INDEX NO. : M-142

RAJAT

TECHNICAL MANUAL
FOR

NO LOAD & BLOCK ROTOR TEST ON THREE PHASE INDUCTION MOTOR

Manufactured by :

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NO LOAD AND BLOCK ROTOR TEST

AIM :

Perform NO LOAD and BLOCK ROTOR Test on 3 phase induction motor.

INSTRUMENTS REQUIRED ON CONTROL PANEL :

S. No.	Name	Type	Range	Qty
1.	Ammeter	MI (Panel type)	5 A	1
2.	Voltmeter	MI (Panel type)	0-500 V	1
3.	Wattmeter (U.P.F.)	Dynamometer	5/10 A, 150/300/600 V	2
4.	3 phase Variac	Fully variable	6A	1

MACHINE REQUIRED :

A.C. Motor 2/3 H.P. 3 Phase 415 V 1440 RPM with Drum Brake Loading Arrangement (Mechanical Loading).

THEORY :

NO-LOAD TEST **:**

Objectives : To determine for an induction motor on no-load, relationship between

(a) Applied voltage and speed,
(b) Applied voltage and stator current
(c) Applied voltage and power factor
(d) Applied voltage and power input

Brief theory : In this experiment it is intended to study the effect of variation of applied voltage on the speed, power input, power factor, stator current of an induction motor running on no-load. The effect of change of applied voltage on the above mentioned quantities are explained as follows :

(a) Effect on Speed : Speed remains practically constant untill very low voltage are reached. Unless heavily loaded, the speed of an induction motor is affected very little by fluctuations of voltage.

(b) Effect on Stator Current : As applied voltage is increased, stator current rises gradually on account of the increase in magnetising current required to produce the stator flux. The component of the stator current which provides the ampere-turns balancing the rotor ampere-turns will steadily diminish as the rotor current decrease with the increase in rotor speed. The increase in the magnetising component is however, more than sufficient to balance this decrease. At very low voltages the induction is so low that almost the whole of the stator current is employed in balancing the rotor current. At normal voltage the rotor current requires only a small proportion of the stator currents to balance them. The higher saturation of the magnetic circuit requires a much stronger magnetising current to maintain the air-gap flux.

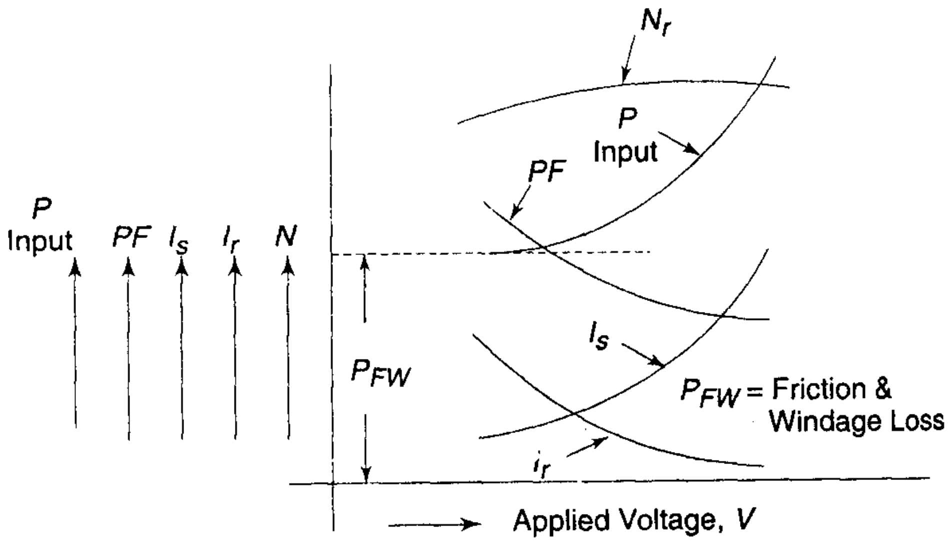


Fig – 'A' : Effect of change of applied voltage on speed, Rotor current, Stator Current, Power factor and power input of an induction motor running on no-load.

(c) Effect on Power Factor : As explained above, the magnetising component of the stator current becomes larger as the voltage increase. Thus, there is a continuous increase in the power factor angle and hence a fall in power factor.

