www.ijaceeonline.com ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 4, Issue 3, March 2019, pp. 10–14

Simulation of Rotor Magnetic Field Based Vector Controlled Speed Control of Three Phase Induction Motor System Using MATLAB

Musuwathi Radhakrishnan Kaushik
UG Scholar, Department of Electrical and Electronics Engineering,
SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
Email: kaushikmr1999@gmail.com

Antony Ranjeev
UG Scholar, Department of Electrical and Electronics Engineering,
SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
Email: ranjeev280@gmail.com

Anand Aswin
UG Scholar, Department of Electrical and Electronics Engineering,
SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
Email: aswin97@gmail.com

Solaimalai Senthilmurugan
Assistant Professor (Sr. G), Department of Electrical and Electronics Engineering,
SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India
Email: sen.accet@gmail.com

Abstract: *The most efficient speed control technique of an induction motor is the vector control method. This paper mainly deals with simulation of rotor magnetic field-based vector-controlled system using MATLAB. The speed of the motor is controlled by varying the frequency. The variation in frequency is achieved by the inverter, with the help of vector control model. The available control technique such as variation in supply voltage, variation of number of poles has low efficiency and high maintenance cost. This efficiency can be improved by the vector controlled magnetic field. Since, the voltage is directly proportional to the frequency, the speed of the motor can not only be controlled by the frequency but also by maintaining the voltage-frequency ratio. The results show good performance, more efficiency which reduces the losses in the machine.*

Keyword: *Induction motor; Vector control; Rotor magnetic field; Variable frequency drive (VFD).*

1. INTRODUCTION

Induction motors are asynchronous AC motors. These induction motors are not dependent on the commutators [1]. Therefore, the induction motors are used in high power applications and also are mainly used in the heavy industries and machine tools [2]. The speed of the induction motors is directly proportional to the frequency [3]. The induction motors are thus simple, robust, reliable and of relatively lower cost [4]. Yet in the industrial processes which require variable speed, the induction motors have a setback, but such a drawback in the induction motor system can be easily solved by introducing the vector-controlled based model of the induction motor [5]. The vector-controlled system is nothing but the use of the advanced technology in electronics to control the induction motor known as the variable frequency drive (VFD) [6].

A variable frequency drive is a power electronic based system used to control the motor speed and torque by varying the input voltage and frequency supplied to the motor [7]. A variable frequency drive can also be called as an adjustable speed drive, Microdrive, inverter, AC drive and an adjustable frequency drive.

Cite this paper:

Musuwathi Radhakrishnan Kaushik, Antony Ranjeev, Anand Aswin, Solaimalai Senthilmurugan, “Simulation of rotor-magnetic field-based vector-controlled speed control of three phase induction motor system using MATLAB”, Vol. 4, No. 3, pp.10-14, March 2019.

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 4, Issue 3, March 2019, pp. 10–14

A variable frequency drive has many advantages:

- Elimination of expensive mechanical drive components
- Increased motor longevity
- Energy savings
- Reduced power line disturbances
- Reduced risk of motor during start and stopping periods.

Variable frequency drives control the speed of the motors by maintaining a constant voltage to frequency ratio. The variable frequency drives are used in numerous applications because of their less maintenance costs and increased life span [8]. The variable drives are used in traction systems (in India it is being used by the Delhi metro rail corporation). They are also used in modern lifts, escalators and pumping systems and in the energy efficient refrigerators [9]. The variable frequency drive not only controls the speed of the motor but also protects it from the overcurrent during the starting and stopping conditions [10].

2. VARIABLE FREQUENCY DRIVE OPERATION

A variable frequency drive operates with the help of a converter. The converter consists of six diodes, which allow the current flow only in one direction. The diode bridge is used in the converters to reduce the harmonics present in the circuit. There are six current pulses generated as each diode is opened and closed. This is the standard configuration of the variable frequency drive. The variable frequency drive consists of three parts- rectifier, filter and the switching section that uses the transistors or insulated gate bipolar transistors (IGBT) to invert the DC voltage back to AC voltage with the proper frequency.

The rectifier converts the AC into the DC. The filter circuit consists of some filters like capacitor, inductor or capacitor-inductor that removes any harmonics or ripples present in the circuit. The third is the inverter circuit which converts the DC voltage back to the AC voltage. The principle of the inverter is that it controls the DC voltage in such a manner that it receives a pulsating voltage which looks similar to the AC. In a variable frequency drive the voltage to frequency ratio is maintained. The most common method used for controlling the motor voltage is the pulse width modulation technique. In this technique the inverter switches are used to divide simulated output sine waveform into the series of narrow voltage pulses and modulate the width of these pulses.

