A Comparative Study of Sine-Triangular and Space Vector PWM Inverter Fed Induction Motor Drive

Anita Gupta, Harsh Gupta and Arvind K. Tiwari

***ABSTRACT*-PWM technique is used to generate the required voltage or current to feed the motor. Space Vector Modulation (SVM) method is increasingly used for AC drives with the condition that the harmonic current is as small as possible and the maximum output voltage is as large as possible. The paper presents a comparative study of sine-triangular and space vector PWM based inverter control of induction motor (IM) drives. Analog controllers are not suitable for precise operation. With the availability of high computational power processors TMS320F240 it has been possible to realize precise digital vector control algorithms. The proposed algorithm is implemented in Matlab Simulink environment.**

Keywords: **PWM, Space Vector, Induction Machine, Vector Control.**

1. Introduction

The paper describes the most efficient form of vector control scheme: the SVPWM (Space Vector Pulse Width Modulation) over other PWM techniques [3]-[10]. It is based on three major points: the machine current and voltage space vectors, the transformation of a three phase speed and time dependent system into a two co-ordinate time invariant system and effective *pulse width modulation* (PWM) pattern generation. Due to these factors, control of AC machine acquires every advantage of DC machine control and frees itself from the mechanical commutation drawbacks. Furthermore, this control structure, by achieving a very accurate steady state and transient control, leads to high dynamic performance in terms of response times and power conversion. The Field Orientated Control (FOC) [1] consists of controlling the stator currents represented vector.
The introduction of space vectors, originally only for the purpose of analysis of three-phase machines, has led to the development of an inherently digital modulation method, in contrast to some mere digital approximations to traditional analogue techniques. This technique is nowadays commonly known as space vector modulation (SVM). This paper presents extensive introduction to theory and implementation of SVM. Organization pf paper is as follows:

Section 2, presents implementation philosophy of SVM and Sine Triangular PWM. Section 3 presents simulated results of proposed algorithm followed by conclusion in section 4.

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2. The Space Vector PWM

2.1 The 3-phase Inverter

The structure of a typical 3-phase power inverter is shown in Figure 1, where V_A V_B, V_C are the voltages applied to the star-connected motor windings, and V_{DC} is the continuous inverter input voltage.

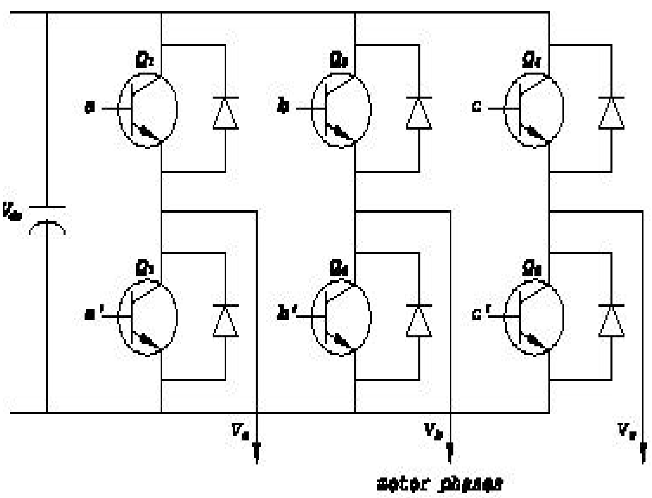

Figure 1: Basic scheme of 3-phase inverter and AC-motor

The six switches can be power BJT, GTO, IGBT etc. The *ON-OFF* sequence of all these devices must respect the following conditions:

- Three of the switches must always be ON and three always OFF.
- The upper and the lower switches of the same leg are driven with two complementary pulsed signals.

In this way no vertical conduction is possible, providing care is taken to ensure that there is no overlap in the power switch transitions.
Next Section, presents technique for generating such pulsed signals.

2.2Space Vector Pulse Width Modulation (SVPWM):

Space Vector PWM supplies the AC machine with the desired phase voltages. The SVPWM [1][2][4]-[6][8] method of generating the pulsed signals fits the above requirements and minimizes the harmonic contents. Note that the harmonic contents determine the copper losses of the machine which account for a major portion of the machine losses. Taking into consideration the two constraints quoted in Section 2.1 there are eight possible combinations for the switch commands. These eight switch combinations determine eight phase voltage configurations. The diagram below depicts these combinations.