Frictional losses of the motor are practically constant as the speed does not change with voltage. The loss component of the stator current, I_W is due to frictional losses and iron-losses. As voltage is increased, iron-loss component and magnetising component of stator current will increase. The increase in magnetising current will be more than the increase in iron-loss component of stator current. Thus there will be a fall in power factor as the voltage is increased.

(d) Effect on Power Input : No-load power input is spent in overcoming both iron and frictional losses. As stated earlier, frictional losses are nearly constant at all voltages (until the motor speed falls rapidly), while the iron-losses continue to increase with the increase in the applied voltage.

In fig, by extrapolating the power input curve to the left until it cuts the ordinate of zero voltage, when there can be no iron-loss, it is possible to make a rough estimate of the power spent in friction and windage.

The effect of change of stator input voltage on the above-mentioned quantities are shown graphically.

<u>PROCEDURE</u> :

To obtain on load current and its power factor angle ϕ no load test is performed at rated voltage and frequency. Let the readings of ammeter, voltmeter and two wattmeters connected in the circuit be, I_0, V_0, W_{01} and W_{02} respectively during no load test. Then,

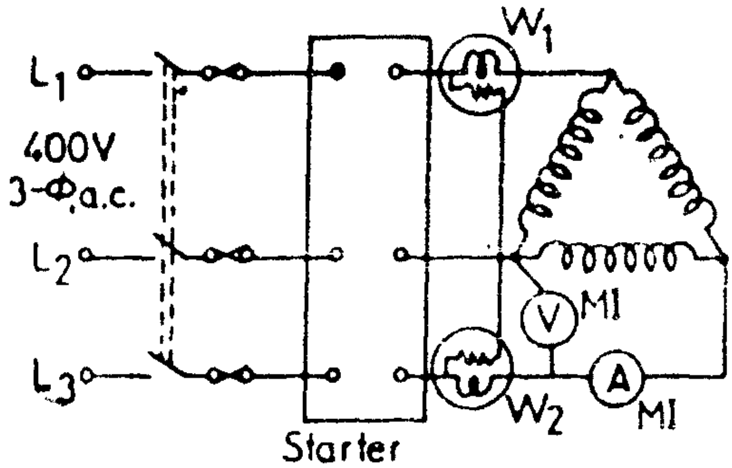
$$\tan \varnothing = \sqrt{3}\ \frac{W_{01} - W_{02}}{W_{01} + W_{02}}$$

Hence, no load power factor angle ϕ can be calculated from the readings of two wattmeters. No load current, I_0 has been directly measured by the ammeter.

CIRCUIT DIAGRAM

Circuit shown as per attached sheet for NO LOAD & BLOCKED ROTOR Test. To obtain more reliable values range of both the wattmeter should be 2.5 A, 500 V for NO LOAD Test. Where as it should be 5 A, 300 V for BLOCK ROTOR Test. Similarly the range of Ammeter and Voltmeter during No Load Test should be 5 A, 500 V while 10 A, 250 V for Block Rotor Test.

FOR NO-LOAD TEST



STEPS FOR PERFORMING NO LOAD TEST :

1. Connect the circuit as per diagram shown on attached sheet.
2. Ensure Motor is unloaded and the Variac is set at zero position.
3. Switch on the 3 phase A.C. supply and gradually increase the voltage through variac till its rated value. Thus the Motor is running at rated speed under NO LOAD condition.
4. Record the readings of all the meters connected in the circuit and tabulate observation. Calculate the power input and power factor for each reading. Plot characteristic of quantities as indicated in figure 'A'.

BLOCK ROTOR TEST :

Objectives : To determine for an induction motor on BLOCK ROTOR Test, relationship between

(a) applied Voltage and Input Power,
(b) applied Voltage and Stator Current

Brief theory : This test is similar to short-circuit on a transformer. This experiment is performed on a three-phase Squirrel Cage Induction Motor when the rotor is not allowed to rotate (performed by tightening the belt).

The effect of variation of stator voltage on input power, and stator current are explained as follows :-

(a) Effect on input Power : When the rotor is blocked, only a small amount of voltage can be applied across stator terminals to allow up to normal full-load current to flow through the windings. The iron losses will be very small as at that low voltage magnetisation will be low. The power taken by the motor when the rotor is blocked is, therefore, almost entirely due to copper losses. With the increase in stator applied voltage, the losses will increase as the square of the current.

