

Performance Evaluation of Multilevel Inverter Using SVPWM Technique

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ABSTRACT: Multilevel inverters have been widely used in medium and high voltage applications. The general function of the multilevel inverter is to synthesize a desired AC voltage from several levels of DC voltages. As the number of voltage level increases, the harmonic content decreases significantly. Different modulation techniques have been proposed to control the multilevel inverter. This paper presents switching strategies for multilevel inverters based on space vector PWM (SVPWM) and sine-triangle PWM (SPWM). The study of space vector modulation technique reveals that it utilizes DC bus voltage more efficiently, generates less harmonic distortion and improves harmonic performance when compared with Sinusoidal PWM (SPWM) technique. The main objective of this study is to reduce total harmonic distortion and comparison of THD. In this paper a model for Space vector PWM is made and simulated using MATLAB/SIMULINK software and its performance is compared with Sinusoidal PWM.

KEYWORDS: Space vector PWM, Sine triangle PWM, Harmonics, Total harmonic distortion

I. INTRODUCTION

DC power can be converted into AC power at desired output voltage and frequency by using a power electronics device called as Inverter. Depending on voltage levels of the output voltage waveforms, the inverters can be classified as Two-level inverters and Multi-level inverters. The inverters with voltage level 3 or more are referred as Multi-level inverters. These multilevel inverters are used to increase inverter operating voltage, to increase power ratings, to minimize THD with low switching frequency and to reduce EMI due to lower voltage steps[1]. Multilevel approach has several advantages such as good power quality, good electromagnetic compatibility, low switching losses and high capability.

Pulse width modulation (PWM) control strategies concerns about the development of new techniques to reduce the total harmonic distortion (THD). PWM techniques can be broadly classified into two categories depending on the method of switching signal generation namely Sine triangle PWM (SPWM) and Space Vector PWM (SVPWM).

Though the principle of five-level SVPWM is similar to that of three-level SVPWM, the five-level SVPWM algorithm is complicated compared to two-level inverters and three-level inverters due to more number of switching states.

II. SPWM

The most common PWM approach is sinusoidal PWM. In this method a triangular wave is compared to a sinusoidal wave of the desired frequency and the relative levels of the two waveforms is used to control the switching of devices in each phase leg of the inverter[2]-[4].

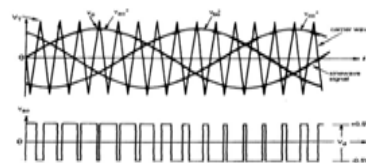
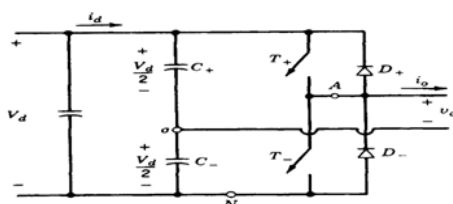


FIGURE 1: Single leg of inverter FIGURE 2: Generation of pulses

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III. SVPWM

Space Vector Modulation (SVM) was originally developed as vector approach to Pulse Width Modulation (PWM) for three phase inverters [5]. It is a more sophisticated technique for generating sine wave that provides a higher voltage to the motor with lower total harmonic distortion. The main aim of any modulation technique is to obtain variable output having a maximum fundamental component with minimum harmonics[5]-[6]. Space Vector PWM (SVPWM) method is an advanced computation intensive PWM method and possibly the best techniques for variable frequency drive application [5].

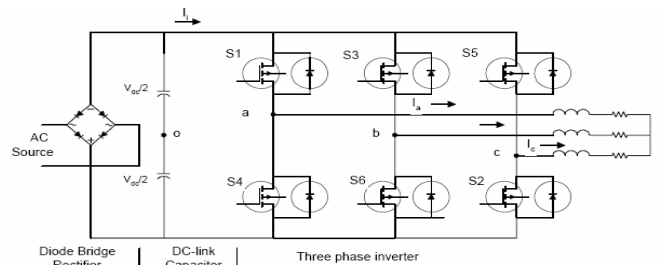


FIGURE 3: Two level inverter

IV PRINCIPLES OF SVPWM

SVPWM is based on the fact that there are only two independent variables in a three-phase voltage system. We can use orthogonal coordinates to represent the 3- phase voltage in the phasor diagram. The task of SVM is to use the combinations of switching states to approximate the locus of V_{ref} , the eight possible switching states of the inverter are represented as two null vector vectors and six active vectors as listed in the Table 1.

