



Harmonics Elimination of Induction Motor by SVPWM Effective Technique

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ABSTRACT: For employing pulse width modulation (PWM) three phase switching converters, Space vector modulation (SVM) is an effective method that can be applied. Operation of converter hardware for smooth working is increased with the help of SVM. On comparing with sinusoidal PWM, it is observed that SVM can accomplish a higher AC voltage level (15% more in magnitude). In this work we have developed a SVM models in Matlab/Simulink, which is a most common and well known packages for power system dynamic research. To illustrate the principles of SVM based sinusoidal waveform synthesis, theory of space vector is clearly described. The three unique inputs of this include: (i) A saw tooth triangular waveform is used to produce repeating switching period for digital control (ii) A method to incorporate blocks with different sampling rates is employed to generate SVM pulses (iii) Matlab/Simulink model is developed. The models that are developed are very useful to extend detailed SVM enabled power converters in power system studies. A complete tutorial of the developed model progress procedure and the simulation results for SVPWM and SPWM are provided with comparison to displayed the accuracy of the SVM models.

KEYWORDS: Space Vector Modulation (SVM), MATLAB/Simulink

I. INTRODUCTION

Variable voltage and frequency supply for ac drives is usually obtained from a three-phase Voltage Source Inverter (VSI). A number of PWM techniques have been developed in the past to obtain variable voltage and frequency supply. The most popular ones are carrier-based sinusoidal PWM and space vector modulation (SVM) PWM [1]. The output voltage per phase for a sinusoidal PWM based three phase converter is limited to 0.5 Vdc(peak value) and the line-to-line RMS voltage is 0.612Vd. SVM is another direct digital PWM technique proposed in 1982 [2]. It has become a basic power processing technique in three-phase converters [3]. SVM based converter can have a higher output voltage output at 0.707Vdc (Line-to-line, RMS). Therefore, SVM improves ac voltage by 15.15% [4]. Furthermore, SVM algorithms can be easily implemented using digital controllers [5]. A model of SVM on MATLAB/Simulink has been developed [1]. Matlab /Simulink is one most popular software packages for power electronics and power systems studies. The main focus of this work is to develop effective models of SVM on MATLAB/Simulink. The paper organized in six sections, related work is given in section II, two level SVPWM inverter analysis is given in section III, the MATLAB/Simulink model and the simulation results given for SVM, are described in section IV and in section V respectively followed by the conclusion of the paper.

II. RELATED WORK

Moulin et al, in the paper, "Support Vector Machines for Transient Stability Analysis of Large-Scale Power Systems" [6] discussed about the classifier based on learning method. They have used to deal with the problem of high dimensionality. The high dimensionality associated with power systems has led to the expansion and implementation of feature selection methods to make the application more reasonable in real time. They noticed that SVM's performed better when complete set of variables are used that guarantees that their implicit feature selection ability and the legality of the developments on generalization control. The system related to SVM learning permits us for a deep understanding of its practical use.

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Abduesslam et al, in the paper, "Voltage problem area Classification using Support Vector Machine SVM" [7] discussed about problem of voltage classification based on support vector machine of electrical power system that makes the use of type of least squares svm. They have used the approach where data was collected from the time domain simulation that uses input to the classification and PTSI estimation on LMS machine. To evaluate the effectiveness of the system they have compared with Learning vector quantization. They analysed that voltage problem when used with SVM in power systems with the help of conventional method needs long computational time and thus to speed up in the prediction method LS-SVM and LVQ techniques are utilized. They have tested on 39 buses and 19 load buses and evaluate that LS-SVM is far better approach than LVQ.

Zhenq et al, "Transient Stability Assessment of Power System Based on Support Vector Machine" [8] discussed that machine learning methods are capable tools for transient stability assessment of power system. Support vector machine (SVM) is used to evaluate the transient stability of power system after error occur on lines of transmission. Single machine characteristics are noticed as inputs of the SVM classifier. Experimental outcomes in IEEE 50-generator test system shows that, characteristics of single machine with small inertia coefficient are effectual in TSA, and the SVM classifier with RBF kernel when utilize this single machine features can attain satisfying classification accuracy.

III. ANALYSIS OF TWO LEVEL SVPWM INVERTER

Space Vector Modulation (SVM) [1] was originally developed as vector approach to Pulse Width Modulation for three phase inverters. It is a more sophisticated technique for generating sine wave that provides higher voltages with lower total harmonic distortion. The circuit model of a typical three-phase two level voltage source PWM inverter is shown in "Figure.1". S_1 to S_6 are the six power switches that shape the output, which are controlled by the switching variable a, a', b, b', c and c' . When an upper transistor is switched on, i.e., when a, b or c is 1, the corresponding lower transistor is switched on, i.e., the corresponding a', b' or c' is zero. Therefore, the on and off states of the transistors can be used to determine the output voltage. In this PWM technique 180° conduction is used for generating the gating signals. If two switches, one upper and one lower switch conduct at the same time such that the output voltage is $\pm V_s$. the switch state is 1. If these two switches are off at the same time, the switch state is 0.

