SIMULATION AND COMPARISON OF SPWM AND SVPWM CONTROL FOR THREE PHASE R-L LOAD

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ABSTRACT

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. 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). There is an increasing trend of using space vector PWM (SVPWM) because of their easier digital realization and better dc bus utilization. In this paper first a model for Space vector PWM is made and simulated using MATLAB/SIMULINK software and its performance is compared with Sinusoidal PWM. The simulation study reveals that Space vector PWM utilizes dc bus voltage more effectively and generates less THD when compared with sine PWM.

Keywords: *SVPWM, SPWM, THD.*

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I. INTRODUCTION

Pulse Width Modulation is a technique in which a fixed dc input voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is the most popular method of controlling the output voltage and this method is termed as *pulse-width modulation* control To implement voltage control and harmonic reduction for the load, PWM is an internal voltage control method. It gives the best results compared to any other external control techniques. A suitable pulse width modulation (PWM) technique is employed [1] in order to obtain the required output voltage in the line side of the inverter. The Dual-PWM VF Speed Regulation System based on vector control [2], can reduce harmonic pollution to power grid, and improve the efficiency of power used. There are a number of PWM methods for variable frequency voltage-sourced inverters. Among these, PWM strategies based on the concept of voltage space vectors [3], [4] have established numerous advantages in practice. They are capable of producing the highest achievable fundamental output voltage with low harmonic distortion of the output current, and are well suited for microprocessor implementation [5]. A suitable pulse width modulation (PWM) technique is employed to obtain the required output voltage in the line side of the inverter. The different methods for PWM generation can be broadly classified into Triangle comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM). In TCPWM methods such as sine-triangle PWM, three phase reference modulating signals are compared against a common triangular carrier to generate the PWM signals for the three phases. In SVPWM methods, a revolving reference voltage vector is provided as voltage reference instead of three phase modulating waves. The magnitude and frequency of the fundamental component in the line side are controlled by the magnitude and frequency, respectively, of the reference vector. The study of space vector modulation technique reveals that space vector modulation technique utilizes DC bus voltage more efficiently and generates less harmonic distortion when compared with Sinusoidal PWM (SPWM) technique

Sinusoidal PWM (SPWM)

The sinusoidal PWM (SPWM) method also known as the triangulation, sub harmonic, or sub oscillation method, is very popular in industrial applications. For realizing SPWM, a high-frequency triangular carrier wave is compared with a sinusoidal reference of the desired frequency. The commutation of the modulated pulse and intersection of sine and square waves determines the switching instant. When the modulating signal is a sinusoid of amplitude Am, and the amplitude of the triangular carrier is Ac, the ratio m=Am/Ac is known as the modulation index. Note that controlling the modulation index there for controls the amplitude of the applied output voltage. With a sufficiently high carrier frequency, the high frequency components do not propagate significantly in the ac network (or load) due the presence of the inductive elements.

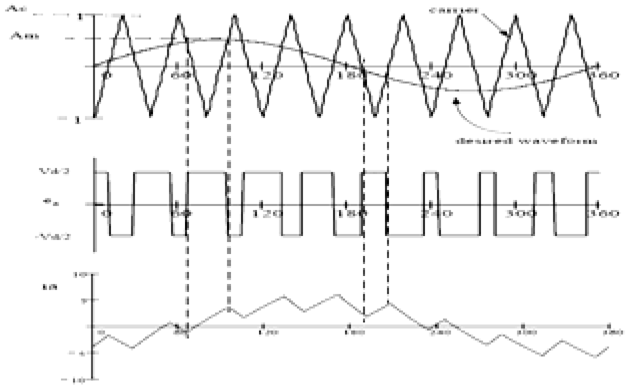


Fig 1 Principal of SPWM

Space Vector Pulse Width Modulation(SVPWM)

SVPWM based converters supplies the AC machine with the desired phase voltages. The space vector modulation concept is used to calculate the duty cycle of the switches which is imperative implementation of digital control theory of PWM modulators. The modulating signal is generated by injecting selected harmonics to the sine wave. This results in flat-topped waveform and reduces the amount of over modulation. It provides a higher fundamental amplitude and low distortion of the output voltage. The modulating signal is generally composed of fundamental plus harmonics.

