Csvpwm Algorithm for Induction Motor Drive Implementation Using Dspace

[1]Y.CHINTU SAGAR. [2]S. ABDUL RAZAK MIAH and [3]S. FARZANA

[1]Assistant Professor, Electrical and Electronics Engineering, ASKW, KURNOOL, A.P, INDIA,

chintusagar@ashokacollege.in

[2]Assistant Professor, Electrical and Electronics Engineering, ASKW, KURNOOL, A.P, INDIA, sarazak43@gmail.com

[3]Assistant Professor, Electrical and Electronics Engineering, ASKW, KURNOOL, A.P, INDIA, ls.fara1034@gmail.com

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Abstract: This paper presents performance of conventional space vector based pulse width modulation (CSVPWM) algorithm for voltage source inverters fed INDUCTION MOTOR drive using dSPACE. The proposed algorithm is valid for advanced modulation indicators. To reduce the harmonious distortion and to increase the dc bus application of the inverter when compared with the sinusoidal PWM (SPWM) algorithm, this paper has been concentrated on the perpetration of conventional space vector based PWM algorithm. The main purpose of this system work is to determine whether dSPACE can be used in controlling power electronics operations. From the test done, control of induction motor was successfully executed using dSPACE which means this process is attainable. The proposed PWM algorithms have been developed by using the generalization of sector selection. To validate the proposed algorithm, numerical simulation and real time studies have been carried out and results are presented.

Index Terms— dSPACE, Matlab/Simulink, CSVPWM, Induction Motor Drive.

I INTRODUCTION

Due to the inventions of fast switching power semiconductor devices and motor control algorithms, a growing interest is set up in a more precise pulse width modulation (PWM) system. During the late decades several PWM algorithms have been studied considerably. Various PWM techniques have been developed to achieve wide direct modulation range, smaller switching loss, smaller total harmonious distortion (THD) and easy execution and smaller calculation time. A large variety of algorithms for PWM exist, and an inspection of these was given in (1). There are two popular approaches for the execution of PWM algorithms, namely triangular comparison (TC) approach and space vector (SV) approach. For a long period, TC approach based PWM techniques were extensively used in ultimate usages. The initial modulation signals for TC approach based PWM are sinusoidal. But, the addition of the zero sequence signals to the sinusoidal signals results in several non-sinusoidal signals. Compared with sinusoidal PWM (SPWM) algorithm non-sinusoidal PWM algorithms can extend the direct modulation range for line- to- line voltages. Different zero-sequence signals lead to different non-sinusoidal PWM modulators (2). But this paper presents only conventional space vector approach (CSVPWM).

Currently, due to the development of digital signal processors, SVPWM has got one of the most popular PWM techniques for three-phase inverters (3)-(4). It uses the SV approach to calculate the duty cycle of the switches. The main features of this PWM algorithm are easy digital accomplishment and wide linear modulation range for output line- to- line voltages. The equality between TC and SV approaches has studied in (5) and concluded that SV approach offers further degrees of freedom compared to TC approach.

Though, the SVPWM gives superior performance, it gives higher switching losses of the inverter as it has continuous modulating signal. Hence, to reduce the switching losses of the inverter, presently discontinuous PWM (DPWM) algorithms are becoming popular. The generation of these DPWM algorithms is given in detail in (6)-(8). Even so, this paper presents only the conventional space vector approach and it requires angle and sector information and hence increases the complexity involved in the algorithm.

In this paper, space vector based PWM algorithms for AC drives are presented by using the generalization of sector selection. Likewise, the simulation and hardware execution of the proposed CSVPWM technique have been developed and is discussed and results are provided to validate the drawn conclusions.

II Conventional SVPWM algorithm

The main purpose of the voltage source inverter (VSI) is to induce three-phase voltage with controllable amplitude, and frequency. General 2- level, 3- phase VSI feeding three-phase induction motor is shown in Fig 1.

