ISSN 2709-3409 (Online)

JOURNAL OF TERTIARY AND INDUSTRIAL SCIENCES

A MULTIDISCIPLINARY JOURNAL OF THE HIGHER TECHNICAL TEACHERS' TRAINING COLLEGE, KUMBA

VOLUME 3, NUMBER 1
MARCH, 2023

PUBLISHER: HIGHER TECHNICAL TEACHERS' TRAINING COLLEGE (HTTTC)
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ISSN 2709-3409 (Online)

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JOURNAL OF TERTIARY AND INDUSTRIAL SCIENCES
VOLUME 3, NUMBER 1, MARCH 2023

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DESIGN OF GRAPHICAL USER INTERFACES FOR INDUCTION MOTOR ANALYSIS

By

MBI BARNABAS BISONG[1]

Abstract
In the domain of engineering, laboratory practice is essential and with computer aided teaching tools, the transmission of knowledge to students become easily. Induction motor been one of the electric machines taught for undergraduate programs, to analyse this machine to obtain its parameters, most of the calculations are done manually and time consuming. Also, representing the curves to observe the behaviour of the machine from starting to normal running condition is mostly kept aside which made it difficult for the learners to master the behaviour of the machine. The experiments which are been performed in the laboratory by students contains lots of iterations and lengthy calculations which make it difficult to solve mentally. To remedy these situations, three simulation platforms have been designed using MATLAB/GUI to facilitate the understanding of this machine. The design platforms are: three phase induction motor performances analysis platform (were data from the no-load test, blocked rotor test and the DC test are inserted to calculate the machine parameters and visualized the curves), three phase induction motor parameters platform (known machine parameters are inserted here for observation of the curves only) and single phase induction motor platform: here, the platform is divided into two sections, a section for laboratory test data and a section for the calculated parameters to observe only the curve. With a simple mouse click on the corresponding pushbutton, the action is executed.
Keywords: Blocked rotor, Induction motor, GUI, Matlab and Platform.

1. Introduction

In almost all the developed countries, more than 50% of the electric energy generated is consumed by electric drives (Munira and Aftab, 2013). Induction motor (IM) or the asynchronous motor has many advantages such as simple construction and high strength. It can be divided into two types depending on the type of input supply: single phase and three phase induction motor or it can be divided according to the type of rotor, squirrel cage and slipring motor (wound motor) (Heba and Hassan, 2021). Induction machines (IMs) are widely used in many industrial drive systems, due to their attractive characteristics such as relatively low cost, reasonable size, robustness, and low maintenance requirements. They are used both for conventional and high-performance drive applications. Most of these applications require adjustable speed drives and appropriate control performances (Sang-Hoon et al.,

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ISSN 2709-3409 (Online)

2017). The experiments which are been performed in the laboratory by students contains lots of iterations and lengthy calculations. To analyse this machine to obtain its parameters, most of the calculations are done manually and time consuming after laboratory tests. Also, representing the curves to observe the behaviour of the machine from starting to normal running condition is mostly kept aside which made it difficult for the learners to master the characteristics of the machine. There are several MATLAB toolboxes for processing and plotting of waveforms from analysed data (Bhaska and Writwik, 2013). Virtual instrumentation has a vital role in testing and experimentation of electrical machines and drives to increase the accuracy and efficiency of analytical part in the experiment (Krishna and Dolly, 2018). A graphical user interface (GUI) is a graphical display that contains devices, or components, that enable a user to perform interactive tasks and a graphical user interface (GUI) is a pictorial interface to a program (Harish, 2013). With the advent of low-cost personal computers and various easily accessible software packages, an educational tool platform designed on Matlab/gui environment addresses these difficulties. The computer models and simulations of induction motors by enabling the instructor through the computer-generated graphics will help to illustrate easily steady-state operation of the motor under various loading conditions (Saffet and Chika, 2005).

2. Literature Review

Sunil et al. (2012) worked on Performance evaluation of three phase induction motor based on no load and blocked rotor test using Matlab. In this work the result of indirect test (no load and blocked rotor) on three phase induction motor and Thevenin equivalent circuit parameters are obtained, and also the performance parameters by generating graphical user interface (GUI) by using Matlab programming are evaluated. The various characteristic curves can be obtained speed-slip, torque-slip, efficiency-slip and torque-speed

Ramprasath and Manojkumar (2015) carried out Modelling and Analysis of Induction Motor using LabVIEW. In this paper induction motor was modelled with the help of LabVIEW software this allows the authors to model and simulate the motor in order to analyse the performance. The induction motor modelled here was based on the mathematical equations.

Suryasen and Harish (2013) provide GUI based power system simulation tool that can be used as an educational tool for analysis of power system. GUI figure file is developed in MATLAB environment for performance of transmission line, Y bus formation, Power angle curve, Fault studies, line flow and losses. The user can enter the data and obtained the results quickly in the form of data or figures.