$$V_r = 1.15 sin\omega t + 0.27 sin\omega t - 0.029 sin\omega t \qquad (1)$$

The modulating signal with third and ninth harmonic injections is shown in figure 6. The signal with third and ninth harmonic does not affect the quality of output voltage, because the output of a three-phase converter does not contain triplen harmonics. If only the third harmonics is injected, Vr is given by

$$V_r = 1.15 sin\omega t + 0.19 sin3\omega t \qquad (2)$$

This is same as injecting triplen harmonics to a sine wave. The line to line voltage amplitude of the fundamental component is approximately 15% more than that of a normal sinusoidal PWM.

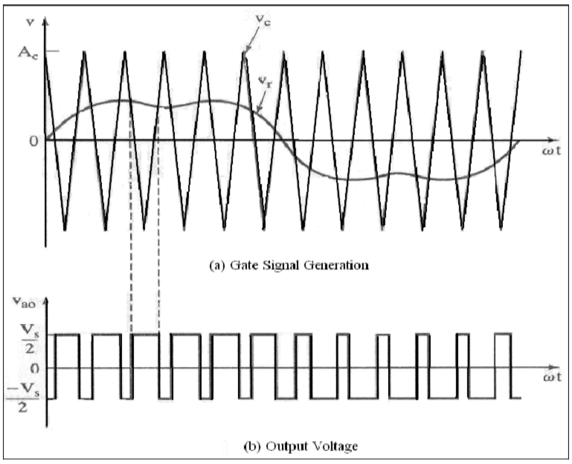


Fig.2. Modulation Waveform of SVPWM

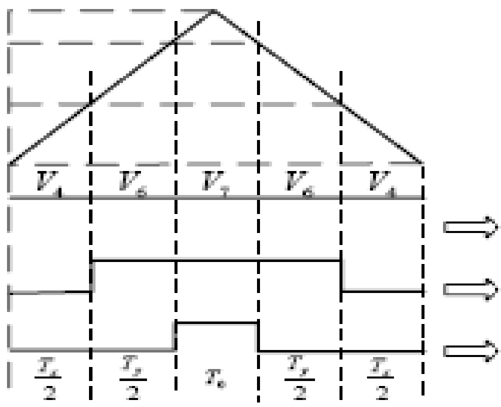


Fig 3 Switching Pattern of SVPWM

Figure 3 shows the switching pattern of the SVPWM technique. Its sequences are symmetrical too. This technique lowers the switching times. The space vector concept, which is derived from the rotating field of induction motor, is used for modulating the inverter output voltage. In this modulation technique the three phase quantities can be transformed to their equivalent two-phase quantity either in synchronously rotating frame (or) stationary frame. From these two-phase components, the reference vector magnitude can be found and used for modulating the inverter output. The process of obtaining the rotating space vector is explained in the following section, considering the stationary reference frame. Considering the stationary reference frame let the three-phase sinusoidal voltage component be

$$Va = VmSin\omega t \quad (3)$$

$$Vb = VmSin(\omega t-2\pi/3) \quad (4)$$

$$Vc = VmSin(\omega t-4\pi/3) \quad (5)$$

$$f_{dq0} = K_s f_{abc} \quad (6)$$

$$K_S = \frac{2}{3}\begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & -\sqrt{3}/2 & -\sqrt{3}/2 \\ 1/2 & 1/2 & 1/2 \end{bmatrix}$$

