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Design of Three Phase SVPWM Inverter Using dsPIC

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ABSTRACT

Induction motor is widely used in many industrial application. But in recent years use of DC motor is also increased due to development in renewable energy sources. DC motor has many problems like low torque, power loss, rigidness, high maintenance, high weight and high volume. To overcome all this problem DC motor should be replaced by induction motor using renewable energy sources. This paper describes the design of three phase voltage source inverter using SVPWM method.

Three phase inverter consists of semiconductor switches in order to convert DC input voltage into three phase AC voltage. These switches required gate pulses for turning them ON. There are different PWM methods like Sinusoidal PWM (SPWM), Third Harmonic Injection PWM (THIPWM) and Space Vector PWM (SVPWM). Among all this method SVPWM is more efficient method which reduces harmonics in the output current. In this paper results of MATLAB SIMULINK model and hardware prototype model are compared.

Keywords: VSI, SVPWM, THD, dsPIC, Induction Motor

I. INTRODUCTION

Induction or asynchronous motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor therefore does not require mechanical commutation, separate-excitation or self-excitation for all or part of the energy transferred from stator to rotor, as in universal, DC and large synchronous motors. An induction motor's rotor can be either wound type or squirrel-cage type. Three-phase squirrel-cage induction motors are widely used in industrial drives because they are rugged, reliable and economical.

Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications. Variable voltage and variable frequency drives are also used in variable.

There are different PWM methods used for turning ON the switches. Space vector modulation (SPM) is an algorithm for the control of pulse width modulation (PWM). It is an effective method of generating AC voltages to drive three phase AC motors varying speed. There are various approaches of SVM that result in different output and computational requirements.

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II. VOLTAGE SOURCE INVERTER

In VSI the input voltage is maintained constant and the amplitude of the output voltage is independent of the nature of the load. But the output current waveform as well as magnitude depends upon nature of load impedance. Three phase VSI are more common for providing adjustable frequency power to industrial applications as compared to single phase inverters. The VSIs take dc supply from a battery or more usually from a 3-ϕ bridge rectifier.

A basic three phase VSI is a six step bridge inverter, consisting of minimum six power electronics switches (i.e. MOSFETs, Thyristors) and six feedback diodes. A step can be defined as the change in firing from one switch to the next switch in proper sequence. For a six step inverter each step is of 60º interval for one cycle of 360º. That means the switches would be gated at regular intervals of 60º in proper sequence to get a three phase ac output voltage at the output terminal of VSI. Fig.2.7 shows the power circuit diagram of three phase VSI using six MOSFETs and six diodes connected antiparallel to the MOSFETs. The capacitor connected into the input terminals is to maintain the input dc voltage constant and this also suppresses the harmonics fed back to the dc source. Three phase load is star connected.