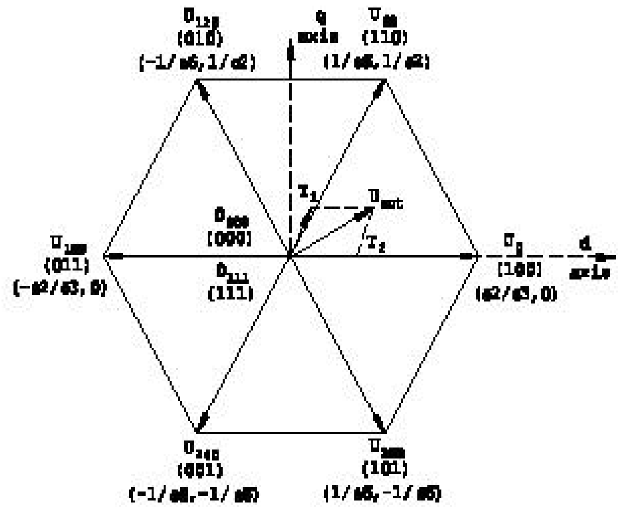

Figure 2 SVPWM, vectors and sectors

The vectors divide the plan into six sectors. Depending on the sector that the voltage reference is in, two adjacent vectors are chosen. The binary representations of two adjacent basic vectors differ in only one bit, so that only one of the upper transistors switches when the switching pattern moves from one vector to the adjacent one. The two vectors are time weighted in a sample period T to produce the desired output voltage.

Assuming that the reference vector $\bar{V}_{ref}$ is in the 3° sector, we have the following situation:

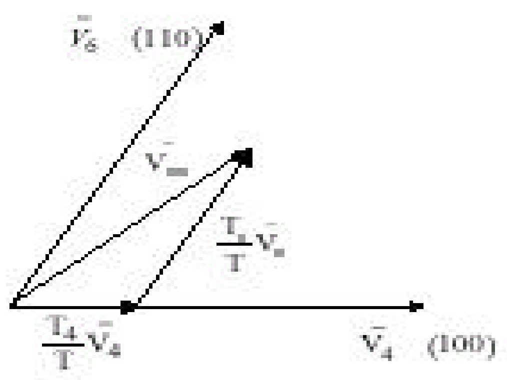

Figure3 Reference vector as a combination of adjacent vectors

Where T4 and T6 are the times during which the vectors $\bar{V}_4$ and $\bar{V}_6$ are applied and T_0 the time during which the zero vectors are applied. When the reference voltage (output of the inverse Park transformation) and the sample periods are known, the following system makes it possible to determine the uncertainties T_4 ,T_6 and T_0.

$$T = T_4 + T_6 + T_0 \quad (1)$$

$$\bar{V}_{ref} = T_4/T\ \bar{V}_4 + T_6/T\ \bar{V}_6 \quad (2)$$

Under these constraints the locus of the reference vector is the inside of a hexagon whose vertices are formed by the tips of the eight vectors. The generated space vector PWM waveforms are symmetrical with respect to the middle of each PWM period [1]. The diagram shows the waveforms in the example presented above.

Fig. 5 diagram shows the pattern of SVPWM for each sector.

In conclusion, the inputs for the SVPWM are the reference vector components ($v_{\alpha Sr}$, $v_{\beta Sr}$) and the outputs are the times to apply each of the relevant sector limiting vectors.

2.3 Comparison of SV & Sine-Triangular PWM

Fig. 6a presents generation of Sine Triangular PWM. The SVPWM generates minimum harmonic distortion of the currents in the winding of 3-phase induction motor. SV Modulation also provides a more efficient use of the supply voltage in comparison with sinusoidal modulation methods. In fact, with conventional sinusoidal modulation [1] in which the sinusoidal signals are compared with a triangular carrier, we know that the locus of the reference vector is the inside of a circle with a radius of $1/2V_{DC}$.

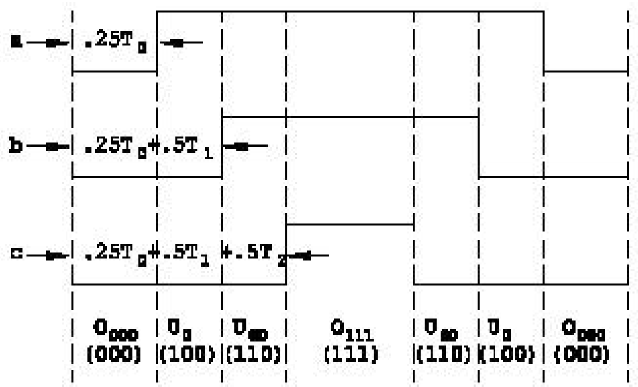

Fig. 4 Pattern of SVPWM in the sector 3

In the SV modulation it can be shown that the length of each of the six vectors is $2/3V_{DC}$. In steady state the reference vector magnitude might be constant. This fact makes the SV modulation reference vector locus smaller than the hexagon described above. This locus narrows itself to the circle inscribed within the hexagon, thus having a radius of $1/3V_{DC}$. In Figure 6b below the different reference vector loci are presented.

