ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

IJESRT

INTERNATIONAL JOURNAL OF ENGINEERING SCIENCES & RESEARCH TECHNOLOGY

Speed Control and THD for Three Phase Induction Motor Using Simulink

Priya Janak [1], Ranvir Kaur [2]
[*1] Student, M.tech EE Department, BBSBEC, Fatehgarh Sahib, Punjab, India
[2] EE Department , BBSBEC , Fatehgarh Sahib , Punjab, India

Abstract

Sinusoidal Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Be it domestic application or industry, motion control is required everywhere. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Recent developments in speed control methods of the induction motor have led to their large scale use in almost all electrical drives. Variable voltage and frequency supply to ac drives is invariably obtained from a three-phase voltage source inverter, which is carrier-based sinusoidal PWM. Simulink is utilized with MATLAB to get a reliable and flexible simulation. PWM technique is proven to be an effective way of controlling speed of induction motor. In ac motor drives, SPWM inverters make it possible to control both frequency and magnitude of the voltage and current applied to a motor. As a result, PWM inverter-powered motor drives are more variable and offer in a wide range better efficiency and higher performance when compared to fixed frequency motor drives. Three phase voltage-fed PWM inverters are recently showing growing popularity for multi-megawatt industrial drive applications. Simulation results are obtained using MATLAB/Simulink environment for effectiveness of the study.

Keyword: ASD(Adjustable speed drive) MATLAB, SPWM , MOSFET, Induction Motor Drive..

Introduction

Three phase induction motors are most widely used motors for any industrial control and automation. It is often required to control the output voltage of inverter for the constant voltage/frequency (V/F) control of an induction motor. PWM (Pulse Width Modulation) based firing of inverter provides the best constant V/F control of an induction motor. Amongst the various PWM techniques, the sinusoidal PWM is good enough and most popular. Induction Motors are often termed the "Workhorse of the Industry". Be it domestic application or industry, motion control is required everywhere. The systems that are employed for this purpose are called drives. Such a system, if makes use of electric motors is known as an electrical drive. An adjustable speed drive (ASD) is a device used to provide continuous range process speed control (as compared to discrete speed control as in gearboxes or multi-speed motors). An ASD is capable of adjusting both speed and torque from an induction or synchronous motor. An electric ASD is an electrical system used to control motor speed. ASDs may be referred to by a variety of names, such as variable speed drives, adjustable frequency drives or variable frequency inverters. The latter two terms will only be used to refer to certain AC systems, as is often the practice, although some DC drives are also based on the principle of adjustable frequency.

Speed control techniques of induction motors can be broadly classified into two types – scalar control and vector control. Scalar control involves controlling the magnitude of voltage or frequency of the induction motor. Three phase induction motors are reliable, robust, and highly durable and of course need less maintenance.. Many advanced semiconductor devices are available today in power electronics market like BJT, MOSFET, IGBT, etc. for control of Electric Drives .In our work MOSFET (metal oxide semiconductor field-effect transistor) is used as a semiconductor device

Speed control techniques

When power is supplied to an induction motor with specified frequency and voltage, it runs at its rated speed. There are various methods for the speed control of an Induction Motor and are briefly explained:

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

.Voltage Control: As the voltage decreases, the torque decreases (the torque developed in an induction motor is proportional to the square of the terminal voltage). Practically this is confined to 80-100% control. Unfortunately this is not an effective control.

• **Frequency Control:** This is by far the most efficient way to control the speed. However, one has to make sure that the machine does not saturate. Since the flux is proportional to *V/f*, this control has to assure that the magnitude of the voltage is proportional to the speed. Power electronic circuits are best suited for this kind of control.

• **Vector Control:** The magnetizing current always lags (inductive) the voltage by 90° and the torque producing current is always in phase with the voltage. In vector control the magnetizing current (*Id*) is controlled in one control loop and the torque producing current (*Iq*) in another. The two vectors *Id* and *Iq* which are always 90° apart, are then added (vector sum) and sent to the modulator, which turns the vector information into a rotating PWM modulated 3-phase system with the correct frequency and voltage. This will reduce torque pulsation and a robust control with fast dynamic response for the induction motor is achieved.

• **Changing Stator Poles:** For a stator which has several independent windings, one can connect them is series for starting, essentially building N*poles. The speed of machine will be reduced by the same factor. As the machine speed increases, one can switch the stator connection to a parallel connection, hence reducing the amount of poles and hence accelerating the machine. This method is simple, but can really accommodate only 2 speeds.

