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# TESTING OF 3 PHASE INDUCTION MOTOR USING MATLAB/SIMULINK FOR UNDERGRADUATE ELECTRIC MACHINERY COURSES

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***Abstract-***

***Induction motors are the most widely used electrical motors in the industry due to their reliability, low cost and robustness. For industrial applications, 3- phase induction motors are the prime movers for the vast majority of machines.***

***This paper describes the different tests like no load test, blocked rotor test and also of three phase induction motor. All tests are performed on MATLAB/Simulink software. The equivalent circuit model and results analysis is also presented. The proposed tests have been successfully included into undergraduate machinery courses.***

***Keywords— 3 phase Induction Motor, MATLAB/ Simulink software, No load test, Blocked rotor test***

## INTRODUCTION

Asynchronous machines are considered nowadays the most commonly used electrical machines, which are mainly used as electrical induction motors and sometimes as generators. This is mainly due to the simplicity of composition, low price, light weight, high reliability, easy to command and control performance and not containing parts that could easily breakdown compared with DC machines and synchronous machines.

Induction motors are the preferred choice for industrial motors due to their rugged construction and the ability to control the speed of the motor. This paper tests parameters of three phase induction by performing different tests such as no-load; blocked-rotor tests which can be effectively simulated using MATLAB. Today, Computer-aided teaching tools have become an essential part for theory class and also for laboratory experiments in engineering education. The simulations of motors (induction), as teaching device, gives additional support to the classroom teaching by enabling through the computer-generated graphics, so it is easily understand operation of the motor under various loading conditions. The simulation tool gives the opportunity to the students to verify their results with the laboratory experiments and also gives comparison opportunity which helps students to realize the limitations of hardware experiments.

In the undergraduate electrical machinery course it covers the basic construction, working and steady-state operation of the three phase induction motor in which the per-phase equivalent circuit is used to calculate various motor quantities, such as input current, power, power factor, developed torque, and efficiency. To understand and study these parameters the two tests are performed namely no-load and blocked-rotor test. Also, at no load induction motor has very low power factor. It improves at increasing load from no load to full load. Low power factor becomes a problem in industry where multiple large motors are used so there is necessity to correct the power factor. So it is important to understand the concept of power factor and this can be achieved by adding capacitive load to the inductive load in the power system. The concept of power factor improvement is presented with equivalent circuit model.

In the laboratory the hardware of machine model is available; the student performed their experiments which is included as per the syllabus and become familiar with the induction motor operation. Generally, during performance of experiment the students apply their theory knowledge which is covered in classroom also the experimental manual is provided to the students at least a week before which covered the detailed procedure of the experiments. The two-hour laboratory time is allotted for students in which they have to make the set up and perform the experiment on induction motor, take the necessary measurements, and make the conclusion of various conditions of motor. Due to this time limitations, students are only in hurry to finish the experiments, which probably prevents them from getting a desired knowledge of motor during the laboratory practice.

Therefore, simulation tools can help the students to understand experiments on induction motor before coming to the laboratory. The objective of this paper is to present simulation models of these induction motor experiments in an effort to design a computational laboratory. The no-load and blocked-rotor simulation models are developed as stand-alone applications using MATLAB/Simulink.

## II. INDUCTION MOTOR TESTS

The per phase equivalent circuit of an induction motor as shown in fig 1, in this circuit, $R_1$ represent stator resistance and $X_1$ leakage reactance, respectively; and $R_2$ denote the rotor resistance and $X_2$ leakage reactance referred to the stator, respectively; $R_C$ resistance stands for core losses; $X_m$ represents magnetizing reactance; and S denotes the slip. The equivalent circuit is used to calculate the various operating quantities, such as stator current, input power, losses, induced torque, and efficiency. The core losses can be included in efficiency calculations along with the friction, windage, and stray losses. The parameters can be obtained by performing no load and blocked rotor test.

