

LabVIEW based Induction Machines Laboratory for Engineering Education

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Abstract: - The Laboratory session in any engineering program particularly in Electrical Engineering is critical as these Labs are designed for students in accordance with theoretical course work. Software based Laboratory experiments have become current day need due to its impacts on flexible learning of students and understanding abilities. This motivation deals with Simulation of Induction Machines Laboratory experiments which are part of Lab work at undergraduate Electrical Engineering level using Laboratory Virtual Instrument Engineering Workbench (LabVIEW). The reason behind the selection of LabVIEW software among others is because of its strong graphical interface, user friendly tools and highly understandable approach. After completion of this software based Induction Machines Lab session along with hardware experiments, students will be in better position to attain strong concepts for one of the core Electrical Engineering subject. Moreover, LabView based Induction Machines Lab is economical and user friendly.

Key-Words: - Induction Machines, Simulation, LabVIEW, Engineering Education

1 Introduction

This research paper is the continuation of previous research published in ICCESSE 2010 (Cape Town, South Africa) in which Electrical Machines-I (EE243) experiments (DC Machines and Transformer) have been simulated using LabVIEW software. The rest of Electrical Machines Lab course is covered in the subjected title Electrical Machines-II (EE350) or AC Machines course (Induction and Synchronous Machines). These courses are being taught at Rachna College of Engineering & Technology (RCET), Gujranwala, Pk. in 4th and 5th term respectively at undergraduate Electrical Engineering [1].

Induction Machines experiments are simulated in this research work comprehensively based upon exact hardware Machines Lab ratings. The portion of synchronous machine has not been not covered yet, however, during literature survey some of the related stuff regarding synchronous machine is available [2] – [4].

Machine's Modelling involved in LabVIEW software is mathematical based. Equations are derived first then converted into models for further implementation in LabVIEW for graphical analysis [5].

The application of LabVIEW software in class-work learning and Lab-performance is not a new idea but it is first time that complete package of Lab session of Electrical Machines followed by exact hardware Lab specifications have been simulated during this research work [6] – [11].

List of experiments related to Induction Machine in LabVIEW is follows:

- Equivalent circuit parameters of an Induction Motor
- Load Test of a Three Phase Induction Motor
- Load Test of a Single Phase Induction Motor
- Torque Speed relationship of an Induction Motor
- Induction Motor as an Induction Generator
- Circuit model parameters of an Induction Motor

Section 2 of this research paper is review of LabVIEW software introduction.

Section 3 explains the Simulation of Induction Machines experiments using LabVIEW.

Section 4 concludes this research work significance for under-graduate engineering students.

At the end of this research paper, Section 5 provides the references involved as literature survey.

2 Review of LabVIEW software Introduction

As mentioned earlier, this research paper is second part of Electrical Machines Laboratory experiments performance using Laboratory Virtual Instrument Engineering Workbench (LabVIEW) software. LabVIEW is graphical software which shows the model of Machines and requires no programming for simulation. Mathematical equations showing Inputs/Outputs can directly be inserted in it which results in graphical interfacing mode.

Due to these valuable properties of LabVIEW it is preferred on MATLAB/Simulink for Machines modelling and analysis [12].

3 Simulation of Induction Machines Laboratory Experiments

3.1 Equivalent Circuit Parameters of an Induction Motor

In block diagram different components are arranged related to the designing of an induction motor from the function menu and assembled according to the requirements. These block units helped to make a general layout of an induction motor. The specifications of different components are shown in Front Panel. These components can be dealt by using Front Panel. Block diagram for the determination of equivalent circuit parameters of an induction motor is shown in Fig. 1.