$$f_{dq0} = [f_d f_q f_0]^T$$

$$f_{abc} = [f_a f_b f_c]^T$$

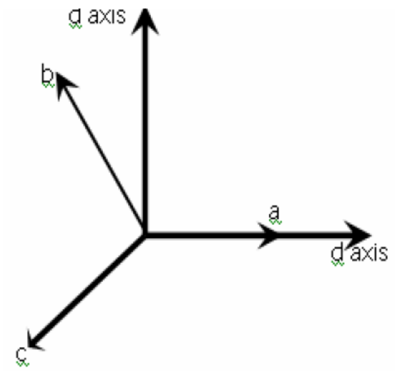


Fig. 4 Vector relations for SVPWM

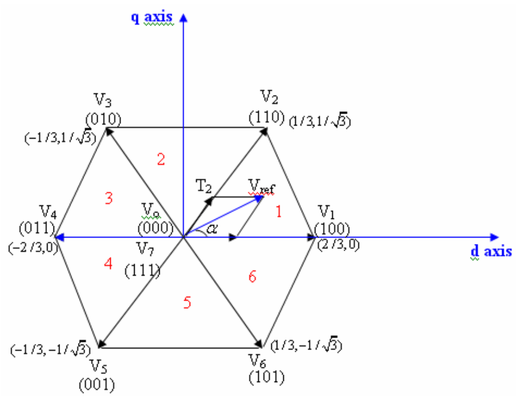


Fig 5 Eight Vector Stste

Table 1 Switching Patterns and Output Vectors

Voltage vectors	Switching vectors			Line to neutral voltage			Line to line voltage		
	A	B	C	V_{an}	V_{bn}	V_{cn}	V_{ab}	V_{bc}	V_0
V_0	0	0	0	0	0	0	0	0	0
V_1	1	0	0	2/3	-1/3	-1/3	1	0	-1
V_2	1	1	0	1/3	1/3	-2/3	0	1	-1
V_3	0	1	0	-1/3	2/3	-1/3	-1	1	0
V_4	0	1	1	-2/3	1/3	1/3	-1	0	1
V_5	0	0	1	-1/3	1/3	2/3	0	-1	1
V_6	1	0	1	1/3	-2/3	1/3	1	-1	0
V_7	1	1	1	0	0	0	0	0	0

For 180° mode of operation, there exist six switching states and additionally two more states, which make all three switches of either upper arms or lower arms ON. To code these eight states in binary (one-zero representation), it is required to have three bits ($2^3 = 8$). And also, as always upper and lower switches are commutated in complementary fashion, it is enough to represent the status of either upper or lower arm switches. In the following discussion, status of the upper bridge switches will be represented and the lower switches will it's complementary. Let "1" denote the switch is ON and "0" denote the switch in OFF. Table-1 gives the details of different phase and line voltages for the eight states.

II SIMULATION OF SPWM and SVPWM

Simulation test beds using MATLAB/SIMULINK were constructed to validate the effectiveness of the SPWM and SVPWM. The block diagram for Sinusoidal pulse width modulation and Space Vector Pulse width modulated inverter fed three phase R-L load shown in Figure (6,7). Parameters used for the simulation are shown below for three-phase R-L load

Load resistance = 1 ohm/phase,

Load inductance = 1e-3 H/phase.

Voltage input to the inverter = 300 V.

Frequency base up to which harmonics are considered = 1000 HZ.

