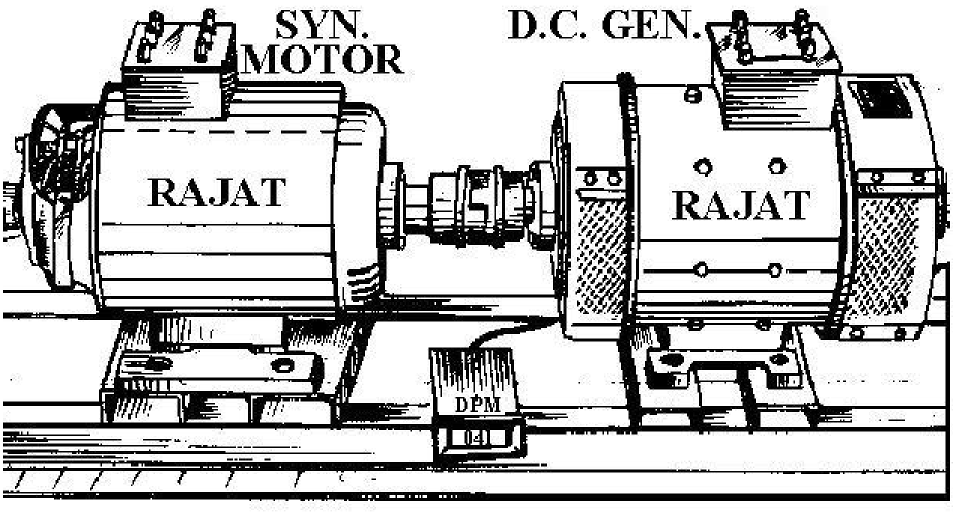
INDEX NO. : M-99

RAJAT

TECHNICAL MANUAL
FOR

V CURVES OF SYNCHRONOUS MOTOR WITH PANEL



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TO DRAW V CURVES OF SYNCHRONOUS MOTOR THROUGH ELECTRICAL LOADING

AIM : (a) To study the effect of variation of field current upon the stator current and power factor with synchronous motor running at no load, hence to draw V and inverted V curves of the motor.

(b) To repeat the above, with synchronous motor loaded to half the full load and 3/4 the full load.

CONTROL PANEL FOR V CURVES OF SYNCHRONOUS MOTOR THROUGH ELECTRICAL LOADING USING DOL STARTER

For drawing V curves and inverted V curves of synchronous motor following measuring instruments and accessories are fitted on Bakelite sheet fixed to MS iron angle frame.

FOR DC GENERATOR (SHUNT TYPE) FOR ELECTRICAL LOADING

® MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No. (Generator Voltage)
® MC Ammeter 96 x 96 mm flush mounted 0-10 A. – 1 No (Load Current)
® Field Rheostat 1.4A, 230Ohms – 1 No.

FOR SYNCHRONOUS MOTOR

® MI Voltmeter 96 x 96 mm flush mounted 0-600V – 1 No. (V_L) (Line Voltage)
® MI Ammeter 96 x 96 mm flush mounted 0-5 A. – 1 No (I_a) (Armature Current)
® Power Factor meter, Flush mounted, 96 x 96 mm - 1 No. (Power factor meter of syn motor)
® MCB TP
® Indicating Light
® Excitation Controlling Arrangement
® DOL Starter
® Excitation Switch

FOR EXCITOR

® MC Voltmeter 96 x 96 mm flush mounted 0-300V – 1 No. (V_f) (Field Excitation Voltage)
® MC Ammeter 96 x 96 mm flush mounted 0-2.5 A. – 1 No (I_f) (Field Current)
® DP MCB, 2 Amp

Specifications : DC GENERATOR

Type	:	DC Shunt wound, Screen Protected, Horizontal foot mounted, Fan cooled with Interpole.
Capacity	:	1.5 KW
RPM	:	1500
Volts	:	230/220V
Insulation	:	Class ‘B’

Connections	:	All the terminals of Armature, Shunt field shall be brought over to a bakelite sheet fixed to CI Terminal box fitted on the top of Motor.