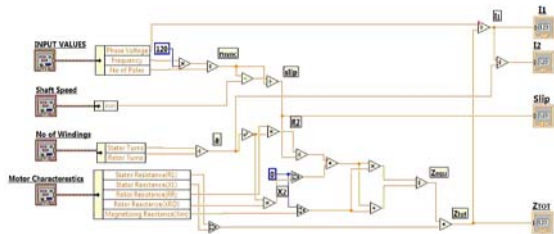


Fig. 1. Block diagram of equivalent circuit parameters of an induction motor

Front Panel diagram for equivalent circuit model parameters of an Induction Motor is shown in Fig. 2, where different design parameters and the input parameters are shown. The induction motor can be designed by using the Phase Voltage (V_{ph}), Number of Poles, Frequency, Stator and Rotor Turns parameters. Another block in design Parameter unit is Motor Characteristic, which has the values of Stator Resistance (R_1), Stator Reactance (X_1), Rotor Resistance (R_R), Rotor Reactance (X_{RO}), Magnetizing Reactance (X_m), Core Resistance (R_C). Here, the only input parameter is Rotor mechanical shaft speed (n_m). The value of the Rotor mechanical shaft speed must be less than the synchronous speed.

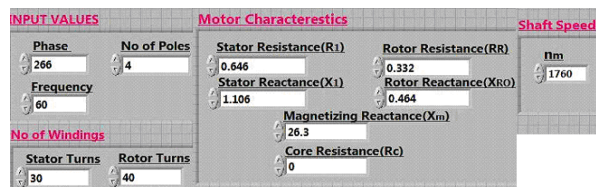


Fig.2: Design and input parameters of an induction motor

The value of Slip (S), Stator Current (I_1), Rotor Current (I_2) and Equivalent Impedance (Z_{tot}) are verified in the Result Phase unit. It is observed experimentally that by increasing the Rotor's mechanical shaft speed, the values of Slip, Stator Current and Rotor Current

increases and the value of Equivalent Impedance decreases. These results are shown in the Table 1.

TABLE 1
Results for Equivalent Circuit parameters of an Induction Motor

Slip	0.0222222
I_1	27.0063-12.3954j
I_2	36.0084-16.5272j
Z_{tot}	8.13565+3.73412j

3.2 Load Test of a Three Phase Induction Motor

Fig. 3 shows the block diagram for load test of three-phase Induction Motor which is modeled using block units, and it helps to make a general layout of an induction motor.

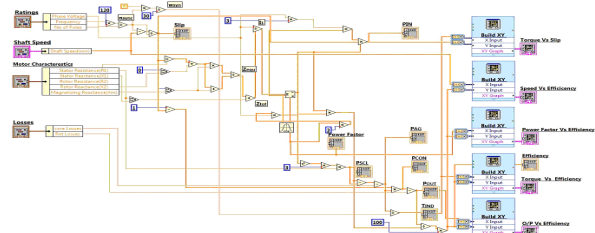


Fig. 3: Block diagram for load test of three phase induction motor

The induction motor is designed by using the Phase Voltage, No. of Poles, Frequency, Rotational and Core Losses parameters. Another block in design parameter unit is Motor Characteristics, which has the values of Stator Resistance (R_1), Stator Reactance (X_1), Rotor Resistance (R_R), Rotor Reactance (X_{RO}), Magnetizing Reactance (X_m), Core Resistance (R_C).

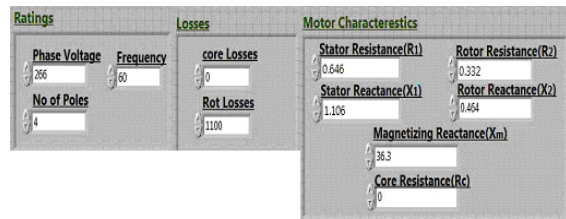


Fig. 4: Design parameters of three phase induction motor

The Input parameter is only the rotor's mechanical shaft speed (n_m). The value of the rotor's mechanical shaft speed must be less than the synchronous speed. By changing this value results will also be changed.

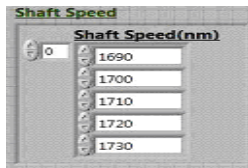


Fig. 5. Input parameters of three phase induction motor

During the designing of an induction motor for this experiment, it is observed that if the rotor's mechanical shaft speed becomes greater than the synchronous speed then induction motor will act as an induction generator and direction of the induced torque will be reversed and the rotor's mechanical shaft speed increases by 1796 r/min, and rotational losses should be less than 325 watt. The value of Slip, Power Factor, Induced Torque, Output Power and Efficiency are verified during this experiment. While the other parameters, in Result phase unit, are used to understand the behavior of the induction motor. By increasing the rotor's mechanical shaft speed, the values of Slip, Power Factor, Induced Torque and Output Power decreases but the Efficiency increases. Graphs in Fig.'s 7, 8, 9, 10 and 11 show the behavior of three phase induction motor during this experiment. It is observed during experiment that by increase in Output Power, Power Factor and Torque, the Efficiency decreases as shown in Fig.'s 7, 8 and 9 respectively.

