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Performance Analysis of SPWM and SVPWM Based Three Phase Voltage source Inverter

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***Abstract* :**Three phase voltage-fed PWM inverters are finding increased use in high power industrial drive applications. Various modulation techniques have been developed to obtain sinusoidal output with better harmonic quality. Among them, the space vector pulse width modulation technique provides low THD and larger under modulation range compared to sinusoidal pulse width modulation technique. A revolving reference vector is generated as voltage reference instead of three phase modulating signal in space vector based pulse width modulation technique.

Keywords : PWM, SPWM, THD

1. INTRODUCTION

A three-phase ac voltage is generated from a fixed dc voltage using a voltage source inverter (VSI) with variable magnitude and frequency. It is widely used to supply a three-phase induction motor. To obtain variable voltage and frequency various pulse width modulation schemes are used [1]. Among them two popular methods namely triangle comparison based PWM ,SPWM and space vector based PWM namely SVPWM are generally used.. To generate pulses in SPWM, three phase reference modulating signals are compared against universal triangular carrier. In SVPWM methods a revolving reference voltage vector is generated for different sectors in order generate different duty cycle. This technique ensures efficient utilization of DC bus voltage. Also less harmonic distortion is observed compared with SPWM technique [2].

2. THREE PHASE VOLTAGE SOURCE INVERTERS

2.1. Working principle

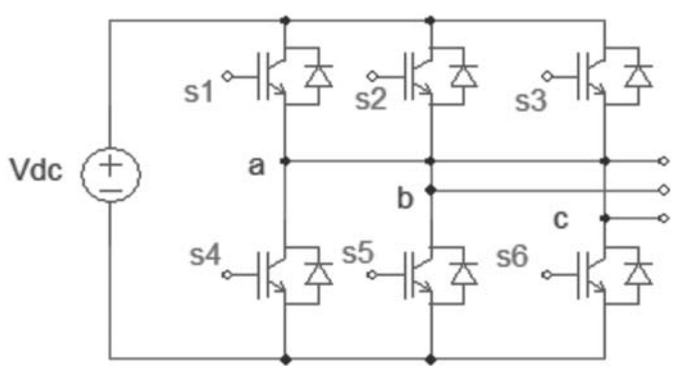

Fig. 1. Three phase voltage source inverter.

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The standard three-phase VSI topology is shown in figure 1. It is composed of six switches with freewheeling diode in parallel with each of them. By comparing the modulating waves with the carrier wave switching signals for each of the devices are obtained. Out of eight valid states, two are zero states and the remaining states, called active states produce non-zero ac output voltages. The power devices can be BJT, GTO, IGBT, etc. The working power level, switching frequency, and acceptable inverter power losses are the key factors in selecting a particular switch for the application. Two switches on the same leg cannot be closed or opened at the same time.

2.2. Pulse width Modulation Technique

In this method the on and off period of inverter switch are controlled to obtain the desired output voltage. Thereby modulating these pulses, a fixed DC voltage is converted into output controlled voltage. The advantage is that lower order harmonics can be eliminated and higher order harmonics can be filtered. The width of these pulses is so modulated that control of inverter output voltage is done and reduction in its harmonic content is achieved.

2.3. SPWM

Sinusoidal pulse width modulation (SPWM) has gained more attention in industrial applications. The modulation strategy will influence the dynamics of the system significantly. The switching can be unipolar or bipolar. In unipolar voltage switching the output voltage switches between 0 and Vdc. Three modulating signals that are 120° out of phase are used to produce load voltages. Figure.6 shows the ideal waveforms of three-phase VSI SPWM. The condition for generating switching signals is given below.

