Labview Based Laboratory Typed Test Setup for the Determination of Induction Motor Performance Characteristics

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Abstract – Induction motors are widely used due to their rugged, robust and easy to care features. Since they are heavily used in industry, testing of three phase induction motors have play a vital role. In order to determine motor equivalent circuit parameters, efficiency of motor, squirrel caged laboratory sized an induction motor test set-up is prepared. It is suitable for the induction motor with the frame size of 100 and 112. A virtual Instrumentation typed engineering workbench (called as LabVIEW) software packet, is utilized as a graphical user interface program. Motor input power is measured by measuring the input voltage, current and power factor with the help of Hall Effect voltage and current transformers. Also, the output power is measured by measuring the speed and torque with the help of an encoder and torque sensor. All outputs of the voltage and current transformer, encoder and temperature, torque sensors are given to the Data Acquisition Card (DAQ) which acquires the data for processing and then the equivalent circuit parameters, efficiency, performance and loading characteristics are found out, using LabVIEW based user interface. It is suggested to use this test rig for the quality control of produced motors in industry, and an educational experiment setup in the school laboratories.

Keywords: Induction motor, Performance characteristics, LabVIEW, Test setup, Equivalent circuit

1. Introduction

Induction motors are widely used in industrial application such as fans, compressors, pumps, conveyor, winders, mills, transports, elevators, home appliances. It is an important task to determine the efficiency of the induction motor. It is useful to illustrate the operation of induction motor under various loading conditions. The test setup or virtual instruments enable to enhance or verify the results of laboratory experiments of electrical machine. They help students to understand theoretical aspects and predict the motor performances. It also enhances instructors’ ability to teach electrical machine courses as mentioned in [1].

A new technique for efficiency measurement is proposed in [2]. An automatic procedure using Matlab software to enhance learning of induction motor laboratory tests is described in [3]. It helps to determine the equivalent circuit parameters deduced from experimental tests and provides induction motor characteristics. It also implies a positive impact on students learning experience in electrical machinery course.

An another approach for teaching the concept of electric machines laboratory using specially designed exercises based on Matlab/Simulink is presented in [4]. This work provides a simulation tool to analyze performance characteristics of induction motor.

Matlab/Simulink based interactive simulation tool for the no load test, load test and blocked rotor test on three phase induction motors is provided in [5]. Equivalent circuit model and torque equation are used for modeling by ignoring magnetic saturation. The developed program can plot all relevant graphs and circle diagram of the given motor. A dynamic model of induction motor based on LabVIEW is proposed in [6]. The effectiveness of motor model and the motor steady state performance are showed. Up to now, there are several published works about Matlab / Simulink based test or simulation tools, but LabVIEW based studies are limited [7]. Effects on induction motor efficiency, comparison of efficency standards are discussed in [8], and major differences between these standards are seen about the treatment of stray losses.

The objective of this work is providing a LabVIEW based an experimental test setup for the induction motor to aid teaching of electrical machine course in electrical engineering. It requires to find out equivalent circuit parameters by performing DC, no load, and blocked rotor tests on laboratory typed induction motor. In this work, transducers are used for measuring input voltages, currents, the motor speed and torque. The output of them are first conditioned and then acquired by the DAQ card. The results are processed and displayed using LabVIEW based front panel.
2. Description of the Test Setup

The block diagram of the overall setup and image of main part of the test rig are given in Fig. 1 and Fig. 2 respectively. The system depicted in Fig. 1 consists of hall effect typed voltage and current transformers, torque sensor capable of measuring the values of 0-50 Nm and providing 0-5V linear DC output voltage, rotary type incremental encoder providing 1024 pulse per revolution and temperature transducer.

LA 55-P typed three current sensors used to measure motor phase currents reduced 1000 times. Voltage transformers drop supply voltage to the range of zero to five volts. As seen from Fig. 2, small sized squirrel caged three phase induction motor is loaded by magnetic brake. Tested motor nameplate is as following; 2.2 kW, 940 rpm, 380 V Y connected, 5.4 A, Cos $\Phi$ 0.76, 50Hz.

