SYNCHRONOUS MOTORS

Generator can run as a Motor. Similarly, if a Three phase supply is given to the stator of a 3-phase ator, it works as a motor. The Motor or device which converts Electrical energy into Mechanical energy n at synchronous speed is called **Synchronous Motor**.

Synchronous Motors works on at synchronous speed and cannot work other than synchronous speed and ed is also constant irrespective of load. The synchronous motor run at synchronous speed is given by

$$N_s = \frac{120f}{P} \quad (3.101)$$

ed of rotation which depends upon the frequency of the source. If the frequency is fixed and the motor onstant speed irrespective of load or three phase supply voltage.

Synchronous Motor are not used so much because the above motor run at constant speed. The eristics features are follows:

They run at Synchronous speed. The speed can be changed by changing the frequency.

$$N_s = \frac{120f}{P} \quad (3.102)$$

It is Not inherently self starting.

It can be operated at Wide range of power factor bond, leading and lagging.

erent applications at synchronous motor are as follows :

The Power house or Power station but has connection to improve the power factor.

The constant speed equipment applications such as Fans, Blowers, Centrifugal pump, Air compressors. Motor generator set, etc.

It is used is the mill industries such as Textile mills, Rubber mills, Cement factory.

nstruction of Three phase Synchronous Motor

achine there is no constructional difference between the generator and motor. Similarly, there is no onal difference between Synchronous Motor and Alternator both are considered as synchronous

hronous Motor is a machine which operates at synchronous speed and converts Electrical energy anical energy. The Schematic diagram for Three phase Synchronous Motor as shown in Fig 3.74. The us Motor has the following 2-parts: Stator and Rotor

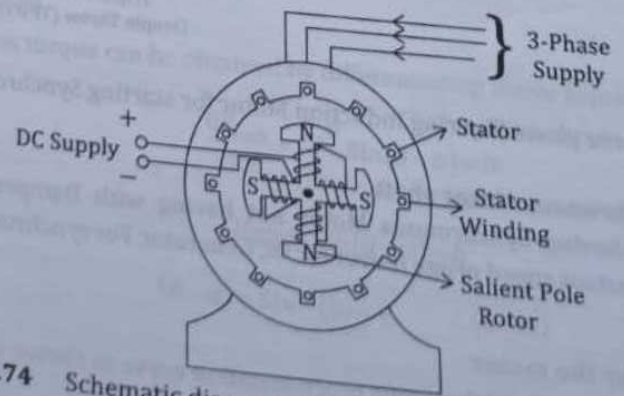


Fig3.74 Schematic diagram of Three phase Synchronous Motor

3.9.2 Method of Starting

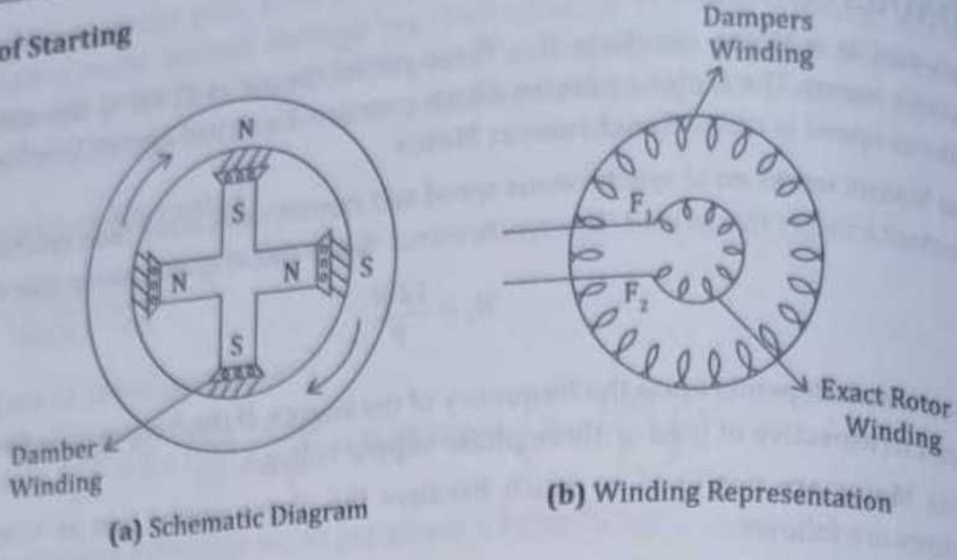


Fig 3.76 Damper winding provided for Starting Synchronous Motor

winding of an Induction Motor. The Schematic diagram of Damper winding with Synchronous Motor as shown in Fig.3.76

By using Slip ring Induction Motor

The Slip ring Induction Motor starting method as shown in Fig.3.77. The Main elements are: 3-Three phase Star or Delta winding provided for stator and rotor, slip ring and brushed DC Supply through Triple Pole Double Throw (TPDT) switch with starting resistance.

