Analysis Of Insulated Core Three Phase Induction Motor In MATLAB

Mr.Aditya A. Gavhale[1],Prof. A.V. Mohod[2]
[1]*Student Ram Meghe College of Engineering and management Amravati.*
[2]*Professor, Ram Meghe College of Engineering and management Amravati*

***Abstract*—Energy efficiency improvement is the main target of many recent studies in various domains, especially for electrical drives which constitute the core of industrial applications. The simulation of induction motors is based on static and dynamic models that allow the study of their mechanical performances, as well as their power consumption and losses. However, the commonly used dynamic model doesn't take into consideration the core losses in the motor, which have a significant impact on its energy efficiency. The purpose of this paper is to present two methods for including core losses in the dynamic model of squirrel cage induction motors (IM) in addition to the copper and mechanical losses that are already taken into consideration in the commonly used model. Core losses are introduced as an equivalent torque reduction in the mechanical equation, or as an equivalent resistor in the model's equations. The proposed model is essential for future studies aiming to improve the energy efficiency of the motor. Both methods are analyzed and simulated using Matlab/Simulink and the obtained results are experimentally validated. The performances of these proposed methods are compared in order to find the best suitable method for future applications and induction motor studies.**

I. INTRODUCTION

Electric motors have been the most significant invention in human era in 18th century after the law of electromagnetic induction by faraday. In 19th and 20th century it has undergone tremendous development for industrial purpose. These motors have been used widely in all industries also for domestic applications. After the invention of Induction motors the use of induction motors has become cheaper and more efficient. No doubt Induction motor has great use in field of electrical technology to drive various type of load. Still Induction motor faces many problems that are discussed below related to efficiency of Induction Motor.

A. Induction motor problems

Every machine in world needs to be ideal one but in actual practice none of exits. Efficiency is of prime concern for every machine specially in case of rotating machines. The efficiency of any machine decreases due to the various type's losses. Following are the losses which are in case of induction motor when it drives load.

- Friction and windage loss 5% - 10%
- Iron or core losses 15% - 25%
- Stator losses 25% - 40%
- Rotor losses 15% - 25%
- Stray load losses 10% - 20%

The stator and rotor core consist the maximum number of losses. These losses occurring due to the following reasons:

- Magnetic core of stator and rotor
- Stampings used in iron material

So, we have design insulated material for motor which will overcome above problems. Now this thought gives rise to new technology

B. Insulated Core Induction Motor.

What is Insulated Core Induction Motor

The induction motor consists of magnetic cores. Due to this magnetic core flux linkage takes place. The magnetic core is made up of some magnetic material, hence there occurs some magnetic saturation at some point of time. Due to this, magnetic saturation hysteresis losses take place. Also, Eddy current losses are present in the induction motors. Due to this losses present, the efficiency of the motor decreases which is a great worry of concern for the machine designers.

The insulated core induction motor induction motor was inscribed from the thought that, if the flux linkage takes place through air or nonmagnetic material instead of magnetic material, then these losses can be stopped.

- An Insulated stator;
- An Insulated rotor,

- A rotating shaft,
- An induction rod inserted into the interior of insulated core induction motor rotor to guide a magnetic flux;
- A stator positioned around insulated rotor

Insulated core induction motor rotor is a squirrel cage-shaped conduction cylinder and composite material or polymer resin, of Insulated core induction motor. cylinder to make up for the low stiffness of said squirrel cage-shaped conduction cylinder, said composite material or polymer resin includes powder having high magnetic permeability, such as iron or ferrite powder, to make up for the low magnetic permeability of said squirrel cage-shaped conduction cylinder, further comprising heat pipes, said heat pipes being inserted into the slots of said squirrel cage-shaped conduction cylinder in order to dissipate heat.

C. Principle of Insulated Core Induction Motor

The basic principle of insulated core induction motor induction motor is similar to that of induction motor. It is based on the faraday's law of electromagnetic induction. The AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations. The rotor creates at a lower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the later is short-circuited or closed through external impedance. The rotating magnetic flux induces currents in the winding of the rotor in a manner similar to currents induced in transformer's secondary windings. This induced emf drives its own current as rotor winding is short circuited now current carrying conductor place in magnetic field experiences torque hence rotor rotates. For construction insulated core electric motor core the different types of liquids and powders are used to make the fiber core material. The content used is having different percentage that is very important while manufacturing of material. If any percentage changes, the properties of material also changes and the product cannot be sustained as per the requirements for insulated core induction motor induction motor.

