International Journal of Advanced Scientific Technologies , Engineering and Management Sciences (IJASTEMS-ISSN: 2454-356X) Volume.3,Special Issue.1,April.2017

Space Vector Modulation Algorithm (SVM) for Multilevel Inverters

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Abstract—Nowadays, many industrial applications may require high power. However, some applications in the industries may require medium or low power for their continuous operation. Using a high power source for all industrial loads may prove beneficial to some motors requiring high power, while it may damage the other loads. Hence the multilevel inverter has been introduced as an alternative in high power and medium voltage situations. Modulation methods are mainly employed for controlling the output voltage of inverter for achieving desired ac input voltage for various loads. Therefore various modulation methods are used to control inverter output voltage and output frequency, thus minimizing harmonic distortions. Among various modulation schemes, space vector modulation scheme is found to be superior and also various SVM algorithms are available. But their results show harmonic distortion because of the influence of common mode voltage and dead time effect and hence become more complex. For reducing these complexities, an algorithm has been proposed to create a new switching sequence for multilevel inverter using SVM.

Index Terms— Multilevel inverter, PWM(pulse width modulation), Space vector modulation(SVM), Reference vector, Sector, Common mode elimination, Total harmonic distortion

I. INTRODUCTION

Inverters form an important class of power electronic circuits, which convert DC power to AC power. Using few control circuits and switches, one can get AC at any required voltage and frequency. A multilevel inverter is a power electronic device which is capable of providing desired alternating voltage level at the output using multiple lower level DC voltages as an input. Multilevel inverters can increase the power by (m-1) times than that of two level inverters through the series connection of power semiconductor devices. Mostly a two-level inverter is used in order to generate the AC voltage from DC voltage. First take the case of a two-level inverter. A two-level Inverter creates two different voltages for the load i.e. suppose we are providing V_{dc} as an input to a two level inverter then it will provide + $V_{dc/2}$ and – $V_{dc/2}$ on output. In order to build an AC voltage, these two newly generated voltages are usually switched. Although this method of creating AC is effective, but it has few drawbacks as it creates harmonic distortions in output voltage and also has a high d_v/d_t as compared to that of a multilevel inverter. Normally this method works, but in few applications it creates problems particularly those where low distortion in the output voltage is required. The concept of Multilevel Inverter (MLI) is a kind of modification of two-level inverter. In multilevel inverters we do not deal with the two level voltage, instead, in order to create a smoother stepped output waveform, more than two voltage levels are combined together and the output waveform obtained in this case has lower dv/dt and also lower harmonic distortions. Smoothness of the waveform is proportional to the voltage levels. As we increase the voltage level the waveform becomes smoother but the complexity of controller circuit and components also increases along with the increased levels. Various Pulse Width Modulation (PWM) schemes have been devised for the inverters in order to achieve the voltage control. Of these schemes, the sine-triangle and space vector modulation schemes have emerged as the most popular and versatile PWM schemes.

The SVPWM technique can increase the fundamental component by up to 27.39% of that of PWM. The fundamental voltage can be increased up to a square wave mode where a modulation index of unity is reached.

SVPWM is accomplished by rotating a reference vector around the state diagram, which is composed of six basic non-zero vectors forming a hexagon. A circle can be inscribed inside the state map and corresponds to sinusoidal operation. The area inside the inscribed circle is called the linear modulation region or under-modulation region. The area between the inside circle and outside circle of the hexagon is called the nonlinear modulation region or over-modulation region. The concepts in the operation of linear and nonlinear modulation regions depend on the modulation index, which indirectly reflects on the inverter utilization capability.

The SVPWM has the constant switching time calculations for each state. This SVPWM can easily be changed to higher levels. SVPWM has good utilization of the DC link voltage, low current ripple and relative easy hardware implementation. Compared to the PWM, the SVPWM has a 15% higher utilization ratio of the voltage.

As the number of level increases, the redundant switching states increase and also the complexity of selection of the switching states increase.

II. LITERATURE SURVEY

A. *Simplified space vector PWM Method*

This system was proposed in accordance with the study made by Jae Hyeong Seo, Chang Ho Choi and Dong Seok Hyun [1]. This method is based on the simplification of the space–vector diagram of a three-level inverter into that of a two-level inverter. By this method, all the remaining procedures necessary for the three-level SVPWM are done like conventional two-level inverter and the execution time is greatly reduced. The control algorithms are implemented more easily. And the proposed method can be applied to the multi-level inverters above three-level. This SVPWM method was verified by experiment with a 1000 KVA three-level insulated gate bipolar transistor (IGBT) inverter.

