SPACE VECTOR PWM TECHNIQUE FOR AN OPTIMAL VECTOR CONTROLLED INDUCTION MOTOR

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ABSTRACT:

This paper presents a Space vector PWM control technique for Voltage Source Fed Induction Motor VSFIM. Such PWM algorithm is suitable for microprocessor based control. Spectral analysis of the output voltage is evaluated in order to predict the effect of the proposed PWM technique on the motor dynamical performances. Simulation results of this technique is presented for the optimal vector control a three phase induction motor.

I INTRODUCTION:

With the advances in VLSI technology there has been a general tendency to develop and implement various PWM strategies using microprocessors [1]. Another approach uses numerical criterion to calculate the desired switching patterns. The criterion is related to performance of the drive system, such as total harmonic distortion (THD) of the motor current, torque pulsation etc… Optimal PWM obtained this way are generally implemented using look-up tables containing the switching angles. This requires a large numbers of tables for in order to guarantee an acceptable frequency and voltage resolution. A possible solution to this drawback is to store a set of patterns within the hole operation range and use interpolation techniques to compute the intermediate patterns [2]. Some optimal switching techniques uses the harmonic elimination method to suppress selected harmonics in the PWM waveform.

II SVM PWM TECHNIQUE

The Pulse Width modulation technique permits to obtain three phase system voltages, which can be applied to the controlled machine. Space Vector Modulation (SVM) principle differs from other PWM processes in the fact that all three drive signals for the inverter will be created simultaneously. The implementation of SVM process in digital systems necessitates less operation time and also less program memory.

The SVM algorithm is based on the principle of the space vector $\underline{u}^*$, which describes all three output voltages $\underline{u}_a$, $\underline{u}_b$ and $\underline{u}_c$:

$\underline{u}^* = 2/3 \, . \, (\underline{u}_a + \underline{a} \, . \, \underline{u}_b + \underline{a}^2 \, . \, \underline{u}_c)$ where

$\underline{a} = -1/2 + j \, . \, v3/2$

We can distinguish six sectors limited by eight discrete vectors $\underline{u}_0 \ldots \underline{u}_7$ (Fig.1), which correspond to the $2^3 = 8$ possible switching states of the power switches of the inverter.

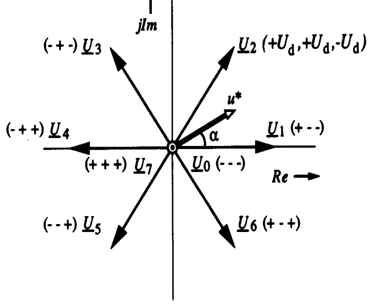

Figure 1 Space vector Modulation

The amplitude of u_0 and u_7 equals 0. The other vectors $\underline{u}_1 \ldots \underline{u}_6$ have the same amplitude and are 60 degrees shifted.

By varying the relative on-switching time Tc of the different vectors, the space vector $\underline{u}^*$ and also the output voltages $\underline{u}_a$, $\underline{u}_b$ and $\underline{u}_c$ can be varied and is defined as:

$$\underline{u}_a = \mathrm{Re}\ (\ \underline{u}^*\ )$$

$$\underline{u}_b = \mathrm{Re}\ (\ \underline{u}^* \ .\ \underline{a}^{-1})$$

$$\underline{u}_c = \mathrm{Re}\ (\ \underline{u}^* \ .\ \underline{a}^{-2})$$

During a switching period T_c and considering for example the first sector, the vectors $\underline{u}_0$, $\underline{u}_1$ and $\underline{u}_2$ will be switched on alternatively (Fig. 2).

