MODELING AND SIMULATION OF MODIFIED SINE PWM VSI FED INDUCTION MOTOR DRIVE

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ABSTRACT

The modeling and simulation of modified sine PWM VSI fed three phase induction motor drive are presented. The PWM VSI fed Induction Motor drive system is modeled using the blocks of simulink. Single phase AC is converted into DC using rectifier. DC is converted into variable frequency, variable voltage AC using inverter. The speed is controlled by varying the frequency. Detailed modeling, simulation and implementation of the drive system are given in this paper. Speed response and harmonic analysis are also presented. This drive has advantages like reduced hardware and increased efficiency. The simulation results are compared with the theoretical results.

Keywords: Induction motor, Mat lab, VSI, Sine PWM.

I. INTRODUCTION

Three phase induction motors are the most widely used motors for industrial control and automation. Hence they are often called the workhorse of the motion industries. They are robust, reliable, less maintenance and high durability. When power is supplied to an induction motor with recommended specified voltage and frequency, it runs at its rated speed. However many applications need variable speed variations for improve the quality of the product. By the development of power electronic devices and control systems have to mature to allow these components to be used for speed control of AC and DC motors control in place of conventional
methods. This type of control not only controls the speed of AC and DC motors, but can improve the motor’s dynamic and steady state characteristics.

Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Three phase voltage-fed PWM inverters are recently showing growing popularity for multi-megawatt industrial drive applications. The main reasons for this popularity are easy sharing of large voltage between the series devices and the improvement of the harmonic quality. Variable voltage and frequency supply to AC drives is invariably obtained from a three-phase voltage source inverter. A number of Pulse width modulation (PWM) schemes are used to obtain variable voltage and frequency supply. The most widely used PWM schemes for three-phase voltage source inverters are carrier-based sinusoidal PWM and space vector PWM (SVPWM).

II. MODIFIED SINE PULSE WIDTH MODULATION

For wide variation in drive speed, the frequency of the applied AC voltage needs to be varied over a wide range. The applied voltage also needs to vary almost linearly with the frequency. The switches of the PWM inverters are turned on and off at significant higher frequencies than the fundamental frequency of the output voltage waveform. The harmonic content in the output of the inverter can be reduced by employing pulse-width modulation (PWM). The PWM techniques and strategies have been the subject of intensive research since 1970’s were to fabricate a sinusoidal AC output voltage. The classical Sinusoidal pulse-width modulation (SPWM) is the basis of state-of-the-art PWM techniques. Sinusoidal PWM (SPWM) is effective in reducing lower order harmonics while varying the output voltage and gone through many revisions and it has a history of three decades.

In Sine PWM Inverter, the width of the voltage pulses over the output cycle, vary in a sinusoidal manner. The scheme, in its simplified form, involves comparison of a high frequency triangular carrier voltage with a sinusoidal modulating signal that represents the desired fundamental component of the pole voltage waveform. The peak magnitude of the modulating signal should remain limited to the peak magnitude of the carrier signal. The comparator output is then used to control the high side and low side switches of the particular pole. Some of the following constraints for slow varying sinusoidal voltage be considered as the modulating signal are 1) The peak magnitude of the sinusoidal signal is less than or equal to the peak magnitude of the carrier signal. This ensures that the instantaneous magnitude of the modulating signal never exceeds the peak magnitude of the carrier signal. 2) The frequency of the modulating signal is several orders lower than the frequency of the carrier signal. A typical figure will be 50 Hz for the modulating signal and 20 KHZ for the carrier signal. Under such high frequency ratio’s the magnitude of the modulating signal will be virtually constant over any particular carrier signal time period. 3) A three phase Sine-PWM inverter would require a balanced set of three
sinusoidal modulating signals along with a triangular carrier signal of high frequency. For a variable voltage-variable frequency (VVVF) type inverter, a typical requirement for adjustable speed drives of AC motor, the magnitude as well as frequency of the fundamental component of the inverters output voltage needs to be controlled. This calls for generation of three phase balanced modulating signals of variable magnitude voltage and frequency which it may be emphasized, need to have identical magnitudes and phase difference of 120 degrees between them at all operation frequencies. Generating a balanced three phase sinusoidal wave forms of controllable magnitude and frequency is a pretty difficult task for an analog circuit and hence a mixed analog and digital circuits is often preferred.

The widths of the pulses near peak of the sine wave do not change much when modulation index is changed. According to M.H. Rashid in this method carrier triangular wave is suppressed at 30° in the neighborhood of peak of sine wave. Hence triangular wave is present for the period of first 60° and last 60° of the half cycle of sine wave. The middle 60° of the sine wave do not have triangular wave. Hence the generated PWM has less number of pulses as compared to sinusoidal wave. This type of modulation is known as Modified SPWM. Its RMS value can be changed by changing the amplitude of sinusoidal wave. This modulation scheme reduces harmonic content and switching losses but implementation of this scheme is tougher than Sinusoidal PWM technique.