Specifications : AUTO SYNCHRONOUS MOTOR

Type	:	Salient Pole rotating field type, auto Induction Start. Screen protected, Horizontal foot mounted, Fan cooled separately excited.
Capacity	:	3 HP
RPM	:	1500 at 50 Hz (± 3%).
Volts	:	415 V
Insulation	:	Class 'B'
Frequency	:	50 Hz (± 3%).
Power Factor	:	- 0.75 LAG to + 0.75 LEAD
Connections	:	Star

Excitation	:	Separately.
Type	:	Static type through Rectifier with controlling arrangement.
Make	:	Own 'RAJAT'

ACCESSORIES :

To perform Electrical Loading on DC Shunt Generator we have to use single phase lamp load.

THEORY :

With constant mechanical load on the synchronous motor, the variation of field current changes the armature current drawn by the motor and also its operating power factor. As such, the behaviour of the synchronous motor is described below under three different modes of field excitation.

1. **Normal Excitation** :

The armature current is minimum at a particular value of field current, which is called the normal field excitation. The operation power factor of the motor is unit at this excitation and thus the motor is equivalent to a resistive type of load.

2. **Under Excitation** :

When the field current is decreased gradually below the normal excitation, the armature current increase and the operating power factor of the motor decreases. The power factor under this condition is lagging. Thus, the synchronous motor draws a lagging current, when it is under excited and is equivalent to an inductive load.

3. **Over Excitation** :

When the field current is increased gradually beyond the normal excitation, the armature current again increase and the operating power factor increases. However, the power factor is leading under this condition. Hence, the synchronous motor draws a leading current, when it is over excited and is equivalent to a capacitive load.

If the above variation of field current and the corresponding armature current are plotted for a constant mechanical load, a curve of the shape of ‘V’ is obtained as shown in fig ‘A’. Such a characteristic of synchronous motor is commonly called as ‘V’ curve of the motor. The characteristic curve plotted between input power factor and the field current for a constant mechanical load on the motor are of the shape of inverted ‘V’ and are known as inverted ‘V’ curves.

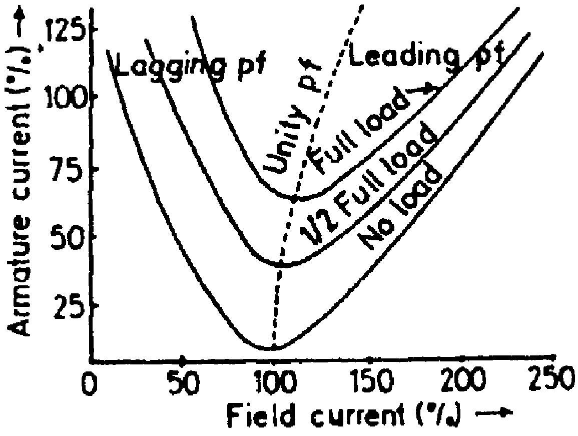

Fig ‘A’ – V curves of synchronous motor.

For increased constant mechanical load on the motor, ‘V’ curves bodily shift upwards as shown in fig ‘A’. The curve joining the minimum current points of various ‘V’ curves plotted for different mechanical loads, is normally called a unity power factor compounding curve.

CIRCUIT DIAGRAM :