Pichai (2016) describes a simple and efficient analytical technique to determine speed-torque performance curve of induction motor from manufacturer data. The obtained speed-torque curve is verified against that derived from the conventional equivalent model where the motor's parameters are already known. The motor's performance torque curves derived with an aid of the analytical formula from the manufacturer catalogue are also presented.

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Rade and Veselko (2013) published on Determination of the Torque-Speed Characteristic of Induction Motor in Electric Machinery Education. The paper describes the measuring method for determination of the torque-speed characteristic of an induction machine used in electric machinery classes performed at the Polytechnic of Zagreb. The torque-speed characteristic is determined by recording and differentiating speed signal during the starting. Data is gathered using a measuring system based on a simple digital acquisition card, and processed in custom software, built with LabVIEW, on a personal computer.
Abhishake and Rupam (2017) worked on Analysis of Self-Excited Induction Generator Using Gui. This paper provides a steady state analysis of three phases self-excited induction generator. The problem is formulated as a multi-dimensional optimization problem. The constraint is used to minimize a cost function of the total impedance or admittance of the circuit of the generator to obtain the frequency and other performance of the machine.
Renjini (2019) presented on Speed estimation of induction motor using LabVIEW. In this paper a comparative analysis of different speed estimation methods is done. The comparative study of different methods shows that the motor current signature analysis (MCSA) is more accurate in speed estimation. This technique is experimentally verified on a 5HP, 3.7kW, 1430rpm 415V, 50Hz, 7.5A, 3Ø squirrel cage induction motor using LabVIEW. The experimental and simulation results shows that the overall speed estimation error is within 5 rpm.

3. Methodology

3.1. Equivalent circuit analysis

The equivalent circuit of any machine shows the various parameter of the machine such as its ohmic losses and also other losses. The losses are modelled just by inductor and resistor. The copper losses are occurred in the windings so the winding resistance is taken into account.
The parameters of the equivalent circuit of an induction motor (with a single-cage rotor model) are usually determined from some test data such as stator resistance measurement, no-load, and locked-rotor test data (Haque, 2008).

a. Equivalent circuit of a three-phase induction motor

Three-phase asynchronous machines, or induction machines, have been widely employed since the beginning of the modern industry, due to their robustness, easy application, flexibility, ability to work in harsh environments, and low cost. Therefore, several methods of calculation, both in steady and dynamic states, have been developed to analyse the machine behaviour in relation of its connected mechanical load and its influence to the connected electrical power systems (Guimarães et al, 2014). Assuming the three phases to be balanced, the analysis of a 3-ϕ induction motor can be made by analysing the equivalent circuit of only one of the phases. We now derive the per-phase equivalent circuit of an IM. An induction motor can be considered as a rotating transformer whose magnetic circuit is separated by an air gap. The stator is considered as primary and rotor is taken as secondary winding. Air gap between the two is considered as the core of the transformer. Induction machine is

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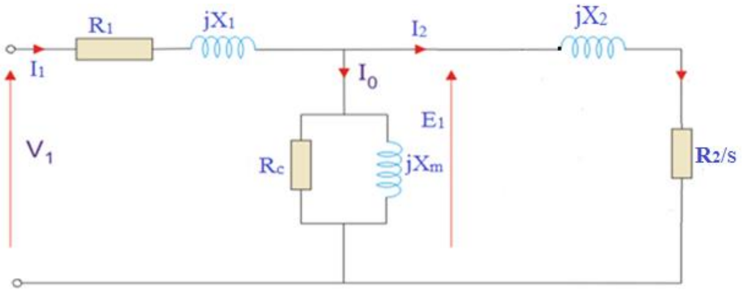
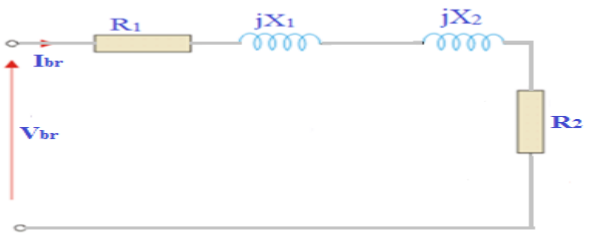
different from other type of electric motors in the sense that secondary currents are produced by induction, as in a transformer. And they are not being supplied by a dc exciter or other external power sources, as in other machines (Munira and Aftab, 2013). Characteristics of the three-phase induction motors can be analysed by using a conventional equivalent circuit. The parameters of the circuit can be obtained through of several experiment's results in the laboratory such as dc test, no-load test, and blocked-rotor test (Zuriman et al., 2017). The determination of equivalent circuit parameters for AC induction motors represents an important task in an electrical machine laboratory. Frequently used open-circuit, short circuit and dc tests answer these requirements (Moshe and Efim, 2021).

