FULL PAPER
International Journal of Recent Trends in Engineering, Vol 2, No. 5, November 2009

Simulation of Six Switch Three Phase Inverter Fed Induction Motor Drive System

S.Sankar[1], E.Partheepan[2], and S.Vinayagam[3]

Abstract*-- This paper presents an entire implementation of Induction Motor using Six- Switch Three-Phase Inverter (SSTPI) for high performance industrial drive systems. In the proposed Realization, instead of a usual 6-switch three-phase inverter (SSTPI) is used. The microcontroller is implemented in real time operation system. This reduces the price of the inverter, the switching losses, and the complication of the control board for generating 6 PWM logic signals. The complete microcontroller based SSTPI for the induction drive system is verified by simulation using Pspice / Matlab and also experimentally by using microcontroller – 89C2051. The FSTPI fed drive with a conventional SSTP inverter fed drive is also made in terms of speed response and total harmonic distortion (THD) of the stator current. Theoretical and experimental results of the proposed drive verify the robustness of the drive.

***Index Terms*-- PWM, FSTPI, SSTPI, Stator and Rotor current control.**

I. INTRODUCTION

OVER the years induction motor (IM) has been utilized as a workhorse in the industry due to its easy build, high robustness, and generally satisfactory efficiency [1]. By tradition, 6-switch 3- phase inverters have been widely used for variable speed IM drives. Recently, several scientific researchers have been done for Four-Switch Three-Phase Inverters (FSTPI) with the target for reducing the cost of electric drives. Several inverter schemes with reduced number of switches have been proposed. Most of the reported works on FSTPI for IM drives [2-6] did not investigate the close-loop vector control scheme with the space vector PWM for VSI, which is important for high performance drives: robotics, rolling mills, machine tools, etc. the invent of high speed power semiconductor devices three-phase inverters play the key role for variable speed ac motor drives. Traditionally, 6-switch, 3-phase (SSTP) inverters have been widely utilized for variable speed PMSM drives. These inverters have some drawbacks, which involve the losses of the six switches as well as the complexity of the control algorithms and interface circuits to generate six PWM logic signals. Recently, some efforts have been made on the application of 4- switch, 3-phase (FSTP) inverter for uninterruptible power supply and variable speed drives [1-5]. This is due to some advantages of the FSTP inverter over the conventional SSTP inverter such as; reduced price due to reduction in number of switches, reduced switching losses, reduced number of interface circuits to supply logic signals for the switches, easier control algorithms to generate logic signals, less chances of destroying the switches due to lesser interaction among switches and less real-time computational burden. Most of the reported works on FSTP inverter for machine drives did not consider the closed loop vector control scheme, which is essential for high performance drives [2-4]. Usually, high performance motor drives used in robotics, rolling mills, machine tools, etc. Require fast and accurate response, quick recovery of speed from any disturbances and insensitivity to parameter variations.

Most of the past research on variable speed IM drives mainly concentrated on the development of the efficient control algorithms for high performance drives [6-9]. However, the cost, simplicity and flexibility of the overall drive system which become some of the most important factors did not get that much attention to the researchers. That is why, despite tremendous research in this area most of the developed control system failed to attract the industry. Thus, the main issue of this paper is to develop a cost effective, simple and efficient high performance IM drive system. In this paper, a cost effective 3-phase inverter fed salient pole IM drive is developed and successfully implemented in real-time for a prototype 1 hp motor. The proposed inverter fed IM drive is found acceptable considering its cost reduction and other advantageous features.

II. DESIGN OF 6 SWITCH 3 PHASE INVERTER SYSTEM

The power circuit of the Induction motor fed from a six switch three-phase (SSTP) voltage-source inverter is shown in Fig. 1. The circuit consists of two parts; first part is a front-end rectifier powered from dc supply. The input dc voltage is smoothed through a two series connected capacitors. The second part of the power circuit

