## EXPERIMENT No. 5

# NO LOAD TESTS ON A DC SHUNT MOTOR

Name__________________________________________ ID No.______________________

Sec.No _______________________ Batch No.____________ Marks obtained____________

Date_________________________ Instructor's signature_____________________________

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## A. SWINBURNE'S TEST

### 1. Objective

To determine the performance of the given DC shunt machine in both generator and motor modes of operation.

### 2. Name plate ratings of the machine to be tested:

…………………………………………………………………………………………

…………………………………………………………………………………………

### 3. Range of Instruments and other Accessories

| S. No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
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## 4. Circuit Diagram

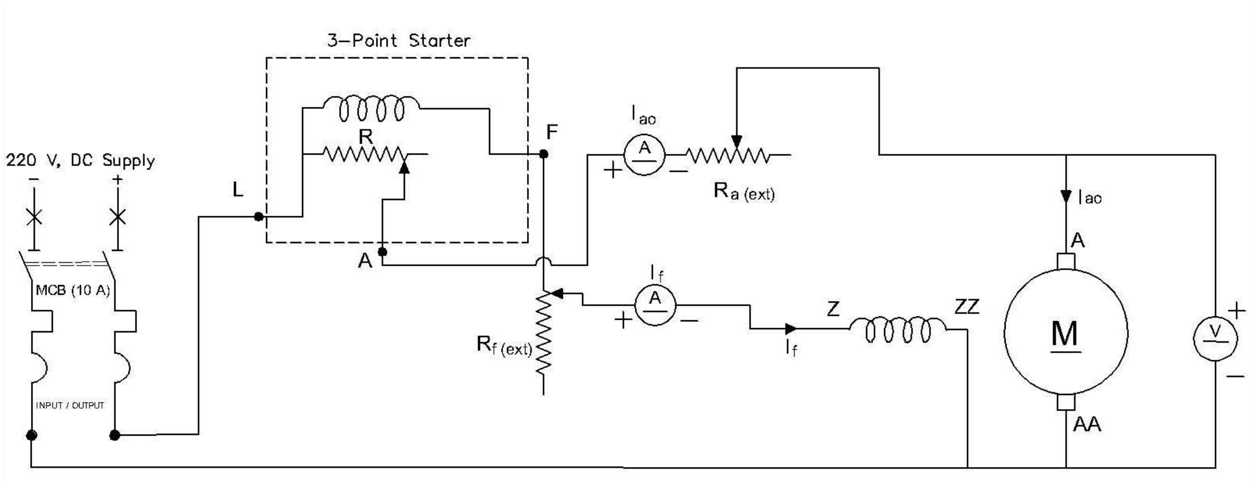


***Fig. 5.1***

## 5. Methodology

Connect the machine under test as in the circuit diagram of Fig. 5.1. Start the motor by including maximum external resistance ($R_a$) in armature circuit and fully cutting out regulating resistance ($R_f$) in the field circuit.

- Adjust external resistance in armature to give rated at voltage at machine terminals.
- Adjust regulating resistance in the field circuit to give rated speed at no–load.

### Readings

Applied voltage, V =

Armature current, $I_{a0}$ =

Field current, $I_f$ =

Now, measure the armature resistance by connecting a voltmeter across A–AA, an ammeter and an external resistance in series, across a DC source (do not connect field circuit).

$R_a =$

## 6. Calculations

$I_{L0} = I_{a0} + I_f =$

Constant loss, $P_k = \left(VI_{L0} - I_{a0}^2 R_a\right) =$

Armature copper loss (variable loss), $P_v = I_a^2 R_a =$

Total loss, $P_L = P_k + P_v =$

Efficiency can now be calculated as:

## Generator Operation

V = _______________,  $I_f$ = ________________,  $P_k$ = ______________,  $R_a$ = _____________