• **Rotor Resistance:** For the starting, one can insert a variable resistance in the rotor (slip rings) and hence cause the developed torque to vary, hence control the speed.

• **Doubly Fed Motor** A special application can be to inject a current in the rotor. Hence the air gap flux will depend upon the difference of frequency between stator and rotor currents, and therefore the speed can be varied by varying the rotor frequency.

• **Kramer Circuit**

With the method of variable resistor in the rotor circuit, a lot of power is dissipated in this additional resistor. With the Kramer method, one takes the rotor windings, and feed a 3-phase rectifier. This DC voltage is then fed through an inverter back to the source. Here only the component losses are accounted for. The excess power not transformed in mechanical torque will be fed back to the source.

Sinusoidal pulse width modulation

The PWM technique generates rectangular wave forms with modulated width in order to obtain variable voltage and frequency to supply an induction motor. It applies to motor control, as it is a way of delivering energy through a succession of pulses rather than a continuously varying (analog) signal. By increasing or decreasing pulse width, the controller regulates energy flow to the motor shaft.

This is most popular method of controlling the output voltage and this method is termed as pulse width modulation technique. PWM is an internal control method and it gives better result than any external control methods. There are number of PWM methods for variable frequency voltage-sourced inverters. A suitable PWM technique is employed in order to obtain the required output voltage in the line side of the inverter. In this technique a high frequency triangular carrier wave is compared with the sinusoidal reference wave determines the switching instant as shown in figure 1

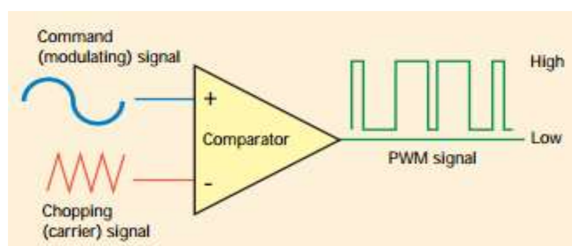


Figure 1

When the modulating signal is a sinusoidal signal of amplitude Am, and the amplitude of triangular carrier wave is Ac, then the ratio m=Am/Ac, is known as the modulation index. It is to be noted that by controlling the modulation index one can control the amplitude of applied output voltage. For wide variation in drive speed, frequency of the applied AC voltage needs to be varied over a wide range. The applied voltage also needs to be varying almost linearly with the frequency. The harmonic content in the output of the inverter can be reduced by employing pulse width modulation (PWM). Sinusoidal PWM

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

(SPWM) is affecting in reducing lower order harmonics while varying the output voltage and gone through many revisions and it has a history of three decades. Figure 2 shows the three phase PWM signal.

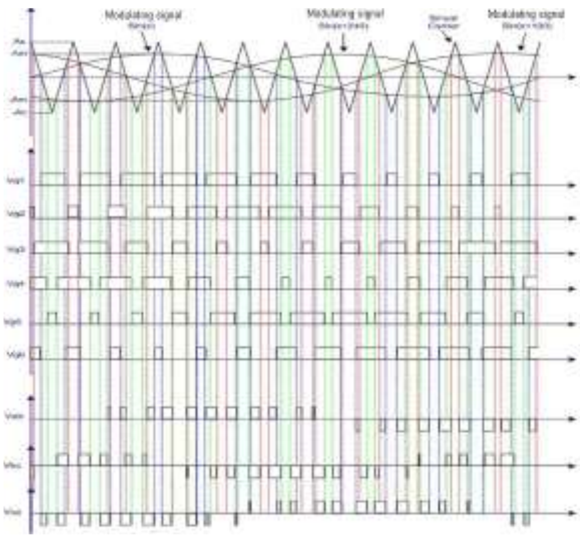


Figure 2

$$\text{Amplitude Modulation, } M_a = \frac{A_s}{A_c}$$

$$\text{Frequency Modulation, } M_f = \frac{f_s}{f_c}$$

Percentage of individual harmonics is calculated by the eqn.

$$\%\frac{rms(n)}{V_{DC}} = 100\left(\frac{4}{n\pi\sqrt{2}}\sum_{p=1}^{M_f}(-1)^{i+1}\cos n\alpha_i\right)$$

where, n= nth harmonics.