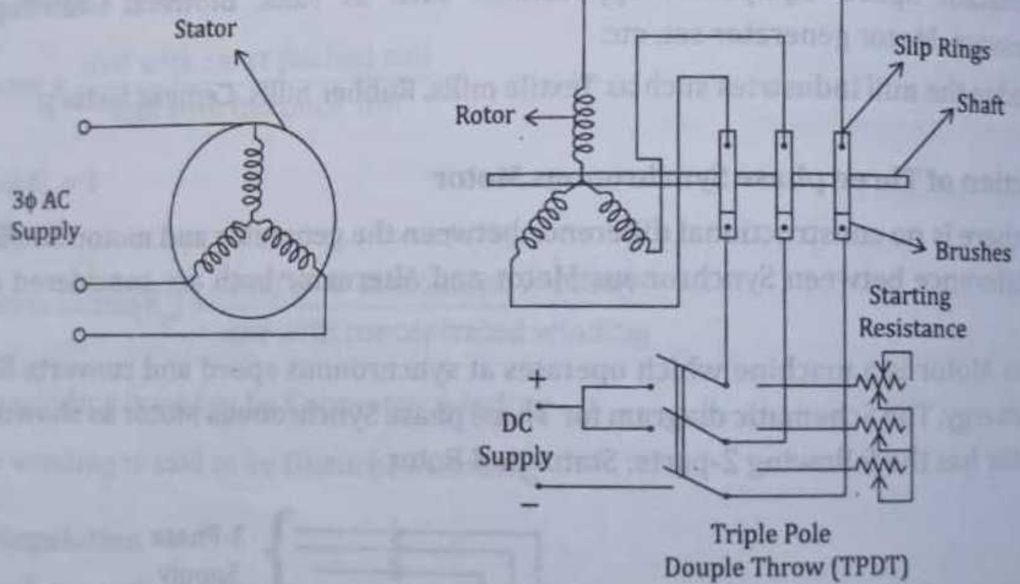


Fig 3.77 Three phase Slip ring Induction Motor for starting Synchronous Motor

DC Motor coupled to Synchronous Motor shaft

In some times laboratory having Synchronous Motor not having with Damper winding. Generally, the Synchronous motor with constant speed prime mover for DC Generator. For synchronisation, the DC Generator is operated as motor.

3.9.3 Torque developed by the motor

The Torque developed by the motor and the Angle representation curve as shown in Fig3.78.

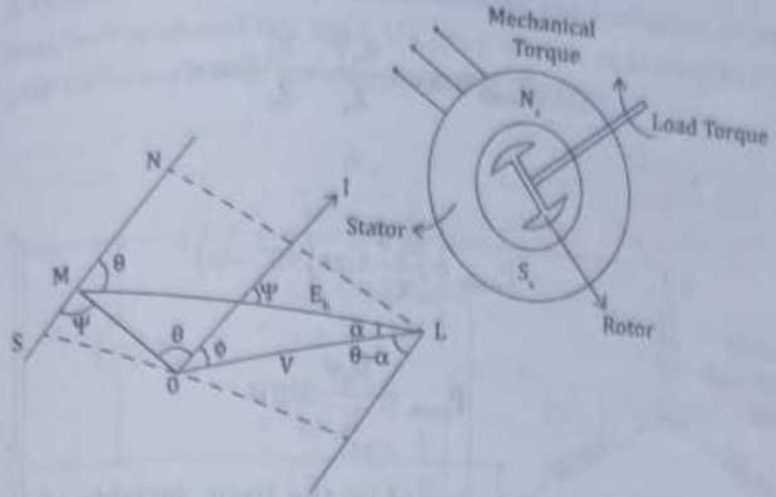


Fig 3.78 Torque developed by motor and the angle changes

OL = Supply voltage per phase
I = Armature current
LM = Back emf at load angle α
OM = Resultant voltage
The internal angle between I lags and lead V by angle φ and lags behind E_b

$$\theta = \tan^{-1}\left(\frac{X_s}{R_a}\right) \tag{3.104}$$

Mechanical power developed per phase

$$P_{mech} = E_b I \cos\Psi$$

$$P_{mech/phase} = E_b\left[\frac{V}{Z_s}\cos(\theta-\alpha) - \frac{E_b}{Z_s}\cos\theta\right] \tag{3.105}$$

$$P_{mech/phase} = \frac{E_b V}{Z_s}\cos(\theta-\alpha) - \frac{E_b^2}{Z_s}\cos\theta$$

The expression for Mechanical power developed interms of Load angle (α) and Internal angle (θ) of motor depends on constant voltage (V) and back emf (E_b).