If $V_{ma} > v_{cr}$, switch S_1 on S_4 off

$$V_{an} = V_{dc}$$

If $V_{ma} < v_{cr}$, switch S_4 on and S_1 is off

$$V_{an} = 0$$

2.4. Space Vector modulation PWM

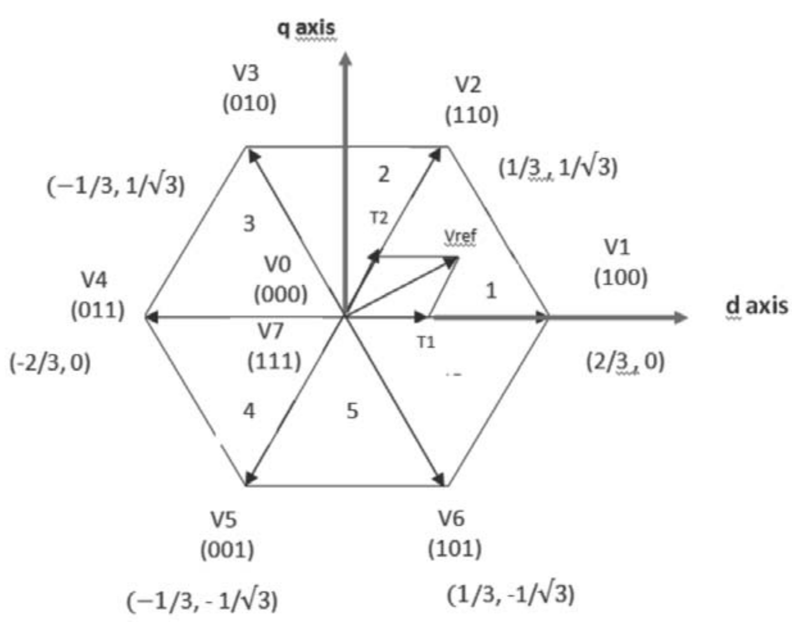

Fig. 2. Basic switching vectors and sectors

In this technique the voltage source inverter takes eight distinct states for all the switches in order to have the output current continuous. It includes six active states and two zero states. Whenever upper switch in an inverter leg is on it is denoted by state'1' and the inverter output is positive while lower switch is on the state '0' is used for the indication and the inverter terminal voltage is zero. The table 1 represents all eight possible combinations of switching states. The six active vectors v_1 to v_6 are used to represent the states which form a regular hexagon with six equal sectors. The zero vectors v_0 and v_7 lies on the center of the hexagon. The reference voltage vector v_{ref} rotates in space at an angular velocity ω. The six active voltage space vectors are shown on the same graph with an equal magnitude of v_{dc} /3 and a phase displacement of 60°. The rotating reference vector remains within the hexagon in linear region of operation. The radius of the largest circle that can be inscribed within the hexagon represents the highest output voltage of the inverter.

Table 1. Space vectors and switch states

Sl No	*Space vectors*	*Vector state*	*Switches on*	*Vector representation*
1.	$v_1^\wedge$	100	S_1, S_5, S_6	$v_1^\wedge = \frac{2}{3} v_d e^{j0}$
2.	$v_2^\wedge$	110	S_1, S_2, S_6	$v_2^\wedge = \frac{2}{3} v_d e^{j\frac{\pi}{3}}$
3.	$v_3^\wedge$	010	S_4, S_2, S_6	$v_3^\wedge = \frac{2}{3} v_d e^{j\frac{2\pi}{3}}$
4.	$v_4^\wedge$	011	S_4, S_2, S_3	$v_4^\wedge = \frac{2}{3} v_d e^{j\frac{3\pi}{3}}$
5.	$v_5^\wedge$	001	S_4, S_5, S_3	$v_5^\wedge = \frac{2}{3} v_d e^{j\frac{4\pi}{3}}$
6.	$v_6^\wedge$	101	S_1, S_5, S_3	$v_6^\wedge = \frac{2}{3} v_d e^{j\frac{5\pi}{3}}$
7.	$v_7^\wedge$	111	S_1, S_2, S_3	$v_7^\wedge = 0$
8.	$v_8^\wedge$	000	S_4, S_5, S_6	$v_0^\wedge = 0$

The duty cycle computation is done for each triangular sector formed by two state vectors. For sector 1 let T1 and T2 be the subinterval duration for active vectors V1 and V2 then time for zero voltage vector is given by

$$T_0 = T_S - T_1 - T_2$$

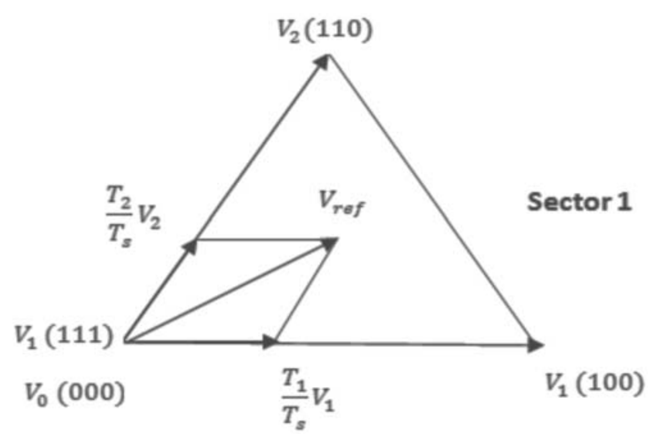

Fig. 3. Reference vector v_{ref} generation in sector 1

The figure 3 shows the reference vector generated using active state vectors v_1 and v_2. The switching pattern for sector 1 is shown below.

