Australian Journal of Basic and Applied Sciences, 9(35) November 2015, Pages: 130-135

ISSN:1991-8178

Australian Journal of Basic and Applied Sciences

Journal home page: www.ajbasweb.com

A Comparative Approachof Pwm and Svpwm Control for Nine Switch Inverter

[1]M.Nirmala, [2]Dr.k.Baskaran and [3]K.Saranya

[1,2]*Electrical and Electronics Engineering, Kumaraguru college of technology, India,*
[2]*Electrical and Electronics Engineering, Government College of Technology,Coimbatore, India.*
[3]*Electrical and Electronics Engineering, Kumaraguru college of technology, India,*

ARTICLE INFO

Article history:
Received 10 October 2015
Accepted 30 November 2015
Available online 24 December 2015

Keywords:
Induction motor drive, Nine switch inverter, PWM, space vector PWM, Total harmonic distortion

ABSTRACT

Inverters are used as DC/AC converters to control frequency and amplitude of the voltage applied to ac loads. There are many applications where two or more ac loads require independent control. Hence a nine-switch three leg inverter is capable of generating six phase output voltage (two groups of three phases) from the single common dc bus is proposed. The proposed configuration is used to give a steady output voltage to the AC machines with low complexity, high reliability and high efficiency. In this paper, the comparison of PWM and SVPWM switching techniques used for this inverter topology are discussed and for the implementation of the proposed drive the MATLAB/SIMLINK environment has been used. The performance of the inverter is verified in terms of waveforms developed by the motor.

To Cite This Article: M.Nirmala, Dr.k.Baskaran and K.Saranya., A Comparative Approachof Pwm and Svpwm Control for Nine Switch Inverter. ***Aust. J. Basic & Appl. Sci.,*** *9(35): 130-135, 2015*

INTRODUCTION

In many applications such as variable-speed wind-energy conversion system (Chinchilla, M., 2006) and hybrid electric vehicles (Ali Emadi, 2006; Oak Ridge National Laboratory, 2005), two inverters are used for power conversion. In these applications, two AC loads are connected to a common DC bus through the inverters. While 12 semiconductor switches are needed for implementation of two inverters, several integrated dual output inverters have been proposed by researchers to reduce size and cost of power converters in these applications. Five leg inverter with ten semiconductor switches is an example of integrated converters (Jones, M., 2008). In, another dual-output inverter including only nine switches was proposed for control of two motors independently (Kominami, T. and Y. Fujimoto, 2007) (Fig. 1). This nine-switch inverter (NSI) have been proposed to reduce the cost and size of converters. Nine switch inverter (Dehghan, S.M., 2010; Liu, C., 2009) consists of three legs and nine switches. It consists of higher, middle and lower switches. The higher switches are used to supply first motor, the lower switches are used to supply second motor. The middle switches are shared between both the motors. Based on the supply used the nine switch inverters are used in various applications. The nine switch inverter is used as an AC/AC converter (Liu, C., 2009; Congwei, L., 2009) which has the advantages such as sinusoidal steady inputs and outputs, unity power factor and low cost due to less number of semiconductor switches. The performance of nine switch inverter can be improved by using space vector width modulation (Dehghan, S.M., 2010). The modulation of carrier and reference signal is used to produce pulse width modulated output. The closed loop speed control method will provide steady speed even in the unstable range.The main problems faced are about the reduction of harmonic content in inverter circuits. The conventional square wave inverter used in low or medium power applications suffers from a serious disadvantage such as lower order harmonics in the output voltage. One of the solutions to enhance the harmonic free environment in high power converters is to use PWM control techniques.PWM switching strategies not only addresses the primary issues viz, less THD, effective dc bus utilization etc but also take care of secondary issues like EMI reduction and switching loss. Real-time method of PWM generation can be broadly classified into Triangle comparison based PWM (TCPWM) and Space Vector based PWM (SVPWM). In SVPWM methods, the voltage reference is provided using a revolving reference vector. In this case magnitude and frequency of the fundamental component in the line side are controlled by the magnitude and frequency, respectively, of the reference voltage vector. Space

Corresponding Author: M.Nirmala, Electrical and Electronics Engineering, Kumaraguru college of technology, India
E-mail: sarakaran10@gmail.com.

vector modulation utilizes dc bus voltage more efficiently and generates less harmonic distortion.

