PROGRAMABLE LABORATORY INVERTOR AND SPACE VECTOR PWM

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ABSTRACT

This paper describes space vector pulse width modulation. For implementation this technique is use programmable laboratory inverter that was designed on Department of Power Electrical and Electronic Engineering on VUT Brno. This sort of algorithm for control of AC drives serve as demonstration exercise in curse of microprocessor control of electric motor. This exercise demonstrates usage of digital signal processors for control of speed of AC motors.

1 INTRODUCTION

Sinusoidal PWM has been a very popular technique used in AC motor control. This relatively unsophisticated method employs a triangular carrier wave modulated by a sine wave and the points of intersection determine the switching points of the power devices in the inverter. However, this method is unable to make full use of the inverter's supply voltage and the asymmetrical nature of the PWM switching characteristics produces relatively high harmonic distortion in the supply.

Space Vector PWM (SVPWM) is a more sophisticated technique for generating a fundamental sine wave that provides a higher voltage to the motor and lower total harmonic distortion, it is also compatible for use in vector control (Field orientation) of AC motors. This application note describes the theory of SVPWM and applies it to a practical example using a 56F803 16-bit digital signal processor and Programmable laboratory inverter designed on Dept. of Power Electrical And Electronic Engineering [8], [9].

2 PROGRAMMABLE LABORATORY INVERTOR

Programmable laboratory inverter was designed on Department of Power Electrical and Electronic Engineering. It consists of Digital Signal Processor DSP56F803, DC supply (for supply power electronics, sensors and other electronics), driver for power transistors and set of sensors. Programmable laboratory inverter is described in [8], [9].

3 SPACE VECTOR PWM MODULATION

Consider first the 3-phase inverter shown below (figure 1)

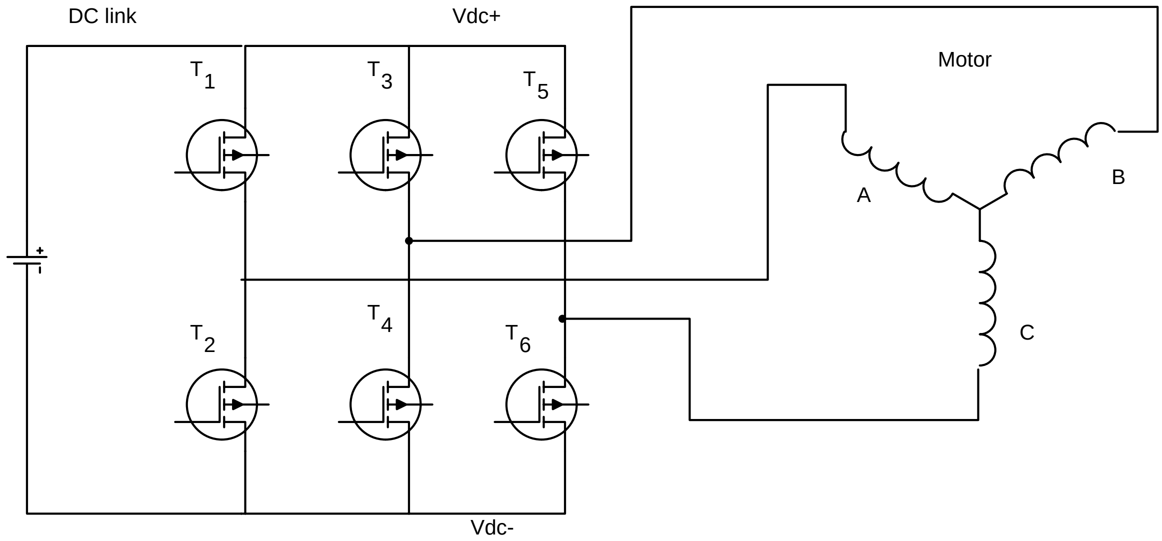

Fig. 1: *Typical Inverter Bridge Configuration*

The six-transistor combination in the inverter has eight permissible switching states. Tab. 1 summarises these states along with the corresponding line to neutral voltage applied to the motor.