Maximum Power Developed

The condition for Maximum torque can be obtained by differentiating above express.

$$\frac{dP_{mech}}{d\alpha} = \frac{E_b V}{Z_s}\sin(\theta-\alpha) = 0$$

$$\text{Hence } \sin(\theta-\alpha) = 0$$

$$(\theta-\alpha) = \sin^{-1}(0) = 0 \qquad \therefore (\theta-\alpha)$$

Value of maximum power

$$P_{mech}\max = \frac{E_b V}{Z_s} - \frac{E_b^2}{Z_s}\cos\alpha$$

When $\cos\theta = 0$

$$P_{mech} = \frac{E_b V}{X_s}\cos(90^\circ - \alpha)$$

$$P_{mech} = \frac{E_b V}{X_s}\sin\alpha$$

(3.106)

The value of mechanical power developed interms of 'α' the basic variable of synchronous machine. The torque versus coupling angle characteristics curve as shown in Fig 3.79.

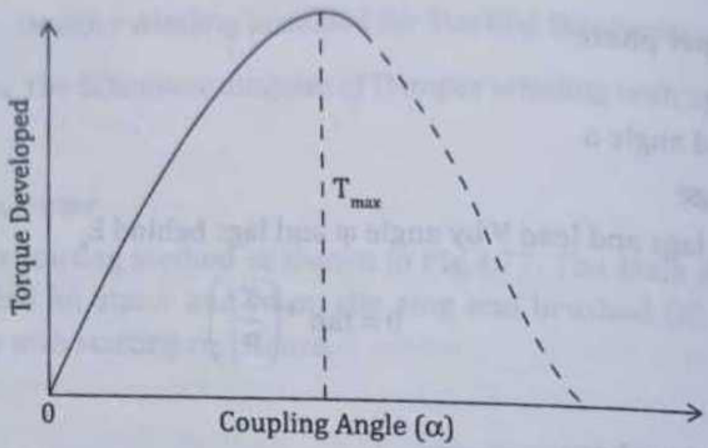


Fig 3.79 Torque versus Coupling angle Characteristic curve

3.9.4 V-curves for Synchronous Motor

The Synchronous Motor in which the Mechanical load is constant and the Output power is constant in case the losses are neglected.

Case 1 : For 100% Excitation

In 100% excitation the back emf is equal to applied voltage ($E_b = V$) and current (i) lags behind the voltage (V) by the small angle of φ and

$$\tan\theta = \frac{X_s}{R_a} \quad (3.107)$$

Case 2 : For excitation less than 100%

For under excitation condition the value of $E_b < V$ in which the magnitude increases and the phase angle reduces.

Case 3 : For Excitation more than 100%

For excitation greater than 100%, $E_b > V$ the motor is otherwise said to be over excitation.

Case 4 : The current drawn by the motor would be minimum

The Experimental set up for obtaining V-curve and Inverted V-Curve is shown in Fig3.80. The stator is connected with 3-phase supply through Wattmeter, Ammeter and Wattmeter. A rheostat potential divider arrangement is used for field excitation. By controlling the voltage by rheostat the field is changed.

The power factor of a synchronous motor is controlled by the variation of armature current (I_a) versus field current (I_f) for no load, half load and full load. V-Curve format is shown in Fig.3.81(a). The Power factor versus field current (I_f) with different loads are shown in Fig 3.81(b).