II. OBJECTIVE OF THESIS

The main objective of propose methodologies are as follows:

1) Analysis of three phase induction motor.
2) Improve the performance of three phase induction motor.
3) Analyze the insulated induction motor.

A. State of art

This dissertation work aims at to achieve three phase induction motor fault analysis system. The main objectives of this project are:

1. To study the existing three phase induction motor fault analysis technique.

Selection of proper MATLAB simulation blocks for designing three phase induction motor fault analysis system in MATLAB Simulink atmosphere.

Selection of proper insulation values for induction motor.

B. Introduction

An induction motor comprises a magnetic circuit interlinking two electric circuits which are placed on the two main parts of the machine: (i) the stationary part called the stator and (ii) the rotating part called the rotor. Power is transferred from one part to the other by electromagnetic induction. For this induction machine is referred as an electromechanical energy conversion device which converts electrical energy into mechanical energy [1]. Rotor is supported on bearings at each end. Generally, both the stator and rotor consist of two circuits: (a) an electric circuit to carry current and normally made of insulated copper or insulated aluminum and (b) a magnetic circuit, shown in figure 3.2, to carry the magnetic flux made of laminated magnetic material normally steel (figure 1).

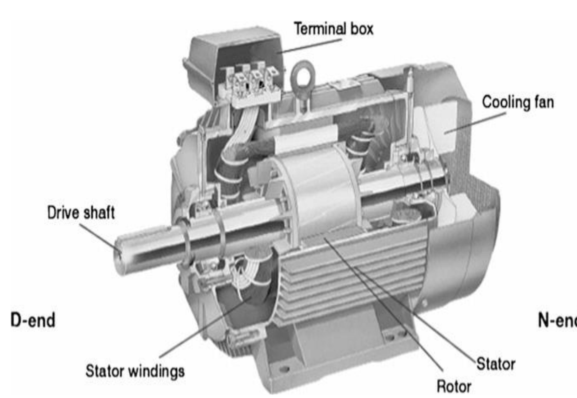

Figure 1: An induction motor (dissected)

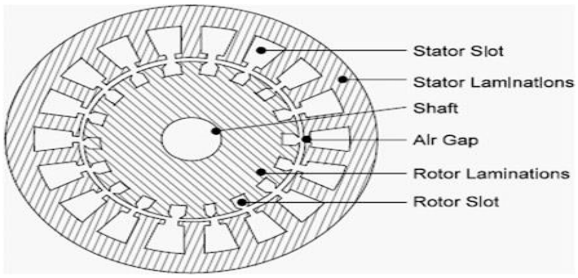

Figure 1.2: Magnetic circuit of stator and rotor of an induction motor

III. CONSTRUCTION

1.5.1 Stator: The stator, shown in figure 3.3, is the outer stationary part of the motor. It consists of (i) the outer cylindrical frame, (ii) the magnetic path, and (iii) a set of insulated electrical windings. (i) The outer cylindrical frame: It is made either of cast iron or cast aluminium alloy or welded fabricated sheet steel. This includes normally feet for foot mounting of the motor or a flange for any other types of mounting of the motor.

(ii) The magnetic path: It comprises a set of slotted high-grade alloy steel laminations supported into the outer cylindrical stator frame. The magnetic path is laminated to reduce eddy current losses and heating.

(iii) A set of insulated electrical windings: For a 3-phase motor, the stator circuit has three sets of coils, one for each phase, which is separated by 120° and is excited by a three-phase supply. These coils are placed inside the slots of the laminated magnetic path.

1.5.2 Rotor: It is the rotating part of the motor. It is placed inside the stator bore and rotates coaxially with the stator. Like the stator, rotor is also made of a set of slotted thin sheets, called laminations, of electromagnetic substance (special core steel) pressed together in the form of a cylinder. Thin sheets are insulated from each other by means of paper, varnish [2]. Slots consist of the electrical circuit and the cylindrical electromagnetic substance acts as magnetic path. Rotor winding of an induction motor may be of two types: (a) squirrel-cage type and (b) wound type. Depending on the rotor winding induction motors are classified into two groups [1–3]: (i) squirrel-cage type induction motor and (ii) wound-rotor type induction motor. (i) Squirrel-cage type induction motor: Here rotor comprises a set of bars made of either copper or aluminum or alloy as rotor conductors which are embeddedin rotor slots. This gives a very rugged construction of the rotor. Rotor bars are connected on both ends to an end ring to make a close path. Figure 3.4 shows a squirrel-cage type rotor.

