International Journal of Scientific & Engineering Research, Volume 4, Issue 3, March-2013
ISSN 2229-5518

Generation of Space Vector PWM Using Microcontroller Atmega 16

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Abstract— This paper describes the use of a microcontroller atmega 16 to generate the space vector pulse width modulation (SVPWM) signals. The main feature of the research is the simplicity of the hardware and easy to digitally programmed. Testing and analyzing system is done at no load condition with varying carrier frequency, amplitude, and sinusoidal frequency. Varying carrier frequency is done by utilizing software with code vision AVR tools, while the amplitude and the sinusoidal frequency are varied by using potentiometers as analog input data. Based on the results of testing and analyzing, it is shown that the SVPWM signals could be implemented with microcontroller Atmega 16 at carrier frequency 490 Hz and THD at sinusoidal frequency of 25Hz, 50Hz, and 100Hz is about 13.85%, 23.89%, and 17.43%..

Index Terms— Space Vector PWM, microcontroller, software, varying carrier frequency, amplitude, sinusoidal frequency, analog input.

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1 Introduction

Nowadays, harmonic pollution in electrical power systems due to nonlinear loads such as Inverter power converter has become a serious problem. Inverter power converter is a voltage converter DC to AC with adjustable voltage and output frequency so that applicable to control three phase AC induction motor. There are some inverter type between it is an inverter power converter with the SVPWM (Space Vector Pulse Width Modulation)[1]. Advantage of technique SVPWM is very economic and practical to be applied operation of three phase AC induction motor. Besides if generation of signal SVPWM is done digitally will be able to be obtained system work short exchange is more impenetrably to noise. Design of a signal generator SVPWM applies microcontroller to have some advantages that is easy to be program and inverter circuit to become simple. To eliminate or reduce harmonics in the power systems, a number of methods have been developed and put into practice. SVPWM methods is used to generate active power filter. The active power filter built fom SVPWM can be programmed with microcontroller. In this research using microcontroller atmega 16 which is the local content. Therefore, we can design a power converter to supply DC power to its own load and, at the same time, operates as an active filter to supply to the AC line a compensating current equal to the harmonic current produced by the nonlinear load This paper presents an active filter in power inverter control method entitled SVPWM strategy based on microcontroller atmega 16 [2][3].

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2 Principle of SVPWM

The principle of Space Vector PWM is based on the fact that there are only eight possible switch combinations for a three phase inverter. The basic inverter switch states are shown in Figure 1. Two of these states (SV_0 and SV_7) correspond to short circuit while the other six can be considered to form stationary vectors in the d-q plane as shown in Fig.2. The magnitude of each of the six active vectors corresponding to the maximum possible phase voltage is:

$$V_m = \frac{2}{3} V_{dc} \quad (1)$$

Having identified the stationary vectors, at any point in time, an arbitrary target output voltage vector can then be made up by the summation (“averaging”) of the adjacent space vectors within one switching period. Target vectors in the other five segments of the hexagon are clearly obtained in a similar manner. The geometric summation shown in Fig.2. can be expressed mathematically as [5],

$$Tsv_1 V_m + Tsv_2 V_m (\cos\frac{\pi}{3} + jsin\frac{\pi}{3}) - \frac{\Delta T}{2} V_0 (\cos\theta_0 + j\sin\theta_0) \quad (2)$$

for each switching period ΔT.
Equating real and imaginary components yield the solution,

$$Tsv_1 = \frac{V_0}{V_m}\frac{\sin(\frac{\pi}{3}-\theta_0)}{\sin\frac{\pi}{3}}\frac{\Delta T}{2} \quad \text{(active time for sv1)} \qquad (3)$$

$$Tsv_2 = \frac{V_0}{V_m}\frac{\sin\theta_0}{\sin\frac{\pi}{3}}\frac{\Delta T}{2} \quad \text{(active time for sv2)} \qquad (4)$$