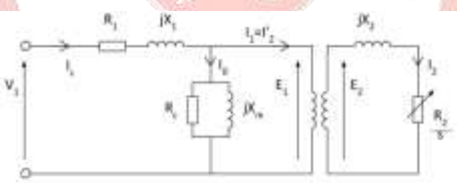

Fig.1 Per phase equivalent circuit of induction motor

1. No Load Test

This test is just similar to open circuit test on transformer. The motor is uncoupled from its load and the rated voltage at rated frequency is applied to the stator to run the motor without load. The input power is measured by the two wattmeter method. The ammeter and voltmeter measures the no load current and rated voltage of the motor. The no load current is 20% to 30% of full load current. The motor is running on no load so total power is equal to constant iron loss, friction and windage loss of the motor. The experimental set up as shown in fig.2.

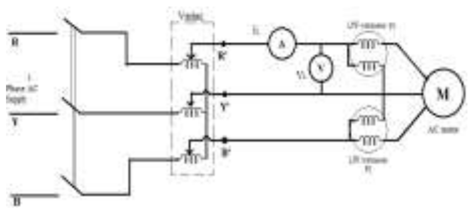

Fig.2 Experimental setup of the no-load test

Friction and windage loss can be separated from no load loss (input power). From experimental set up the rotational losses is calculated with the help of measuring instruments, the same model is provided for the simulation purpose to check the results with given practical values.

The no-load test simulation model is presented in fig 3. The three-phase balanced Y-connected ac supply whose per-phase voltage is 220 V is applied to the stator terminal of the induction motor. The output terminals of induction motor are short circuited. The mechanical torque $T_m$ is set to be zero to

simulate the no-load condition. The equivalent circuit parameters obtained from experimental data and the numbers of poles are specified using the induction motor-block dialogue box. Three current measurement blocks are used to measure the instantaneous current of each phase. The output of each current measurement block is connected to a root-mean-square (rms) block, called signal rms, to determine the rms value of each phase current. The outputs of the voltage measurement block and the current measurement block of phase A are connected to a power measurement block, called the active and reactive power measurement, that computes the active power and reactive power. A machine measurement block is used to get the mechanical speed. Through the scope and display block, the waveform and the steady-state value of the rotor speed can easily be measure. There is difference in the values obtained from simulation model and practical set up. In experimental set-up the real input power is measured, while per-phase-based real and reactive power is measured in simulation model. However this difference is not significant since under the three phase balanced operation, computations are usually performed using phase quantities.

Input line voltage = $V_l$

Total 3 phase input power at no load = $P_{0i/p}$ (line)

Input line current = $I_0$

Input phase voltage = $V_p$

Power input on open circuit $P_0 = \sqrt{3}\, V_l I_0 \cos \Phi_o$

The phase voltage can be calculated as; $V_p = V_l / \sqrt{3}$

No load impedance per phase will be $Z_{NL} = V_p / I_p$

No load resistance is; $R_{NL} = P_0 / 3I_p^2$

No load reactance is; $X_{NL} = \sqrt{(Z_{NL}^2 - R_{NL}^2)}$

Where $X_{NL} = X_1 + X_m$

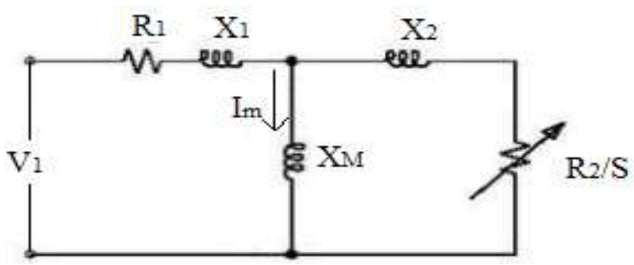


Fig. 3 equivalent circuit of no load test

2. Blocked Rotor Test

This test is analogous to the short circuit test of a transformer. The shaft of the motor is locked so that it cannot move and rotor winding is short circuited. A reduced voltage at rated frequency is applied to the stator through starter so that full load rated current flows in the stator. The power input is equal to the sum of copper losses of stator and rotor for all three phases. This is due to the reduced voltage is applied to the stator and rotation is not allowed and therefore core and mechanical losses are negligible.

