

## Modelling and Analysis of Induction Motor using LabVIEW

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### ABSTRACT

Induction motor characteristics became complex to study, after the invention of drives where the motor incorporated with power electronic switches such as thyristor, diodes, GTO, and MOSFET. Induction motor characteristics can be studied and modelled with software such as Finite Element Analysis and Laboratory Virtual Instrument Engineering Workbench. Finite Element Analysis is used to study and model the motor might be complex and the time taken to compute was unreliable. In this paper induction motor was modeled with the help of LabVIEW software this allows us to model and simulate the motor in order to analyze the performance. The induction motor modelled here was based on the mathematical equations.

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## 1. INTRODUCTION

Induction motor designing based on the equation is bit complex, because equation whose terms are not of the first degree and more over it is a strongly coupled system. The input and output variable relationship is almost complex thus simulation of induction motor physically is hard. Most commonly employed software are PSpice, Finite Element Analysis, Matrix Laboratory and Laboratory Virtual Instrument Engineering Workbench other software rather than is, are created based on the text lines. LabVIEW software is based on the graphical programming environment. LabVIEW software has a dynamic nature which contributes to this dynamic tracking of processing the data. The changes in this data can be observed continuously. Dynamic analyzing is established based on both the mathematical and physical model. Normally equivalent circuit of induction motor resembles the equivalent circuit of transformer where the airgap between the stator and rotor in the induction motor differentiate from the transformer. LabVIEW software of following qualities such as multi-dimensional plots, xy graphs, report generation in excel, word makes this software accessible and has a unique feature, which simplifies the simulation process [1].

The dynamic and steady state analysis of induction motor are difficult to compute so modelling a motor using mathematical model helps to eliminate the further consequences. So the determination of parameters must be accurate for carrying out multiple analysis. Machine performance changes as the coupled system inertia changes it also contributes to the change in the load torque. Motor constancy changes if the motor inertia and load torque of that motor changes. Identifying faults in electric motor using LabVIEW is growing research area where many researchers giving their valuable contribution to find out faults in motor. Electric motor comprises of numerous motor which are developed and improved day by day in that Induction motor monitoring and faults diagnosis is a feature rich area because induction motor is the widely used motor which occupies nearly 75 % of drives in industries so only they're widely known as the work horse of an industry [2-3].

## 2. PRELIMINARY EQUIVALENT CIRCUIT & MATHEMATICAL EXPRESSION

Induction motor is commonly known as the work horse of an industry owing to the robust nature, rugged construction and reliable operation. When an alternating current is provided to the secondary winding circuit of the induction motor it produces the revolving magnetic flux around the stator. Air gap act as the dielectric medium which separates the rotor from the stator without having any physical contact. This revolving magnetic flux cuts the rotor windings axially as a result it produces an induced electromotive force in the rotor which is sinusoidal in nature. In a squirrel cage induction motor the end rings are short circuited, which provides the path for the induced current to flow across the rotor windings. The current induced in the rotor starts to circulate which produces a magnetic field in a direction opposite to the cause. Production of torque is owing to the fundamental interaction between these two counter balancing magnetic fields due to the applied voltage to the stator [4].

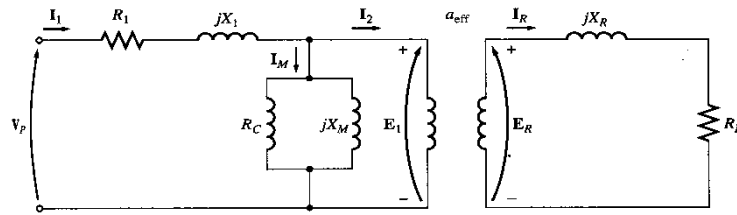


Figure 1. Equivalent Circuit Parameters of an Induction Motor

Slip is defined as the ratio of the difference between the synchronous speed and the actual motor speed to the ratio of the synchronous speed.