TABLE I.
SWITCHING STATES OF THE TWO LEVEL INVERTER

Space vector	Switching State	'On' Switches
Zero Vector	V_7	1,3,5
	V_0	4,6,2
Active vector	V_1	4,6,5
	V_2	4,3,2
	V_3	4,3,5
	V_4	1,6,2
	V_5	1,6,5
	V_6	1,3,2

These vectors ($V_1 \sim V_6$) can be used to frame the vector plane, which is illustrated in Fig: 4. The rotating reference vector can be approximated in each switching cycle by switching between the adjacent active vectors and the zero vectors. In order to maintain the effective switching frequency at a minimal value, the sequence of the toggling between these vectors is organized in such a way that only one leg is affected in every step. For a given magnitude and position V_{ref} , can be synthesized by three nearby stationary vectors, based on which, the switching states of the inverter can be selected and gate signals for the active switches can be generated. When V_{ref} , passes through sectors one by one, different sets of switches will be turned on and off. As a result, when V_{ref} rotates one revolution in space, the inverter output voltage varies one cycle over time.

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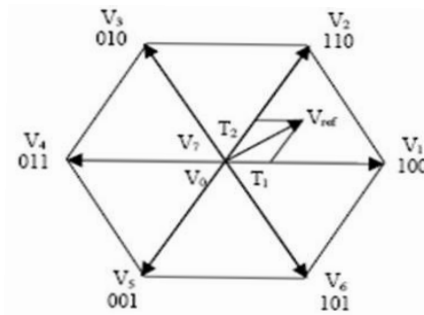


FIGURE 4:vector plane

Three stationary vectors can synthesize the reference V_{ref} . The dwell time for the stationary vectors essentially represents the duty-cycle time (on-state or off-state time) of the chosen switches during a sampling period T_s of the modulation scheme. The dwell time calculation is based on, "volt-second balancing" principle, that is, the product of the reference voltage V_{ref} and sampling period T_s equals the sum of the voltage multiplied by the time interval of chosen space vectors. For example, when V_{ref} falls into sector I as shown in Fig: 2, it can be synthesized by V_1 , V_2 and V_0 . The volt second balance equation is

$$V_{ref} T_s = V_1 T_0 + V_2 T_b + V_0 T_a$$

$$T_s = T_a + T_b + T_c$$

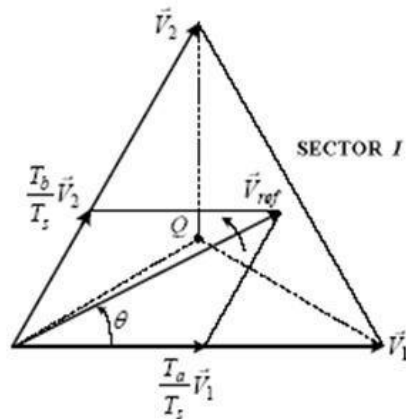


FIGURE.5. V_{ref} synthesized by V_1 , V_2 and V_0

For linear modulation range, the dwell times can be calculated as:

$$T_a = T_s V_{ref} / V_d \sin(\theta) \quad T_b = (T_s V_{ref} / V_d) \sin(\theta - 60^\circ) \quad T_0 = T_s - T_a - T_b$$

$$T_0 = T_s - T_a - T_b$$

The SIMULINK Implementation of the system has been carried out in the following sequence:

