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DSP-Based SVPWM Signal Generation Algorithm for Three Phase Inverter

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Abstract: This paper deals with real time implementation of DSP based SVPWM control algorithm for 3 stage 3-leg IGBT voltage source inverter. This strategy is helpful to control the speed of VSI fed 3 phase induction motor. The pulses are generated using DSP controller Texas instrument TMS320F28335. The algorithm is designed using MATLAB and converted into C language using code composer studio (CCS) environment so that it can be reused easily to provide flexibility in terms of changing the PWM switching frequency and VSI frequency to trigger the inverter. Result of input and output are captured using Digital signal oscilloscope (DSO). This work is a piece of research work that intends to build up a sensorless vector control of 3 phase induction motor.

Keywords: Digital Signal processing, Space Vector Pulse Width Modulation (SVPWM), Voltage source inverter, induction motor

I. INTRODUCTION

Mechanical energy is needed in the daily life use as well as in the industry. Superior electric Motor drives are viewed as a key prerequisite for cutting edge modern applications. Electric motors are very efficient. Their efficiencies fluctuate from 85% to 95% for motor of sizes extending from 10 HP to 500 HP. They are extremely dependable, tough and cover more than 90% of the introduced limit of electric motor in the modern area. Because of an extensive introduced base of motor utilizing power, even a little change in effectiveness can bring about noteworthy reserve funds from a more extensive national viewpoint. Speed of motor need to be change in many applications so pulse width modulation technique is more efficient and pulse width modulation technique provides higher level of performance. Speed of motor can be adjusted by changing the frequency applied to motor. The high switching techniques give better quality output but at the expense of the switching losses [1]. Different pulse width modulation (PWM) techniques have different switching pattern and best technique need to be implemented[2]. The DSP controller can reduce the number of control circuit components and can optimize the drive performance. It Generate high-resolution PWM signals for efficient control of the power electronic inverter and reduction of harmonics and provide a single chip drive control system and reduce the drive system cost.[3]

II. SPACE VECTOR PWM

PWM system or technique is used to deliver the required voltage or current to feed the motor or phase signals. All things considered, the PWM schemes create the switching position patterns by comparing three-phase sinusoidal waveforms and a triangular waveform. In PWM fed IGBT based inverter upper IGBTs (T1, T3, T5) and lower IGBTs (T4, T6, T2) are must complimentary on-off. The gate signals S1, S3 and S5 are control the upper transistors, and similarly S4, S6 and S2 are control the lower transistors. For commonsense security thought, a dead band ought to be embedded into the ideal PWM waveform. Dead-band is the name given to the time distinction between the commutation of the upper and lower transistor of one phase. The point of the dead-band is to secure the IGBTs during commutation by maintaining a strategic distance from conduction overlap and after that high transient current[4].

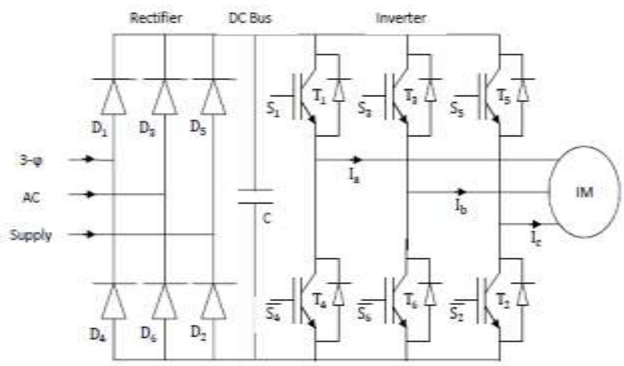


Figure1. IGBT Based Three Phase Inverter Controlled by Six PWM Signals.

The output of three-phase voltage source inverter can be molded utilizing the Space Vector PWM strategy. The upper level switches are on, i.e., S1, S3 and S5 is 1, the comparing lower switches S4, S6 S2 are 0.

The relation or connection between the phase voltage and line to line voltages to the switching conditions of the two level inverter are given as follow.

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix}$$

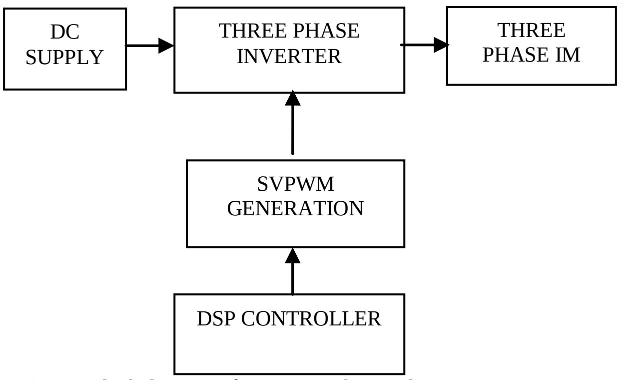
Where

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{1}{3} V_{dc} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} s_1 \\ s_3 \\ s_5 \end{bmatrix}$$

There are eight different combinations are available to express output voltage of inverter based on switching pattern[5].