$$000 \rightarrow 100 \rightarrow 110 \rightarrow 111 \rightarrow 111 \rightarrow 110 \rightarrow 100 \rightarrow 000$$

The zero vector switches from state 000 to 100 for fraction of T1 duration, after which it shift to state 110 and stays for T2 duration then switches back to null vector for T0/2 duration. It happens in one subinterval of switching period. Later from V7 vector it shifts to V2 for T2 duration and then to V1 for T1 duration and back to V0 state. The figure 4a-4h represents the switch states for different sectors. For example the active vector 100 indicates the top switch of first leg of inverter is on and bottom switch of other two legs are on. When all the top switches are on it shift to state 111 while all bottom switches on indicates it is state 000. The switching sequence for various switches in sector I is given in figure 5.

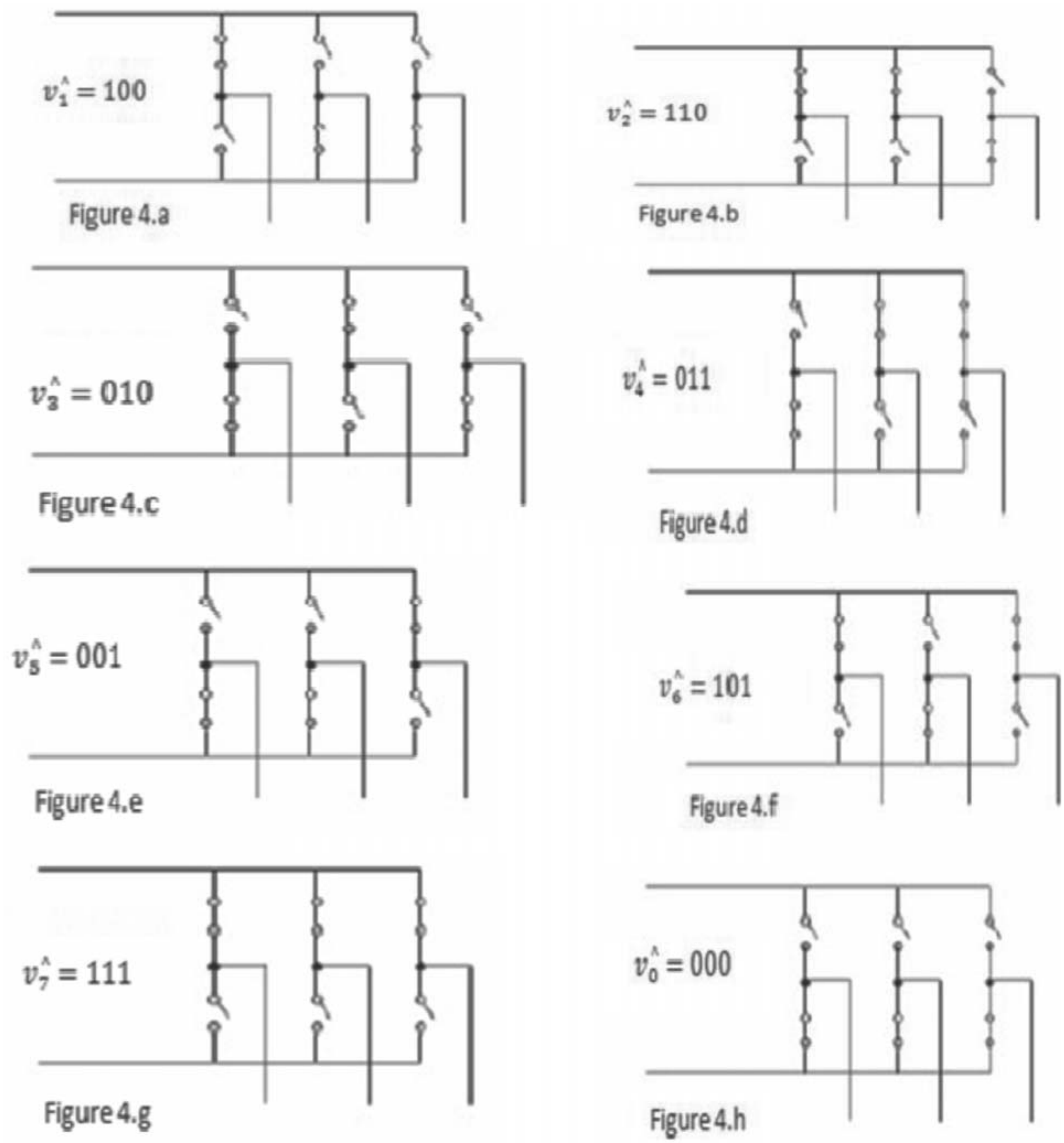

Fig. (*4a*-*4h*). Switch states for eight state vectors

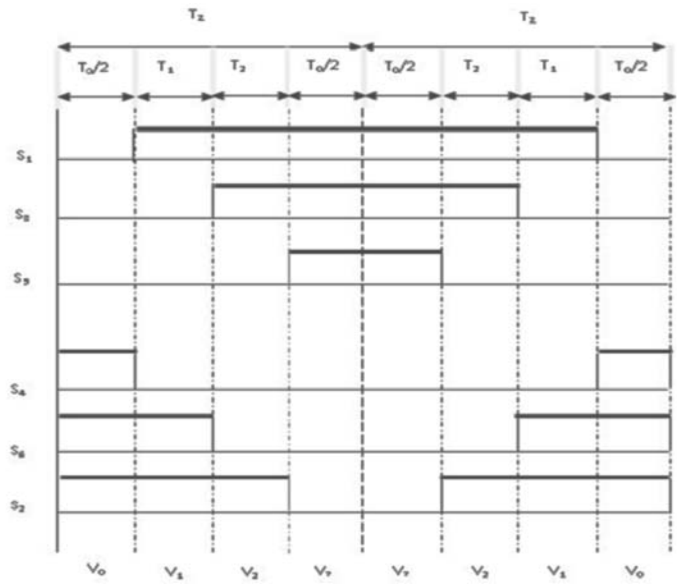

Fig. 5. Switching time for sector I

3. THE PROPOSED SYSTEM AND RESULT

The figure 6 represents the simulink diagram of three phase inverter. Figure 5 shows the three phase ac modulating signal required for SPWM technique. It is then compared with triangular carrier to generate necessary pulses to drive inverter switches. Figure 8 represents the gating pulses generated under SPWM technique.