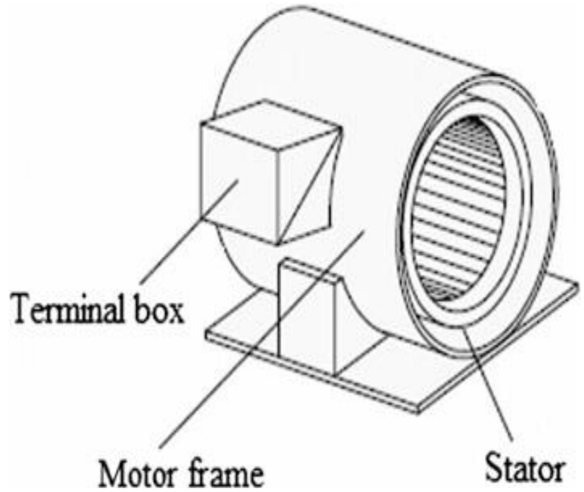

Figure 1.3: Stator of an induction motor

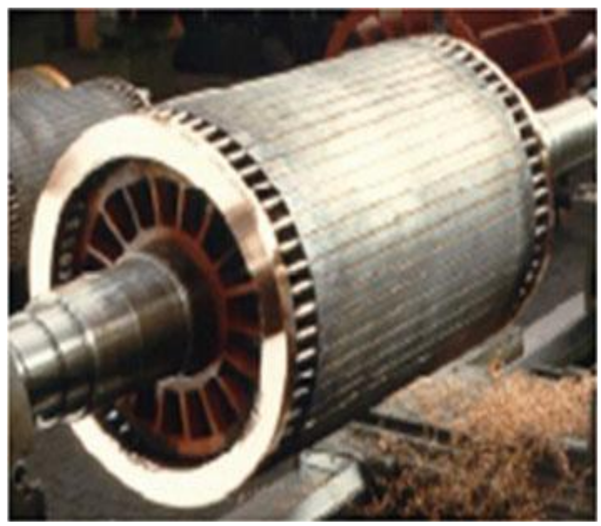

Figure 1.4: Squirrel-cage rotor

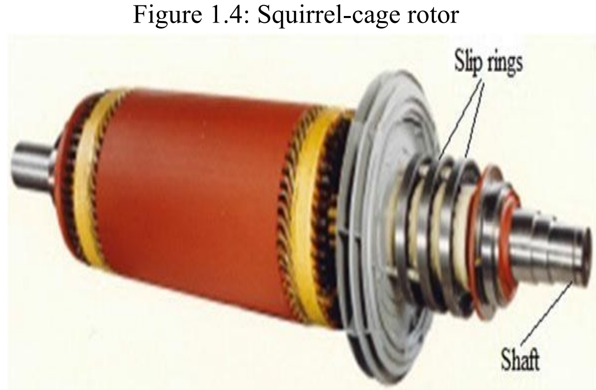

Figure 1.5: Slip ring rotor

(ii) Wound-rotor type induction motor: In this case rotor conductors are insulated windings which are not shorted by end rings but the terminals of windings are brought out to connect them to three numbers of insulated slip rings which are mounted on the shaft, as shown in figure 3.5. External electrical connections to the rotor are made through brushes placed on the slip rings. For the presence of these slip rings this type of motor is also called slip ring induction motor.

A. Insulated Three Phase Induction Motor

An insulated induction motor is not a specific type of motor but rather refers to an induction motor that has enhanced electrical insulation to protect it against issues like high voltage stresses, particularly in applications involving variable frequency drives (VFDs) or harsh environments.:

IV. KEY FEATURES OF INSULATED INDUCTION MOTORS: IMPROVED INSULATION SYSTEM

The windings are coated with high-grade insulation to withstand voltage surges and high-frequency switching from VFDs.

This prevents premature failure caused by partial discharges or insulation breakdown.

A. Bearing Insulation:

Bearings may include insulating layers or ceramic coatings to prevent electrical arcing. This is essential when shaft currents are induced by VFD operations or other high-frequency effects. Without this, bearing currents can cause pitting, fluting, and eventual motor failure.

B. Environmental Protection:

Insulation may also protect against moisture, dust, or corrosive environments, depending on the motor’s application.

C. Voltage Withstand Capability:

Insulated motors are designed to handle the higher voltage spikes common in systems controlled by fast-switching semiconductor devices like IGBTs in modern drives.

1.7 Construction of insulated induction motor

The construction of an insulated induction motor is similar to a standard induction motor but with added insulation features to protect against electrical stresses, such as voltage spikes, partial discharges, and bearing currents. Below is an overview of its key components and their construction:

1.Stator:

Core: Made of laminated steel to minimize eddy current losses.

