# SIMULATION AS AN EFFECTIVE TOOL TO COMPARE THE PERFORMANCE OF SPWM AND SVPWM FED TWO LEVEL INVERTER

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**Abstract -** *Pulse width modulation (PWM) inverters are among the most used power electronic circuits in practical application. These inverters are capable of producing ac voltage of variable magnitude as well as variable frequency. PWM inverters are most commonly used in adjustable speed ac motor drive which eliminates the need to feed the motor with variable voltage variable frequency supply. Generation of PWM can be broadly classified in to Triangular Comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM). Most commonly used TCPWM methods is sine-triangular PWM in which three phase reference modulating signal are compared against common triangular carrier signal to generate PWM signals for the three phase Inverter. In SVPWM methods, a revolving voltage vector reference is made as voltage reference instead of three phase modulating wave. SVPWM has become the significant PWM technique for three phase voltage source inverters for the control of AC Induction Motor, Brushless DC Motor, Switched Reluctance Motor and Permanent Magnet Synchronous Motor. This paper deals with the design and comparison of SPWM and SVPWM for three phase inverter in MATLAB/SIMULINK.*

***Key Words*: Voltage source inverter, Pulse width modulation, Pole voltage, Sinusoidal PWM, Space vector PWM.**

## 1. INTRODUCTION

Variable Speed Drives (VSDs) also known as adjustable speed drives, are large industrial electric motor whose speed can be adjusted by means of an external controller. AC drives are more powerful than DC drives as AC motors offers increased reliability with reduced maintenance as compared to DC motor. This is a very significant factor in favor ac variable speed drive. AC drives necessitate high power variable voltage variable frequency supply [1]. The most common solution employed for VSDs is the voltage source inverter fed AC motor there the output of the voltage source inverter is varied. The various methods for control of output voltage are: (a) External control of ac output voltage, (b) External control of dc input voltage, (c) Internal control of inverter. In external type of control, circuit becomes bulky, expensive and complex. In internal inverter control, output voltage of the inverter can be controlled within the inverter itself. The two feasible ways of doing this are (a) Series inverter control [2] (b) Pulse Width Modulation [PWM] control. 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. The PWM inverters presents many advantages [3]: High efficiency (up to 97%), low sensitivity to line transients, open-circuit protection, high input power factor, multimode application capability, small relative size, common bus regeneration, wide speed range and excellent speed regulation. This control gives better results than an external control method. For variable frequency voltage sourced inverters which can be broadly classified in to Triangular Comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM). In TCPWM methods such as sine-triangular PWM, three phase reference modulating signal are compared against common triangular carrier to generate PWM signals for the three phase Inverter. In SVPWM methods, a revolving voltage vector reference is provided as voltage reference as a replacement for the three phase modulating wave.

## 2. THREE PHASE INVERTER

The structure of three phase power inverter is shown in Fig. 1. There are six switches. These six switches can be can be power BJT, GTO, IGBT etc. There are eight valid switching states. The switches of any leg of the inverter (S1 and S4, S3 and S6 or S5 and S2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of the any leg of the inverter cannot be switched off concurrently as this will result in voltages that will depend upon the respective line current polarity. Of the eight valid states, two of them generate zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states make nonzero ac output voltages.

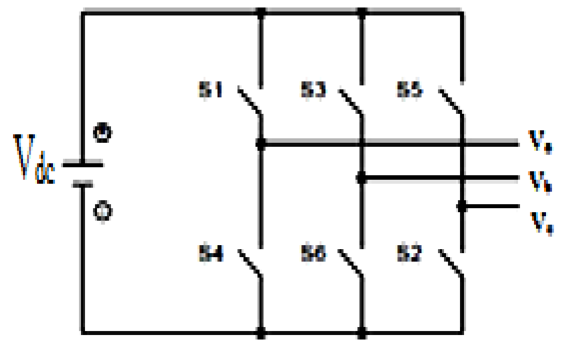



**Fig -1**: Voltage Sourced Inverter

## 3. SINUSOIDAL PWM

The Sinusoidal PWM scheme, which is represented schematically in Fig. 2, in its simplified form, involves comparison of the desired reference waveform (modulating signal) with a high frequency triangular (carrier) wave. Either the positive or negative dc bus voltage is applied at the output that depends on whether the signal voltage is smaller or larger than the carrier waveform,. The resulting chopped waveform contains a duplication of the desired waveform in its low frequency components, with the higher frequency components being at frequencies near to the carrier frequency.