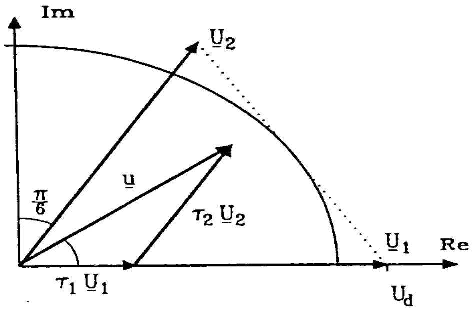

Figure 2 Definition of the Space vector

Depending on the switching times t_0, t_1 and t_2 the space vector $\underline{u}^*$ is defined as:

$$\underline{u}^* = 1/T_c \ .\ (\ t_0 \ .\ \underline{u}_0 + t_1 \ .\ \underline{u}_1 + t_2 \ .\ \underline{u}_2\ )$$

$$\underline{u}^* \ = \tau_0 \ .\ \underline{u}_0 + \tau_1 \ .\ \underline{u}_1 + \tau_2 \ .\ \underline{u}_2$$

$$\underline{u}^* \ = \tau_1 \ .\ \underline{u}_1 + \tau_2 \ .\ \underline{u}_2$$

where

$$t_0 + t_1 + t_2 = T_c \ \text{ and}$$

$$\tau_0 + \tau_1 + \tau_2 \ = 1$$

τ_0, τ_1 and τ_2 are the relative values of the on-switching times. They are defined as:

$$\tau_1 = m \ .\ \cos\ (\ \alpha + \pi/6)$$

$$\tau_2 = m \ .\ \sin\ \ \alpha$$

$$\tau_0 = 1 - \tau_1 - \tau_2$$

Their values are implemented in a table for a modulation factor m = 1. Then it will be easy to calculate the space vector $\underline{u}^*$ and the output voltages $\underline{u}_a$, $\underline{u}_b$ and $\underline{u}_c$.

The voltage vector $\underline{u}^*$ can be provided directly by the optimal vector control laws w_1, $vs\alpha$ and $vs\beta$ define in [1]. In order to generate the phase voltages $\underline{u}_a$, $\underline{u}_b$ and $\underline{u}_c$ corresponding to the desired voltage vector $\underline{u}^*$ the following SVM strategy is proposed.

As shown in Figure 3, the proposed inverter can be presented by three ideal single-pole double-throw switches QA, QB and QC.

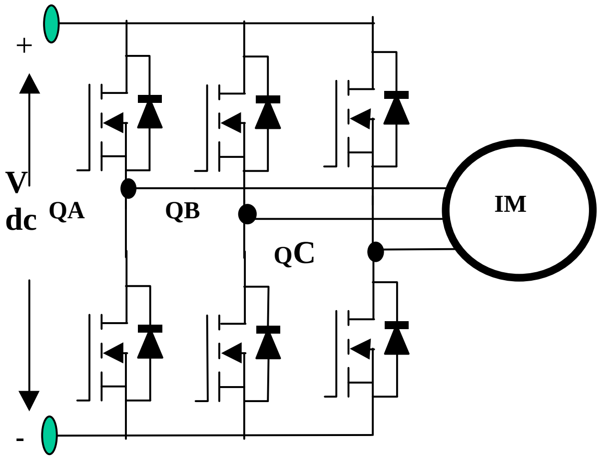

Figure 3 Voltage-source inverter-fed PMSM

The inverter conduction state is represented by the logic variables SA,SB,SC. A logic 1 means that the upper switch is conducting and a logic '0' means that the lower switch is conducting. The switching of QA,QB and QC creates 8 operating states for the inverter as indicated in table 1.

Table 1: Inverter voltage without neutral connection

SC	SB	SA	$\underline{u}^*$	mode	Sequence	ma	mb	mc
0	0	1	u1	Active	1	-1/3	-1/3	2/3
0	1	1	u3	Active	3	-2/3	1/3	1/3
0	1	0	u2	Active	2	-1/3	2/3	-1/3
1	1	0	u5	Active	6	1/3	1/3	-2/3
1	0	0	u4	Active	4	2/3	-1/3	-1/3
1	0	1	u6	Active	5	1/3	-2/3	1/3
1	1	1	u7	FRW	7	0	0	0
0	0	0	u0	FRW	0	0	0	0

III SIMULATION RESULTS AND PERFORMANCE ANALYSIS

The proposed PWM algorithm is tested using the optimal vector controller proposed in [3]. At the steady state where the stator frequency is ws = 256 rad /sec (fs= 40.75 Hz), The rotor speed is Nr=982 Rpm . The desired (α,β) voltages and space vector mopdule are respectively Vsα =2.77 V , Vsβ=74.4311V and $\underline{u}^*$=74.48 V . In order to evaluate the performances of such PWM, different switching frequencies Fc were used for testing. Figure 4 shows different phase A stator voltage generated at switching frequencies Fc= 1kHz, Fc= 3kHz, Fc= 5kHz, Fc= 10kHz.