$$s = \frac{n_s - n_m}{n_s}$$

In general induction motor the torque is directly proportional to the product of the rotor current and flux per stator pole. The electromagnetic torque in synchronous watt can be expressed as:

$$T = \frac{3}{2\pi n_s} * \frac{sE_2^2 R_2}{R_2^2 + (sX_2)^2}$$

Stator copper loss which occurs at the induction motor:

$$P_{SCL} = I_1^2 R_1$$

Rotor copper loss which occurs at the induction motor:

$$P_{RCL} = I_2^2 R_2$$

Input power which of the induction motor:

$$P_{in} = \sqrt{3} V_L I_L \cos \theta = 3 V_{ph} I_{ph} \cos \theta$$

Air gap power of the induction motor:

$$P_{AG} = P_{in} - (P_{SCL} + P_{Core})$$

Core loss which occurs at the induction motor:

$$P_{core} = P_{AG} - P_{RCL}$$

Output power which of the induction motor:

$$P_{out} = P_{core} - (P_{f+w} + P_{stary})$$

Torque induced which occurs at the induction motor:

$$\tau_{ind} = \frac{P_{conv}}{\omega_m}$$

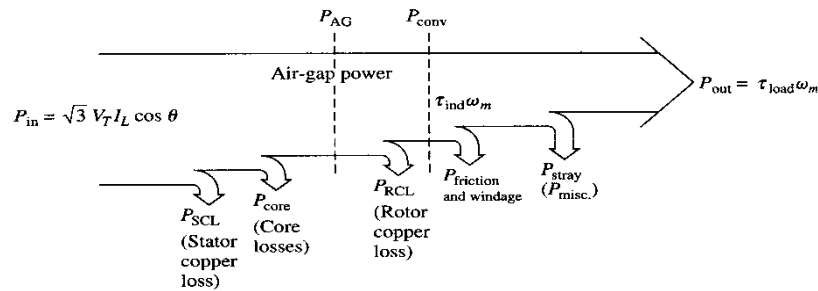


Figure 2. Power flow diagram of the induction motor

### 3. LabVIEW INTRODUCTION & BUILDING THE MODEL

National Instruments developed LabVIEW software for the first time in the year 1986 for the Apple Macintosh Company. It was conceptualized as a programming environment for hardware control. The introduction of an interface between the Personnel Computer and the instrument which is to be controlled by software was the main aim. The graphical user interface which is used to simulate the controlled instrument on the computer monitor itself with the help of LabVIEW software. LabVIEW is also a graphical programming language, it is familiarly known as “G code”. Applications created in LabVIEW are called “Virtual Instruments” [5]. Nowadays LabVIEW software is also compatible with other operating system such as Windows and Linux, etc. The word LabVIEW is an acronym for Laboratory Virtual Instrument Engineering Workbench which is a graphical programming language based on graphical icons instead of number of programming codes for simulation purpose. LabVIEW software allows the user to build their own set of virtual instrument easily. These programs are known as Virtual Instruments, or VIs, due to their operational replica of physical instruments, like temperature monitor, spectral scopes, pressure gauges, cathode ray oscilloscopes, and multi-meters etc. The inputs are known as controls and the outputs are known as indicators are placed on the graphic user interface (GUI) called Front Panel (FP). They communicate with each block diagram through terminals of the icons. In LabVIEW the data flow of the program will be from left to write, but in C/C++ programming codes will be executed in order of top to bottom, errors in the LabVIEW will be easily identified during the execution of the program itself [6].

### 4. SIMULATION OF INDUCTION MOTOR CHARACTERISTICS USING LabVIEW

Machine’s modelling developed in LabVIEW software is based on the mathematical expressions. Mathematical equations are first derived then converted into models using icons from the arithmetic board for further implementation in LabVIEW for graphical analysis [7]. List of simulation for Induction Machine in LabVIEW follows:

- a) Simulation Torque Vs Speed relationship of an Induction Motor
- b) Simulation of Induction Motor Load Test

The above said simulation can be build using the parameters. Parameters which are used to model the induction motor are described below with their corresponding symbols to have a clear idea before modelling motor. The simulations performed here to analyses the modelled motor with its characteristics which can be compared to the healthy motor in real time and it moreover helps to achieve the improvements in motor modelling before manufacturing it in factories. By changing the above input parameters corresponding values can be obtained in the form of graphical representation. By changing the given load changes in the motor speed and torque can be achsievedand their corresponding characteristics of induction motor can be displayed in the form of graph representation. By changing the individual parameter for a particular speed will also be displayed in this simulation. Here core loss is the considered as the constant loss of a particular induction motor which is to be modeled [8-17].