Percentage of total RMS of the output, when M_f is even

$$\%\text{Vn} = 100 \times \sqrt{\frac{2}{\pi}\sum_{p=1}^{\frac{Mf}{2}}(\alpha_{2p} - \alpha_{2p-1})}$$

When M_f is odd

$$\%\text{Vn} = 100 \times \sqrt{\left[\frac{2}{\pi}\sum_{p=1}^{\frac{Mf-1}{2}}(\alpha_{2p} - \alpha_{2p-1}) + \frac{\pi}{2} - \alpha_{M_f}\right]}$$

Total harmonics distortion (THD) is given by,

$$THD = \frac{V_h}{V_1}$$

$$\text{Where, } V_h = \sqrt{\sum_{n=2,3,..}^{\infty} V_n^{\,2}} \text{ or, } V_h = \sqrt{V_{out}^{\,2} - V_1^{\,2}}$$

And, V1 = Fundamental component

Merits of pwm inverters over conventional control

Sinusoidal Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. . Be it domestic application or industry, motion control is required everywhere. Since motor speed depends on the speed of the rotating field, speed control can be affected by changing the frequency of the AC power supplied to the motor.
As in most machines the induction motor is designed to work with the flux density just below the saturation point over most of its operating
range to achieve optimum efficiency.
The flux density **B** is given by:

$$B = k_2 \frac{V}{f}$$

Where **V** is the applied voltage, ***f*** is the supply frequency and $\mathbf{k_2}$ is a constant depending on the shape and configuration of the stator poles. For speed control, the supply voltage must increase in step with the frequency which is done by PWM technique otherwise the flux in the machine will deviate from the desired optimum operating point.

Practical motor controllers based on frequency control must therefore have a means of simultaneously controlling the motor supply voltage. This is known as Volts/Hertz control. A motor requires very high currents to operate. Being able to vary their speed with PWM increases the efficiency of the total system by quite a bit. PWM is more effective at controlling motor speeds at low r.p.m than linear methods. Increased noise immunity is yet another benefit of choosing

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

PWM over analog control, so by using pulse width modulation technique the width of the pulse can be changed so that the frequency and timing of the signal can be changed. And the power content of the signal can be maintained.

- Direct on line starting of induction motors cause current peaks that can harm the motor, PWM frequency inverters provide softer starting, resulting in cost reduction with regard to maintenance.
- Industrial systems are often oversized due to an expectation of future production increase. PWM inverters allow the proper regulation of the operational speed according to the equipments available and the production needs.
- The power system global efficiency depends not only on the motor, but also on the control. PWM inverters are high efficiency apparatuses. Induction motors also present high efficiency levels, reaching up to 95% or even more in larger machines operating at
Rated conditions. When speed variation is required, the output changes in an optimized Way, directly affecting the energy consumption and leading to high efficiency levels performed by the system.
- PWM frequency inverters suit both variable and constant torque loads. With variable torque loads (low torque demand at low speeds) the motor voltage is decreased to compensate for the efficiency reduction normally resultant from load reduction. With constant torque (or constant power) loads the system efficiency improvement comes from the feasibility of continuous adjustment of speed, with no need to use multiple motors or mechanical variable speed systems (such as pulleys and gears), which introduce additional losses.

Simulation of drive using pwm and results

Here we developed a DC to AC inverter fed to induction motor in Simulink / Matlab with a three phase PWM inverter controlling both the frequency and magnitude of the voltage output. Many advanced semiconductor devices are available today in power electronics market like BJT, MOSFET, IGBT, etc. for control of Electric Drives .In our work MOSFET (metal oxide semiconductor field-effect transistor) is used as a semiconductor device For generation of PWM pulses the technique which is used is comparing sinusoidal control voltage (at the desired output frequency and proportional to the output voltage magnitude) with a triangular waveform at a selected switching frequency. The harmonics in the output voltage appears as sidebands of the switching frequency and its multiples in a PWM inverter. Therefore a high switching frequency results in an essentially sinusoidal current (plus a superimposed small ripple at a high frequency) in the motor. A 3-phase squirrel cage motor rated 5.4 HP, 220 V, 50 Hz, 1430 rpm is fed by a 3-phase MOSFET inverter connected to a DC voltage source of 400 V. The Inverter is modeled using the "Universal Bridge" block and the motor by the "Asynchronous Machine" block. The load torque applied to the machine's shaft is constant i.e 1. Observe that the rotor and stator currents are quite noisy. The noise introduced by the PWM inverter is also observed in the electromagnetic torque waveform Te. However, the motor's inertia prevents this noise from appearing in the motor's speed waveform.