Mr.S.Sankar is a Assistant Professor in Dept.of EEE, Lord Venkateswara Engineering College, Pulliyambakkam, TamilNadu, India.
(*Email: shankar_submanian@yahoo.co.in*)
Mr.E.Partheepan is a Assistant Professor in Dept.of EEE, Lord Venkateswara Engineering College, Pulliyambakkam, TamilNadu, India.
(*Email: ek_parthipan@yahoo.com*)
Mr.S.Vinayagam is a Lecturer in Dept.of Mechanical Engg., Lord Venkateswara Engineering College, Pulliyambakkam, TamilNadu, India.
(*Emai vinayagam_mani@yahoo.co.in*)

is the SSTP inverter. The six switch inverter employs six switches and six diodes to operate two line-to-line voltages V_{cb} and V_{ac}, whereas V_{ba} is generated according to Kirchhoff's voltage law from a split capacitor bank. In the analysis, the inverter switches are considered as ideal switches.

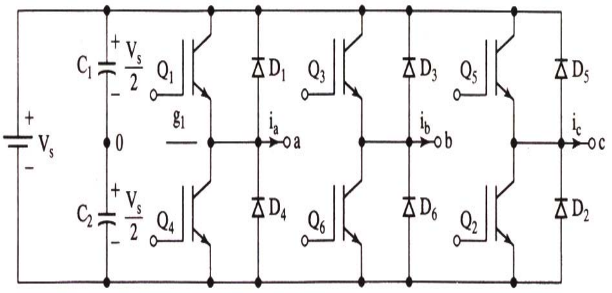

Fig. 1. Circuit diagram of 6 switch 3 phase inverter

The mathematical expressions for SSTPI is follows
Relationship between the switching variable vector [a, b, c]^t and the line-to-line voltage vector

$$\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} = V_{dc} \begin{bmatrix} 1 & -1 & 0 \\ 0 & 1 & -1 \\ -1 & 0 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \quad (1)$$

The relationship between the switching variable vector [a, b, c]^t and the phase voltage vector.

$$\begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} = \frac{V_{dc}}{3} \begin{bmatrix} 2 & -1 & -1 \\ -1 & 2 & -1 \\ -1 & -1 & 2 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \end{bmatrix} \quad (2)$$

$$V_{an} = \frac{V_{dc}}{3}\left[2s_a - s_b - s_c\right] \quad (3)$$

$$V_{bn} = \frac{V_{dc}}{3}\left[-s_a + 2s_b - s_c\right] \quad (4)$$

Determine Vd, Vq, Vref, and angle (α)

$$V_{cn} = \frac{V_{dc}}{3}\left[-s_a - s_b + 2s_c\right] \quad (5)$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix} \begin{bmatrix} V_{an} \\ V_{bn} \\ V_{cn} \end{bmatrix} \quad (6)$$

$$\therefore \alpha = \tan^{-1}\left[\frac{V_q}{V_d}\right] = \omega t = 2\pi f t, \quad (7)$$

Where f = fundamental frequency

$$\therefore \left|\overline{V}_{ref}\right| = \sqrt{V_d^{\,2} + V_q^{\,2}} \quad (8)$$

Determination of time duration period T_1, T_2, T_0

$$\int_0^{T_Z} \overline{V}_{ref}\,dt = \int_0^{T_Z} \overline{V}_1 dt + \int_{T_1}^{T_1+T_2} \overline{V}_2 dt + \int_{T_1+T_2}^{T_Z} \overline{V}_0 dt \quad (9)$$

$$T_z.V_{ref} = T_1.V_1 + T_2.V_2 \quad (10)$$

$$T_z.\left|V_{ref}\right|.\begin{bmatrix} \cos(\alpha) \\ \sin(\alpha) \end{bmatrix} = T_1.\frac{2}{3}.V_{dc}.\begin{bmatrix} 1 \\ 0 \end{bmatrix} + T_2.\frac{2}{3}.V_{dc}.\begin{bmatrix} \cos(\pi/3) \\ \sin(\pi/3) \end{bmatrix}$$

$$(where, 0 \le \alpha \le 60) \quad (11)$$

$$\therefore T_1 = T_z.a.\frac{\sin(\pi/3 - \alpha)}{\sin(\pi/3)} \quad (12)$$

$$\therefore T_2 = T_z.a.\frac{\sin(\alpha)}{\sin(\pi/3)} \quad (13)$$

$$\therefore T_0 = T_z - (T_1 + T_2) \quad (14)$$

$$\left(where\ T_z = \frac{1}{f_s}\ and\ a = \frac{\left|\overline{V}_{ref}\right|}{\frac{2}{3}V_{dc}} \right) \quad (15)$$