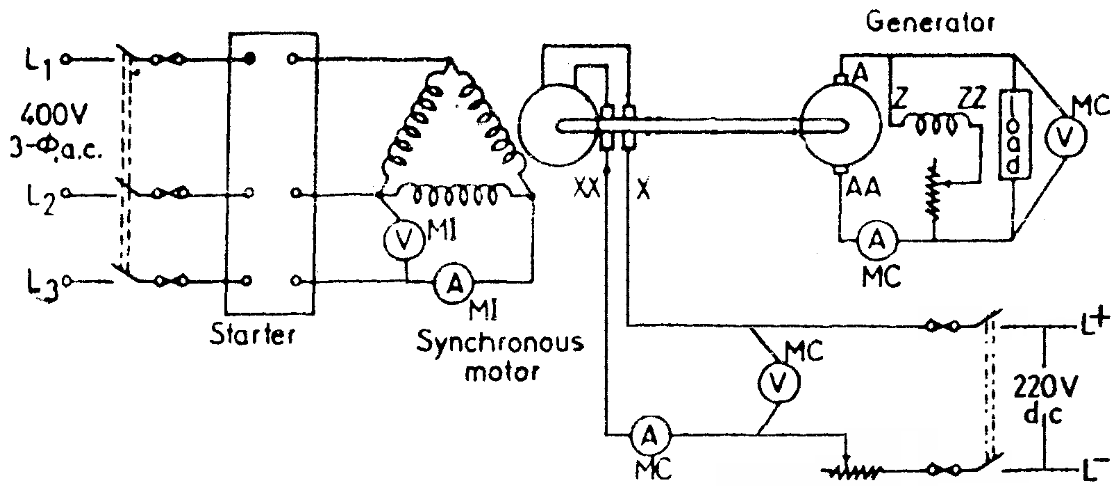

Fig ‘B’ – Schematic Circuit Diagram for Determination of V Curves of synchronous motor.

Fig ‘B’ shows the circuit diagram for the above experiment. The 3 phase synchronous motor whose specifications have been given, is a self starting synchronous motor, provided with an exciter to feed the field winding of the synchronous motor. A direct-on line has been used to safeguard the motor from the sudden failure of power supply and over load on the motor. Meters have been connected on the generator side to have an idea of loading condition on the motor.

CONSTRUCTION

A.C. SYNCHRONOUS MOTOR

The Synchronous Motor is identical with the corresponding Alternator and consists essentially of Stator Armature and Motor (Field), or vice-versn. In Revolving Field type, the stationary armature is attached to the Stator frame, which the field magnets are attached to a frame which revolves with the shaft, while in revolving armature type reverse is the case. In Revolving field type, the field coils are excited by direct current supported through the two sliprings mounted at one end of the shaft. The Rotor and Stator are assembled from thin laminated sheets of silicon steel flash enameled on both sides.

SELF STARTING

The Synchronous Motor is not inherently a self starting machine. As on supplying DC to the rotor winding. North and South poles are produced which lock into position with the rotating field in the armature. Hence, an auxiliary starting device, i.e. a squirrel cage winding on the rotor is provided. After the Motor comes up to a speed which is slightly less than Synchronous, the rotor is energised.

PRECAUTION

When the synchronous Motor is started, its DC Field is not excited until the rotor has reached practically the full Synchronous speed. The DC Field circuit should also be broken during the earlier part of the starting period in view of the high voltages induced in it due to transformer action when the speed is low. Hence the DC Switch provided on starter panel must be in OFF position.

STARTING TORQUE

The starting torque required to bring the rotor upto this speed (near synchronous) is produced by induction.

STARTING SPEED

Because the Motor starts as a squirrel cage Motor, its speed will be slightly less than synchronous.

DAMPER WINDING

In addition to a DC winding on the field, the synchronous Motor is provided with a damper or amortisseur winding. It consists of short circuited bars of copper embedded in slots in the pole faces and joined together at either end by means of end rings. This winding (Squirrel cage winding) enables the motor to obtain sufficient starting torque (pull-in torque) for the motor to start under load.

PRINCIPLE OF WORKING

When the Starting winding in the Synchronous motor is excited by the AC line connection, it immediately sets up a rotating magnetic field. The rotating flux of this field cuts across the damper winding of the rotor and induces secondary currents in the bars of this winding. The reaction between the flux of these secondary current and that of the rotating stator field produced the torque necessary to start the rotor and to bring it to speed.

When the motor has been brought up to nearly Synchronous speed (as an induction motor because of the damper winding) the DC field poles are excited and the strong flux of these poles causes them to be drawn into step of the stator. During normal operation, the rotor continues to revolve at synchronous speed as if the DC poles were locked to the poles of the rotating magnetic field of the stator. Because a synchronous motor has no slip after the rotor is brought up to full speed, no secondary currents are induced in the bays of the damper windings during normal operation.

STARTING OF SYNCHRONOUS MOTOR THROUGH DOL STARTER

GENERAL

When full voltage is connected across the stator terminals of an induction motor, large current is drawn by the windings. This is because, at starting (i.e. before the rotor starts rotating) the induction motor behaves as a short circuited transformer with its secondary, i.e. the rotor separated from the primary, i.e. the stator by a small air-gap.