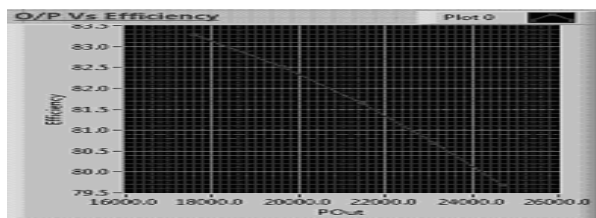


Fig. 7. Output Power vs. Efficiency

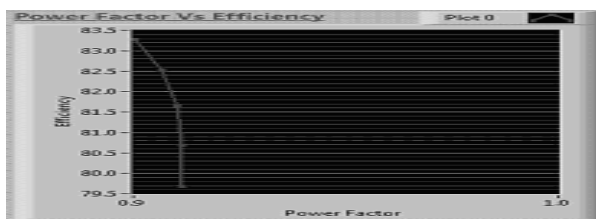


Fig. 8. Power Factor vs. Efficiency

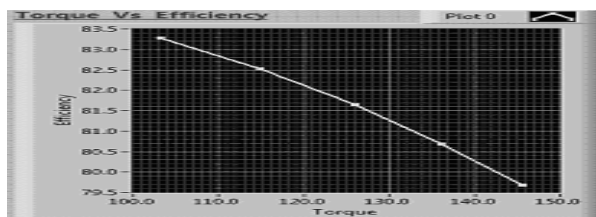


Fig. 9. Torque vs. Efficiency

Fig 10 shows that with the increase in the Torque, the value of Slip also increases.

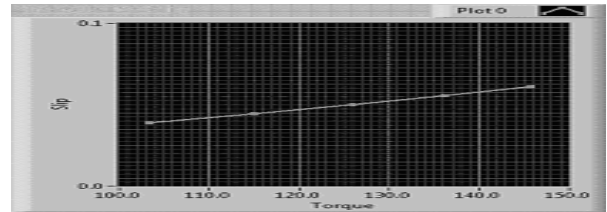


Fig. 10. Torque vs. Slip

The graph between Speed and Efficiency shows that with the increase in the rotor's mechanical shaft speed, Efficiency goes on increasing which can be observed in Fig. 11.

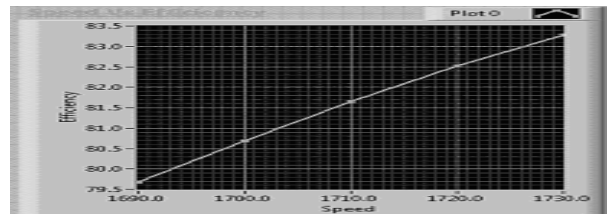


Fig. 11. Speed vs. Efficiency

3.3 Load Test of a Single Phase Induction Motor

Block diagram for the load test of a single phase induction motor is shown in Fig. 12.

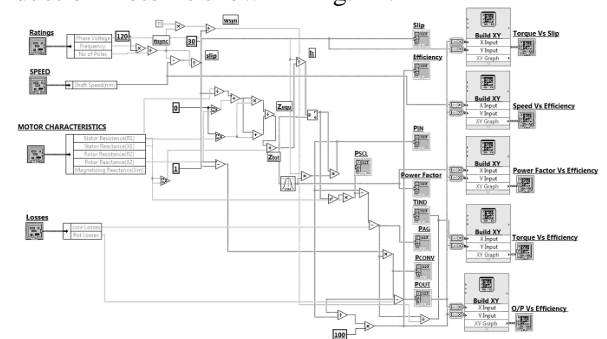


Fig. 12. Block diagram of load characteristics of single phase induction motor

The single phase induction motor is also designed by using the Phase Voltage, No. of Poles, Frequency, Rotational and Core Losses parameters. Other parameters in design block are Motor Characteristic, which has the values of Stator Resistance (R_1), Stator Reactance (X_1), Rotor Resistance (R_R), Rotor Reactance (X_{R0}), Magnetizing Reactance (X_m), Core Resistance (R_C). The Input parameter is again here the rotor's mechanical shaft speed (n_m). These design and input parameters for a single phase induction motor are given in the Fig 13.