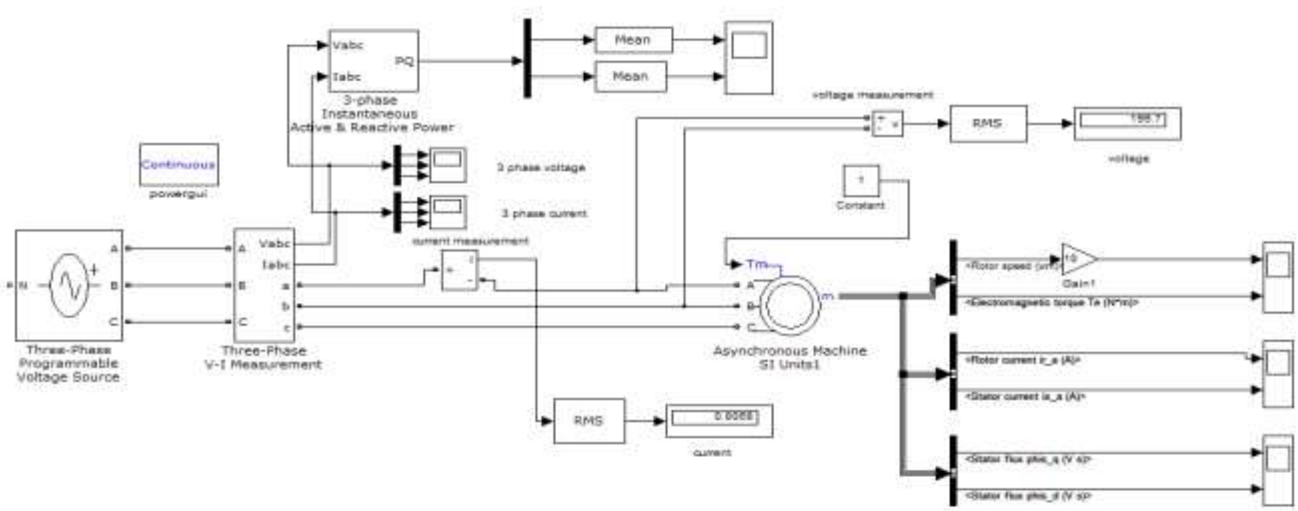


Figure 3 Simulink Model (without using three phase PWM fed inverter)