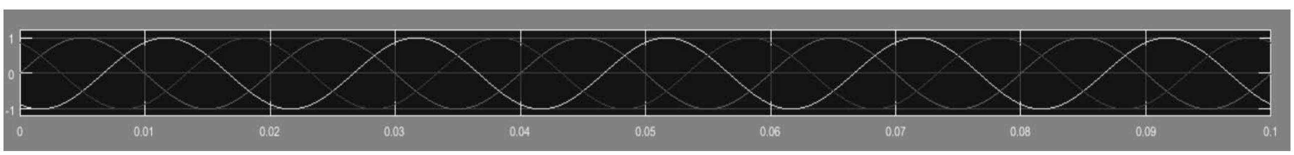

Fig. 6. Three phase signals for generation of gating pulses

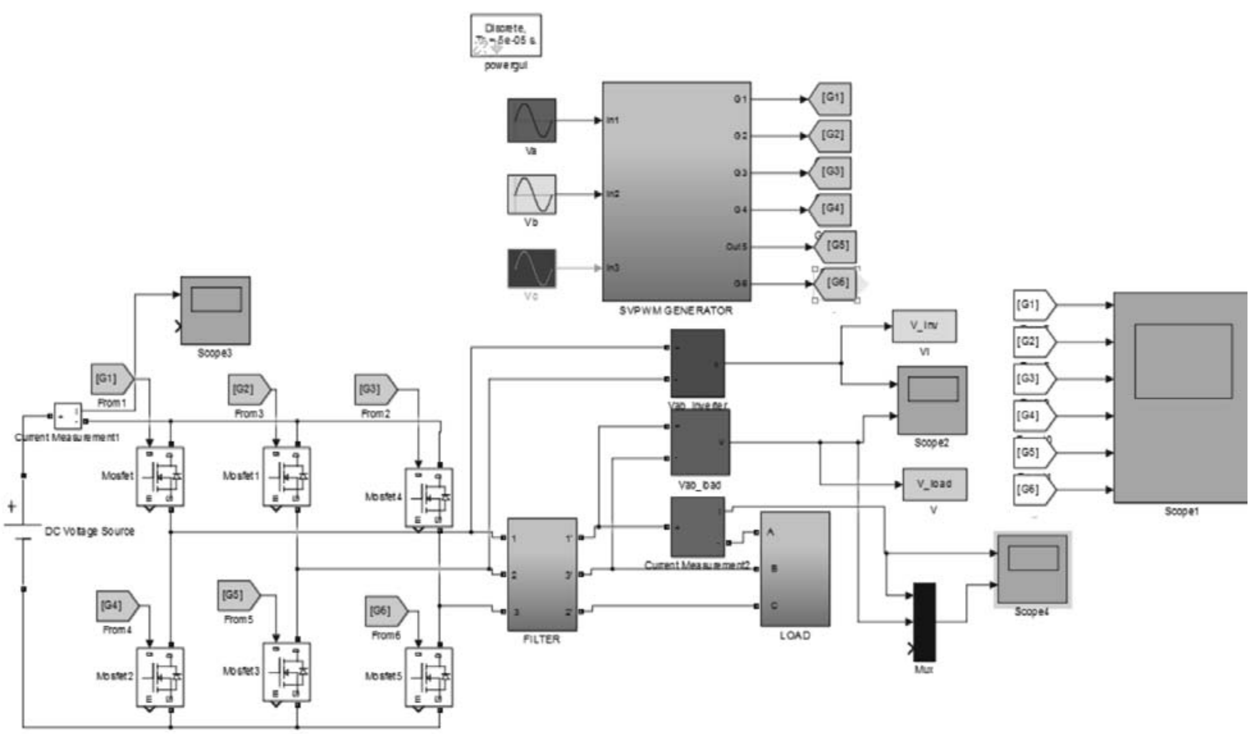

Fig. 7. Simulink diagram of three phase Inverter

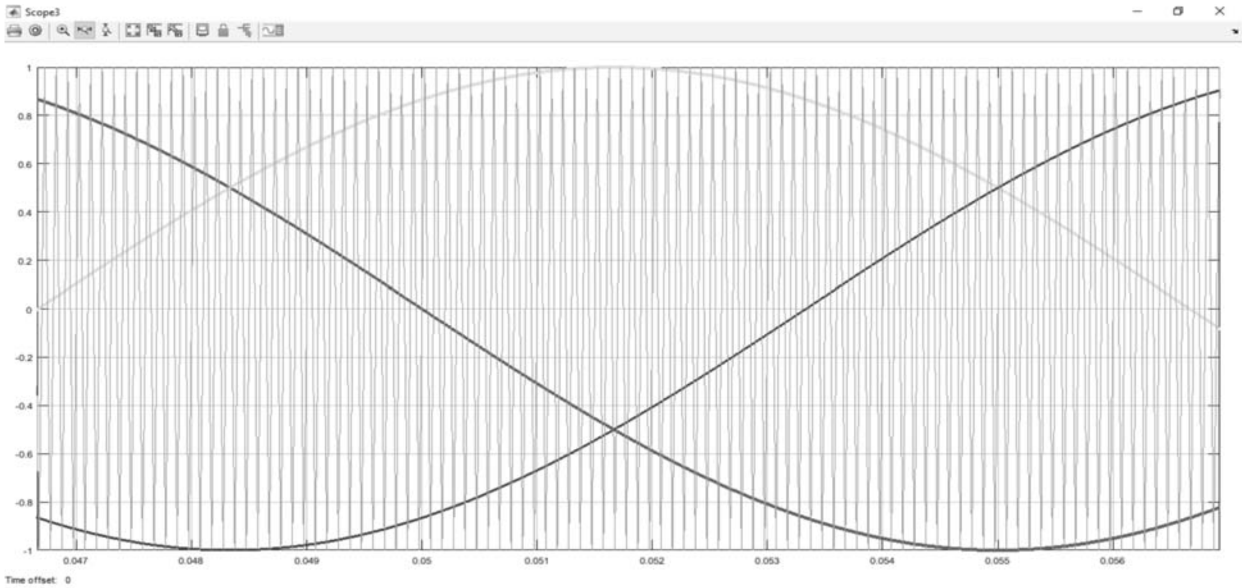

Fig. 8. Triangular carrier with three phase sine waveform

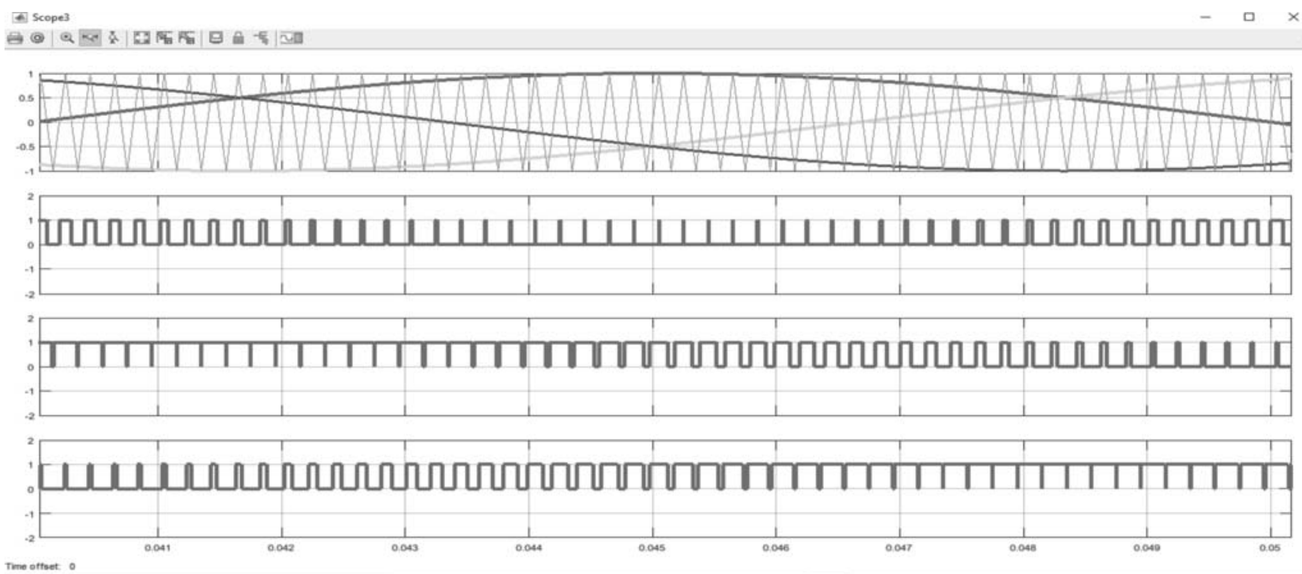

