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Performance Analysis of Squirrel Cage Induction Motor using Finite Element Method

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Abstract

In this paper, the performance of the Squirrel Cage Induction Motor is analyzed using the Finite Element Method. Magnetic flux lines, Magnetic flux density, and transient analysis using the Maxwell two-dimensional (2D) model are analyzed and animated using the 2D finite element method in ANSYS Maxwell 2D. A 3-phase Sinusoidal Pulse Width Modulated (SPWM) Inverter is simulated in Ansys Simplorer Software is examined. MATLAB-SIMULINK is used for the analysis, of the close loop V/f control speed control technique of the Induction Motor in MATLAB, using the PID controller. The variation of torque and rotor speed for target reference speeds and sudden load changes is observed.

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I. Introduction

The electrical machine converts electrical energy into mechanical energy and vice versa. Induction motors play a significant role in daily living. Motors consume the most electrical energy in the industrial sector as a result of their well-known advantages, which include mechanical rigidity, consistent quality, and low cost[1]. Induction motors with squirrel cages come in a variety of conventional designs to meet the various starting and running needs of various industrial applications. The most popular motors used in industrial systems for motion control and regularly powered home appliances are AC induction motors. An AC induction motor, like other motors, consists of a fixed outer section called the stator and an internal rotating portion called the rotor separated by a precisely designed air gap. The rotating magnetic field in the stator is obtained by providing a 3-phase supply to AC induction motor and results into speed, torque according to loading condition and supply variation [2].

II. Establishment of Finite Element Method of Induction motor

Finite element analysis is a numerical method for calculating approximate solutions to complex partial differential equations. In this method, the field region is segmented into elements, or sub-regions, where the unknown quantities, such as a scalar or vector potential, are represented by interpolation functions containing, as unknowns, the potential values at the relevant nodes of each element. It is possible to determine the potential values of the nodes using either direct or iterative methods [3].

The motor parameters such as the diameter of the stator and rotor, losses, conductors per slot, etc. are entered in the Ansys RMXprt module to model the motor. By using the model of RMXprt, 2-D models has been derived in Ansys Maxwell which is used for analysis using the finite element method. Table-1 shows the various parameter that is used to model the squirrel cage induction motor. By setting the excitation source and specifying the boundary conditions the motor gets accurate electromagnetic analysis results for the motor.

The stator design has a three-phase 4-pole distributed winding having 36 slots in the stator with a 175 mm outer diameter and 121 mm inner diameter with the core length of the stator 150 mm and 36 conductors per slot. With an air gap of 0.35 mm between the rotor and stator. The rotor design has 30 slots with an outer diameter of 120.3 mm and an inner diameter of 38 mm. The length of the rotor is 150 mm. The material assigned for laminated steels of the rotor and stator is M19_24G from the Ansys library.

Table-1 Squirrel Cage Induction Motor parameters

Parameter	Value	Parameter	Value
No. of stator poles	4	No. of rotor poles	4
No. of stator slots	36	Outer diameter of rotor	120.3 mm
Outer diameter of the stator	175 mm	Inner diameter of rotor	38 mm
Inner diameter of the stator	121 mm	Length of shaft	150 mm
Stacking Factor	0.92	Frictional Loss	60 W
Winding layers	1	Windage loss	0 W
Conductors per slot	20		

RMXPrt model of the Squirrel Cage Induction Motor according to the parameter mentioned in Table-1 is shown in Figure-1.

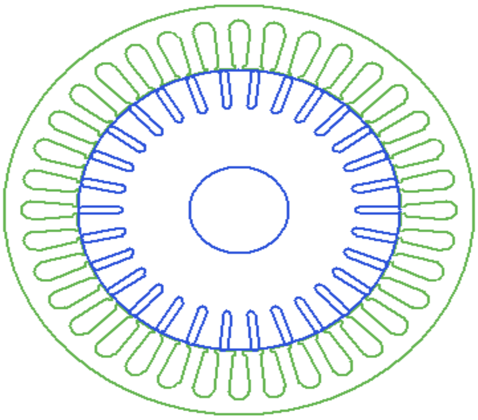

Figure-1: RMXprt model of the squirrel cage induction motor

In table-2 the solution data for the squirrel cage induction motor has been given.