$I_{LFL} = I_{aFL} - I_f =$ ___________

| $I_L$ (% of $I_{LFL}$) | 20 | 40 | 60 | 80 | 100 | 120 |
|---|---|---|---|---|---|---|
| $P_{out} = VI_L$ | | | | | | |
| $I_a = I_L + I_f$ | | | | | | |
| $P_v = I_a^2 R_a$ | | | | | | |
| $P_L = P_k + P_v$ | | | | | | |
| $P_{in} = P_{out} + P_L$ | | | | | | |
| Efficiency (%) | | | | | | |

## Motor Operation

**V = _______________,  $I_f$ = ________________,  $P_k$ = ______________,  $R_a$ = _____________**

$I_{LFL} = I_{aFL} + I_f =$ ___________

| $I_L$(% of $I_{LFL}$) | 20 | 40 | 60 | 80 | 100 | 120 |
|---|---|---|---|---|---|---|
| $P_{in} = VI_L$ | | | | | | |
| $I_a = I_L - I_f$ | | | | | | |
| $P_v = I_a^2 R_a$ | | | | | | |
| $P_L = P_k + P_v$ | | | | | | |
| $P_{out} = P_{in} - P_L$ | | | | | | |
| % Efficiency | | | | | | |

**Sample Calculation:**

**a) Generator mode**

**b) Motor mode**

**7. Graph to be drawn**

1. Efficiency vs. output (kW) for generator operation
2. Efficiency vs. output (kW) for motor operation

**8. Results**

## B. SPEED CONTROL OF A DC MOTOR (NO-LOAD)

**1. Introduction**

The DC motors are, in general, much more adaptable speed drives than AC motors. The speed of DC motor depends upon the following relations.

$$n = K_n \left( \frac{V_a - I_a R_a}{\varphi} \right) \tag{2.5}$$

where $V_a$ = voltage across armature terminals

Armature voltage drop is quite small and can be ignored. Thus,

$$n \approx K_n \left( \frac{V_a}{\varphi} \right) \tag{2.6}$$

As per the magnetization characteristic,

$$\varphi = F(I_f); \quad \text{(F is function of)} \tag{2.7}$$

So from eq. (2.6),

$$n = K_n \left( \frac{V_a}{F(I_f)} \right) \tag{2.8}$$

In the linear region of magnetization, $\varphi = K_f I_f$ and so

$$n = K_n \left( \frac{V_a}{I_f} \right) \tag{2.9}$$

This equation gives two methods of speed control.

Variation of field excitation (keeping $V_a$ constant): Field control.

Variation of voltage across armature ($V_a$) (keeping field current constant): Armature control.

**2. Objective**

To obtain the speed control characteristics of a DC motor at no load.

**3. Name plate rating:**

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

**4. Rating of instruments and accessories (standard format)**

| S. No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
| | | | | | |
| | | | | | |
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| | | | | | |
| | | | | | |

**5. Connection Diagram**

The circuit diagram for speed control is given in Fig.2.1.

**6. Methodology**

**Field Control**

Start the motor with field regulating resistor ($R_f$) at minimum value and armature resistance ($R_a$) at maximum value. Increases $R_f$ till the machine runs at rated r.p.m. Further, increase the field resistance $R_f$ and note down the speed for the corresponding value of field current.

Take one more set of reading at about 20% lower than rated $V_a$.

**Readings**

**1) $V_a$ = ____________________.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $I_f$ | | | | | | | |
| N | | | | | | | |

**2) $V_a$ = ___________________.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $I_f$ | | | | | | | |
| N | | | | | | | |

**Armature Control**

Here, since speed is directly proportional to the armature voltage, keeping field current constant, speed lower than rated can be obtained.

Now, connect the motor as in Fig.2.1. Switch on the mains and run the machine at rated r.p.m. as in field control. Keeping field current constant, vary the voltage across armature by adjusting $R_a$. At each value of voltage across armature, note the corresponding speed.

This method is however not suitable for big machines, where Ward–Leonard test is employed.

Take one more set at about 20% lower $I_f$.

