Experiment-7: No-Load and Blocked Rotor test on a 3-Φ Induction Motor

Group number 22:

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Aim:-

- *To compute the equivalent circuit parameters of a 3-Φ induction machine using the no-load and blocked rotor tests in SIMULINK.*

Equivalent circuit arrangement:-

Figure-1 shows the equivalent circuit of a 3-Φ induction motor under the balanced mode of operation. To perform any analysis on induction motors, the equivalent circuit has to be drawn, for which, the circuit parameters are determined by using no-load and blocked rotor tests.

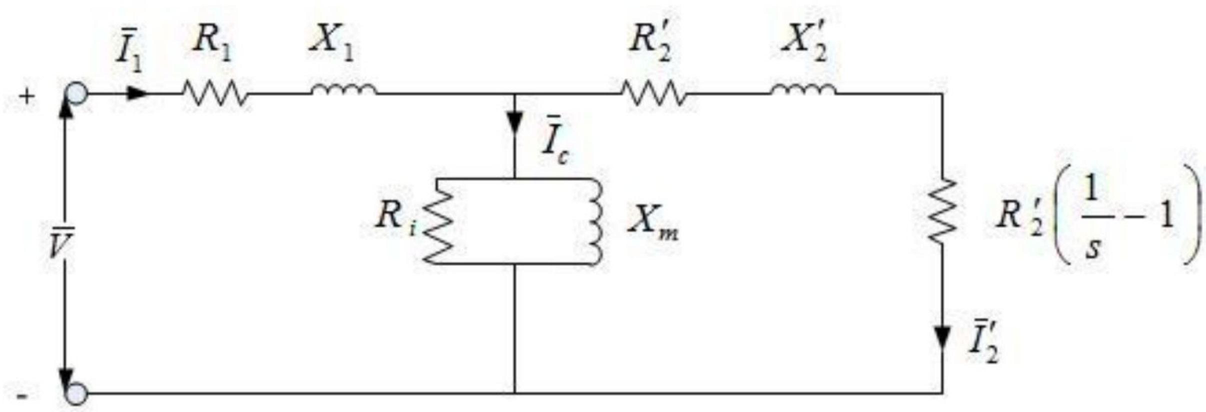


FIGURE 1: EQUIVALENT CIRCUIT OF AN INDUCTION MOTOR

The equivalent circuit shown in Figure-1 is basically the positive sequence representation of the actual 3-Φ equivalent circuit model of the induction motor. Since the motor is operating under a balanced condition, the negative and zero sequence networks are having no contribution to the performance of the induction motor.

Circuit Arrangement:-

The circuit arrangement for the experiment is shown in Figure-2. The measuring instruments such as a voltmeter, an ammeter, a frequency meter, two wattmeters, and a star-delta switch are required for conducting the experiment.

The purpose of connecting a frequency meter is to get accurate information of the prevailing supply frequency. The rotor circuit for the particular experiment should be directly shorted. On the other hand, the stator circuit should be first connected in star and then in the delta, and readings should be taken for each configuration. The objective behind employing a switch before the induction motor is to facilitate the above star-delta conversion.