WORKING PRINCIPLE :

At starting, when the rotor is at standstill, emf is induced in the rotor circuit exactly similar to the emf induced in the secondary windings of a transformer. This induced emf of the rotor will circulate a very large current through its windings. The primary will draw very large current from the supply mains to balance the rotor ampere-turn. To limit the stator and rotor currents at starting to a safe value, it may be necessary to reduce the stator supply voltage to a low value.

With full voltage applied across stator terminals, the starting current will be very high. This current will however be gradually decreasing as the motor will pick up speed. The current drawn by the motor during the time of starting with full-voltage connected across the stator terminals is shown in Fig ‘A’.

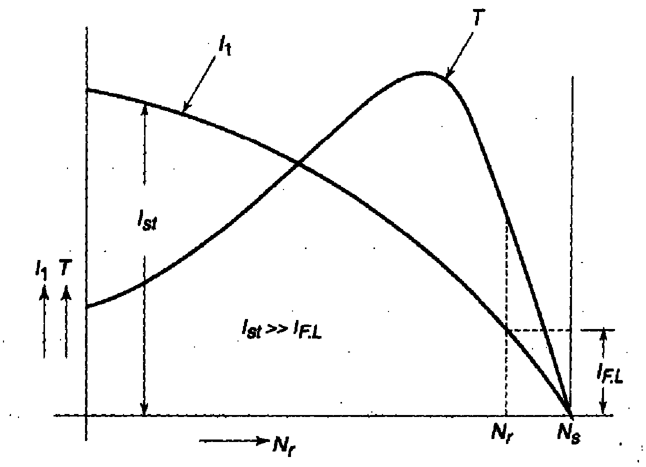

Fig – ‘A’ : Current drawn by an induction Motor When started direct-on-line.

If induction motor is started direct-on-line, such a heavy starting current of short duration may not cause harm to the motor since the construction of induction motors are rugged. Moreover, it takes time for intolerable temperature rise to endanger the insulation of the motor windings. But this heavy inrush of current will cause a large voltage drop in the lines leading to the motor. Other motors and equipment connected to the supply lines will receive reduced voltage. The reader must have observed that the lights in his home dim momentarily at the instant the refrigerator motor start. The situations in this case may not be so objectionable as the motor installed in the refrigerator is of a small size. In industrial installations, however, if a number of large motors are started direct-on-line, the voltage drop will be very high and may be really objectionable for the other types of loads connected to the system. The amount of voltage drop will not only be dependent on the size of the motor but also on factors like the capacity of the power supply system, the size and length of the line leading to the motors, etc. Indian electricity Rule stricts direct-on-line starting of three-phase induction motors above 5 hp. For such motors, methods are to be found out to apply reduced voltage at starting across the windings, such that the motor starting current is reduced considerably.

Direct-on-line method of starting of induction motors, applicable up to a rating of 5 hp, is shown in Fig. 'B'. In the circuit in addition to fuses, thermal overload relay has been used to protect the motor windings against over-load. When the ON push-button is pressed, the connector coil A becomes energised and its open contacts are closed. The motor gets connected across the supply mains through the main contacts of the contactor. The motor continues to get supply even when the pressure on the push button is released, since the contactor coil will then get supply through the contact a of the contactor. Contact a of the contactor A is coil gets de-energised; the main contact of the contactor opens and the motor stops. In case of over-load on the motor, the contact e of the over-load relay (OLR) will open, and subsequently the motor will stop. Fuses are provided for short-circuit protection.