Table-2: Solution data for a Three-Phase Induction Motor

Name	Value
Operation Type	Motor
Load Type	Constant Power
Rated Output Power	3800 W
Rated Voltage	380 V
Rated Speed	1420 RPM
Operating Temperature	75 Cel

Figure-2 displays the mesh design of the modeled motor according to the solution setup which shows dense mesh along the air gap. The mesh helps to reduce the time to get accurate results. Ansys software produces the mesh of the Maxwell 2-D motor model which provides accurate solutions and complex computational analysis methods such as Finite Element Analysis (FEA) can be employed [4,5,6].

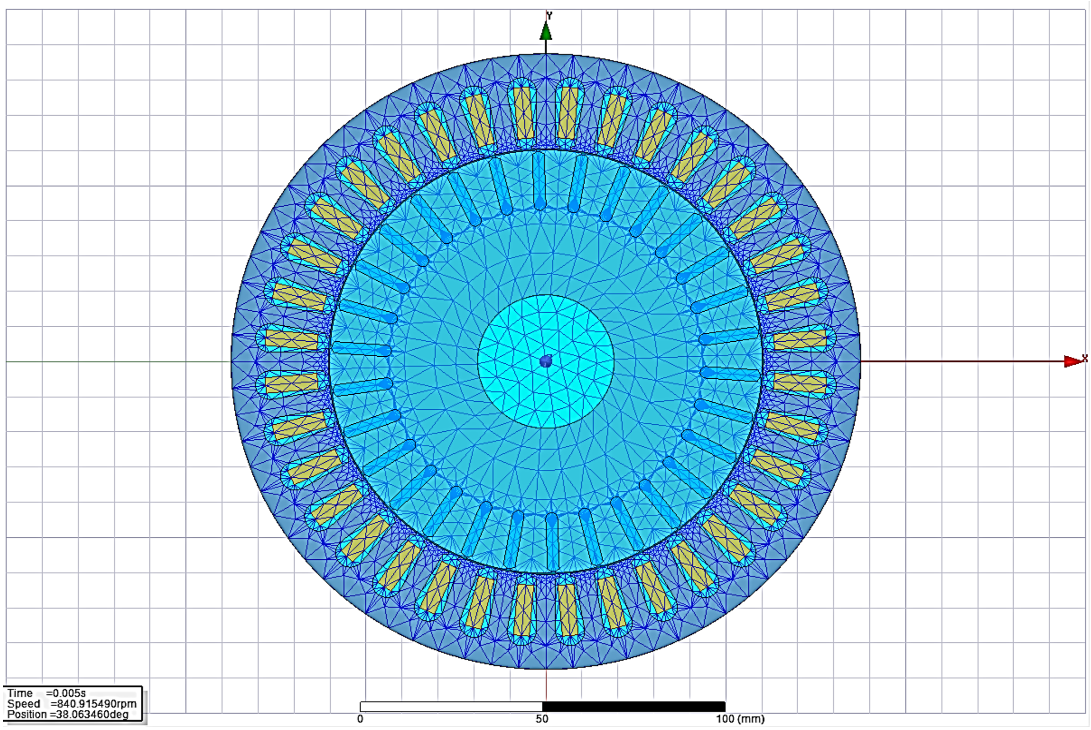

Figure 2: Mesh design of the three-phase induction motor

In Figure-3 the distribution of flux orientation for the motor has been displayed. This plot is used to verify that four poles are been formed (shown by the vectors).