Windings: Copper or aluminum windings are coated with high-grade insulation, such as polyester, epoxy, or mica-based materials.

Reinforced insulation layers are used to withstand high-frequency switching surges from variable frequency drives (VFDs).

Slot Insulation: Insulation paper or material (e.g., Nomex) is placed between the windings and the stator slots to provide additional protection.

2. Rotor:

Squirrel Cage (Common Type): Typically made of aluminum or copper bars short-circuited at both ends by rings.Insulation is not required for the rotor as it is a short-circuited component, but care is taken to prevent induced shaft currents.

Wound Rotor (Less Common): If a wound rotor is used, its windings are also insulated, similar to stator windings.

3. Bearings: Insulated Bearings: Ceramic or hybrid bearings are used to prevent electrical currents from passing through the bearings, which can cause fluting and pitting.

Shaft Grounding Devices: Shaft grounding brushes or rings are added to divert stray currents away from the bearings.

4. Insulation System: Varnishing: Windings are impregnated with varnish to improve mechanical strength and insulation.

High-Voltage Insulation: Designed to handle voltage transients, particularly in VFD applications.

Partial Discharge Resistance: Special insulation materials reduce the risk of partial discharges caused by high-frequency switching.

5. Frame: Typically made of cast iron, steel, or aluminium. The frame may be designed with sealed or enclosed housings to protect the motor in harsh environments.

7. Terminal Box: Isolated Connections: Terminal boxes are designed with insulated bushings to prevent voltage leakage or arcing.

Surge Protection: Surge suppressors (like MOVs or TVS diodes) may be incorporated to protect against voltage spikes.

8. Special Coatings: Anti-Corrosion Coatings: For motors used in corrosive environments.

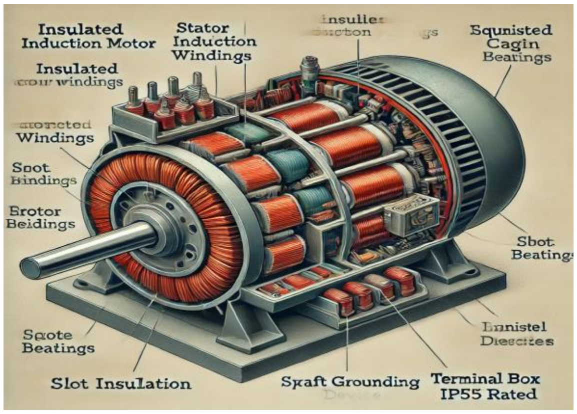

figure 1.6 insulated induction motor

The specifications of an insulated induction motor vary depending on the application, size, and insulation requirements. Below is a general outline of typical specifications:

1.8 Block diagram

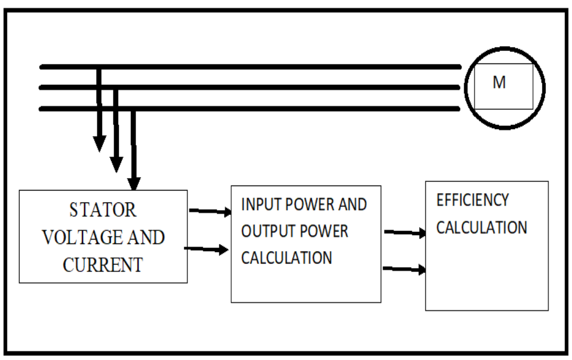

Figure 1.7: Generalized block diagram of propose approach

The figure appears to depict a block diagram of a system used for calculating the efficiency of an electrical machine (denoted as "M" in the diagram). Here's an explanation of the key components:

1. Stator Voltage and Current Measurement:

- The leftmost block shows that the stator's voltage and current are measured. These signals represent the input electrical power provided to the machine.

2. Input Power and Output Power Calculation:

- The second block takes the stator voltage and current measurements and uses them to calculate the input power. Additionally, the mechanical output power of the machine (likely derived from torque and speed measurements) is determined here.

3. Efficiency Calculation:

- The third block uses the input and output power values to calculate the efficiency of the machine. Efficiency is typically calculated as: Efficiency= (Output Power/Input Power) ×100%

V. CONNECTIONS

- The arrows represent the flow of data, starting from the measured electrical signals, proceeding to power calculations, and finally to efficiency computation.

5.2. Project Implementation

This project implementation will be done using MATLAB Simulink software. The major blocks will be design in MATLAB simulink as follows:

- Simulation of power system using simpower system toolbox.
- Simulation of general three phase induction motor using sim power system toolbox.
- Simulation of insulated three phase induction motor using sim power system toolbox.
- Simulation of insulation and general induction motor efficiency and compare the result of both simulations.