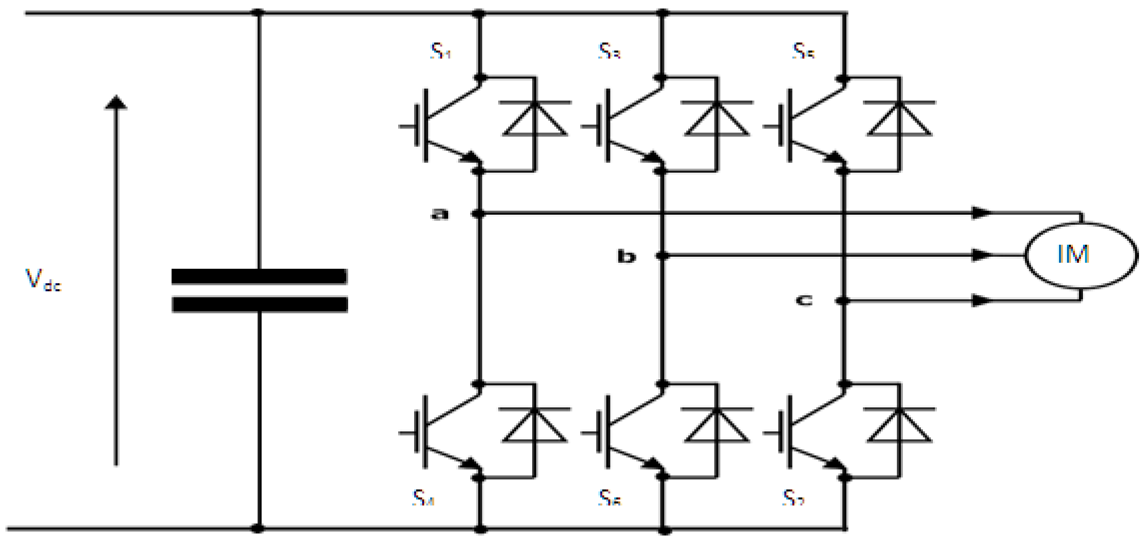

Fig 1. Three phase VSI using MOSFETs

The six switches are divided into two groups; upper three switches as positive group (i.e.S1,S3,S5) and lower three as negative group of switches (i.e.S4,S6,S2). There are two possible gating patterns to the switches i.e. there are two conduction modes: 1. 180º conduction mode and 2. 120º conduction mode. In each pattern the gating signals are applied and removed at an interval of 60º of the output voltage waveform. In 180º mode three switches are on at a time, two from positive group and one from negative group or vice versa, each switch conducts for 180º of a cycle. In 120º mode each switch conduct for 120º in one cycle and two switches remain turned on at a time, one from positive group and one from negative group. But no two switches of the same leg should be turned on simultaneously in both cases as this condition would short circuit the dc source. In 120º conduction mode the chances of short circuit of the dc link voltage source is avoided as each switch conduct for 120º in one cycle, so there is an interval of 60º in each cycle when no switch is in conduction mode and the output voltage at this time interval is zero. In general there is a 60º interval between turning off one switch and turning on of the complimentary switch in the same leg. This 60º interval is sufficient for the outgoing switch to regain its forward blocking capability. The standard three-phase VSI topology has eight valid switching states which are given in Table 2.1. Of the eight valid switching states, two are zero voltage states(0and7inTable2.1) which produce zero ac line voltages and in this case, the ac line currents freewheel through either the upper or lower components. The remaining states(1neto6inTable2.1) are active states which produce non-zero ac output voltages. The inverter moves from one state to another in order to generate a given voltage waveform. Thus the resulting ac output line voltages consist of discrete values of voltages such as Vs/2 ,0,-Vs/2 for topology shown in fig 2.7 .The corresponding output voltage is stepped one having values one having values 3Vs/2,Vs/2,0,-Vs/2,-3Vs/2 and line voltage waveform is quasi-square wave type having discrete values Vs/2,0,-Vs/2. In 120 degree mode the phase voltage waveform is quasi-square type.

State	Sa	Sb	Sc	Vector
0	0	0	0	V_0
1	1	0	0	V_1
2	1	1	0	V_2
3	0	1	0	V_3
4	0	1	1	V_4
5	0	0	1	V_5
6	1	0	1	V_6
7	1	1	1	V_7

Table 1 Switching states of a three phase VSI

III. SPACE VECTOR PULSE WIDTH MODULATION

Space Vector Pulse Width Modulation (SVPWM) technique is an advanced computational intensive PWM algorithm for voltage source converter. This paper describes the digital implementation of SVPWM method using dsPIC. The main focus of the study was to design and develop the mathematical model of SVPWM to drive the three-phase inverter. In the last couple of decades, Pulse Width Modulation (PWM) technique has been used to achieve variable voltage and frequency in power converters. Originally, Space Vector Modulation (SVM) was developed as a vector approach to PWM for three-phase inverters. This technique is more convenient to obtain higher voltage to the motor with lower THD for generating sine wave. The SVPWM technique can be implemented to generate switching signal into the three-phase inverter to drive asynchronous Induction motor.[2]

SVPWM uses the rotating synchronous reference frame. To implement the space vector PWM the voltages in the abc reference frame to be transformed in to the stationary dq reference frame which consists of horizontal and vertical axis. Following figure shows abc to dq transformation and space vector trajectory.