Fig. 9. Gate pulses for the upper three switches of SPWM inverter

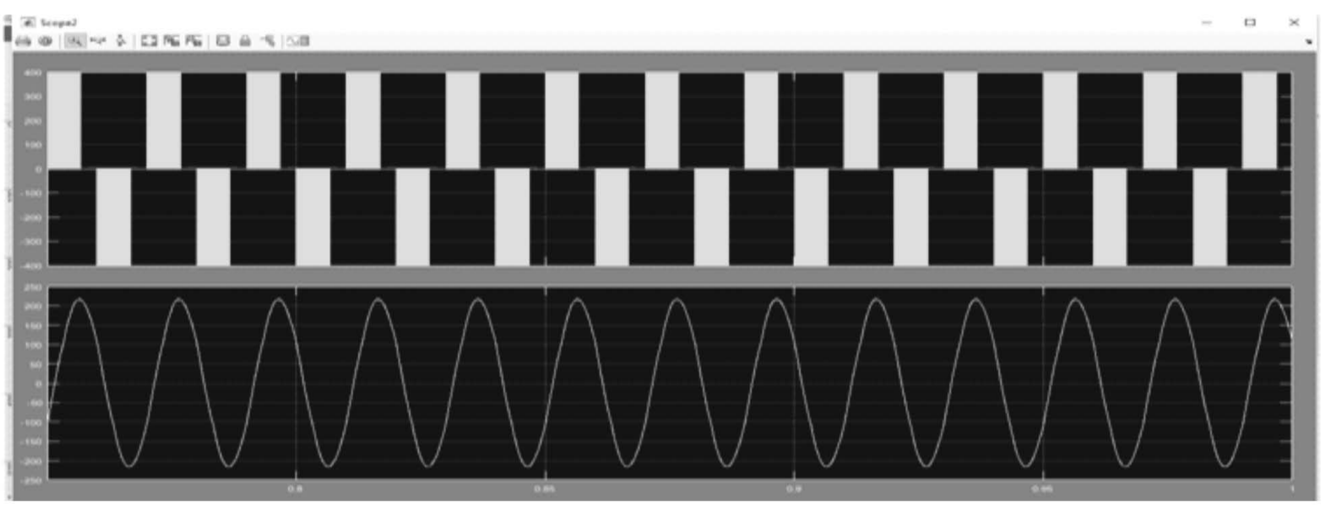

Fig. 10. Output voltage of SPWM inverter without and with filter

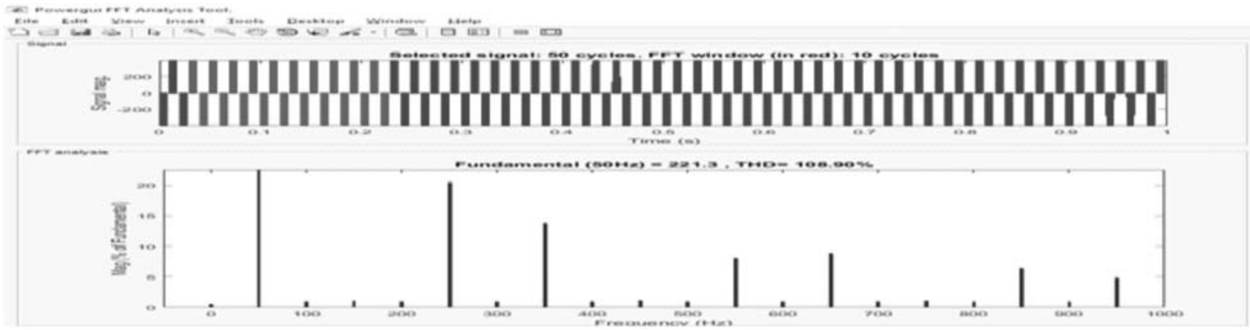

Fig. 11. FFT analysis of load voltage without filter for SPWM inverter

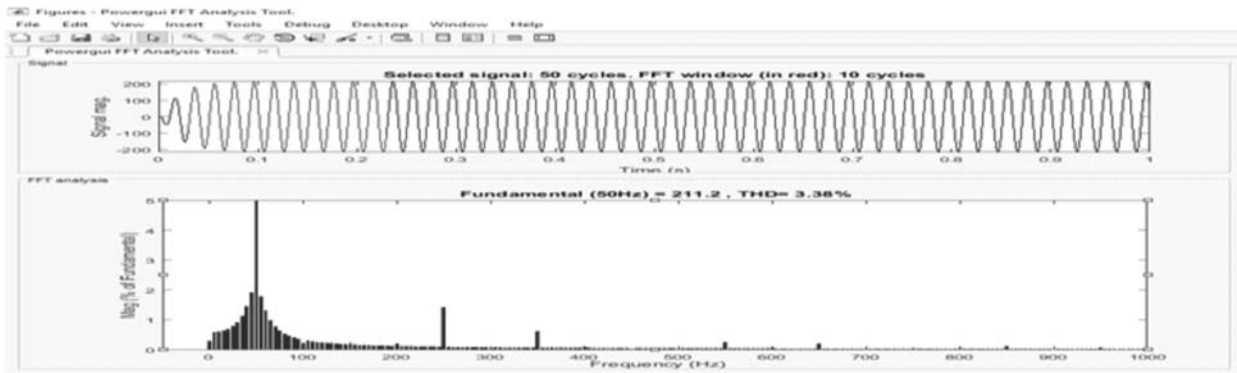