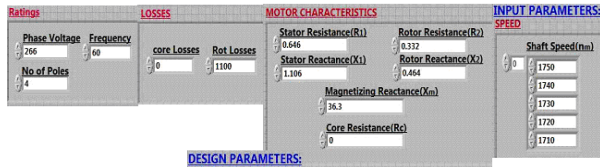


Fig. 13: Design and input parameters of single phase induction motor

Fig.'s 15, 16 and 17 respectively show the linear relation between (Output Power, Power Factor and Torque) vs. Efficiency.

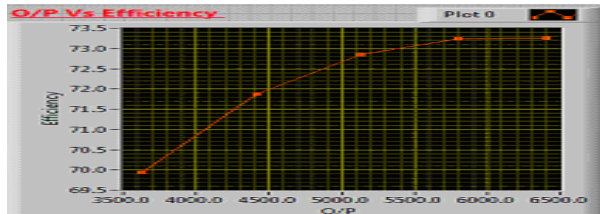


Fig. 15. Output Power vs. Efficiency

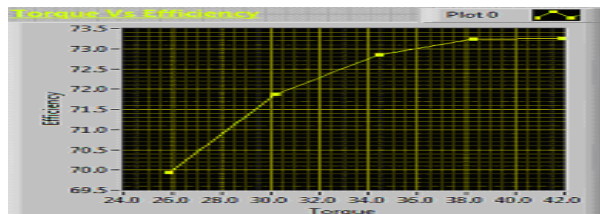


Fig. 16. Torque vs. Efficiency

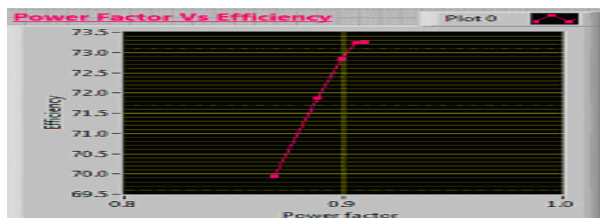


Fig. 17. Power Factor vs. Efficiency

Fig. 18 shows the relationship between Speed and Efficiency, and it is observed that with the increase in the rotor's mechanical shaft speed, Efficiency goes on decreasing.

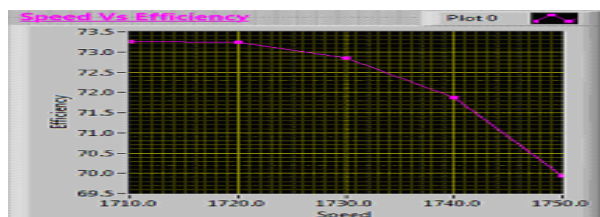


Fig. 18. Speed vs. Efficiency

Fig. 19 shows that with the increase in Torque, the value of Slip also increases for the single phase induction motor.

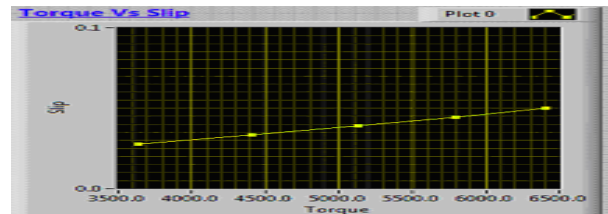


Fig. 19. Torque vs. Slip

3.4 Torque Speed Relationship of an Induction Motor

Block diagram for the torque speed relationship of the induction motor is given in Fig. 20.