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Simulation Results

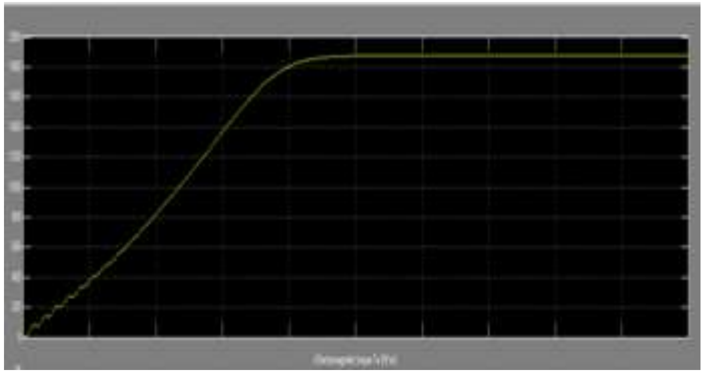


Figure 4: Speed v/s time

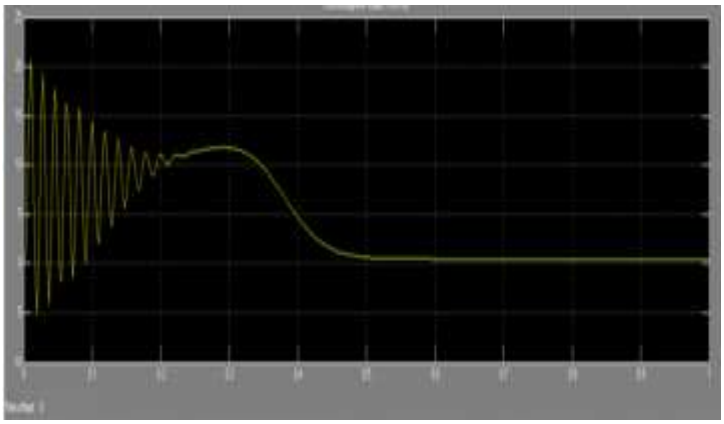


Figure 5: Electromagnetic torque v/s time

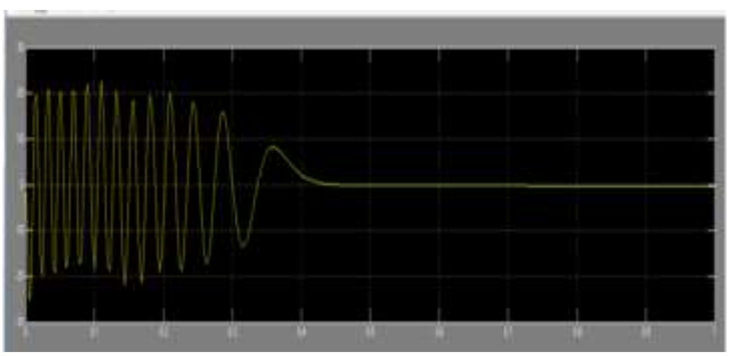
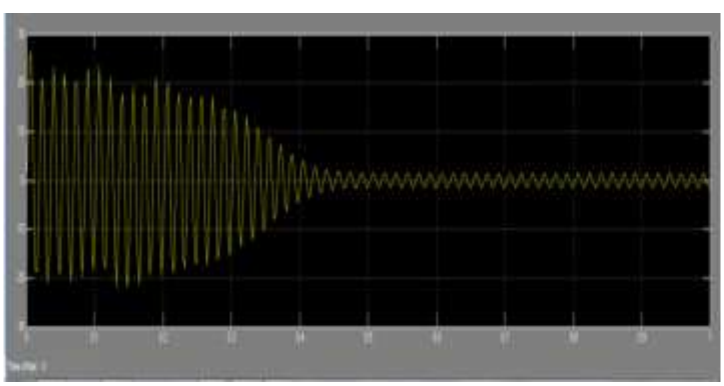


Figure 6 :Rotor current v/s time



ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Figure 7: Stator current v/s time