III. INVERTER BLOCK OF SSTPI

Two independent sinusoidal band hysteresis current controllers are used to force the phases 'a', 'b' and 'c' currents to follow their commands [7]. These commands are generated from the vector control and speed control loops. The outputs of the controllers are in form of six logics. The inverter main block of SSTPI is as shown in the Fig.2. Those logics are used to switch on and off the inverter power switches. In speed control loop, a proportional integral (PI) controller is used to regulate the speed to follow its command speed.

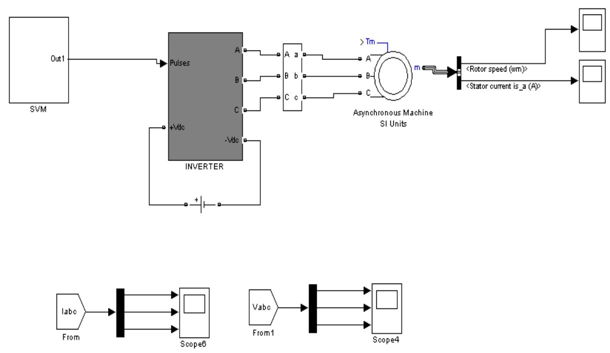

Fig. 2 . Six switch three phase inverter main block

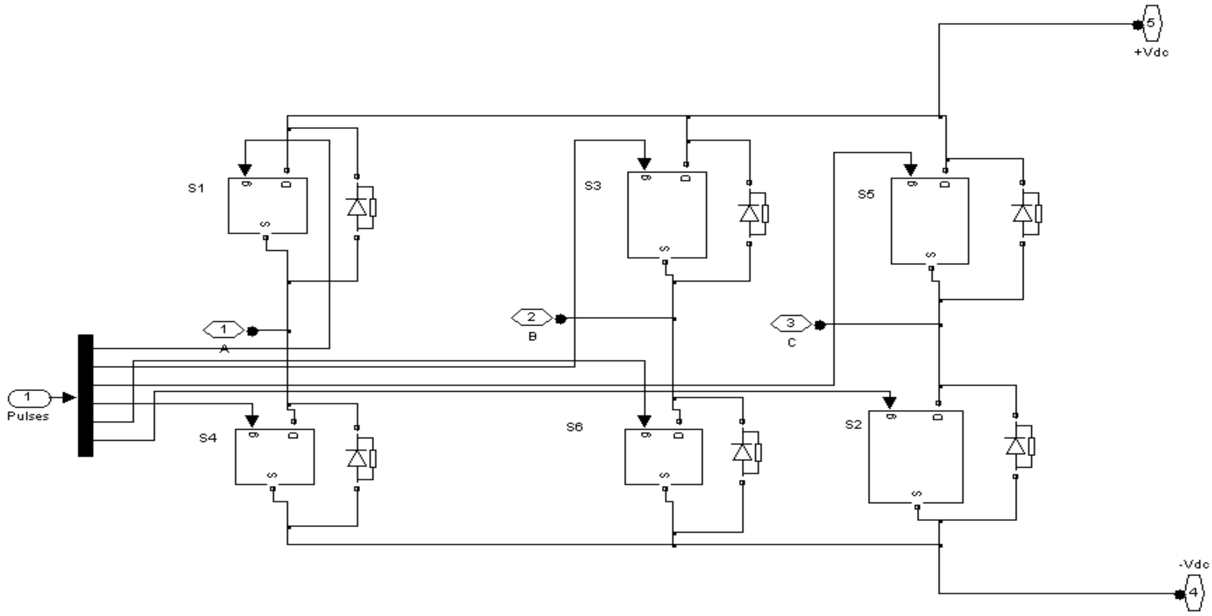

Fig. 3. Inverter block of SSTPI

In order to verify the effectiveness of the proposed inverter configuration and its control strategy, a computer simulation model is developed in Matlab/Simulink software according to Fig.3. Then, the experimental implementation of the control scheme is established according to Fig.4. The experimental set up incorporates a microcontroller based is based on 89C2051 is shown in the Fig.5. Two phase currents ia and ib are sensed by Hall- effect current sensors. Also the position of the rotor is sensed by an incremental encoder and fed to the encoder interface on the DSP board. The control algorithm is executed by TI 'C' compiler and downloaded to the board through host computer. The outputs of the board are four logic signals, which are fed to the proposed FSTP inverter through driver/isolation circuits. The sampling time for experimental implementation is chosen as 100 μ sec.