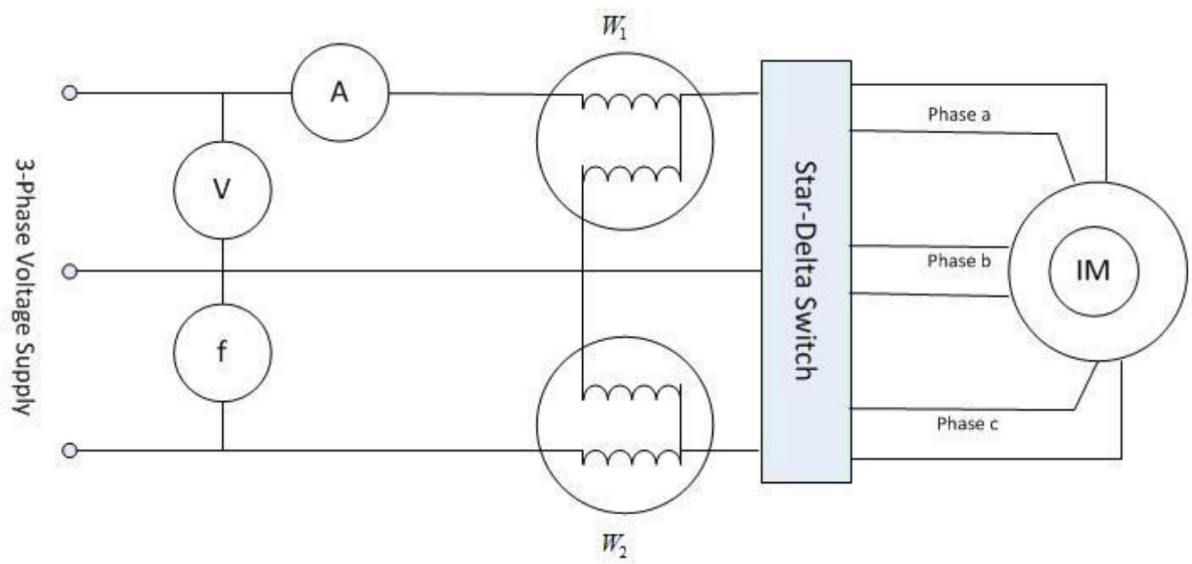


FIGURE 2: EXPERIMENTAL SETUP

Test Procedure:-

Two separate tests are to be performed to determine the equivalent circuit parameters of an induction machine. Those tests are named as a no-load test and the blocked rotor test.

1. As the name itself suggests, for the no-load test, the rotor is allowed to rotate freely without any load. Hence, the drum-brake arrangement has to be set into a completely relaxed position for the no-load test.

2. The supply voltage to the stator terminal is now to be increased gradually up to the rated value. Subsequently, the voltmeter, ammeter, wattmeter and frequency meter readings are to be taken. The speed of rotation of the rotor is also to be measured by using a Tachometer. Let the voltmeter, ammeter, and tachometer readings that are obtained from the no-load test be indicated by V_0, I_0, and n_0, respectively. Here, n_0 is expressed in r.p.m. In the same way, the wattmeter readings for the no-load test be symbolized as W^0_1 and W^0_2, respectively. The slip of the induction-motor corresponding to no-load can then be calculated as follows

$$S_0 = (60f - 2n_0)/60f \qquad (1)$$

Note that the multiplier 2 does occur here with N_0 since all our induction motors are 4-pole machines. Next, the no-load power consumption of the induction motor can be calculated as,

$$P_0 = W^0_1 + W^0_2 \qquad (2)$$

The next task is to determine the input impedance across the stator terminal under the no-load condition. This can be calculated simply by using the following formulae.

$$Z_0 = (V_0)/(\sqrt{}3*I_0) \qquad (3)$$

$$R_0 = (P_0)/(3*I_0^2) \qquad (4)$$

$$X_0 = \sqrt{}(Z_0^2 - R_0^2) \qquad (5)$$

3. *In contrast to the no-load test, the brake should be sufficiently tightened to prevent rotor movement in the blocked rotor test. In the blocked rotor test, the stator voltage should be gradually increased until the rated current is established in the stator circuit. Similarly, to the no-load test, the input impedance across the stator terminal under the blocked rotor condition can be determined as follows.*

$$Z_{BR} = (V_{BR})/(\sqrt{}3*I_{BR}) \qquad (6)$$

$$R_{BR} = (P_{BR})/(3*I_{BR}^2) \qquad (7)$$

$$X_{BR} = \sqrt{}(Z_{BR}^2 - R_{BR}^2) \qquad (8)$$

With the no-load and blocked rotor input impedances are determined, the equivalent circuit parameters can be obtained through the following approximate formulae.