Table 1. Motor internal parameter

Parameters	Symbols	Input values
Rotor Resistance	$R_1$	8.6
Rotor Reactance	$R_2$	0.332
Stator Resistance	$S_1$	1.106
Stator Reactance	$S_2$	0.464
Magnetizing Reactance	$X_m$	26.3

Motor internal parameter are taken from the best operating conditions of induction motor these values are made constant for the simulations of motor. For a particular operating load condition these values are made constant. Parameters can be changed before simulating for different load condition. They corresponding characteristics curve can be drawn.

Table 2. Motor input terminal

Parameters	Symbols	Input values
Phase voltage	$V_{ph}$	220
Frequency	$H_z$	50
Number of poles	P	4

Values are made constant throughout the simulation because small changes in these input values will deviate simulation result.

Table 3. Motor core loss

Parameters	Symbols	Input values
Core Loss	L	300

Core loss are made constantly throughout the simulation because they won't change for a motor throughout its lifetime. So it's made as constant in this simulation.

## 5. MOTOR LOAD TEST SELECTION

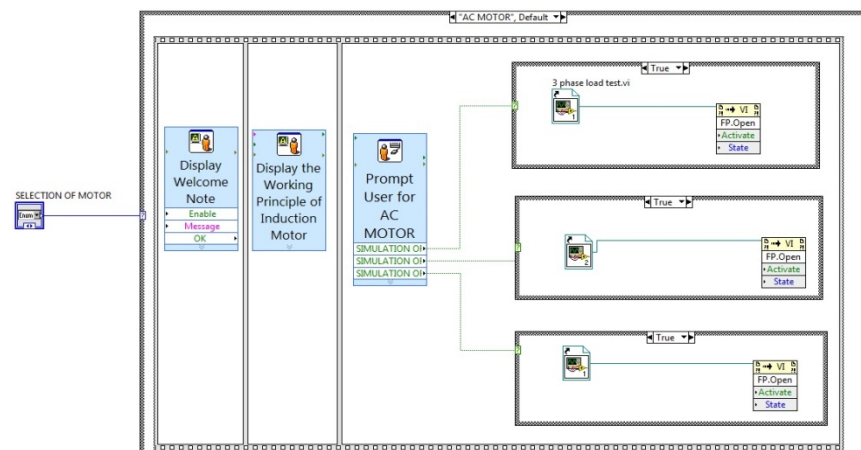


Figure 3. Motor load test selection block diagram window

AC induction motors are broadly classified according to their phases such as single phase and three phase induction motors. In this simulation, motor characteristics of single phase induction motor are tested. Testing and analysis of motor includes the torque vs speed characteristics test and motor load test which consists of remaining characteristics excluding the torque vs speed characteristics. Torque vs speed characteristics are given prime importance because selection of motor is purely depend upon this

characteristics, after this load curve analysis the other factors are also considered such as power rating, power factor, torque induced for a particular load these characteristics can also be displayed using the motor load test characteristics. Selection of load test is nothing but gives the user to select the motor characteristics because if the user wants to analyse the torque vs speed characteristics this allows the user to select or if the user wants to analyse the motor characteristics then this program allows them to continue in that required field. Basically LabVIEW flat sequence structure option enables the user for the selection process. The enum will basically work towards the default selection. Inside the flat sequence it will have the sub VI's which call the motor characteristics. The block diagram panel describes the execution structure of the program which has been developed with a flat sequence structure in LabVIEW, their program flow is illustrated in Figure 3.