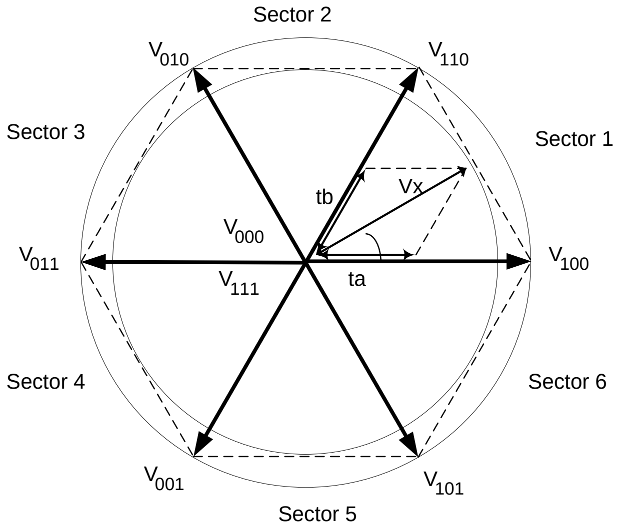

Fig. 2: *Space Vector Diagram – Line to Neutral Voltages*

State	On Devices	Van	Vbn	Vcn	Space Voltage Vector
0	T2,T4,T6	0	0	0	V_0(000)
1	T1,T4,T6	2/3 Vdc	-1/3 Vdc	-2/3 Vdc	V_1 (100)
2	T1,T3,T6	1/3 Vdc	1/3 Vdc	-1/3 Vdc	V_2 (110)
3	T3,T2,T6	- 1/3 Vdc	2/3 Vdc	-1/3 Vdc	V_3 (010)
4	T2,T3,T5	-2/3 Vdc	1/3 Vdc	1/3 Vdc	V_4 (011)
5	T2,T4,T5	-1/3 Vdc	-1/3 Vdc	2/3 Vdc	V_5 (001)
6	T1,T4,T5	1/3 Vdc	-2/3 Vdc	1/3 Vdc	V_6 (101)
7	T1,T3,T5	0	0	0	V_7 (111)

Tab. 1: *Inverter Switching States*

The inverter has six states when a voltage is applied to the motor and two states (0 and 7) when the motor is shorted through the upper or lower transistors resulting in zero volts being applied to the motor. The six vectors including the zero voltage vectors can be expressed geometrically as shown in Fig. 2. SVPWM seeks to average out the adjacent vectors for each sector. Using the appropriate PWM signals a vector is produced that transitions smoothly between sectors and thus provide sinusoidal line to line voltages to the motor. In order to generate the PWM signals that produce the rotating vector, formulae must be derived to determine the PWM time intervals for each sector.

Consider sector 1 in figure 3, bounded by Vectors 100, 110 and the null vectors 000 and 111.The vector Vx within this sector can be resolved as

$$V_x \cdot \sin\left(\frac{\pi}{3} - \alpha\right) = V_a \cdot \sin\frac{\pi}{3} \tag{1.}$$

$$V_x \cdot \sin\alpha = V_b \cdot \sin\frac{\pi}{3} \tag{2.}$$

Therefore

$$V_a = \frac{2}{\sqrt{3}} \cdot V_x \cdot \sin\left(\frac{\pi}{3} - \alpha\right) \tag{3.}$$

$$V_b = \frac{2}{\sqrt{3}} \cdot V_x \cdot \sin\alpha \tag{4.}$$

Where V_a and V_b are the components of V_x aligned in the directions of V_{100} and V_{110} respectively. V_x can be approximated by applying V_{100} for a percentage of time t_a and V_{110} for a percentage of time t_b over a period T_0. Using vector addition gives

$$V_x = V_a + V_b = V_{100} \cdot \frac{t_a}{T_0} + V_{110} \cdot \frac{t_b}{T_0} + \left(V_{000}\ or\ V_{111}\right) \cdot \frac{t_0}{T_0} \tag{5.}$$

Or

$$V_x \cdot T_0 = V_{100} \cdot t_a + V_{110} \cdot t_b + (V_{000}\ or\ \mathrm{V}_{111}) \cdot t_0 \qquad (6.)$$

Where

$$t_a = \frac{V_a}{V_{100}} \cdot T_0 ; t_b = \frac{V_b}{V_{100}} \cdot T_0 ; t_0 = T_0 \cdot (1 - t_a - t_b) \qquad (7, 8, 9.)$$

Substituting equations 3 and 4 into 7 and 8 then

$$t_a = U\left[\cos\alpha - \frac{1}{\sqrt{3}}\sin\alpha\right] \qquad (10.)$$

$$t_b = \frac{2}{\sqrt{3}} \cdot U \cdot \sin\alpha \qquad (11.)$$

Where U is the ration $\frac{V_x}{V_{100,110}}$ (sometimes referred to as the modulation index) for the period T_0 in segment 1. Knowing the values of t_a and t_b we can construct a symmetrical switching pattern for two consecutive periods of T_0 as shown in figure 3 that satisfy equations 7, 8 and 9.

