

Research on Space Vector Pulse Width Modulation Power

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Abstract

Space vector pulse wide modulation(SVPWM) have less harmonic than SPWM, it is easy to digitalize, and it is used in high voltage field more and more. In this paper, the principle is analyzed detailed, and simulated by Simulink, the simulation result show that the space vector pulse wide modulation scheme is feasible. The SVPWM power system hardware and software is designed at last.

Keywords: SVPWM; DSP; simulation; inverter

1. Introduction

People pay attention to SVPWM when it was born, its unique modulation mode, Take the motor and PWM inverter as one body, to acquire the circle magnetic field for the motor is its target, it based on the ideal magnetic field circle in the AC motor which is supplied by three phases symmetric sine voltage. Magnetic field effective vectors which are produced by different switch modes are used to approach the based circle, that is using the polygon to approach the circle. Theory analysis and the experiment show that SVPWM have many merits such as less torque pulsation, lower noise, high utilization on rate [1-3].

2. Space Vector Theory

Space vector has six non-zero vectors whose included angle are 60° and two zero voltage vector, show as the Figure 1.

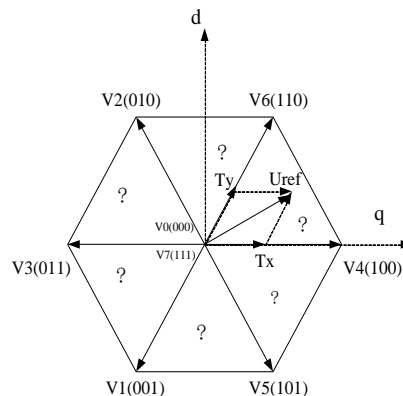


Figure 1. Based Vector Figure

The key to realizing the control method of producing space vector symmetric PWM is how to control the amplitude, position and action time of the voltage vector. Vector synthesis algorithm is used in engineer usually, this algorithm divide the magnetic field circle into six areas, in every area two adjacent vectors and a zero vector are choose to synthesis any vector in the sector area by rule of the voltage-second balance [4].

For example, Figure 2 show that \vec{U}_{oL} is synthesized by two state space vectors and one zero space vector when it in any vector.

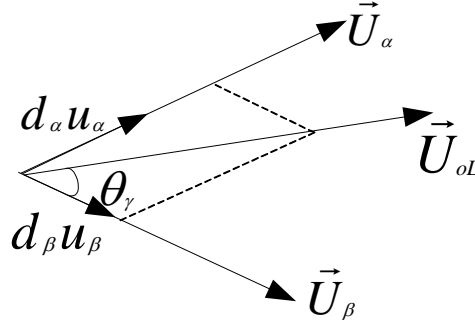


Figure 2. Voltage Space Vector Synthesis

The math function is:

$$\vec{U}_{oL} = d_{\alpha} \vec{U}_{\alpha} + d_{\beta} \vec{U}_{\beta} + d_{0\gamma} \vec{U}_0 \quad (1)$$

$d_{\alpha}, d_{\beta}, d_{0\gamma}$ —voltage space vector $\vec{U}_{\alpha}, \vec{U}_{\beta}$ and \vec{U}_0 duty cycle respectively, limited by followed function:

$$0 \leq d_{\alpha}, d_{\beta}, d_{0\gamma} \leq 1, \quad d_{\alpha} + d_{\beta} + d_{0\gamma} = 1$$

Switch period is T_s , d_{α}, d_{β} and $d_{0\gamma}$ is obtained by sine theory respectively:

$$\begin{aligned} d_{\alpha} &= T_{\alpha} / T_s = m_{\gamma} \sin(60^{\circ} - \theta_{\gamma}) \\ d_{\beta} &= T_{\beta} / T_s = m_{\gamma} \sin \theta_{\gamma} \\ d_{0\gamma} &= T_{0\gamma} / T_s = 1 - d_{\alpha} - d_{\beta} \end{aligned} \quad (2)$$

m_{γ} —voltage modulation coefficient, $0 \leq m_{\gamma} \leq 1$;

$T_{\alpha}, T_{\beta}, T_{0\gamma}$ —voltage space vector $\vec{U}_{\alpha}, \vec{U}_{\beta}$ and \vec{U}_0 switch on time.

3. Simulation Method and Results

3.1. Section Judging

It is defined that:

$$\begin{aligned} U_{ref1} &= U_d, U_{ref2} = \frac{\sqrt{3}}{2} U_q - \frac{1}{2} U_d \\ U_{ref3} &= -\frac{\sqrt{3}}{2} U_q - \frac{1}{2} U_d \end{aligned}$$

Rules: if $U_{ref1} > 0$, then $A = 1$, else $A = 0$, if $U_{ref2} > 0$, then $B = 1$, else $B = 0$, if $U_{ref3} > 0$, then $C = 1$, else $C = 0$

$N = A + 2B + 4C$ the relationship table of sections and N is obtained, show as Table 1.