Whole sensor outputs are sampled with frequency of 6 kHz and recorded. Then, equivalent circuit parameters are calculated and performance characteristics are determined. LabVIEW is a useful program for graphical user interface and provides interactive design tool to enhance teaching of characteristics of induction machines (see [10]).

To calculate the input power of the induction motor, the phase voltage and current signals are acquired from a voltage and a current transducer. The voltage transformer steps down motor supply voltage to the range of between 0 and 5V. In coming reduced phase voltage is multiplied by a constant multiplication factor for representing their actual magnitude. The phase current also step downed and converted to voltage by a parallel resistance. Next, the output of signal conditioning circuit is given to the LabVIEW through the DAQ, where the signal is converted into digital form and is acquired by LabVIEW.

The main menu shown in Fig. 3 consists of eight different tests. These are inputting the motor nameplate, selection of DC, no load, blocked rotor tests, calculation of equivalent circuit parameters, plotting of performance characteristics and loading analysis of motor in different speeds, and finally verification of values, written in motor nameplate.

3. Induction Motor DC Test

When DC test tag clicked on Fig. 3, DC test sub VI activated shown as in Fig. 4. This test is performed to compute the stator winding resistance.

For this purpose, a DC voltage is applied to the connection of the two stator phase windings. Tested motor is Y-connected. The applied voltage is increased step by step until rated motor current is reached. This current and voltage across two phases are recorded. Stator resistance is computed as

$$R_s = R_s + R_s = 2R_s, R_s = \frac{R_s}{2}$$  \hspace{1cm} (1)

Fig. 3. Front panel of developed user interface of induction motor test setup

Fig. 4. Front panel of DC test sub virtual instrument (VI)
This resistance value is multiplied with a constant value of 1.11 to include skin effect [11]. When you see the alert message of “Induction motor DC test is completed” you press the save button to record the values.

4. Blocked Rotor Test

This test is performed to determine rotor resistance and stator and rotor reactances. In the experiment the rotor of the induction motor is blocked by the help of special mechanism. Reduced motor voltage is applied to stator windings. It is increased in a small steps by using auto transformer until the rated current flows through the stator windings. When the alert of “Induction motor blocked rotor test is completed” is seen on the user interface panel (see Fig. 5.), whole measured data are recorded for the calculation of rotor leakage reactance.

5. No load Test of Induction Motor

When No Load test tag is clicked in main menu shown on Fig. 3, a sub VI is activated shown as in Fig. 6. The purpose of this test is finding the core and rotational loss value of the motor, and to determine magnetizing reactance. In this part, nominal voltage at rated frequency is applied to stator windings at motor no load. Input power, voltage, and phase currents are measured. Phase difference (Φ) is calculated by finding the angle between the sampled current and the voltage. Then, the power factor (cos Φ) is found.

To find the power factor, the pulse duration of the pulses generated by the comparator and the total period of the incoming current or voltage signal is calculated. This is done by using the timing and transition measurements block and a sub VI which employs the following formulae to calculate the power factor and phase difference:

\[ \text{Phase difference} = \frac{\text{Pulse duration}}{\text{Total period}} \times 360 \]  
(2)

\[ \text{Power factor} = \cos\left(\frac{\text{Phase difference} \times \pi}{180}\right) \]  
(3)

The cosine of the phase difference is calculated to get the power factor value. This is done using a sub VI in real time.

Now, the active and reactive input powers can be calculated using these three parameters. The input power of the motor is calculated as follows.

\[ \text{Input power} = 3V_i I_i \cos \Phi \]  
(4)

The output power is found by measuring the speed and the torque of the motor at different load conditions. The torque sensor converts the rotational force of the motor into dc voltage. The system has an encoder to measure the speed of the motor. Using these torque and speed measurements the output power of the motor can be calculated. The torque value is displayed and the value is further used for the measurement of the output power. The values of torque and speed readings are substituted in the equation 5 to obtain the output power.

\[ \text{Input power} = \frac{2\pi NT}{60} \]  
(5)

where N stands for mechanical speed (rpm), and T (Nm) for motor torque. Finally, motor efficiency is calculated by the ratio of the output power to the input power [11-12].