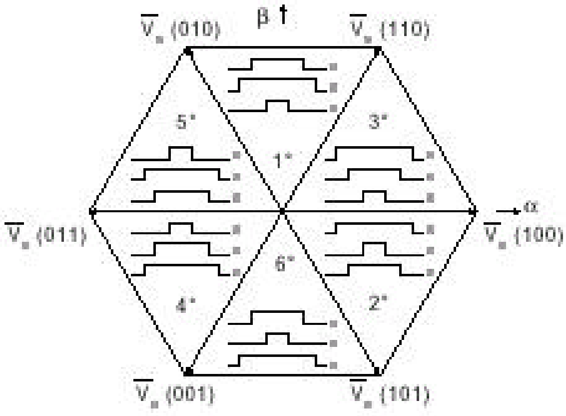

Figure5 Hexagon of SVPWM, pattern

Therefore, the maximum output voltage based on the Space Vector theory is 2/√3(OM/ON) times as large as that of the conventional sinusoidal modulation. This explains why, with SVPWM, we have a more efficient use of the supply voltage than with the sinusoidal PWM method.

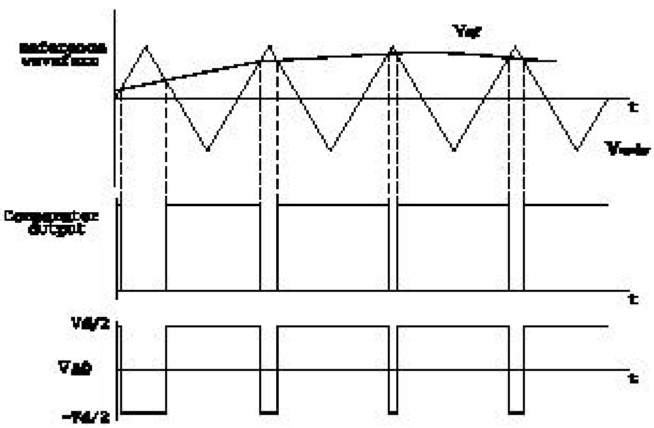

Fig. 6a Generation of Sine Triangular PWM

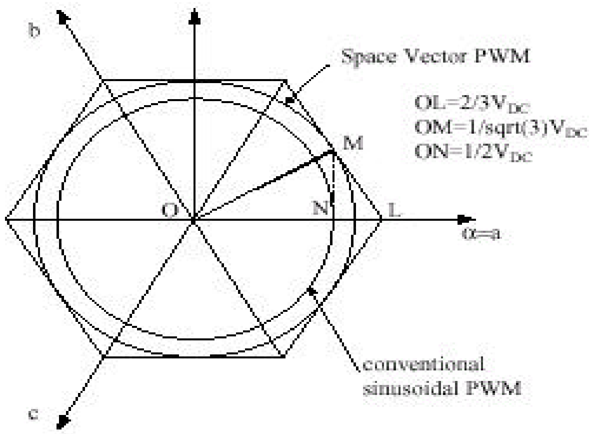

Fig. 6b Locus comparison SV-sinusoidal PWM

3. Results and Discussion

Fig. 7 displays the simulated model of vector controlled induction motor in Matlab-Simulink environment.

Fig.8 shows the six pulses generated by SVM which are applied to 3-phase inverter. In Fig. 9 Vab, Vbc and Vca are the outputs of the 3-phase inverter which are given to the 3-phase IM drive. The fundamental voltages obtained by both the conventional and SVM are as shown in the Fig. 10a and 10b. From the figure 10b it is clear that SVM output contains less harmonic distortion compared to conventional PWM. Fig.10b shows the higher modulation index with ripple free response in SVM technique as compared with conventional PWM (fig. 10a).