Table 1. Relationship of Sections and N

N	1	2	3	4	5	6
Section No.	II	VI	I	IV	III	V

3.2. Function X, Y, Z and Vector Time T₁, T₂

It is defined that:

$$X = \sqrt{3}U_d T_s / U_E \quad Y = \left(\frac{3}{2}U_q + \frac{\sqrt{3}}{2}U_d \right) T_s / U_E,$$

$$Z = \left(-\frac{3}{2}U_q + \frac{\sqrt{3}}{2}U_d \right) T_s / U_E$$

To different section, value of Tx, Ty can be obtained from Table 2.

Table 2. Tx and Ty Value Table

N	I	II	III	IV	V	VI
T _x	Z	Y	-Z	-X	X	-Y
T _y	Y	-X	X	Z	-Y	-Z

3.3. A, B, C Three Phase switch time T_{cm1}, T_{cm2}, T_{cm3}

It is defined that:

$$T_a = (T_s - T_x - T_y) / 4, \quad T_b = T_a + T_x / 2,$$

$$T_c = T_b + T_y / 2$$

In different section, A,B,C three phase switch time Tcm1,Tcm2,Tcm3, evaluation according to Table 3.

Table 3. Tcm1, Tcm2, Tcm3 Evaluation Table

Section No.	I	II	III	IV	V	VI
T _{cm1}	T _a	T _b	T _c	T _c	T _b	T _a
T _{cm2}	T _b	T _a	T _a	T _b	T _c	T _c
T _{cm3}	T _c	T _c	T _b	T _a	T _a	T _b

3.4. Simulation Results

The inverter DC input voltage UE=300V, Ts=0.0002s:

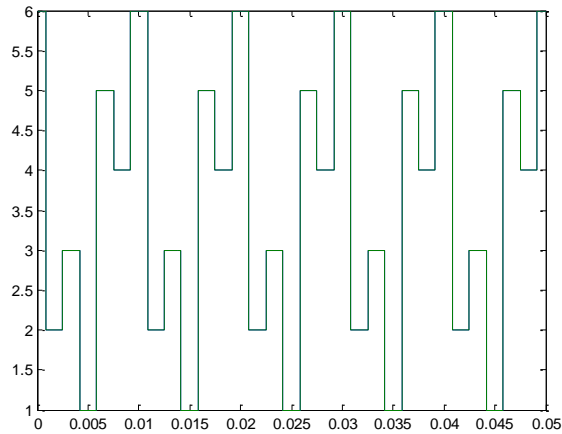


Figure 3. Section N Wave Form

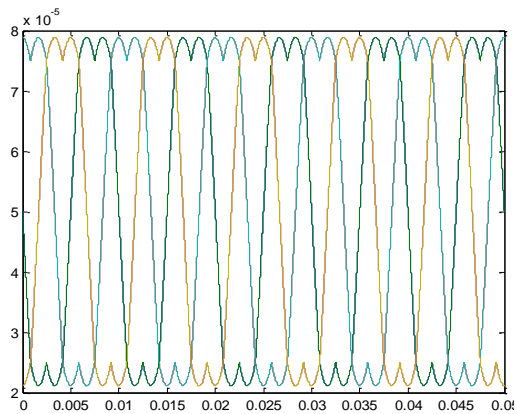


Figure 4. Tcmx(x=1,2,3) Waveform

The power may be divided into six block: rectification circuit, inverter circuit, drive circuit, auxiliary power circuit, filter circuit, control circuit [5].

The rectification circuit is a three phases AC/DC transform circuit, it transforms the AC380V/50Hz power into stable DC power for inverter circuit through transformer by rectification filter circuit.

4. Structure of Variable Frequency Power

In this paper, the variable frequency power is designed, show as Figure 6.

The inverter circuit realize the DC/AC power transform, that is the SVPWM which is produced by DSP control the IGBT switch mode through the drive circuit, and the wave that needed is produced [6].

The drive circuit is the interface between electronics circuit and control circuit, is the important part of the power electronics device, influence the performance of whole device, its task is transform the sign from information electronic circuit into the sign which can control the switch mode of power electronic device. And the drive circuit separate the control circuit and main circuit [7, 8].

The auxiliary power supply the DC power for control circuit to ensure the system working stable and reliable.