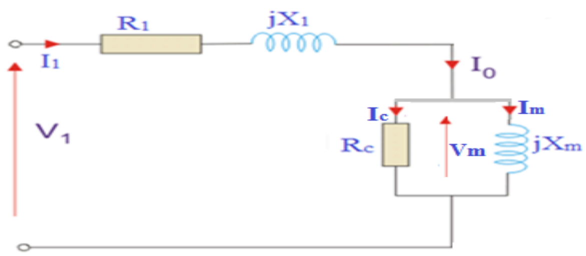


Where:
R_1: Stator resistance.
X_1: Stator reactance.
R_c: Core loss component.
X_m: Magnetizing reactance of the winding
R_2: Rotor resistance.
X_2: Rotor reactance
s: Slip

Source: Researcher, 2023

Figure 1: Per phase equivalent circuit of a three-phase induction motor referred to stator.





Source: Researcher, 2023

Figure 2: Blocked rotor equivalent circuit Figure 3: No load equivalent circuit

- **Blocked rotor equivalent circuit parameters**

The blocked-rotor test on an induction motor is performed to determine some of its equivalent circuit parameters and slip = 1 (Ahmed, 2019).

The blocked rotor equivalent impedance is:

$$Z_{br} = \frac{V_{br}}{I_{br}} \quad (1)$$

The blocked rotor resistance is:

$$R_{br} = \frac{P_{br}}{I_{br}^2} \quad (2)$$

The rotor resistance is:

$$R_2 = R_{br} - R_1 \quad (3)$$

The blocked rotor reactance:

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$X_{br} = Z_{br} \sin\theta,$ (4)

The rotor reactance:

$X_2 = X_{br} - X_{1.}$ (5)

The separation of X_1 and X_2 is difficult and require additional tests to be carried out. It is often necessary to assume that they are equal. Therefore,

$X_2 = X_1 = \frac{X_{br}}{2}$ (6)

- **No-load test equivalent circuit parameters**

The motor is supplied with its rated voltage, but has no mechanical load coupled to it, it will accelerate up to almost synchronous speed (there will always be a very small difference between the rotor speed and synchronous speed owing to friction). Since the slip is very close to zero, the impedance of the branch containing R2/s + jX2 will become infinitely large that is open and the circuit becomes as shown in figure 3. Furthermore, the impedance of the parallel branch containing Rc and Xm is far larger than the series components R1 and X1, and so R1 and X1 may be ignored also. The value of Rc and Xm depend on the supply voltage. The values of Rc and Xm can be obtained as follows:

The current through Xm,

$I_m = I_1 \sin\theta_0$ (7)

The current through Rc,

$I_c = I_1 \cos\theta_0$ (8)

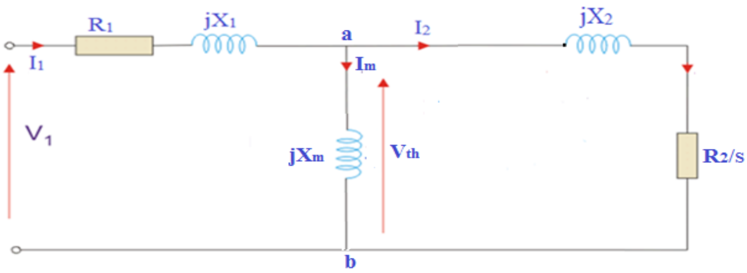
The magnetizing resistance

$X_m = \frac{V_1}{I_m}$ (9)

and the core resistance

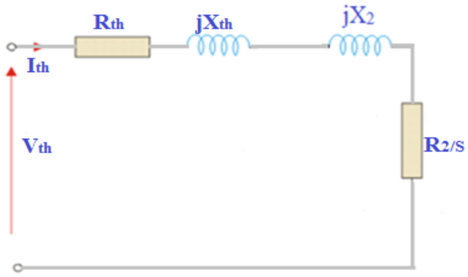
$R_c = \frac{V_1}{I_c}$ (10)

b. Torque, power and Thevenin's Theorem



Source: Researcher, 2023

Figure 4: Equivalent circuit to determine Thevenin's parameters



Source: Researcher, 2023

Figure 5: Thevenin equivalent circuit

Considering figure 4, the Thevenin voltage (open-circuit voltage) for the stator portion of the equivalent circuit is:

$V_{th} = \frac{jX_m}{R_1 + j[X_1 + X_m]} V_1$ (11)

The Thevenin impedance (impedance seen after shorting the voltage) is expressed as

$Z_{th} = \frac{jX_m[R_1 + jX_1]}{R_1 + j[X_1 + X_m]} = Rth + jXth$ (12)

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Inserting the Thevenin equivalent source into the induction machine equivalent circuit yields the following equivalent circuit of figure 5. The torque equation

$$T = \frac{3I_2^2}{s\omega_s} \tag{13}$$

Rotor current $I_2 = \frac{V_{th}}{Z_{th}} = \frac{V_{th}}{\sqrt{\left[R_{th}+\frac{R_2}{s}\right]^2+[X_{th}+X_2]^2}}$ (14)

This implies the torque equation becomes:

$$T = \frac{3V_{th}^2}{\left[R_{th}+\frac{R_2}{s}\right]^2+[X_{th}+X_2]^2}\frac{R_2}{s}\frac{1}{\omega_s} \tag{15}$$

Maximum torque occurs when the power transferred to R_2/s is maximum and this condition occurs when R_2/s equals the magnitude of the impedance $R_{th} + j(X_{th} + X_2)$ and the corresponding maximum torque or pull-out torque of an induction motor is expressed as

$$T_{max} = \frac{1}{2\omega_s}\ x\ \frac{3V_{th}^2}{R_{th}+\sqrt{R_{th}^2+[X_{th}+X_2]^2}} \tag{16}$$

3.2. Simulation Platforms

A graphical user interface (GUI) is a pictorial interface to a program (Suryasen and Harish 2013).