III. SIMULATION AND HARDWARE IMPLEMENTATION

Block diagram of PWM switching pulse generation using controller for IM is shown in fig 2



Figur2. Block diagram of PWM switching pulse generation using DSP

Figure 3 shows the simulink model of SVPWM generation which is implemented in DSP processor.

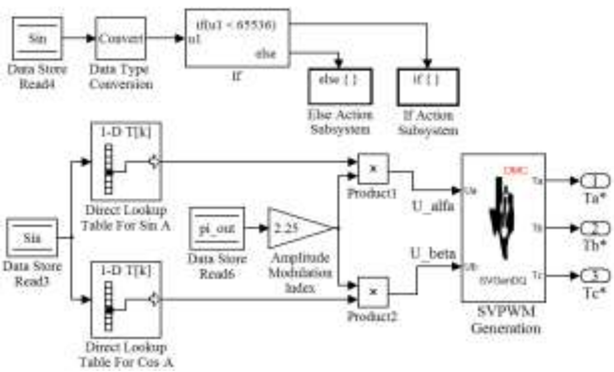


Figure3.MATLAB/SIMULINK Model for Space Vector Sinusoidal Signal Generation

The frequency modulation index of sinusoidal signal is derived by given derivation

F_c (Carrier frequency) = 10 KHz,

F_m (Main supply frequency) = 50 Hz

n (No. of sample) = $\frac{Fc}{Fm} = \frac{10000}{50} = 200$

DSP sample = 2^{16} = 65536

Sample step count $S_c = \frac{\text{Dsp Sample}}{n} = \frac{65536}{200} = 327$

Frequency step count = $\frac{Sc}{\text{Motor Speed}}$

$= \frac{327}{1500} = 0.218$

Modulation Index (MI_f) = 0.218.

Amplitude of Sinusoidal signal = 3750

Maximum Amplitude of Sinusoidal signal = 90% of Available Maximum Amplitude of Sinusoidal signal

Required Maximum Amplitude of Sinusoidal signal = $\frac{90*3750}{100}$

Required Maximum Amplitude of Sinusoidal signal = 3375

Amplitude step count = $\frac{\text{Required Maximum Amplitude}}{\text{Rated speed of Motor}}$ (5)

$= \frac{3375}{1500} = 2.25$

So Amplitude Modulation Index (MI_A) = 0.218

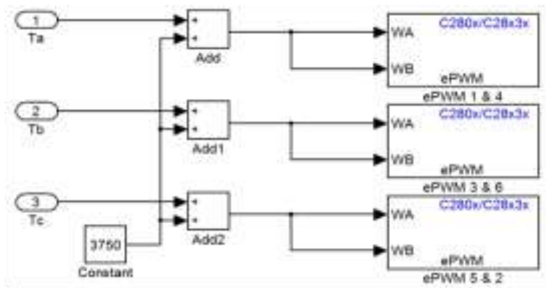


Figure.4. SIMULINK Model of ePWM Module for PWM Generation

The TMS320F28335 has six free improved PWM (ePWM) modules included. It can generate complex PWM waveform. Each of ePWM modules has two output channels: ePWMA and ePWMB having a place with the ePWMx module. Each ePWM module contains seven sub modules, which can understand diverse capacities in the era of PWM waveforms.

In the practical DSP implementation, the PWM waveform generation is accomplished by the comparison between time base counter (TBCTR) value (the carrier wave) and a set-point (the reference wave) which is store in a counter-compare register (CMPx). When time-base counter (TBCTR) is equal to CMPA in up count mode then it set the ePWMA register and clear in down count mode as shown in Fig 5.

