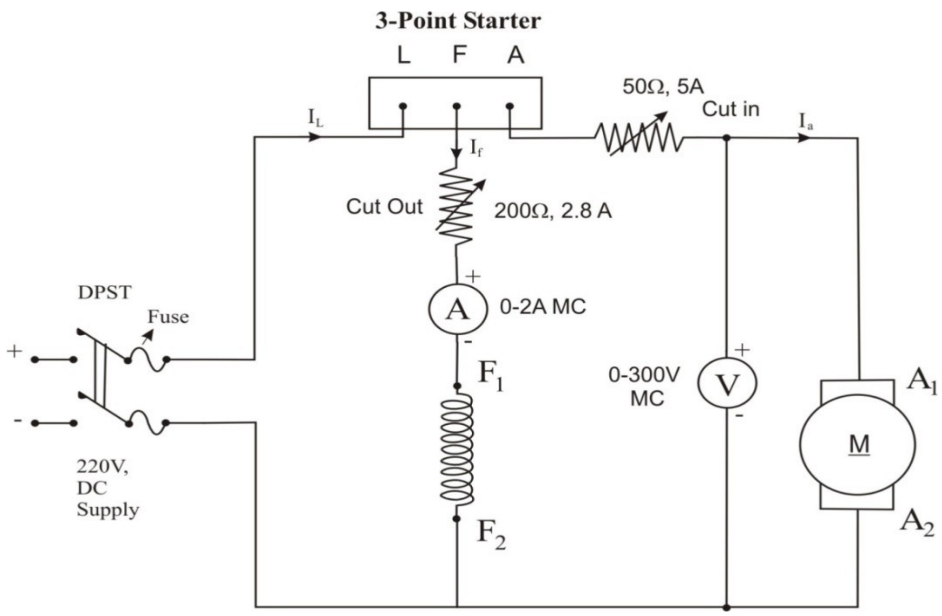
**Armature control method:**

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat in cut-out position (200Ω/2.8A) and armature rheostat in cut in position (50Ω, 5A).
3. Switch ON the supply by closing the DPST switch.
4. Keep the field current to a constant value, gradually cut-out the armature rheostat step by step and note down the armature voltage and speed reading at each step.
5. Keep all rheostats to their original position and switch OFF the supply.
6. Plot the graph of armature voltage V/S speed of motor.

**Flux control or Field control method:**

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat in cut-out position (200Ω/2.8A) and armature rheostat in cut in position (50Ω/5A).
3. Switch ON the supply by closing the DPST switch.
4. Gradually cut out the armature rheostat to bring motor to rated speed.
5. Keep the armature voltage to a constant value then gradually cut in the field rheostat step by step and note down the field current and speed at each step.
6. Bring all rheostats to original position and switch OFF the supply.
7. Plot the graph of field current V/S speed of motor.

## 2.6 Circuit Diagram




## 2.7 Specifications & Tabulation

**Specifications:**

1. Power =_____ KW
2. Voltage =_____V
3. Current =_____A
4. Speed = _____rpm

**TABULATION:**

**Armature Control method:**
**Field current remains constant.**
**For $I_F$=**

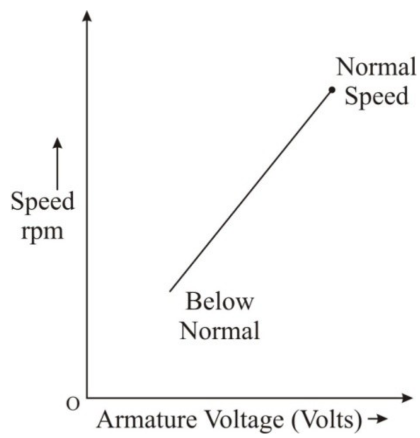
| S.No. | Armature voltage in Volts | Speed in rpm |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

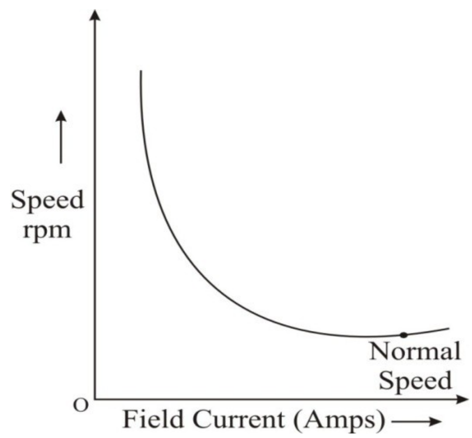
**Flux control method or Field control method:**
**Armature Voltage remains constant.**
**For $V_A$=**

| S.No. | Field current in Amps | Speed in rpm |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |

## 2.8 Formula / Calculations

## 2.9 Nature of Graph



## 2.10 Results

## 2.11 Conclusion

## 2.12 Remarks

**Faculty Signature**

## 3.0 **Experiment 03:** Swinburne's Test on dc motor.

## 3.1 Learning Objectives

To conduct test for pre-determination of the performance characteristics of dc machines

## 3.2 Aim

To perform the Swinburne's test on DC shunt motor to find efficiency at different load conditions.

## 3.3 Materials / Equipments Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | 3-Point starter | - | 01 |
| 2 | Rheostat | 200Ω,2.8A | 01 |
| 3 | Ammeter | 0-5A | 01 |
| 4 | Ammeter | 0-2A | 01 |
| 5 | Voltmeter | 0-300V | 01 |
| 6 | Multimeter | -- | 01 |
| 7 | Tachometer | -- | 01 |
| 8 | Connecting wires | -- | Few |

## 3.4 Theory

In this method the dc machine is run as motor at no load and losses of the machine are determined once the losses of the machine are known its efficiency at any desired load can be determined in advance It may be noted that this method is applicable to those machines in which flux is practically constant at all loads ex: shunt and compound machines.

The motor is run on no-load at its rated voltage at the starting some resistance is connected in series with the armature which is cut when motor attains sufficient speed.. Speed is adjusted to the rated speed with the help of shunt field rheostat. The no load armature current is measured by ammeter $A_1$ and the shunt current is measured by ammeter $A_2$.

Advantages of Swinburne's Test:

i) The power required to carry out the test is small because it is a no-load test. Therefore this method is quite economical.
ii) The efficiency can be determined at ay load because constant losses are known.
iii) This test is very convenient.

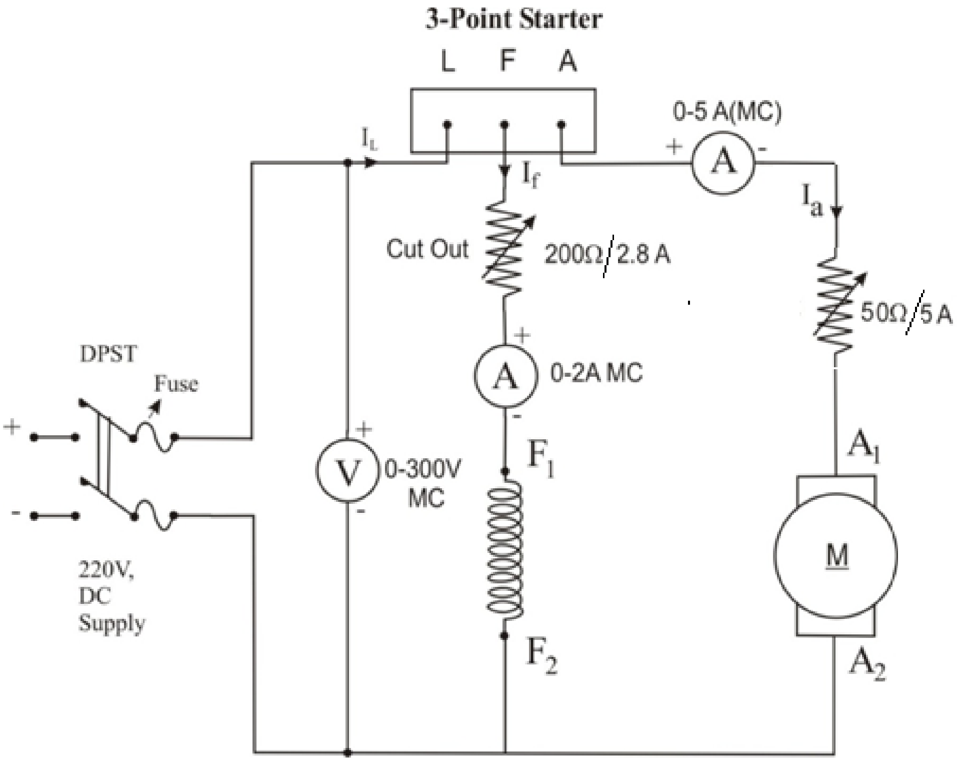
Disadvantages of Swinburne's Test:

i) It does not take into account the stray load losses that occur when the machine is loaded.
ii) This test does not enable us to check the performance of the machine on full load.
iii) This test does not give quite accurate efficiency of the machine. It is because iron losses under actual load are greater than those measured. This is mainly due to armature reaction distorting the field.

## 3.5 Procedure

1. Connections are made as per the circuit diagram.
2. Keep field rheostat in cut out position 200Ω/2.8A & Armature rheostat in Cut in position 50Ω/5A.
3. Switch ON the supply by closing the DPST switch.
4. Gradually cut out the armature rheostat & cut in the field rheostat step by step to bring motor to the rated speed.
5. Note down the corresponding reading of ammeter and voltmeter.
6. Bring field rheostat to its original position and switch OFF the supply.

## 3.6 Circuit Diagram




## 3.7 Specifications & Tabulation

**Specifications:**

1. Power =_____ KW
2. Voltage = _____V
3. Current =_____A
4. Speed = _____rpm

**TABULATION:**

| Supply Voltage in Volts | Armature Current in $I_{a0}$ Amps | Field Current $I_{sh}$ | No load Current $I_L$ Amps | Speed in rpm |
|---|---|---|---|---|
| | | | | |

## 3.8 Formula / Calculations

Armature resistance $R_a$=_________Ω

Determination of constant losses:

Armature resistance =Ra =______Ω

Input to motor on no load = $VI_L$ = _______ W

Armature copper loss = $I^2_{a0}R_a$ = __________ W

Constant losses = No load input to motor – No load armature copper losses

$W_0 = VI_L - (I^2_{a0} R_a)$

= __________W

Efficiency of Motor at Full load:

Full load rated current ($I_{FL}$) = __________A

Armature current $I_a = I_{FL} - I_{sh}$ =________A

Input to motor at full load = $VI_{FL}$ =_____

Armature copper loss =$I^2_a R_a$ =______W

Shunt field copper loss =$VI_{sh}$ =_____W

Total copper loss = armature copper losses + field copper losses

= $I^2_a$ Ra + V $I_{sh}$

=

=_________W

Total losses = Constant losses + Total copper losses

= $W_0 + I^2_a R_a + VI_{sh}$

=_______W

Output power = Input power – Total losses

=$VI_{FL}$ – total losses

=

=_________W

Efficiency (η) = $\frac{\text{Output power}}{\text{Input power}}$ X 100

=------------------

=________%

## 3.9 Results & Analysis

| Load | Full Load | ½ Load | ¾ th Load | ¼ th Load |
|---|---|---|---|---|
| % Efficiency | | | | |

## 3.10 Conclusion

## 3.11 Remarks

**Faculty Signature**

## 4.0 **Experiment 04:** Regenerative test on dc shunt machines.

## 4.1 Learning Objectives

To conduct test for pre-determination of the performance characteristics of dc machines

## 4.2 Aim

To determine the efficiency of dc machine by Hopkinson's test or regenerative test or back-to-back test.