**Readings**

**1) $I_f$ = __________________.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $V_a$ | | | | | | | |
| n | | | | | | | |

**2) $I_f$ = __________________.**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| $V_a$ | | | | | | | |
| n | | | | | | | |

## 7. Calculations: NIL

## 8. Graphs to be drawn

1. Speed vs. field current (field control)
2. Speed vs. voltage across armature (armature control)

## 9. Results

The speed characteristics are as shown in the graphs

## EXPERIMENT No. 6

# NO LOAD TESTS ON DC SHUNT GENERATOR

Name________________________________________ ID No.______________________

Sec.No ______________________ Batch No.____________ Marks obtained____________

Date_________________________ Instructor's signature_____________________________

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**A. Open-Circuit Test**

**B. Critical Speed of a DC Shunt Generator**

## A. OPEN–CIRCUIT TEST

### 1. Objective

To obtain the magnetization characteristic, and determine the critical field resistance and critical speed of the given DC shunt generator.

### 2. Name plate ratings:

………………………………………………………………………………………………

………………………………………………………………………………………………

### 3. Range of instruments and accessories (standard format)

| S.No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
| | | | | | |
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## 4. Connection Diagram

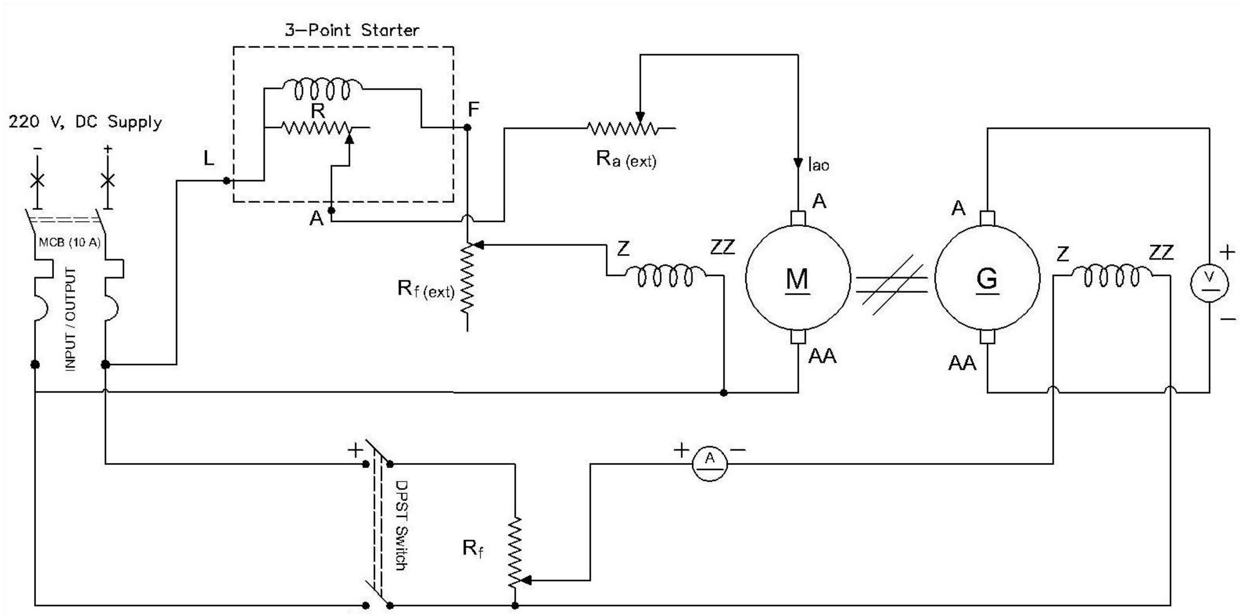


*Fig.6.1*

## 5. Methodology

1. Connect the generator as shown in Fig.6.1
2. Switch on the DC mains.
3. Start the DC motor and adjust to the rated speed of the generator.
4. Slowly increase the voltage across generator field with the help of jockey of the potential divider. Note down the induced e.m.f. and field current.
5. Repeat the process until the voltage reads 20% more than the rated value. Throughout the experiment the speed is kept constant at the rated value.