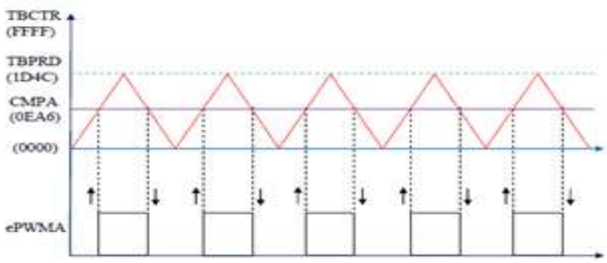


Fig.5 PWM Wave generation by ePWM module

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In this section real time algorithm was implemented using CCS version 3.3 and DSP TMS230F28335 module, PWM isolator module, 3 phase 3-leg IGBT inverter with switching frequency upto 10 kHz, input DC voltage 750V, output AC voltage of 3 phase 415V,Output AC current 8A and frequency 50Hz. Experiment hardware set up is shown in figure.

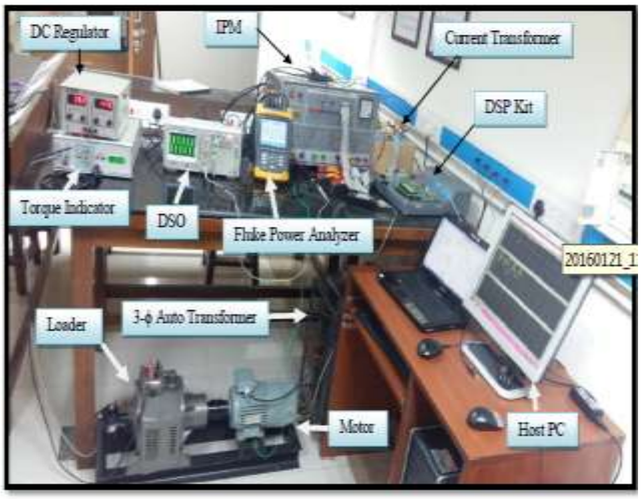

Figure.6 Real Image of Experiment Hardware Setup

IV. Simulation And Experimental Result Of SVPWM

The SVPWM algorithm implemented by DSP is simulated before continuing through the exploratory attempts to confirm its outcomes. In the primary simulation, SVPWM algorithm is simulated orderly and all the software variables in the algorithm are compared with the experimental DSP program outputs. It is demonstrated that both of the outcomes are the same and right

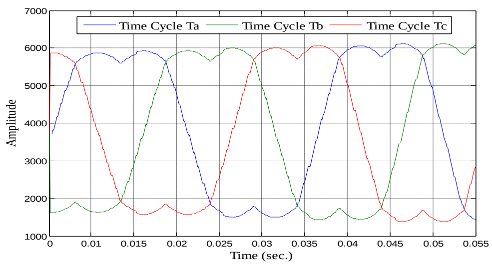

Figure7. Simulated Waveforms of Duty Cycle Ta, Tb, Tc

In Figue 7 duty cycles of three PWM switches are shown (Ta Tb Tc). The experimental outputs affirm the hypothetical and simulation output. Given two reference voltage vectors connected with the reference current and torque requirement, SVPWM software parameters are watched and compared with the simulated ones. The Figure 8shows three phases outputs of SVPWM in a large time scale.

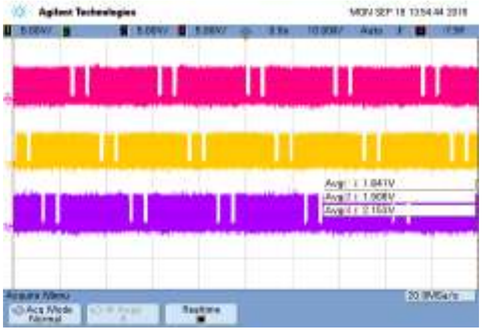

Figure8.SVPWM Output of Three Phases

When zoomed into Fig. 8 as seen in Fig. 9 one can see the symmetrical SVPWM in a small timescale. A SVPWM designer must check the accuracy of the six PWM output produced by this SVPWM module.

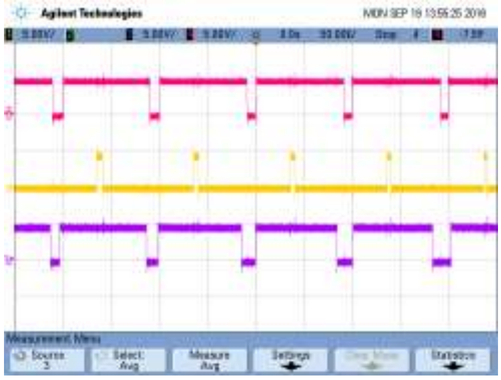

Figure9. SVPWM Output of Three Phases in Small Time-Scale

A basic low–pass channel RC circuit might be utilized to filter out the high frequency components.