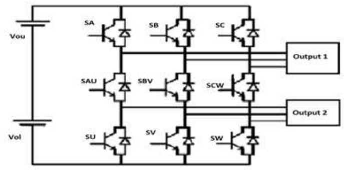

Fig 1: Nine Switch Inverter topology.

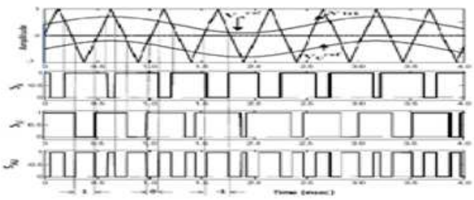

Fig.2: Reference signal for inv1 ,inv 2 and carrier signal.

II. Nine Switch Inverter Operation:

2.1Basic Structure:

The structure of the *nine-switch inverter* is presented in Figure 1. This consists of two three-phase inverters combined with three common switches (SAU, SBV, and SCW). The upper portion in Fig. 1 is called *Inv1*, and the lower part is called *Inv2*. The *Inv1* consists of switches SA, SB, SC, SAU, SBV, and SCW and *Inv2* consists of the switches SAU, SBV,SCW, SU, SV and SW. The balanced loads are supplied from these inverters.

2.2Method of PWM Realization:

The conventional triangular carrier based PWM method is adopted for upper and lower inverter. The two sinusoidal reference signals are required for controlling the output voltages of this inverter.The pulse width modulation of *Inv1* is obtained at the upper part of a triangular wave, and the pulse width modulation of *Inv2* is calculated at its lower part, as shown in Fig. 2. Let voltage reference for *Inv1* is V_{Aref} and reference for *Inv2* is V_{uref}. Assume that V_{Aref} and V_{uref} are given by

$$V_A^{ref} = A_1\sin(2\pi f_1 t + \varphi_1)$$

$$V_U^{ref} = A_2\sin(2\pi f_2 t + \varphi_2)$$

where*A1*, *A2* are amplitudes, *f1*, *f2*, are frequencies, and φ_1 , φ_2 are phase angle.

The gating signal for the switch SA is generated by comparing reference signal (V_{Aref}) with the upper half of the triangular waveform. Similarly, by comparing lower reference signal (V_{uref}) with lower half of the triangular waveform to get the pulse for switch SU. The modulation for upper inverter is in the range 0 to 1 while for lower inverter it is from 0 to -1. The gating signal for the middle switches is obtained by XOR operation of the two signals obtained from upper and lower switch.

III. Carrier Based Pwm Method:

The carrier based PWM control method for a nine-switch inverter is shown in Fig. 3. Thereare two reference signals for every phase. The upper and lower reference signals are related to upper and lower outputs respectively. The gate signal for the upper switch of a leg is generated by comparing the carrier signal and the upper reference signal of the corresponding phase (*VrefUJ*).Similarly, the gate signal for lower switch is generated from the carrier signal and lower reference signal of the related phase (*VrefLJ*). The gate signal for mid switch is generated by the logical XOR operation of the upper and lower switches. With this method, in each inverter leg, two switches are always ON. Fig. 4 shows carrier based PWM method switching vectors. There are six vectors in each switching cycle for both outputs: two non-zero vectors, one zero vectors (000), two none-zero vectors and one zero vector (111) {two active – short zero (000) – two active – long zero (111)}. When one of the outputs have an active or short zero (000) vector, the other output has long zero (111) vector.

IV. Svpwm For Nine- Switch Inverter:

The combination of switching vector of both outputs in Fig.4 creates a specific sequence as shown in Fig. 5. This sequence is used to design SVM method. There are 12 vectors in each switching cycle: two upper active (*VAU*) ,zero (*VZ*): two upper active (*VAU*) , zero (*VZ*) ; two lower active (*VAL*),zero (*VZ*); two lower active (*VAL*),zero (*VZ*)}. Other switching vectors are listed in TABLE I. The vectors *V1-V6* are upper active vectors. In these vectors, the upper output is in active state, and the lower output is in zero state. There is an inverse logic in lower active vectors (*V7-V12*). In zero vectors

(*V13-V15*), both outputs are in zero state. An inverter leg may be in {1}, {0} or {-1} states. The state of semiconductors in these states is illustrated in TABLE II.