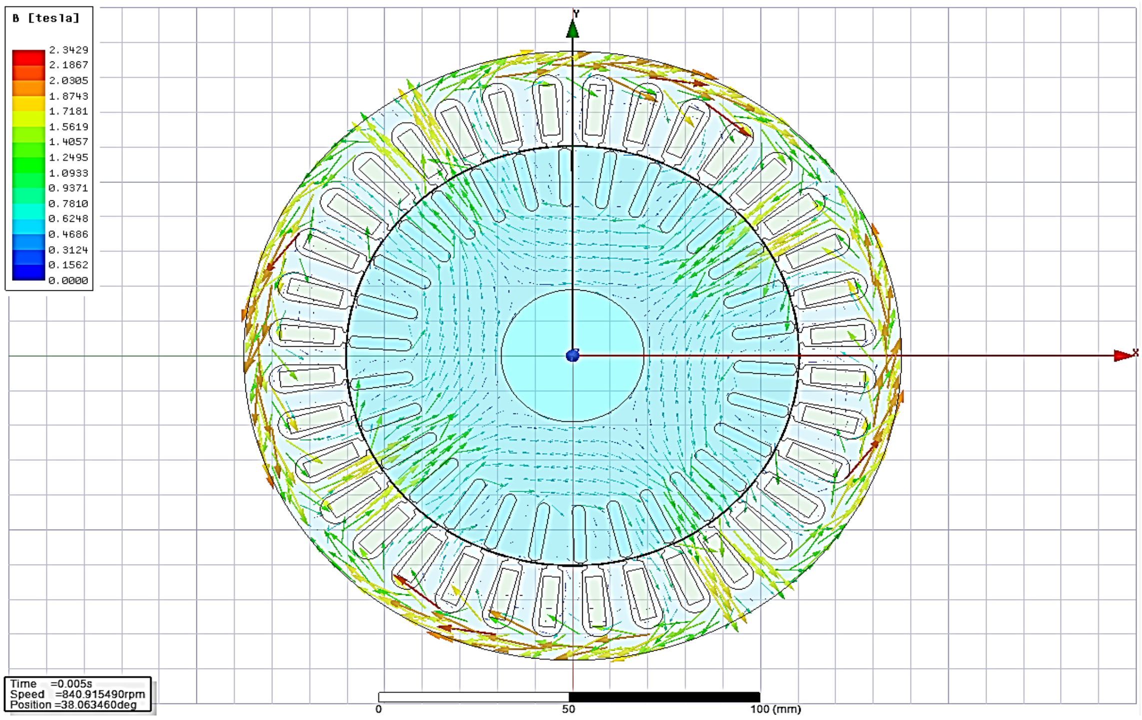

Figure-3: Magnetic field orientation

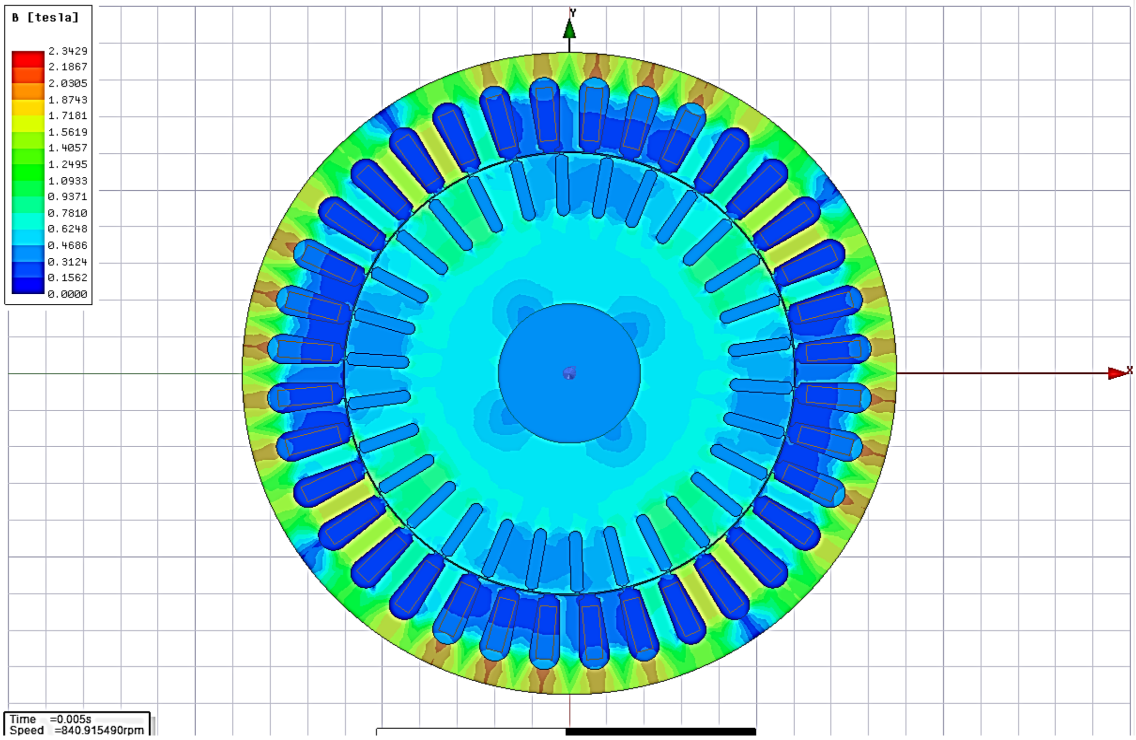

Figure-4: Flux density distribution plot

The flux density distribution of the modeled motor has been shown in Figure-4 which is obtained by the Finite Element Analysis. The maximum flux density is 2.3429 Tesla for 0.005s. At the poles, the flux density is higher.