Frequency of fundamental component = 50 HZ

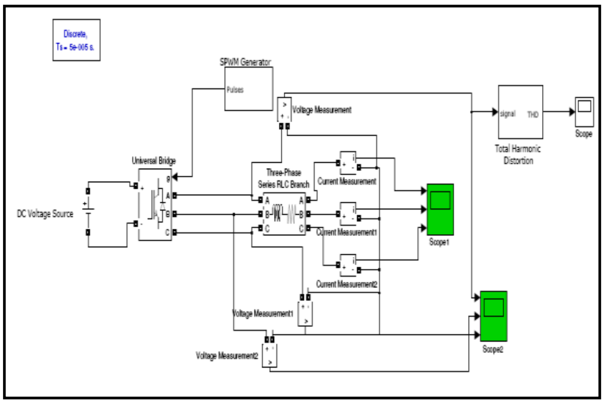


Fig.6 Matlab/Simulink Blocks for Employing SPWM Technique

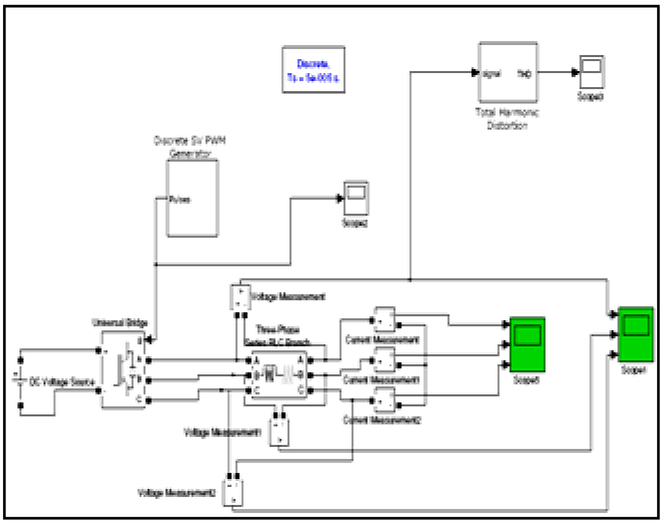


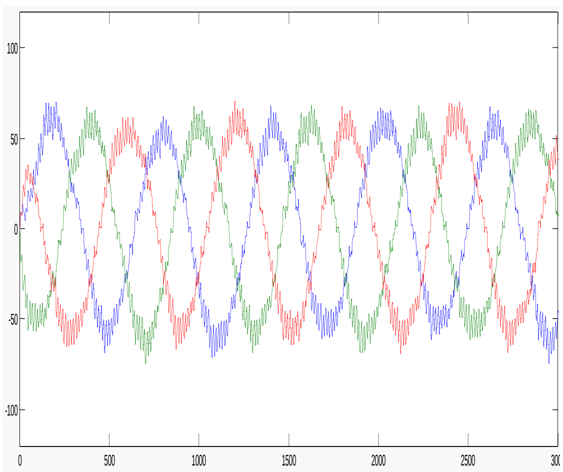
Fig.7. Matlab/Simulink Blocks for Employing SVPWM Technique

III SIMULATION RESULTS OF SPWM AND SVPWM

The objective of Pulse Width Modulation techniques is enhancement of fundamental output voltage and reduction of harmonic content in Three Phase Voltage Source Inverters. In this paper different PWM techniques are compared in terms of Total Harmonic Distortion (THD). Simulink Models has been developed for Sinusoidal PWM (SPWM), Space vector PWM (SVPWM). Simulation has been carried out by varying the modulation index between 0 and 1. The load current waveform and its FFT analysis has been shown in given figure for three phase R-L load .Finally performance of SVPWM has been compared with conventional Sine PWM.