The user will be welcome by a welcoming message which will be displayed while running the the VI in LabVIEW.

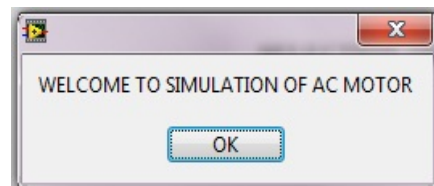


Figure 4. Welcome message

Front panel discloses the title of the project and helps the user to select the VI's of appropriate motor to study their mechanical and electrical characteristics of a particular induction motor. During the running of the virtual instrumentation the selection of motor and their characteristics appear on the LabVIEW windows which enables the user to proceed according to the selection of motor load test or torque vs speed characteristics of the induction motor. The Figure 4 shows motor load test selection in LabVIEW software.

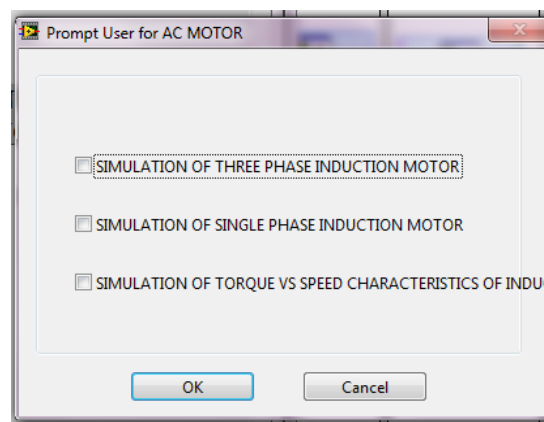


Figure 5. Motor load test selection front panel window

This command will wait for the user to select the motor load test this will be displayed in the figure displayed above.

### 5.1. Simulation of Torque vs Speed Characteristics of Induction Motor

Simulation of torque vs speed characteristics of induction motor is shown in the Figure 6. This modelling in LabVIEW is based on the mathematical model which was discussed. This simulation is governed by a set of equation was used to build the models in the LabVIEW software. The modelled can be analysed by giving load. The front panel discloses in the load settings. The three main parameters are given as input they are motor terminal inputs, motor internal characteristics and motor loss. The motor loss specified here is fixed loss where every motor has its own loss. The motor model is constructed using the GUI, where the icons are drawn from the programming palette which consists of numeric palette and xy graphs palette.

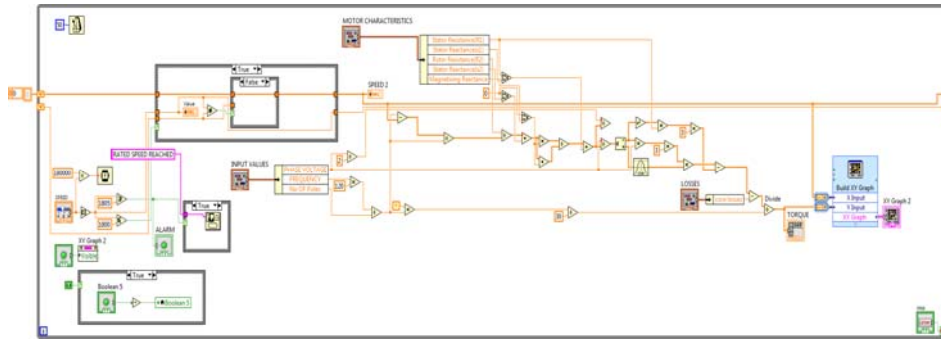


Figure 6. Block diagram window of torque vs speed characteristics of induction motor

The arithmetic palette comprises of various icons which helps to build these models, the motor modelled here are based on the mathematical equation. Mechanical characteristics of induction motor are to be analysed in that torque vs speed characteristics plays a major role in analyses of induction motor. Whenever the speed gets changed is nothing but when the load gets changed corresponding speed and torque equations gets changed. This diagram comprises of three different types of torque positions knows as starting torque, pull up torque, full load torque.