III. Simplorer modeling of Control System

For the transient analysis, the squirrel cage induction motor is connected to a source. A three-phase Sinusoidal Pulse Width Modulation inverter is modeled using Simplorer software.

Sinusoidal Pulse Width Modulation

Sinusoidal PWM varies the width of each pulse in proportion to the amplitude of the sine wave evaluated at the pulse's center. Two types of switches are employed to supply gate signals to the switches in an inverter: unipolar and bipolar voltage switching. If the triangle carrier wave is in either the positive or negative polarity range of changes, the resulting SPWM wave only exists in the polar range; this sort of switching is known as the unipolar control mode. In contrast to the triangle carrier wave, which is in a continuous range between positive and negative polarity, the SPWM wave lies between positive and negative polarity changes; this switching is referred to as bipolar control.The inverter is powered by a constant dc voltage Vdc and has three phase output with two IGBTs in each. With SPWM control, the inverter's switches are governed by a comparison between a sinusoidal signal and a triangular signal [7,8]. The sinusoidal wave determines the fundamental frequency of the inverter output, whereas the triangle wave determines the switching frequency. Each transistor has a 180-degree conducting angle. Each of the six modes of operation functions for a duration of 60 degrees.

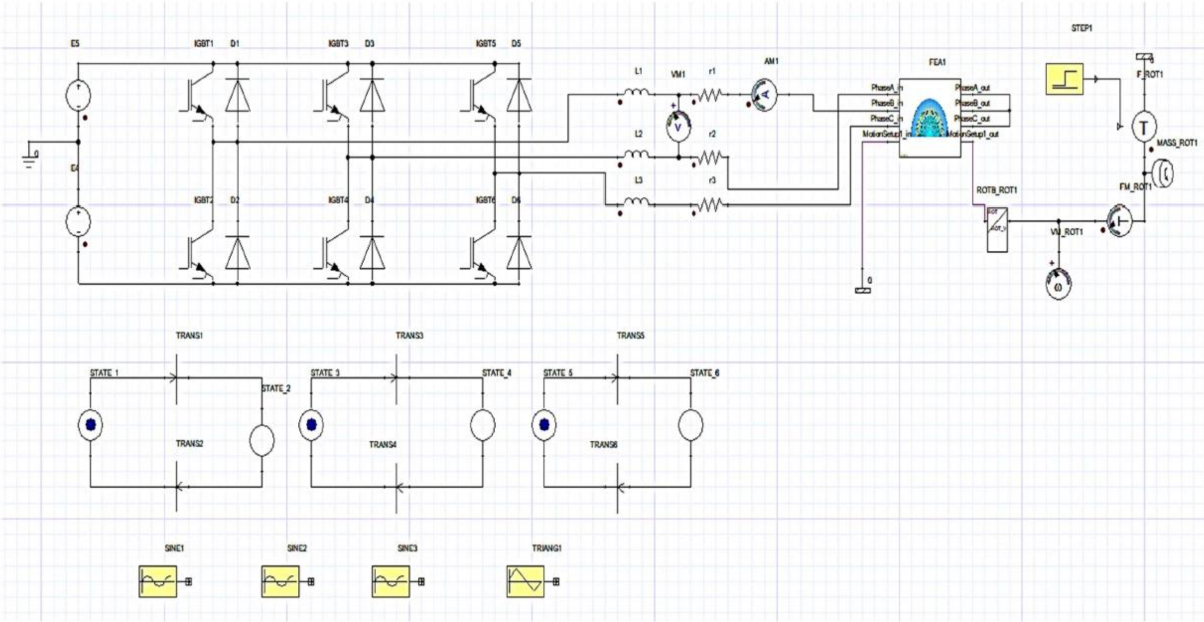

Figure 5: SPWM inverter connected to Squirrel Cage Induction Motor modeled in Simplorer

In figure-5 the SPWM inverter modeled in Simplorer is shown connected as an external source for the squirrel cage induction motor. Its performance is evaluated on parameters such as rotor speed and torque. At time t = 0.5 ms. the load increases from 1 Nm to 3 Nm as a step input is fed to the motor. It is observed that when the load increases the torque increases and the speed of the rotor decreases.