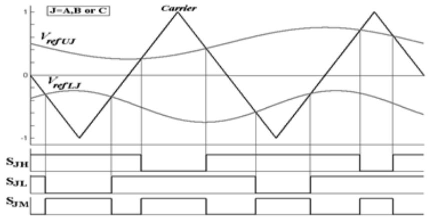

Fig. 3: Carrier based PWM method for nine-switch inverter.

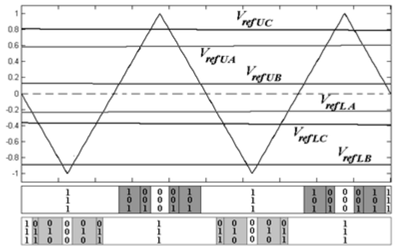

Fig. 4: Carrier based PWM method switching vector.

TABLE I
SVM SWITCHING VECTORS

Vector	Leg A	Leg B	Leg C	Type
1	1	0	0	Upper Active
2	1	1	0	Upper Active
3	0	1	0	Upper Active
4	0	1	1	Upper Active
5	0	0	1	Upper Active
6	1	0	1	Upper Active
7	-1	1	1	Lower Active
8	-1	-1	1	Lower Active
9	1	-1	1	Lower Active
10	1	-1	-1	Lower Active
11	1	1	-1	Lower Active
12	-1	1	-1	Lower Active
13	1	1	1	Zero
14	0	0	0	Zero
15	-1	-1	-1	Zero

TABLE II
STATE OF SWITCHES IN TABLE 1 VECTORS.

	S_{JU}	S_{JM}	S_{JL}
1	ON	OFF	ON
0	OFF	ON	ON
-1	ON	ON	OFF

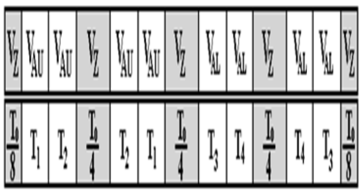

Fig.5: SVM switching vector sequence.

Australian Journal of Basic and Applied Sciences, 9(35) November 2015, Pages: 130-135

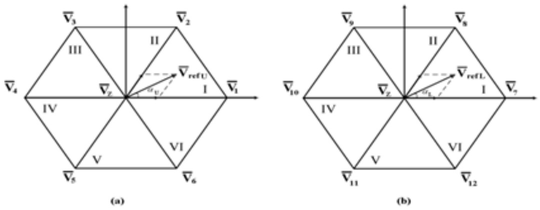

Fig.6: Space vector diagrams for nine switch inverter: a) Upper output, b)Lower output.

To determine correct active vectors, two space vector diagrams are proposed as shown in Fig. 6. The diagram (a) and (b) are used to determine the upper and lower activevectors respectively. The SVM active vectors are determined with regard to location of the upper reference signal (*VrefU*) in the diagram (a) and the lower reference signal (*VrefL*) in the diagram (b). The reference signals for the upper and lower outputs are defined as:

Vref U =Vref U∠<U (1)

Vref L = Vref L∠<L (2)

where

$\alpha U= 2\pi\ fU\ t + \varphi U$ (3)

$\alpha L = 2\pi\ fL\ t + \varphi\ L$ (4)

where*fU*and *fL*are the frequencies, and φ*U*and φ*L*are the phases. All zero vectors *V13, V14* and *V15* can be used for zero states.