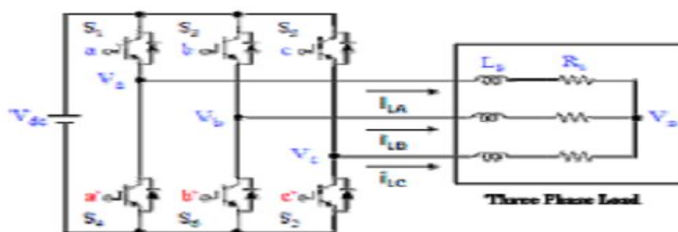


Figure.1 Three phase two level voltage source inverter

The space vector diagram of a five level inverter can be thought that is composed of six small hexagons that are the space vector diagrams of the three level inverters. Each of these six hexagons constituting the space vector diagram of a three level inverter, centres on the six apexes of the medium hexagon. To simplify into the space vector diagram of a three level inverter, two steps have to be taken. Firstly, from the location of a given reference voltage, one hexagon has to be selected among the six hexagons. Secondly, we substrate the amount of the center voltage of the selected hexagon, from the original reference voltage. By these two steps, the five level space vector planes is transformed to the three level space vector plane. In turn, the space vector diagram of the three level inverter, can be thought that it is composed of six small hexagons that are the space vector diagram of conventional two level inverter. These hexagons are centred on the six apexes of the inner hexagon as shown in fig. 2. To simplify into the space vector diagram of a two level inverter, we have to take the two steps mentioned above.

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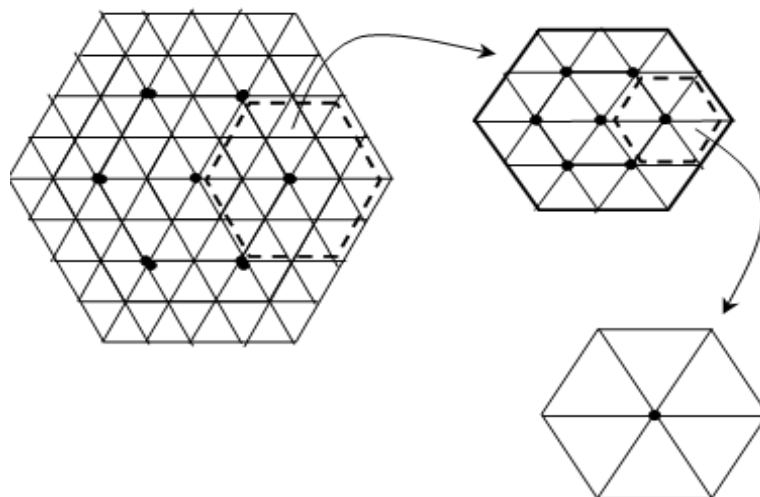


Figure.2 Simplification of a five level space vector diagram into two level space vector diagrams

III. MATLAB/SIMULINK MODEL

This section gives the step by step development of MATLAB/Simulink model for SVPWM. The Simulink model is shown in Fig. 3. The MATLAB code used to generate the gate control signal is also explained. Each subsystem is described.

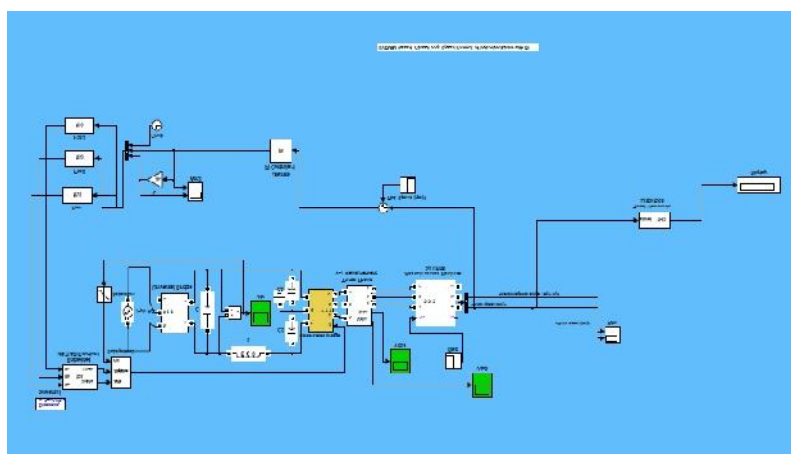


Fig. 3. MATLAB simulation System Topology

A. System Topology

Fig. 3 shows the system topology of the system topology. The simulation is built by six subsystems with a repeating sequence work as the reference time signal. The six subsystems are Sinusoid Wave generator, Space vector Calculator, Zero Holder, Gate Controller, Three-phase PWM inverter and Low Pass Filter.