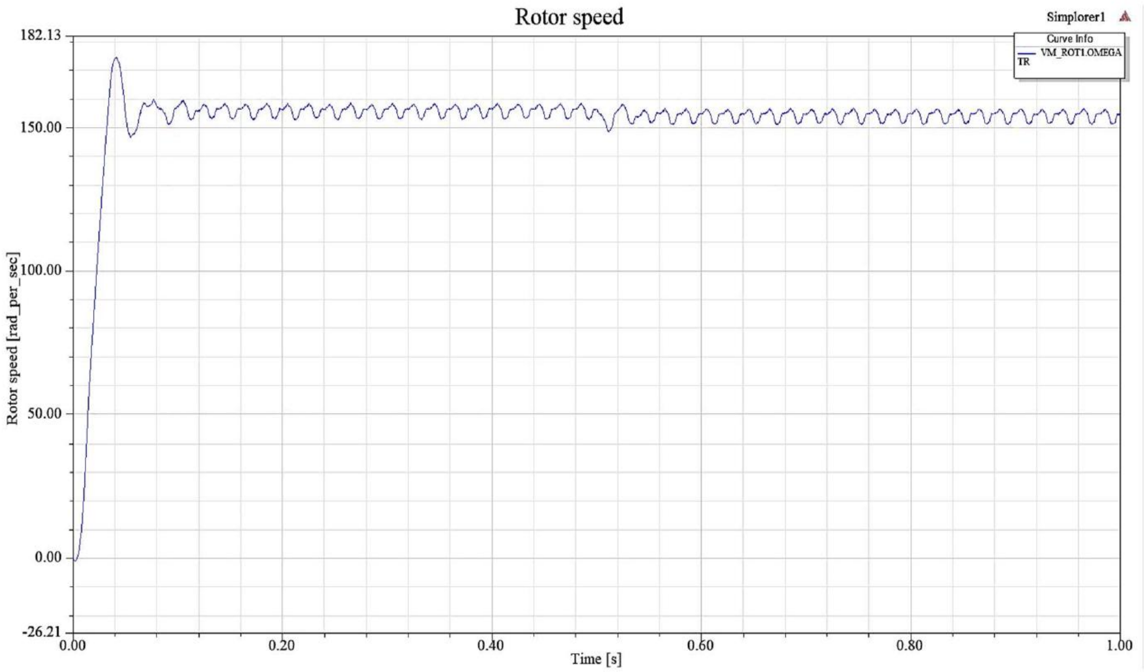

Figure-6: Speed vs Time Graph of Squirrel Cage Induction Motor fed by SPWM inverter source with sudden loading at t = 0.50 sec.