As per the system, if these six small hexagons are shifted toward the center of the inner hexagon by Vdc/3, the space–vector diagram of a three-level inverter is simplified to that of a two-level inverter. The basic steps involved here are: First, from the location of a given reference voltage, one hexagon has to be selected among the six hexagons. Secondly the original reference voltage vector has to be subtracted by the amount of the center voltage vector of the selected hexagon. By these two steps, the three-level space–vector plane is transformed to the two-level space–vector plane. Then a determination of switching sequence and the calculation of the voltage vector duration time are done as conventional two-level SVPWM method. This approach can be extended to high power and high performance applications, which is one of the advantages of using simplified SVPWM technique. The preferred SVPWM method has the following features. 1) The switching sequence is determined without a look-up table, so the memory of the controller can be saved. 2) The dwelling times of voltage vectors are calculated in the same manner as two-level SVPWM thus reduces the execution time of the three- level SVPWM. 3) It is easy to implement the control algorithm. 4) It can be applied to multi-level.

B. *General Space Vector PWM Control Algorithm*

This method was proposed by Wei and Sanmin [2]. To solve the problem of computational complexity due to the large number of space vectors and redundant switching states, a general space vector PWM algorithm has been proposed. Based on this algorithm, the location of the reference voltage vector can be easily determined and the calculation of dwell times becomes very simple. More importantly, the proposed algorithm is general and can be directly applied to the cascaded H-bridge inverter for any voltage levels which makes it prominent over the simplified space vector modulation. In addition, a new switching sequence, Large-Small Alternation (LSA), was proposed for the minimization of total harmonic distortion. By using a 7-level cascaded H-bridge inverter drive system this algorithm can be verified.

C. *A Unified Space Vector Pulse Width Modulation*

Two isolated dc voltage sources are used for the proposed scheme [5]. The gate pulses for the dual inverter are generated by the concept of unified SVPWM in accordance with the voltage-second integral principle. The principle states that the ratio of the two dc-link voltages that are taken must be an arbitrary positive value. This technique simplifies the region identification in sectors and reduces total switching frequency of the dual inverter. Here the two inverters are controlled simultaneously and the values of the two isolated dc sources are different. The region divisions in a sector are done according to the relationship between the time durations of the voltage vectors and the sampling period. In addition, to this the total switching frequency is reduced to one-third of that of the dual SVPWM algorithm, and a good performance is obtained for a wide speed range. The better performance of this scheme can be verified experimentally.

III. PROPOSED METHOD

The main drawback of SVM algorithm is total harmonic distortion found in the output voltage. The SVM can be extended to any number of voltage levels. As the number of voltage level increases the output waveform becomes smoother, thereby increasing the circuit complexity. In order to overcome these, various SVM algorithms were designed and verified.

By analyzing all SVM algorithms, there are some **inferences** due to common mode voltage and dead time effect. Therefore, by merging a new block for eliminating the common mode voltage to the SVM block, a new scheme is proposed for improving the states of SVM. In this configuration an open end winding scheme is used with dual two level inverter configuration . hence the space vectors prodced by this scheme is same to that of the three level inverter.The opened stator winding is connected with inverters and SVM is used for controlling those inverters. Before applying switching sequence into inverter block there is another stage for eliminating common mode voltage. Then the selected switching states will be fed into the inverter, thus minimizing harmonics.

IV. SIMULATION RESULTS

Figure.1 shows the Simulink model for the proposed work and corresponding results are shown in Table I. In order to verify the effectiveness of the proposed SVM algorithm, it is implemented on a dual two-level inverter system based on an open winding. To test the output performance of the proposed method, the fast Fourier transformation (FFT) analysis results under different ratios of dc-link voltages are tabulated in Table I.

It can be seen that the output performance is satisfying with various values of two dc link voltages.

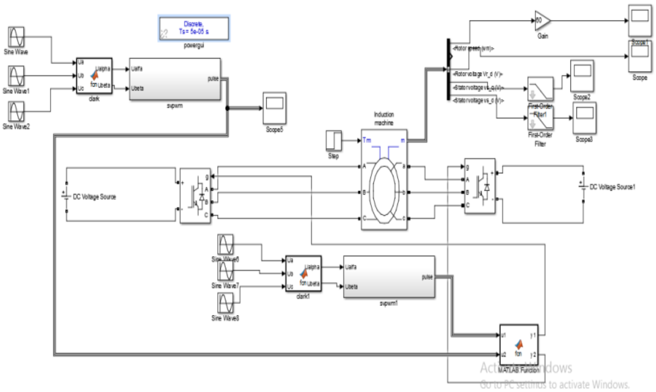

Figure.1 : SIMULINK BLOCK

Table I
THD of Proposed Method

V_1	V_2	THD With CMVE(%)	THD Without CMVE(%)
100	50	1.9	2.06
200	50	1.02	1.18

CMV-Common Mode Voltage
CMVE-Common Mode Voltage Elimination

V. CONCLUSION

Among all the methods for SVM algorithms discussed above, it can be concluded that analyzing the proposed space vector modulation aspects can give a better output result with small distortion. But such systems would be more complex when we go for higher levels. By analyzing the features of other techniques with respect to total harmonic distortion present in the output the proposed work shows less distortion and hence it is more preferable.

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