**Readings**

Residual voltage before introducing the field =

Rated speed, n =

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| $I_f$ | | | | | | | | | | |
| $E_a$ | | | | | | | | | | |

## 6. Calculations: NIL

7. **Graph to be drawn**

   (1) Magnetization characteristics

8. **Results**

   (a) Critical field resistance $R_c$ at rated speed (from the graph) =

   (b) Critical speed at $I_f$, corresponding to rated e.m.f. =

## B. Critical Speed of a DC shunt Generator

1. **Objective**

   To determine the critical speed of a DC generator.

2. **Name plate ratings:**

   ……………………………………………………………………………………………

   ……………………………………………………………………………………………

3. **Range of instruments and accessories (standard format)**

| S.No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
| | | | | | |
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4. **Connection Diagram:**

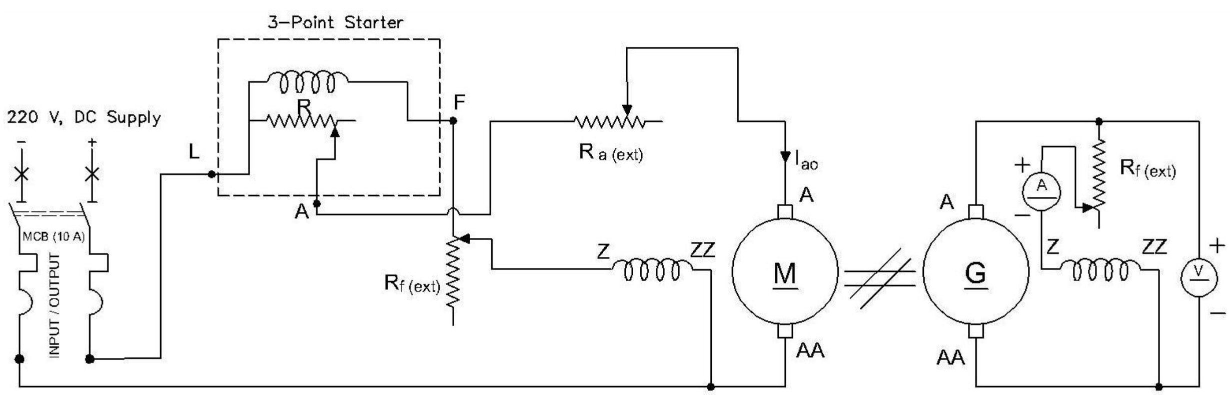


*Fig.6.2*

## 5. Methodology

1. Connect as shown in Fig.6.2
2. Switch on the mains.
3. Adjust the speed of the motor to the rated of generator.
4. Keeping the field circuit resistance unaltered, reduce the speed by armature control. Note down the speed and e.m.f. induced.

### Readings

Field current, $I_f$ =

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| N | | | | | | | | | | |
| $V_0 = E_a$ | | | | | | | | | | |

## 6. Calculations: NIL

## 7. Graph to be drawn

(1) e.m.f. induced vs. speed

## 8. Results

(a) Critical speed at $I_f$, corresponding to rated e.m.f. =

(b) Critical speed of Generator =

## EXPERIMENT No.7

# TESTS ON A THREE-PHASE INDUCTION MOTOR

**Name________________________________________ ID No.______________________**

**Sec.No __________________ Batch No.____________ Marks obtained _______________**

**Date_________________________ Instructor's signature ___________________________**

**-----------------------------------------------------------------------------------------------------------**

## 1. Objective

To determine the circuit model parameters and estimate the performance of a three-phase induction motor.

## 2. Name plate ratings:

**…………………………………………………………………………………………………**

**…………………………………………………………………………………………………**

## 3. Range of instruments and other accessories (standard format)

| S.No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
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## 4. Connection Diagram

