Experiment No. 05
No load test and blocked rotor tests of a 3-phase induction motor

Name		Date	
Roll No.		Marks	

OBJECTIVE:

1) To perform No load test and Blocked rotor test on a three-phase induction motor.

APPARATUS REQUIRED			
Sl. No.	Apparatus	Technical Specification	Quantities
1	Induction Motor with BR arrangement		
2	Autotransformer (Variac)		
3	Voltmeter		
4	Ammeter		
5	Wattmeter		

THEORY:

No-Load (NL) Test In this test the motor is run on no-load at rated voltage and frequency. The applied voltage and current and power input to motor are measured by the metering as per Fig. 1. Lets the meter readings be

$$Powerinput = P_o(3 - phase)$$
$$Current = I_O(\ Average\ of\ the\ three\ meter\ reading)$$
$$_Voltage = Vo(line - to - line\ rated\ voltage)$$

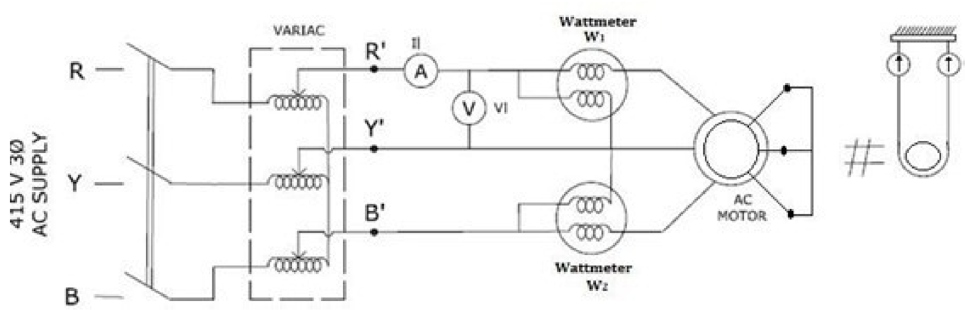

Figure 1

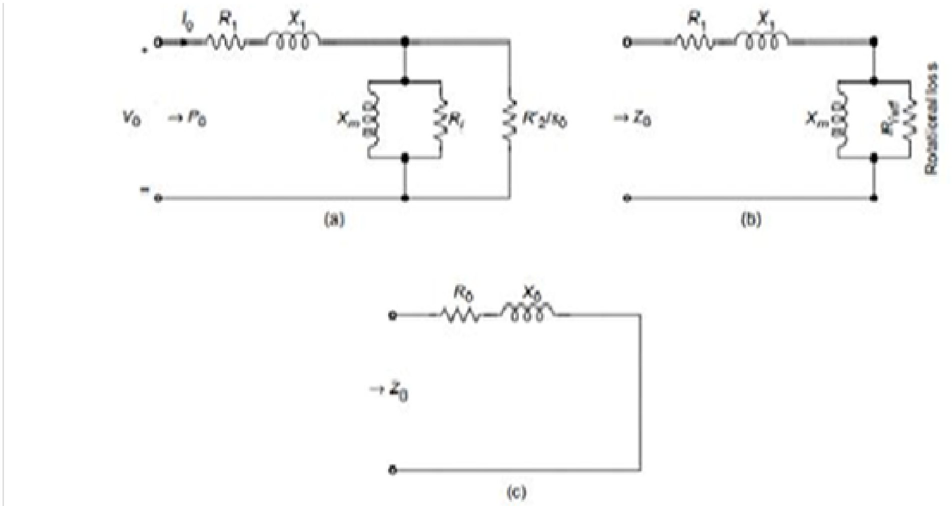

Figure 2: Circuit Model at No Load

Power input at no-load (P0) provides losses only as the shaft output is zero. These losses comprise, P0 (no-load loss) = Pc1 (stator copper loss) + [Pi (iron/core loss) + Pwf (windage and friction loss) = Rotational loss]

wherein core loss occurs only in the stator as the slip is extremely low (of the order of 0.001) and so the frequency of rotor current is as low as 0.05 Hz. The magnitude of no-load current in an induction motor is about 30-40% of full- load current because of the air-gap. So the stator copper loss at no-load needs to be accounted for. This can be estimated by measuring dc stator resistance and correcting to ac value (50 Hz) and corrected for temperature