FOR MODULATION 0.4

(A) SPWM



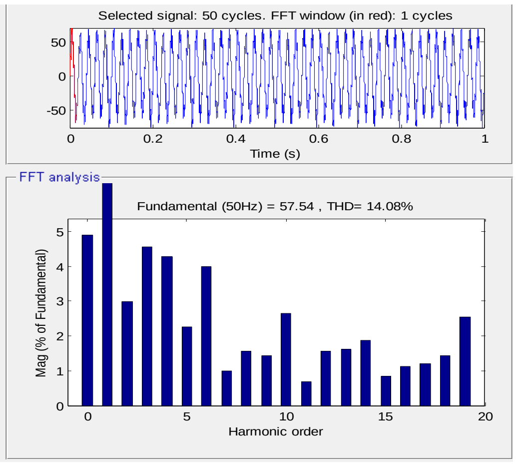


Fig 8 Load Current Waveform and FFT Analysis

(B) SVPWM

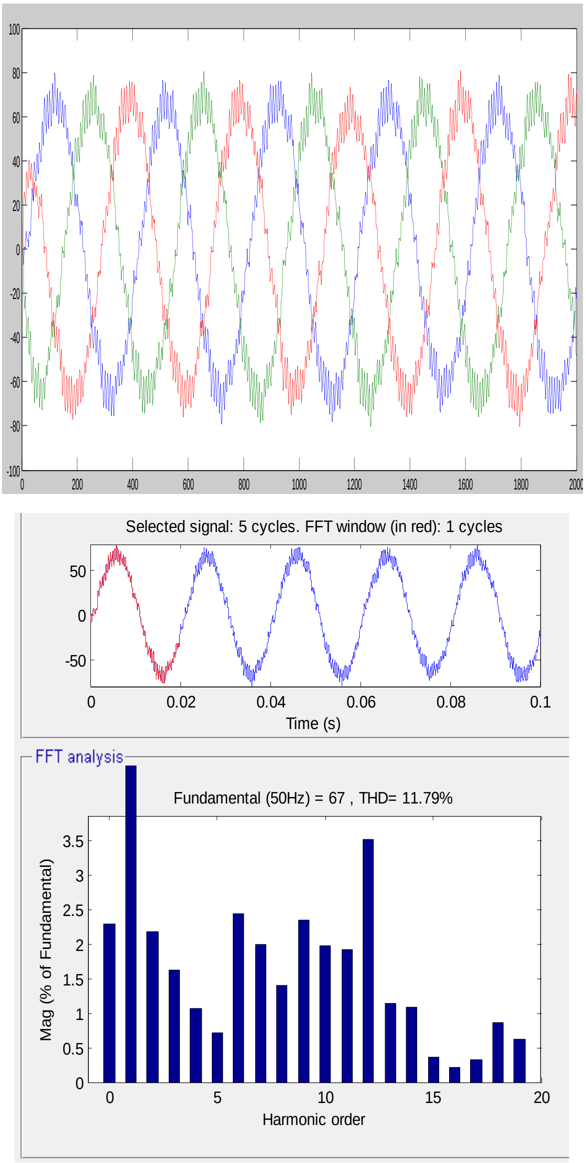


Fig 9 Load Current Waveform and FFT Analysis