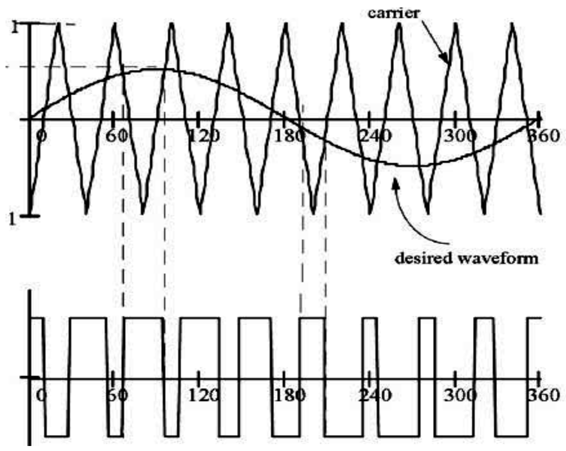



**Fig -2**: Principle of Pulse Width Modulation

## 4. SPACE VECTOR PWM

Space Vector Modulation (SVM) has been developed as a vector approach to PWM for three phase inverter. It is a most sophisticated technique for generating sine wave that provides a higher voltage to the motor with very low harmonic distortion [4]. The main aim of any modulating technique is to achieve variable output having a maximum fundamental component with minimum harmonics. SVPWM method is an advance, computation concentrated PWM method. It is perhaps the best technique for variable frequency drive application. In space vector concept, first the three phase quantity can be transformed into their equivalent two-phase quantity either in to synchronously rotating reference frame or stationary frame. From these two phase components, the reference voltage vector magnitude can be found and used for modulating inverter output [5]. The process of obtaining the rotating space vector is explained in the following sections.

Considering the stationary reference frame, let the three phase sinusoidal voltage component be

$$V_a = V_m \mathrm{Sin}(wt) \quad (1)$$
$$V_b = V_m \mathrm{Sin}(wt - (2\pi/3)) \quad (2)$$
$$V_c = V_m \mathrm{Sin}(wt - (4\pi/3)) \quad (3)$$

### 4.1 Determination of $V_d$, $V_q$, $V_{ref}$, and α

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & \frac{-1}{2} & \frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad (4)$$

$$V_{ref} = \sqrt{V_d^{\,2} + V_q^{\,2}} \quad (5)$$

$$\alpha = \tan^{-1} \frac{V_q}{V_d} \quad (6)$$

### 4.2 Calculation of switching time duration $T_a$, $T_b$, $T_0$ [6]:

$$T_a = \left[ \frac{\sqrt{3} * T_z * V_{ref}}{V_{dc}} \sin \frac{n}{3}\pi \cos\alpha + \cos \frac{n}{3}\pi \sin\alpha \right] \quad (7)$$

$$T_b = \left[ \frac{\sqrt{3} * T_z * V_{ref}}{V_{dc}} - \sin \frac{n-1}{3}\pi \cos\alpha + \cos \frac{n-1}{3}\pi \sin\alpha \right] \quad (8)$$

$$T_0 = T_z - T_a - T_b \quad (9)$$

Where $T_z = 1/f_z$ (10)

### 4.3 Switching time determination of of each transistor ($S_1$ to $S_6$) [6]:

The switching patterns of Space Vector PWM at each sector are shown in Fig. 3. There is no extra switching state needed when changing the vector as it start an end with zero vector. The even numbers travel clockwise in a sector and uneven numbers travels vice versa.

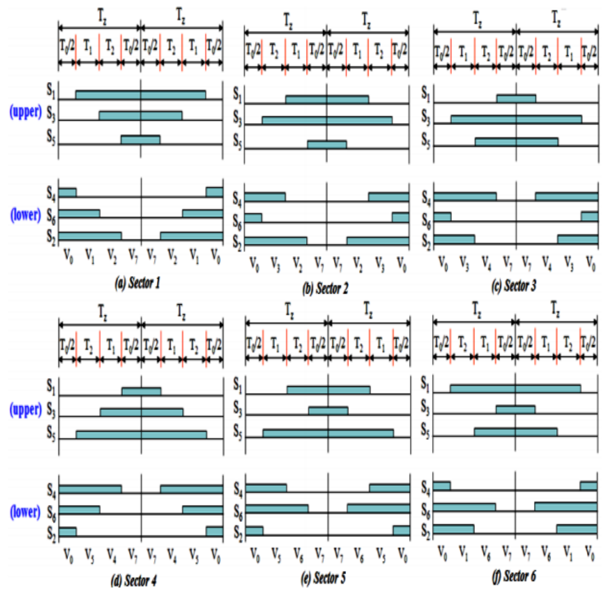



**Fig -3:** Principle of Pulse Width Modulation

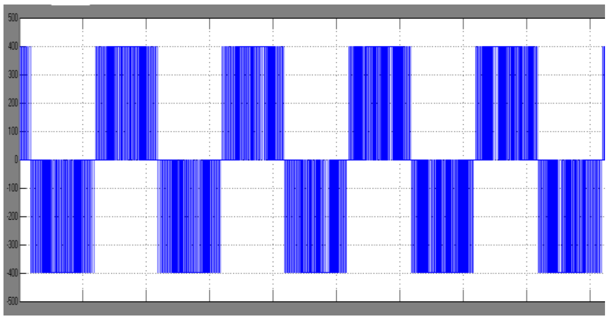
Based on Fig. 3, the switching time at each sector can be summarizes in Table 1 [6]