- Calculation of 3 phase voltages (MATLAB Fcn is used)
- Calculation of V_α and V_β (3 phase to 2 phase transformation block is used)
- Calculation V_{ref} and α (Polar to Rectangle block is used. The inputs to this block are V_α and V_β and outputs of this block are V_{ref} and α .)
- Calculation of T_a , T_b , T_0 (Sub-system is shown in Fig.9)
- Calculation of sector value

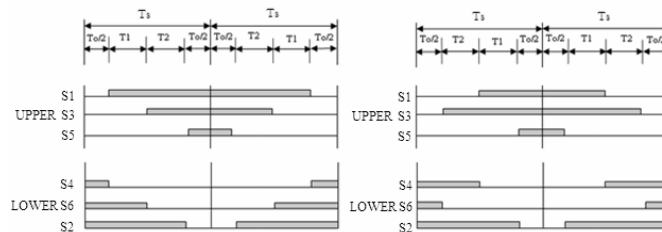
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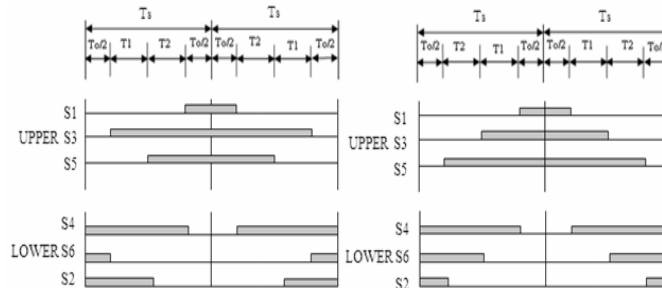
Vol. 4, Special Issue 13, December 2015

- Calculation cumulative sum of Ta, Tb, T0 (Sub-system is shown in Fig. 10)
- Calculation of Tn (Sub-system is shown in Fig. 11)
- Determination of switching states (look-up table is used)
- Realization of switching states (multi-port switch is used)
- Derivation of 6 individual gate pulses to two level Inverter

SWITCHING TIME CALCULATION AT EACH SECTOR



(a)SVPWM Switching Pattern at Sector 1 and 2



(b)SVPWM Switching Pattern at Sector 3 and 4

(c)SVPWM Switching Pattern at Sector 5 and 6

FIGURE: 6(a), (b), (c) Space Vector PWM switching patterns at each sector

V. SIMULATION RESULTS TABLE

2: Simulation parameters

The multicarrier waves that are more than one triangular wave are compared with the sine wave at the desired frequency. When the value of reference signal is more than modulation waveform, the PWM is in high state, otherwise it is in low state.

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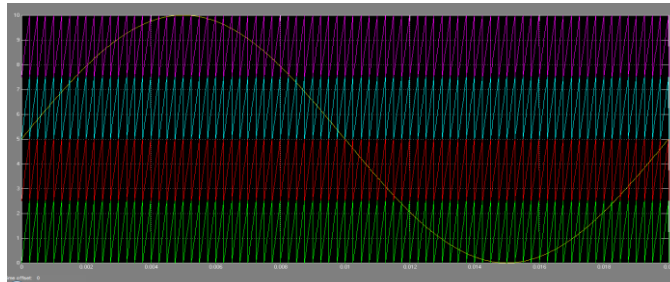
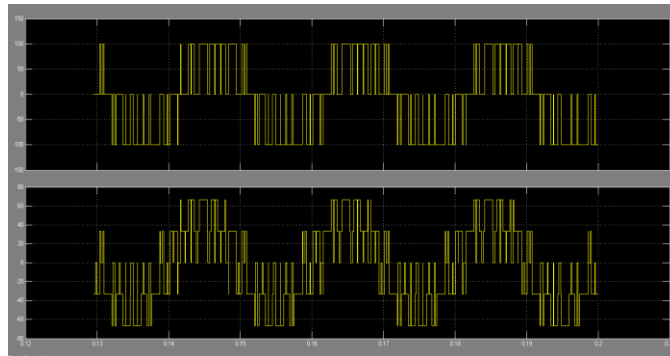


FIGURE 7: Multicarrier sinusoidal PWM

The pulses so formed is used to control the switching devices. Two level inverter is modelled in the MATLAB SIMULINK environment. Fig7 shows the result of two level 3 phase inverter using PWM technique. Under the simulation parameters shown in table2 two level inverter is simulated. simulation results shows that it has THD of 67%.