2.1 Mathematical Model

Voltage equation in dq coordinate:

$$\vartheta_{ds} = R_s i_{ds} + p\varphi_{ds} - \omega_e \varphi_{qs}$$

$$\vartheta_{qs} = R_s i_{qs} + p\varphi_{qs} - \omega_e \varphi_{ds}$$

$$\vartheta_{dr} = R_r i_{dr} + p\varphi_{dr} - (\omega_e - \omega_r)\varphi_{qr}$$

$$\vartheta_{qr} = R_r i_{qr} + p\varphi_{qr} + (\omega_e - \omega_r)\varphi_{dr}$$

Here,
p is the d/dt operator.
R_s is the resistance of the stator windings.
R_r is the resistance of the rotor windings.
ω_e is the motor synchronous speed.
ω_r is the rotor speed.

To get a squirrel cage induction motor, the rotor is short circuit, which implies that $\vartheta_{dr} = \vartheta_{qr} = 0$.

Flux equation in dq coordinate:

$$\varphi_{qs} = L_s i_{qs} + L_m i_{qr}$$

$$\varphi_{ds} = L_s i_{ds} + L_m i_{dr}$$

$$\varphi_{qr} = L_r i_{qr} + L_m i_{qs}$$

$$\varphi_{dr} = L_r i_{dr} + L_m i_{ds}$$

L_m is the mutual inductance between the stator and the rotor equivalent windings.

L_s is the self-inductance of the equivalent 2-phase winding of the stator.

L_r is the self-inductance of the equivalent 2-phase winding of the rotor.

Torque equation in dq coordinate:

$$T_e = n_p L_m (i_{qs} i_{dr} - i_{ds} i_{qr})$$

When the two-phase synchronous rolling coordinate is oriented by the rotor flux $\varphi_{dr} = \varphi_r, \varphi_{qr} = 0$.

$$T_e = n_p L_m / L_r (i_{qs} \varphi_{dr})$$

Where, n_p is the motor's pole pair.

Motion equation:

Neglecting the viscous friction and the turn-round resilience in the transmission of the electrical drive system, the motion equation is

$$T_e = T_L + J/n_p (\frac{d\omega_r}{dt})$$

T_L is the load torque and J is the moment of inertia.

2.2 SIMULINK MODEL OF THE VECTOR CONTROL SYSTEM

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 4, Issue 3, March 2019, pp. 10–14

The vector-controlled system of the induction motor consists of the converter model and the inverter model. The torque is exerted on the load by the three-phase induction motor when it acts as a converter. The induction motor is modelled based on the above equations. The inverter model has the diode bridge circuit which converts the DC voltage back to AC voltage and gives the output waveform. The complete model of the three-phase induction is simulated by using the Pulse Width Modulation technique with the inverter circuit (Fig. 1).

Parameter	Value
Supply Voltage	440 volts
Supply Frequency	50Hz
Rotor Type	Squirrel-cage
Motor Rating	5 HP
Number of poles	4
Normal speed	1440rpm