## 4.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Ammeter | 0-20A MC | 3Nos |
| 2 | Ammeter | 0-2A MC | 2 No |
| 3 | Voltmeter | 0-300V MC | 2 No |
| 4 | Rheostat | 200Ω, 2.8A | 2 No |
| 5 | 3-Point Starter | -- | 1 No |
| 6 | Connecting wires | -- | Few |

## 4.4 Theory

By this method, full-load test can be carried out on two shunt machines, preferably identical ones, without wasting their outputs. The two machines are mechanically coupled and are so adjusted electrically that one of them runs as a motor and the other as a generator. The mechanical output of the motor drives the generator and the electrical output of generator is used in supplying the greater part of input to the motor. If there were no losses in the machines, they would have run without any external power supply. But due to these losses, generator output is not sufficient to drive the motor and vice-versa. The losses are supplied either by an extra motor which is belt-connected to the motor-generator set, or by electrically from the supply mains. The two shunt machines are connected in parallel. They are, to begin with, started as unloaded motors. Then, the field of one is weakened and that of the other is strengthened so that the former runs as a motor and the latter as a generator. The usual method of procedure is as follows: Machine **M** is started up from the supply mains with the help of a starter whereas main switch S of the other machine is kept open. Its speed is adjusted to normal value by means of its field regulator. Machine **M** drives machine **G** as a generator and its voltage is read on voltmeter V. The voltage of **G** is adjusted by its field regulator until voltmeter across switch reads zero, thereby showing that its voltage is the same, both in polarity and magnitude as that of the main supply. Thereafter, S is closed to parallel the machines. By adjusting the respective field regulators, any load can now be thrown on to the machines. Generator current $I_1$ can be adjusted to any desired value by increasing the excitation of **G** or by reducing the excitation of **M** and the corresponding values of different ammeters are read. The electrical output of the generator plus the small power taken from the supply is taken by the motor and is given out as a mechanical power after supplying the motor losses. This test is called as regenerative or back to back test which can be carried out on two identical dc machine mechanically coupled to each other and simultaneously tested. Thus the full load test can be carried out on two identical shunt machine with output of one machine is made to act as an input to other.

Advantages:

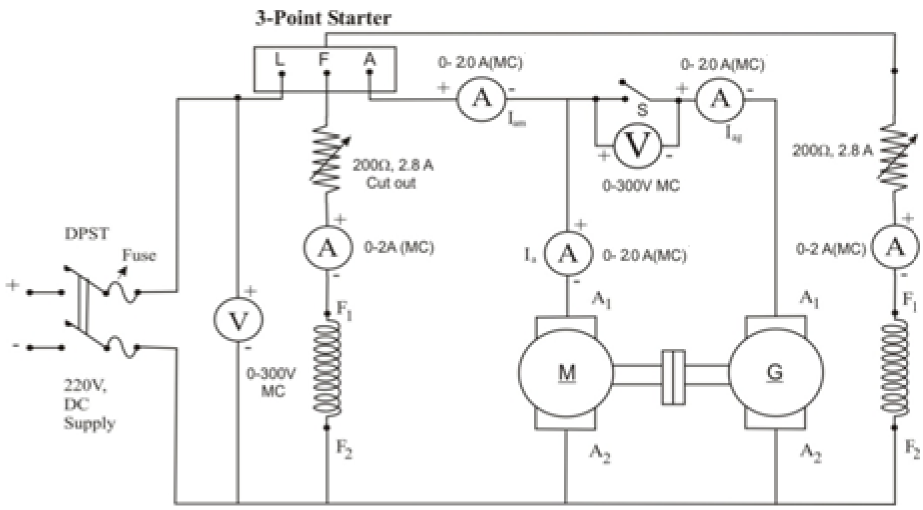
1. The power required for conducting the test is small compared to full load power of the two machines.
2. Since the machines are operated at full load condition change in iron losses due to flux at full load will be included in the calculation.

3. As machines are tested under full load condition the temperature rise and quantity of commutation of the two machines can be observed.
4. The test is economical as power required to conduct the test is very small which is just sufficient to meet the losses.

## 4.5 Procedure

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat of motor in cut-out position 200Ω,/2.8A, and field rheostat of generator in cut-in position 200Ω/2.8A.
3. Keep the switch in open position.
4. Switch ON the supply by closing the DPST switch.
5. Gradually, cut in the field Rheostat step by step to bring to motor the rated speed.
6. By varying the field Rheostat of generator, make the zero voltage in voltmeter then close the switch 'S'.
7. By varying the field Rheostat of the generator in step note down corresponding ammeter and voltmeter.
8. Repeat the procedure until rated current flows in motor and generator side.
9. Bring all rheostats to their original position.
10. Switch OFF the supply.

## 4.6 Circuit Diagram




## 4.7 Specifications & Tabulation

**Specification:**

**For Motor**:

1. Power =_____ KW
2. Voltage = _____V
3. Current =_____A
4. Speed = _____rpm

**For Generator:**

1. Power =_____ KW
2. Voltage = _____V
3. Current =_____A
4. Speed = _____rpm

**TABULATION:**

| Sl. No . | Supply Voltage V in (Volts) | Motor Armature current $I_{am}$ in (Amps) | Generator Armature current $I_{ag}$ in (Amps) | Field current of motor $I_{fm}$ (Amps) | Field current of Generator $I_{fg}$ (Amps) | Armature current $I_a$ (Amps) |
|---|---|---|---|---|---|---|
| | | | | | | |

## 4.8 Formula / Calculations

Armature resistance of motor = $r_m$ = ______Ω

Armature resistance of Generator = $r_g$ =________ Ω

$2W_s$ = total stray loss

= $VI_a - [(I_{am} + I_{ag})^2 r_m + I^2_{ag} r_g]$

=

$2W_s$ = _________W

Stray loss for each machine = $\left(\frac{2W_s}{2}\right)$

$W_s$ = _________W

<u>Efficiency of machine working as motor</u>

Shunt field copper loss = V $I_{fm}$ =_____________________= _______________Watt

Armature Copper loss = $(I_{am} + I_{ag})^2 r_m$

=_____________W

Total losses = $W_s + V I_{fm} + (I_{am} + I_{ag})^2 r_m$

=

= ______________W

Efficiency (η % motor) = $\frac{\text{Input power} - \text{total losses}}{\text{Input power}} \times 100$

= $\frac{V(I_{fm} + I_{am} + I_{ag}) - (Ws + VI_{fm} + (I_{am} + I_{ag})^2 r_m}{V(I_{fm} + I_{am} + I_{ag})}$

=________________________

% Efficiency of motor(η) = ______________%

<u>Efficiency of machine working as Generator</u>

Shunt field copper loss = V $I_{fg}$ =_____________________= _______________Watt

Armature Copper loss = $(I_{ag})^2 r_g$

=_____________W

Total losses = $W_s + V I_g + (I_{ag})^2 r_g$

=

= ______________W

Efficiency (η % Generator) = $\frac{\text{Output power}}{\text{Output power} + \text{total losses}} \times 100$

= $\frac{VI_{ag}}{VI_{ag} + [Ws + VI_{fg} + I^2_{ag} r_g]}$ =

=_____________________________________________

=________________________

% Efficiency of Generator (η) = ______________%

## 4.9 Results & Analysis

## 4.10 Conclusion

## 4.12 Remarks

**Faculty Signature**

## 5.0 **Experiment 05:** Load test on three phase induction motor.

## 5.1 Learning Objectives

To conduct test on induction motor to determine the performance characteristics

## 5.2 Aim

To determine the following characteristics of induction motor by conducting the load test on it.

i) Speed Vs Output power
ii) Percentage efficiency Vs Output power
iii) P.f Vs Output power

## 5.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | 0-600V | 1No |
| 2 | Ammeter | 0-10A | 1No |
| 3 | Wattmeter | 0-600V/10A,UPF | 2Nos |
| 4 | 3-Phase IM | 5HP, 3-phase, 415V, 6A,1500rpm, 50Hz | 1No |
| 5 | 3-Phase Auto-Transformer | 415V/0-440V, 50Hz | 1No |
| 6 | Connecting wires | -- | Few |

## 5.4 Theory

The load test on induction motor is performed to compute its complete performance i.e. torque, slip, efficiency, power factor etc. During this test, the motor is operated at rated voltage and frequency and normally loaded mechanically by brake and pulley arrangement from the observed data, the performance can be calculated, following the steps given below.

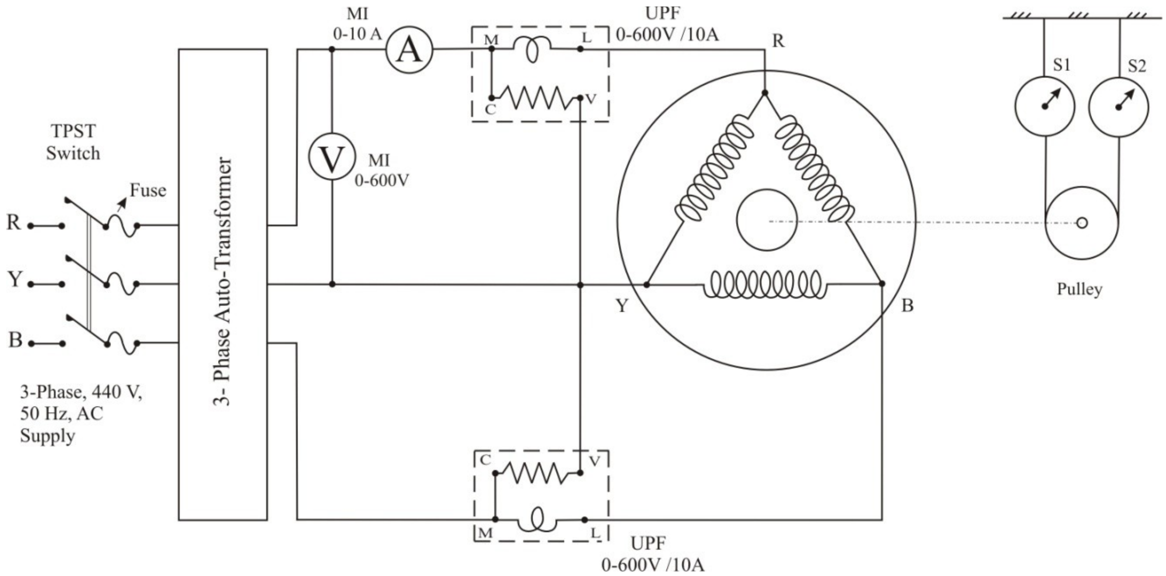
**SLIP** : The speed of rotor, Nr droops slightly as the load on the motor is increased. The synchronous speed, Ns of the rotating magnetic field is calculated, based on the number of poles, P and the supply frequency, f i.e.

Normally, the range of slip at full load is from 2 to 5 percent.

## 5.5 Procedure

1. Connections are made as per the circuit diagram.
2. Ensure position of the auto transformer knob at its zero position and load on the induction motor.
3. Then switch ON the 3-ϕ supply.
4. Go on varying the 3-ϕ auto transformer and bring the induction motor to its rated speed by applying its rated voltage through dimmer stat.
5. Go on varying the load on the induction motor in steps and note down reading of the motor connected in circuit.
6. Repeat this procedure until ammeter shows the rated value of induction motor.
7. Bring back the load to its original position.
8. Switch OFF the supply.