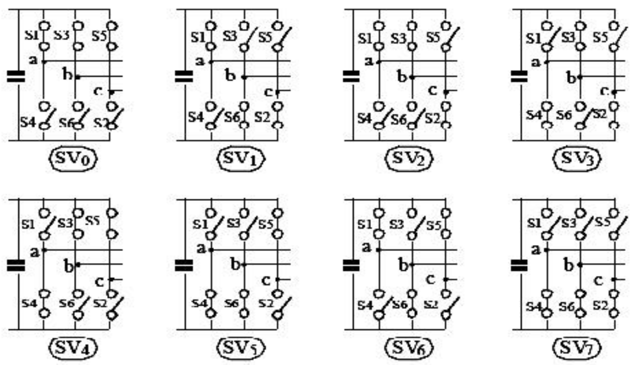

Fig. 1. Eight possible switch combinations for a three phase

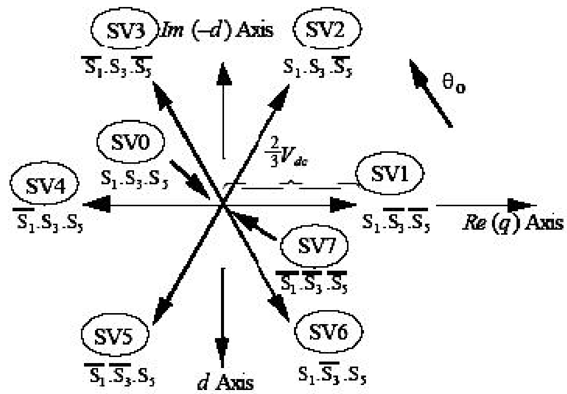

Fig 2. Space Vector representation

Since $0 \le Tsv_1, Tsv_2 \le \frac{\Delta T}{2}$, the maximum possible magnitude for *Vo* is *V*m, which can occur at $\theta = 0 \ or \ \frac{\pi}{3}$. From simple geometry, the limiting case for the constraint $Tsv_1 + Tsv_2 \le \frac{\Delta T}{2}$ occurs at $\theta_0 = \frac{\pi}{6}$ which means,

$$\frac{Tsv_1 + Tsv_2}{\frac{\Delta T}{2}} = \frac{V_0}{V_m}\frac{2\sin\frac{\pi}{6}}{\sin\frac{\pi}{3}} \le 1 \qquad (5)$$

and this relationship constrains the maximum possible magnitude of V_0 to,

$$V_0 = V_m \sin(\frac{\pi}{3}) = \frac{1}{\sqrt{3}}V_{bus} \qquad (6)$$

where Vbus is the D.C link voltage. Since Vo is the magnitude of the output phase voltage, the maximum possible line to line output voltage using Space Vector PWM must equal,

$$V_{0(L-L)} = \sqrt{3} * V_0 = V_{bus} \qquad (7)$$

So duration of time switching or duty cycle for sector 1,2...6 can expressed in tables of 1 as follows:

Table 1. Expressions of the duty cycles in each sector[5]

Sector Number	θ	d_k	d_{k+1}
1	$\left[0,\frac{\pi}{3}\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{\pi}{3}-\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\theta)$
2	$\left[\frac{\pi}{3},\frac{2\pi}{3}\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{\pi}{3}+\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{5\pi}{3}+\theta)$
3	$\left[\frac{2\pi}{3},\pi\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{4\pi}{3}+\theta)$
4	$\left[\pi,\frac{4\pi}{3}\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{5\pi}{3}+\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(2\pi-\theta)$
5	$\left[\frac{4\pi}{3},\frac{5\pi}{3}\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{4\pi}{3}+\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{2\pi}{3}+\theta)$
6	$\left[\frac{5\pi}{3},2\pi\right]$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(2\pi-\theta)$	$\frac{2}{\sqrt{3}}\frac{V_s}{E}\sin(\frac{\pi}{3}+\theta)$

This result represents that SVPWM is an intrinsically a regular sampled process, since in essence it matches the sum of two space vector volt– second averages over a half carrier period to a sampled target volt–second average [2].

Hardware Implementation

This section presents the hardware implementation in the laboratory. There are several steps involved in implementing the hardware which can be represented in the block diagram shown in Fig.3. Here 5 V DC supply is given to Atmega 16 μ- controller and the Timer circuit , the output of the **μ-** controller is fed to interfacing circuit, than to the opto isolator circuit , which isolates the high voltage of the inverter circuit (400V dc) from the rest of low voltage TTL and other low voltage components. The output of the opto isolator and the interface circuit is fed to the gate of each switching device. Each opto isolator is excited by independent power supply for isolation purpose. The microcontroller needs to supply signals to a controller which controls an inductive load such as a motor. Back EMF spikes from an inductive load can easily glitch, or destroy a microcontroller. Back EMF spikes typically manifest themselves as very short duration spikes which may or may not contain enough energy to actually destroy a microcontroller. Hence by using the opto coupler such high voltage spikes etc can be prevented[1].