TABLE I MOTOR RATINGS

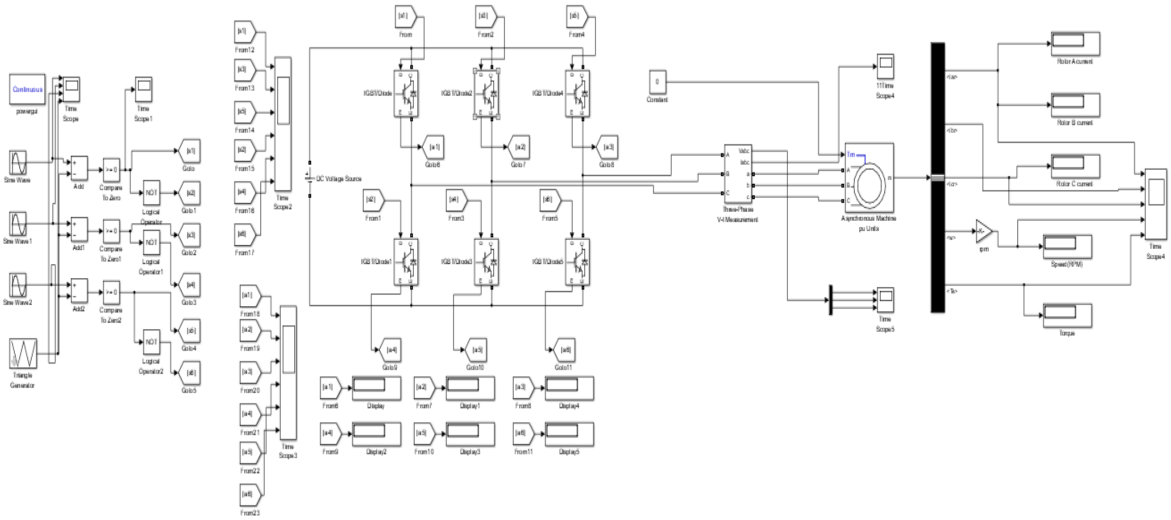

Figure 1 Simulink Model

3. SIMULINK RESULT AND ANALYSIS

Using the vector-controlled model, the various parameters of the rotor flux system can be seen from the simulation diagram and also with the help of the consequent graphs obtained from executing the simulation model.

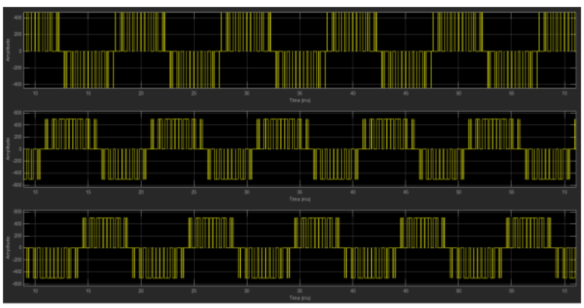

Figure 2 Voltage vs. Time

This scope shows the variation of the voltage of the Simulink model with respect to time. There are three input parameters in this case V_a, V_b and V_c whose output with respect to time is shown (Fig. 2).

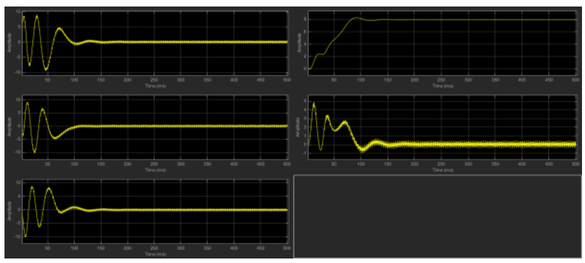

Figure 3 Current, Speed, Torque vs. Time

This scope shows the relation between the different values of current, speed and torque varying with respect to time. There are five input parameters. The first three graphs correspond to the first three inputs which are the currents I_a, I_b and I_c. The next graph shows the relation between the speed and time. The last graph shows the relation between the torque and time (Fig. 3).

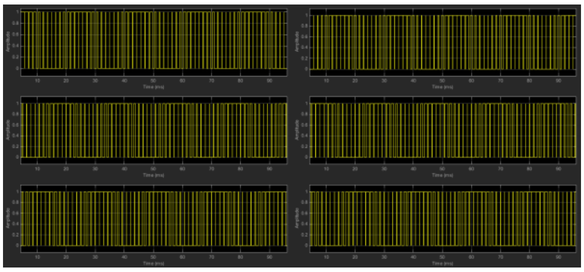

Figure 4 PWM graph

This scope shows the generation of the wave with pulse width modulation (Fig. 4).

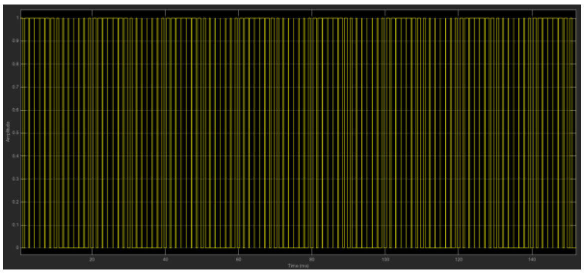

Figure 5 Sinusoidal PWM

This scope shows the sinusoidal pulse width modulation with time. It modulates the triangle wave by comparing with the ADD function and the logical NOT gate with only one input (Fig. 5).

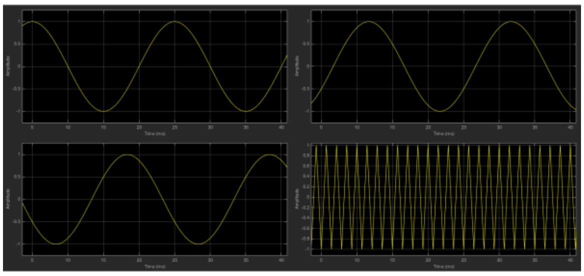

Figure 6 Sine wave and triangle wave generator

This scope shows the relation of the sine wave and triangle wave with respect to time. The first three graphs show the sine wave and time relation while the last graph shows the triangle wave- time relation (Fig. 6).