## 5.6 Circuit Diagram




## 5.7 Specifications & Tabulations

**Specifications:**

HP = _______

Phase = _____

Voltage = _____V

Current = _____Amps

RPM = _____rpm

Radius of the break drum = r

$$r = \frac{\text{Circumference of brake}}{2\pi}$$

**TABULATION:**

| S.no | $V_0$ volts | $I_L$ Amps | $W_1$ Watts | $W_2$ Watts | Speed In rpm | $S_1$ In Kg | $S_2$ in Kg |
|---|---|---|---|---|---|---|---|
| 1. | | | | | | | |
| 2. | | | | | | | |
| 3. | | | | | | | |
| 4. | | | | | | | |
| 5. | | | | | | | |
| 6. | | | | | | | |
| 7. | | | | | | | |

| S.no | Input In HP | Output In HP | Torque N-M | PF | %η | S% |
|---|---|---|---|---|---|---|
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |
| 7. | | | | | | |

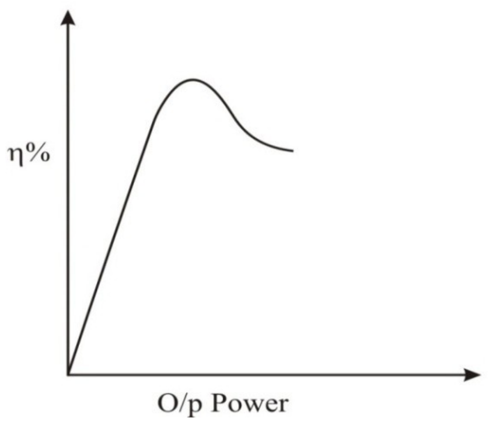
## 5.8 Formula / Calculations

1. Input power in HP = $\frac{W_1+W_2}{735.5}$
2. Output power in HP= $\frac{2\pi NT}{60 \times 735.5}$
3. Torque = (Difference between S1 & S2) Radius of brake drum X 9.81 N-M
4. Power factor = $cos\left\{tan^{-1}\left[\frac{\sqrt{3}\,(W_2-W_1)}{(W_1+W_2)}\right]\right\}$
5. % Efficiency = $\frac{Output\ \ power}{Input\ \ power} \times 100$
6. % Slip = $\frac{N_S-N}{N_S} \times 100$

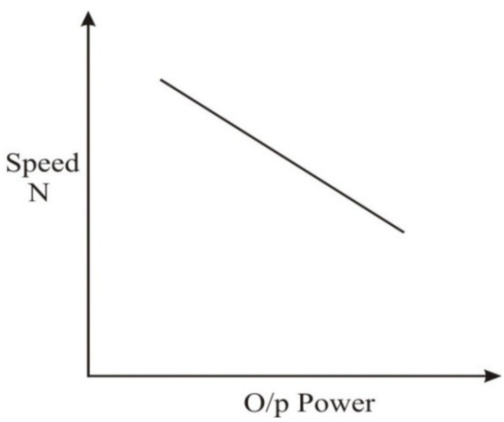
Wattmeter constant = $\frac{\text{Voltage range} \times \text{Current Range}}{\text{Full Scale Division of Wattmeter}}$

## 5.9 Nature of Graphs

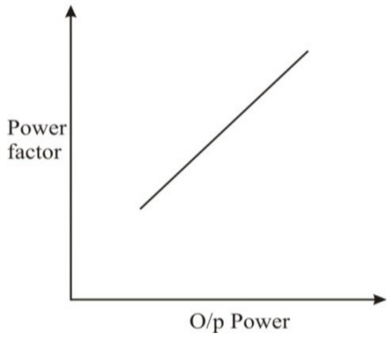
A) η V/s Output power




B) Speed V/s Output power



C) Power factor V/s Output power




## 5.10 Results & Analysis

% Efficiency of motor = _______%

Input power = ________HP

Output power =_______HP

## 5.11 Conclusion

## 5.12 Remarks

**Faculty Signature**

## 6.0 Experiment 06 : No load and Blocked rotor test on three phase induction motor to draw (i) equivalent circuit and (ii) circle diagram. Determination of performance parameters at different load conditions from (i) and (ii)..

## 6.1 Learning Objectives

To conduct test on induction motor to determine the performance characteristics

## 6.2 Aim

No load and blocked rotor test on three phase induction motor to draw (i) equivalent circuit and (ii) circle diagram. Determination of performance parameters at different load conditions from (i) and (ii).

## 6.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | MI 0-600V | 1 No |
| 2 | Ammeter | MI 0-10A | 1 No |
| 3 | Wattmeter | 600V/10A UPF | 2 No |
| 4 | 3-ϕ auto transformer | 415V/0-440V,10A, 50Hz | 1 No |
| 5 | 3-Phase IM | 5HP, 3-phase, 415V, 6A,1500rpm, 50Hz | 1No |
| 6 | Connecting wires | -- | Few |

## 6.4 Theory

If the motor is run at rated voltage and frequency without any mechanical load, it will
draw power necessary to supply the no load losses. The no load current will have two
components. The active component and the magnetizing component, the former being very
small as the no load losses are small. The power factor at no load is therefore very low. The
no load power factor is always less than 0.5 and hence at no load one of the wattmeter at
input side reads negative.

The no load input $W_0$ to the stator consists of

1. Small stator copper loss
2. Core losses
3. The loss due to friction and windage.

The rotor copper loss can be neglected, since slip is small at no load.

**Blocked rotor test :-**

The stator is supplied with a low voltage of rated frequency just sufficient to circulate
rated current through the stator with the rotor blocked and short circuited. The power input,
current and the voltage applied are noted down. The power input during the blocked rotor test

is wholly consumed in the stator and rotor copper losses. The core loss is low because the applied voltage is only a small percentage of the normal voltage. Again since the rotor is at stand still the mechanical losses are absent. Hence the blocked rotor input can be taken as approximately equal to the copper losses.

## 6.5 Procedure

FOR NO-LOAD TEST:

1. Connections are made as per the circuit diagram.
2. Ensure position of the auto transformer knob at its zero position
3. Then switch ON the 3-ϕ supply.
4. Go on varying the 3-ϕ auto transformer knob gradually and apply the rated voltage and bring the induction motor to its rated speed.
5. Note down the readings of all the meters connected in the circuit.
6. Bring back the auto-transformer to its original position.
7. Switch OFF the supply.

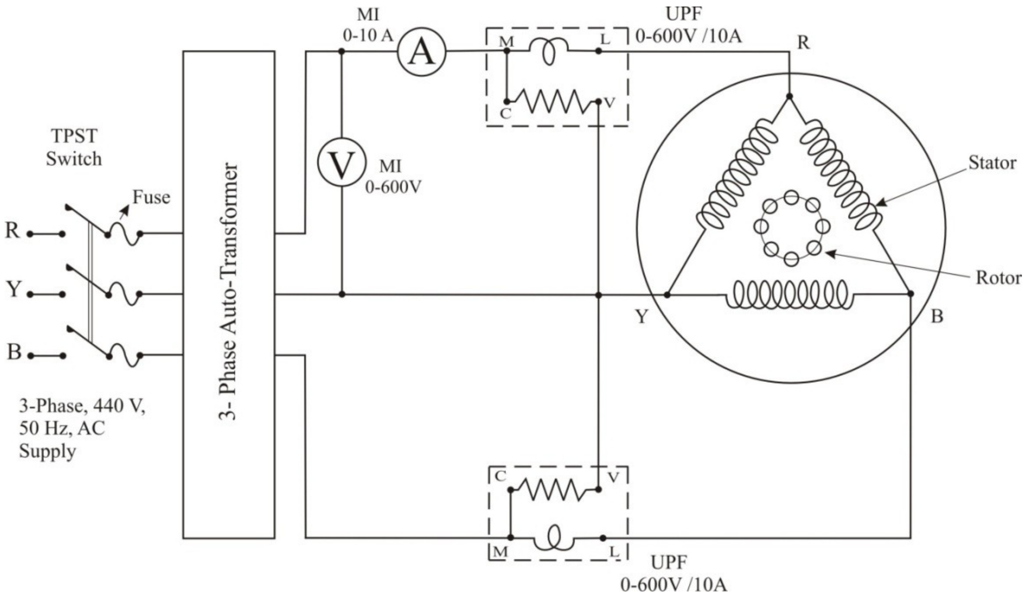
BLOCKED ROTOR TEST:

1. Connections are made as per the circuit diagram.
2. Ensure position of the auto transformer knob at its zero position and block the rotor of induction motor with the help of hand or a mechanical device if provided.
3. Then switch ON the 3-ϕ supply.
4. Go on varying the 3-ϕ auto transformer knob gradually and apply the voltage such that the ammeter connected in the circuit shows rated current of induction motor.
5. Note down the reading of all the meters connected in the circuit.
6. Bring back the load to its original position.
7. Switch OFF the supply.

**PROCEDURE FOR DRAWING THE CIRCLE DIAGRAM:**

1. Take reference phasor V as vertical (Y-axis).
2. Select suitable current scale such that diameter of circle is about 20-30cm.
3. From no-load test, $I_0$ and $\phi_0$ are obtained. Draw vector $I_0$, lagging V by an angle $\phi_0$. This is line 00'.
4. Draw horizontal line through extremity of $I_0$ i.e. 0' parallel to horizontal axis.
5. Draw the current $I_{SN}$ calculated from $I_{SC}$ with some scale. Lagging V by angle $Q_{SC}$, from the origin 0. This is phasor OA.
6. Join O'A. The line O'A is the output line.
7. Draw a perpendicular bisector of O'A. Extend it to meet line O'B at point C. This is the centre of the circle.
8. Draw the circle, with 'C' as a center and radius equal to O'C this meets the horizontal line drawn from O' at B.
9. Draw the perpendicular from point A on the horizontal axis, to meet O'B line at F and meets horizontal axis at D.
10. To determine torque line, determine the rotor and stator resistance per phase of induction motor.
11. Bisect the line AFE and join O'E which is the torque line.
12. Length 'AE' is rotor copper loss and 'EF' is stator copper loss and FD is fixed loss in the induction motor.
13. To determine the full load point 'P' extend the line 'AP' from A to A'.
14. Draw a parallel line to the output line O'A from point A' to meet the circle at point P
15. Join 'O' and 'P' to get 'OP'.

## 6.6 Circuit Diagram




## 6.7 Specifications & Tabulations

**OBSERVATION:**

INDUCTION MOTOR

HP: ___________HP

Volts : ________V

Current: _______Amps

Speed : _______rpm

**TABULATION:**

FOR NO LOAD TEST:

| $I_0$ Amps | $V_0$ Volts | $W_1$ Watts | $W_2$ Watts | $W_0=W_1+W_2$ Watts |
|---|---|---|---|---|
| | | | | |

FOR BLOCKED ROTOR TEST:

| $I_{SC}$ Amps | $V_{SC}$ Volts | $W_1$ Watts | $W_2$ Watts | $WSC=W_1+W_2$ Watts |
|---|---|---|---|---|
| | | | | |

## 6.8 Formula / Calculations

$I_{SN} = I_{SC}\left(\frac{V_L}{V_{SC}}\right) =$

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

$\cos\emptyset_{SC} = \frac{W_{SN}}{\sqrt{3}V_L\, I_{SN}} =$

$\cos\emptyset_0 = \frac{W_0}{\sqrt{3}V_0\, I_0} =$ $\emptyset_0 =$

Power scale = $\frac{W_{SN}}{AD}$ =

AA’ = $\frac{3 \times 735.5}{PS}$ =

**Results from Circle Diagram:**

Motor Efficiency = $\frac{PQ}{PT}$ =

Total Motor input PT X PS =

Total Motor output PQ X PS =

Maximum O/P = MN =

Maximum I/P = LL’ =

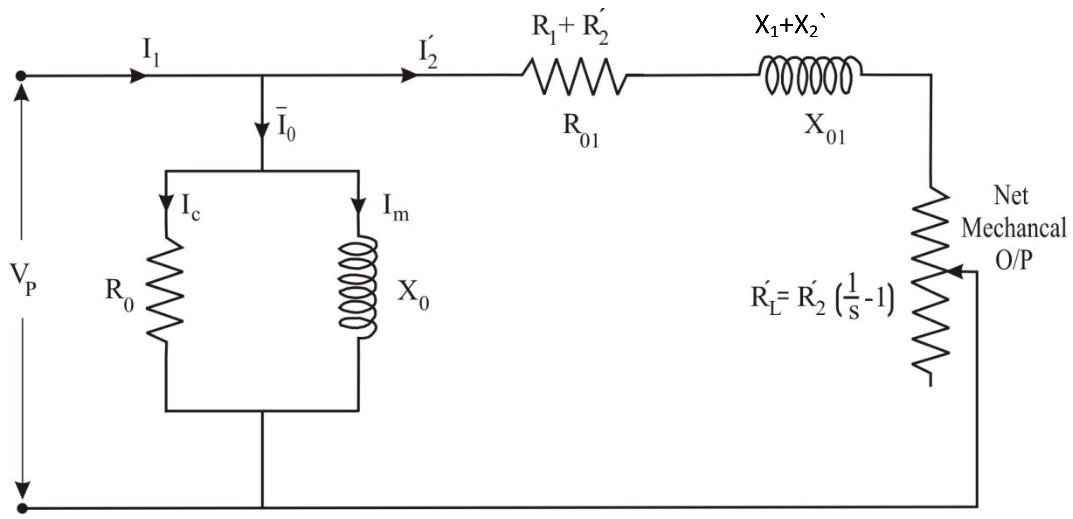
Fixed Losses = ST=

Total Losses = QT=

Rotor Copper loss= QR=

Stator Copper loss =SR=

**EQUIVALENT CIRCUIT REFERRED TO STATOR SIDE**



**CALCULATIONS:**

**i) Determination of Equivalent Circuit Parameters:**

**From No-Load Test:**

$V_L$= Input line Voltage = _________Volts.