$$R_{iwf} = X_m^2/(R_0-R_1) \qquad (9)$$

$$X_m = X_0 + X_1 \qquad (10)$$

$$X_1 + X_2^{'} = X_{BR} \qquad (11)$$

$$R^{'}_2 = (R_{BR} - R_1)*((X_m+X_2)/X_m)^2 \qquad (12)$$

$$R_{iwf} = (R_1R^{'}_2)/(R^{'}_2 - s_0R_1) \qquad (13)$$

Equations (9)-(12) along with (13) in effect define a set of five equations with seven variables, which can never be solved. To resolve this issue, the stator resistance is to be separately determined through a direct current test. Here, you have to apply a DC voltage (less than the rated voltage) across any phase of the stator winding. The corresponding current magnitude is to be noted. The DC value of R1 can then be calculated as follows.

$$R^{dc}_1 = V_{dc}/k*I_{dc} \qquad (14)$$

Here,

K is equal to one of the stator is in star and three if it is in the delta. The value that is obtained from (14) can be corrected for AC by employing the following formula.

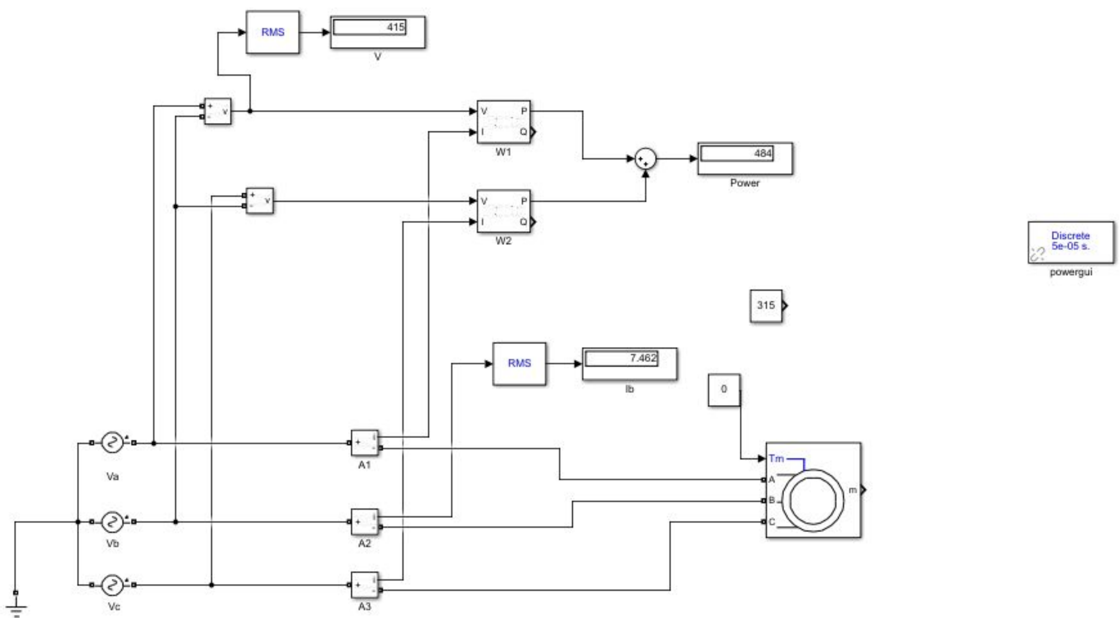
$$R_1 = R^{dc}_1/\square \qquad (15)$$

where,

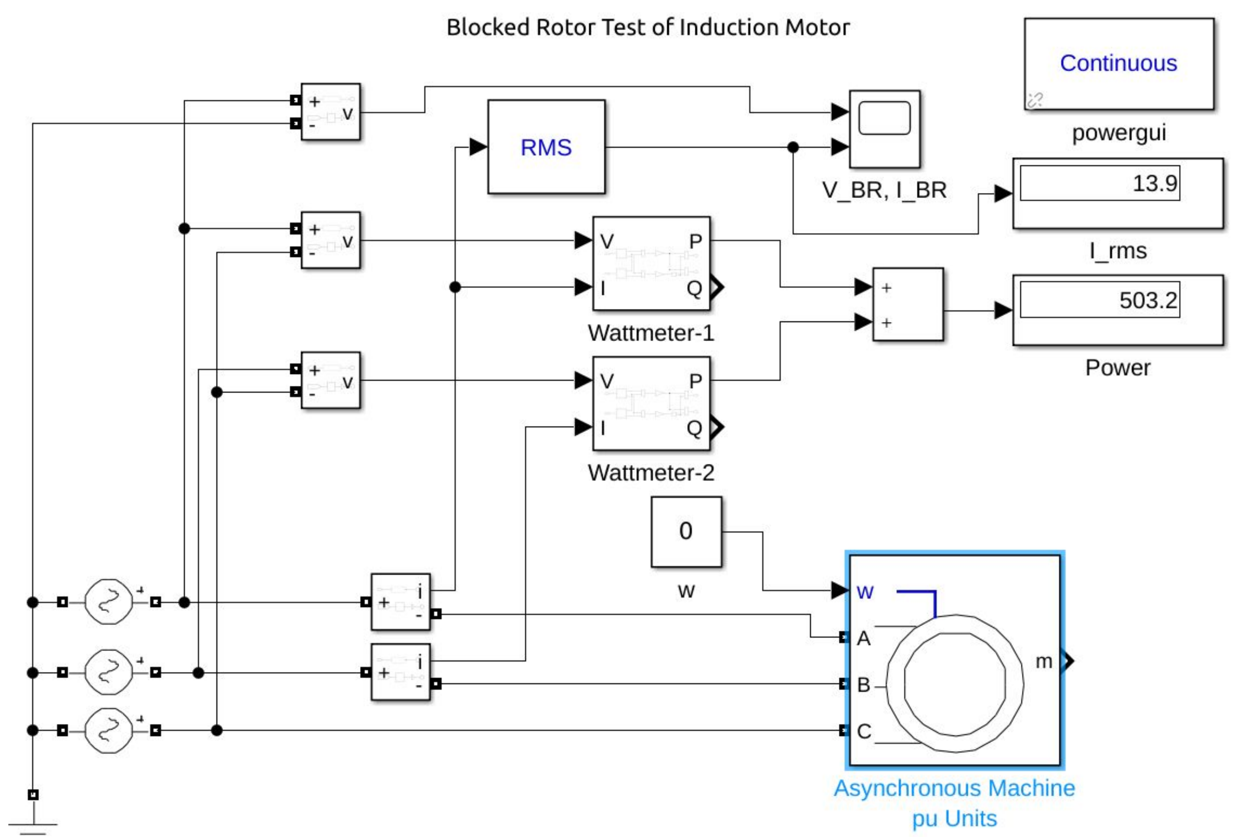
$$\square = \sqrt{}(\rho/\square f\mu) \qquad (16)$$

*Here, ρ and μ indicate the resistivity and magnetic permeability, respectively, of the conductor material. For copper, these values are 1.68 * 10^(-8) Ω-m and 1.257 * 10^(-6) H/mH/m, respectively. In addition to the direct determination of R_1, the value of X_1 is further assumed to be equal to X'_2 to obtain the equivalent circuit parameters from (9)-(13).*

Circuit Diagram for No-Load Test:



Circuit Diagram for Blocked Rotor Test:



Calculations

Assumptions

Configuration of Induction Motor = 10HP, 415 V, 50 Hz

⇒ P_{out} = 415 V

⇒ Assuming Efficiency = 88%

⇒ Power Factor at Full-Load = 0.85

General Readings

$P_{in} = \frac{100}{88} \times P_{out} = \frac{100}{88} \times 10 \times 746 = 8477.27$ Watts.