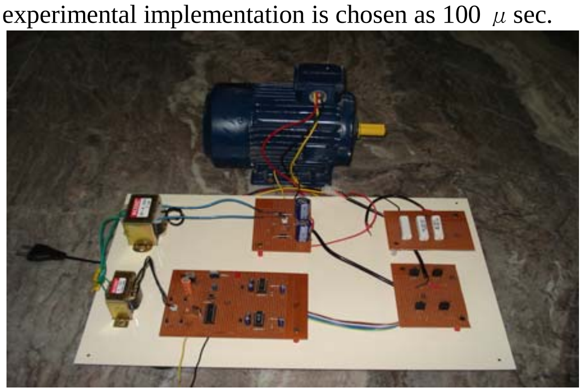

Fig. 4. Hardware Unit of induction motor drive.

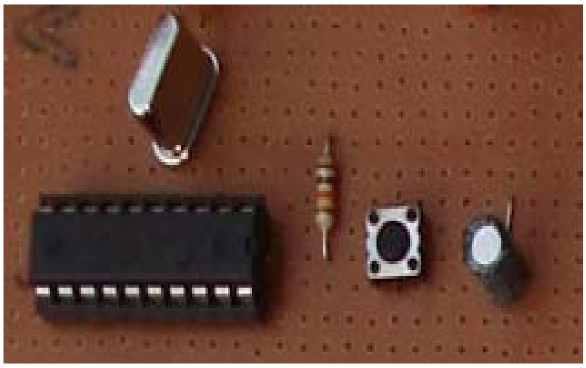

Fig. 5. Microcontroller At89c2051

IV. RESULTS AND DISCUSSIONS

Numerous simulation and experimental results are obtained for a prototype 1 hp IPM motor. Sample results are presented below. Here as shown in the Fig.6. Shows the simulation starting responses of the induction motor fed from the proposed switch, three phase inverter. In this system Fig.6 (a) shows the stator current of SSTPI under the operating conditions [10]. The stator currents of individual phase are represented without any harmonic disturbance .The rotor speed curve is also analyzed and the graph is plotted is as shown in the Fig.6 (b) .The speed and time both are in linear variations, after to reaches the maximum speed it is saturated. When the harmonic spectrum analyses are performed and the

FET as well as the harmonic variations with frequency is as shown in the Fig.6 (c).

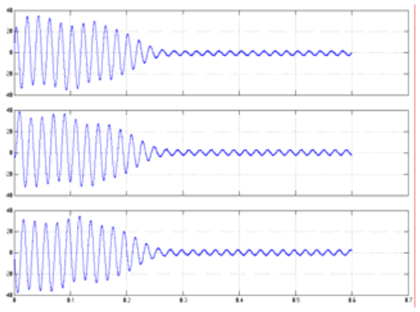

Fig. 6 (a). Waveforms for stator current of SSTPI (stator current Vs time)

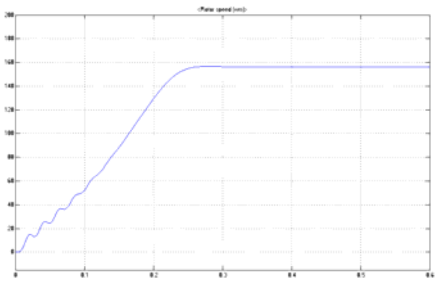

Fig. 6 (b). Waveforms for rotor speed curve (Speed Vs time)