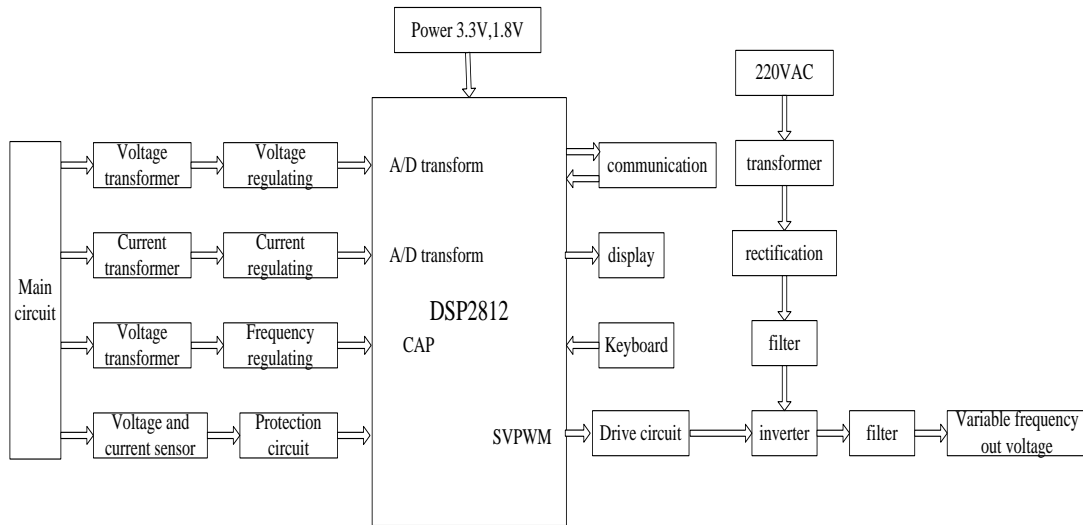


Figure 6. Variable Frequency Power Block Diagram

The auxiliary power supply the DC power for control circuit to ensure the system working stable and reliable.

The DSP control circuit block detects the three phase voltage signal, current signal and frequency signal from the voltage sampling circuit, current sampling circuit and frequency sampling circuit. Producing SVPWM control signal according to control algorithm and strategy to control electronic device switch mode through the drive circuit to stabilize the output voltage, at the same time, detect the input voltage, current and frequency from the sampling circuit [9].

5. Main Circuit and Drive Circuit

Three phases voltage inverter structure show as Figure 7, two power igtb switch mode is different in one bridge.

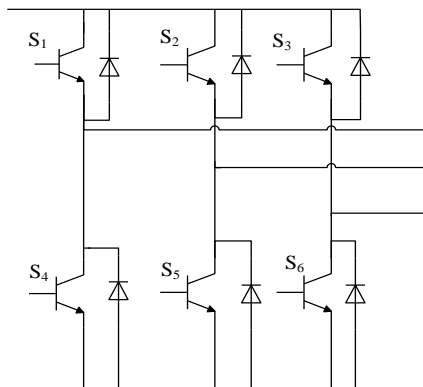


Figure 7. Variable Frequency Power Main Circuit

In this paper the EXB841 is choose as the drive chip, it can drive 400A/600V IGBT power block, switch frequency 40kHz, there is high isolation optical coupler in the chip, and have over current protection circuit, at present it is used widely, EXB841 drive circuit show as Figure 8.

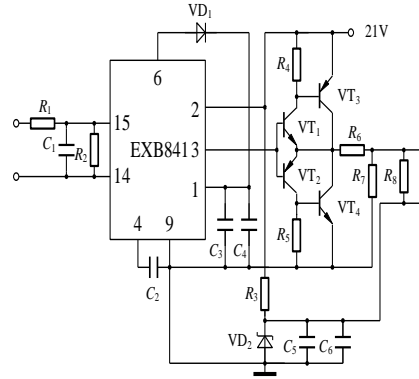


Figure 8. Drive Circuit

6. Software

In this paper, the software contains two parts:

1. PC detection program.
2. Hypogynous machine control program. PC display the parameter setting, frequency and voltage. Hypogynous machine is responsible for serial communication, space vector algorithm calculation, PWM output, voltage, current sampling and fault detection.

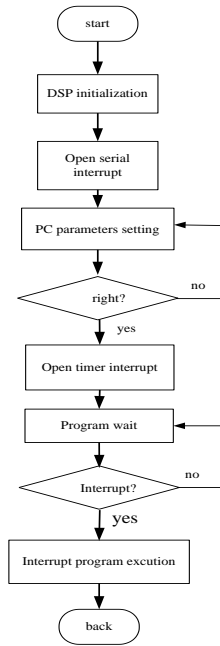


Figure 9. Main Program

7. Conclusions

Space vector pulse width modulation algorithm is easy to realize and improve the voltage coefficient of utilization, the system reliability is improved highly. In this paper, the principle is analyzed deeply and simulated by simulink, elaborate the theory, hardware and software, good results is achieved.

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