4. CONCLUSION

The rotor magnetic field-based vector-controlled is been studied in the paper. The frequency of the motor is being controlled by maintaining the voltage to frequency from the supply to the machine. Thus, the vector controlled magnetic field serves as an effective way in controlling the speed of the motors and also to maintain the longevity of the motor.

REFERENCES

[1] Laxmikant Vishwanath Bagale, and Dr.V.A. Deodhar-Kulkarni. (2013), "Modeling and Simulation of Variable frequency Speed Regulation Vector control System of Induction Motor based on Matlab" *International Journal of Engineering and Innovative Technology,* Vol. 2, Issue. 7, pp. 1-4.

[2] Ravi Khemchandani, Ashish Nipane Singh, and Hitesh Khanna. (2014), "Speed control of Three Phase Induction Motor by Variable Frequency Drive" *International Journal of Research,* Vol. 1, Issue. 11, pp. 1-2.

[3] Jatin A. Patel, and Asst. Prof. Hardik H. Raval. (2015), "Design of Sinusoidal Pulse Width Modulation Inverter" *International Journal For Technological Research In Engineering,* Vol. 2, Issue. 8, pp. 1-7.

[4] Vishnu Priya R., and Sithara K. (2015), "Adaptive Speed Control of Three phase Induction Machine using Variable Frequency Drive in Thermal Power Plant" *International Journal of Innovative Research in Science, Engineering and Technology,* Vol. 4, Issue. 6, pp. 1-6.

[5] Ashish B. Bala, and Prashant P. Jagtap. (2016), "Investigation in Induction Motor Starting and Speed Control with Variable Frequency Drive" *International Research Journal of Engineering and Technology(IRJET),* Vol. 3, Issue. 2, pp. 1-6.

[6] Dhammadip Wasnik, Hari Kumar Naidu, and Pratik Ghutke. (2017), "Speed Control of Induction Motor using Variable Frequency Drives and PLC" *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering,* Vol. 6, Issue. 6, pp. 1-5.

[7] Puja Talukder, Prashant Kumar Soori, and Benetta Aranjo (2012), "Speed Control of Induction Motor using Universal controller", *IEEE International Power Engineering and Optimization Conference,* pp. 1-4.

[8] Pabitra Kumar Behra, Manoj Kumar Behra, and Amit Kumar Sahoo (2014), "Speed Control of Induction Motor using Scalar Control Technique", *International Conference on Emergent Trends in Computing and Communication,* pp. 1-3.

[9] Vaibhav S Yendole, and Parag R. Jawale (2016), "Speed Control of Three Phase Induction Motor by Using V/F Method", *National Conference "CONVERGENCE 2016",* pp. 1-5.

[10] Dinesh Kumar (2017), "Performance Analysis of Three-Phase Induction Motor with AC Direct and VFD", *3rd International Conference on Communication Systems(ICCS),* pp. 1-11.

Authors Biography

M. R. Kaushik, is a UG Scholar. He is currently studying B. Tech. Electrical and Electronics Engineering in SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India. His research interests are electronic devices, electrical machines.

ISSN: 2456 - 3935
International Journal of Advances in Computer and Electronics Engineering
Volume 4, Issue 3, March 2019, pp. 10–14

Ranjeev, is UG Scholar. He is currently studying B. Tech. Electrical and Electronics Engineering in SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India. His research interests are electronic devices, electrical machines.

Aswin, is a UG Scholar. He is currently studying B. Tech. Electrical and Electronics Engineering in SRM Institute of Science and Technology, Kattankulathur, Tamil Nadu, India.. His research interests are electronic devices, electrical machines, power systems.

S. Senthilmurugan, received his diploma in Electrical and Electronics from Alagappa Polytechnic college Karaikudi .DOTE, Chennai, India in 2004. He received his B.E. degree in Electrical and Electronics Engineering from Alagapaa Chettiar College of Engineering and Technology, Karaikudi (Anna University), India in 2007.He received his M.E. degree in Control and Instrumentation Engineering from Anna University, India in 2010. He is currently pursuing Ph.D. in EEE from SRM Institute of Science of Technology, Kattankulathur, India. He is also an Assistant Professor in the Department of Electrical and Electronics Engineering in SRM Institute of Science and Technology, Kattankulathur, India. His research interests are Control Systems, Smart Grid, Virtual Instrumentation, Sensor and Networks. He has also participated in many National and International Conferences and also published papers in many National and International Journals.

Cite this paper:

Musuwathi Radhakrishnan Kaushik, Antony Ranjeev, Anand Aswin, Solaimalai Senthilmurugan, "Simulation of rotor-magnetic field-based vector-controlled speed control of three phase induction motor system using MATLAB", Vol. 4, No. 3, pp.10-14, March 2019.