(b) Effect on Stator Current : The stator current will increase in proportion to the rotor current, as in a transformer, in order to balance the rotor currents.

Figure 'C' shows the effect of change of stator voltage on the quantities.

PROCEDURE :

To obtain short circuit current and its power factor angle, block rotor test is performed on the motor. In this test, rotor is not allowed to move (blocked either by tightening the belt, in case provided or by hand) and reduced voltage (25 to 30 percent of the rated voltage) of rated frequency is applied to the stator winding. This test is performed with rated current following in the stator winding. Let the readings ammeter, voltmeter and two wattmeters be I_{SC}, V_{SC} W_{SC1} and W_{SC2} respectively under block rotor condition. Then,

$$\tan \varnothing_{SC} = \sqrt{3}\,\frac{W_{SC1} - W_{SC2}}{W_{SC1} + W_{SC2}}$$

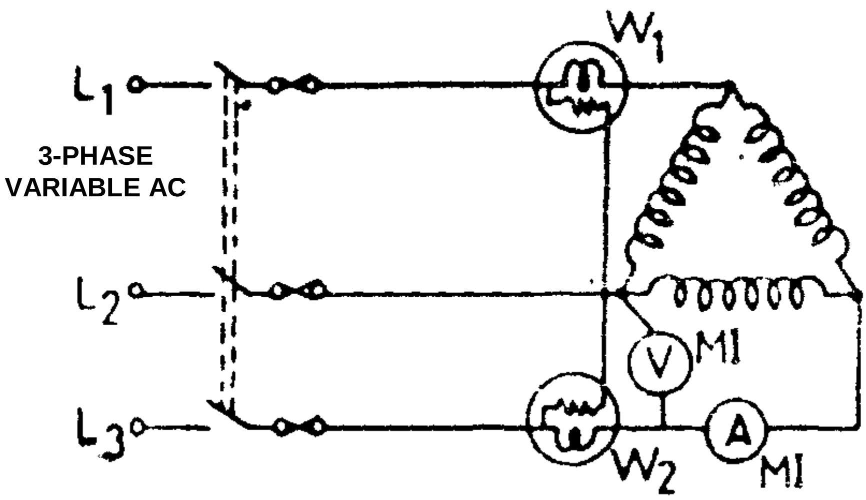
Thus, short circuit power factor angle, $\varnothing_{SC}$ can be calculated from the above equation.

Short circuit current, I_{SC} observed during the block rotor test corresponds to reduced applied voltage, V_{SC}, which should be converted to rated voltage of the motor for plotting the circle diagram. The relation between the short circuit current and the applied voltage is approximately a straight line. Thus, short circuit current, I_{SC} corresponding to rated voltage, V of the motor is given by,

$$\text{Short circuit current, } I_{SC}' = \frac{V}{V_{SC}} \times I_{SC}$$

It may be remembered, that the power factor of the motor is quite low at no load as well as under blocked rotor condition. Thus, one of the wattmeter connected in the circuit will give negative reading in both the test, which may be recorded by reversing by terminals of the pressure coil or the current coil.

CIRCUIT DIAGRAM FOR BLOCKED ROTOR TEST



STEPS FOR PERFORMING BLOCK ROTOR TEST :

1. Connect the circuit as per diagram shown in fig 'B'.
2. Adjust the variac at zero position.
3. Change the ranges of all the instruments for block rotor test as suggest in the discussion on circuit diagram.
4. Block the rotor either by tightening the belt firmly or by hand.
5. Switch-on the ac supply and apply reduced voltage, so that the input current drawn by the motor under blocked rotor condition is equal to the full load current of the motor.
6. Record the readings of all the meters, connected in the circuit.
7. Switch-off the ac supply fed to the motor.
8. Measure the resistance per phase of the stator winding, following ohm's law concept.
9. Tabulate your readings as per table shown. Draw characteristics of the quantities similar to as shown in Fig. – 'C'.