5.3. MATLAB Simulation model

Case (A) General Induction motor

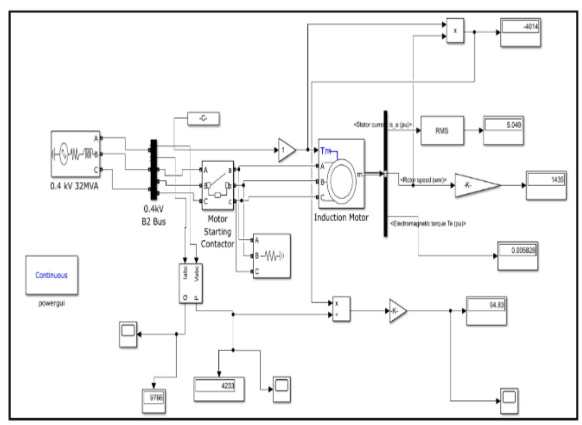

Figure 1.8: MATLAB Simulation model of general induction motor analysis

The image is a detailed simulation block diagram, likely developed in MATLAB/Simulink or a similar simulation tool. It represents the operation of an induction motor connected to a 0.4 kV power system and the calculation of various parameters such as stator current, rotor speed, torque, and efficiency. Below is a breakdown of the main components:

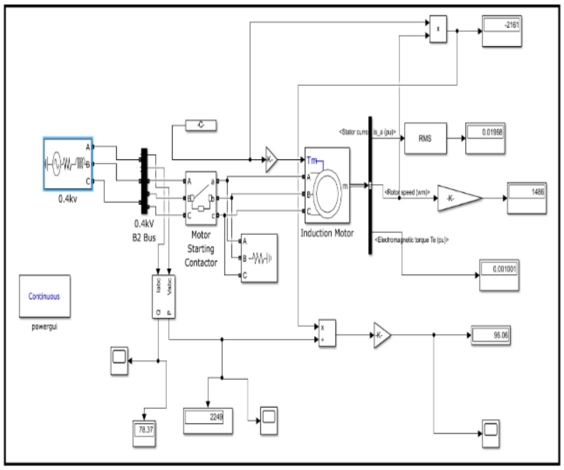

Figure 5.4: MATLAB Simulation model of insulated induction motor fault analysis

A. Key Parameters

1. Machine Rating (Power Output, kW): Determines the energy usage and cost differences.
2. Operating Hours per Year: Affects energy consumption and efficiency-related cost savings.
3. Energy Cost per kWh: Affects the economic impact of efficiency differences.
4. Initial Cost: More efficient machines often have higher upfront costs due to better materials and designs.
5. Lifetime of the Machine: Defines the duration over which energy savings accumulate.

5.1. general condition (Without insulation)

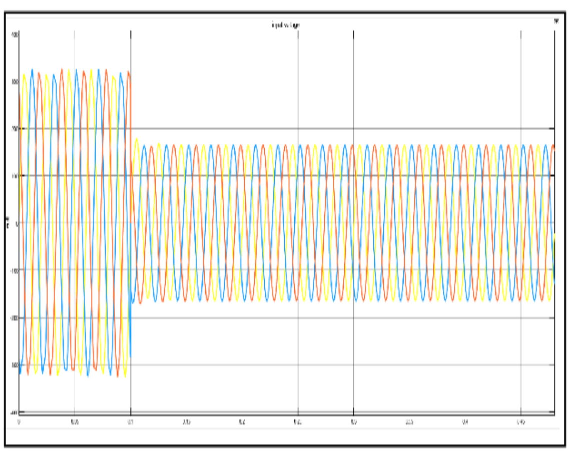

Figure 5.1: Analysis on voltage signal during normal condition

This figure appears to be a time-domain plot of input voltages. Here are the key observations:

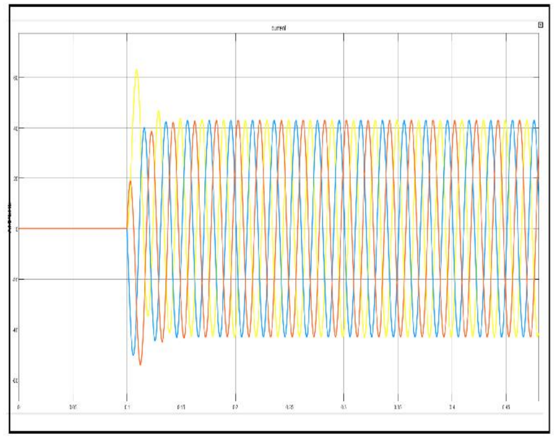

Figure 5.2: Analysis on current signal during normal condition

This type of plot could be from simulations or measurements in electrical systems, such as a power converter, motor control system, or a circuit simulation, where the goal is to analyze how the input voltages behave over time