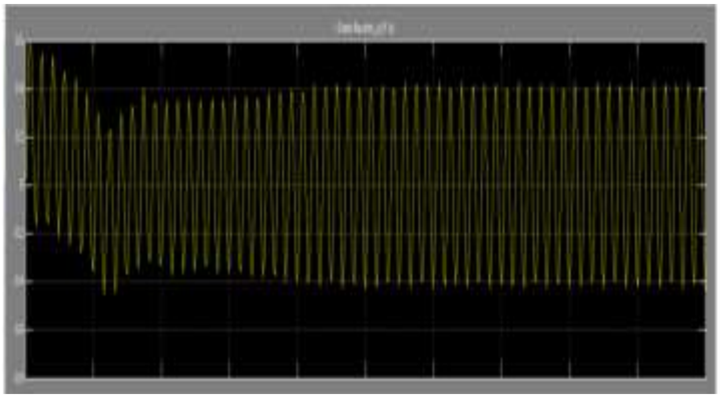


Figure 8 Stator fluxq v/s time

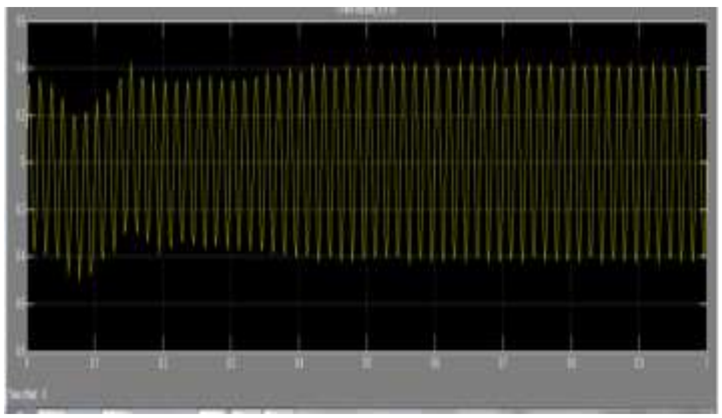


Figure 9 Stator flux$_d$ v/s time

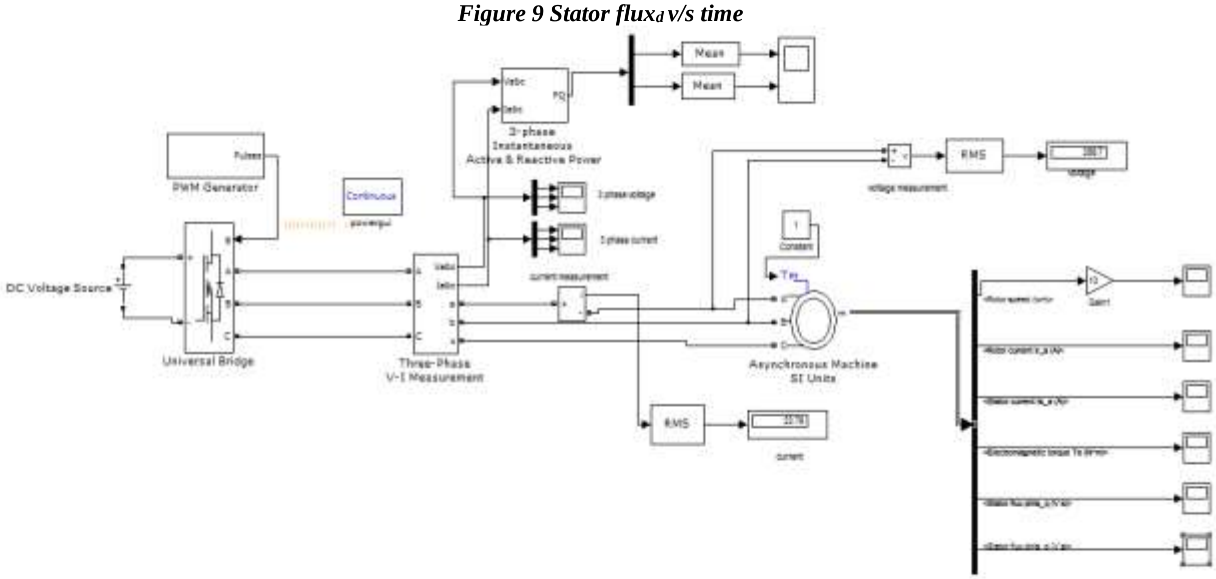


Figure 10 Simulink Model (PWM fed three phase inverter)