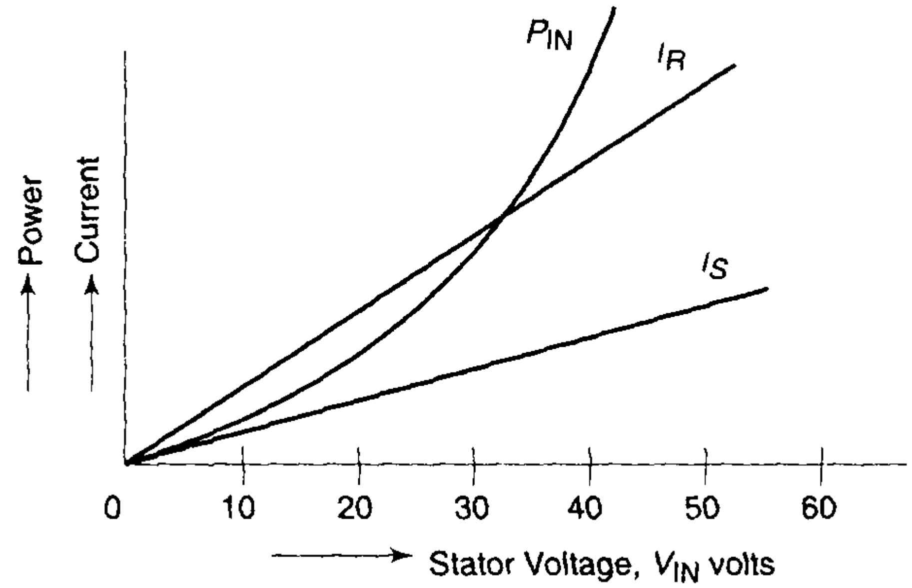


Fig. – 'C' : Effect of exchange of stator applied voltage on power input, rotor and stator current .

OBSERVATION AND RESULT :

S. No.	Stator Voltage V_{SC}	Stator Current I_{SC}	Wattmeter readings		Power input
			W_{SC1}	W_{SC2}	
Take 6-7 Readings					

CONSTRUCTION OF CIRCLE DIAGRAM

Object : To draw circle diagram for a three phase induction motor.

Procedure : To construct the circle diagram three tests are to be performed, namely (a) NO-LOAD TEST. (b) BLOCK ROTOR TEST and (c) STATOR RESISTANCE TEST. Form no-load test I_0 is known and f_0 is found out as (taking all quantities on per phase values).

$$V_1 I_0 \cos \phi_0 = W_0$$

or

$$\phi_0 = \cos^{-1} \frac{W_0}{V_1 I_0}$$

By choosing a proper current scale, I_0 can be drawn as OC shown in fig. 'D' with V_1 as vertical reference axis.

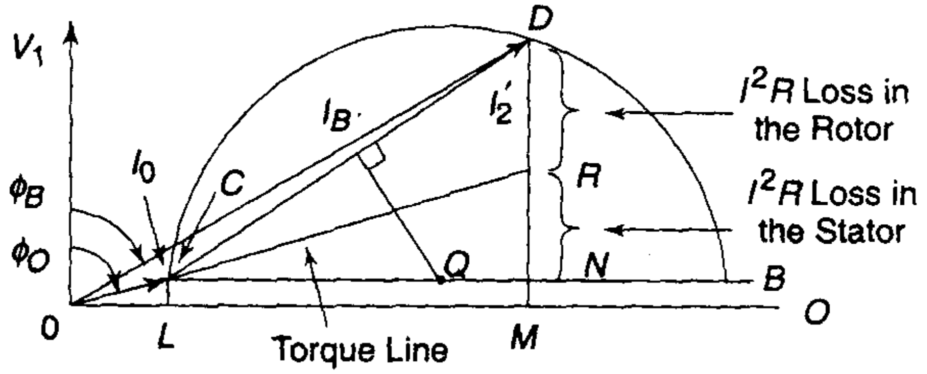


Fig. – 'D' : Circle diagram of an induction motor .

From blocked rotor test I_2 is known. Convert this I_2 at normal voltage level as :

$$I_2 \text{ (at normal voltage)} = I_2 \frac{V_1}{V_S}$$

Power factor under blocked-rotor condition with all quantities on per phase values is given as :

$$\cos \phi_S = \frac{W_S}{V_S I_S}$$

With the same current scale, I_2 corresponding to normal voltage can be drawn at an angle ϕ_S with the vertical axis shown by vector CD. Thus OD represents the total current drawn by the stator. The locus of the current I_1 will pass through the two extreme points, namely through C at no load and through D which corresponds to block rotor condition. The centre of semicircle may be found out thus : draw a perpendicular bisector from the line CD. This will cut the horizontal line CB drawn from C at the point Q. with Q as centre and QC as radius draw a semicircle CDB. Draw also a horizontal line OO parallel to the line CB.