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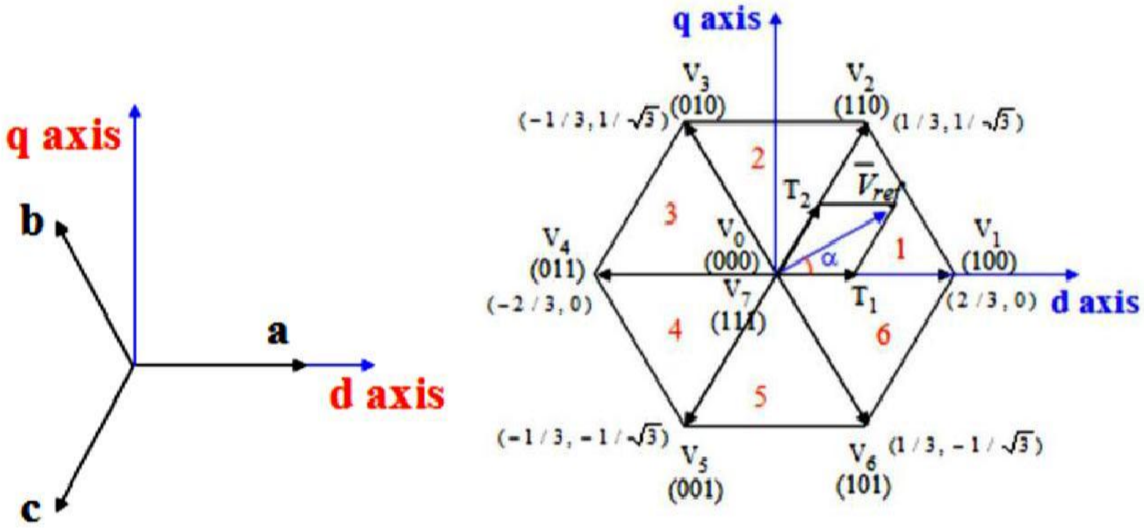

Fig. 2. abc-dq transformation and space vector trajectory.

In SVPWM by using sectors it can identify the location of reference vector and the switches can be operated as per sectors identified. Following equations are used to calculate V_d and V_q.

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad (1)$$

$$\left| |V_{ewf}| = \sqrt{V^2{}_{d+V^2{}_q}} \right| \quad (2)$$

$$\alpha = tan^{-1}\left(\frac{V_d}{V_q}\right) \quad (3)$$

IV. SIMULATION

Following figure shows the mathematical modelling of SVPWM Inverter in MATLAB. In this simulation supply voltage is 400 V. Asynchronous Induction motor is used as a load for three phase inverter.