As the voltage level increases the harmonic content decreases significantly. Simulation results shows that 5 level three phase multilevel inverter has a THD of 17.95% which is comparatively less than the two level inverter. Fig 8 shows the simulation result of 5 level inverter.

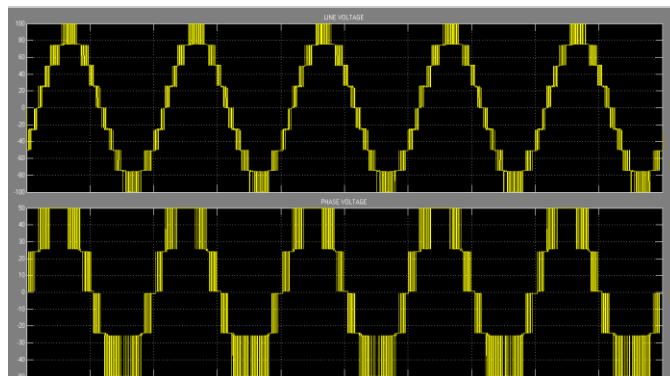


FIGURE 9: Five level multilevel inverter using SPWM

THD of seven level three phase multilevel inverter is found to be very less when compared to 2 level inverter. It is only 9.12%. Fig9 shows seven level inverter using SPWM technique.

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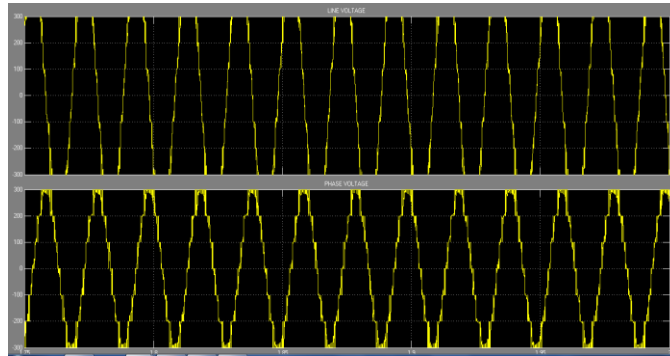


FIGURE 10: Seven level multilevel inverter using SPWM

SVPWM:

2-level and 5-level inverter was modeled in MATLAB SIMULINK environment using SVPWM technique. Fig 11 shows the pulses given for the 2-level inverter.

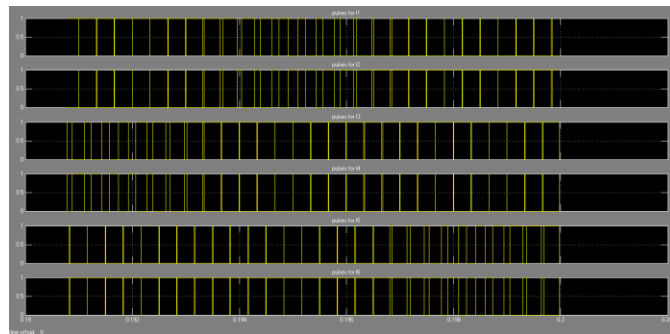


FIGURE 11: pulses for two level inverter using SVPWM technique

SVPWM is an advanced technique. The voltage waveform resulting after simulation of 2-level and 5-level inverter using SVPWM is shown in the fig 12 and fig 14.