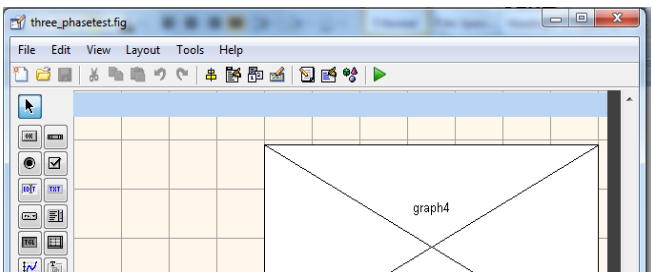
With the simulation platforms designed on Matlab/GUI environment, the end users are capable to analysis the results obtained from the various laboratory tests. The data are inserted in the platform and the pushbuttons are programmed to realise the various tasks prescribed on them with a simple mouse click. The action is imitated and the characteristic curves or parameters of the induction motor are been displayed. The platforms are of two categories, namely: Three-phase simulation platform and Single-phase simulation platform. The type of 3-ϕ induction motor used is the wound rotor induction motor and three tests were carried out: no-load test, blocked rotor test and the DC test.

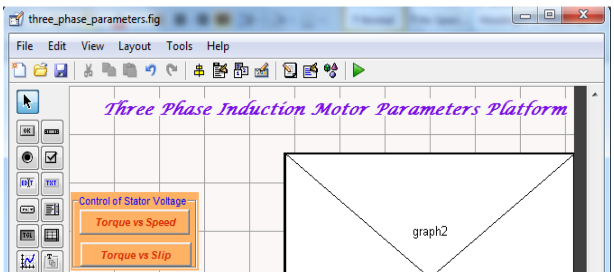
3.2.1. Three-phase simulation platform

Two platforms were designed following the situations that the learners or the lecturers may encounter. That is, in the case were the no-load test, blocked rotor test and the DC test are carried out in the laboratory, the measured quantities are inserted to calculate the machine parameters and observe the behaviour of the corresponding curves, figure 6. The second case is where the machine parameters are known and just the characteristics curves need to be obtained, the data are inserted in figure 7.

3.2.2. Single-phase simulation platform

For single phase analysis, the platform is divided into two sections, namely: parameters simulation where the machine parameters are inserted if already known and test simulation where the results of the laboratory tests are inserted for the machine parameters to be calculated.





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Source: Researcher, 2023

Figure 6: Designed user interface for induction motor for the various tests (no-load, blocker rotor and DC

Source: Researcher, 2023

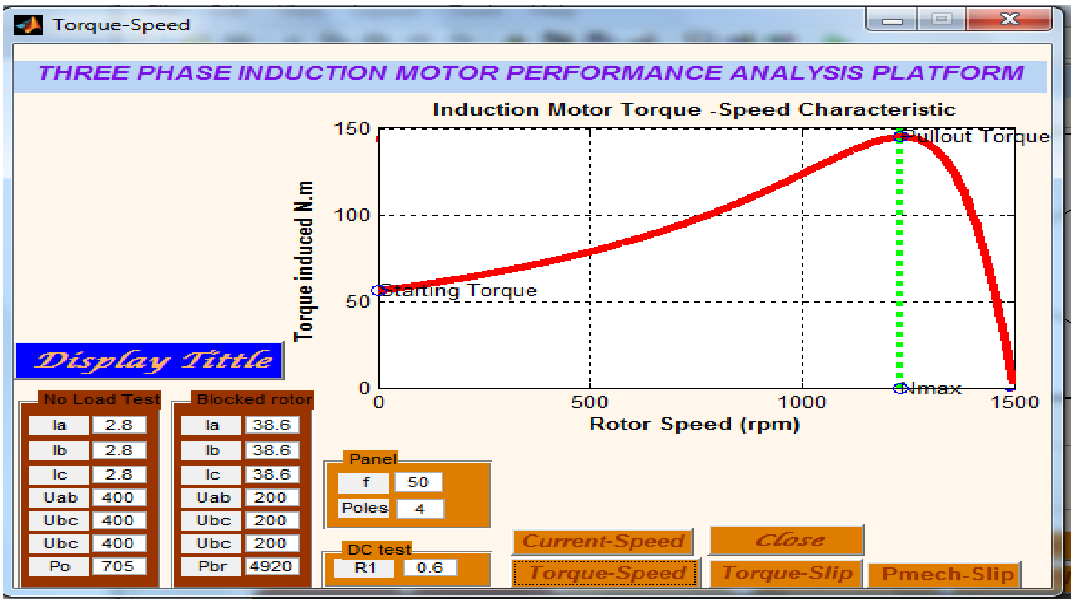
Figure 7: Designed user interface for induction motor for known parametres