$V_p$= Input Voltage per phase = $\frac{V_L}{\sqrt{3}}$ =________Volts.

$P_o$= Total input power at No-load = $W_1 + W_2$ = _________ Watts

$I_o$= Input line current = _________Amps.

$\therefore\ P_o = \sqrt{3}V_L I_0 cos\emptyset_0$

No load power factor, $cos\emptyset_0 = \frac{P_0}{\sqrt{3}V_L I_0}$ =__________

$I_c = I_0 cos\emptyset_0$ =__________ Amps.

$I_m = I_0 \sin\emptyset_0$ = _________ Amps.

$\therefore\ R_0 = \frac{V_P}{I_c}$ =___________Ω.

$X_0 = \frac{V_P}{I_m}$ =___________Ω.

**From blocked Rotor Test:**

$P_{sc}$ = Total 3-phase power Input during short circuit.

= $W_1 + W_2$ =_______Watts.

$I_{sc}$ = Short circuit Line current = _________

Full load motor current = _______Amps.

$V_{sc}$= Phase voltage on short circuit = ________Volts.

$P_{sc} = \sqrt{3}V_{sc}I_{sc}\cos\emptyset_{sc}$

$$\cos\emptyset_{sc} = \frac{P_{sc}}{\sqrt{3}V_{sc}I_{sc}}$$

Total equivalent resistance referred to stator $R_{01} = \frac{\frac{P_{sc}}{3}}{I_{sc}^2}$ = ________ Ω

But, $R_{01} = R_1 + R`_2$

$\therefore\ R_2^{`} = R_{01} - R_1$ = __________ Ω

Where, $R_1$ = Stator resistance per phase =_______ Ω

Equivalent Impedance referred to stator = $Z_{01}$

$Z_{01} = \frac{V_{sc}}{I_{sc}}$ = ___________Ω

∴ Equivalent reactance referred to stator = $X_{01}$

$X_{01}=\sqrt{Z_{01}^2 - R_{01}^2}$ = ______________Ω.

$X_1 = X`_2 = \frac{X_{01}}{2}$ = ________ Ω.

Synchronous speed of motor= Ns= $\frac{120f}{P}$ = ________rpm

∴ Slip $S=\frac{N_s - N}{N_s}$ = _________

Where N= Speed of motor at different loads.

∴ $R_L^` = \frac{R_L^`(1-S)}{S}$ =________ Ω.

**ii) <u>Determination of performance quantities</u>:**

$Z_0 = R_0 \parallel jX_0 = \frac{R_0 \times jX_0}{R_0 + jX_0}$ =________ Ω.

$I_0 = \frac{V_P}{Z_0}$ = =________ Amps.

$\bar{I}_2^` = \frac{V_P}{(R_{01} + R_L^`) + j X_{01}}$ =________ Amps

Total stator current = $\bar{I}_1 = I_0 + I_2^`$
Total Stator input power = $P_{in} = \sqrt{3}\, V_P\, I_1 \cos\emptyset$
$P_{in}$ = __________Watts.
From the equivalent circuit,
Total input impedance

$\bar{z}_f = (R_f + j X_f) = \bar{z}_0 + (R_{01} + R_L^`) + j X_{01}$ =________ Ω.

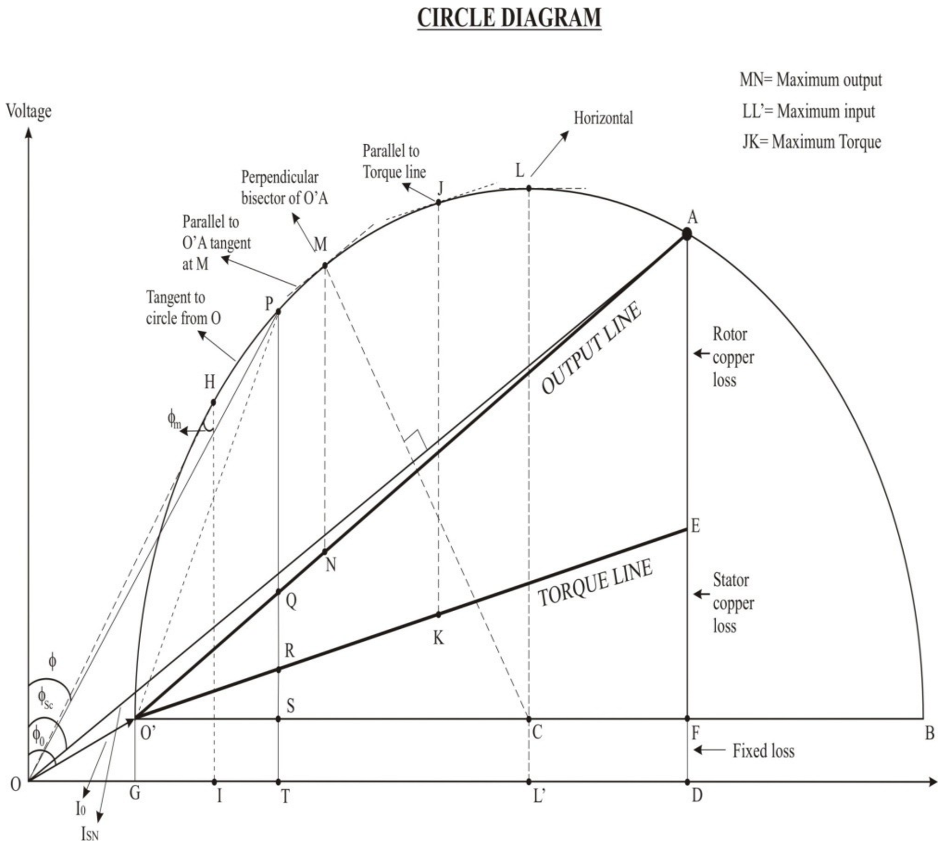
Power across air gap
$P_{Gap} = 3\, \bar{I}_1^2\, Rf$ =__________Watts.
Gross mechanical output
$P_G = (1 - S) P_{Gap}$ =__________Watts.
Rotational losses = Pr = $P_0 - 3\, I_0^2\, R_1$ = __________Watts.

Net mechanical output power
$P_{out} = P_G - P_r$ =__________Watts.
Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100$ = _______%

$\omega_s = \frac{2\pi N_s}{60}$ =__________rad/sec.
Torque (net) = $\frac{P_{out}}{\omega(1-S)}$ = ________N-m.
Stator copper loss = $3 I_1^2 R_1$= _________Watts.
Rotor copper loss = $S \times P_{GAP}$ =_________Watts.
Total losses = Rotational losses + Stator Copper loss + Rotor copper loss = _________Watts.

$P_{in} - P_{out}$ =_________Watts.

## 6.9 Nature of Graph




## 6.10 Results & Analysis

| S. no | Load Current $I_L$ | From Circle Diagram | | | | From Equivalent Circuit | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Stator Copper loss | Rotor Copper loss | Torque | %η | Stator Copper loss | Rotor Copper loss | Torque | %η |
| 1 | 1.5 | | | | | | | | |
| 2 | 3.0 | | | | | | | | |
| 3 | 4.0 | | | | | | | | |
| 4 | 5.0 | | | | | | | | |
| 5 | 6.0 | | | | | | | | |

## 6.11 Conclusion

## 6.12 Remarks

**Faculty Signature**

## 7.0 **Experiment 07:** Load test on single phase induction motor to draw output versus torque, current, power and efficiency characteristics.

## 7.1 Learning Objectives

To conduct load test on single phase induction motor.

## 7.2 Aim

To determine the following performance of 1-ϕ induction motor by conducting the load test on it.

i) Output Vs Torque

ii) Output Vs efficiency

iii) Output Vs power

iv) Output Vs current

## 7.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | MI 0-300V | 1 No |
| 2 | Ammeter | MI 0-10A | 1 No |
| 3 | Wattmeter | MI 300V/10A,UPF | 1 No |
| 4 | 1-phase IM | 1HP, 230V, 7.6A,1500rpm | 1 No |
| 5 | 1-φ Auto-transformer | 230V/0-260V, 50Hz | 1 No |
| 6 | Tachometer | -- | 1 No |
| 7 | Connecting wires | -- | Few |

## 7.4 Theory

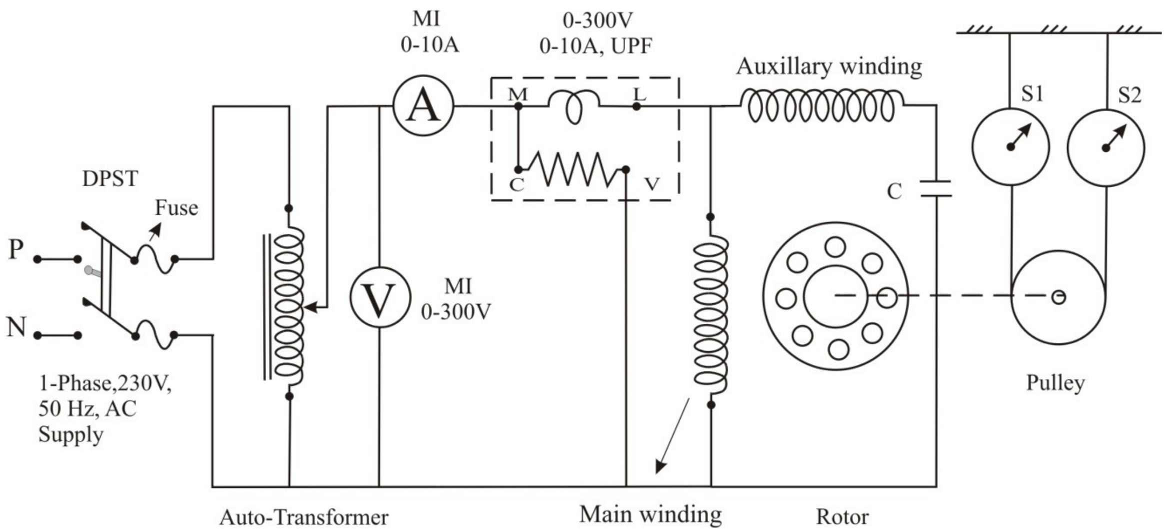
Single phase motors are similar in construction to poly phase squirrel cage induction motor with exception that the stator has single phase winding. Therefore in single phase motors rotating magnetic field if not produced, but only a pulsating field is produced. The torque is also pulsating and hence single phase motors are not self starting. In order to make them self starting, they are converted to two phase motors at starting. A centrifugal switch is used to cut off the starting winding after motor picks up full speed.