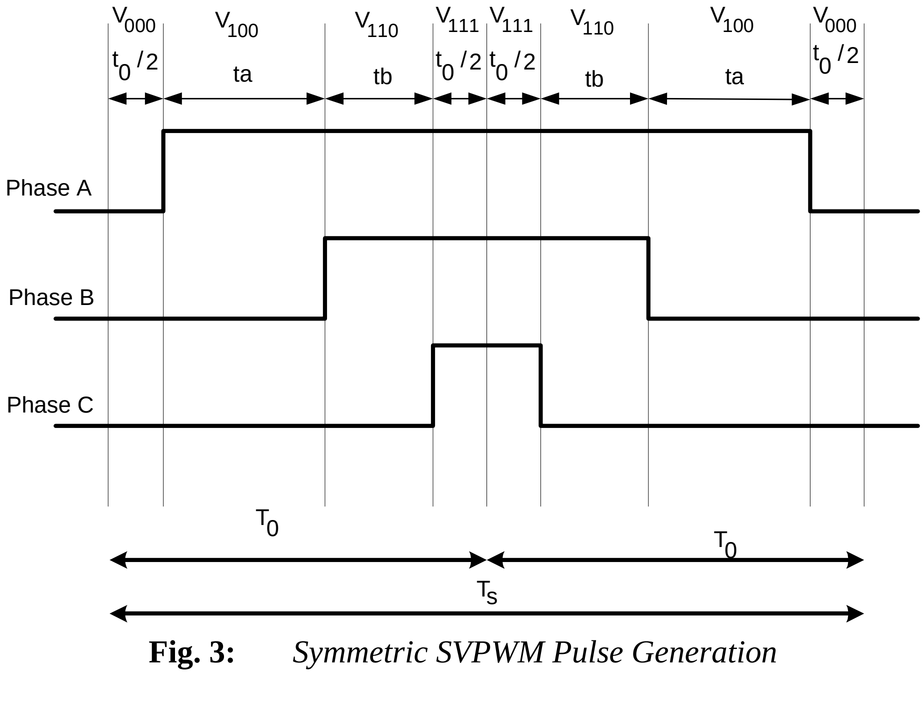

Fig. 3: *Symmetric SVPWM Pulse Generation*

4 SPACE VECTOR PWM GENERATION

An example of use of SV PWM has been created a program that SV PWM is used together with Constant Volts/Herzt control of an AC induction motor. The program is divided into three main parts. First part is an initialization process that is responsible for initialization the system after RESET. It configures the clock settings of the devices, intialises the peripherals that are used for the application and enables the appropriate interrupts.Second part is responsible for calculating the SVPWM timing parameters(it means : calculate $t_{a,}$ t_b and t_0). Third part provides the Motor Speed demand (V/Hz). To this purpose is used one pin of A/D converter and provides a 12-bit resolution from an external Potentiometer.

5 CONCLUSION

This document has presented an overview of SV PWM theory and one way of SV PWM implementation. Program example is given for Motorola DSP56F803 DSP microprocessor and Programmable Laboratory Inverter. Example program of use of SV PWM serve to student's introduction with Programmable Laboratory Inverter and as demonstrational exercise for students. It has been shown that the SV PWM technique utilizes DC bus voltage more efficiently and generates less harmonic distortion in a three-phase voltage-source inverter.

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REFERENCES

[1] Zhou K., Wang D., Relationship Between Space-Vector Modulation and Three Phase Carrier-Based PWM: A Comprehensive Analysis, IEEE Transactions on Industrial Electronics, Vol. 49, No. 1, February 2002, page 186-196

[2] Lee D.C., Lee G-Myoung, Linear Control of Inverter Output Voltage in Overmodulation, IEEE Transactions on Industrial Electronics, Vol. 44, No. 4, August 2002, page 590-592

[3] DSP56F80x User Manual Revision 4.0, Motorola Inc., http://motorola.com/semiconductors

[4] DSP56800 16-Bit Digital Signal Processor, Motorola Inc., http://motorola.com/semiconductors

[5] Field Orientated Control of 3-Phase AC-Motors, Texas Instruments, Literature Number: BPRA073, February 1998

[6] An Introduction to Space Vector Modulation using NEC's 8-bit Motor Control Microcontrollers, NEC Corporation, Document No. U16699EE1V1AN00, May 2004

[7] Gajdůšek, P. Workplace for Control Electrical Motors In Student EEICT 2004, Brno, 2004, s. 454 – 458

[8] Klíma, B., Gajdůšek, P. Programovatelný laboratorní měnič In Elektrické pohony a výkonová elektronika 2004, EPVE 2004, Brno 2004, s. 110 - 113