The switching time intervals of vectors are calculated as:

$$T_1 = \frac{\sqrt{3}}{2}\, m_u\, T \sin\left(\frac{\pi}{3} - \alpha_u\right) \quad (5)$$

$$T_2 = \frac{\sqrt{3}}{2}\, m_u\, T \sin(\alpha_u) \quad (6)$$

$$T_3 = \frac{\sqrt{3}}{2}\, m_L\, T \sin\left(\frac{\pi}{3} - \alpha_L\right) \quad (7)$$

$$T_4 = \frac{\sqrt{3}}{2}\, m_L\, T \sin(\alpha_L) \quad (8)$$

$$T_0 = T - T_1 - T_2 - T_3 - T_4 \quad (9)$$

where*T1* and *T2* are the time interval of upper active vectors, *T3*, *T4* are time of lower active vectors, *To* is time of zero vectors and *T* is switching period. *mU*and *mL* are modulation index and defined by:

$$m_u = \frac{2Vref\ U}{Vi} \quad (10)$$

$$m_L = \frac{2Vref\ L}{Vi} \quad (11)$$

The sum of active vector time intervals must be less or equals to *T*. Thus, the following constrain must be satisfied:

$$(m_u + m_L) \leq \frac{2}{\sqrt{3}} \approx 1.155 \quad (12)$$

There are two odd active vectors (*V1*, *V3*, *V5*, *V8*, *V10* and *V12*) and two even active vectors (*V2*, *V4*, *V6*, *V7*, *V9* and *V11*) in a switching sequence. In an even active vector, two legs are in state {1}, while only one leg is in state {1} in an odd activevector. If even active vectors are placed next to *V13*, number of switching will be reduced even more.

V. Simulation And Results:

Space vector PWM is an advanced technique used for variable frequency drive applications. It utilizes dc bus voltage more effectively and generates less total harmonic distortion. SVPWM utilize a chaotic changing switching frequency to spread the harmonics continuously to a wide band area so that the peak harmonics can be reduced greatly. The Simulink model of Space Vector Pulse width modulated nine switch inverterfed Induction Motors is shown in Figure-8. The phase voltage and phase current are shown in Figures 9and 10 and the line voltage and line current are shown in figures 10 and 11, respectively.

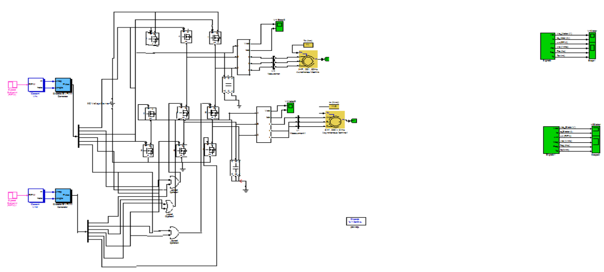

Fig. 7: Simulink model of closed loop SVPWM nine switch inverter.

Finally performance of SVPWM has been compared with conventional PWM. The % THD for PWM and SVPWM are measured and tabulated as shown in table. Therefore from the parameters measured the current THD% of closed loop PWM is reduced by 10% by employing closed loop SVPWM technique.

Australian Journal of Basic and Applied Sciences, 9(35) November 2015, Pages: 130-135

Table 1: Comparision of pwm and svpwm.

Control techniques		% voltage THD	% current THD
PWM	OPEN LOOP	83.07	43.67
PWM	CLOSED LOOP	112.80	12.94
SVPWM	OPEN LOOP	77.19	17.05
SVPWM	CLOSED LOOP	57.75	2.56

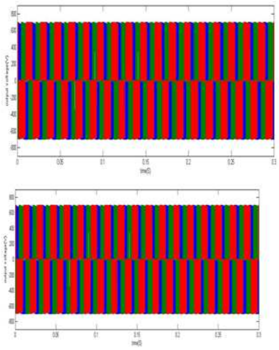

Fig. 8: Phase voltages of both upper and lower load

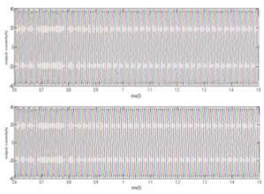

Fig. 9: Phase current of both upper and lower load.

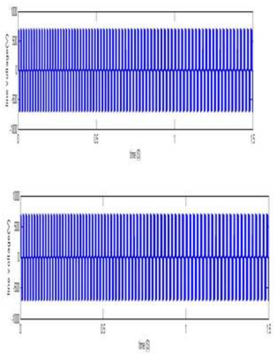

Fig. 10: Line voltages of upper and lower load.

