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Space Vector Pulse Width Modulation for a Two-Level VSI using MATLAB

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Abstract—
Space vector pulse width modulation (SVPWM) is the most popular and advanced technique in the application of variable speed drives. This technique is an alternative method for the determination of switching pulse width and their position. SVPWM has several advantages over the rest of the PWM techniques such as its DC bus voltage utilization, less harmonic distortion in output voltage etc. In this paper, SVPWM is being applied to a two-level VSI and find out phase voltage and its spectrum using MATLAB software.
Index Terms— Voltage source inverter (VSI), pulse width modulation (PWM), space vector pulse width modulation (SVPWM), triangular comparison pulse width modulation (TCPWM).

I. INTRODUCTION

Ac drives require high power variable voltage variable frequency supply. Because of lots of advances in solid state power devices, variable speed AC Induction motors powered by switching power converters are becoming more and more popular. To regulate the frequency and voltage of a motor, switching power converters is generally used because it provides higher efficiency and performance with less noise The Pulse width modulation techniques have been developed in last few decades to fulfill the requirements of ac drives. The main problem for power electronic engineers is to reduce the distortion that will be produced because of harmonic content in inverter circuit.

In the low power application, classical square wave generator was used but it has some disadvantages such as it contains lower order harmonic in output voltage and it is very difficult to reduce them. One of the solutions to enhance the harmonic free environment in high power application is to use PWM techniques. PWM techniques have some advantages such less THD, effective bus voltage utilization etc. PWM techniques are mainly classified into two techniques. They are Triangular comparison based PWM (TCPWM) and Space vector PWM (SVPWM).

In TCPWM technique, three phase modulating signal called reference signal are compared with a triangular wave called carrier signal to generate pulses for three phases. The modulating signal has less frequency than the frequency of carrier signal. The magnitude and frequencies of the fundamental component is to be controlled by varying the magnitude and frequency of the modulating signal. It has poor voltage utilization therefore voltage range has to be extended and harmonics have to be reduced [1].

In SVPWM technique, the voltage reference is provided using a resolving reference vector. The magnitude and frequency of reference voltage vector are used to control the magnitude and frequency of fundamental component at the line side. Space vector modulation utilizes dc bus voltage more efficiently and it will also help to generate less harmonic distortion than the harmonic distortion in the TCPWM [1]

II. SPACE VECTOR PULSE WIDTH MODULATION

Space vector pulse width modulation (SVPWM) technique is most popular and important technique among all PWM techniques for three phase voltage source inverter. It was originally developed as a vector approach to pulse width modulation (PWM) for three phase voltage source inverter. It is more sophisticated technique that provides higher voltage with fewer harmonic. The main aim of any modulating technique is to obtain variable output having a fundamental component with minimum harmonics. SVPWM method is an advanced, computation intensive PWM method and possibly the best techniques for variable frequency drive application [1].

III. PRINCIPLE OF SVPWM

The circuit model of three phase voltage source inverter is shown in Fig.1. There are six power switches (they may be either transistor, MOSFET,

GTO, IGBT etc) that will help to shape the output and these switches are controlled by variables
A , A', B, B', C and C'. When upper switches are on i.e. A, B or C is 1, the corresponding lower switches are switched off i.e. the corresponding A', B' or C' is 0. Therefore, the on and off state of the upper switches S1, S3 and S5 can be used to determine output voltage.
The switches must be controlled so that two switches are not turned ON at the same time in the same leg otherwise leg will be short circuited. This requirement may be met by the complementary operation of the switches within a leg i.e. if A+ is ON the A- will be OFF and vice versa and other switching patterns have been shown in TABLE I. This technique generates less harmonic distortion in the output voltages or currents applied to the phases of induction motor. vectors in each sector as shown in Fig.2. The space vector technique has six active vector [100 110 010 011 001 101] and two zero vectors [000 111] that will help for producing the reference output voltage.

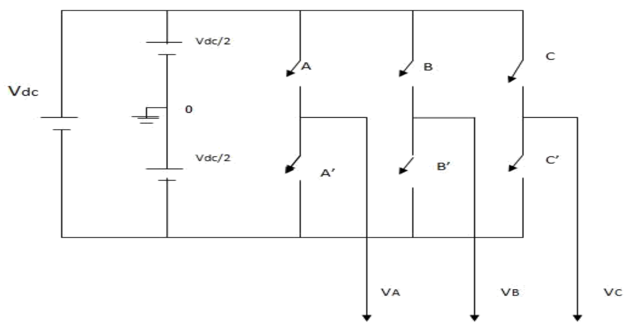
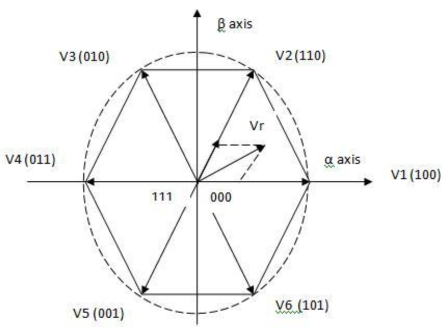