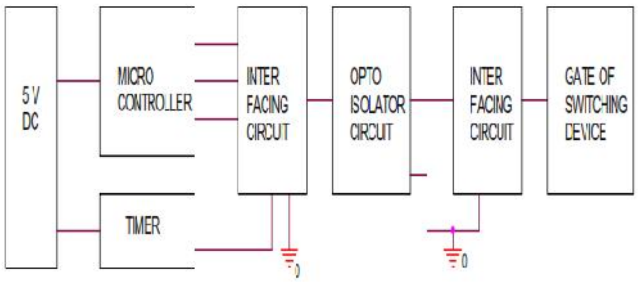

Fig.3. Block Diagram representation of gating signal generation.

3 Experimental Results

To prove that signal formed have been sinusoidal, hence done decrement of form signal pwmA with pwmB causing is obtained form of signal pwmAB like the one shown to Figure 4, 5, and 6 as follows.

- Output of pwm signal at fs = 25 Hertzs

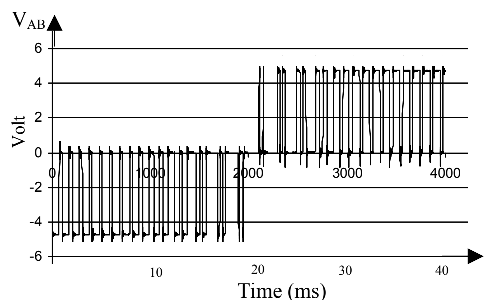

Fig. 3. Pwm Signal_AB at fs=25 Herts

- Output of pwm signal at fs = 50 Hertzs

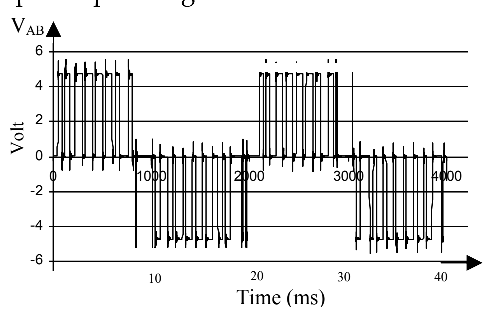

Fig. 4. pwm signal _AB at fs=50 Herts

- Output of pwm signal at fs = 100 Hertzs

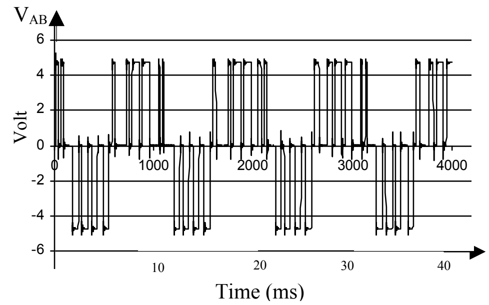

Fig. 5. pwm signal _AB at fs=100 Herts

From the result of testing of hadware and software, shown at fig. 3 resulted Ts= 40ms during one priode at setting point fs=25Hz. For setting point fs=50Hz, obtained Ts=20ms during one priode. While is setting point fs=100Hz, obtained Ts=10ms during one periods. So increasingly is boosted up sinusoidal frequency, hence time switching faster. While the inverter need to be made output voltage wave that is not harmonic because the harmonic can result additional heating at motor so can be made damage to the motor. Therefore spectrum of FFT (fast fourier transform) needed to knows THD (Total Harmonics Distortion). From the result of testing, spectrum of FFT shown to fig. 7, 8, and 9 as follows.