## 7.5 Procedure

1. Connections are made as per the circuit diagram.
2. Ensure position of the auto transformer knob at its zero position and rotor resistance to the zero position.
3. Then switch ON the supply.
4. Go on varying the auto transformer knob up to 230V and note down the corresponding values of ammeter, wattmeter.
5. Note down load on the load on the IM and take down the corresponding readings.
6. Bring back the auto-transformer knob to its original position.

7. Switch OFF the supply.
8. With the help of wire take down the circumference of break drum.

## 7.6 Circuit Diagram




## 7.7 Specifications & Tabulations

**Specification:**

1) Rated voltage =______V
2) HP=_______ HP
3) Voltage = _______V
4) Ampere =________A
5) RPM= ________

**Tabulation:**

| S.no | Voltage In volts | Current I in Amps | Power In watts | Weight in Kgs | Speed in rpm | Torque $T = s \times r \times g$ |
|---|---|---|---|---|---|---|
| 1. | | | | | | |
| 2. | | | | | | |
| 3. | | | | | | |
| 4. | | | | | | |
| 5. | | | | | | |
| 6. | | | | | | |

| Input power $W_i$ (VI) | Output power $\frac{2\pi NT}{60}$ | Power Factor | % Slip | % efficiency |
|---|---|---|---|---|
| | | | | |

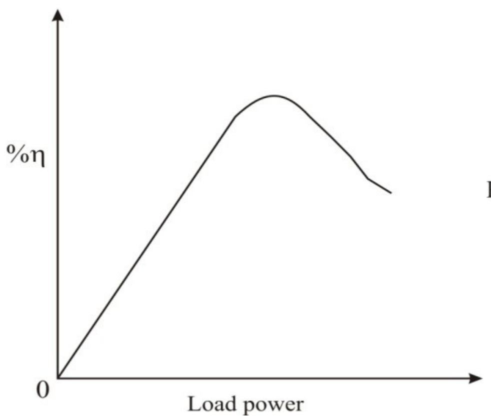
## 7.8 Formula / Calculations

1) Radius of Break drum = $\dfrac{\text{Circumference of a break drum}}{}$
2) Torque= s × r × g N-M
3) Power factor = $\dfrac{W}{VI}$
4) Output power = $\dfrac{2\pi NT}{60}$ Watts
5) % Slip = $\dfrac{(N_S - N)}{N_S} \times 100$
6) % η= $\dfrac{\text{Output power}}{\text{Input power}} \times 100$

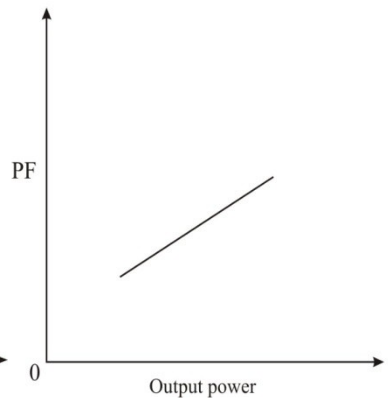
Wattmeter constant = $\dfrac{\text{Voltage range} \times \text{Current Range}}{\text{Full Scale Division of Wattmeter}}$

## 7.9 Nature of Graph

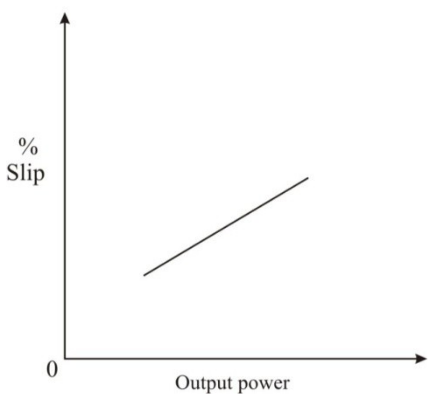
1) EFFICIENCY Vs OUTPUT POWER




2) OUTPUT POWER Vs POWER FACTOR




3) OUTPUT POWER Vs % SLIP



## 7.10 Results & Analysis

## 7.11 Conclusion

## 7.12 Remarks

**Faculty Signature**

## 8.0 Experiment 08: Conduct suitable tests to draw the equivalent circuit of single phase induction motor and determine performance parameters.

## 8.1 Learning Objectives

To conduct No load and block rotor test on single phase and three phase induction motor.

## 8.2 Aim

Draw the equivalent circuit of single phase induction motor and determine performance parameters

## 8.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | MI 0-300V | 1 No |
| 2 | Ammeter | MI 0-10A | 1 No |
| 3 | Wattmeter | MI 300V/10A,UPF | 1 No |
| 4 | 1-phase IM | 1HP, 230V, 7.6A,1500rpm | 1 No |
| 5 | 1-φ Auto-transformer | 230V/0-260V, 50Hz | 1 No |
| 6 | Tachometer | -- | 1 No |
| 7 | Connecting wires | -- | Few |

## 8.4 Theory

Single phase motors are similar in construction to poly phase squirrel cage induction motor with exception that the stator has single phase winding. Therefore in single phase motors rotating magnetic field if not produced, but only a pulsating field is produced. The torque is also pulsating and hence single phase motors are not self starting. In order to make them self starting, they are converted to two phase motors at starting. A centrifugal switch is used to cut off the starting winding after motor picks up full speed.

W' = average voltage x average current = V' I'a.

## 8.5 Procedure

**FOR NO LOAD TEST:-**

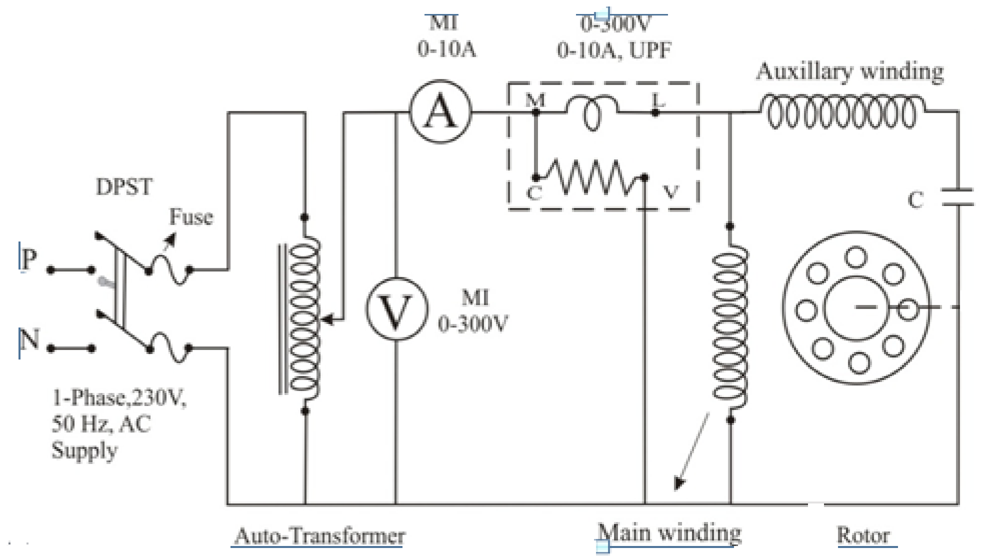
1. Connections are done as shown in the diagram.
2. Supply is switched on with dimmerstat in the minimum position.
3. A low voltage is applied at starting.
4. Gradually as motor picks up speed, the rated voltage is applied.
5. The corresponding meter readings are noted.

**FOR BLOCKED ROTOR TEST:-**

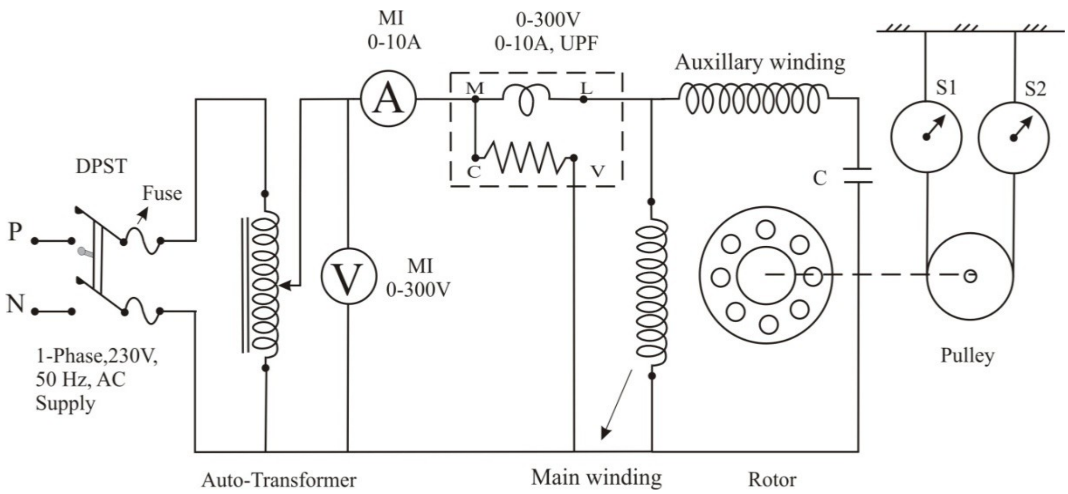
1. For this test, starting winding is disconnected.
2. A small voltage is applied so that the rated current of the motor flows.
3. Corresponding meter readings are noted. (No physical blocking is required since starting windings is not connected).
4. The resistance of stator winding is also measured.

## 8.6 Circuit Diagram

**FOR NO LOAD**




**FOR BLOCKED TOTOR:-**




## 8.7 Specifications & Tabulations

**Specifications:**

For Motor

Voltage _______V

Current _______Amps.

Power _______KW/HP

Speed _______rpm

**TABULATION:**

FOR NO LOAD TEST:

| $I_0$ Amps | $V_0$ Volts | $W_1$ Watts |
|---|---|---|
| | | |

FOR BLOCKED ROTOR TEST:

| $I_{SC}$ Amps | $V_{SC}$ Volts | $W_1$ Watts |
|---|---|---|
| | | |

## 8.8 Formula / Calculations

**FROM NO LOAD TEST**

Wattmeter reading $W_O$=....................W

Voltmeter reading $V_O$=........................V

Ammeter reading $I_O$=...........................A

$W_O = V_O I_O \cos \; o$

$\cos \Phi_O = \frac{W_O}{V_O I_O} =$....................

$\Phi_O =$....................degree,

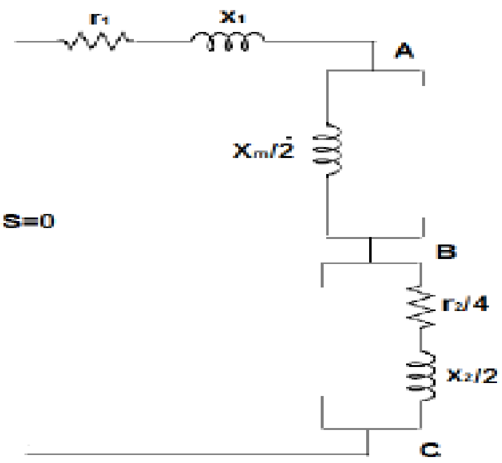
$Z_0 = \frac{V_0}{I_0}$=...............Ω

$X_0 = Z_0 . sin\varphi_0$=...............Ω

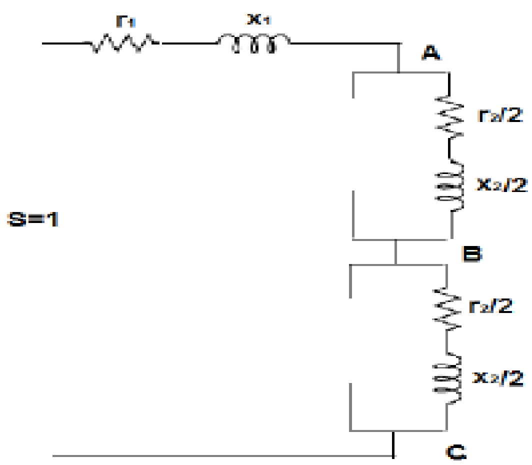
From No-load equivalent circuit, $X_0$ can be written as

$X_0 = X_1 + \frac{X_m}{2} + \frac{X_2}{2}$ (Note: $X_1 = X_2$)

$X_m = 2X_0 - 3X_1$




No load equivalent circuit




Blocked rotor equivalent circuit

**FROM BLOCKED ROTOR TEST**

Wattmeter reading $W_{sc}$ =.......................W

Voltmeter reading $V_{SC}$=.........................V

Ammeter reading $I_{SC}$=............................A

$W_{SC}=V_{SC}\, I_{SC} \cos\ sc$

$\cos\Phi_{SC} = \frac{W_{SC}}{V_{SC} I_{SC}}$ =....................