⇒ $8477.27 = \sqrt{3} \times 415 \times I_{fl} \times 0.85 \Rightarrow \boxed{I_{fl} = 13.874 \text{ Amps}}$

Blocked Rotor Test Readings

I_{BR} = 13.874 Amps

V_{BR} = 39.5 Volts

P_{BR} = 503.2 Watts.

No-Load Readings

P_0 = 484 Watts

I_0 = 7.462 Amps

V_0 = 415 Volts.

R_1 = 0.01965 ohm.

$$Z_{BR} = \frac{V_{BR}}{\sqrt{3}\, I_{BR}} = \frac{39.5}{\sqrt{3} \times 13.874} = 1.643 \text{ ohm}$$

$$R_{BR} = \frac{P_{BR}}{3 I_{BR}^2} = \frac{503.2}{3 \times \cancel{(19.8)^2}} = \frac{503.2}{3(13.874)^2} = 0.871 \text{ ohm}$$

$$X_{BR} = \sqrt{Z_{BR}^2 - R_{BR}^2} = \sqrt{(1.643)^2 - (0.871)^2} = 1.393 \text{ ohm}$$

$$\Rightarrow \boxed{Z_{BR} = 1.643 \text{ ohm}, \quad R_{BR} = 0.871 \text{ ohm}, \quad X_{BR} = 1.393 \text{ ohm}}$$

$$\boxed{X_1 = X_2' = \frac{X_{BR}}{2} = 0.696\,\Omega}$$

$$Z_0 = \frac{V_0}{\sqrt{3} I_0} = \frac{415}{\sqrt{3} \times 7.462} \Rightarrow Z_0 = 32.109 \text{ ohm}$$

$$R_0 = \frac{P_0^2}{3 I_0^2} = \frac{484}{3 \times (7.462)^2} \Rightarrow R_0 = 2.897 \text{ ohm}$$

$$X_0 = \sqrt{Z_0^2 - R_0^2} = \sqrt{(32.109)^2 - (2.897)^2} \Rightarrow X_0 = 31.978 \text{ ohm}$$

$$\Rightarrow \boxed{Z_0 = 32.109\,\Omega, \quad R_0 = 2.897 \text{ ohm}, \quad X_0 = 31.978 \text{ ohm}}$$

$$X_m = X_0 - X_1 = 31.978 - 0.696 \Rightarrow \boxed{X_m = 31.282 \text{ ohm}}$$

$$R_{iwf} = \frac{X_m^2}{R_0 - R_1} = \frac{(31.282)^2}{2.897 - 0.01965} \Rightarrow \boxed{R_{iwf} = 340.09\,\Omega}$$

$$R_2' = (R_{BR} - R_1) \Big/ \left(1 + \frac{X_2}{X_m}\right)^2 = (0.871 - 0.01965) \Big/ \left(1 + \frac{0.0397}{31.282}\right) = 0.87\,\Omega$$

$$\boxed{R_2' = 0.87\,\Omega.}$$

Assuming $X_2 = 0.0397$

Results and conclusions:-

Parameters of Motor:

10 Hp, 415V, 50Hz Induction Motor

$V_{Rated} = 415V$, $I_{Rated} = 13.874A$

Stator in star

Observations:

$V_0 = 415$ V

$I_0 = 7.462$ A

$P_0 = 484$ W

$V_{BR} = 39.5$ V

$I_{BR} = 13.874$ A

$P_{BR} = 503.2$ W

Results:

$Z_0 = 32.109\ \Omega$

$R_0 = 3.897\ \Omega$

$X_0 = 31.978\ \Omega$

$Z_{BR} = 1.643\ \Omega$

$R_{BR} = 0.871\ \Omega$

$X_{BR} = 1.393\ \Omega$

$R_1 = 0.01965\ \Omega$

$R'_2 = 0.87\ \Omega$

$X_1 = 0.696\ \Omega$

$X'_2 = 0.696\ \Omega$

$R_i = 340.09\ \Omega$

$X_m = 31.282\ \Omega$