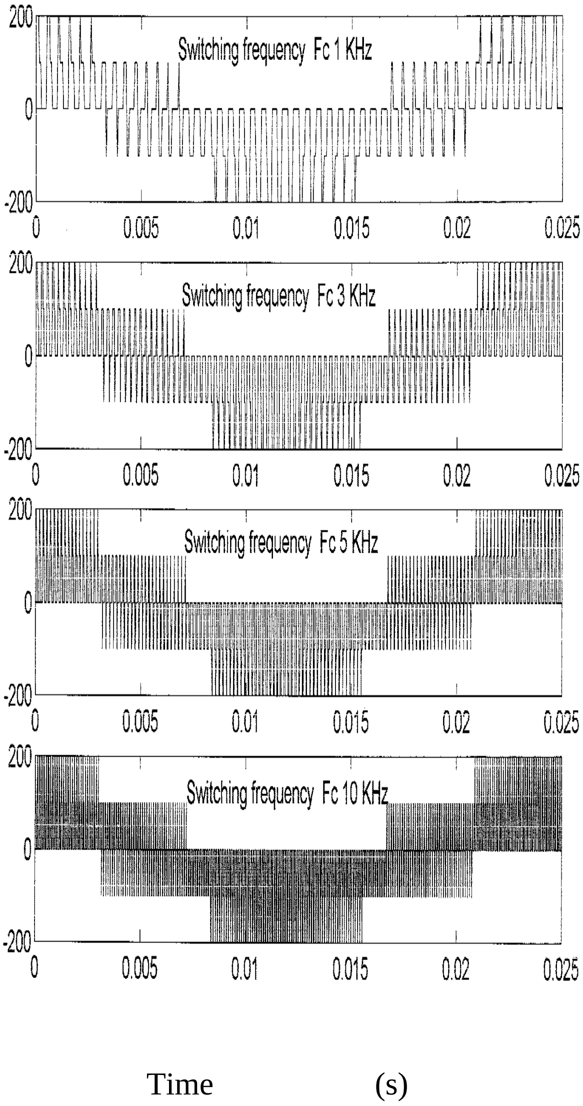

Figure 4 Voltage ua generated by the proposed SVM PWM technique for different switching frequencies Vdc=300V.

A spectral analysis of all waveforms is performed and all harmonics are presented in table-2. These results shows that acceptable motor performances can be obtained at all testing frequencies since the total harmonic distortion (THD) did never reach 10 % . At high switching frequency the PWM converter generate a voltage having an amplitude close to the desired value

Table 2 : Spectral analysis

h	**Harmonics for different Switching frequencies**			
	1 kHz	**3 kHz**	**5 kHz**	**10 kHz**
0	-4.58	-4.58	-4.16	-4.16
1	81.22	80.83	73.33	73.24
2	3.22	2.99	2.64	2.60
3	4.70	4.53	4.06	4.03
4	0.42	0.20	0.11	0.06
5	4.45	5.04	4.80	4.94
6	1.98	1.79	1.58	1.55
7	1.03	1.07	0.99	1.00

CONCLUSION:

An evaluation of the Space vector modulation technique has shown that it has a number of advantages over other PWM techniques. These advantages are mainly linked with real time implementation considerations since it can be easily programmed on a Microprocessor. Such technique have brought improvements to the total harmonic distortion as well as an increase in the range of obtainable fundamental voltages without requiring very large storing memories. The proposed technique is found to be suitable for optimal vector control of the three phase induction motor.

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