The filtered version of the PWM signs is observed by oscilloscope shown in Figure 10

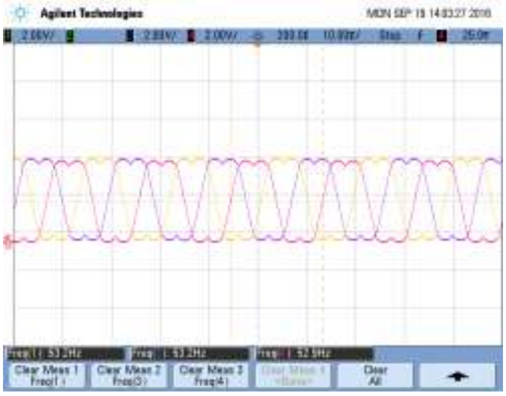

Figure10. Low-Pass Filtered Form of PWM1 PWM2 and PWM5 Pulses

Dead band is obtained by configuring parameter of PWM block. Dead band was programmed for 1.96 microseconds for the implementation and captured in DSO shown in Figure.11.

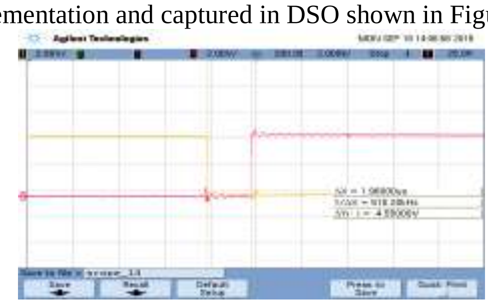

Figure11.Dead Band between normal & inverted drive signal

After applying these pulses on three phase inverter the following output voltage and current waveform has been extract using FLUKE power quality analyzer.

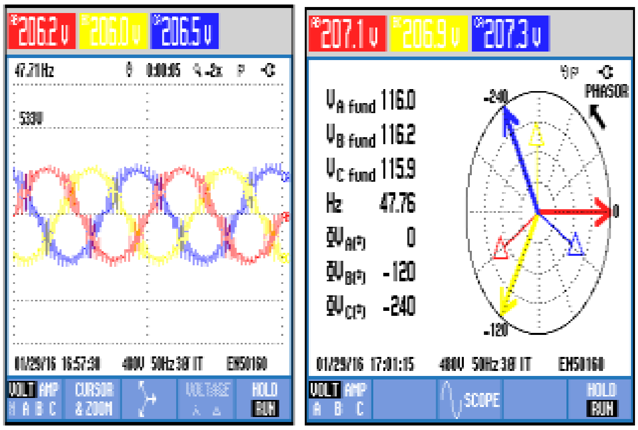

Figure12. Output Phase Voltage Waveform of IPM using SVPWM Technique

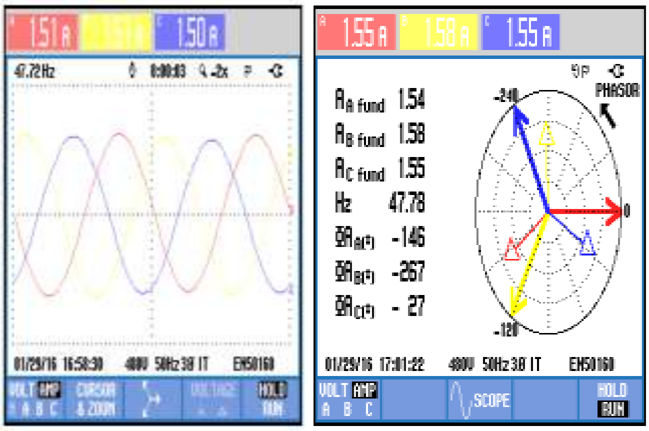

Figure13. Output Phase Current Waveform of IPM using SVPWM Technique

It is worth to mention that if the three-phases are identically generated, but have 120 deg phase shift, the inverters output line voltage will not have any triple harmonics.

Experiment results showed that the SVPWM switching frequency, the number of pulses and the duty cycle generation are flexible.

V. CONCLUSION

This paper presented an algorithm to generate SVPWM signals for 3-phase inverters utilizing Texas Instruments TMS320F28335 DSP. The space vector PWM generation algorithm is written in MATLAB and converted into C language with the help of CCS so it can be reused easily, as far as changing the basic frequency of the inverter output voltage. Output voltage and current's observed with the help of fluke meter. Experimental results prove that when SVPWM technique has been applied on IPM then the output phase voltage and phase current waveform are almost sinusoidal. Implementing sensorless direct field oriented control algorithm based on the introduced structure is the subject of future work.

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