Fig. 12. FFT analysis of load voltage of SPWM Inverter with filter

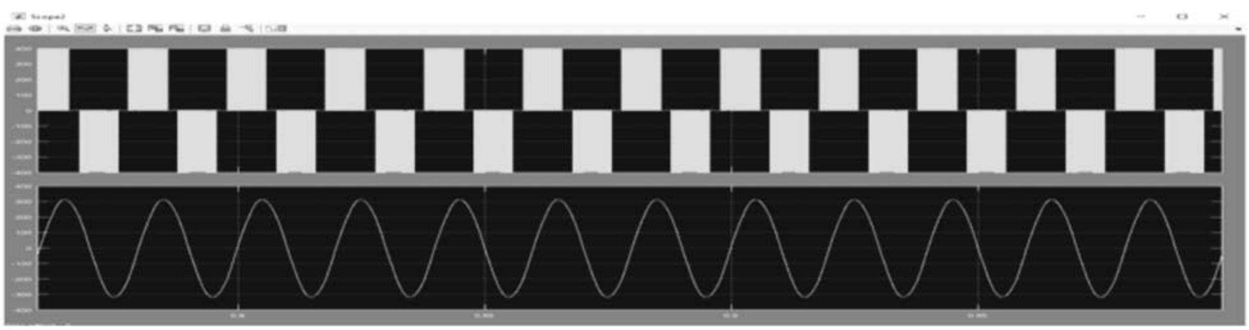

Fig. 13. Output voltage of SVPWM inverter without and with filter

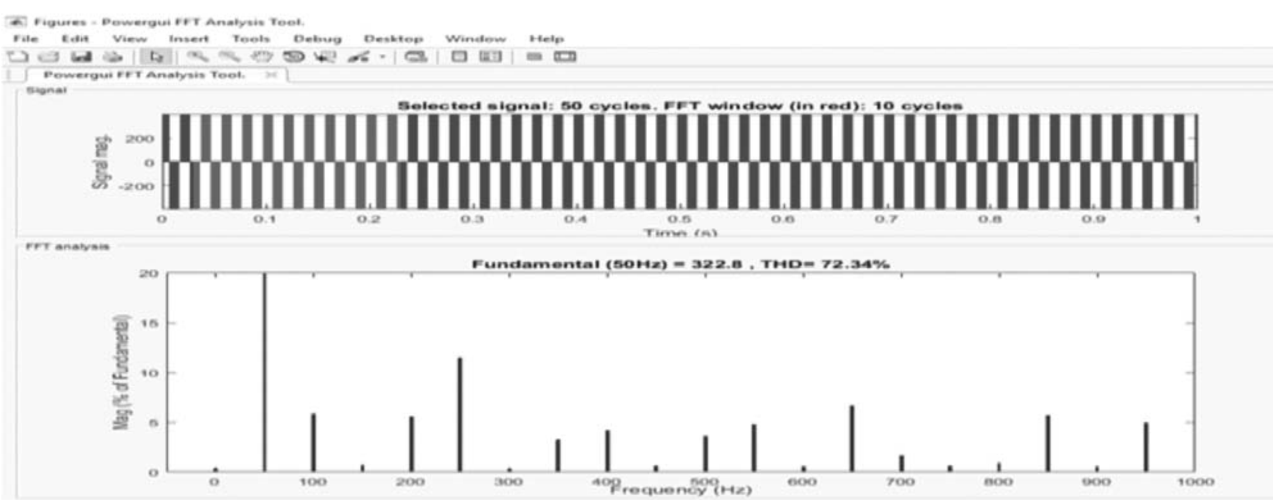

Fig. 14. FFT analysis of load voltage without filter for SVPWM inverter