SPEED	TORQUE
0	105.003
100	110.009
200	115.476
400	128.038
600	143.26
800	161.796
1000	184.101
1200	209.105
1400	228.435
1600	202.098
1650	175.382
1700	134.415
1710	124.206
1720	113.271
1730	101.589
1740	89.1483
1750	75.9373

Figure 7. Torque and speed parameter of induction Motor

This figure shows the values related to changes in the load a relative change in the speed and torque of the motor.

Characteristic curve shown here resembles the NEMA Design A in theoretical it will have low resistance and reactance owing to that it produce very small starting torque and have high breakdown torque when comparing it whether other NEMA Designs. Starting torque of an induction motor is merely known as stalled rotor torque. This load curve shows three different regions of torque there are starting torque, pull out torque and full load torque.

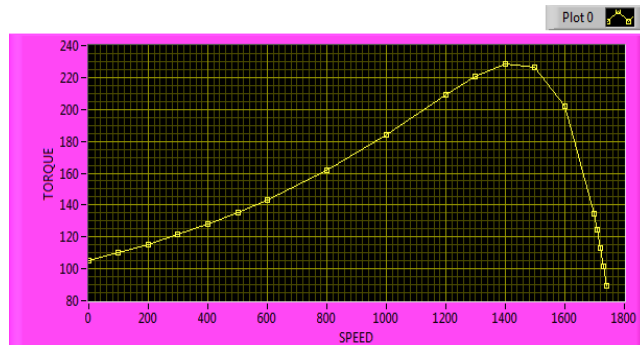


Figure 8. Torque vs speed characteristics of induction motor

**5.2. Simulation of Induction Motor Load Test**

The simulation of induction motor load test comprises of various output parameters which are displayed in the below figure, according to the variation in parameters there are various parameters displayed associated with the speed.

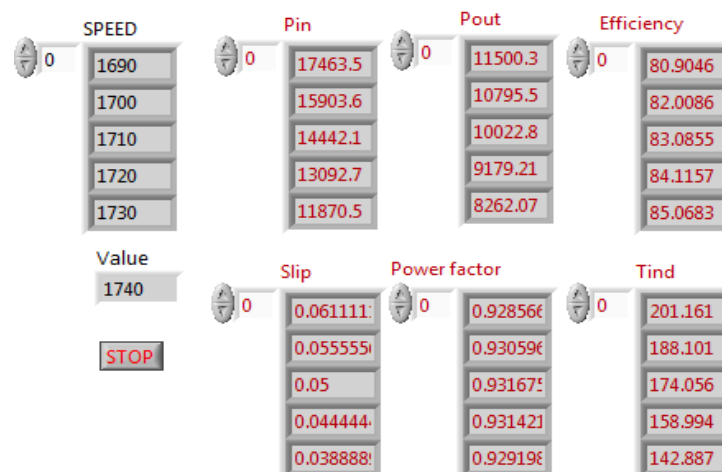


Figure 9. Output parameter of induction motor

During the load test, if the loading of the motor changes there will be a change in parameter such as the input power, power factor, output power, slip, efficiency and torque induced. The changes in this parameter are displayed in the Figure 9. LabVIEW helps to compute quickly so that there will be a quick response to the change in the loading values. The values varies according to the variation on the load, if the load changes abruptly then there will be change in the above said corresponding factors such as input power, output power, efficiency, slip, power factor and the torque induced.

The block diagram consists of parameters in terms of clusters, the input parameters given for motor modelling are the motor terminal input, motor core loss and motor internal characteristics where the motor internal characteristics are stator resistance, stator reactance, rotor resistance, rotor reactance and magnetizing reactance. The values taken here are from the healthy motor conditions, moreover the motor conditions are from calculated for the best working conditions. The core loss are kept constant throughout the motoring operations the motors operating region are in single quadrant operations. The simulation are done with real vales and a real time parameters for cross checking with a real time operation of motor. Faulty conditions are simulated during the running of the program to check how the motors will operate in a real time conditions.