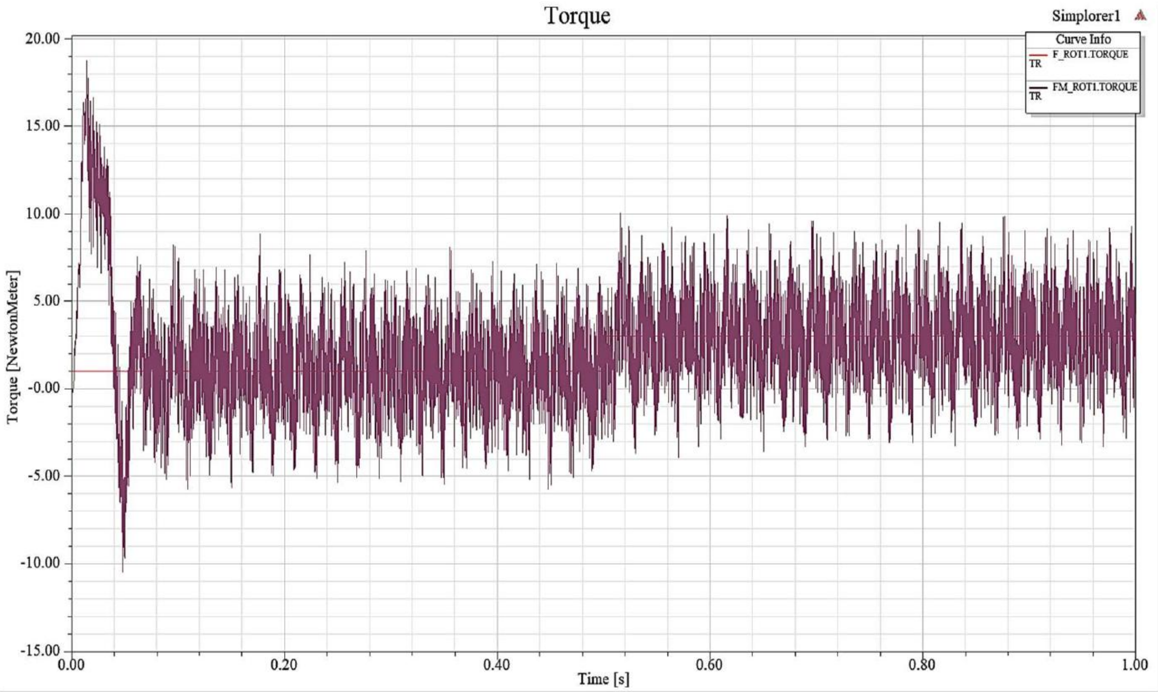

Figure-7: Torque vs Time Graph of Squirrel Cage Induction Motor fed by SPWM inverter source with sudden loading at t = 0.50 sec

IV. Speed Control using Voltage frequency control method.

The constant V/f control approach for induction motors is variable-speed control. In the V/f control approach, we constantly attempt to maintain a constant voltage to current ratio. To implement the voltage frequency control method a three-phase VSI and controller are used to control the speed of a three-phase IM. The frequency and amplitude frequency of VSI are varied to maintain a steady V/f ratio and preserve the motor's reference speed [9].

The figure-8 demonstrate the block diagram of controller simulated in Matlab simulink.

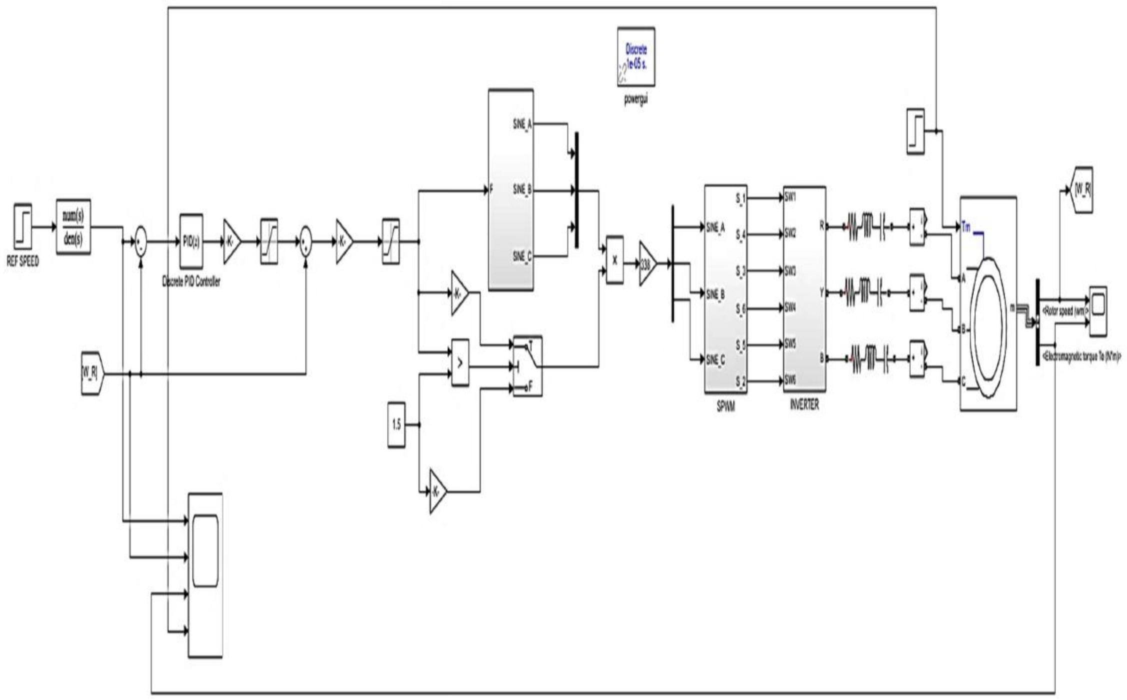

Figure-8:Voltage Frequency control feedback system implemented using Matlab Simulink.