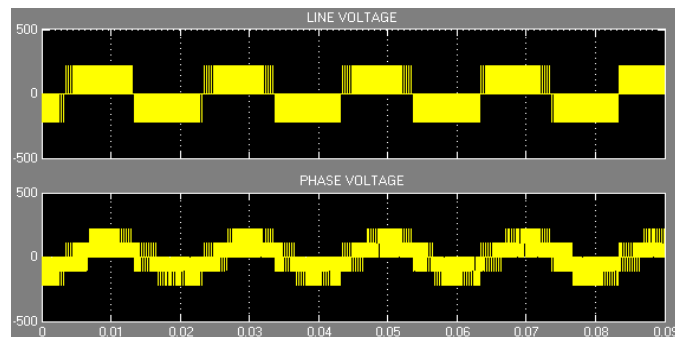


FIGURE 12: 2 level inverter using SVPWM

Total harmonic distortion is found to be less when compared to conventional modulation techniques like SPWM. Here THD is found to be 46.02%, which is less when compared to SPWM of 2-level inverter similarly 24.76% for 5-level inverter.

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Vol. 4, Special Issue 13, December 2015

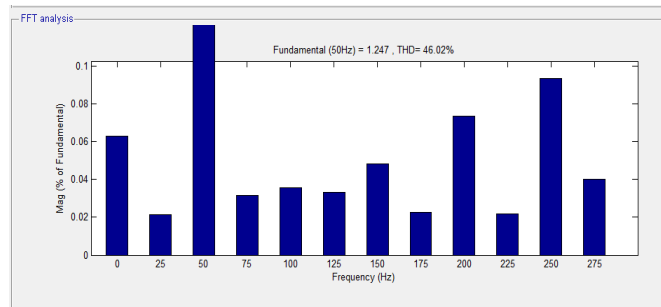


FIGURE 13: FFT analysis of 2-level inverter.

FIGURE 14: 5 level inverter using SVPWM

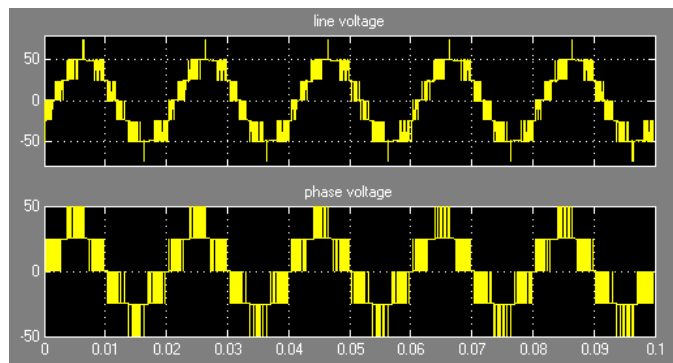
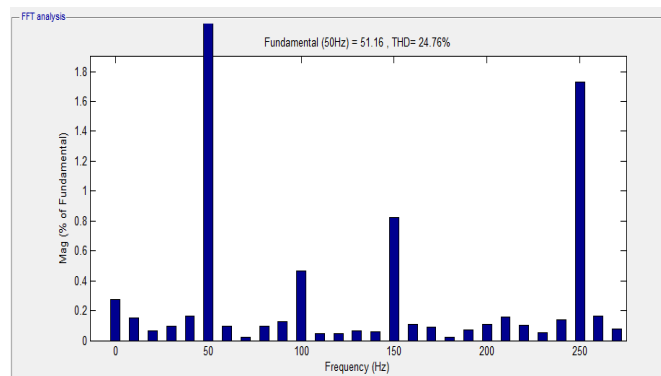


FIGURE 15: FFT analysis of 5-level inverter.

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Vol. 4, Special Issue 13, December 2015

THD COMPARISON:

TABLE 2: Comparison of THD

INVERTER	SPWM	SVPWM
2-level	67.2	46.02
5-level	42.8	24.76

VI. CONCLUSION

The theory of the space vector based PWM and sinusoidal PWM method is explained. In this paper, space vector modulation technique and SPWM technique for multilevel inverter has presented. Simulations in various conditions have been made with the help of the MATLAB-SIMULINK® programming environment. The experimental results are presented for multilevel inverters and the performance of the models is verified. The simulation study reveals that Space vector PWM utilizes dc bus voltage more effectively and generates less THD when compared with sine PWM.

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