**Table -1:** Switching time at each sector

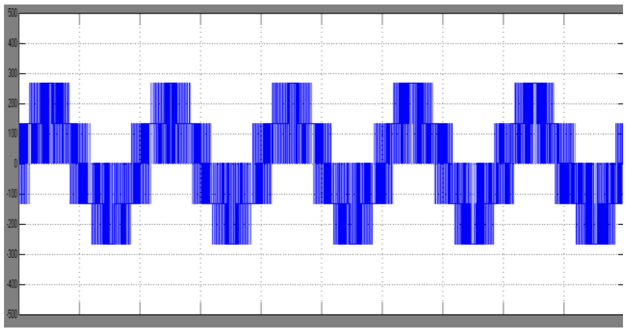
| Sector | Upper switches($S_1$,$S_3$,$S_5$) | Lower switches($S_4$,$S_6$,$S_2$) |
|---|---|---|
| 1 | $S_1 = T_1+T_2+T_0/2$<br>$S_3 = T_2+T_0/2$<br>$S_5 = T_0/2$ | $S_4 = T_0/2$<br>$S_6 = T_1+ T_0/2$<br>$S_2 = T_1+T_2+T_0/2$ |
| 2 | $S_1 = T_1+T_0/2$<br>$S_3 = T_1+T_2+T_0/2$<br>$S_5 = T_0/2$ | $S_4 = T_2+ T_0/2$<br>$S_6 = T_0/2$<br>$S_2 = T_1+T_2+T_0/2$ |
| 3 | $S_1 =T_0/2$<br>$S_3 = T_1+T_2+T_0/2$<br>$S_5 = T_2+T_0/2$ | $S_4 = T_1+T_2+T_0/2$<br>$S_6 = T_0/2$<br>$S_2 = T_1+T_0/2$ |
| 4 | $S_1 =T_0/2$<br>$S_3 = T_1+T_0/2$<br>$S_5 = T_1+T_2+T_0/2$ | $S_4 = T_1+T_2+T_0/2$<br>$S_6 = T_2+T_0/2$<br>$S_2 = T_0/2$ |
| 5 | $S_1 = T_2+T_0/2$<br>$S_3 = T_0/2$<br>$S_5 = T_1+T_2+T_0/2$ | $S_4 = T_1+T_0/2$<br>$S_6 = T_1 +T_2+T_0/2$<br>$S_2 = T_0/2$ |
| 6 | $S_1 = T_1+T_2+T_0/2$<br>$S_3 = T_0/2$<br>$S_5 = T_1+T_0/2$ | $S_4 = T_0/2$<br>$S_6 = T_1+T_2+T_0/2$<br>$S_2 = T_2+T_0/2$ |

## 5. SIMULATION RESULTS

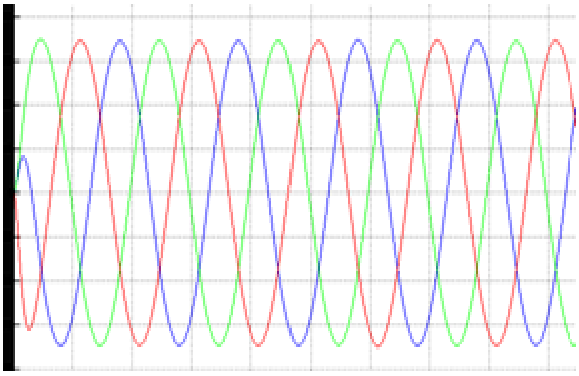
The simulation results of Sinusoidal Pulse Width Modulation of line voltage with filter and line voltage without filter, phase voltage and Total Harmonic Distortion (THD) of line voltage with and without filter are shown in Fig-4 (a) to (e). These results were compared with the simulation results of Space vector Sinusoidal Pulse Width Modulation.