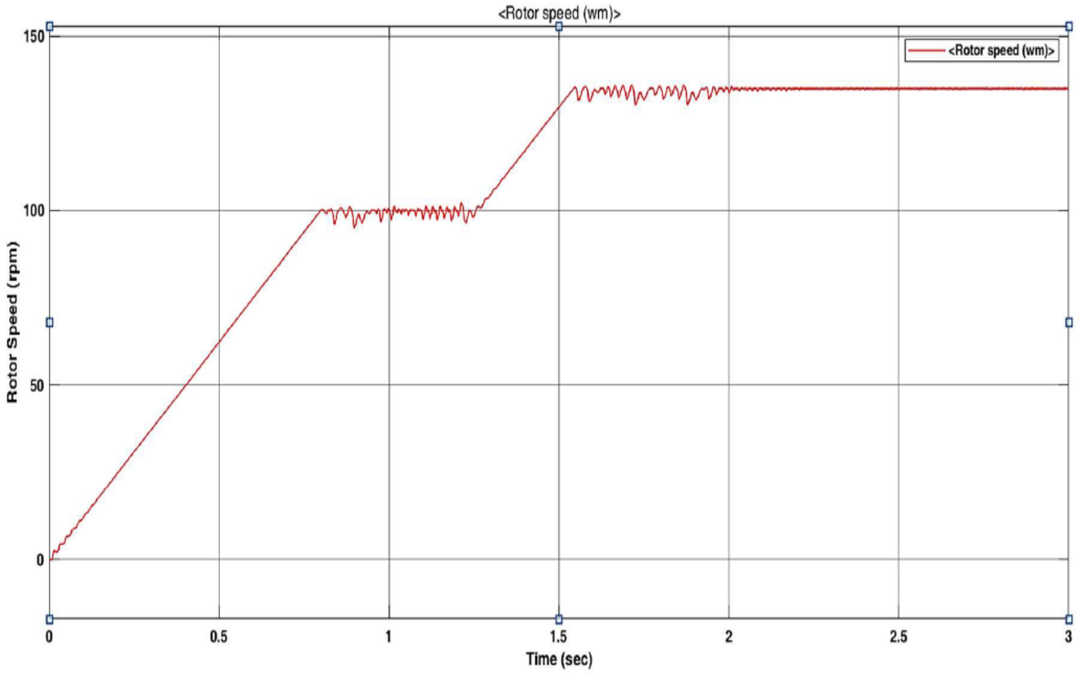

Figure-9: Rotor speed of the motor

In Figure-9 the rotor speed of the motor for the voltage frequency control feedback is shown when the motor is fed with an inverter. At time t =1.2 sec a rise in rotor speed is observed to 142 rpm from 100 rpm initially.