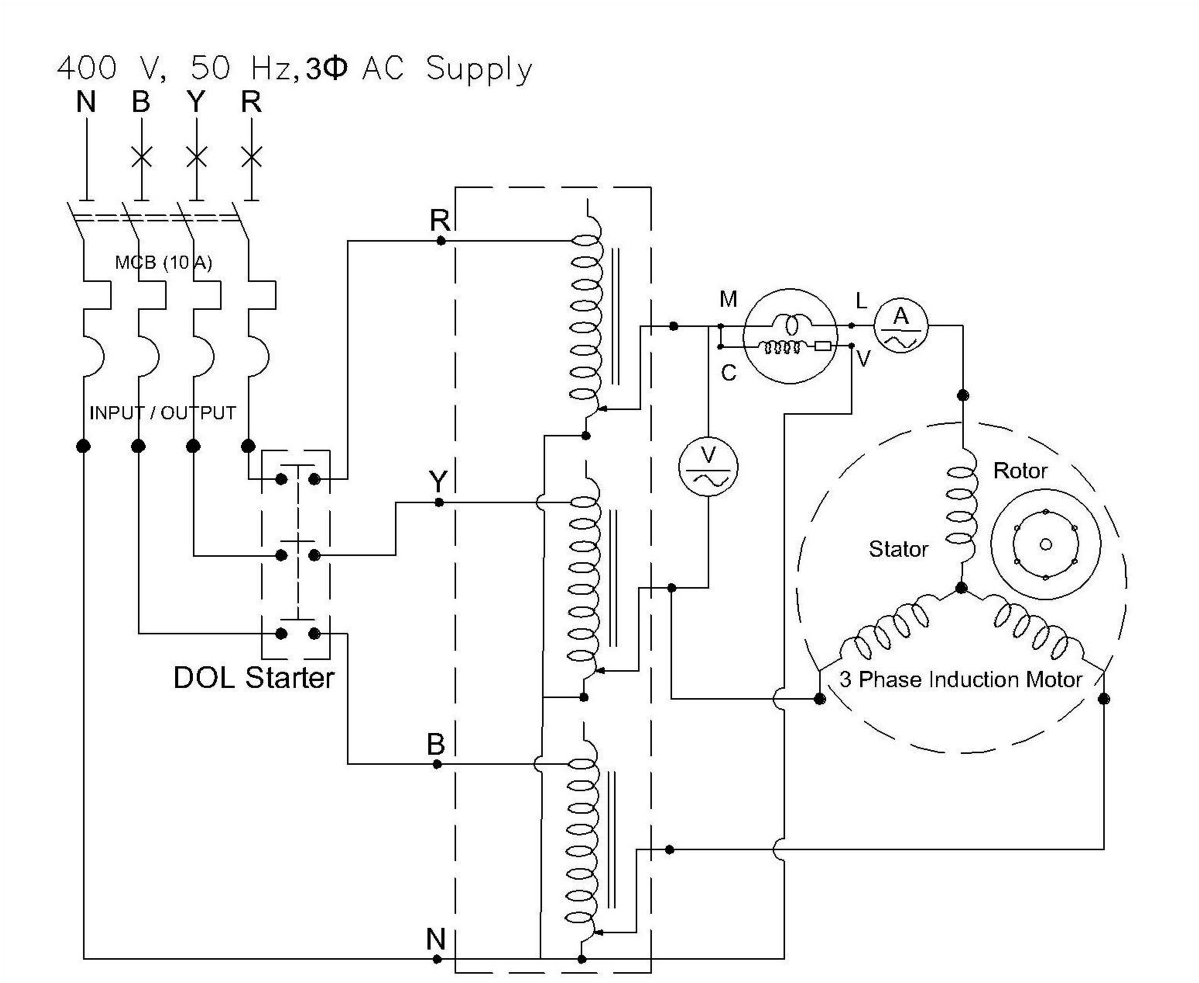



*Fig.7.1.Circuit diagram no load tests on 3 phase IM*

## 5. Methodology

**No-load Test**

Turn the variac handle to zero voltage position, switch on the mains and gradually raise the variac voltage to start the motor. Set the variac handle to a position so as to feed this motor at rated three-phase voltage.

### Readings

Input voltage (line), $V_L$ =

Input current (line), $I_{OL}$ =

Wattmeter reading, W =

Input power, $P_{OT}$ = Iron loss + Windage and friction loss = (3×W) =

**All calculations are done on per phase basis.**

Input voltage (phase), $V_0$ =

Input current (phase), $I_0$ =

Input power (phase), $P_0$ =

**Blocked Rotor Test**

The shaft is held tight so that the rotor is prevented from rotating. With variac in zero position, switch on the mains. Gradually raise the voltage till the motor current reaches full-load value.