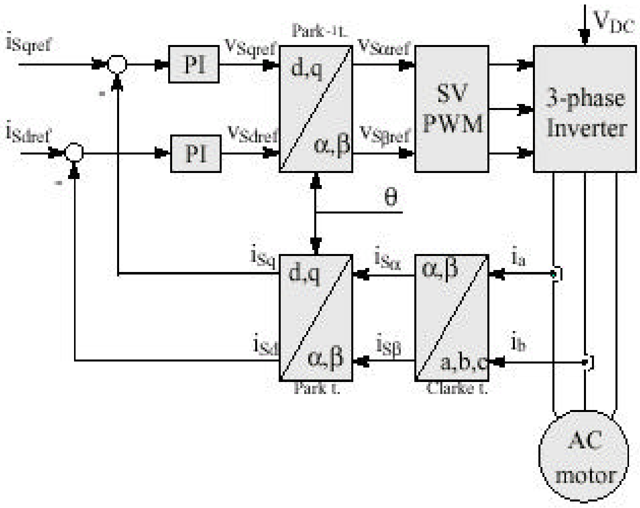

Fig. 7Basic Scheme of Vector Control of Induction Motor Drive

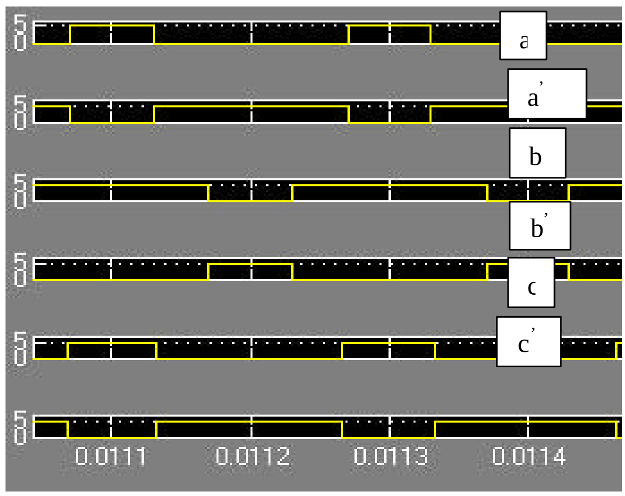

Fig. 8 Six-pulses for the gating of 3-phase inverter

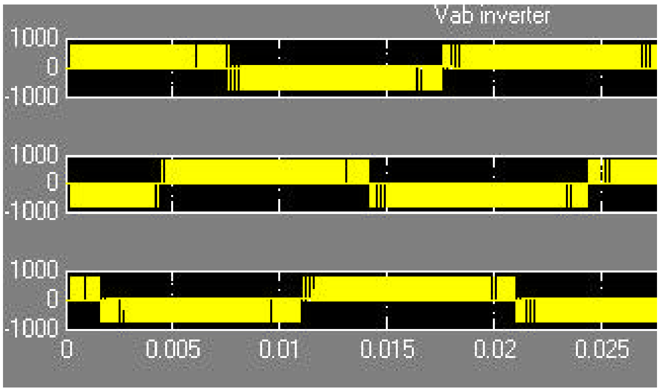

Fig. 9 Out put of Inverter (V_{ab}, V_{bc} and V_{ca})

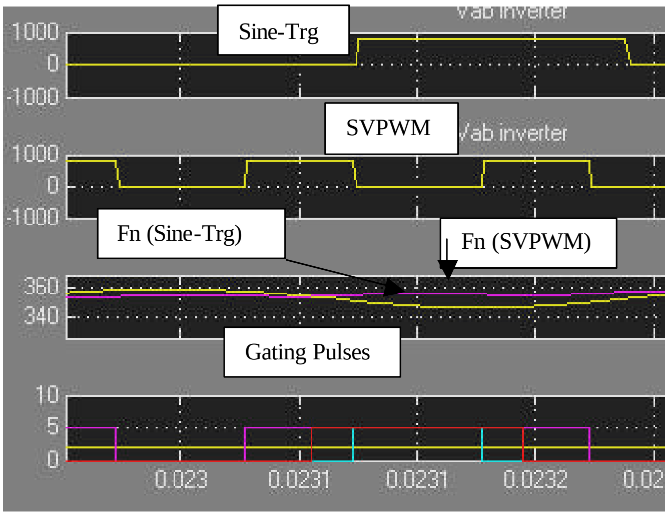

Figure10a Comparison of responses obtained by both the techniques

4. Conclusion

From the results it is observed that vector control of IM drive using the SVPWM produces less harmonic distortion as compared to conventional PWM scheme. The dynamic and transient performance is also improved by using this method.

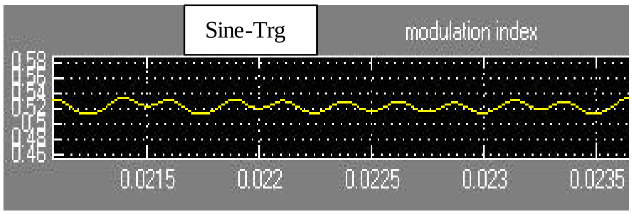

Figure10a Modulation index in conventional technique

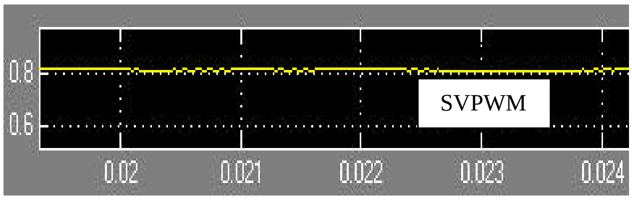

Figure10b Modulation index in SVM technique

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