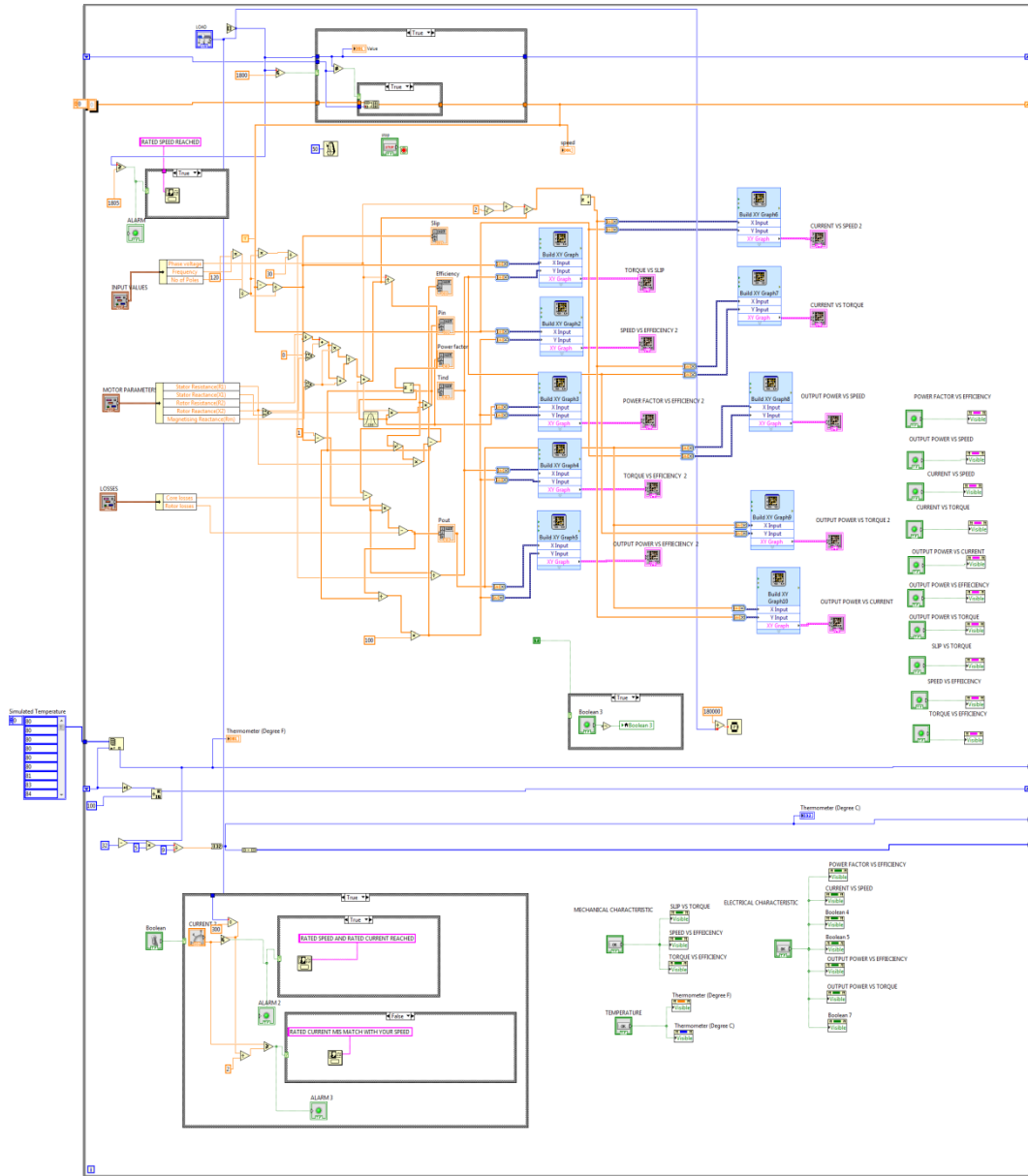


Figure 10. Motor load test of induction motor block diagram window



Figure 11. Output power vs efficiency characteristics of induction motor

During the loading of the motor efficiency tends to increase with the corresponding loading of the machine. When the machine reaches nearer to the full load, the efficiency of the motor will be maximized.