4. Results and discussions

4.1.Characteristic Curves of three-Phase Induction Motor

The most important parameters for the determination of induction motor performances are torque, current, powers, power factor, and efficiency variables.

a) Torque- Speed curve with laboratory tests data

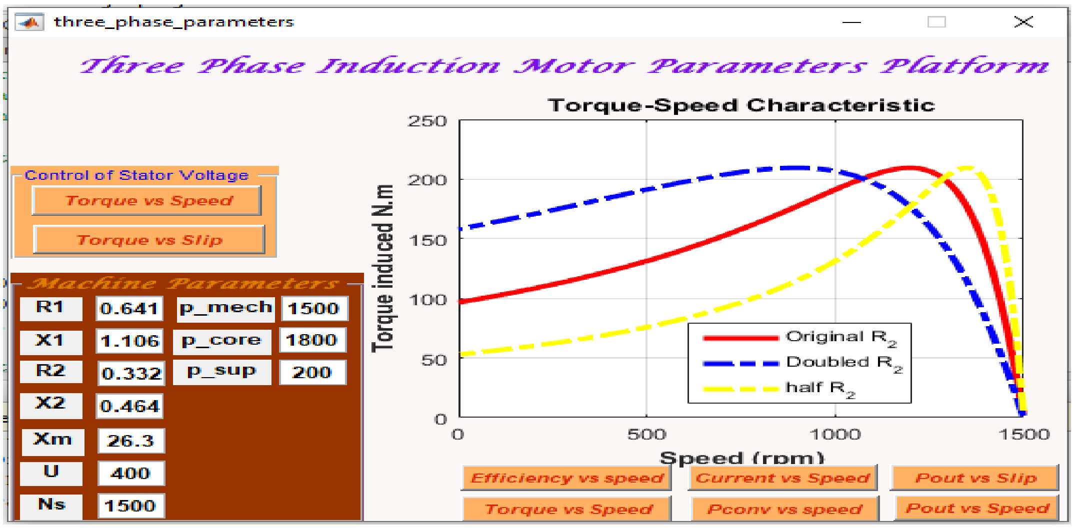


Source: Researcher, 2023

Figure 8: Three phase induction motor torque - speed curve in Matlab/ GUI environment

The data from the no-load test, blocked rotor test and the DC tests are inserted as indicated on the simulation platform. Clicking on the torque-speed pushbutton in figure 8 will permit us to visualise the curve and then the parameters of the motor also obtained per the input data. AS observed, the torque increases as the speed increased. Maximum torque is obtained approximately at speed of 1225 r.p.m. The starting torque and the pull-out torque also indicated on the curve. The starting torque is the developed torque by an electric motor when it starting speed is zero at rated voltage and frequency and the pull-out torque is the maximum torque available before the torque decreases when the machine continues to accelerate at working conditions. If the load torque is more than this value, the machine stalls.

b) Torque- speed characteristic with variable rotor resistance control



Source: Researcher, 2023

Figure 9: Torque- Speed characteristic with variable rotor resistance control

Rotor Resistance Control is one of the methods by which the speed of thewound rotor **induction motor can be controlled.** The speed of the wound rotor induction motor can be controlled by connecting an external resistance in the rotor circuit through slip rings in figure 9, a Matlab code was developed to observe the variation in torque-speed characteristics of a 3-phase induction motor with variable rotor resistance. Following the various value of the rotor resistances the torque-speed curve is been observed. Three values of the rotor resistances were used, that is real value of the rotor resistance (R2), doubled R2 and half value of R2. As the value of R2 increases the curve becomes stiff.

