EXP. No.(5)

No- Load Test & Blocked Rotor Test on Three Phase Induction Motor

Theory:

The complete parameters of an induction motor equivalent circuit, the data of no-load test (Running light test), blocked rotor test and the measurement of dc resistance of stator winding are adequate.

i- No-load test (Running light test):

The motor is run without any mechanical load (Uncoupled to any mechanical load) fed from a balanced voltage to starter terminals at rated frequency and voltage. Current, voltage and power are measured at the motor input. The losses in the No-load test are those due to core losses, winding losses and (friction + wind age) losses. At No-load, The rotor current required is only to develop sufficient power to overcome friction and wind age torque and is, therefore, quit small.

The rotor copper losses during No-load test is thus negligible. The power drawn by induction motor at No-load is to supply the stator copper loss, mechanical losses & iron losses.

The iron and mechanical losses are therefore:

$\mathbf{P_{(iron+(f+w))}=P_o-3I_o^2R_1=P_o'}$

Where:

P_o: Is the power input to the induction machine at No-load, drawing a current I_o.

R_1 is the effective stator resistance.

The alternating current copper losses of a winding is generally more than the dc because of the following additional losses:

1- Losses due to eddy current or (non-uniform) distribution of current in the conductor (skin effaced).
2- Iron losses due to leakage flux in the magnetic material surrounding the conductor. This loss is very small compared to the first one.

To take this losses in to account, the dc resistance is increased by a factor depend up on the frequency of Ac, and the proportion of the conductor and slots. At 50 HZ the dc resistance of the stator of an induction motor of usual design is multiplied by 1.1 to obtain the effective resistance.

If the variation [$P_{iron+(f+w)}$] is plotted with the voltage, the intercept of extrapolation curve on the ordinate represents the mechanical losses, as the iron-losses is zero at zero voltage. Usually, an accurate extrapolation of the curve is difficult, and therefore Pr is plotted as a function of V^2, because this plot is more or less linear.

The curve P'_o=f (v) for weakly saturated machine is almost parabolic as shown in fig (2). Since the mechanical losses remain practically constant and iron losses proportional to the square of the flux density and consequently to the square of the applied voltage, the curve P'_o=f (v) will be a straight line. Extrapolation the curve to the (y-axis), we get mechanical losses op and iron losses at rated voltage V1=BC.

If **P_{iron}=P'_o-P (f+w)**

Is calculated at the rated voltage, the corresponding exciting branch resistance is given by:

$$R_m = \frac{P'_o}{3I_o^2}$$

$$No\ load\ input\ power = Po = \sqrt{3}\ \ V_o I_o\ cos\emptyset$$

$$\emptyset_o = cos^{-1}\frac{P_o}{\sqrt{3}V_o I_o \cos\emptyset}$$

$$cos\emptyset_o = \frac{P_o}{\sqrt{3V_o I_o}}$$

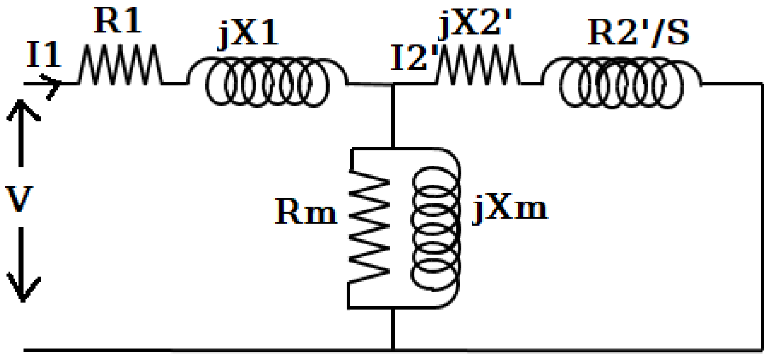
$$sin\emptyset_o = \sqrt{1 - cos\emptyset_o^2}$$

