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Simulation of PMSM Vector Control Based on SVPWM AND SVPWM ALGORITHM

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Abstract. In the field of Permanent Magnet Synchronous Motor (PMSM) control, SVPWM method is one of the new techniques have been developed in recent years. This paper presented the SVPWM method, including the reference voltage projection and the space vector duration calculation. Then the simulation results also are presented.

Introduction

Permanent magnet synchronous motor has the characteristics of high efficiency, which has been widespread application in the various electric drives. The most commonly control approaches are sinusoidal PWM, field-control, the control based on DSP and Space vector PWM (SVPWM).

The SVPWM technique was proposed in recent years and widely used in inverter. Compared to the sinusoidal pulse width modulation and other patterns, SVPWM is more suitable for digital implementation. It aims to control the motor flux vector in a circular orbit, which results in less harmonic distortion, faster dynamic response and wider liner range of fundamental voltage [1]. The SVPWM method is the type which is derived form level SVPWM, that the reference voltage is decomposed and one new hexagon is selected, then the two neatest adjacent vectors and their duration time are determined like two level SVPWM [2].

This paper, the SVPWM method is detailed presented including the reference voltage projection and the space vector duration calculation. And in the paper, it also develops simulation program using Matlab/Simulink.

SVPWM algorithm

A:the three-phase voltage source inverter

SVPWM refers to a special way to determine switching sequence in three-phase voltage source inverters. Eight basic space vectors generate output voltages to motor.

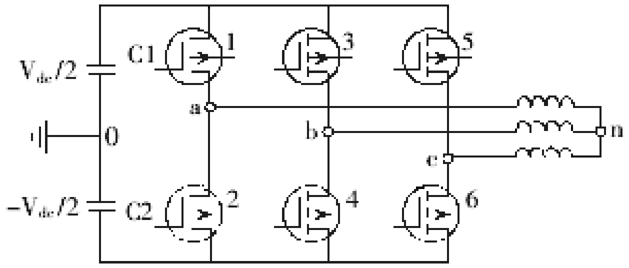

Fig.1 A three phase voltage source inverter

In fig.1 is a three-phase voltage source inverter and V_a, V_b, V_c are the output voltage which modulate PMSM speed. In the three-phase voltage source inverter, c1 and c2, 3 and 4, 5 and 6 is locked each other. On the other words, when c1 (c1=1) is on then c2 (c2=0) is off at the same time.

SVPWM is to determine the switching sequence of upper sides. The on and off status of the three upper transistors compose eight space vectors [3].

B: voltage of Space Vector PWM

The three-phase voltage source inverter has eight switch states, corresponding to 8-space vectors: $U_0, U_{60}, U_{120}, U_{180}, U_{240}$, $U_{300}, O_{000}, O_{111}$, here six states are working non-zero vectors and two states (O_{000}, O_{111}) are zero vectors; the angle between two adjacent non-zero vector is 60 degrees. The space voltage vector PWM is shown as Fig.2 [2].

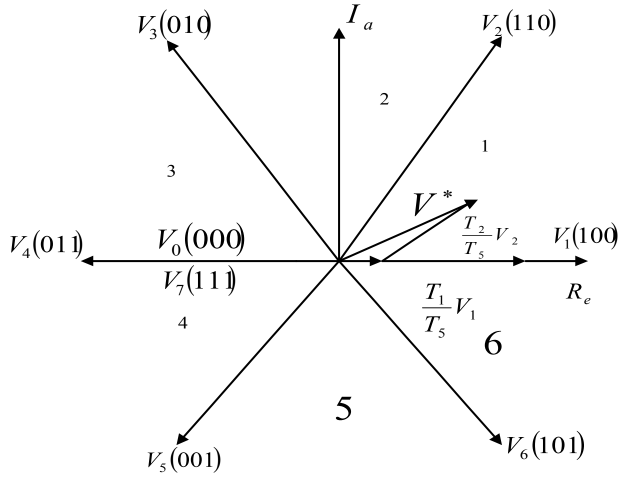

Fig.2: Voltage space vector

The SVPWM method with zero vectors that combined with states O_{000} and O_{111} in each sector is adopted in this paper. The inclusion of zero vectors helps to balance the turn on and turn off periods of the transistors, and thus their power dissipation [3].