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B. Component Description

The sinusoid wave generator generates three phase balanced voltage wave by a clock. To simplify the simulation, the magnitude, frequency and phase angle are all assumed as constant.

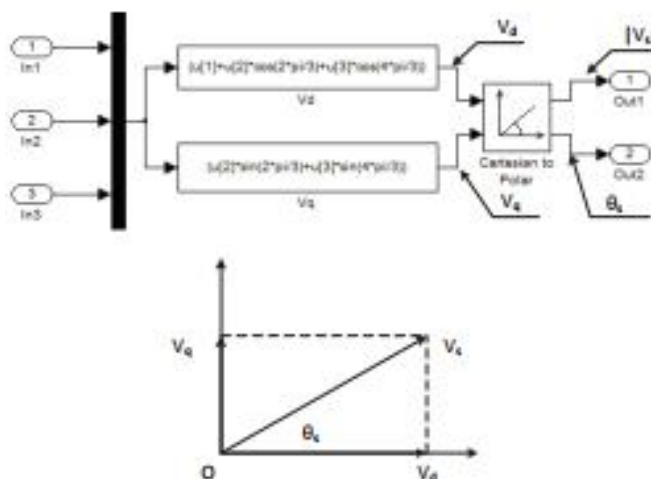


Fig. 4. Space vector calculator

Fig. 4 shows the detail of the space vector calculator. It first calculate V_d and V_q where $V_d = V_a + V_b \cos(2\pi/3) + V_c \cos(4\pi/3)$ and $V_q = V_b \sin(2\pi/3) + V_c \sin(4\pi/3)$. After the coordinates exchange, the output are the magnitude and phase angle of the space vector.

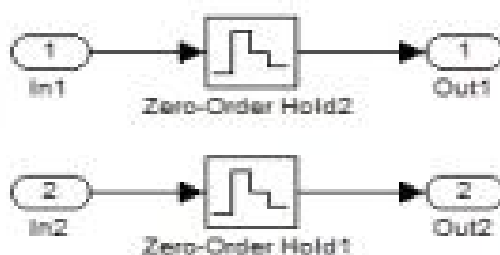


Fig. 5. Zero Holder

To make the magnitude and phase angle of the space vector constant in one sample time, a zero holder is added. Fig. 5 shows the detail of the subsystem. There are two zero holders for $|V_s|$ and θ_s . They receive the value of $|V_s|$ and θ_s and send them to the gate signal controller every sample time. In this simulation the working frequency of the zero holder is 5 KHz, so it send the signal every 0.0002 seconds.

The gate controller is a Matlab function block, it connect to a Matlab program file. The input of this block will be the input of the function and the return value of the function is this block's output. The function will first judge which sector the space vector is in by θ_s and then calculate the time zone T_a and T_b . The time level can be determined by the equation.

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Remarks: the output of the zero holder is at 5 kHz while the output of the repeating sequence should be much higher than 5 kHz. Therefore, a rate transition block should be added between the zero holder and MATLAB function as given in fig.6.