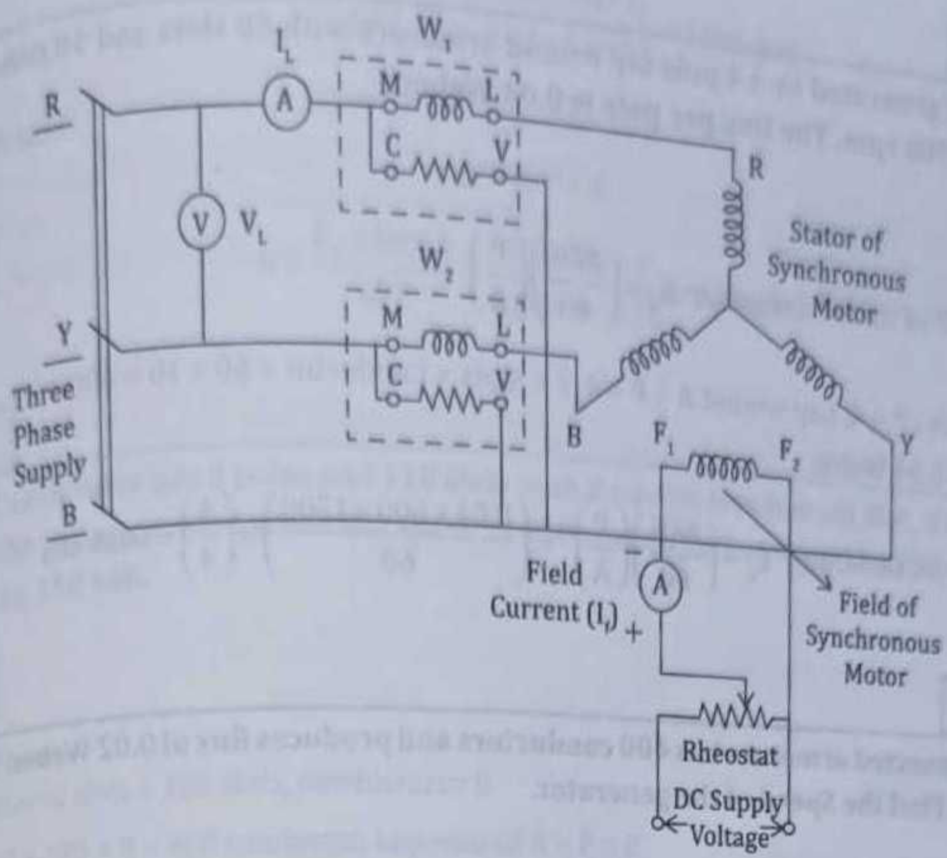
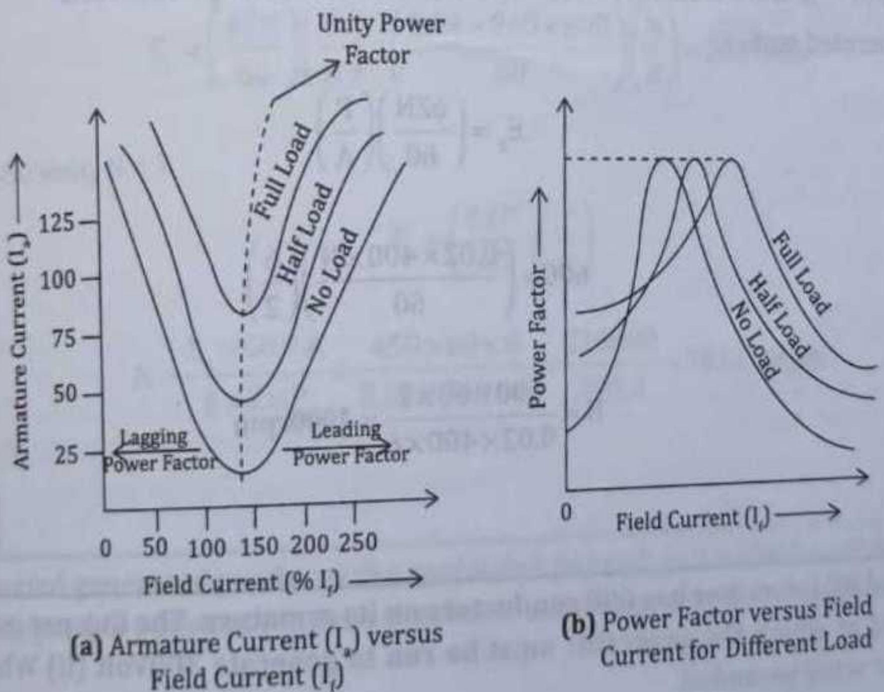


Fig 3.80 Circuit diagram for the Experimental setup of V-curves



(a) Armature Current (I_a) versus Field Current (I_f)

(b) Power Factor versus Field Current for Different Load

Fig 3.81 Curve and Inverted V-current the Synchronous Motor

Various applications of Synchronous Motor

1. It is used for Constant speed equipment such as Fan, Blower and Centrifugal pumps.
2. It is also used in Textile mill, Rubber mill, Kiln dryers, Sugar mills, Machine tools with constant speed applications.