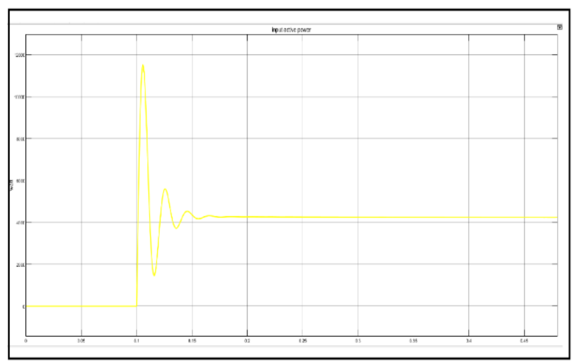

Figure 5.3: Analysis on input active power signal during normal condition

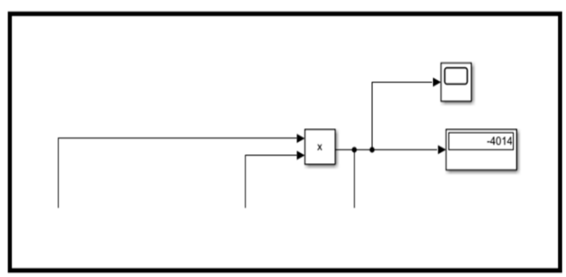

Figure 5.4: Analysis on output power signal during normal condition

This figure is a block diagram, likely representing part of a control or simulation model, possibly created in a simulation tool like MATLAB/Simulink. Here's an explanation of the components:

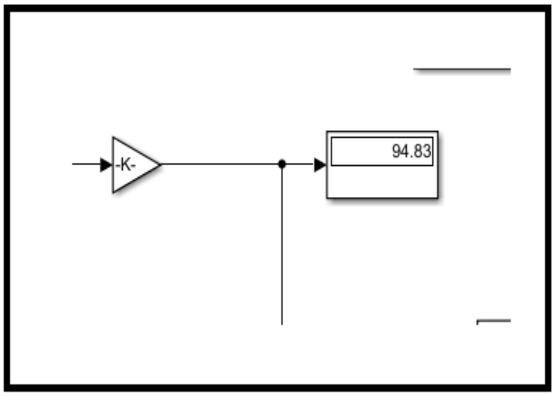

Figure 5.5: Analysis on efficiency signal during normal condition

This figure is another block diagram, likely from a simulation environment, showing a simple operation. Here's an explanation of the components:

6.2. Insulated condition (With insulation)

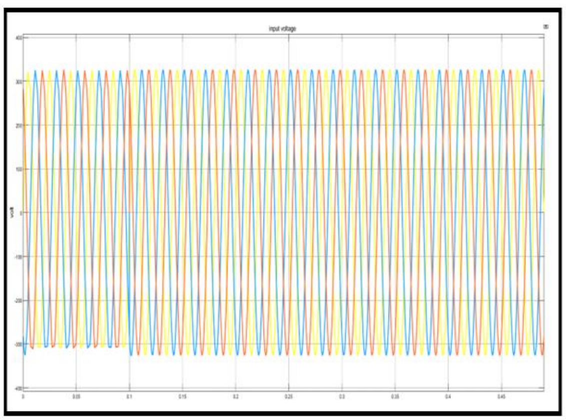

Figure 5.6: Analysis on voltage signal during insulated condition

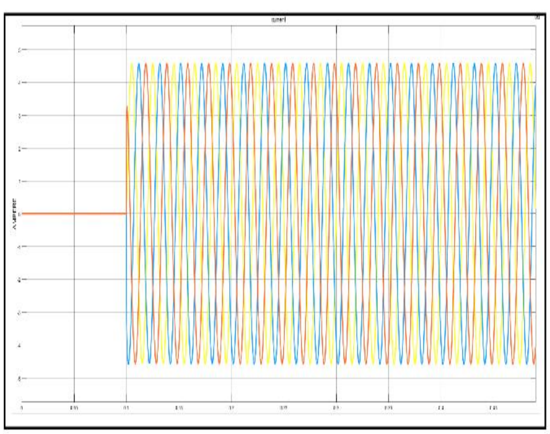

Figure 5.7: Analysis on current signal during insulated condition

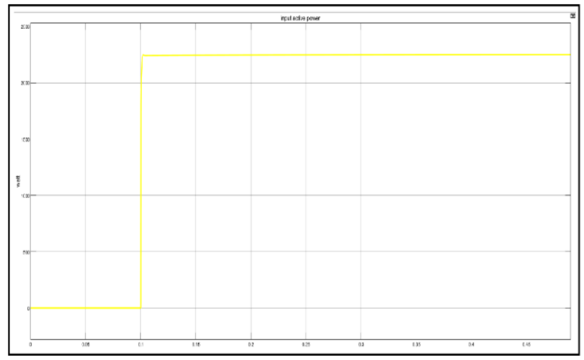

Figure 5.8: Analysis on power signal during insulated condition

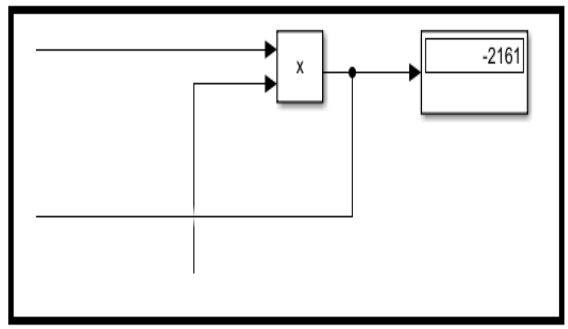

Figure 5.9: Analysis on output power signal during insulated condition

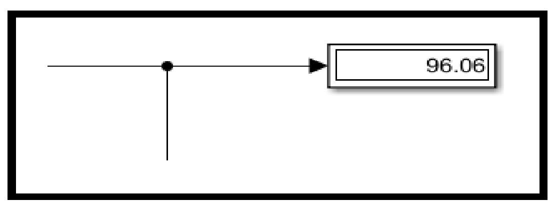

Figure 5.10: Analysis on output efficiency signal during insulated condition

Table 6.9: Comparison of Normal and insulated motor techniques

Sr No	Specification	Normal Motor	Insulated Motor
1	Input power	4233 watts	2249 watt
2	Output power	4014 watts	2161 watt
3	Stator resisitance	0.03513 ohm	6.03
4	Rotor resisitance	0.03488	6.085
5	Stator inductor	0.04586	489.3e-3

6	Rotor inductor	0.04586	489.3e-3
7	Speed RPM	1430	1486
8	efficiency	94.83%	96.06%
9	Electromagnetic torque	0.005828	0.001001
10	Input torque	26.71	61.369

From table 6.9, it is clear that insulated induction motor efficiency is greater than general induction motor, also speed, slip and torque parameter is better than the general induction motor. Als(4000)/(1430*2*pi/60) input torque and electromagnetic torque is given here.

VI. CONCLUSION

After all machine designed, all electrical connection is to be done we conduct taste at MATLAB. The rotor starts rotating with low starting torque when the 3 phase, 440 volt, 50 hz supply given to motor it starts rotating. So, we are making modification to rotor of motor in order to get high starting torque. In this thesis general mode without insulation motor and insulated motor parameter is check properly and run it in the MATLAB software. Efficiency of insulated motor is 96% and non-insulated is 94%.

REFERENCES

[1] Dai Gil Lee; Seung Hwan Chang "Coreless Ac Induction Motor" Patent No.US6384507 B1

[2] Ki-Chan Kim, Dong-Seok Ryu, and Min-Gyu Kim "Characteristics of Ferromagnetic Materials Due to Uneven Magnetic Saturation" IEEE Transactions on magnetic, vol. 47, no. 10, October 2011

[3] S. O. Kwon, J.J.Lee , B. H. Lee , J. H. Kim K.H.Ha, and J. P. Hong "Loss Distribution of Three-Phase Induction Motor and BLDC Motor".IEEE Transactions on magnetic, vol. 45, no. 10, October 2009

[4] M. Faokizono, M. Morikawa, and S. Fujiyama "Distribution of Local Magnetic Properties in Three-phase Induction Motor Model Core". IEEE Transactions on magnetic, vol 35, no 5, September 1999

[5] Július Saitz "Computation of the Core Loss in an Induction Motor Using the Vector Preisach Hysteresis Model Incorporated in Finite Element Analysis". IEEE Transactions on magnetic, vol. 36, no. 4, July 2000

[6] Maria Dems, and Krzysztof Komeza, "Performance Characteristics of a High-Speed Energy-Saving Induction Motor With an Amorphous Stator Core" IEEE Transactions on industrial electronics, vol. 61, no. 6, June 2013