6. Calculation of Equivalent Circuit Parameters

Using the values obtained from DC test, stator resistance is determined as in Table 1. No load test determines the magnetizing reactance. Blocked rotor test determines stator-rotor reactances and resistance.

On the first part of the Fig. 7; motor nameplates, on the second part, test results, and on the third, fourth, fifth parts of the figure, calculated equivalent circuit parameters are displayed. On the sixth part, motor losses are presented. On the seventh and eighth part of the Fig. 7, two different type of calculation of efficiency are determined according to the test standards, namely IEC 34-2 (standard method for
determining losses and efficiency from tests) and IEEE 112-B efficiency testing standards (direct method based on measurements). The calculated efficiency of the induction motor is displayed using an indicator labeled “efficiency” as shown in the front panel. Part 9 gives facility to record whole data in excel format or to reload previous data. All calculated parameters of per phase equivalent circuit are presented in Table 2 and Table 3 using measurement results and values of losses.

Equivalent circuit parameters obtained experimentally and motor equivalent parameters provided by manufacturer are compared. The results indicate that relative errors are negligible and largest error occurs in magnetizing reactance.

LabVIEW block diagram of the some important sub Virtual Instruments for the user interface is given as in Fig. 8. The block diagram show the “wiring” connections for the controls and indicators displayed on the related front panels. From the previous tests, the derivations for the equivalent circuit parameters are obtained and displayed for the user to observe.

### 7. Implementing Performance Analysis

The most important parameters for the determination of induction motor performances are torque, motor current, powers, power factor, and efficiency variables. When Performance tag clicked on Fig. 3, illustration of those
parameters activated and plotted as shown in the front panel of sub VI in Fig. 9. An example of performance graph obtained from equivalent circuit parameters is displayed as in Fig. 9. Here, variation of stator current versus mechanical speed is plotted.

The different performance graphics are displayed as shown in the Fig. 10.

Block diagram for the motor performance is shown as in Fig. 11. It include time plots and numerical data indicators. Some parameters are displayed graphically on a PC, allowing the performance characteristics of the motor to be determined.

8. Implementing Loading Analysis

The purpose of this test is determination of the best motor speed value for the maximum efficiency and power factor value. Test rig provides a facility for the testing of induction to find out motor efficiency for different speeds when it fully loaded on each speed. Variations are measured, and the tabulated readings are shown in Fig. 12. In this experiment, test motor is loaded starting from no load value to the value of twenty five percentages higher than the nominal load value.

Displayed readings are refreshed as chosen value. The
measurement values are saved in excel format, and when
the recording is finished the programme reminds by green
led light. It also provides a facility to reload previous data
and whole graphics are drawn when related button is
clicked.

Individual graphical such as current versus speed is
selected and displayed as seen from Fig. 13.

Fig. 14 shows motor important quantities, such as stator
current, input and output powers, developed torque, and
efficiency as a function of mechanical speed. The efficiency
plot implies that as speed increases, efficiency of the
induction motor also increases.

Block diagrams for the motor loading analysis and
graphical display of selected parameter are shown as in
Figs. 15 and Fig.16. It includes calculation sub VI and
numerical data indicators.

9. Conclusions

In this paper, an automated testing system for induction
motor was designed and developed by using LabVIEW
software. Induction motor tests are performed to obtain
parameters of the per-phase equivalent circuit of small
sized induction motor. Based on the observations, the
efficiency test may be carried out according to the two different standards. Motor equivalent parameters was verified by the manufacturer values. This work also provides an opportunity to verify motor nameplate values. It is not only useful for testing quality of certain frame size of induction motors, but also suitable for educational purposes for teaching of induction motors. Motor characteristics in the full speed range help students to understand the operation of induction motors.

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References


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