$$I_M = I_o sin\emptyset_o$$

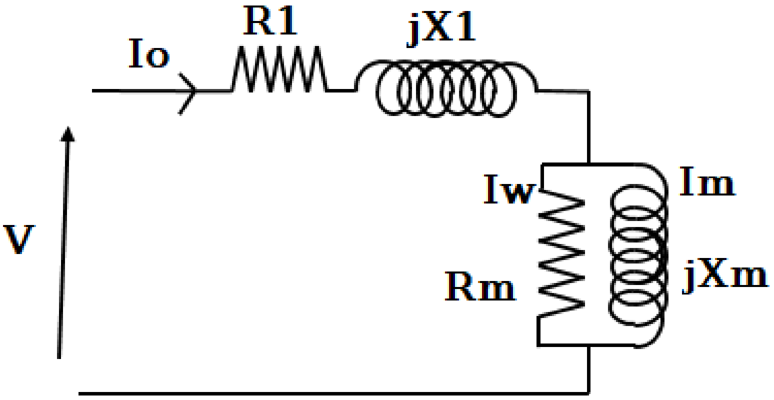
$$I_W = \frac{P_o}{3V_1} = I_o cos\emptyset_o$$

$$X_m = \frac{V_o}{I_M}$$

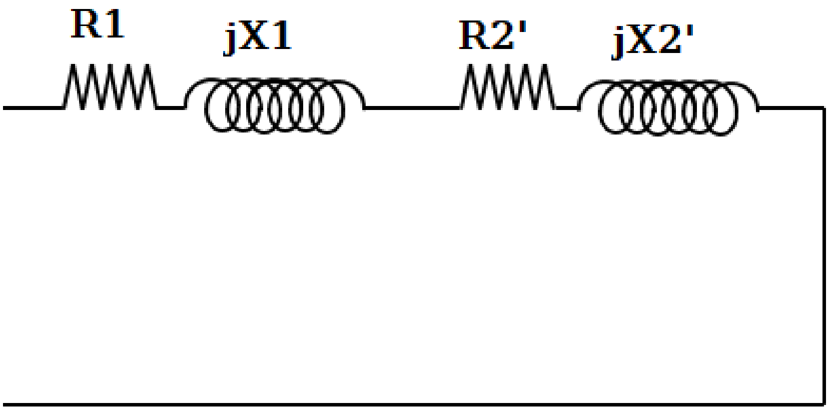
In fig (3), P_o, cos Φ_o, I_o & I_{oM}= Io are shown in fig (3) as a function of V. The curve I_M =I_o sinΦ_o =f (v) has a typical form of the magnetizing curve (its starting part has a linear form).