FOR MODULATION INDEX 0.8

(A) SPWM

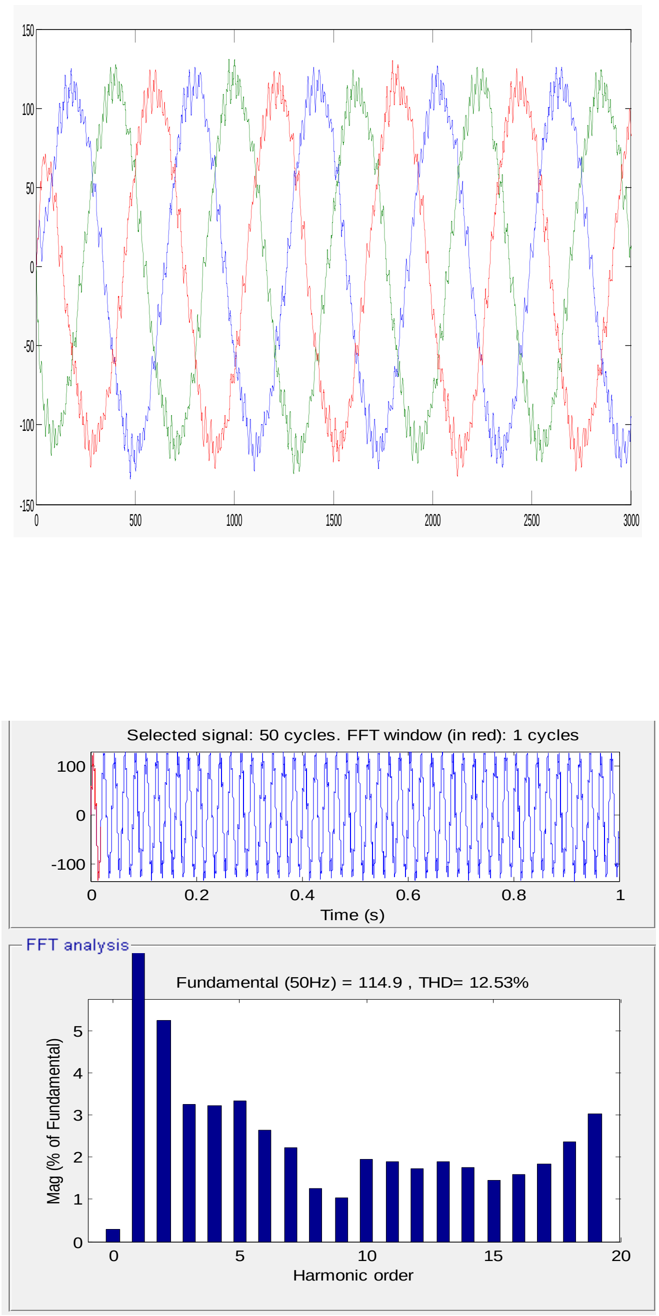


Fig 10 Load Current Waveform and FFT Analysis

(B) SVPWM

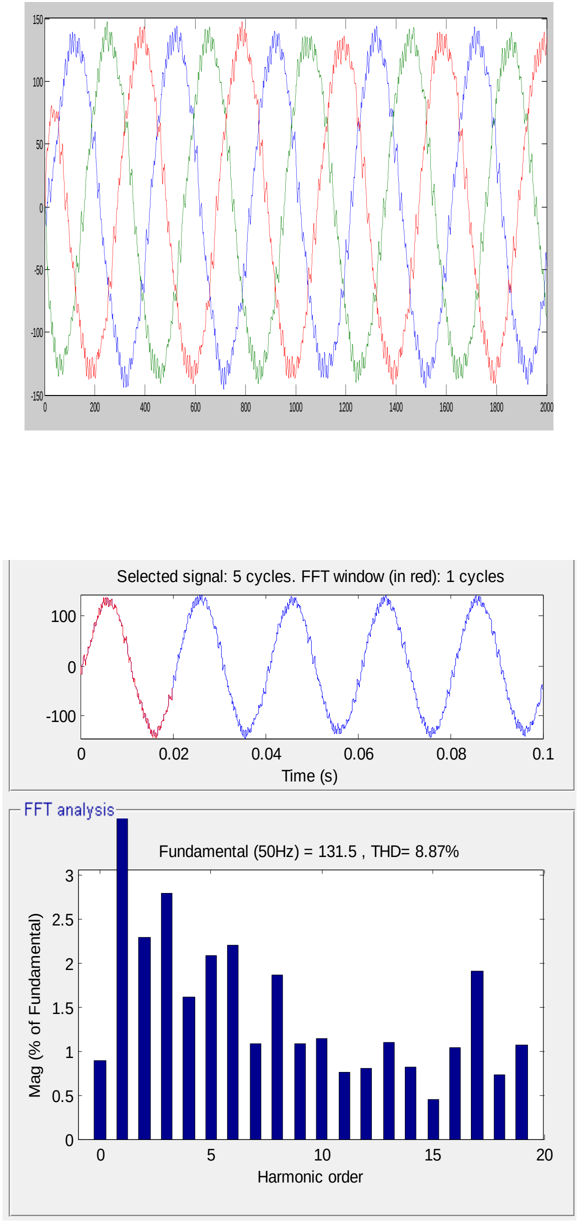
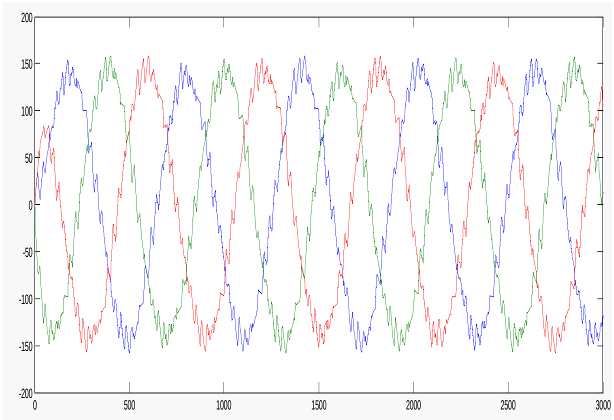