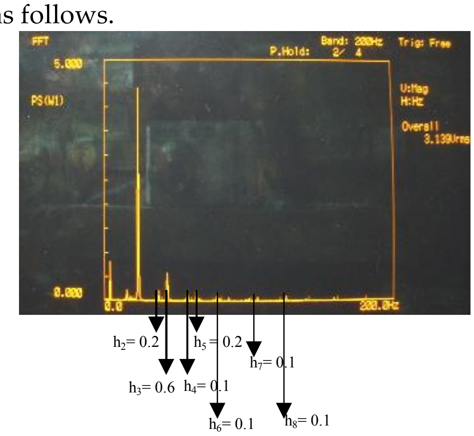

Fig. 6 Spectrum of FFT at fs = 25Hz

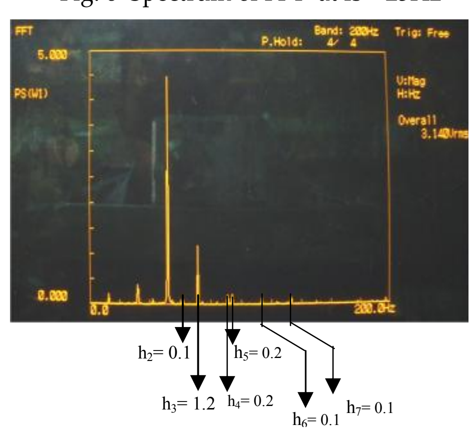

Fig. 7 Spectrum of FFT at fs = 50Hz

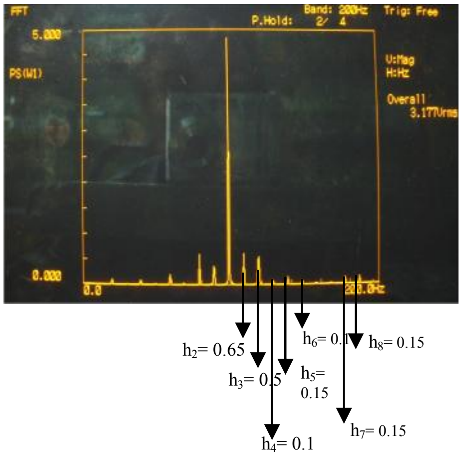

Fig. 8. Spectrum FFT at f_s = 100Hz

Total Harmonic Distortion THD, reflects energy of the waveform harmonic content and is defined as equation of 8[11].

$$THD\ [\%] = 100 * \sqrt{\sum_{h>1}^{h=\infty} \left[\frac{V_h}{V_1}\right]^2}\ \% \quad (8)$$

Where :

V_h : Amplitude harmonic voltage

h : Order harmonic

V_1 : Amplitude fundamental voltage

THD at measuring of fundamental frequency fs = 25Hz

$$THD\ [\%] = 100 * \sqrt{\left[\frac{0.2}{5}\right]^2 + \left[\frac{0.6}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.2}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2}\ \%$$

$$THD\ [\%] = 100 * \sqrt{0.0192}\ \%$$

$$THD\ [\%] = 100 * 0.1385\ \%$$

$$= 13.85\ \%$$

THD at measuring of fundamental frequency fs = 50Hz

$$THD\ [\%] = 100 * \sqrt{\left[\frac{0.1}{5}\right]^2 + \left[\frac{1.2}{5}\right]^2 + \left[\frac{0.2}{5}\right]^2 + \left[\frac{0.2}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2}\ \%$$

$$THD\ [\%] = 100 * \sqrt{0.062}\ \%$$

$$THD\ [\%] = 100 * 0.2489\ \%$$

$$= 24.89\%$$

THD at measuring of fundamental frequency fs = 100Hz

$$THD\ [\%] = 100 * \sqrt{\left[\frac{0.65}{5}\right]^2 + \left[\frac{0.5}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.15}{5}\right]^2 + \left[\frac{0.1}{5}\right]^2 + \left[\frac{0.15}{5}\right]^2 + \left[\frac{0.15}{5}\right]^2}\ \%$$

$$THD\ [\%] = 100 * \sqrt{0.0304}\ \%$$

$$THD\ [\%] = 100 * 0.1743\ \%$$

$$= 17.43\ \%$$

5 Conclusions

Based on the result of design, realization and testing to generate SVPWM signal, hence inferential some things as follows that the Generation of SVPWM signal with the Space Vector method can be realized to carrier frequency is about 490Hz applies microcontroller AVR type Atmega16. And with the space vector PWM method based on microcontroller Atmega16, value THD which is measurable at sinusoidal frequency of 25Hz, 50Hz, and 100Hz is 13.85%, 23.89%, and 17.43%.

6 Acknowledgments

The authors would like to thank The Reseacrh and Development Center for Electricity, New Energy, Renewable, and Energy Conservation, Ministry of Energy and Mineral Resources for their assistance and financial support.

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