$\Phi_{SC}$ =.....................degree

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

$R_{sc} = Z_{sc}.cos\varphi_{sc}$=............Ω

$X_{sc} = Z_{sc}.sin\varphi_{sc}$=...............Ω

From blocked rotor equivalent circuit; $R_{sc}$ and $X_{sc}$ can be written a

$R_{sc} = r_1 + (2 * r_2/2) = r_1 + r_2$

$r_2 = R_{sc} - r_1$

Where $r_1 = 1.2R_a$

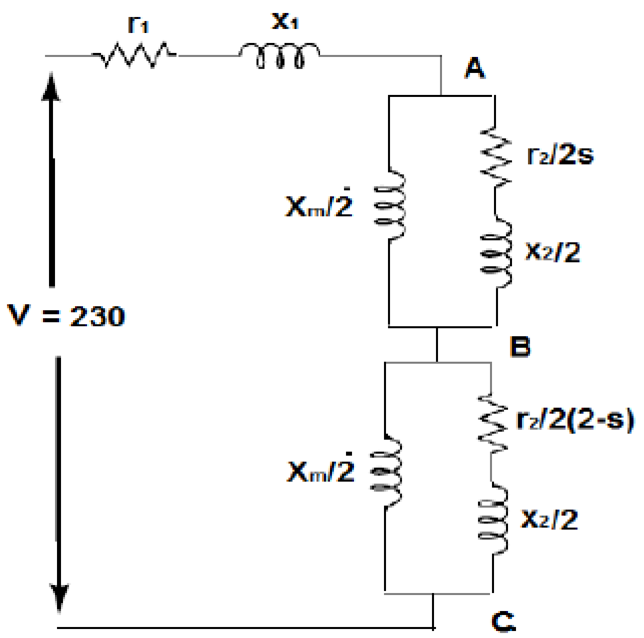
$X_{sc} = x_1 + x_2$

Assuming $x_1 = x_2$, we get

$x_1 = x_2 = X_{sc}/2$.

Thus all the equivalent circuit parameters have been determined.

The final equivalent circuit is given below.



**Current, power factor, efficiency and torque at slip = 5%**

Impedance between A & B = forward impedance

$$Z_f = \frac{\frac{jX_m}{2} * \left(\left(\frac{r}{2s}\right) + jx_2/2\right)}{\frac{jX_m}{2} + \left(\left(\frac{r}{2s}\right) + jx_2/2\right)}$$

$R_f$=Real part of forward impedance

$X_f$=imaginary part of forward impedance

Impedance between B & C = Backward impedance

$$Z_b = \frac{\frac{jX_m}{2} * \left(\left(\frac{r}{2(2-s)}\right) + jx_2/2\right)}{\frac{jX_m}{2} + \left(\left(\frac{r}{2(2-s)}\right) + jx_2/2\right)}$$

$R_b$=Real part of backward impedance

$X_b$=imaginary part of backward impedance.

Total impedance $Z_T = (r_1 + R_f + R_b) + j(x_1 + X_f + X_b) = X < \theta$ (in polar form)

Stator current I = V/$Z_T$

Power factor = cos$\theta$

Power input $P_i = VI\cos\theta$

Constant losses (friction, windage and iron loss), $W_c = W_0 - I_0^2[r_1 + r_2/4]$.

Net torque in synchronous watts = $T_f - T_b = I^2(R_f - R_b)$

Torque in Nm = $\frac{torque\ in\ synch\ watts}{2\pi N_s/60}$

Mechanical power delivered = $P_m = (T_f - T_b)(1-s)$ W

Shaft output = $P_s = P_m - W_c$ W

Efficiency =$(P_s/P_i) * 100$

## 8.9 Graphs / Outputs

## 8.10 Results & Analysis

## 8.11 Conclusion

## 8.12 Remarks

**Faculty Signature**

## 9.0 **Experiment 09:** Retardation test on DC Shunt motor.

## 9.1 Learning Objectives

To conduct test for pre-determination of the performance characteristics of dc machines

## 9.2 Aim

1) To separate the mechanical and iron losses of the given dc shunt machine.

2) Calculate the moment inertia of the rotating system.

## 9.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | 0-300V MC | 1 No |
| 2 | Voltmeter | 0-600V MI | 1 No |
| 3 | Ammeter | 0-10A MC | 1 No |
| 4 | Ammeter | 0-2A MC | 3 Nos |
| 5 | Tachometer | -- | 1 No |
| 6 | Rheostat | 1200Ω,0.6A | 1 No |
| 7 | Rheostat | 200Ω,2.8A | 1 No |
| 8 | Connecting wires | -- | Few |

## 9.4 Theory

Retardation test is also called as running down test.This is very efficient way to find out stray losses in dc shunt motors.In this test we get total stray losses nothing but combination of mechanical (friction & windage) and iron losses of the machine.

Without using flywheel, I is eliminated from the expression by an experiment. First, retardation test is performed with armature alone. The rotational losses are given by;

$$W = 0.011\ IN\ dN/dt_1$$

Next the motor is loaded with a known amount of power W' with a brake. For the same change in speed, $dN/dt_2$ is noted. Then,

$$W + W' = 0.011\ IN \frac{dN}{dt_2}$$

$$\therefore \quad \frac{W + W'}{W} = \frac{dt}{dt_2} = \frac{t_1}{t_2}$$

$$\frac{W'}{W} = \frac{t_1 - t_2}{t_2}$$

$$\therefore \quad W = W' \times \frac{t_1 - t_2}{t_2}$$

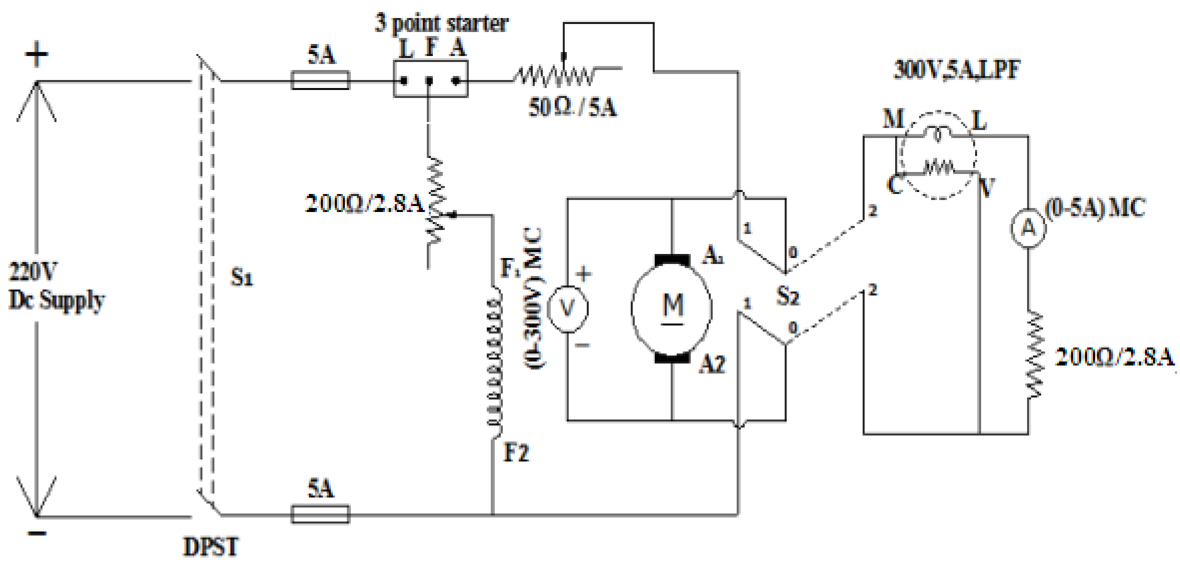
Since the values of W', $t_1$ and $t_2$ are known, the value of W can be determined.

The electric loading in retardation test W' (or extra power loss) is given by;
W' = average voltage x average current = V' I'a.

## 9.5 Procedure

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat at minimum position, armature rheostat at maximum position, load at
   Maximum position, and switch $S_1$ at open position and $S_2$ at position 1.
3. Switch on the power supply by closing the switch $S_1$ and start the motor using three point starter.
4. Adjust the armature and field rheostat to obtain a speed of 1600 rpm.
5. Now cut the power supply by opening the switch $S_1$.
6. Note down the time taken to reach 1200 rpm from 1600 rpm.
7. Repeat the step 1 to 4.
8. Now open the switch $S_2$ from position 1.
9. Note down the time taken to reach 1200 rpm from 1600 rpm.
10. Repeat the step 1 to 4.
11. Now move the switch $S_2$ from position 1 to position 2.
12. Note down the time taken to reach 1200 rpm from 1600 rpm.
13. Also note the wattmeter reading corresponding to 1200 rpm and 1600 rpm.
14. Calculate different losses and moment of inertia of DC machine by using relevant formula.

## 9.6 Circuit Diagram




## 9.7 Specifications & Tabulations

**Specifications:**

For Motor

Voltage : _______V

Current : _______Amps.

Power : _______KW/HP

Speed : _______rpm

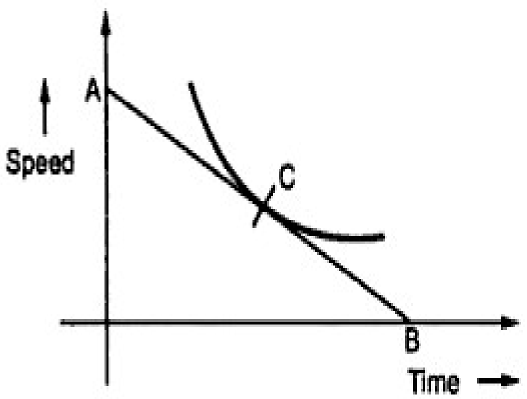
**TABULATION:**

| SL.NO | Switch positions | | Speed(rpm) | | Time taken (s) | Wattmeter reading (W) |
|---|---|---|---|---|---|---|
| | $S_1$ | $S_2$ | From | To | | |
| 1 | Open | Position 1 | 1600 | 1200 | | Nil |
| 2 | Closed | Open from Position 1 | 1600 | 1200 | | Nil |
| 3 | Closed | Move from position 1 to position 2 | 1600 | 1200 | | 1600rpm W1=<br>1200rpm W2= |

## 9.8 Formula / Calculations

W1 =………. (W)
W2 =……….. (W)
t1 =…………. (s)
t2 =…………. (s)
t3 =…………. (s)
Load loss, PL= (W1+W2)/2=……………… (W)
Stray loss, $Ps$=( t3/$t2-t3$) = ……………… (W)
Mechanical loss, $Pm=Ps$ (t2/$t1$)=…………….. (W)
Iron loss = Ps – Pm = ……………... (W)
Moment of Inertia, $I = (60/2\pi)^2 Pm/N \; dt1dN$

## 9.9 Nature of Graphs



## 9.10 Results & Analysis

## 9.11 Conclusion

## 9.12 Remarks

**Faculty Signature**

## 10.0 **Experiment 10:** Conduct an experiment to draw V and Λ curves of synchronous motor at no load and load.

## 10.1 Learning Objectives

To conduct test on synchronous motor to draw the performance curves.