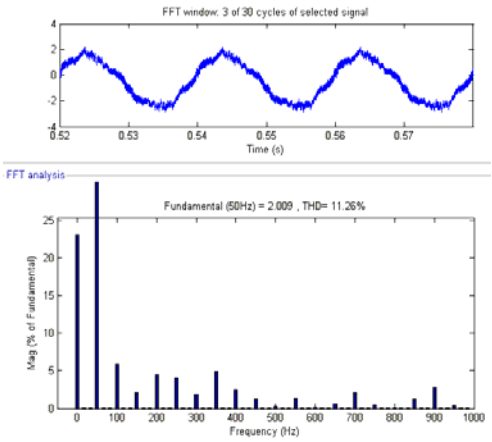

Fig. 6 (c). Wave forms for harmonic spectrum in SSTPI

Fig. 6. Shows the simulation starting responses of the induction motor

V. CONCLUSIONS

A cost effective FSTP inverter fed PMSM drive has been simulated and successfully implemented in real-time using TI TMS320C31 DSP for a prototype1 hp motor. The proposed control approach reduces the cost of the inverter, the switching losses, and the complexity of the control algorithms and interface circuits to generate 6 PWM logic signals. The vector control scheme is incorporated in the integrated drive system to achieve high performance. The performance of the proposed drive is investigated both theoretically and experimentally at different operating conditions. A performance comparison of the proposed FSTP inverter fed drive with a conventional SSTP inverter fed drive is also made in terms of total harmonic distortion (THD) of the stator current and speed response. The proposed FSTP inverter fed PMSM drive is found acceptable considering its cost reduction and other advantageous features.

VI. REFERENCE

[1] F. Blaabjerg, D. O. Neacsu and J. K. Pedersen, "Adaptive SVM to Compensate Dc-Link Voltage Ripple for Four-Switch, Three-Phase Voltage Source Inverter", IEEE Trans. on Power Electronics, Vol. 14, No. 4, July 1999, pp.743-751.

[2] C. B. Jacobina, M. B. R. Correa, E R. C da Silva and A. M. N. Lima, "Induction Motor Drive System for Low Power Applications", IEEE IAS Annual Meeting Conf. Record 1997, New Orleans, Louisiana, USA pp 605-612.

[3] R. J. Cruise, C. F. Landy and M. D. McCulloch,"Evaluation of a Reduced Topology Phase-Converter Operating a Three-phase Induction Motor", IEEE/IEMDC Conf. Record 1999, Seattle, USA, pp.466-468

[4] S. Takijawa, M. Tabata, T. Tanigawa, S. Igarashi and K. Kuroki "High Efficiency Drive Techniques for the Brushless DC Motor Using a Four Switch, Three- Phase Inverter" Proceedings of IPEC 2000, Japan, pp. 1692-1697.

[5] J. S. Larsen, K. Jespersen, M. R. Pedersen, F. Blaabjerg and J. K. Pedersen, "Control of a Complete Digital Based Component-Minimized Single-Phase to Three-Phase AC/DC/AC Converter, IEEE/IECON 1998, Aachen, Germany, pp. 618-625.

[6] M. N. Uddin, and M. A. Rahman, "Fuzzy Logic Based Speed Control of an IPM Synchronous Motor Drive", International Journal of Advanced Computational Intelligence, Vol. 4, No. 3, Dec. 2000, pp. 212-219.

[7] M. N. Uddin, T. S. Radwan, G. H. George and M. A. Rahman, "Performance of Current Controllers for VSI-Fed IPMSM Drive" IEEE Transactions on Industry Applications, vol.36, no. 6, November/ December 2000, pp. 1531-1538.

[8] T. M. Jahns, G. B. Kliman, and T. W. Neumann, " Interior Permanent Magnet Synchronous Motors for Adjustable-Speed Drives", IEEE Transactions on Industry Applications, vol.IA-22, July/August 1986, pp. 738-747.

[9] M. Azizur Rahman, Mahinda Vilathgamuwa, M. Nasir Uddin, and K..J. Tseng, "Nonlinear Control of Interior Permanent Magnet Synchronous Motor", IEEE Trans. on Ind. Applications, Vol. 30, No. 2, March/April 2003, pp. 408-416.

[10] Matlab, Simulink User Guide, The Math Works Inc., 2003.

ACEEE