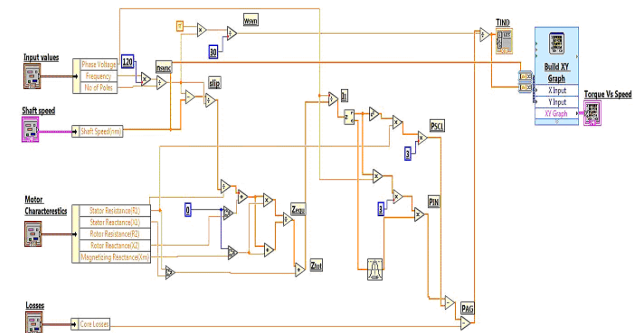


Fig. 20. Block diagram of torque speed relationship of an induction motor

The design parameters for torque speed relationship of an induction motor experiment are given in the Fig. 21.

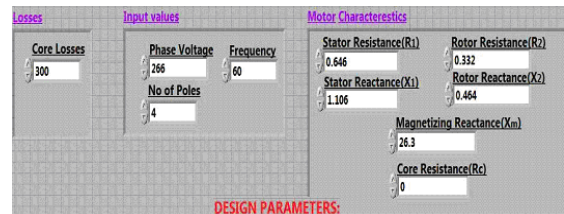


Fig. 21. Design parameters for torque speed relationship of an induction motor

The only Input parameter for this experiment is the rotor's mechanical shaft speed (n_m) which is given in the Fig. 22. The value of the rotor's mechanical shaft speed must be less than the synchronous speed. The result is shown in the 2nd column of this Fig. which shows the different values of the Induced Torque (T_{ind}) against shaft speed. It is observed that with the increase in the rotor's mechanical shaft speed, the value of Induced Torque decreases.



Fig. 22. Input parameters and Results for torque speed relationship of an induction motor

The graph shown in Fig. 23 describes the torque-speed characteristics of an induction motor.

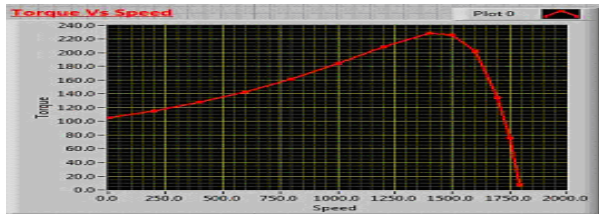


Fig. 23. Torque vs. Speed of an induction motor

3.5 Induction Motor as an Induction Generator

Block diagram to run an induction motor as induction generator is given in the Fig. 24.

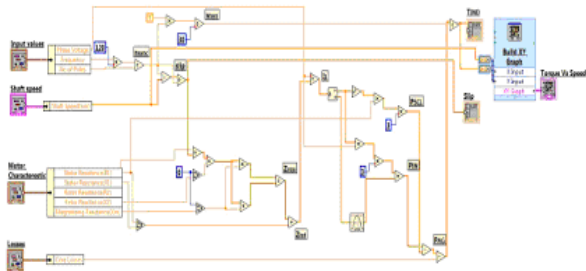


Fig. 24: Block diagram of an induction motor as an induction generator

The design parameters for this experiment are given in the Fig. 25.

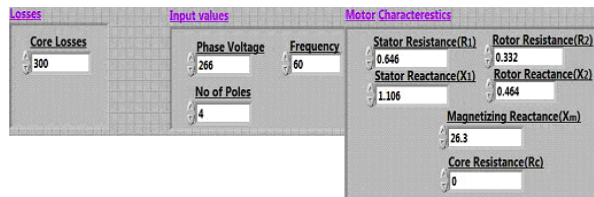


Fig. 25. Design parameters of an induction motor when run as induction generator

The Input parameter the results are shown in the Fig. 25

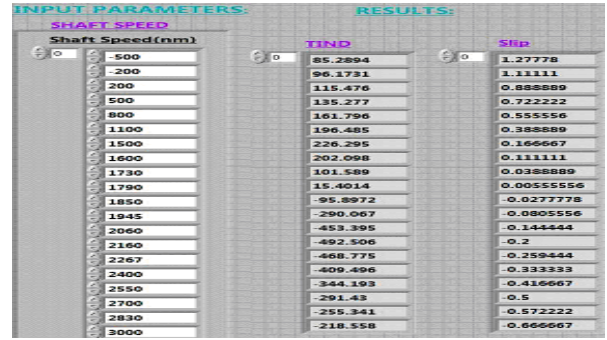


Fig. 25. Input parameters & Results

The graph below is made experimentally by taking Speed on X-axis and Torque on Y-axis as shown in the Fig. 26. This graph shows two regions. One is the motor region and second is the generator region. When the rotor's mechanical shaft speed is less than the synchronous speed, the induction machine will act as an induction motor.