## 10.2 Aim

Determination of 'V' and inverted 'V' curves of synchronous motor.

## 10.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | 0-300V MC | 1 No |
| 2 | Voltmeter | 0-600V MI | 1 No |
| 3 | Ammeter | 0-10A MI | 1 No |
| 4 | Ammeter | 0-2A MC | 3 Nos |
| 5 | Wattmeter | MI 600V/10A,LPF | 2 Nos |
| 6 | 3-phase Autotransformer | 415V/0-440V,10A | 1 No |
| 7 | Tachometer | -- | 1 No |
| 8 | Rheostat | 1200Ω,0.6A | 1 No |
| 9 | Rheostat | 200Ω,2.8A | 1 No |
| 10 | Connecting wires | -- | Few |

## 10.4 Theory

The value of excitation for which back e.m.f $E_b$ is equal (in magnitude) to applied voltage V is known as 100% excitation.

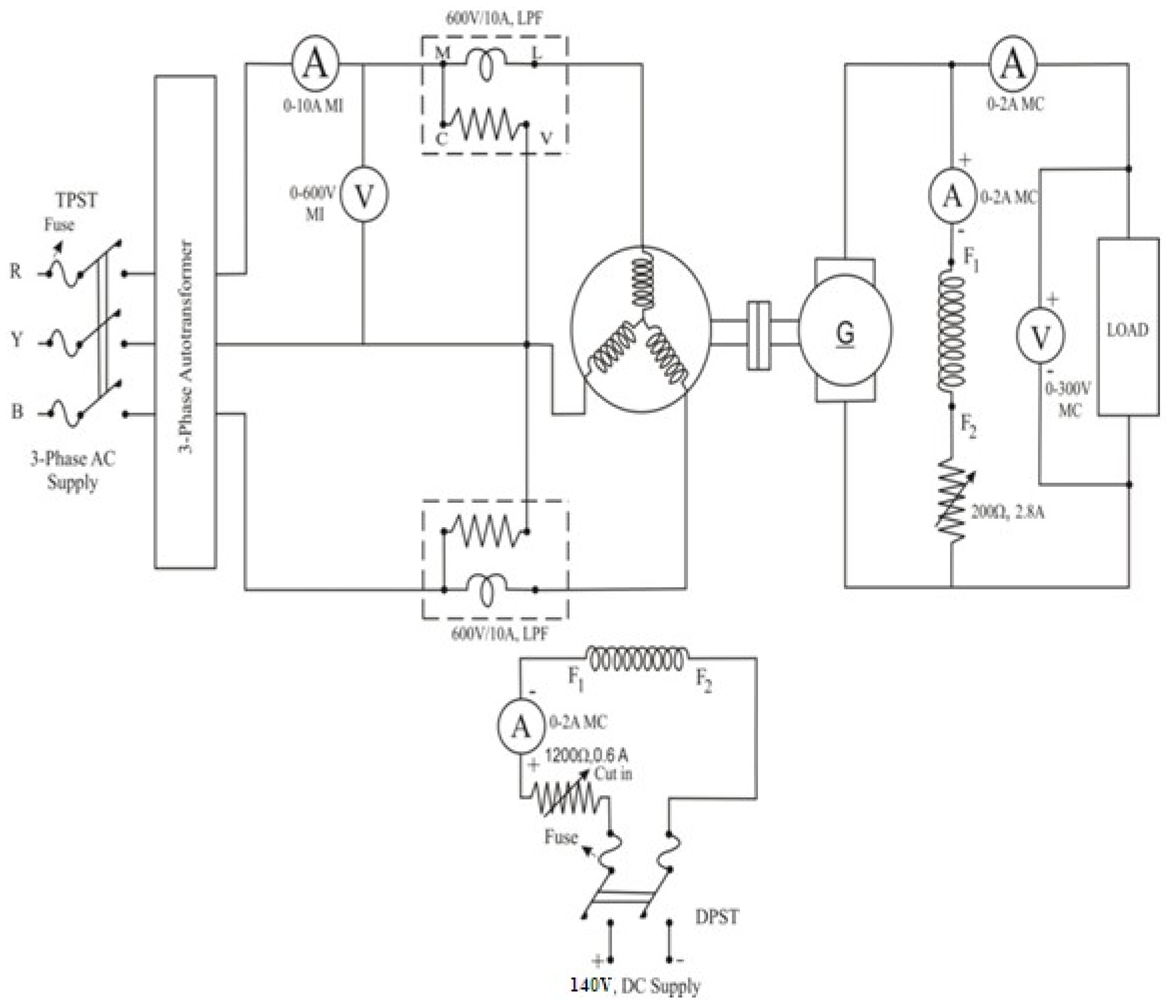
The magnitude of armature current varies with excitation. The current has large value both for low and high values of excitation (though it is lagging for low excitation and leading for higher excitation). In between, it has minimum value corresponding to a certain excitation. The variations of I with excitation are shown in nature of graph fig.(a) which are known a 'V' curves because of their shape.

For the same input, armature current varies over a wide range and so causes the power factor also to vary accordingly. When over-excited, motor runs with leading p.f and with lagging p.f. When under-excited. In between, the p.f. is unity. The variations of p.f. with excitation are shown in fig.(b). The curve for p.f. looks like inverted 'V' curve. It would be noted that minimum armature current corresponds to unity power factor.

## 10.5 Procedure

1. Connections are made as per the circuit diagram.
2. Keep the field rheostat (200Ω, 2.8A) of generator in cut in position and no load connected to generator side.
3. Keep the auto transformer to zero position.
4. Switch ON the mains supply and bring the synchronous motor to its rated voltage with the help of auto transformer.
5. Then excitation voltage (140V) is applied with the help of switch.
6. Go on varying the field of rheostat in motor circuit in steps, keeping the excitation voltage constant.
7. At each step note down the motor readings until the armature currents varies from maximum to minimum.
8. Bring all the components to original position and switch OFF the mains supply.

## 10.6 Circuit Diagram




## 10.7 Specifications & Tabulations

**Specifications:**

| For Motor | | For Generator | |
|---|---|---|---|
| Voltage | _______V | Voltage | _______V |
| Current | _______Amps. | Current | _______Amps. |
| Power | _______KW/HP | Power | _______KVA/KW |
| Speed | _______rpm | Speed | _______rpm |

**TABULATION:**

**For No Load:**

| S. No | Line Voltage Volts | Synchronous motor | | | | Generator | | | cosϕ |
|---|---|---|---|---|---|---|---|---|---|
| | | $I_f$ Amps | $I_a$ Amps | $W_1\times$ Watts | $W_2\times$ Watts | $V_{dc}$ | $I_{fg}$ | $I_{dc}$ | |
| 1. | | | | | | | | | |
| 2. | | | | | | | | | |
| 3. | | | | | | | | | |
| 4. | | | | | | | | | |
| 5. | | | | | | | | | |
| 6. | | | | | | | | | |
| 7. | | | | | | | | | |
| 8. | | | | | | | | | |

**For Load:**

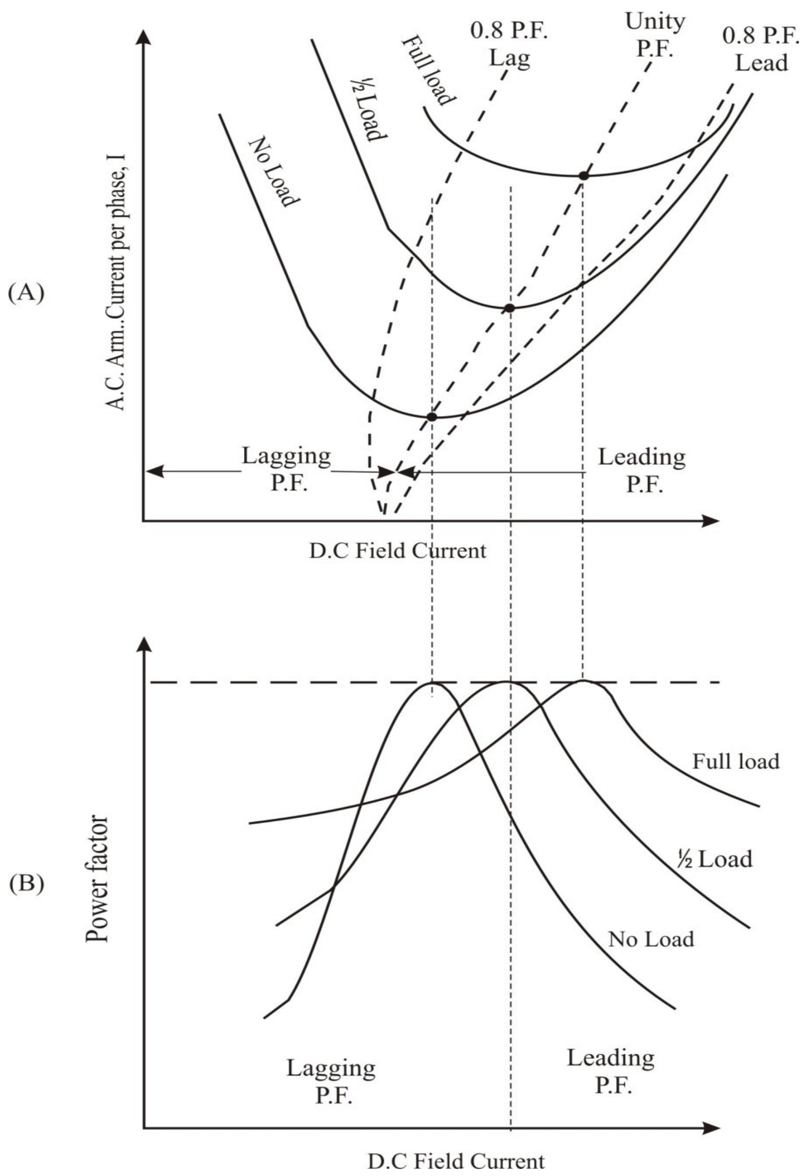
| S. No | Line Voltage Volts | Synchronous motor | | | | Generator | | | cosϕ |
|---|---|---|---|---|---|---|---|---|---|
| | | $I_f$ Amps | $I_a$ Amps | $W_1\times$ Watts | $W_2\times$ Watts | $V_{dc}$ | $I_{fg}$ | $I_{dc}$ | |
| 1. | | | | | | | | | |
| 2. | | | | | | | | | |
| 3. | | | | | | | | | |
| 4. | | | | | | | | | |
| 5. | | | | | | | | | |
| 6. | | | | | | | | | |
| 7. | | | | | | | | | |
| 8. | | | | | | | | | |

## 10.8 Formula / Calculations

$$\text{Wattmeter constant} = \frac{\text{Voltage range} \times \text{Current Range}}{\text{Full Scale Division of Wattmeter}}$$

$$\text{Cos}\phi = cos\left[tan^{-1}\left(\frac{\sqrt{3}(W_1-W_2)}{(W_1+W_2)}\right)\right]$$

## 10.9 Nature of Graph




## 10.10 Results & Analysis

## 10.11 Conclusion

## 10.12 Remarks

**Faculty Signature**

## 11.0 **Experiment 11:** Field test on DC series Motor.

## 11.1 Learning Objectives

To perform tests on dc machines to determine their characteristics

## 11.2 Aim

To determine the efficiency of the two given dc series machines which are mechanically coupled.

## 11.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | 0-300V MC | 1 No |
| 3 | Ammeter | 0-10A MC | 1 No |
| 4 | Ammeter | 0-2A MC | 2 Nos |
| 5 | Tachometer | -- | 1 No |
| 6 | Rheostat | 1200Ω,0.6A | 1 No |
| 7 | Rheostat | 200Ω,2.8A | 1 No |
| 8 | Connecting wires | -- | Few |

## 11.4 Theory

This test is applicable to two similar series motor. The two machines are coupled mechanically one machine runs normally as motor and drive the other as generator whose output is wasted in a variable load. Iron and friction losses of the two machines are made equal by joining the series field of the generator in the motor armature circuit so that both machines are equally excited. The load resistance is varied till the motor current reaches its full load value.