Draw perpendicular lines from the points C and D on the horizontal line as CL and DM. DM cuts the horizontal line CB at N such that NM = CL. As applied voltage V_1 is shown as vertical line, CL which is equal to $I_0 \cos \phi_0$ is proportional to the no load input. Thus the length CL can be equated to the no load input power W_0 which supplies core-loss, friction and windage loss and a small amount of I^2 R-loss.

The power scale can be determined thus

$$\text{Distance CL in cm} = W_0$$

$$\text{Power scale : 1cm} = \frac{W_0}{\text{CL in cm}}$$

For better accuracy power scale should be calculated considering length DM as equivalent to the input under blocked condition.

The vertical distance DM represents the input power under blocked rotor condition with rated voltage applied across the stator. Distance NM has been assumed to be equal to CL representing core loss and friction and windage losses. This is an approximation as under blocked rotor condition, there is no friction and windage loss. The remaining part, DN of the input at blocked rotor condition is wasted as I^2 R-loss in the stator and rotor, the output under blocked rotor condition being zero. If we assume, for the time being stator I^2 R-loss as equal to rotor I^2 R-loss, then we may divide the line DN at R. NR represents the stator I^2 R-loss and RD which is equal to the rotor input is wasted as I^2 R-loss in the rotor.

The line CD represents the output line. The vertical distance above this line up to the periphery of the circle expressed in power scale will represent the output power. The line CR separating the stator and rotor I^2 R-loss is the torque line. Vertical distance above this line up to the periphery of the circle is the developed torque. We have assumed stator and rotor I^2 R-loss to be equal and divided the line DN at R. the exact position of the point R can be located as follows :

Input power, W_S under blocked rotor condition is wasted as I^2 R-loss in the stator and rotor. The stator circuit resistance can be measured as follows :

$$\text{Stator Cu-loss} = 3 I^2_1 R_1$$

$$\text{Rotor } I^2 \text{ R-loss} = W_S - 3 I^2_1 R_1$$

Therefore, for squirrel-cage motors,

$$\frac{RN}{RD} = \frac{3 I^2_1 R_1}{W_S - 3 I^2_1 R_1}$$

For slip ring motors, resistance R_1 and R_2 can be determined and the ratio

$$\frac{RN}{RD} = \frac{I^2_1 R_1}{I^2_2 R_2} = \frac{R_1}{R_2} \left[\frac{I_1}{I_2} \right]^2$$

From the circle diagram as drawn in Fig 'D' we can calculate the various quantities which will illustrate the performance of the motor at any particular load. Let us redraw the circle diagram of Fig 'D' and let us assume that the motor is taking a current represented by OP in Fig 'E'.

The perpendicular line PG represents power input. GH represents fixed losses. HK and KG represents respectively the stator and rotor I^2 R-loss. JP represents output power and KP represents output torque.

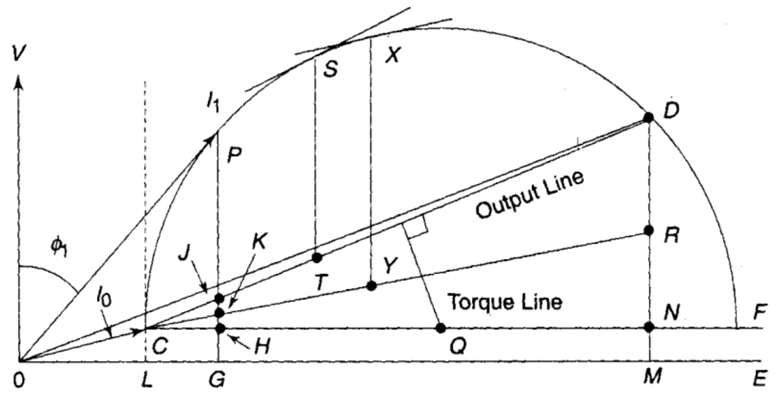


Fig. – 'E' : Method of construction of circle diagram of an induction motor.