### Readings

Input voltage (line), $V_{BRL}$ =

Input current (line), $I_{BRL}$ =

Wattmeter reading, W =

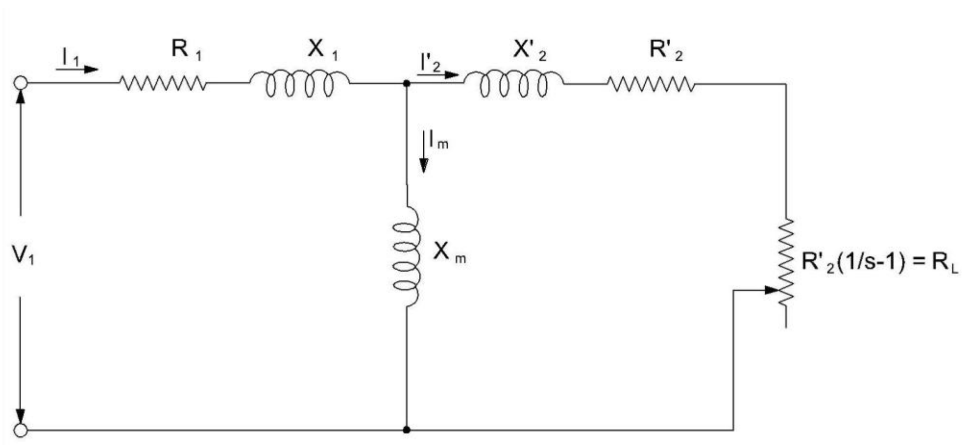
Input power, $P_{BRT}$ = copper losses = (3×W) =

**All calculations are done on per phase basis.**

Input voltage (phase), $V_{BR}$ =

Input current (phase), $I_{BR}$ =

Input power (phase) $P_{BR}$ =




**Measurement of stator resistance**

Apply a DC source across two terminals of motor (stator) and read values of voltage and current.In case of a star-connected machine, anyone of the line terminal and the neutral terminal can be used.But for delta connected machine, the resistance thus measured is a combination of r (resistance per phase of delta winding) and 2r connected in parallel. The value of r can now be calculated.

Average value of stator DC resistance (per phase), $R_1$ =

## 6. Calculations

$$Z_0 = \left( \frac{V_0}{I_0} \right) =$$

$$R_0 = \left( \frac{P_0}{I_0^2} \right) =$$

$$X_0 = \sqrt{\left( Z_0^2 - R_0^2 \right)} =$$

$X_m = \left( X_0 - X_1 \right) =$ (X$_1$ is to be obtained from B.R. test)

Rotational losses of the induction motor, $P_r = \left( 3P_0 - 3I_0^2 R_1 \right) =$

$$Z_{BR} = \left( \frac{V_{BR}}{I_{BR}} \right) =$$

$$R_{BR} = \left( \frac{P_{BR}}{I_{BR}^2} \right) =$$

$$X_{BR} = \sqrt{\left( Z_{BR}^2 - R_{BR}^2 \right)} =$$

$$X_{BR} = X_1 + X_2^{'} =$$

$X_1 = X_2^{'} = \left( \frac{X_{BR}}{2} \right) =$ (Assumption)

$$R_2^{'} = \left( R_{BR} - R_1 \right) \left( \frac{X_m + X_2^{'}}{X_m} \right)^2 =$$

Draw the circuit model indicating the values of the parameters calculated above.

Induction Motor performance can be computed by the following methods:

(a) From equivalent circuit

(b) From circle diagram.

**(a) Determination of performance characteristics from equivalent circuit:**

**Determine the following.**

Rated voltage (phase), V =

$X_1 + X_2^{'} =$

$R_1 + R_2^{'} =$

Load resistance, $R_L = \left( \frac{R_2^{'}(1-s)}{s} \right) =$

Synchronous speed, $n_s$ = r.p.m.;

$\omega_s$ = rad/s.