[7] Guzmán Díaz, Cristina González-Morán, Pablo Arboleya, and Javier Gómez-Aleixandre "Analytical Interpretation and Quantification of Rotational Losses in Stator Cores of Induction Motors" IEEE Transactions on magnetic, vol. 43, no. 10, October 2007

[8] Emmanuel B. Agamloh, Aldo Boglietti, and Andrea Cavagnino, "The Incremental Design Efficiency Improvement of Commercially Manufactured Induction Motors" IEE Transactions on industry applications, vol. 49, no. 6, November/December 2013

[9] Katsumi Yamazaki and Yuta Watanabe "Interbar Current Analysis of Induction Motors Using 3-D Finite-Element Method Considering Lamination of Rotor Core" IEEE Transactions on magnetic, vol. 42, no. 4, April 2006

[10] M. K. Jamil and N. A. Demerdash, "Harmonics and core losses of permanent magnet DC motors controlled by chopper circuits,"IEEE Trans. Energy Convers., vol. 5, no. 2, pp. 408–414, Jun. 1990.

[11] C. P. Steinmetz, "On the law of hysteresis (originally published in1892)," Proc. IEEE, vol. 72, no. 2, pp. 196–221, Feb. 1984.

[12] J. R. Hendershot and T. J. E. Miller, Design of Brushless Permanent Magnet Motors. Mentor, OH: Magna Physics, 1994.

[13] T. J. E. Miller and M. I. McGilp, PC-BDC 6.5 for Windows— Software. Glasgow, U.K.: SPEED Laboratory, Univ. Glasgow, 2004.

[14] G. Bertotti, General properties of power losses in soft ferromagnetic materials," IEEE Trans. Magn., vol. 24, no. 1, pp. 621–630, Jan. 1988.

[15] F. Fiorillo and A. Novikov, "An improved approach to power losses in magnetic laminations under nonsinusoidal induction waveform," IEEE Trans. Magn., vol. 26, no. 5, pp. 2904–2910, Sep. 1990.

[16] G. Bertotti, A. A. Boglietti, M. Chiampi, D. Chiarabaglio, and F. Fiorillo,"An improved

estimation of iron loss in rotating electrical machines,"IEEE Trans. Magn., vol. 27, no. 6, pp. 5007–5009, Nov. 1991. [17] H. Nam, K. H. Ha, J. J. Lee, J. P. Hong, and G. H. Kang, "A study on iron loss analysis method considering the harmonics of the flux density waveform using iron loss curves tested on epstein samples,"IEEE Trans. Magn., vol. 39, no. 3, pt. 1, pp. 1472–1475, May 2003.

[17] F. Fiorillo and A. Novikov, "An improved approach to power losses in magnetic laminations under nonsinusoidal induction waveform,"IEEE Trans. Magn., vol. 26, no. 5, pp. 2904–2910, Sep. 1990.

[18] K.S. Graeid, H.W. Ping, and H.A.F. Mohamed, "Simulink Representation of Induction Motor Reference Frames," in Proceedings of the 2009 International Conference for Technical Postgraduates (TECHPOS), 2009, pp. 1-4.

[19] O. Dordevic, N. Bodo, and M. Jones, "Model of an Induction Machine with an Arbitrary Phase Number in MATLAB / Simulink for Educational Use," in Proceedings of the 2010 International Universities Power Engineering Conference (UPEC), 2010, pp. 1-6.

[20] O. D. Momoh, "Dynamic Simulation of Cage Rotor Induction Machine – A Simplified and Modular Approach," in Proceedings of the 44th IEEE Southeastern Symposium on System Theory, 2012, pp. 200-203.

[21] ellur, D.M. and Kazimierczuk, M.K., "PSPICE and MATLAB Applications in Teaching Power Electronics to Graduate Students at Wright State University," in Proceedings of the 2008 ASEE North Central Section Conference, 2008.

[22] P.C. Krause, O. Wasynczuk, and S.D. Sudhoff, Analysis of Electric Machinery, IEEE Press, NY: 1995. [24] T.A. Lipo, "Electric Machine Analysis and Simulation," Research Report, Wisconsin Electric Machines & Power Electronics Consortium, 2000, pp. 313-324.

[23] A.W. Leedy and R.M. Nelms "Simplified Model of an Inverter-Fed Induction Motor for the Analysis of a DC Power System", in Proceedings of the 36th IEEE Southeastern Symposium on System Theory, 2004, pp. 275- 279.

[24] B. Ozpineci and L.M. Tolbert, "Simulink Implementation of Induction Machine Model-A Modular Approach," in Proceedings of the IEEE International Electric Machines and Drives Conference (IEMDC), 2003, pp. 728-734.