To determine the maximum power developed by motor, draw a line parallel to the output line tangent to the circle at point S. Draw a vertical line ST from the point S to the output line. The length ST represents the maximum output.

Similarly, to determine maximum torque developed by the motor, draw a line parallel to the torque line. The length XY represents the maximum torque.

SAMPLE CALCULATION

A sample calculation is reproduced here below for drawing a circle diagram of a three phase induction motor on the basis of which circle diagram for any rating of induction machine can be drawn :-

Example : A 400 V, 40 hp, 50 Hz, 4 pole delta-connected induction motor gave the following test data.

No-load test : 400 V, 20 A, 1200 W
Blocked-rotor test : 100 V, 45 A, 2800 W

Draw the circle diagram and determine
(a) the line current and power factor rated output;
(b) the maximum output;
(c) the maximum torque;
(d) the full-load efficiency;
(e) the full-load rotor speed;

Assume stator and rotor I^2R-losses to be equal at standstill.

The test data given are assumed to be of line values.

$$\text{No-load power factor, } \cos\phi_0 = \frac{W_O}{\sqrt{3}\ V_1 I_O}$$

$$= \frac{1200}{1.732 \times 400 \times 200}$$

$$\cos\phi_0 = 0.0866$$

$$\phi_0 = 85^O$$

Similarly, power factor under blocked-rotor condition,

$$\cos\phi_S = \frac{2800}{1.732 \times 100 \times 45} = 0.359$$

$$\phi_S = 69^O$$

Input current and input power at blocked rotor condition are at a reduced voltage of 100 V. these quantities are to be converted into rated voltage of 400 V.
Thus,

Input current at blocked-rotor condition at 400 V

$$= 45 \times \frac{400}{100} = 180 \text{ A}$$

Input power at blocked-rotor condition at 400 V

$$= 2800 \left[\frac{400}{100}\right]^2 = 44800 \text{ W}$$

Input power at no-load at 400 V = 1200 W

Let us now choose a convenient current scale of

1 cm = 10 A

The circle diagram shown in Fig. 'F' is constructed through the following steps:

Represent voltage V on the vertical axis. Draw a horizontal line OE from O. Since current scale is 1 cm = 10 A, no-load current of 20 A is equivalent to 2 cm. No-load power factor angle is 85^O. Thus, represent no-load current by the vector OC whose length is 2 cm and is lagging the vertical voltage axis by 85^O.

Similarly, represent the input current of 180 A under blocked rotor condition by a vector CD of 18 cm length and lagging voltage vector by 69^O.

Draw a horizontal line CF from C parallel to the line OE. Join OD. Draw a perpendicular bisector from CD to cut the horizontal line CF at Q. With Q as centre and QC as redius draw a semicircle. From D on the semicircle draw a vertical line DM on the horizontal axis. DM cuts CF at N such that NM = CL. Since stator and rotor I^2R-losses are assumed to be equal, divide DN at R and join CR. Now CD represents the output line and CR represents the torque line.

In the circle diagram, length DM represents input at blocked-rotor condition, such that

$$DM = 44800 \text{ W}$$

$$DM = 6.8 \text{ cm}$$

From this,

$$1 \text{ cm} = \frac{44800}{6.8} = 6588 \text{ W}$$

which is the power scale for the circle diagram.

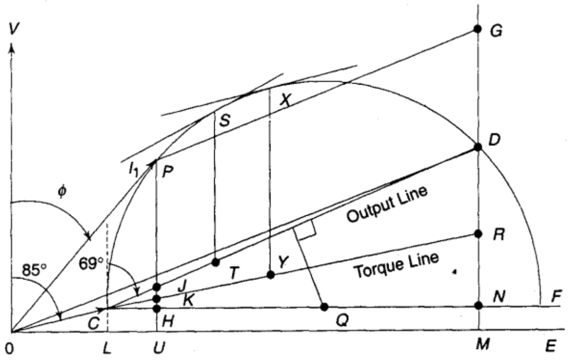


Fig. – 'F' : Circle diagram of an induction motor.

Now, full load output of the motor = 40 hp

= 40 x 735.5

= 29420 W

$$\text{On the power scale 29420 W represent} = \frac{29420}{6588} \quad 4.46 \text{ cm}$$

JP represent 4.46 cm above the output line. To locate the position of JP we may raise the vertical line MD and cut 4.46 cm from it. DG is 4.46 cm in the figure. Now draw a line from G parallel to the output line CD to cut the circle at P. From P drop a vertical line PJ onto the output line. OP represents the full load input current.