$\cos \theta_0 = \frac{P_0}{V_0 I_0} =$

No-load current (phase), $\overline{I_0} = I_0 \angle(-\theta_0) =$

| Slip, s = | 0.0 | 0.01 | 0.02 | 0.04 | 0.06 | 0.08 | 0.1 | 0.3 | 0.5 | 0.7 | 0.85 | 1.0 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| $R_L$ = | | | | | | | | | | | | |
| $R_1 + \left( \frac{R_2^{'}}{s} \right) =$ | | | | | | | | | | | | |
| $Z_2^{'} = \left( \left( R_1 + \frac{R_2{'}}{s} \right) + j\left(X_1 + X_2^{'}\right) \right) =$ | | | | | | | | | | | | |
| $I_2^{'} = \left( \frac{V}{Z_2^{'}} \right) \angle \theta_2 =$ | | | | | | | | | | | | |
| $I_L = \lvert I_L \rvert \angle \theta = I_0 + I_2^{'} =$ | | | | | | | | | | | | |
| $P_{in} = 3VI_L \cos \theta =$ | | | | | | | | | | | | |
| $P_{out} = 3I_2^{'2} R_L - P_r =$ | | | | | | | | | | | | |
| Efficiency, $\eta = \left( \frac{P_{out}}{P_{in}} \right) =$ | | | | | | | | | | | | |
| Power factor, cos θ = | | | | | | | | | | | | |
| Torque, $T = \left( \frac{3I_2^{'2} R_2^{'} / s}{\omega_s} \right)$ | | | | | | | | | | | | |

## 7. Graphs:

Draw the torque-slip characteristics.

**8. Results:** Estimate the starting torque, maximum torque and slip at maximum torque.

**EXPERIMENT No. 8**

# LOAD TEST ON SYNCHRONOUS MACHINE

Name_____________________________________________ ID No.______________________

Sec.No _______________________ Batch No._____________ Marks obtained_____________

Date__________________________ Instructor's signature______________________________

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## 1. Objective

1. To start and synchronize the synchronous machine (SM) to the bus-bars.
2. To conduct load test on the SM as a motor.
3. To conduct load test on the SM as a generator.

## 2. Name plate ratings:

……………………………………………………………………………………………

……………………………………………………………………………………………

## 3. Range of instruments and accessories (standard format)

| S.No. | DESCRIPTION | TYPE | RANGE | MFR. NAME | MFR. NO. |
|---|---|---|---|---|---|
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| | | | | | |
| | | | | | |