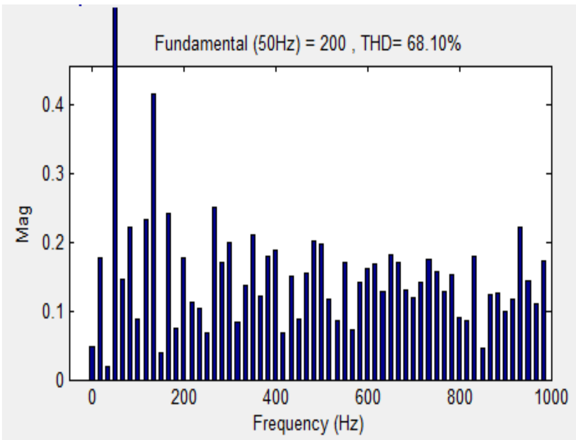
(a) Line voltage without filter



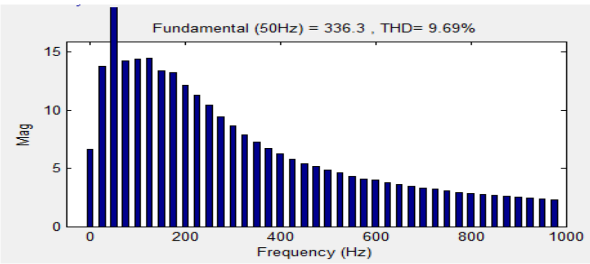
(b) phase voltage without filter



(c) Line voltage with filter

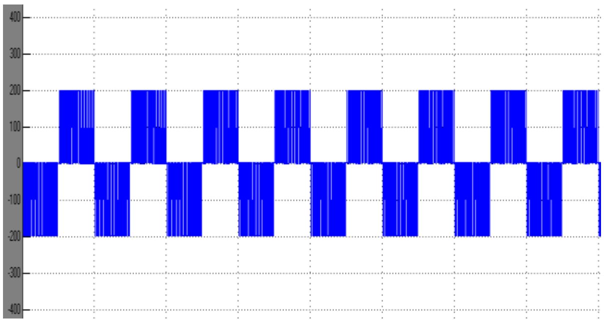



(d) THD of line voltage without filter

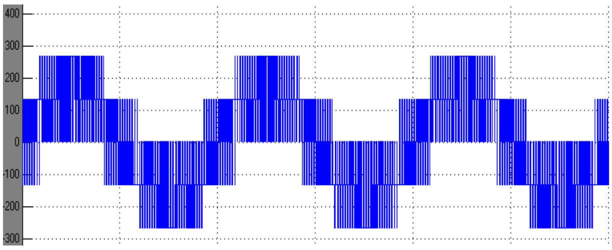



(e) THD of line voltage with filter

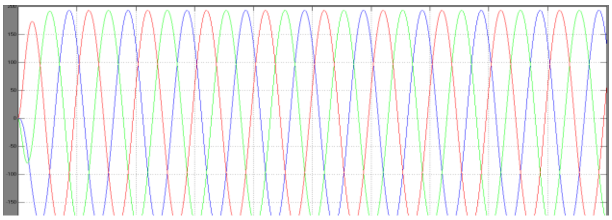
Fig- 4: Simulation results of SPWM



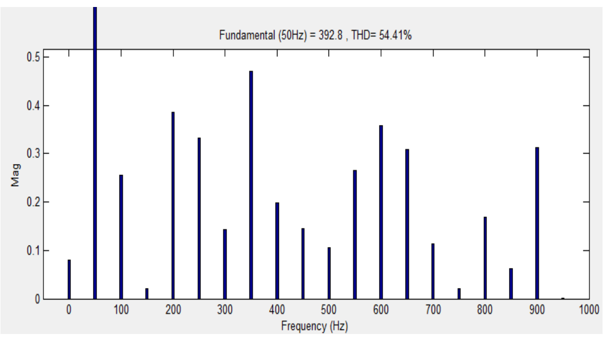
(a) Line voltage without filter



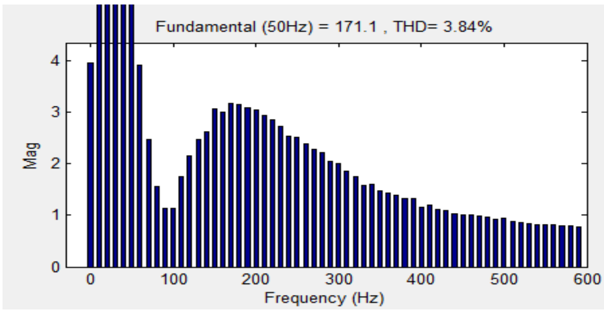
(b) Phase voltage without filter



(c) Line voltage with filter




(d) THD of line voltage without filter




(e) THD of line voltage with filter

Fig- 5: Simulation results of SVPWM

## 6. CONCLUSION

In this paper, voltage source inverter using two different PWM techniques, *i.e*, SPWM and SVPWM are designed and analyzed using MATLAB tools and it was observed that SVPWM is having advanced performance because of less THD. SVPWM make use of advance technique to reduce THD. The switching losses can also be reduced with the help of SVPWM due to the changing of any one switching state which result one single phase voltage alter every time. Thus it can be concluded that SVPWM technique is having higher efficiency and greater performance as compared to SPWM technique.

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