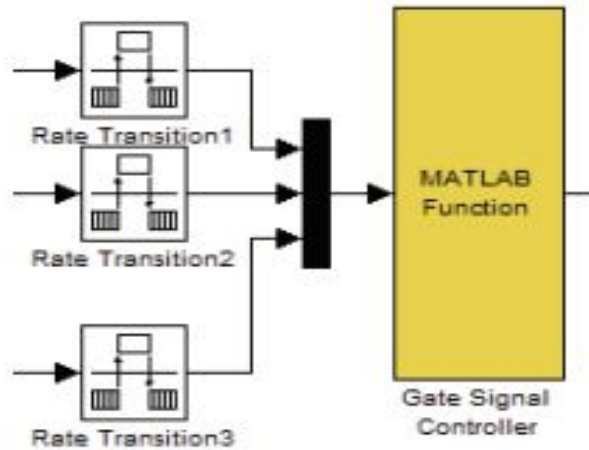


Fig. 6. MATLAB Function

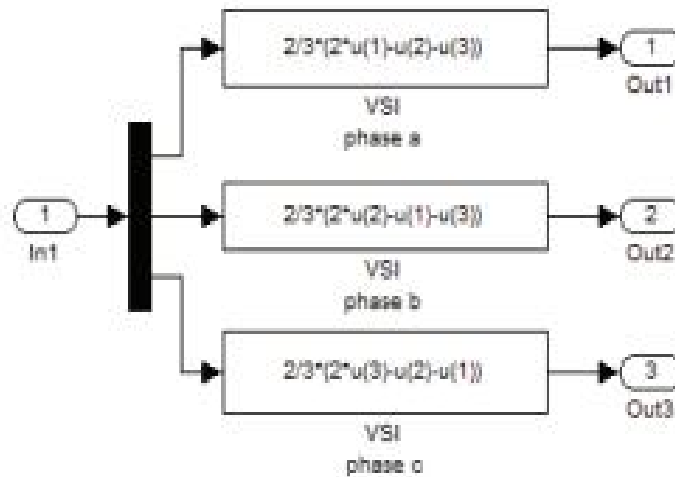


Fig. 7. PWM inverter

Fig. 7 shows the detail of the inverter block. The inverter is represented by one function block for each phase shown in equation 1. $V_{in} \{(V_{AN} + V_{BN} + V_{CN})/3\}$ is changing depending on the different values of G_A , G_B and G_C , which are the gate control pulses that can be 0 or 1.

$$V_{An} = V_{dc}/3 (2G_A - G_B - G_C)$$

$$V_{Bn} = V_{dc}/3 (2G_B - G_A - G_C)$$

$$V_{Cn} = V_{dc}/3 (2G_C - G_B - G_A)$$

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V. SIMULATION RESULT AND COMPARISON IN MATLAB

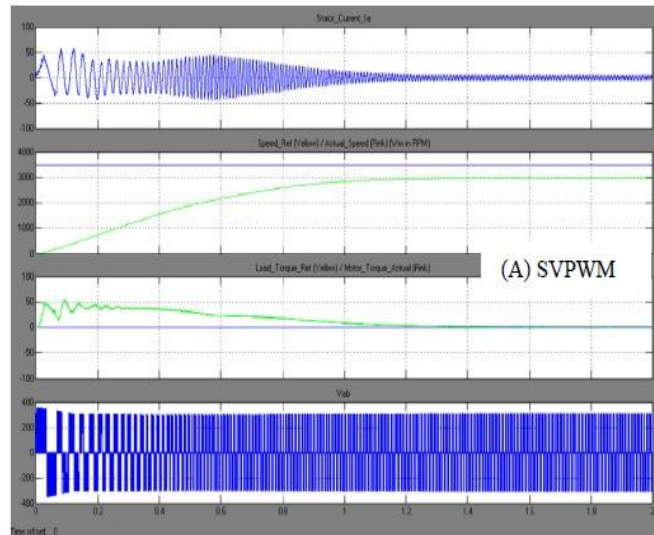


Fig 8 (A): Simulation results showing Stator current, Settling time, Motor torque and VAB at maximum speed for SVPWM

Fig 8(A) shows Simulation results which is implemented in MATLAB and it is showing relationship among Stator current, Settling time, Motor torque and VAB at maximum speed for Support Vector Pulse Width Modulation.

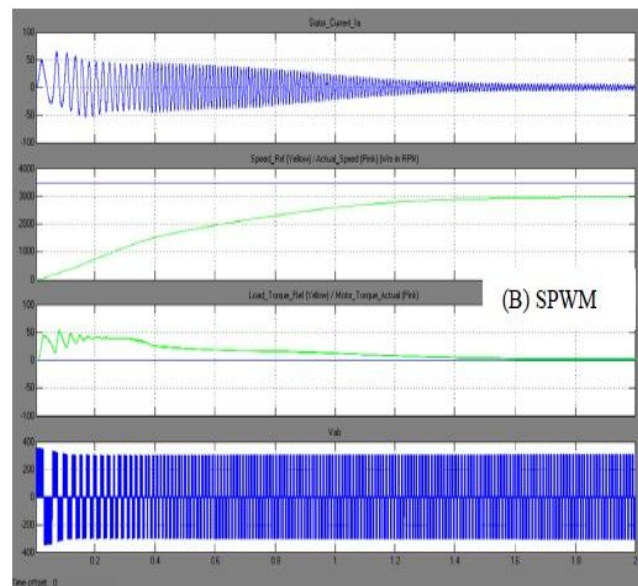


Fig 8 (B): Simulation results showing Stator current, Settling time, Motor torque and VAB at maximum speed for SPWM

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Fig 8(B) shows Simulation results which is implemented in MATLAB and it is showing relationship among Stator current, Settling time, Motor torque and VAB at maximum speed for Pulse Width Modulation. Simulation results showing Stator current, Settling time, Motor torque and VAB at maximum speed for SVPWM and SPWM in fig 8.