If the reference voltage is set in the sector 1, V_{ref} can be compounded by V_4 and V_6 and the equation can be expressed as:

$$\begin{aligned} &V_4 * T_4 + V_6 * T_6 = V_{ref} * T \\ &T = T_4 + T_6 + T_0 \end{aligned} \tag{1}$$

Where T is switch period. T_4, T_6 are operating times corresponding to V_4 and V_6. The voltage vector V_α, V_β in α-β reference coordinate frame is[6]:

$$\begin{aligned} &V_{s\beta ref} = \frac{T_6}{T}\|V_6\|\cos 30^\circ \\ &V_{s\alpha ref} = \frac{T_6}{T}\|V_6\| + x \\ &x = \frac{V_{s\alpha ref}}{\tan 60^\circ} \end{aligned} \tag{2}$$

The amplitude of each basic space vector is $\frac{2U_{dc}}{3}$, so we can get:

$$\begin{aligned} &T_6 = V_{\beta ref} \cdot \sqrt{3}T / U_{dc} \\ &T_4 = \frac{1}{2}\left(\sqrt{3}V_{\alpha ref} - V_{\beta ref}\right) \cdot \sqrt{3} / U_{dc} \end{aligned} \tag{3}$$

Then operating time in other sector corresponding to the voltage can be calculated in the same way [3].

The steps of SVPWM

1) Determination of the sector: Modified the Clark^{-1} transformation before to determine the sector[11]. The Clark^{-1} transformation as followings:

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ \frac{-1}{2} & \frac{\sqrt{3}}{2} \\ \frac{-1}{2} & \frac{-\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_\beta \\ V_\alpha \end{bmatrix} \tag{4}$$

Then, the output waveforms of $V_a, V_b and V_c$ for sinusoid wave input (V_α,V_β) can be calculated. They can determine the sector according to the following rules [6]:

If $V_a > 0$， then a=1 else a=0

If $V_b > 0$ ， then b=1 else b=0

If $V_c > 0$ ， then c=1 else c=0

Sector = a +2b +4c (5)

2) Calculation of T_1 and T_2: To calculate and saturate the duration of two sectors boundary vectors application.

Form equations (5) above, can get that:

$$\begin{aligned} T_X &= \sqrt{3}\frac{T}{V_{DC}}V_{s\beta ref} \\ T_Y &= \frac{T}{2V_{DC}}(3V_{s\alpha ref} + \sqrt{3}V_{s\beta ref}) \\ T_Z &= \frac{T}{2V_{DC}}(-3V_{s\alpha ref} + \sqrt{3}V_{s\beta ref}) \end{aligned} \tag{6}$$

The table 1 shows the time in each sector.

TABLE Ⅰ T_1 and T_2 in specific sectors

S_3	S_1	S_5	S_4	S_6	S_2
$-T_Z$	T_Z	T_X	$-T_X$	$-T_Y$	T_Y
T_X	T_Y	$-T_Y$	T_Z	$-T_Z$	$-T_X$

3) The third step is to compute the three necessary duty cycles. This is shown below:

$$\begin{aligned} t_{aon} &= \frac{T - t_1 - t_2}{2} \\ t_{bon} &= t_{aon} + t_1 \\ t_{con} &= t_{bon} + t_2 \end{aligned} \tag{7}$$

4) The last step is to assign right duty cycle (t_{xon}) to the right motor phase according to the sector. The table 2 below depicts this determination.

Table 2 Assigning the Right Duty Cycle to the Right Motor Phase

Sector / Phase	1	2	3	4	5	6
T_a	T_{aon}	T_{bon}	T_{con}	T_{con}	T_{bon}	T_{aon}
T_b	T_{bon}	T_{aon}	T_{aon}	T_{bon}	T_{con}	T_{con}
T_c	T_{con}	T_{con}	T_{bon}	T_{aon}	T_{aon}	T_{bon}

Simulink and results

After analyzing the SVPWM method and getting the steps of determine the voltage, the simulation mode of SVPWM apply for PMSM system is established. The simulation model is under the environment of MATLAB 7.1/Simulinkusing due to its rich module libraries. The system structure is shown in fig.3, and the results of it are also shown.

Set the motor speed is 100rad/s as the reference speed and start motor with no-load. PWM cycle T=0.0001s, the load increases to 5 Nm. Simulation time is 0.06s, and the simulation waveform is shown in figure. 3.

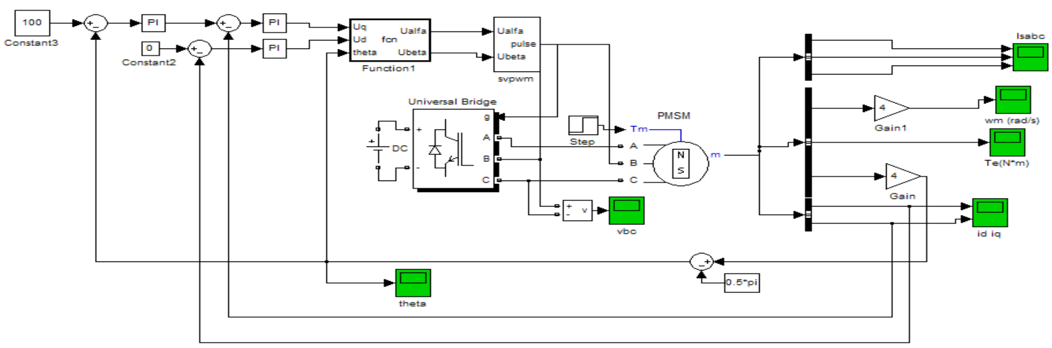

Fig .3 Simulation model of SVPWM system

Here is the waveform of torque via the experiment as shown in figure.4 , we could get that the torque is large at the beginning; the torque is descend along with the time and then is close to zero at the end.