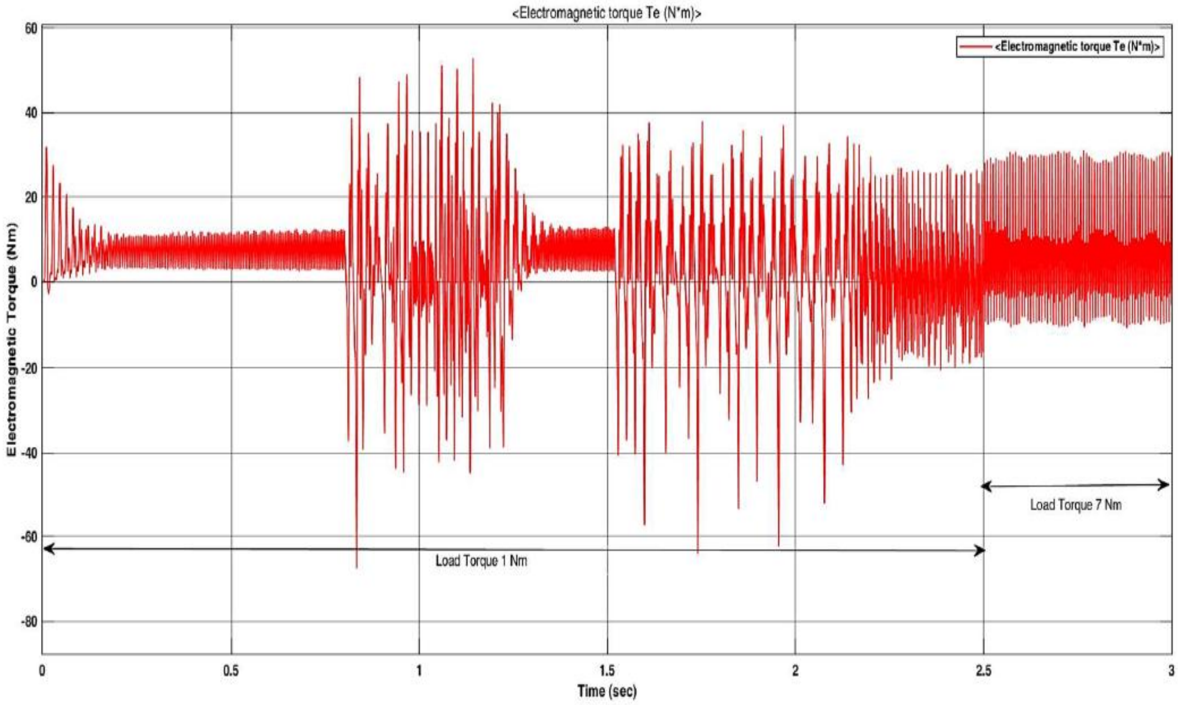

Figure-10: Electromagnetic torque of the motor

In Figure-10 electromagnetic torque of the motor when the motor is fed by an inverter with a voltage frequency control feedback system. At time t = 2.5 sec the load increases from 1 Nm to 7 Nm as a step input is fed to the motor. It is observed that when the load increases the electromagnetic torque increases

V. Conclusion:

The performance of the Squirrel Cage Induction Motor is analyzed in this paper using the finite element method. The motor is modelled using ANSYS Maxwell Software. The finite element method is used for the transient analysis of the simulated Squirrel cage induction motor in ANSYS Maxwell software for a better understanding of the magnetic field and flux pattern.A three-phase Sinusoidal Pulse Width Modulation inverter (SPWM inverter) is modeled for the source of the motor and simulated in AnsysSimplorer Software and dynamic analysis of the software has been examined. Speed control technique such as voltage frequency control has been implemented using Matlab Simulink. The performance of the motor has been analyzed on the parameters such as speed and electromagnetic torque for the sudden variation of the load is observed.

References

[1]. Ferkova, Z. (2014, May). Comparison of two-phase induction motor modeling in ANSYS Maxwell 2D and 3D program. In 2014 ELEKTRO (pp. 279-284). IEEE.

[2]. Mansour, Fady. (2020). Induction Motors: Construction, Principle of Operation, Power and Torque Calculations, Characteristics, and Speed Control. 10.13140/RG.2.2.15490.71360.

[3]. Ling, Z., Zhou, L., Guo, S., & Zhang, Y. (2014). Equivalent circuit parameters calculation of induction motor by finite element analysis. IEEE Transactions on Magnetics, 50(2), 833-836.

[4]. Liang, X., Ali, M. Z., & Zhang, H. (2019). Induction motors fault diagnosis using finite element method: a review. IEEE Transactions on Industry Applications, 56(2), 1205-1217.

[5]. R. Saxena, G. Banerji, A. Srivastava and H. Rawat, "Performance Analysis of Axially Laminated Anisotropic Synchronous Reluctance Motor", *7th InternationalConference on Electric Power Systems WSEAS*, 2007.

[6]. H. S. Rawat, A. Srivastava, "Comparison of Axially and Transversally Laminated Synchronous Reluctance Motors by Using FEM Based Analysis", in International Journal of Electrical Electronics and Computer Science Engineering, Volume 4, Issue 5 (October 2017)

[7]. Bharti, R., Kumar, M., & Prasad, B. M. (2019, March). V/f control of three-phase induction motor. In 2019 International Conference on Vision Towards Emerging Trends in Communication and Networking (ViTECoN) (pp. 1-4). IEEE.

[8]. Murdianto, F. D., Nansur, A. R., Hermawan, A. S. L., & Kurniawan, R. B. I. (2018, November). Performance Evaluation of Speed Controller Using Fuzzy Mamdani in Single Phase Induction Motor. In 2018 3rd International Conference on Information Technology, Information System and Electrical Engineering (ICITISEE) (pp. 412-417). IEEE.

[9]. Bose, U., Divya, K., Jyothi, V., & Sreejith, S. (2014, March). Performance analysis of four-switch three-phase inverter-fed induction motor drive. In 2014 Power and Energy Systems: Towards Sustainable Energy (pp. 1-6). IEEE.