Full load current, OP = 6.1 cm x 10 A

Input line current at full load = 61 A

Power factor all full load

$$\cos \phi = \cos 34^{O}$$

$$= 0.829$$

Input = PU in cm x power scale
= 5.1 x 6488 W

Output = PJ in cm x power scale
= 4.46 x 6488 W

$$\text{Efficiency} = \frac{\text{Output}}{\text{Input}} = \frac{PJ}{PU} = \frac{4.46}{5.1}$$
$$= 0.874 = 87.4\ \%$$

To determine the maximum output, draw a line parallel to the output line, tangent to the semicircle at point S. the vertical distance ST represents the maximum output.

In this case ST measures 6.7 cm
Using power scale of 1 cm = 6588 W

Maximum output = 6.7 x 6588 W

= 60 hp

To determine the maximum torque, draw a line parallel to the torque line, tangent to the circle at point X. the vertical distance XY represents the maximum torque. In this case XY is 8.1 cm. Using power scale, maximum torque = 6588 x 8.1 Syn. W = 53363 Syn. W.

To determine full load rotor speed we can use the relation

Rotor I^2R-loss = Slip x Rotor input

At full-load rotor I^2R-loss is represented by the distance JK which is equal to 0,3 cm. Rotor input is represented by PK and is equal to 4.65 cm.