Comparison of Sine PWM and SVM controlled induction motor drives are given by K. Vijaya Bhaskar Reddy [1]. This paper deals with comparison of space vector modulated inverter fed induction motor drives by using simulation and compared with analytical results. Harmonic elimination in three phase VSI inverters by particle swarm optimization is given by Mohamed Azad [2]. This paper presents accurate solutions for non-linear transcendental equations of the selective harmonic elimination technique used in three phase PWM inverters feeding the induction motor by particle swarm optimization. Control of voltage source inverters using SPWM strategy for adjustable speed drives is given by Sabrije. F. osmanaj[3]. This paper analysis the theoretical and modulation form for control strategy and simulation results of SPWM three phase VSI inverter are presented by the different switching conditions. Simulation and comparison of SPWM and SVPWM control for three phase inverter is given by K. Vinoth kumar [4]. In this paper first a model for SVPWM is made and is simulated using matlab simulink software and its performance is compared with SPWM. Modulation technique using Boundary pulse width for single phase power inverter is given by O.Aloquili[5]. This paper presents of small boundary PWM techniques are developed to improve the inverter operation based on minimum harmonic contents in the output voltage. Use of PWM techniques for power quality improvement is given by Mahesh. A. patel. [6] is paper discussed the effects of harmonics on the power quality of the power supply and also discussed the different configurations of PWM techniques for harmonic reductions and improvement of fundamental voltage. Compensation method eliminating voltage distortions in PWM inverter is given by H.Sediki[7]. The proposed method produces the same inverter output voltages by online
compensation method. FPGA based speed control of AC servo motor using sinusoidal PWM is
given by Kariappa.B.S. [8]. This paper presents a Xilinx field programmable gate array (FGPA)
based speed control of AC servo motor using SPWM technique. Voltage and current Harmonic
Variations in Three-Phase Induction Motors with different Stator Coil Pitches is given by Yasar
Birbir[9].This paper presents firstly a sinusoidal pulse width modulation (SPWM) inverter
feeding five different chorded three phase induction motors were tested for low order odd
harmonic voltage component and efficiently at different loads. Secondly the motors fed by sine
voltage again were tested for low order odd harmonic voltage and current component and
efficient at different loads. A review of three PWM techniques is given by Zhenyu Yu[10]. This
paper presents with emphasis on implementation and shown the experimental results.

The above literature does not deal with simulink modeling of modified Sine PWM VSI fed
three phase induction motor. This work deals with modeling and simulation of modified Sine
PWM VSI fed three phase induction motor drive.

III. MODELING OF INDUCTION MOTOR

The stator equations are as follows

\[
V_{a1} = R_1 i_{a1} + L_1 \frac{di_{a1}}{dt} + e_{a1} \quad [1]
\]
\[
V_{a2} = R_2 i_{a2} + L_1 \frac{di_{a2}}{dt} + e_{a2} \quad [4]
\]
\[
V_{b1} = R_1 i_{b1} + L_1 \frac{di_{b1}}{dt} + e_{b1} \quad [2]
\]
\[
V_{b2} = R_2 i_{b2} + L_1 \frac{di_{b2}}{dt} + e_{b2} \quad [5]
\]
\[
V_{c1} = R_1 i_{c1} + L_1 \frac{di_{c1}}{dt} + e_{c1} \quad [3]
\]
\[
V_{c2} = R_2 i_{c2} + L_1 \frac{di_{c2}}{dt} + e_{c2} \quad [6]
\]
\[
T_d = T_{w} \frac{d}{dt} + B_w \quad [7]
\]

IV. SIMULATION RESULTS

In three-phase inverter fed drive system, AC is converted into DC using uncontrolled
rectifier. DC is converted into variable voltage variable frequency AC using three-phase PWM
inverter. The variable voltage variable frequency supply is applied to the motor. The circuit of
six switch three phase inverter system is shown in Figure 2a. The inverter circuit with modified
sine PWM is shown in Figure 2b. The rectifier is shown as a subsystem. The rectifier part of a
AC to AC converter is shown in Figure 2c. AC input voltage applied to the single phase rectifier
is shown in Figure 2d. The output of the rectifier with capacitor filter is shown in Figure 2e. A
high frequency carrier waveform with dead band is considered for modified sine PWM
generation as shown in Figure 2f. Driving pulses used for Q_1, Q_4 & Q_5 are shown in figure 2g.
The phase voltage waveforms are shown in Figure 2h. The three phase balanced voltages are
displaced by 120 degrees. The line current waveforms are shown in Figure 2i. The speed
response curve is shown in Figure 2j. The speed increases and settles at 1480 rpm. FFT analysis
is done for the current waveform and spectrum is shown in Figure 2k. The THD is 7.74%.
FIGURE 2a. Six switch three phase circuit diagram

Figure 2b. Inverter circuit diagram

Figure 2c. Rectifier circuit diagram
Figure 2d. AC input voltage waveform

Figure 2e. Rectifier output voltage waveform

Figure 2f. Blocks of MSPWM
Figure 2g. Modified SINE PWM Pulses for Q1, Q4 & Q5  

Figure 2h. Phase voltage waveforms  

Figure 2i. Line current waveforms
CONCLUSION

The AC to AC converter fed induction motor drive is modeled and simulated using simulink. Modified Sine PWM is used to reduce the switching losses. The contribution of this work is the development of modified Sine PWM model using the blocks of simulink. Modified Sine PWM inverter fed induction motor drive is a viable alternative to the VSI fed induction motor drive due to the reduced switching losses. The harmonics are slightly reduced due to a larger pulse in the middle. The simulation results are in line with the predictions.

REFERENCES


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