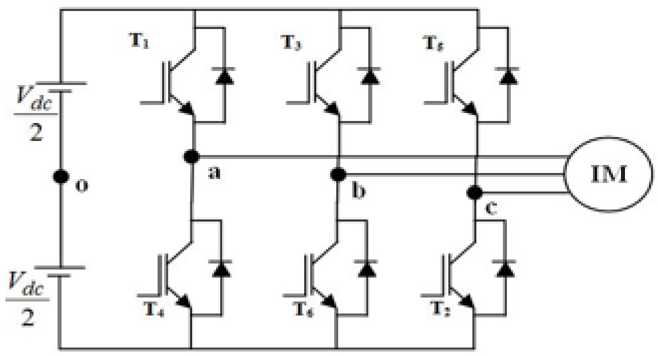

Figure1. 2-level, 3-phase voltage source inverter feeding induction motor

From Fig. 1, it can be observed that the two switching devices on the same leg cannot be turned on and cannot be turned off at the same time, which will affect in the uncertain voltage to the connected phase. Therefore the nature of the two switches on the same leg is supplementary. The switching-on and switching-off sequences of switching device are represented by an existence function, which has a value of symmetry when it is turned on and becomes zero when it's turned off. The reality function of VSI consisting of switching devices Ti is represented by Si, i = 1, 2,...6. Hence, S1, S4 which take values of zero or symmetry individually, are the existence functions of the top device(T1) and lowermost device(T4) of the inverter leg which is connected to phase ‘a’.

$$S_1 + S_4 = 1;\; S_3 + S_6 = 1;\; S_5 + S_2 = 1 \qquad (1)$$

As seen from Fig 1, there are completely six switching devices and only three of them are independent. The combination of these three switching states gives out eight possible voltage vectors. At any time, the inverter has to operate one of these voltage vectors. Out of eight voltage vectors, two are zero voltage vectors (V_0 and V_7) and remaining six (V_1 to V_6) are active voltage vectors. In the space vector plane, all the voltage vectors can be represented as shown in Fig 2.

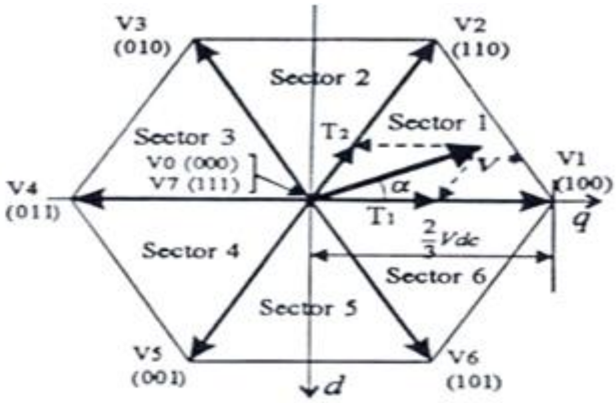

Figure 2. Voltage space vectors produced by a voltage source inverter

For a given set of inverter phase voltages (V_{an}, V_{bn}, V_{cn}), the space vector can be constructed as

$$V_s = \frac{2}{3}\left(V_{an} + V_{bn} e^{j\frac{2\pi}{3}} + V_{cn} e^{j\frac{4\pi}{3}} \right) (2)$$

From (2), it is easily shown that the active voltage vectors or active states can be represented as

$$V_k = \frac{2}{3} V_{dc} e^{j(k-1)\frac{\pi}{3}} \qquad \text{where } k = 1,2,\ldots,6 \qquad (3)$$

By maintaining the volt-second balance, a combination of switching states can be applied to induce given sample in an average sense during a sub cycle. The voltage vector in Fig. 2 represents the reference voltage space vector or sample, corresponding to the required value of the essential elements for the output phase voltages. But, there is no direct way to produce the sample and hence the sample can be reproduced in the average sense. The reference vector is tried at equal intervals of time, referred to as sample time period. Different voltage vectors that can be produced by the inverter are applied over different durations with in a sample time period such that the average vector produced over the sub cycle is equal to the tested value of the reference vector, both in terms of magnitude and angle. As all the six sectors are symmetrical, presently the discussion is limited to sector- I only. Let and be the durations for which the active states 1 and 2 are to be applied individually in given sample time period. Let be the total duration for which the zero states are to be applied. From the principle of a volt-time balance, and can be calculated as

$$T_1 = \frac{2\sqrt{3}}{\pi} M\left[Sin(60^o - \alpha)\right]T_s \quad (4)$$

$$T_2 = \frac{2\sqrt{3}}{\pi} M\left[Sin(\alpha)\right]T_s \quad (5)$$

$$T_Z = T_s - T_1 - T_2 \quad (6)$$

Where M is known as the modulation index and defined as given in (7).