TABLE 1: COMPARISON OF FUNDAMENTAL, THD (TOTAL HARMONICS DISPLAY) & SETTling TIME

Converter Topology	fundamental (50 Hz)	THD	Settling time (max. speed)
SVPWM	272.4 V	42.03 %	1.30 sec
SPWM	234.9 V	75.96 %	1.75 sec

The above data in the table 1 is taken by the simulated model and already show in the above graph which is taken by the with SVPWM and Without SVPWM or with PI Techniques as shown in fig 8 (A) and (B). In the above table 1, it is show that the SVPWM is much better as compared to the SPWM or called with PI. Because of total harmonics calculated by the SVPWM method is less than that of SPWM method. And voltage performance is very good as well as settling time. Settling time is showing the how much time is taken by the machine, come to the steady state condition or come in stable condition.

TABLE 2: SIMULATION PARAMETERS

3 Φ , 220V,50Hz	Solver=Ode 45	Bridge arm s=3	p=2
V/f=3.2	fc = ± 4500 Hz	P=2	Rs = 500 Ω
Cs = 1e-9	Ts = 2e-6	Tm = 10e-6	Tc = 50e-6

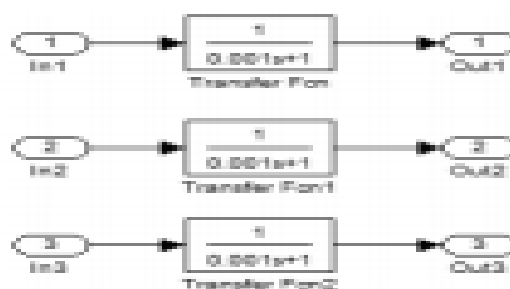


Fig. 9. Low pass filter

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At the end of the simple low pass filter is added in order to make the waveform looks nice. The low pass filter is accomplished by s-function. The transfer function of the filter is

$$G(s) = \frac{1}{(0.001s+1)}$$

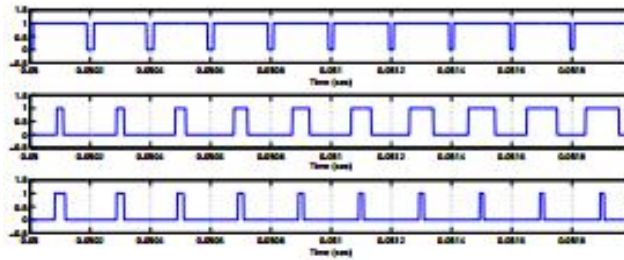


Fig. 10. Gate Control Signal MATLAB/SIMULINK

There are many ways of output after simulating this model into MATLAB. Which are discussed in fig 10 and 11. The output from the gate controller is shown in Fig. 10.

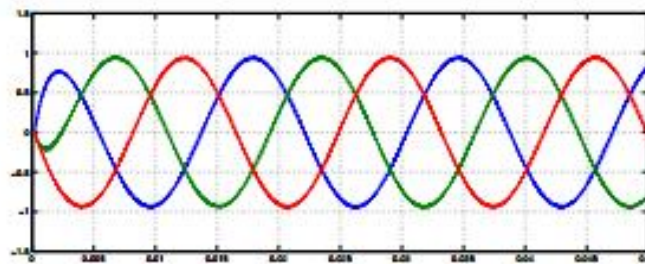


Fig. 11. Three Phase Output Voltage After Filter in MATLAB/SIMULINK

After execution of the simulation of the model, voltage after the filter is shown in Fig. 11. Also it shows that how this voltage is getting influenced.

VI. CONCLUSION

As seen from the above experimental results and comparisons, the developed MATLAB/SIMULINK model Space Vector PWM is superior as compared to Sinusoidal PWM in many aspects like :

- 1) The Modulation Index is higher for SVPWM as compared to SPWM.
- 2) The output voltage is about 15% more in case of SVPWM as compared to SPWM.
- 3) The current and torque harmonics produced are much less in case of SVPWM.

However, despite all the above mentioned advantages that SVPWM enjoys over SPWM, SVPWM algorithm used in three-level inverters is more complex because of large number of inverter switching states. Hence we see that there is a certain trade off that exists while using SVPWM for inverters for Adjustable speed Drive Operations. Due to this we have to choose carefully as to which of the two techniques to use weighing the pros and cons of each method.



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