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

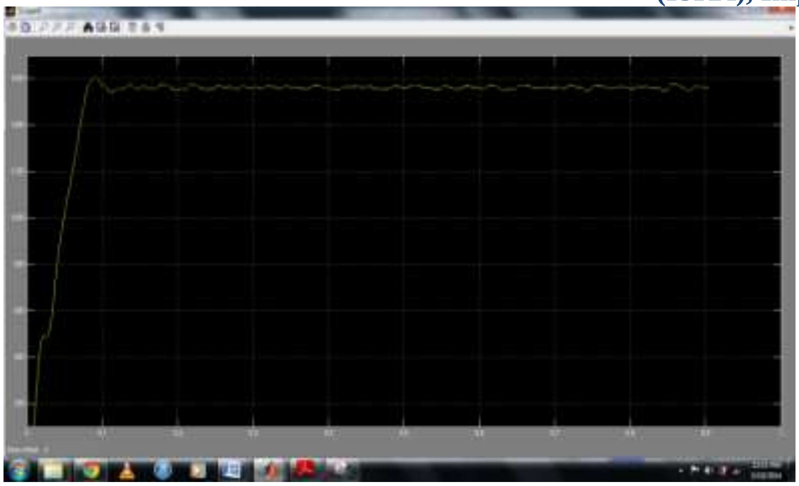


Figure 11: Motor speed v/s time

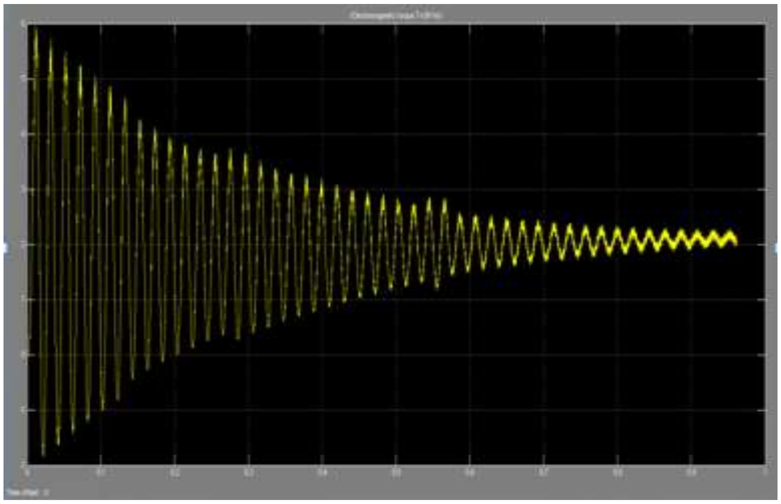


Figure 12: Electromagnetic torque v/s time

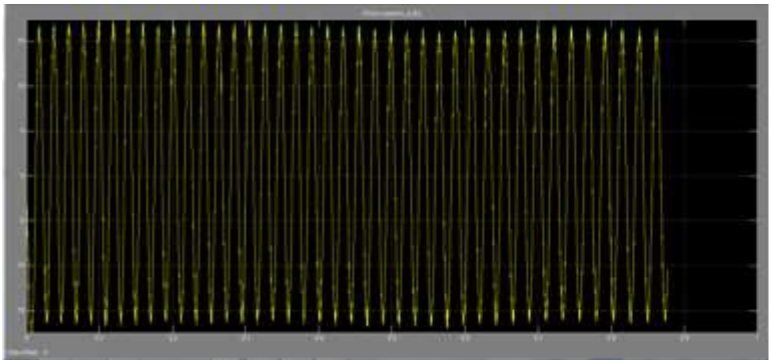


Figure 13: Rotor current v/s time

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

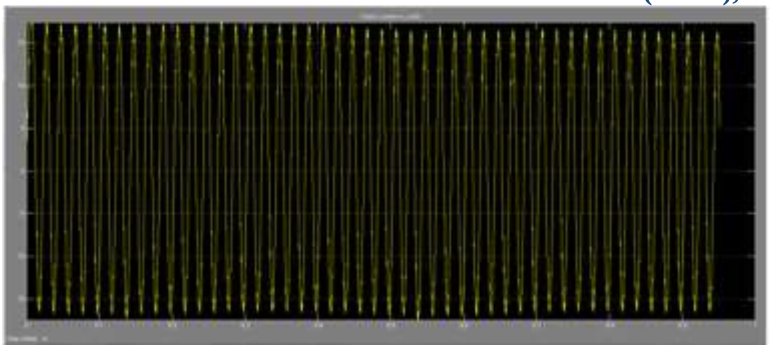


Figure 14: Stator current v/s time

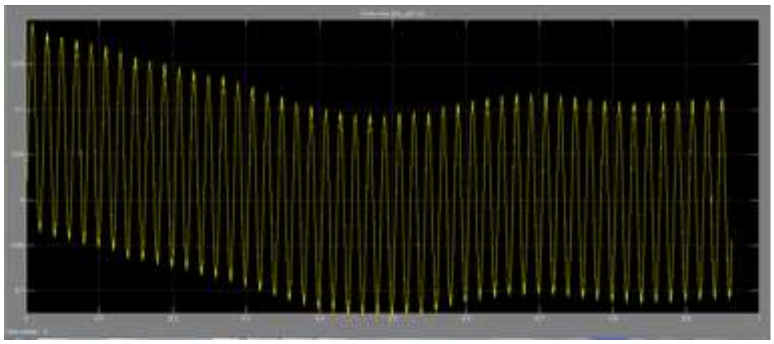


Figure 15: Stator flux$_q$ v/s time

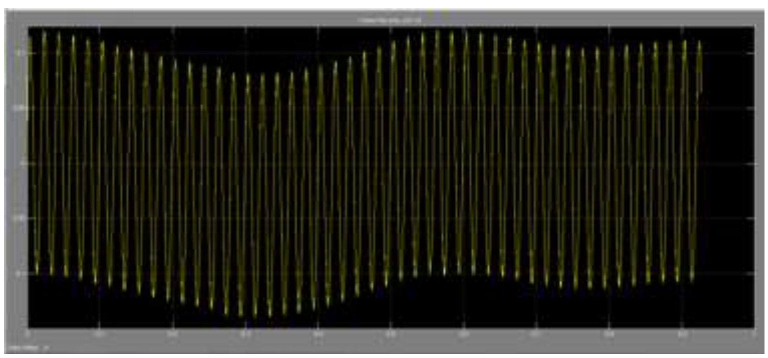


Figure 16 Stator flux$_d$ v/s time

Table 1: Modulation Index and its effects on THD of current and voltage

MODULATION INDEX	THD OF CURRENT (%)	THD OF VOLTAGE (%)
0.2	0.04518	2.522
0.4	0.0402	1.637
0.6	0.0329	1.208
0.8	0.0258	0.9185
1	0.0167	0.6688