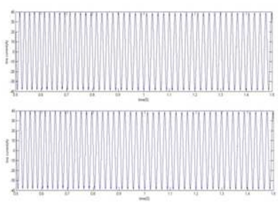

Fig .11: Line current of both upper and lower load

V. Conclusion:

Space vector Modulation Technique has become the most popular and important PWM technique for the control of AC Induction, Brushless DC, Switched Reluctance and Permanent Magnet Synchronous Motors. In this paper first comparative analysis of Space Vector PWM with conventional SPWM for nine switch inverter is carried out. The Simulation study reveals that SVPWM gives 10% enhanced fundamental output with better quality i.e. lesser THD compared to SPWM. PWM strategies viz. SPWM and SVPWM are implemented in

MATLAB/SIMULINK software and its performance is compared with conventional PWM techniques. Owing to their fixed carrier frequencies, conventional PWM strategies, there are cluster harmonics around the multiples of carrier frequency. PWM strategies viz. Sinusoidal PWM and SVPWM utilize a changing carrier frequency to spread the harmonics continuously to a wideband area so that the peak harmonics are reduced greatly. The inherent advantages of the nine switch inverter are its cost effectiveness and improved reliability due to less switch count.

REFERENCES

Chinchilla, M., S. Arnaltes and J.C. Burgos, 2006. “Control of Permanent-Magnet Generators Applied to Variable-Speed Wind-Energy Systems Connected to the Grid,” IEEE Transaction on Energy Conversion, 21(1): 130-135.

Ali Emadi, Sheldon S. Williamson and AlirezaKhaligh, 2006. “Power Electronics Intensive Solutions for Advanced Electric, Hybrid Electric, and Fuel Cell Vehicular Power Systems,” *IEEE Transactions on PowerElectronics*, 21(3): 567-577.

Oak Ridge National Laboratory, 2005. *Evaluation of 2004 Toyota Prius Hybrid Electric Drive System*, U.S. Department Energy System.

Jones, M., S.N. Vukosavic, D. Dujic, E. Levi and P. Wright, 2008. “Five-leg inverter PWM technique for reduced switch count two-motor constant power applications,” *IET Electr. Power Appl.*, 2(5): 275-287.

Kominami, T. and Y. Fujimoto, 2007. "A Novel Nine-Switch Inverter for Independent Control of Two Three-phase Loads," *IEEE IndustryApplications Society Annual Conference (IAS)*, 2346-2350.

Liu, C., B. Wu, N. Zargari and D. Xu, 2009. "A Novel Three-phase Three-leg AC/AC Converter Using Nine IGBTs", *IEEE Transaction on PowerElectronic*,. 24(5): 1151-1160.

Liu, C., B. Wu, N. Zargari and D. Xu, 2007. "A novel nine-switch PWM rectifier-inverter topology for three-phase UPS applications", *EuropeanConference on Power Electronics and Applications*.

Jahns, T.M. and E.J. Wildi, 1988. “Integrated current sensor configurations for AC motor drives,” U.S. Patent, 4: 777 579.

Liu, C., B. Wu, N. Zargari, D. Xu, 2009. Wang, J.“A novel three-phase three leg AC/AC converter using nine IGBTs”, IEEE Trans. Power Electron.

Congwei, L., W. Bin, N. Zargari, D. Xu, 2009. “A novel nine-switch PWM rectifier-inverter topology for three-phase UPS applications”, EPE J.

Dehghan, S.M., M. Mohamadian, A. Yazdian, F. Ashrafzadeh, 2010. “Space vector modulation for nine-switch converters”, IEEE Trans. Power Electron.

Dehghan, S.M., M. Mohamadian, A. Yazdian, 2010. “Current-type nine switch inverters”, J. Power Electron.

Dehghan, S.M., M. Mohamadian, Yazdian, 2010. ”A Hybrid electric vehicle based on bidirectional Z-source nine-switch inverter”, IEEE Trans. Veh. Technol.

Nho, N.V. and M.J. Youn, 2006. “Comprehensive study on space-vector-PWM and carrier-based-PWM correlation in multilevel invertors” IEEE Proc.-Electr. Power Appl., 153(1): 149-158.