Line current on short circuit = $I_{sc}$

Line voltage on short circuit = $V_{sc}$

Power input on short circuit $Psc = \sqrt{3}\, V_{sc} I_{sc} \cos \Phi_{sc}$

Equivalent resistance of motor referred to stator $R_e = Psc / I^2_{sc}$

Equivalent impedance of motor referred to stator $Z_e = Vsc / I_{sc}$

Equivalent reactance of motor referred to stator $X_e = \sqrt{Z^2_e - R^2_e}$

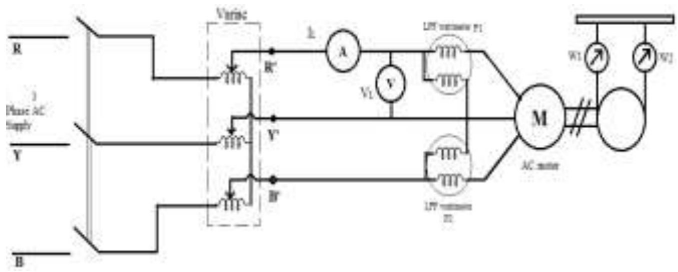


Fig.4 Experimental setup of the blocked rotor test

The simulink model for blocked rotor test is same as that for the no load test however the value of input voltage is adjusted so that the current display the rated phase current. To make the mechanical speed of rotor to zero rad/s, inertia of the machine is set to infinity in the machine dialogue box. In blocked rotor test, the mechanical torque is no longer 0; its value used for the model is set to 5 N-m. For electrical parameters of the machine, entered in the machine dialogue box, the values of active and reactive powers are computed.

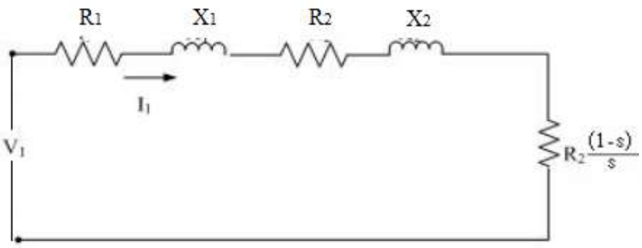


Fig. 5 equivalent circuit of blocked rotor test

## III. EXPERIMENTAL RESULTS

The squirrel cage induction motor with variable transformer is used to provide input voltage. We calculate the line to line voltage and line current with the help of meters. The wattmeter is connected to measure the power.

Table 1

Observation Table for No load Test

| Sr no. | line Voltage (V) | line Current (A) | Power (W) | Frequency (Hz) |
|---|---|---|---|---|
| 1 | 415 | 1.8 | 650 | 50 |

Table 2

Observation Table for Blocked Rotor Test

| Sr | line voltage | line current | power | Frequency |
|---|---|---|---|---|

| no. | (V) | (A) | (W) | (Hz) |
|---|---|---|---|---|
| 1 | 240 | 8 | 2400 | 50 |

The above results are compute in simulated software to check the result.

Here we conducted No-load test and Blocked rotor test on induction motor. These tests are carried out to find the various parameters of induction motor. The basic induction motor project simulation model is developed shown in figure.6 below.