## 4. Connection Diagram

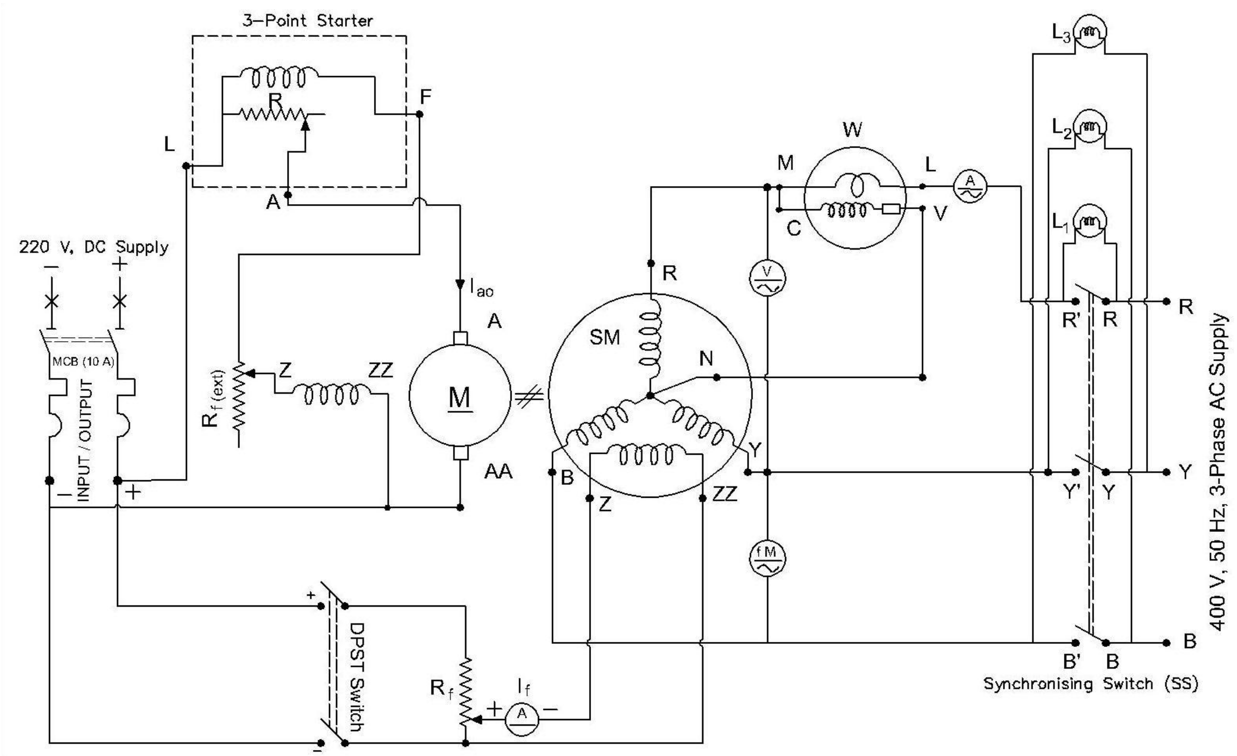


*Fig. 8.1*

## 5. Methodology

### Starting and Synchronization

Keeping the synchronizing switch open, start the DC motor which acts as a prime-mover for the SM which at present acts as an open-circuited generator. Adjust the set speed by adjusting the DC motor field regulator and the field current of SM by its field potentiometer such that the machine voltage and frequency are nearly the same as that of the bus-bars. This can be checked by means of DPDT switch. The set of synchronizing lamps ($L_1$, $L_2$, and $L_3$) are wired in a sequence. Each of the lamp (or pair of lamps) will go bright and dark alternatively and will light up in sequence giving a flicker. In other words, when the frequencies are very close to each other, there is hardly any flickering and the glow of lamps is nearly stable. Direction of light sequence indicates the frequency which is higher or lower. Switch on the synchronizing switch at the instance when $L_1$ is dark and $L_2$ and $L_3$ are equally bright (In case the operation is delayed, wait for such occurrence in the second cycle).

The SM is now synchronized to the bus-bars and is in a floating state.

**A. Load Test on Synchronous Generator**

1. The machine is floating on the mains.
2. Decrease the field excitation of the DC machine. The field current decreases and correspondingly the speed should increase. But as the machine is synchronized to the bus-bars, its speed can't change. So $E_g$ decreases, resulting in more power being drawn from the mains. Therefore, mechanical power being supplied to the SM increases which then act as a generating machine, feeding power to the bus-bars.
3. Gradually reduce the SM field current by increasing its regulating resistance. The SM armature current will pass through a minimum value (at unity pf) and then begin to increase. Do not permit it to exceed 4.0 A and take readings indicated below.
4. Decrease the field excitation of the DC machine further. Keeping the input to the DC motor constant at the new value, repeat step 3. Record the readings in Tables.

## 6. Calculations

**Power factor, (pf) =** $\cos\theta = \dfrac{P_{in}}{\sqrt{3}V_L I_g} =$

**Set 1: $P_{in}$ (kW) =**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **$I_f$ (A)** | | | | | | | |
| **$I_g$ (A)** | | | | | | | |
| **pf** | | | | | | | |

**Set 2: $P_{in}$ (kW) =**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **$I_f$ (A)** | | | | | | | |
| **$I_g$ (A)** | | | | | | | |
| **pf** | | | | | | | |

## 7. Graphs to be drawn

(a) V-curve, $I_a$ vs. $I_f$ at a particular load.

(b) Inverted V-curve, pf vs. $I_f$ at a particular load.

## 8. Results

V-curves and inverted V-curves of the given synchronous generator are as shown in graph.