Fig.1. Two-level voltage source inverter

The space vector concept is being derived from the rotating field of induction motor and it is used to modulate the inverter output voltage. In this modulation the three phase quantities can be transformed into their equivalent two phase quantity either in synchronously rotating frame or stationary frame. While considering the stationary reference frame let the three phase sinusoidal voltage component be [2, 3],



IV. SOFTWARE IMPLEMENTATION OF SVPWM

SVPWM can be imlemented by the following steps-

Step1- First transform three phase to two phase quantity and then find out V_{α}, V_{β}, V_r and angle α. With the help of Clark's transformation, V_{α}, V_{β} V_r and angle α can be determined as follows -

The SVPWM technique is used to generate a reference voltage vector by modulating the Switching time of space

Voltage Vectors	**Switching vectors**						**Phase voltages**		
V0-V7	A+	B+	C+	A-	B-	C-	Vab	Vbc	Vca
000	OFF	OFF	OFF	ON	ON	ON	0	0	0
100	ON	OFF	OFF	OFF	ON	ON	+Vdc	0	-Vdc
110	ON	ON	OFF	ON	OFF	OFF	0	+Vdc	-Vdc
010	OFF	ON	OFF	ON	OFF	ON	-Vdc	+Vdc	0
011	OFF	ON	ON	ON	OFF	OFF	-Vdc	0	+Vdc
001	OFF	OFF	ON	ON	ON	OFF	0	-Vdc	+Vdc
101	ON	OFF	ON	OFF	ON	OFF	+Vdc	-Vdc	0
111	ON	ON	ON	OFF	OFF	OFF	0	0	0

Equations (4) and (5) can be written in matrix form as follows,

[ ] − [√ √] [ ] (6)

Space vector representation of three phase quantity is given by the following equation

(7)

Where $= e^{2\pi j/3}$

The magnitude of reference vector is

| | √ (8)

$\alpha = \tan^{-1}(V_\beta/V_\alpha) = 2\pi ft$

Where, f = fundamental frequency

Step2- Determine the switching time duration T_0, T_1 and T_2.

From Fig.3, Reference space vector V_r, present in sector 1, is generated as a combination of two active vectors V_1, V_2 (100, 110) and two zero vectors V_0, V_7 (000, 111). According to the volt – sec method,

∫ ∫ ∫ ∫ (9)

| | (10)

As, $Vr=Vr.e^{j\theta}$, $V_0=0$, $V_1=2.V_{dc}/3$ and $V_2=2.V_{dc}.e^{j2\pi/3}/3$

| | [(11)

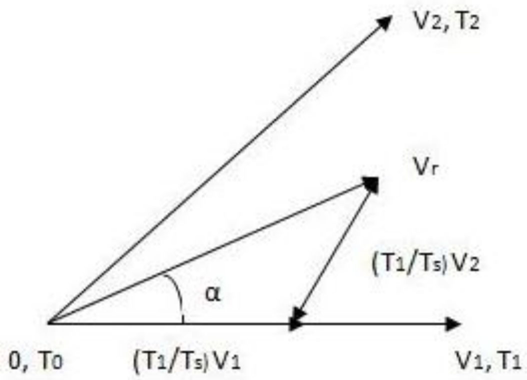


Fig.3. Reference vector as a combination of adjacent vectors at sector 1

Where, T_0, T_1 and T_2 are the time durations for vectors V_0, V_1, V_2 in sector1 (i.e. for $0 \le \alpha \le 60$).

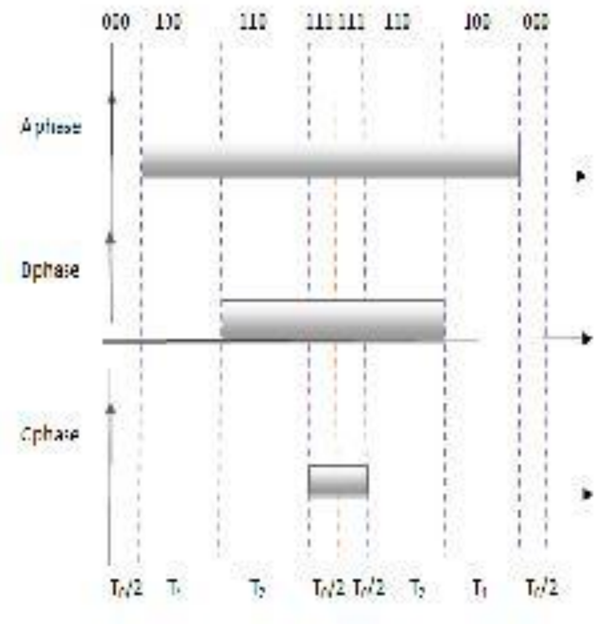


Fig.4. Gating pulse for the A, B and C phases in sector 1

Step3- Determine the switching time duration for other sectors switching time duration at any sector has been shown in TABLE II. T_1 and T_2 is given in the following equations