(a)Exact equivalent circuit



(b)No-load equivalent circuit



(c)Short circuit of equivalent circuit

Fig (1) a-b-c Equivalent circuit of induction motor

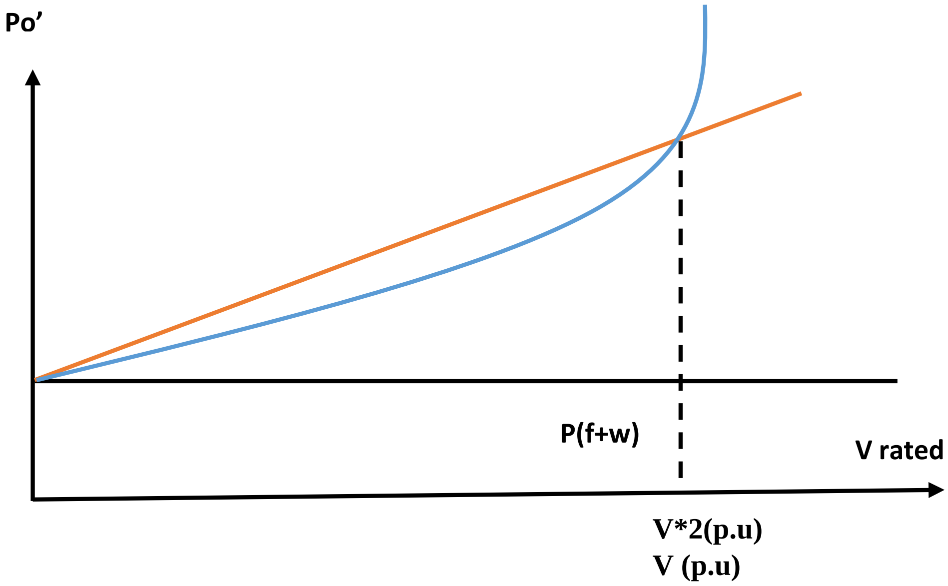


Fig (2) Variation of no-load loss with $(voltage)^2$ where (rated voltage)

ii- Blocked-rotor test (short circuit test):

The leakage reactance of an induction motor is effected by a magnetic saturation and the frequency of the rotor current. The equivalent circuit parameters are, therefore, determined for those values of current and rotor frequency at which the computation from equivalent circuit are desired. The effect of rotor frequency on stand still leakage reactance as obtained from blocked rotor test data is usually neglected in case of small motors except those with deep bar or double cage rotor. Therefore, to determine the parameters of the equivalent circuit applicable for normal range of operation of the motor, the motor test conducted at normal frequency and the current is kept at rated value.

When the rotor is locked and stator is supplied with a 3-phase low voltage, the slip is equal to one. There is no mechanical power output. Since the test voltage is low and the rotor impedance.

$$X_2' + \frac{R_2'}{s} = X_2' + R_2'$$

Compared with that of mutual branch, the later can be neglected and now the equivalent circuit reduced to that shown in fig (1.c).

It is evident that $I_{sc}=I_{rated}$ and the phase value of this current is:

$$I_{sc} = \frac{V_{sc}}{(R + R_2') + j(X_1 + X_2')} = \frac{V_{sc}}{R_{eq} + jX_{eq}} = \frac{V_{sc}}{Z_{eq}}$$

$$Z_{eq} = \frac{V_{sc}}{I_{sc}}$$

$$R_{eq} = \frac{P_{sc}}{I_{sc}^2}$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2}$$

If we know R1, then R2'=Req-R1

If we don't know, we assume R1=R2'=$\frac{R_{eq}}{2}$

There is no practical method to separated X1&X2'.

For wound rotor machine they are assumed to be equal (X1=X2'=0.5Xsc).

In case of cage-rotor machine, Xsc is distributed between stator & rotor as given in table (1) according to IEEE and NEMA standard).

Class of motor	**Fraction of Xsc**	
	X1	X2'
1. Class A (normal starting current & torque)	0.5	0.5
2. Class B (normal starting torque, low starting current)	0.4	0.6
3. Class C (high starting torque, low starting current)	0.3	0.7
4. Class D (high starting torque, high slip)	0.5	0.5

Table (1) Distribution of Leakage Reactance

The power Psc required by the machine at start circuit is consumed by the stator and rotor copper losses, neglecting a small iron losses because of small test voltage during the short circuit test.

Psc=Pcus+Pcur

=312 sc Req=312 sc (R1=R2')