c) Current- speed characteristics with variable rotor resistances

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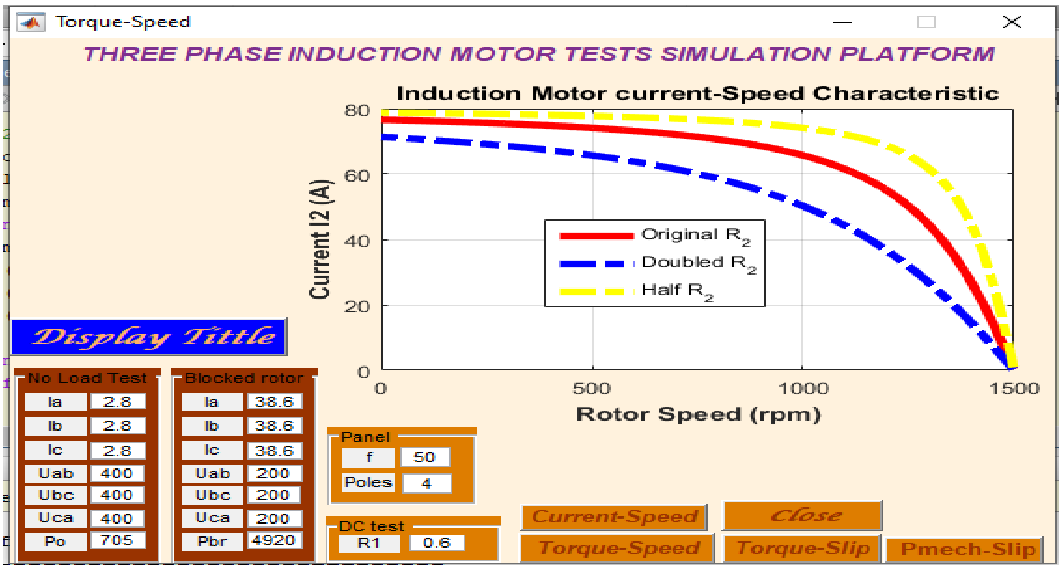
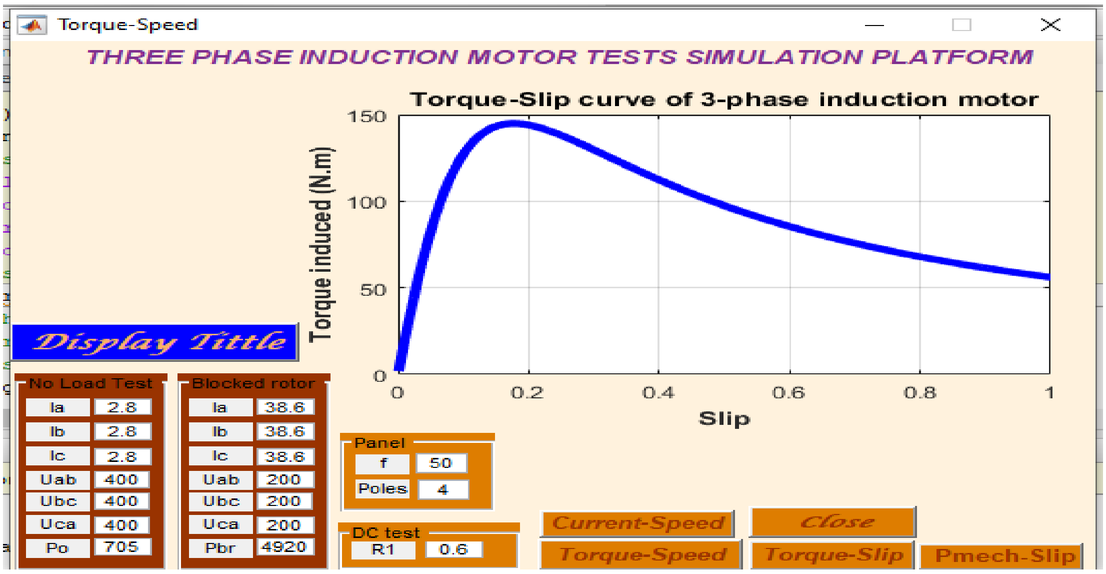


Source: Researcher, 2023

Figure 10: Current- Speed characteristics with variable rotor resistance

In figure 10, to by clicking on the pushbutton current-speed, the motor parameters are obtained as shown in Table 1 and also the characteristics curve. The current decreases as the load increases and in figure11, maximum torque occurred at slip approximately 0.18, as the slip is increasing the torque drops.



Source: Researcher, 2023
Figure 11: Torque and Slip curve

Table 1: Simulation results of a three-phase induction from figure 10

--	Full load Impedance = Zbr = 1.1007+2.7816i ohm
Frequency = f = 50 Hz	Rotor resistance = R2 = 0.5007 ohms
Number of poles = P = 4	Approximate X2 = X2 = 1.3908 ohms
No load calculations of equivalent parameters	Approximate Reactance = X1 = 1.3908 ohms
--	Thevenin parameters
Stator Resistance = R1 = 0.6 ohm	--
Line to line voltage = U = 400 V	Thevenin Voltage = Vth = 227.3683 V
No load Current = I1 = 2.8 A	Thevenin Impedance = Zth = 0.58156+1.3733i ohms
No load Input Power Pin = Pin = 705 W	