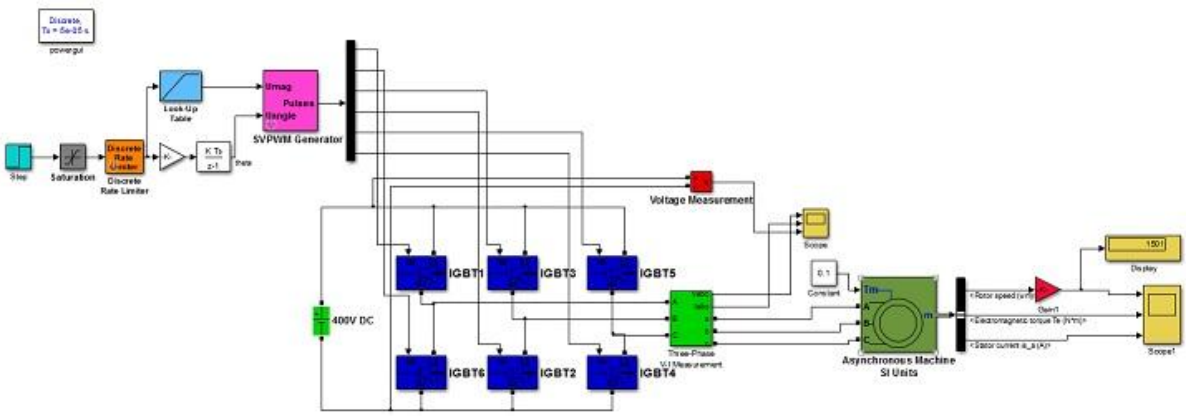

Fig. 3 MATLAB Simulation SVPWM Inverter

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V. SIMULATION RESULTS

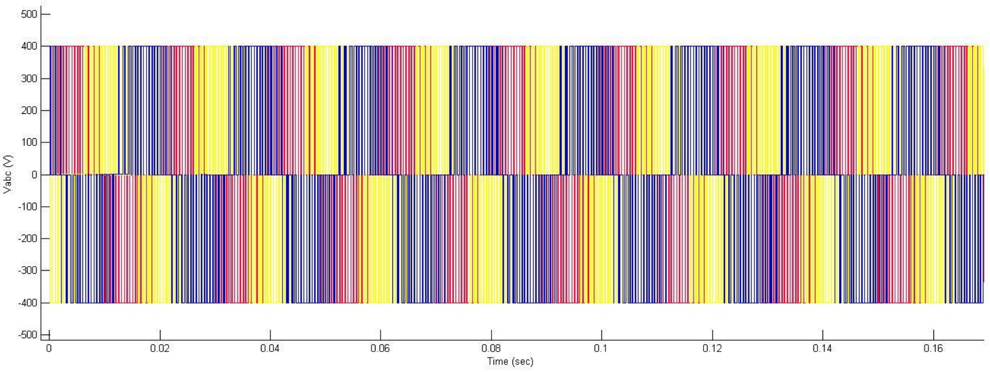

Fig. 4 V_{abc} Vs time

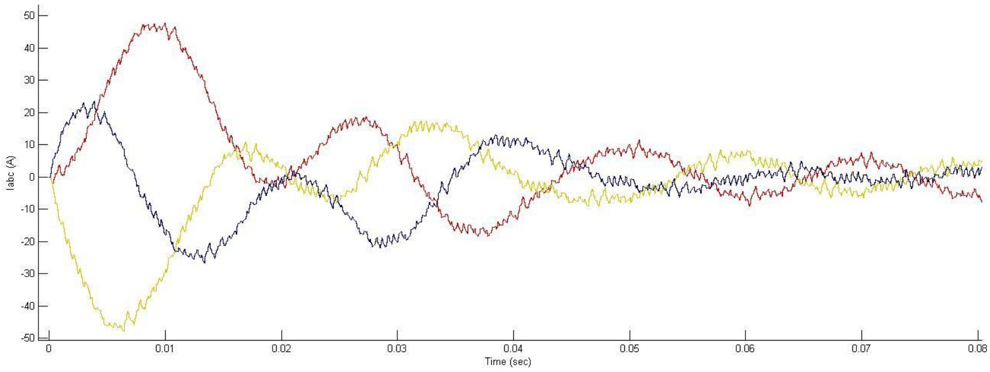

Fig. 5 I_{abc} Vs time

VI. HARDWARE PROTOTYPE MODEL

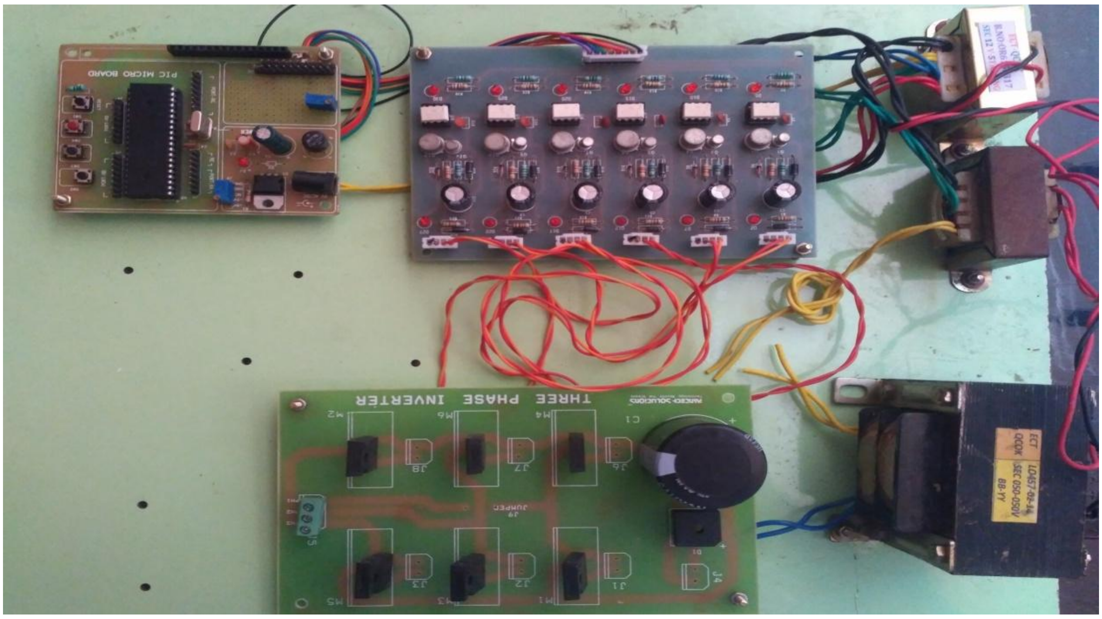

Fig. 6 Hardware Prototype Model.

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VII. CONCLUSION

In simulation of SVPWM inverter THD of output current is 5.21%. Whereas in SPWM inverter we are getting 6.11% THD. In hardware implementation the THD of output current is 4.26% which is matching with IEEE standards.

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