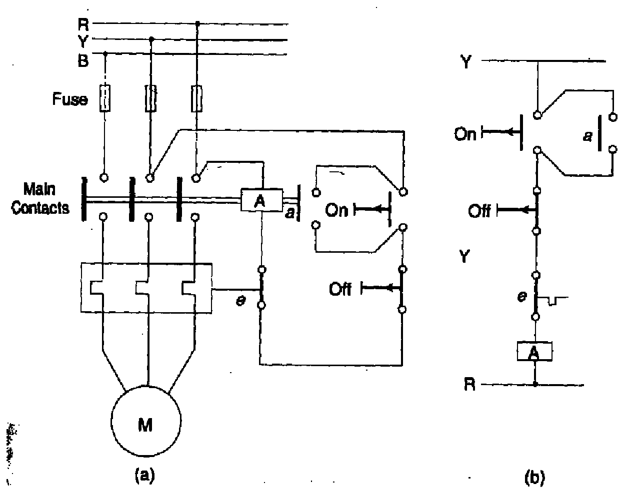

Fig – 'B' . Push button operated direct-on-line starting of a three-phase induction motor (a) Complete Wiring diagram (b) Schematic diagram of the control circuit.

WORKING PRINCIPLE

This method of starting an Induction Motor by limited the starting current has an Auto Transformer. The primary of which is connected to the line, whilst the secondary, giving a reduced voltage, is connected to the starter of the Induction Motor. The effect of the reduced voltage on the Motor is to reduce, proportionally, the strength of the rotating field.

This in turn reduces the E.M.F. generated in the Rotor circuit and hence the rotor current also. Since the torque developed is proportional to the product of the rotor current and the strength of the rotating field, it is seen that it is proportional to the square of the voltage applied to the stator. A reduction in applied voltage at starting, therefore, cause a considerable drop in the starting torque, but is necessary in view of the reduction in the starting current, which it also bring about. By the action of the Auto Transformer, however, the current drawn from the line is less than that supplied to the Motor, so that the Motor can take excess current without an overload being put upon the mains.

CONNECTIONS FOR SYNCHRONOUS MOTOR

Connect the AC three phase main lines to terminals L1, L2 & L3. Connect the terminals R, Y, B (Stator terminals) and Z, ZZ (Field) of Motor to respective terminals on starter front panel.

CONNECTIONS FOR DC GENERATOR (USE FOR ELECTRICAL LOADING)

DC Shunt Generator has terminals A & AA (Armature), Z, ZZ (Field), AA & ZZ are shorted forming L. The respective MC Voltmeter & Ammeter and Loading Rheostat (for loading purpose) are connected as per the diagram given in attached sheet.

WORKING OF CONTROL PANEL TO DRAW V CURVES OF SYNCHRONOUS MOTOR

1. Connect the ac three phase mains to terminals marked L1', L2', L3'. Switch ON the MCB.

2. Connect single phase AC supply on terminals marked L & Ne in order to get variable DC Excitation for field circuit of auto Syn Motor. MCB is to be turned ON only when the DC excitation is to be given to the field of Auto Syn Motor.

3. Before starting the synchronous motor make sure that the DC excitation switch is in OFF position.

4. For starting the MG set press green push button of DOL starter in the marked direction (by arrow). The synchronous will start as induction motor. The corresponding current will be shown by ammeter and the power factor lag shown by three phase power factor meter. Note the readings of (I_a). Also note the corresponding terminals voltage of shunt generator.

5. Switch ON the DC Excitation switch. The armature current will slightly decrease. Note this reading.

6. Now gradually move the static excitation controller (Variac) in clockwise direction by a few step and note the corresponding decrease in armature current (I_a) and field excitation current (I_f). Vary the excitation till the armature current is minimum. After this point on moving the Knob of Variac, the armature current will increase and note corresponding armature current and field current values. Vary the excitation uptill the rated value of synchronous motor. This value will correspond to synchronous motor at no load.

7. Adjust the voltage of DC generator coupled to synchronous motor to rated value by varying the field rheostat of DC generator (1.2 Amp, 260 Ohms).

8. Now connect load on DC Generator at terminals L1 & L2 by means of single phase loading rheostat/Lamp Load. Now draw the V curves at one fourth load, half load and three fourth load by gradually loading in steps.

9. Now for various load settings on DC generator repeat steps No. 2 to 5. The load setting must be maintained constantly for drawing V curves at that particular load.

OBSERVATIONS : May be tabulated as follows.

S. No.	V	I_t	I_a	V_{dc}	I_{dc}	cos f

PANEL FOR V CURVES OF SYNCHRONOUS MOTOR