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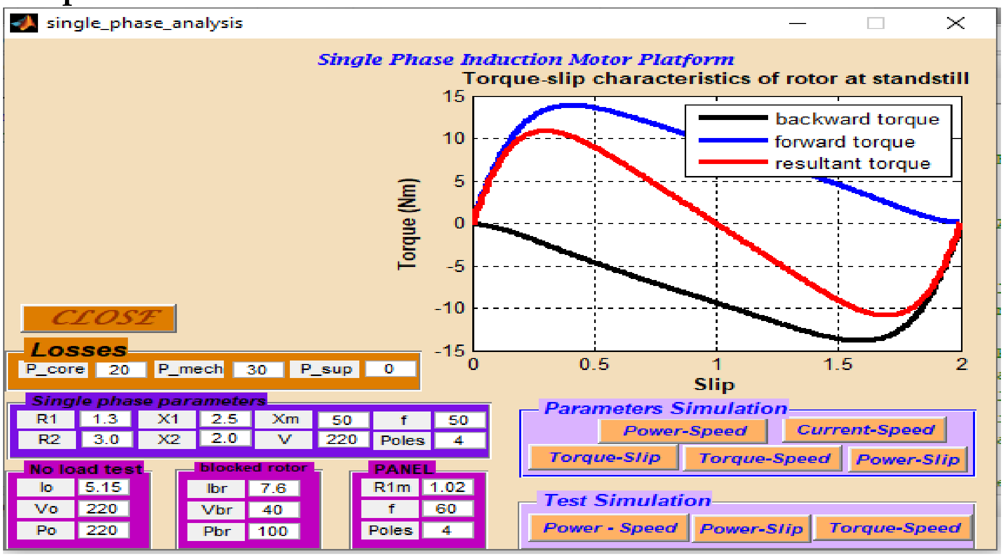
Source: Researcher, 2023

4.2. Characteristic Curves of Single-Phase Induction Motor

a) Torque-Slip characteristic of rotor at standstill



Source: Researcher, 2023

Figure 12: Torque-slip characteristic of rotor at standstill

The construction parts on of single-phase induction motor consist of main two parts: Stationary stator and revolving rotor. The stator separates from rotor by small air gap

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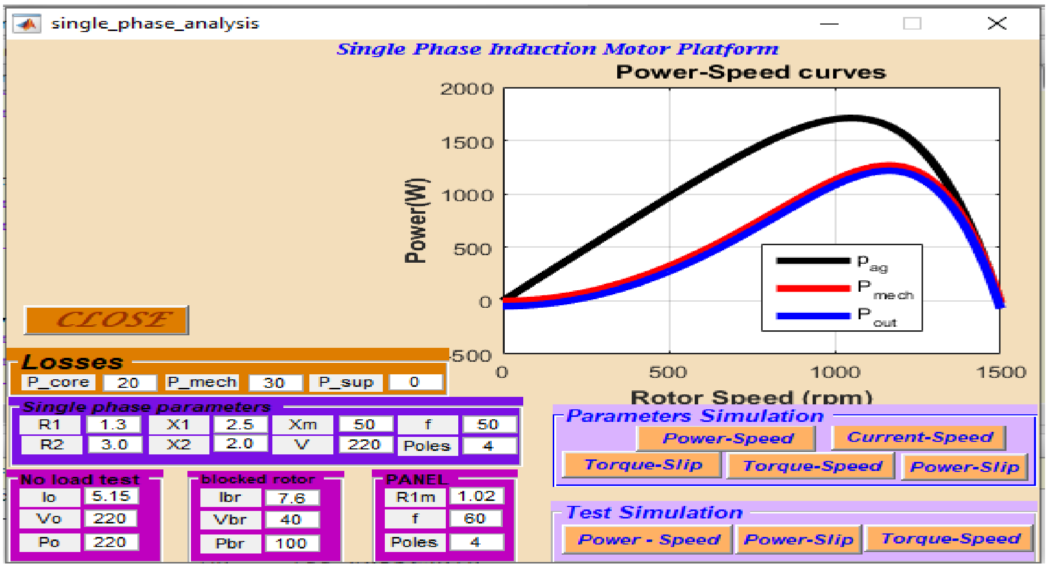
have ranges from 0.4 mm to 4 mm depends to size of motor (Ahmed, 2019). Measurement and determination of parameters of single-phase induction machines is quite a difficult task in comparison with symmetrical three-phase induction machines. Single-phase induction machines (SPIM) have been used for a long time because of their simple construction and because the single-phase power supply is available in almost every household. Single-phase power supplied to single phase winding is a source of pulsating field in a machine that can be resolved into two equal revolving fields rotating in opposite direction as shown in figure 12. Thus, the machine does not produce starting torque (Hrabovcova *et al*, 2010).

b) Power-Speed characteristics of a single-phase induction motor



Source: Researcher, 2023

Figure 13: Power-Speed characteristics of a single-phase induction motor

Figure 13 shows the variation of powers at each point of the motor. The power with the highest amplitude is the air-gap power followed by the mechanical power (also known as converted power that is, from electrical to mechanical). After the losses have been removed, we can now obtain the output power with the lowest amplitude.

5. Conclusion

In this paper, the characteristic curves on both single-phase and three-phase induction motors using stator parameters and laboratory test data were displayed. The Matlab-gui environment was used to design the various simulation platforms: (1) the three phase induction motor performances analysis platform. In this platform, when the indirect tests (dc, no load and blocked rotor) tests are carried out in the laboratory, the data are inserted in the various section. The various inscription on the pushbutton gives the curves to be displayed and the parameters are determined by a mouse click on any of the pushbutton. (2) Three phase induction motor parameters platform: in this platform, if the parameters of the motor are known and the corresponding characteristic curves need to be visualized, then the known parameters are inserted here. Also, with a mouse click on the respective pushbutton the curve is displayed. (3) Single phase induction motor platform. Here, the platform is divided into two sections, a section for the indirect tests to determine the parameters and visualized the corresponding curve or a section for the calculated parameters to observe only the curve.