Figure 12. Output power vs torque characteristics of induction motor

Torque vs output power characteristics is linear in nature. When the torque increase the output power also tend to increase to maintain the stability of the motor. If there is a sudden disruption, then this will cause the instability in nature.

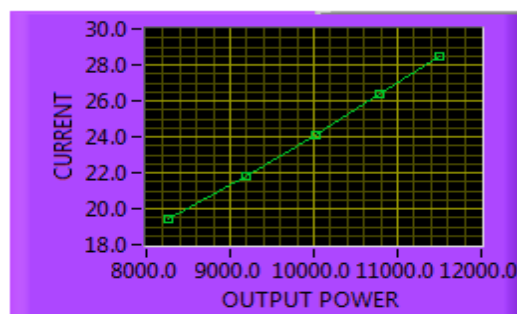


Figure 13. Output power vs current characteristics of induction motor

Current vs output power characteristics is linear in nature. When the output power increase the current also tend to increase to maintain the stability of the motor. If there is a loading of the motor current will change according to the loading of the motor.

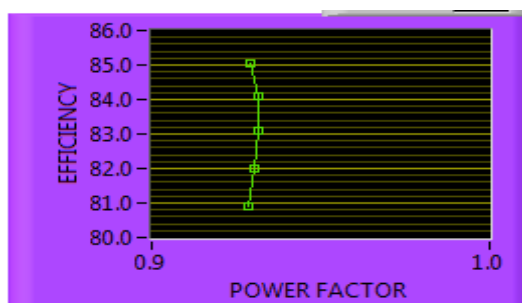


Figure14. Power factor vs efficiency characteristics of induction motor

Power factor vs efficiency characteristics show when the motor gets loaded to the rated speed the power factor of the motor also gets improved which is nearly to the unity power factor. The power factor of the motor also gets improved if the motor is loaded is nearer to the rated speed, but in most of the industries they're loaded optimally and not to the full range.

Efficiency increases with the Speed of the motor if the motor is loaded to the rated speed then the efficiency will be maximized if the motor is loaded above the rated speed both the efficiency and the power factor will be decreased.

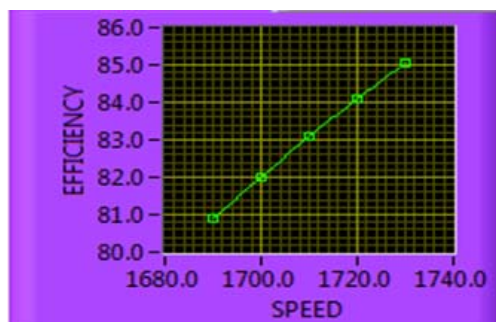


Figure 15. Speed vs efficiency characteristics of induction motor

## 6. CONCLUSION

The analysis of this experimental result shows that induction motor model was built with the LabVIEW software. It can be used to model and simulate the working process of induction motor by which motor performance calculated, is set to compare with the real time operating consideration of the induction motor for the optimal operation of machines. The creation of the induction motor model can be bundled into a sub-Virtual Instrumentation, for further experimental studies. This type of work can be further proceeded to the other machines such as DC machine and special electrical machine. It helps the manufacturer to study the motor performance before manufacturing it. Modelling the electric motor in LabVIEW, gives the possibility, to use the capabilities of this powerful graphical programming language, in studying various problems, related to this component of the power system. Since LabVIEW interfaces easily to a large number of hardware by multifunctional data acquisition cards, electric motors model can be easily modelled and they are used to study the various characteristics of motors. Analysis can be further used to study the performance of the motor, because testing a motor in real time situation requires huge initial investment and requires time. If the motor fails to achieve the rated efficiency, efficacy, then it became useless. This modelling and analysis aid to avoid these type of losses such recoverable financial loss and non-recoverable time loss and provide the best platform to study the characteristics of the motor.

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