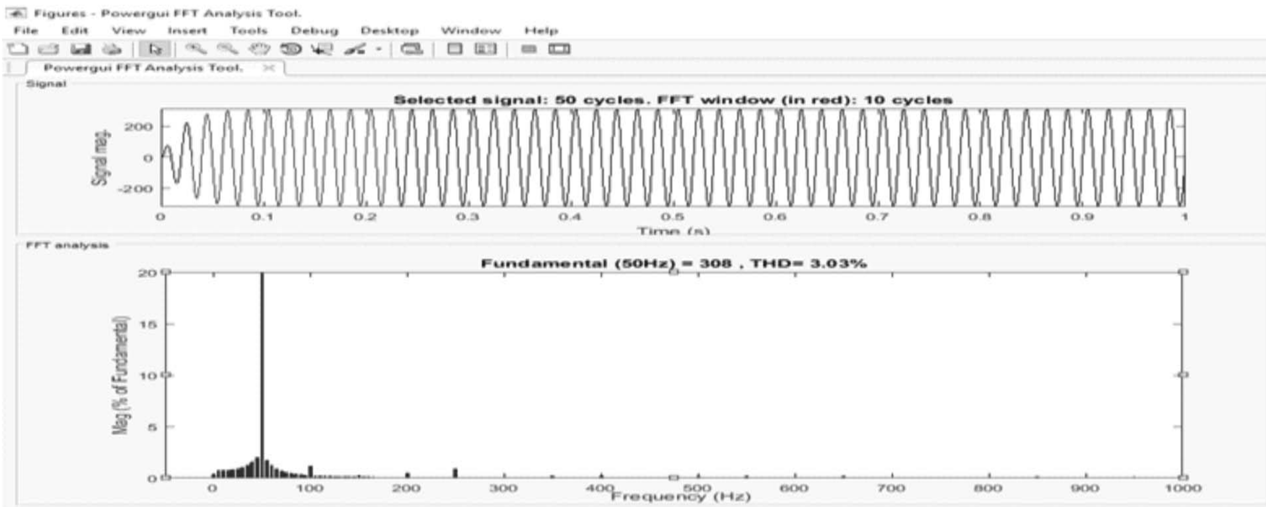

Fig. 15. FFT analysis of load voltage of SVPWM Inverter with filter

4. CONCLUSION

The system consists of a three-phase two-level PWM voltage source inverter using the DC voltage of 400V, carrier frequency of 5KHz and generated frequency of 50 Hz. The following observation is made between space vectors PWM and sinusoidal PWM. The modulation index is higher for SVPWM as compared to SPWM and the output voltage is about 15% more in case of SVPWM as compared to SPWM. Also there is reduction in THD in case when modulated using space vector technique.

5. REFERENCES

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