The mechanical power developed corresponds to Pwf only and so, as already mentioned above the slip is very low and the output resistance R'2 (1/s– 1) = very large Also $R_2/s >> X_2$ and so X_2 can be ignored. The corresponding no-load circuit model is drawn in Fig. 2(a) wherein R_2/s appears in parallel to R_i . By combining the parallel shunt resistances, the final circuit at no-load is as given in Fig. 2(b). Here Riwf accounts for rotational loss, i.e., core loss and windage and friction loss. Magnitude-wise $R_{iwf} >> X_m$. R1, the stator resistance, is found by dc testing of the stator winding and correcting the value to AC operation (at 50 Hz). X_1, the stator leakage reactance, will be found from the blocked-rotor test which follows. We can then find X_m and R_{iwf} from the no-load (NL) test data. By simplification of the circuit of Fig. 2 (b).

$$Z_{NL} = Z_O = \frac{V_o}{I_O\sqrt{3}} \tag{1}$$

$$R_{NL} = R_O = \frac{P_O}{\left(I_O\sqrt{3}\right)^2} \tag{2}$$

$$X_{NL} = X_O = \sqrt{{Z_O}^2 - {R_O}^2} \tag{3}$$

By substituting the values of R'o and X'o, we obtain X'm and R'iwf.

From the NL test data (V_0, I_0, P_0) or (V_{NL}, I_{NL}, P_{NL}) we can find from the circuit of Fig. 2 (c).

$$R_0 = R_1 + \frac{x_m^2/R_{ifw}}{1 + (x_m/R_{iwf})^2} \tag{4}$$

$X_0 = X_1 + \frac{x_m}{1+(x_m/R_{iwf})^2}$

The equivalent circuit is drawn in fig 2(c)
It can be justifiably assumed that (Xm/Riwf)2 = 0, so we get from the above equation:

$$R_{iw_f} = \frac{X_m^2}{R_0 - R_1} \tag{5}$$

$$Xm = Xo - X1 \tag{6}$$

Blocked Rotor Test: :

This test is analogous to the short circuit test of a transformer. In this test, the shaft of the motor is clamped (locked) so that it cannot move and rotor winding is short-circuited.

Fig. 2 Blocked Rotor test on 3 phase induction motor.

In a slip-ring motor, the rotor winding is short-circuited through slip-rings and in cage motors, the rotor bars are permanently short-circuited. This test also called the locked-rotor test. The circuit diagram for blocked rotor test is shown in Fig. 2 reduced voltage at reduced frequency is applied to the stator through a3-phase auto- transformer so that full-load rated current flows in the stator. The following readings are obtained:

1) Total power input on short-circuit P_{BR} = algebraic sum of the two watt-meter readings.The power input in this test is equal to the sum of copper losses of stator and rotor for all the three phases; this is due to the fact that a reduced voltage is applied to the stator, and rotation is not allowed and, therefore, core and mechanical losses are negligible.
2) Reading of ammeter I_{BR} = line current (stator current)
3) Reading of voltmeter V_{BR} = line to line voltage
4) Cos(φ_{BR}) = power factor on short circuit

From the Block Rotor test data (V_{BR}, I_{BR}, P_{BR}) we can find from the circuit of Fig. 3(b).

$$Z_{BR} = \frac{V_{BR}}{I_{BR}/\sqrt{3}}$$

$$R_{BR} = \frac{P_{BR}}{(I_{BR}/\sqrt{3})^2}$$

$$X_{BR} = ({Z_{BR}}^2 - {R_{BR}}^2)^{1/2}$$

$$X_1 = X_2' = X_{BR}/2$$

It is to be noted that the blocked-rotor test should be performed under the same conditions of rotor current and frequency that will exist under normal operating conditions. At normal operating conditions, the slip of most induction motors is only 2 to 4 per cent, and the resulting rotor frequency is in the range of1 to 2 Hz for a stator frequency of 50 Hz. Therefore the blocked rotor test should be performed at a reduced frequency because the rotor effective resistance and leakage reactance at the reduced frequency (corresponding to lower values of slip) may differ considerably from their values at the rated frequency. In order to obtain accurate 'results, the blocked-rotor test is performed at a frequency 25 percent or less of the rated frequency. The leakage reactance's at the rated frequency are obtained by considering that the reactance is proportional to the frequency. However, for motors of less than 20 kW rating, the effects of frequency are negligible and the blocked-rotor test can be performed directly at the rated frequency.