In the figure.5, at the beginning of the waveform of speed there is a bit ascended and then get stead.

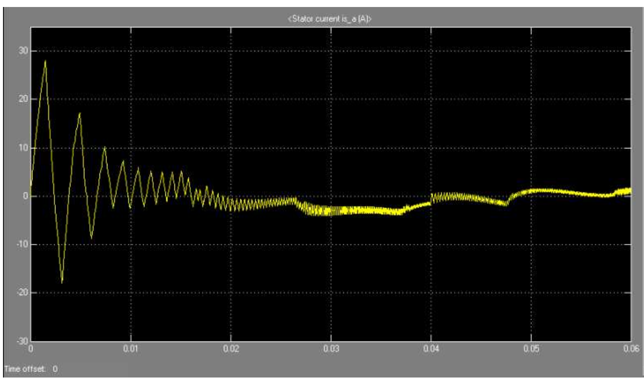

Fig .4: Waveform of torque

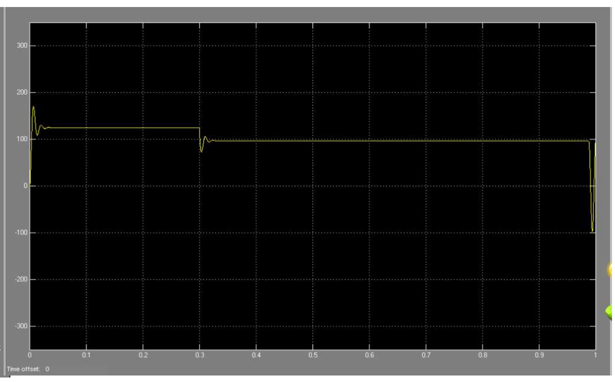

Fig .5: Waveform of t speed

In the figure.6 and figure.7, there are waveforms of three currents and voltage.

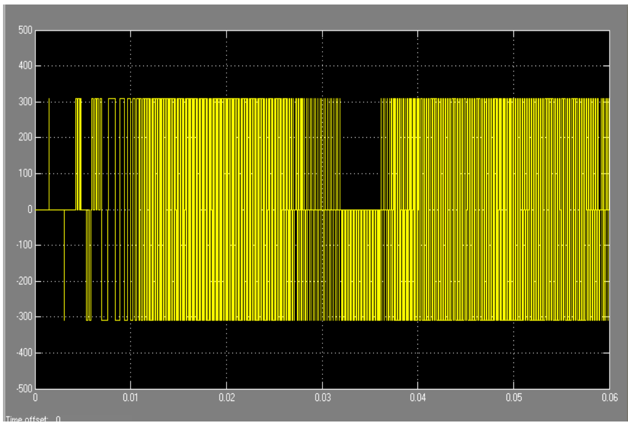

Fig .6: Waveform of current

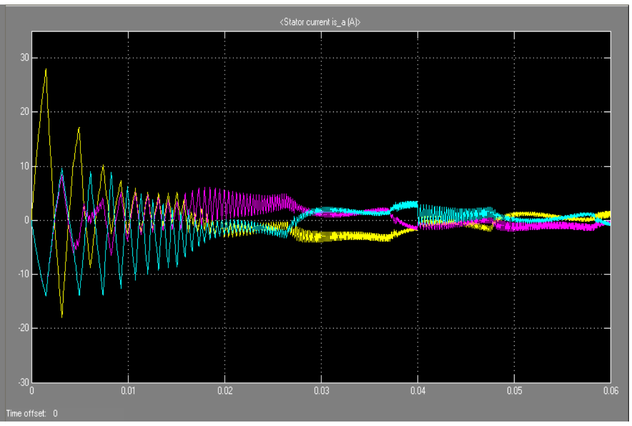

Fig .7: Waveform of and voltage

Simulation results are in accord with the performance characteristic of PMSM, which proves the accuracy of the SVPWM algorithm and the control model, and provides theory basis for actual design of control system.

CONCLISIONS

This paper proposed one phase voltage coordination projection based on SVPWM algorithm, presented the method to calculate the duration , selected redundant switch vectors , presented the SVPWM method and the simulation of SVPWM the PMSM.

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