The portion of the graph showing the positive value of Induced Torque above the zero-axis is the motor region. When the rotor's mechanical shaft speed is greater than the synchronous speed, the induction machine will act as an induction generator.

The portion of the graph showing the negative value of Induced Torque below the zero-axis is the generator region.

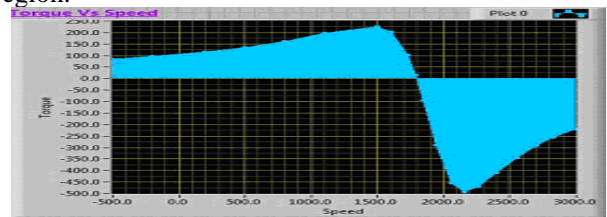


Fig. 26. Torque vs. Speed

3.6 Circuit Model Parameters of an Induction Motors

Block Diagram for the circuit model parameters of the induction motor is shown in Fig. 27. These block units helped us to make a general layout of the induction motor.

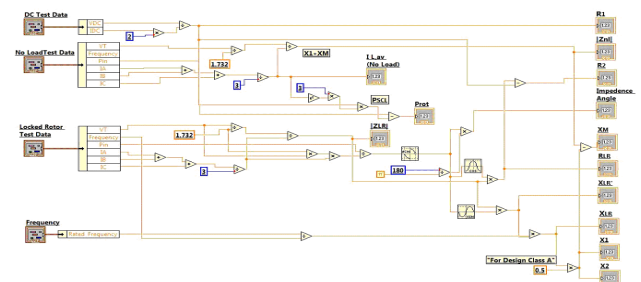


Fig. 27. Block diagram of circuit model parameters of an induction motor

The input parameters for this experiment are Frequency, DC Test data values (V_{DC} , I_{DC}), No Load Test Data Values (V_T , I_A , I_B , I_C , P_{IN} , and F) and Locked Rotor Test data values (V_T , I_A , I_B , I_C , P_{IN} , and F) which are given in the Fig. 28.

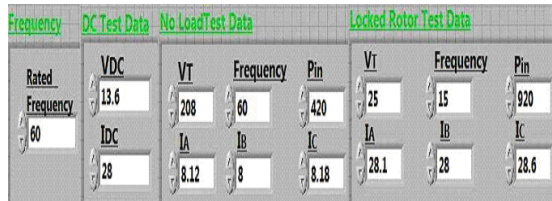


Fig. 28. Input parameters for circuit parameters of an induction motor

Experimental results of these three Tests are verified one by one.

DC Test is used to calculate the value of Stator Resistance (R_1).

No Load Test is used to calculate the Rotational Losses (P_{rot}) and No Load Impedance (Z_{nl}).

Locked rotor Test is used to calculate Locked Rotor Resistance (R_{LR}) and Locked Rotor Reactance (X_{LR}). These circuit parameter results are shown in the Fig. 29.

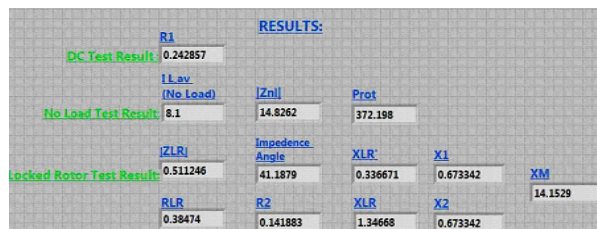


Fig. 29. Circuit parameters results of An Induction Motor

4 Conclusion

The idea of Induction Machines Lab experiments Simulation using LabVIEW software is being successfully put into operation at RCET Electrical Engineering Department (EE Deptt.) which results in outstanding feedback of students Lab work evaluation. The same idea can also be extended for other courses Lab sessions in parallel with hardware based Labs. The Simulation performed during this research work can also utilized as on-line experiments performance not only at Campus level but also at National and International levels using latest information technology tools.

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