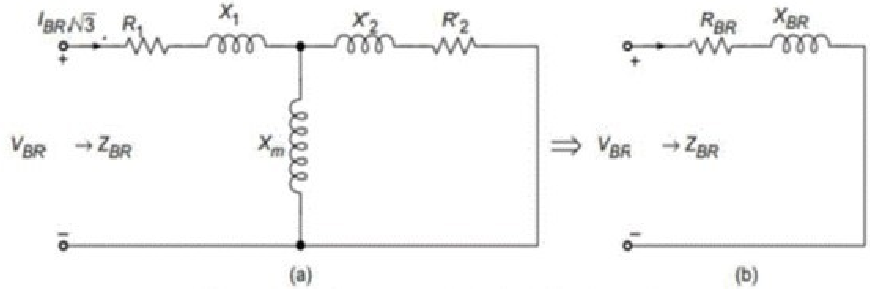

Figure 3: Circuit Model in Block Rotor Test

In the calculation of power Two Wattmeter method is used
$W_1 = VI\cos(\phi + 30)$
$W_2 = VI\cos(\phi - 30)$

Sl. No.	Power factor [pf] (Phase angle)	Wattmeter readings (W)		Remarks
		W_1	W_2	
1.	pf = unity [1.0] ($\phi = 0°$)	+ve	+ve	$W_1 = W_2$
2.	$0.5 < \text{pf} < 1.0$ ($60° > \phi > 0°$)	+ve	+ve	$W_1 > W_2$
3.	pf = 0.5 ($\phi = 60°$)	+ve	zero (0.0)	Total power = W_1
4.	$0.0 < \text{pf} < 0.5$ ($90° > \phi > 60°$)	+ve	-ve	$\lvert W_1 \rvert > \lvert W_2 \rvert$ (Total power = +ve)
5.	pf = zero [0.0] ($\phi = 90°$)	+ve	-ve	$\lvert W_1 \rvert = \lvert W_2 \rvert$ (Total power = zero (0.0))

Figure 4: 2-Wattmeter Method Readings at different power factor

PROCEDURE:

No-load test:

1) Note down the machine ratings and calculate rated current of the machine
2) Disconnect any mechanical load connected to the induction motor.
3) Gradually apply three phase voltage across motor stator terminals via the autotransformer
4) As the stator voltage is increased, the machine speeds up. Make sure the voltage is applied such that the machine does not speed up too fast
5) Adjust the stator voltage to its rated value
6) Note down no-load quantities such as V_{NL}, I_{NL}, P_{NL}
7) Slowly decrease the stator voltage to zero and disconnect the supply.

Blocked rotor test:

1) Note down the machine ratings and calculate rated current of the machine
2) Fasten the machine rotor shaft to the fixed disc with the help of screws provided. Make sure the rotor shaft is tightly held in position.
3) Slowly increase the three-phase stator voltage from zero with the help of autotransformer

4) Stop when rated current is established in the machine stator
5) Record relevant quantities from the power analyzer.

OBSERVATIONS AND CALCULATIONS:

Test	Line Voltage (V)	Line Amps (I)	Watt Meters		Input Power (P1+P2)
			P1	P2	
No Load					
Blocked Rotar					

PRECAUTIONS:

Following precautions are important for conducting this experiment:

1) All the connections should be neat and tight.
2) The meters used should be of proper range.
3) Before switching on the supply the zero settings of all the meters should be checked.
4) While performing the polarity test, full rated voltage shouldn't be applied. Only less than half the rated voltage should be applied.
5) While performing the load test, we must use an ammeter in series with the Wattmeter it is to check that the current through the wattmeter doesn't exceed the rating of wattmeter.

CALCULATIONS:

1. Calculate slip S.
2. Draw the equivalent circuit diagram of three phase induction motor with parameter values.
3. Draw the circuit Diagram of blocked rotor tests of a 3-phase induction motor.

Calculation and Conclusion