— | | (—)

— | | (—)

Where n=1 to 6

TABLE II. Switching time for all sectors (i.e. S1 to S6)

Sectors	T_1	T_2	T_0
1	–		
2	—	–	
3		—	
4	—	—	
5	—	—	
6		—	

V. RESULTS

Space vector PWM technique has been implemented for two-level three phase VSI using MATLAB. Phase voltage Vab has been found out at modulation index 0.61 and 0.86.

At modulation index=0.61

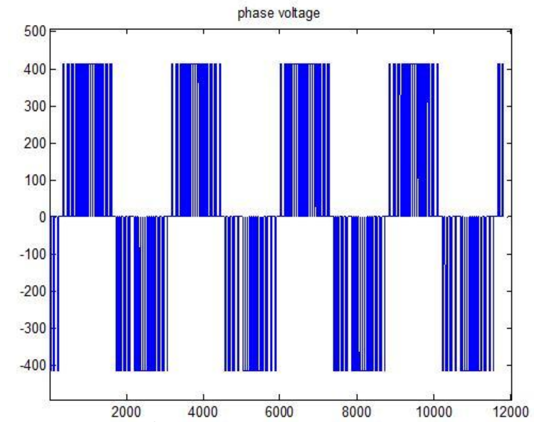


Fig.5. Response of phase voltage (Vab) in volts

THD=3.3%

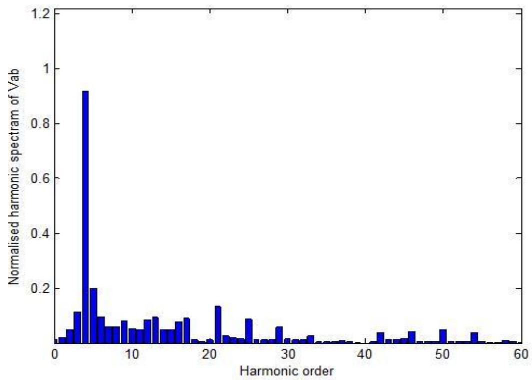


Fig.8. FFT analysis of Vab

At modulation index=0.86

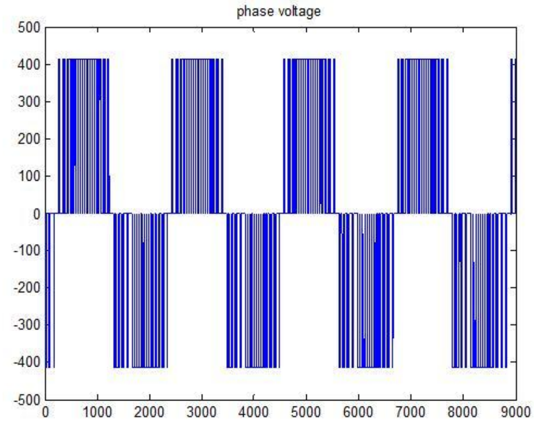


Fig.7. Response of phase voltage (Vab) in volts

THD=1.3%

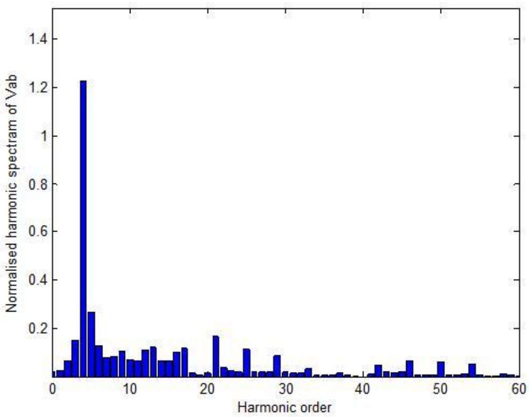


Fig.8. FFT analysis of Vab

VI. CONCLUSION

Owing to lots of advantages, SVPWM is a popular choice for controlling an inverter and it provides better switching performance over the rest of the PWM techniques. SVPWM technique has been easily programmed for 2-level three phase VSI in MATLAB environment. There is an ease to find out how much harmonics are present in output voltage of an inverter using FFT analysis.

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