ISSN: 2277-9655
Scientific Journal Impact Factor: 3.449
(ISRA), Impact Factor: 1.852

Here simulation and analysis of PWM inverter fed Induction motor drive is carried out. Firstly we have simulate three phase induction motor with simple a.c supply and observe different parameters. Then secondly we have simulated the PWM fed induction motor and obtain the THD of phase current and voltage at different modulation in

Conclusion

The main aim of this paper was to reduce THD of phase currents and voltages by varying the carrier frequency of carrier wave i.e. by varying the modulation index between 0.1to1.0 and through this paper we have fulfilled our aim to great extent. Varying the modulation index to minimize the total harmonic distortion is only possible when the three phase squirrel cage induction motor is fed through PWM inverter in which

Voltage and frequency to the motor can be varied. It has been clearly shown through results that by varying modulation index from low to high value we can minimize the THD of phase currents and voltage and enhance the performance of the motor when motor is supplied with PWM inverter. The variation in modulation index allows proper speed regulation according to the requirement of induction motor drive and also the proper optimization of the output.

References

1. *"Control of VSI using spwm strategy for adjustable speed motors." 14th International Research/Expert Conference "Trends in the Development of Machinery and Associated Technology" TMT 2010, Mediterranean Cruise, 11- 18 September 2010.*
2. *"Simulation and comparison of spwm and svpwm control for three-phase RL load." IJREAS Volume 2, Issue 2 (February 2012) ISSN: 2249-3905.*
3. *Pankaj H Zope, Pravin G.Bhangale, Prashant Sonare ,S. R.Suralkar* **"***Design and Implementation of carrier based Sinusoidal PWM Inverter." International journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering. Vol. 1***,** *Issue 4, October 2012.*
4. *"Performance of Sinusoidal Pulse Width Modulation based Three Phase Inverter." International Conference on Emerging Frontiers in Technology for Rural Area (EFITRA) 2012 Proceedings published in International Journal of Computer Applications® (IJCA).*
5. *"Modeling and Simulation of Modified Sine PWM VSI Fed Induction Motor Drive." International journal of Electrical Engineering & Technology , Volume 3, Issue 2, July – September 2012.*
6. *"Carrier Pulse width Modulation for Three Phase Multilevel Inverter to Minimize THD and enhance the Performance of Induction motor." National Conference on Innovative Paradigms in Engineering & Technology (NCIPET- 2012) Proceedings published by International Journal of Computer Applications ® (IJCA)*
7. *Khaleed E Addoweesh, et.al, " Induction Motor Speed Control Using a Microprocessor-Based PWM Inverter", IEEE Transactions on Industrial Electronics, Vol 36, No 4, Nov 1989, pp 516-522.*
8. *Prasad N Enjeti, et.al, "A new PWM Speed Control System for High Performance AC Motor Drives", IEEE Transactions on Industrial Electronics. Vol 37, No 2, April 1990, pp. 143-151.*
9. *I. Maswood, M.A. Rahman, "Performance of 3-Phase Induction Motor FED from Improved Delta PWM Voltage Source Inverter", Power Engineering Society Winter Meeting, 2000. IEEE, pp. 381-386.*
10. *Stephen J. Chapman, "Electric Machinery Fundamentals", McGraw Hill International Edition, 4th Edition, 2005.*
11. *Shao Limin, et all, "Study on Real-Time Test Bench of Speed Governor using Matlab/xPC target", The eight international conference on electronic Measurement and Instruments, 2007, pp 27-31.*
12. *Quiñones-Reyes P, et all, "Reconfigurable Fuzzy Takagi Sugeno Networked Control using EDF Scheduling in xPC Target", Proceedings of the Electronics, Robotics and Automotive Mechanics Conference (CERMA'06), 2006.*
13. *Jens Bathelt, Anders Jonsson, "How to Implement the Virtual Machine Concept Using xPC Target", Nordic MATLAB Conference 2003*
14. *Staff of Lab-Volt (Quebec) Ltd, "Familiarization with the Lab-Volt Power Electronics Equipment*", Lab-Volt Ltd., 2nd Edition, 2001.721