$$M = \frac{\pi v_{ref}}{V_{dc}} \quad (7)$$

In the SVPWM algorithm, the maximum modulation index is 0.906 (1). In the SVPWM strategy, the total zero voltage vector time is uniformly distributed between V_0 and V_7. Further, in this technique, the zero voltage vector time is distributed symmetrically at the initial and end of the sub cycle in a symmetrical manner. Also, to minimize the switching frequency of the inverter, it has desirable that switching should take a place in one phase of the inverter only for a transition from one state to another. Therefore, SVPWM uses 0127-7210 in first sector, 0327- 7230 in other sector and so on. Table- 1 depicts the switching sequence for all the sectors.

TABLE 1

SWITCHING SEQUENCES IN ALL SECTORS FOR SVPWM

Sector number	On-sequence	Off-sequence
1	0-1-2-7	7-2-1-0
2	0-3-2-7	7-2-3-0
3	0-3-4-7	7-4-3-0
4	0-5-4-7	7-4-5-0
5	0-5-6-7	7-6-5-0
6	0-1-6-7	7-6-1-0

Also, with the SVPWM algorithm, the modulation index and dc bus application can be increased when compared with the SPWM algorithm (1).

III SIMULATION RESULTS AND DISCUSSIONS

To validate the proposed PWM algorithms, several numerical simulation studies have been carried out using Matlab- Simulink. To maintain constant average switching frequency, the switching frequency of SVPWM algorithm is taken as. For the simulation studies, the average switching frequency of the inverter is taken as 10 kHz and the dc link voltage is taken as 600 V. The simulation results of various PWM algorithms are shown in fromFig. 3 – Fig4

Here only, modulating waveforms and pole voltages of the inverter have shown. From the simulation results it can be observed that the proposed approach gives same results when compared with the being approaches. Also, the SVPWM algorithm gives continuous pulse pattern and hence gives further switching losses of the inverter.