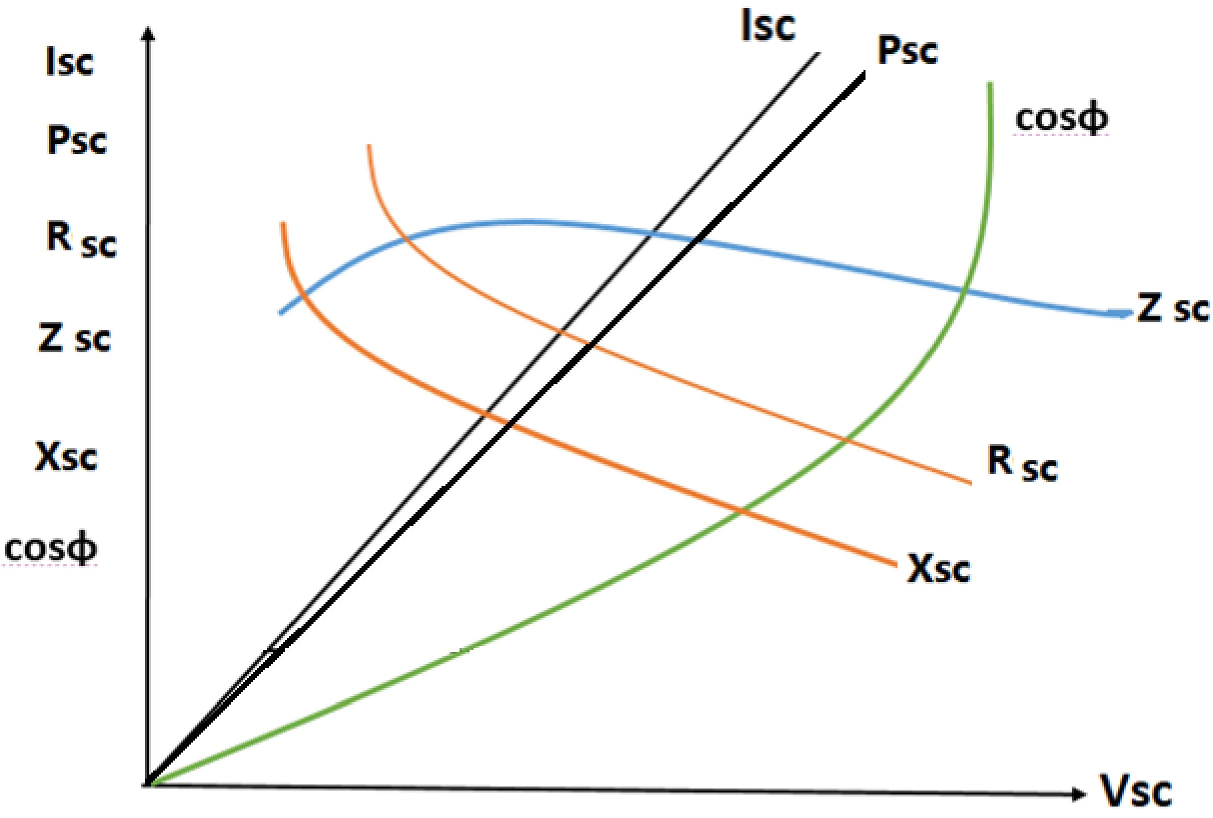
Assuming that stator & rotor leakage flux are similar in a medium with constant permeability, the reactance is almost constant, (Xeq=constant), similarly Req=constant. Therefore Zeq =constant and hence the relationship Isc=f (Vsc) is almost a linear one. Correspondingly cos Φsc =$\frac{Req}{Zeq}$, shows a constant value, whereas the input power as a function of the applied voltage is parabolic. Typical curves are shown in fig (4).

The starting current of the machine when rated voltage is applied is determined by:

I_{sc} (starting) =I_{sc} ($\frac{V_{rated}}{V_{sc}}$)

And the input power at starting on full voltage is given by:

$$P_{sc(starting)} = P_{sc}(\frac{V_{rated}}{V_{sc}})^2$$



Variation of Short Circuit Quantities with Vsc

Fig.(3)

Procedure:

1. Connect the circuit as shown in fig (4).
2. If the motor is of slip-ring induction motor, open circuit the rotor winding when at rest, supply rated ac voltage to the stator. Measure the voltage appearing across a pair of slip rings of the rotor.
3. Start the motor on no-load. Take the readings of all instruments while the voltage is reduced in steps from 120% to 20% rated in accurate step.
4. Lock the rotor securely so that it cannot rotate. Short circuit the rotor terminals, supply the stator with a reduced voltage. Take readings of all instruments while the voltages is reduced from that which gives 20% I rated [Reading should be taken quickly to avoid over heating because of lock of ventilation].
5. Measure the stator & rotor (if is a slip ring motor) resistance by using voltmeters, ammeters & low dc voltage. To obtain ac or effective value of resistance multiplying dc resistance by a factor (1.1), which is return to skin effect factor.