6. Acknowledgments

I would like to thank Prof. Nfah Mbaka Eustace, University of Bamenda and Dr. Aloyem Kaze Claude Vidal, University of Buea for their supports to do this work.

7. References

Abhishake, J., Rupam, S., 2017. Analysis of Self-Excited Induction Generator Using Gui. International Journal of Engineering Research & Technology (IJERT) ISSN: 2278-0181, ICADEMS - 2017 Conference Proceedings

Ahmed, M. T. I., 2019. Single-Phase Induction Motors. https://www.researchgate.net /publication/33283529 (Accessed: 5 May 2022)

Bhaska, L., Writwik, B., 2013. MATLAB Based Model for Analysis of the Effect of Equivalent Circuit Parameters of an Asynchronous Motor on its Dynamic Characteristics. IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) e-ISSN: 2278-1676, p-ISSN: 2320-3331, Volume 7, Issue 1, PP 60-6.

Guimarães, J.M.C., Bernardes, J.V., Hermeto, A.E., et al, 2014. Determination of Three-phase Induction Motors Model Parameters from Catalog Information. IEEE

Haque, M. H., 2008. Determination of NEMA Design Induction Motor Parameters from Manufacturer Data IEEE transactions on energy conversion, vol. 23, no. 4.

Harish, R., 2013.GUI based power system simulation tool International Journal of Innovative Technology and Exploring Engineering (IJITEE) ISSN: 2278-3075, Volume-2, Issue-3.

Heba, A. A., Hassan, F., F., 2021.Volts/Hz Control of Three Phase Induction Machine: Matlab Simulink. Journal of Physics: Conference Series, 1818 (2021) 01208

Hrabovcova, V., Kalamen, l., Sekerak P., et al, 2010. Determination of Single-Phase Induction Motor Parameters. IEEE 978-1-4244-4987

Krishna, P. G., Dolly, M. A., 2018. Speed estimation and equivalent circuit parameter determination of induction motor using virtual instrumentation. International Conference

Moshe, A., Efim, L., 2021. Estimation of the Equivalent Circuit Parameters of Induction Motors by Laboratory Test https://www.google.com/search?q=induction+motor+equivalent+parameters&source (Accessed: 10 February 2023).

Munira, B., Aftab, A., 2013. Mathematical modeling and speed torque analysis of three phase squirrel cage induction motor using Matlab simulink for electrical machines laboratory International Electrical Engineering Journal (IEEJ) Vol. 4, No. 1, pp. 880-889

ISSN 2709-3409 (Online)

Pichai, A., 2016. Analytical approach to determine speed-torque curve of induction motor from manufacturer data. International Electrical Engineering Congress, iEECON2016, March 2-4, Chiang Mai, Thailand.

Rade, B., Veselko, T., 2013. Determination of the Torque-Speed Characteristic of Induction Motor in Electric Machinery Education. https://www.google.com/search?q=Determination+of+the+TorqueSpeed+Characteristic++of+Induction+Motor+in+Electric+Machinery++Education (Accessed: 26 October 2022)

Ramprasath, E., Manojkumar, P., 2015. Modelling and Analysis of Induction Motor using LabVIEW. International Journal of Power Electronics and Drive System (IJPEDS) (5) 3: 344~354, ISSN: 2088-8694

Renjini, E. N., Sruthi, D., Jeanmary, J., 2019. Speed estimation of induction motor using LabVIEW. Journal of Applied Science and Computations, Volume VI, Issue II

Saffet, A., Chika, O., N., 2005. Induction Motor Tests Using MATLAB/Simulink and Their Integration into Undergraduate Electric Machinery Courses. IEEE Transactions on Education, VOL. 48, NO. 1

Sang-Hoon. L., Hak-Jun, L., Young-Doo, Y., et al, 2017. Identification of Induction Motor Parameters at Standstill Based on Integral Calculation. EEE transactions on industry applications, vol. 53, NO. 3

Sunil, S., K. Gautam, K., Vijay, B., 2012. Performance evaluation of three phase induction motor based on no load and blocked rotor test using Matlab. International Journal of Science, Environment and Technology, Vol. 1, No 5, 541 - 547

Suryasen, K., Harish, A., 2013. GUI based power system simulation tool. International Journal of Innovative Technology and Exploring Engineering (IJITEE), Volume-2, Issue-3, ISSN: 2278-3075

Zuriman, A., Erhaneli, E., Busran, B., 2017. A new equivalent circuit of the three-phase induction motor (case studies: current and power factor of the motor). ARPN Journal of Engineering and Applied Sciences, VOL. 12, NO. 23