thus, $$\text{slip } S = \frac{0.3}{4.65} = 0.0646$$

Synchronous speed,

$$N_S = \frac{120f}{P} = \frac{120 \times 50}{4}$$
$$= 1500 \text{ rpm}$$

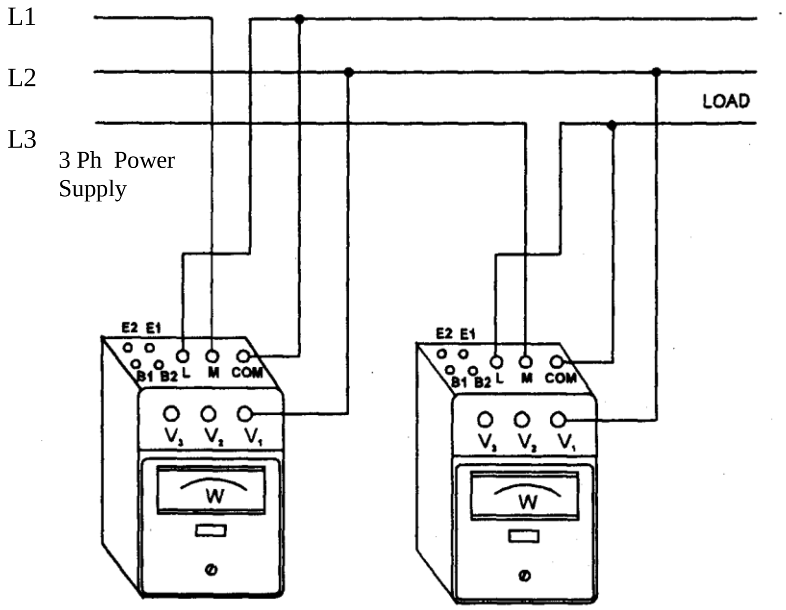
Slip, $$S = \frac{N_S - N_r}{N_S}$$

or $$0.0646 = \frac{1500 - N_r}{1500}$$

Therefore, rotor speed at full-load
$$N_r = 1403 \text{ rpm}$$

CONNECTION DIAGRAM FOR MEASUREMENT OF POWER BY TWO WATTMETER METHOD

A. WATTMETERS

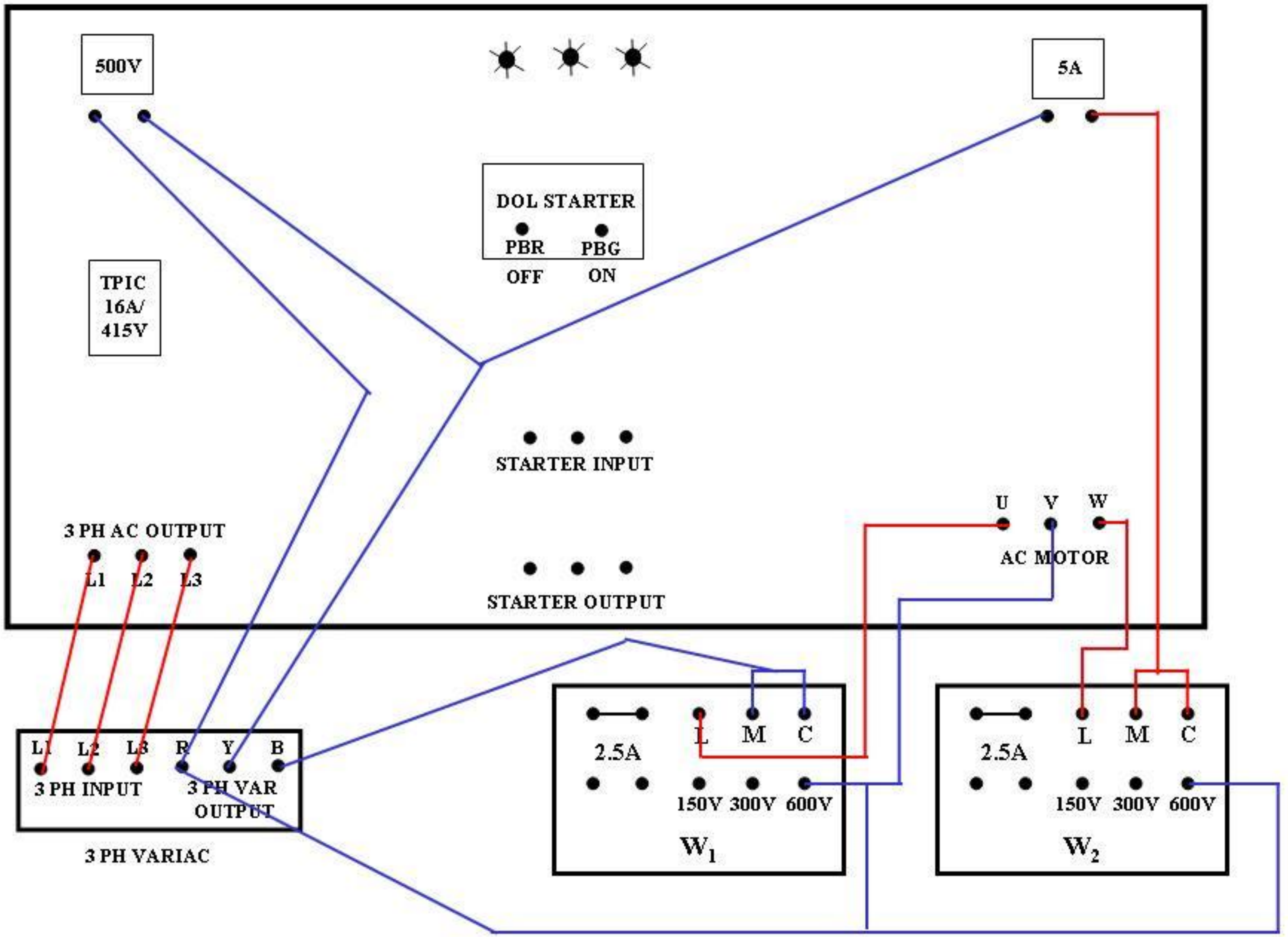


The three-phase power measurement is conducted by connecting two wattmeters, as shown in above Fig. The power value is indicated by the algebraical addition of the indication value on the two wattmeters. When the power factor of the circuit being measured is greater than 50%, both meters will indicated “positive” values. The total load power is then calculated by the addition of these two values.

However, if the power factor of the circuit is less than 50%, one of the two wattmeters will give a negative indication (the pointer will deflect to the left). If this occurs, reverse the voltage connections of the meter with the negative deflection. This and the meter should then indicate on the other meter, to obtain the total load power.

In duel current range wattmeter for lower current range short the terminal B1 & B2 (series connection) & for higher current range short the terminal B1 -E1 & B2 -E2 (Parallel connection).

PANEL LAYOUT FOR BLOCKED ROTOR TEST ON INDUCTION MOTOR



PANEL LAYOUT FOR NO LOAD TEST ON INDUCTION MOTOR