Testing of series motors in the laboratory is rather more difficult compared to testing of shunt motors. This is because:

(a) The field current varies over a wide range during normal working conditions of a series motor. Therefore, tests made at a constant excitation are no value.

(b) On no- load, the series motor attains dangerously high speed. So no – load test is not possible.

Field's Test is conducted on series machines to obtain its efficiency.

In this test,

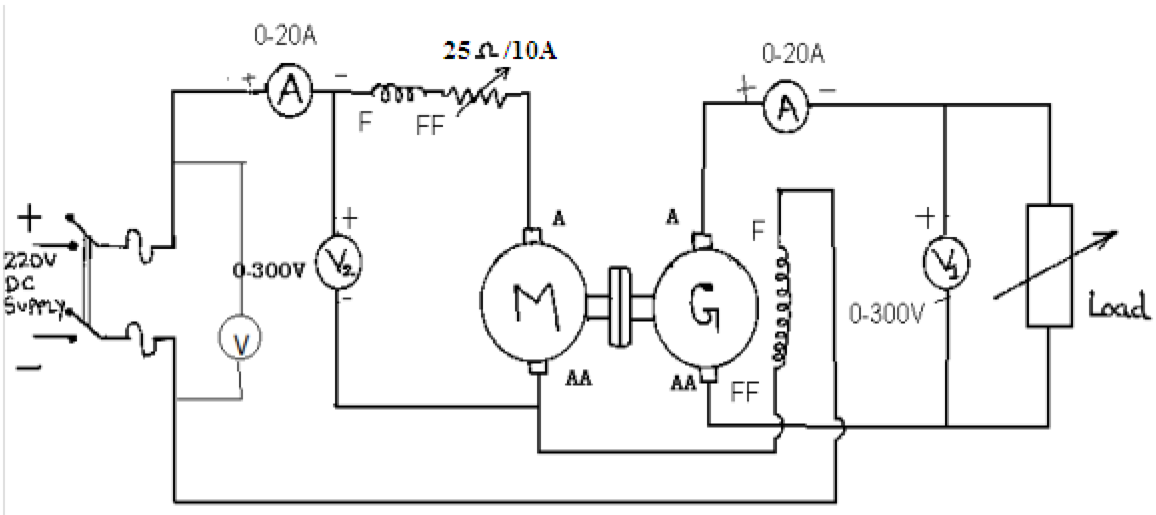
- Two similar rating series machines are mechanically coupled.
- One series machine runs as a motor and drives another series machine, which runs as a generator.

- The series field winding of the generator is connected in series with the motor series field winding as shown in the figure.
- This test is not a regenerative test.

## 11.5 Procedure

1. Note down the ratings of the dc series motor and dc series generator.
2. Set the dc drive potentiometers at zero positions.
3. Put a minimum load of 400W on the generator.
4. Connect the circuit as shown in the circuit diagram.
5. Push the START button and gradually increase the armature voltage and simultaneously add the loads till the armature current $I_a$ or $I_f$ reaches the rated value.
6. Reduce the loads one by one till the motor speed does not exceed 1800rpm.
7. Note down the readings at different loads.
8. Gradually, reduce the armature voltage of the prime mover.
9. Keep a minimum load of 400W and then switch off the supply.

## 11.6 Circuit Diagram




## 11.7 Specifications & Tabulations

**Specifications:**

For Motor

Voltage _______V

Current _______Amps.

Power _______KW/HP

Speed _______rpm

For Generator

Voltage _______V

Current _______Amps.

Power _______KVA/KW

Speed _______rpm

Armature resistance of the motor ($R_{a1}$) =

Series field resistance of the motor($R_{Se1}$) =

Armature resistance of the generator ($R_{a2}$) =

Series field resistance of the generator($R_{Se2}$) =

**TABULATION:**

| | | | | | | |
|---|---|---|---|---|---|---|
| Supply Voltage $V_1$ volts | | | | | | |
| Current drawn from the supply $I_1$ amps | | | | | | |
| Load Voltage $V_L$ volts | | | | | | |
| Load Current $I_L$ amps | | | | | | |
| Speed N rpm | | | | | | |

## 11.8 Formula / Calculations

Let $I_1$ = Current drawn from the supply
$V_1$ = Voltage across the motor or supply
$I_2$ = Current flows into the load
$V_2$ = Voltage across the load
Power drawn from the supply ($P_{in}$) = $V_1 I_1$ Watts
Power consumed in the load ($P_{out}$) = $V_2 I_2$ Watts
Total losses in the two machines ($W_L$) = ($V_1 I_1 - V_2 I_2$) Watts
Total copper losses in the two machines ($W_{Cu}$)= $I_1^2 (R_{a1} + R_{Se1} + R_{Se2}) + I_2^2 R_{a2}$
Stray losses in two machines (Iron losses + Mechanical losses) = $W_L - W_{Cu}$
Stray losses of each machine = $W_{Stray} = \frac{W_L - W_{Cu}}{2}$

***For motor:***
Power input to the motor $P_{in} = V_1 I_1 - I_1^2 R_{Se2}$
Total losses in the motor $W_{ml} = W_S + I_1^2 (R_{a1} + R_{Se2})$
Motor output = $P_{in} - W_{ml}$

% Efficiency of the motor $\eta_m = \frac{P_{in} - W_{ml}}{P_{in}} * 100$

***For Generator:***
Power input of the Generator $P_{out} = V_2 I_2$
Total losses in the Generator $W_{gl} = W_S + I_1^2 R_{Se2} + I_2^2 R_{a2}$
Input to the Generator $P_{in} = P_{out} + W_{gl}$
% Efficiency of the generator $\eta_g = P_{out}/P_{in} \times 100$
% $\eta_g = \frac{V_2 I_2}{V_2 I_2 + W_{gl}}$

## 11.9 Graphs / Outputs

## 11.10 Results & Analysis

## 11.11 Conclusion

## 11.12 Remarks

**Faculty Signature**

## 12.0 **Experiment 12:** Load test on Induction Generator.

## 12.1 Learning Objectives

To conduct load test on induction generator.

## 12.2 Aim

1) To operate the given 3 phase induction machine as i) induction motor and ii) Induction generator.

**2.** To obtain the overall efficiency vs. output charactereristics.

## 12.3 Material / Equipment Required

| S.no | Particulars | Range | Quantity |
|---|---|---|---|
| 1 | Voltmeter | MI 0-300V | 1 No |
| 2 | Ammeter | MI 0-10A | 1 No |
| 3 | Wattmeter | MI 300V/10A,UPF | 1 No |
| 4 | 1-phase IM | 1HP, 230V, 7.6A,1500rpm | 1 No |
| 5 | 1-φ Auto-transformer | 230V/0-260V, 50Hz | 1 No |
| 6 | Tachometer | -- | 1 No |
| 7 | Connecting wires | -- | Few |

## 12.4 Theory

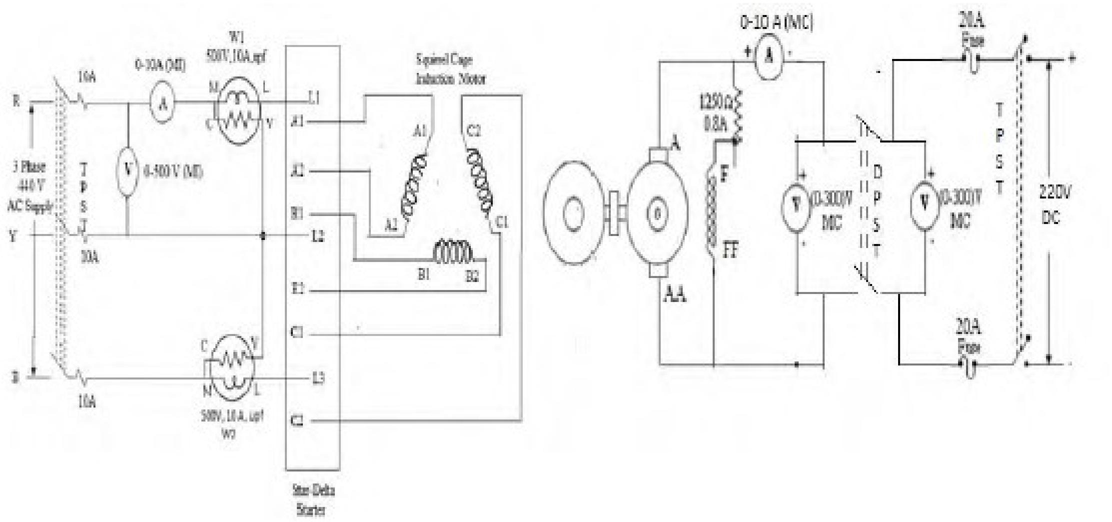
An induction motor running above its synchronous speed (super synchronous speed)
has negative slip and will act as a generator if the stator magnetizing current is supplied either from the synchronous mains or from a set of capacitors connected across its terminal. It's seldom used for the purpose of generator operation but finds application in the electrical braking purpose.

## 12.5 Procedure

1. Connections are done as shown in the diagram.
2. Keeping DPST in open position, start the set from the ac side using $\Upsilon / \Delta$ starter. If the direction of rotation is opposite to the marked direction for the DC machine, restart the induction motor after interchanging any two phases.
3. With the DPST open, the DC supply is switched on. Adjust the field rheostat such that the generated voltage and the DC supply voltage are equal in magnitude (check readings on $V_2$ and $V_3$ ). Also confirm that polarity is the same and if not interchange any two leads.

4. Now close the DPST switch to bring the DC machine in floating condition. Adjust the excitation in such a way that the DC machine acts as a generator and the induction machine continues to run as a motor. For this effect reduce the field rheostat resistance.
5. For different values of field current note all the meter readings. Now bring the field rheostat again to the floating condition and continue to decrease the excitation to make the DC machine run as a motor and the induction machine as a generator. The meter readings are noted for different values of field current.

## 12.6 Circuit Diagram




## 12.7 Specifications & Tabulations

1. Rated voltage =______V
2. HP=_______ HP
3. Voltage = _______V
4. Ampere =________A
5. RPM= ________

**For generator:**

| Operating mode | $I_{ac}$ (A) | $V_{ac}$ (V) | Wattmeter reading | | Output (W) | $I_{dc}$ (A) | $V_{dc}$ (V) | Input (W) | %η |
|---|---|---|---|---|---|---|---|---|---|
| | | | W1 | W2 | | | | | |
| Generating Action | | | | | | | | | |

## 12.8 Formula / Calculations

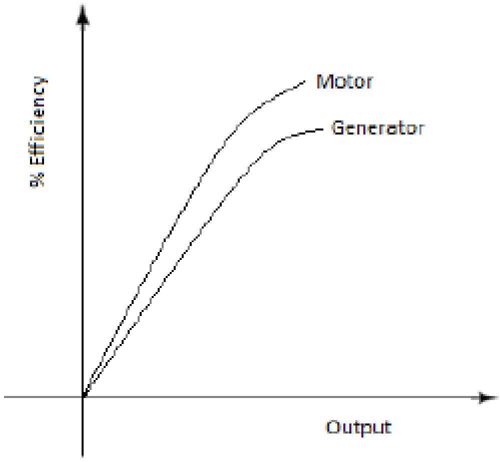
Generator Action

Input power $=I_{dc}*V_{dc}$ =..............watts

Output power = W1+W2=...........watts

% efficiency = (output/input)*100 =...........%

## 12.9 Nature of Graph




## 12.10 Results & Analysis

## 12.11 Conclusion

## 12.12 Remarks

**Faculty Signature**