Graphs & Calculation:

1. Plot Po, Io, and IoM& cos ф as a function of one graph.
2. Plot $Po' = (\frac{V}{V_{rated}})^2$ and $(\frac{V}{V_{rated}})$ the iron losses &mechanical loss at rated voltage.
3. Find the following from no-load test:
   Turn ratio=$\frac{V_s}{V_r}$, Im, Iw, Rm, Xm.
4. From blocked rotor test data, find Zeq, Req and Xeq for the rated current.
5. Plot Isc, Psc, and cosф, as a function of Vsc on one graph.
6. Draw the equivalent circuit of the motor, showing the value of parameter of the circuit.

Discussion:

1. Give the slip value of the motor at the following speeds, stand still, 20% of synchronous speed & synchronous speed.
2. Calculate the frequency of the rotor currents and voltages at the above speed.
3. Upon what factors to the following quantities depend, Piron, P (f+w), Xm, Iw, and I_M.

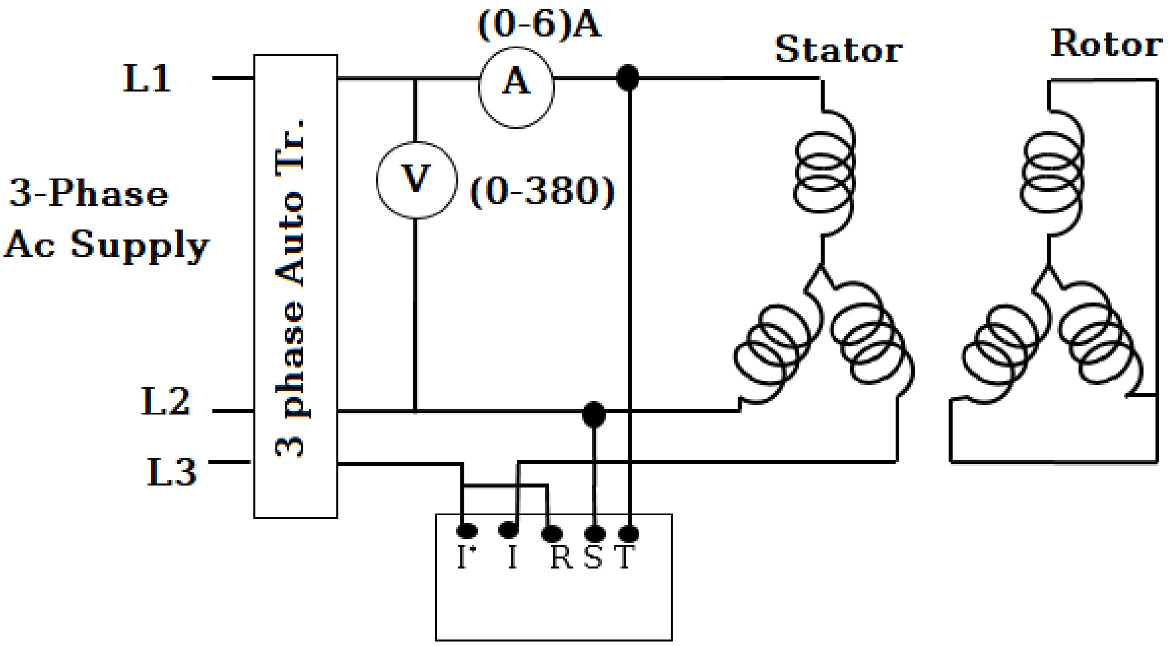


Fig (4) Circuit Diagram