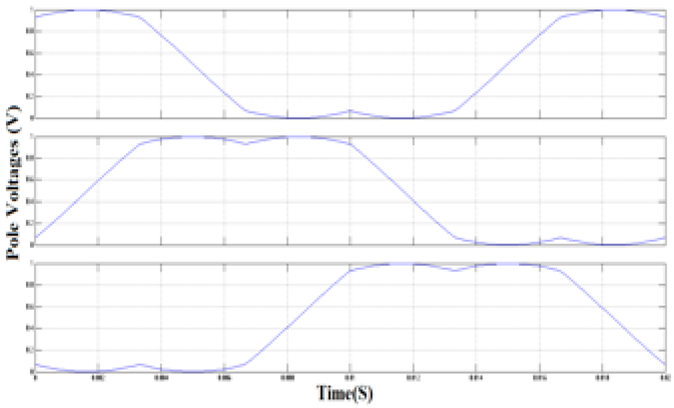

Figure 3. Simulation Results of Proposed SVPWM Algorithm modulating waves

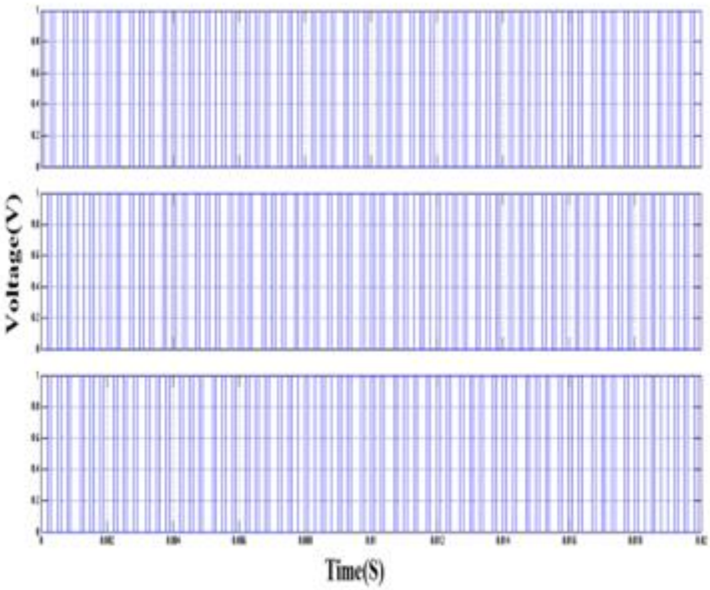

Figure 4. Simulation Results of Proposed SVPWM Algorithm Pulses

IV HARDWARE IMPLEMENTATION RESULTS AND DISCUSSIONS

The widespread simulation environment – the Matlab Simulink – is constantly used also in study of electrical drives. The Simulink, by using of the Real Time Interface (RTI) is able to link the simulation files to the real world, namely is possible to connect the variables of simulation structure to physical input-output units, (analog to digital- and digital analog inverters, digital in/ outs etc). Using suitable hardware it's possible to produce code, (executed on the target processor) based on simulation structure. In this way the time-consuming programming can be avoided and results a more powerful and effective development procedure. This approach was used by dSPACE in design of its DS series of regulator cards, devoted for real time control of fast processes like electrical drives. The DS1104 card contains all necessary peripherals and calculating power(offered by a PowerPC master-processor and TMS320F240 slave DSP) for implementation of complex drives structures. The software associated to the card provides the control for the implementation process from simulation up to real time experimentation. The CSVPWM Pulses are first designed in MATLAB/ SIMULINK environment and relative coding are written to produce the pulses and by using dSPACE software conversion tool the M- files are converted in to the C coding. That means simulation digital pulses are converted in to analog pulses. Therefore, the triggering pulses are given to the inverter and the induction motor operates. From the test done, control of induction motor was successfully executed using dSPACE which means this process is feasible. The proposed PWM algorithms have been developed by using the concept of sector selection

Figure 5. Real Time Implementation

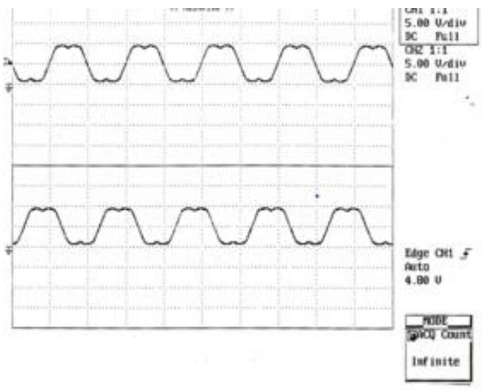

Figure 6. Real Time Implementation Results

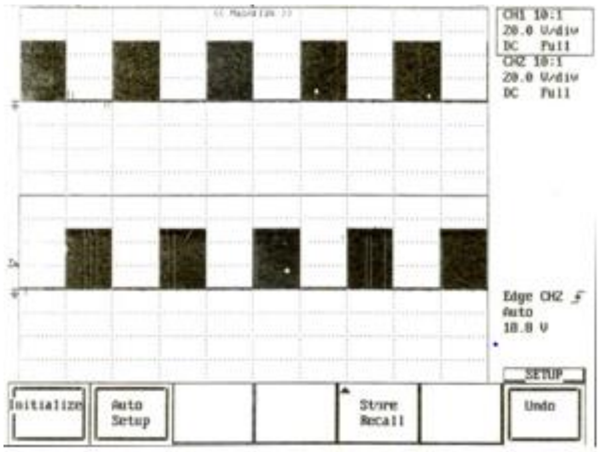

Figure 7. Real Time Implementation Results

V CONCLUSION

The simple proposed CSVPWM algorithm has been developed and simulation and real time results are presented in this paper. The proposed conventional space vector pulse width modulation algorithm uses the concept of sector selection. And it requires sector and angles calculations. Also, the proposed algorithm uses sector and angle calculations. It requires the angle and sector calculations and hence increases the complexity involved in the algorithm. From the test done, control of induction motor was successfully enforced using dSPACE which means this process is feasible. And speed of the Induction motor was controlled successfully by varying the frequency or voltage in the Matlabsimulink environment without disturbing the hardware equipment using dSPACE.

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