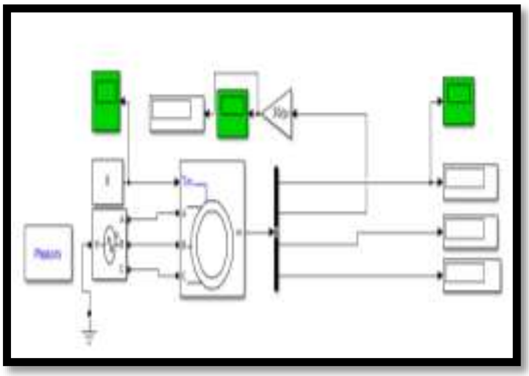

Fig 6:- Basic simulation model for three phase induction motor

The simulation model for No-load test is shown in figure 7 below

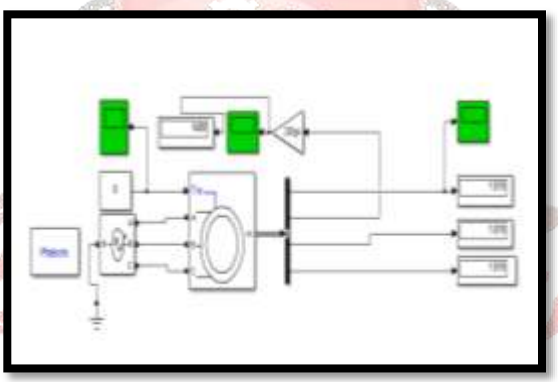

Fig 7:- Simulation model for No Load Test

The simulation model for Blocked test is shown in figure 8

below

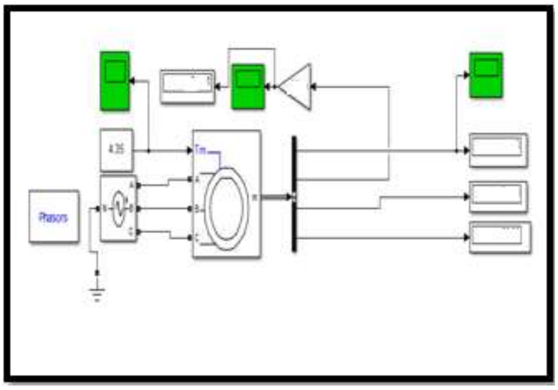

Fig 8:- Simulation model for Blocked Rotor Test

The following results are to be obtained which provide the verification of test o the simulation software.

Results for No Load test:

I) No load Current Waveform:

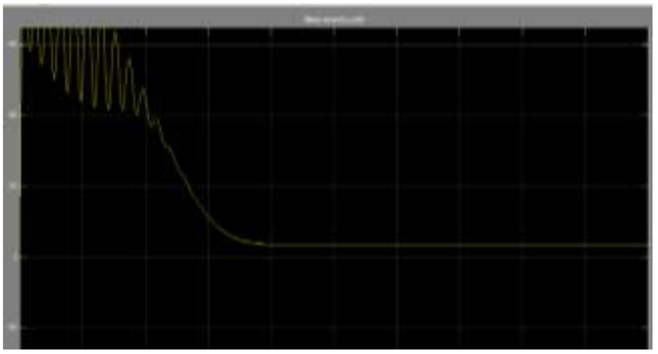

Fig 9:- No Load Current Waveform

II) No load Speed:

Fig 10:- No Load Speed Waveform

Results for Blocked Load test:
I) Short Circuit Current:

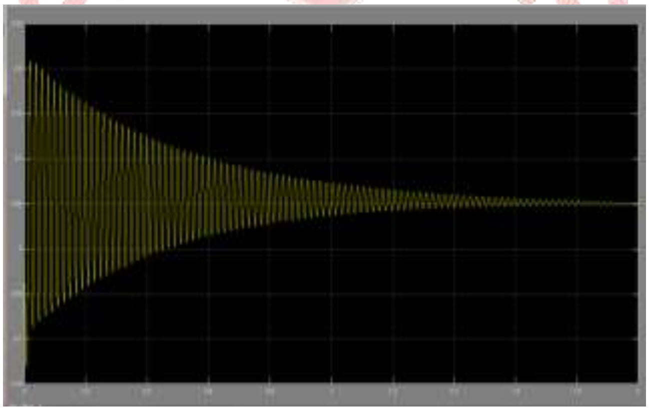

Fig 11:- Blocked Rotor Current Waveform

## IV. ADVANTAGES AND DISADVANTAGES

**Advantages:**

- MATLAB testing can be possible without using the hardware assembly
- The time required for this MATLAB testing is much less as compared to hardware testing.
- It is simple to test any type of load machine

**Disadvantages:**

- The results obtained by simulation are approximate to practical results

## V. CONCLUSION

The study presented in this paper is an important demonstration in educational domain for the students of Electrical Engineering. Different parameters of induction motor can be determined by performing No load test and Block Rotor test. The simulation data of no-load and blocked rotor test of motor has explained in detail and compared with the corresponding experimental setup. The error study shows that MATLAB with Simulink is a trustworthy simulation tool to model induction motor.

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