CHAPTER – 3

MODIFIED SINE PWM VSI FED INDUCTION MOTOR DRIVE

3.1 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 of 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 to improve the quality of the product. The development of power electronic devices and control systems has 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).

3.2 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 which 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 has 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 ratios 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 (VVF) 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 may be emphasized, and need to have identical magnitudes and phase difference of 120 degrees between them at all operation frequencies. Generating a balanced three phase sinusoidal waveforms of controllable magnitude and frequency is a 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 does 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.

3.3. MODELLING OF INDUCTION MOTOR

The stator equations are as follows

\[ V_{a1} = R_1 i_{a1} + L_1 di_{a1}/dt + e_{a1} \]  \[3.1\]
\[ V_{b1} = R_1 i_{b1} + L_1 di_{b1}/dt + e_{b1} \]  \[3.2\]
\[ V_{c1} = R_1 i_{c1} + L_1 di_{c1}/dt + e_{c1} \]  \[3.3\]

The rotor equations are as follows

\[ o R_2 i_{a2} + L_2 di_{a2}/dt + e_{a2} \]  \[3.4\]
\[ o R_2 i_{b2} + L_2 di_{b2}/dt + e_{b2} \]  \[3.5\]
\[ o R_2 i_{c2} + L_2 di_{c2}/dt + e_{c2} \]  \[3.6\]

Torque balance equation is as follows:

\[ T_d = T_1 + Jdw/dt + Bw \]  \[3.7\]
3.4 SIMULATION RESULTS

The block diagram of PWM Inverter fed Induction Motor drive as shown in fig 3.1.

Fig3.1 Block diagram of PWM Inverter fed Induction Motor

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 3.2. The inverter circuit with modified sine PWM is shown in Figure 3.3. The rectifier is shown as a subsystem. The rectifier part of a AC to AC converter is shown in Figure 3.4. AC input voltage applied to the single phase rectifier is shown in Figure 3.5. The output of the rectifier with capacitor filter is shown in Figure 3.6. A frequency carrier waveform with deadband is considered for modified sine PWM generation as shown in Figure 3.7. Driving pulses used for Q1, Q4 & Q5 are shown in figure 3.8. The phase voltage waveforms are shown in Figure 3.9. The three phase balanced voltages are displaced by 120 degrees. The line current waveforms are shown in Figure 3.10. The speed response curve is shown in Figure 3.11. The speed increases and settles at 1480 rpm. FFT analysis is done for the current waveform and spectrum is shown in Figure 3.12. The THD is 7.74%.
FIGURE 3.2 Six switch three phase circuit

Figure 3.3 Inverter circuit

Figure 3.4 Rectifier circuit
Figure 3.5 AC Input Voltage

Figure 3.6 Output Voltage of Rectifier
Figure 3.7 Blocks of MSPWM

Figure 3.8 Modified Sine PWM pulses for Q1, Q4 & Q5
Figure 3.9 Phase Voltages

Figure 3.10 Line currents
Figure 3.11 Rotor speed in RPM

Figure 3.12 FFT analyses for current

Fundamental (50Hz) = 12.79%, THD = 7.74%
3.5 CONCLUSION

The AC to AC converter fed induction motor drive is modelled and simulated using Simulink. Modified Sine PWM is used to reduce switching losses. 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 the presence of large pulse in the middle. The simulation results are in line with the predictions.