Fig 11 Load Current Waveform and FFT Analysis

FOR MODULATION INDEX 1

(A) SPWM



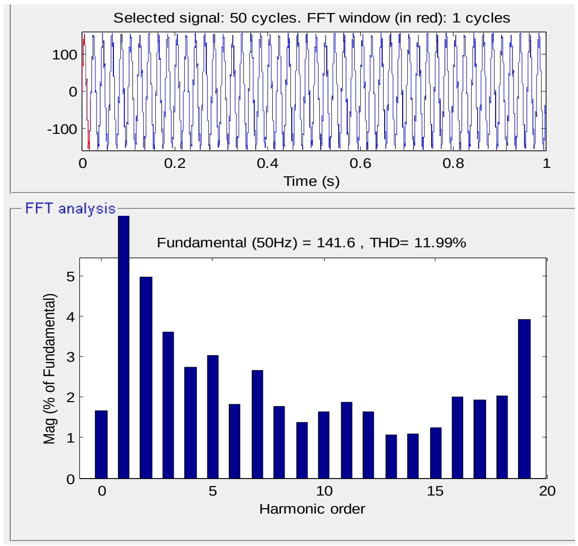


Fig 12 Load Current Waveform and FFT Analysis

(B) SVPWM

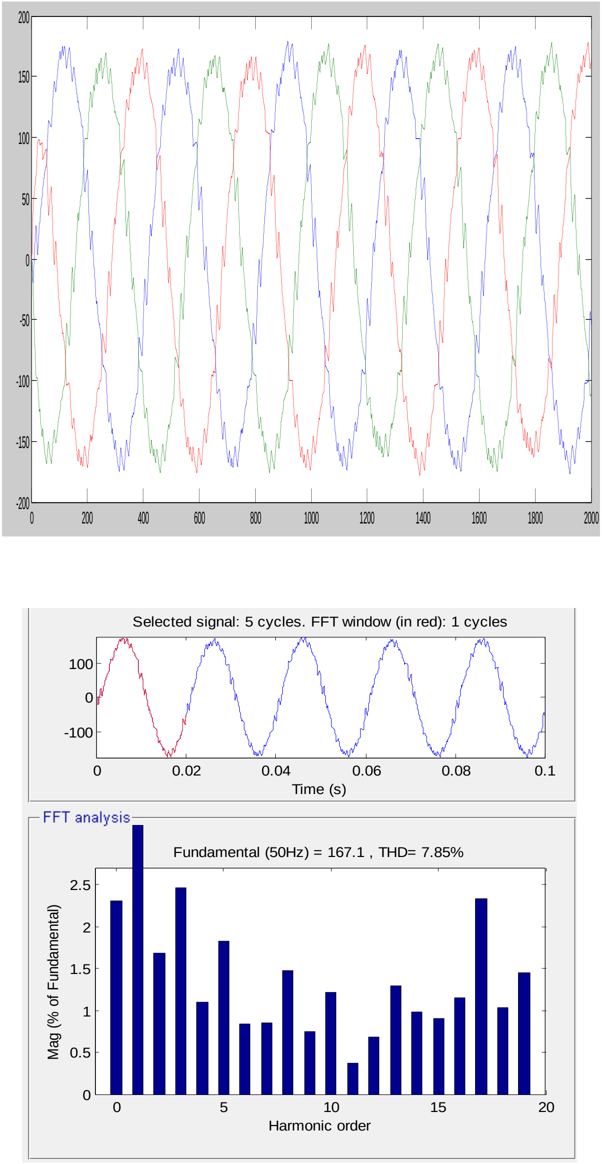


Fig 13 Load Current Waveform and FFT Analysis

IV CONCLUSION

Space vector Modulation Technique has become the most popular and important PWM technique for Three Phase Voltage Source Inverters. In this paper the comparative analysis of Space Vector PWM with conventional SPWM for a three phase inverter is carried out. The Simulation study reveals that SVPWM gives enhanced fundamental output with better quality i.e. lesser THD compared to SPWM.

Table 2 Comparison Of Simulation Results

SPWM				
M.I	Current		Voltage	
	THD (%)	Fundamental component (in %)	THD(%)	Fundamental component (in %)
0.4	14.08	57.54	159.96	61.3
0.6	13.13	85.9	120.8	89.25
0.8	12.53	114.9	90.85	121.3
1.0	11.99	141.6	70.21	148.1

SVPWM				
Modulation index	Current		Voltage	
	Total harmonic distortion (in %)	Fundamental component (in %)	Total harmonic distortion (in %)	Fundamental component (in %)
0.4	11.79	67	145.83	70.25
0.6	10.44	99.08	103.64	105.3
0.8	8.87	131.5	76.87	137.2
1.0	7.85	167.1	49.24	176.9

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