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# PERFORMANCE ANALYSIS OF A FOUR-SWITCH THREE-PHASE INVERTER FED INDUCTION MOTOR DRIVE

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## ABSTRACT

This paper investigates the performance of a 4-switch, 3-phase inverter (4S3P) fed cost effective induction motor (IM) drive system for high performance industrial drive systems. In the proposed approach, instead of a conventional 6-switch, 3-phase inverter (6S3P) a 4-switch, 3-phase inverter (4S3P) is utilized. This reduces the cost of the inverter, the switching losses, and the complexity of the control algorithms and interface circuits to generate 6PWM logic signals. Also it reduces the computation for real-time implementation. The complete vector control scheme for the IM drive fed from the proposed 4S3P inverter is implemented in real-time using digital signal processor for a prototype 1hp motor. A performance comparison of the proposed 4S3P inverter fed drive with a conventional 6S3P inverter fed drive is also made in terms of speed response and total harmonic distortion (THD) of the stator current. A general pulse width modulation (PWM) method for control of 4S3P inverters is presented.

***Keywords-*** *Four Switch three phase (4S3P),Six Switch Three phase (6S3P), Induction Motor (IM), Total Harmonic Distortion (THD), Pulse Width Modulation (PWM).*

## 1. INTRODUCTION

A standard three-phase voltage source inverter utilizes three legs [six-switch three-phase voltage source inverter (SSTPI)], with a pair of complementary power switches per phase. A reduced switch count voltage source inverter [four switch three-phase voltage source inverter (FSTPI)] uses only two legs, with four switches. Several articles report on FSTPI structure regarding inverter performance and switch control. The FSTPI structure generates four active vectors in the plane, instead of six, as generated by the SSTPI topology.

This paper presents a general method to generate pulse width modulated (PWM) signals for control of four-switch, three phase voltage source inverters, even when there are voltage oscillations across the two dc-link capacitors. The method is based on the so called space vector modulation, and includes the scalar version. The proposed method provides a simple way to select either three, or four vectors to synthesize the desired output voltage during the switching period. In the proposed approach, the selection between three or four vectors is parameterized by a single variable. This permits to implement all alternatives, thus allowing for a fair comparison of the different modulation techniques. The influence of different switching patterns on output voltage symmetry, current waveform, switching frequency and common mode voltage is examined. The paper also discusses how the use of the wye and delta connections of the motor windings affects the implementation of the pulse width modulator.

## 2. PROPOSED WOEK

In this paper, a cost-effective, simple and efficient four switch three phase inverter (FSTPI) is developed. The four switches make the inverter less costly and also the switching losses are reduced. There are less chances of destroying the switches due to lesser interaction among switches and less complexity of control algorithms and interface circuits as compared to the conventional 6S3P Inverter. Furthermore, the proposed control approach reduces the computation for real-time implementation. A performance comparison of the proposed four-switch three-phase inverter fed drive with a conventional six-switch three-phase inverter fed drive is also made in terms of total harmonic distortion (THD) of the stator current and speed response.

### Six-Switch Three-Phase Inverter

Three phase inverters are used for high power applications. A three phase inverter output can be obtained from configuration of six transistors and six diodes. The three phase inverter can be either operated in 180 degree conduction mode or 120 degree conduction mode. The basic diagram of a three phase inverter is shown in Fig. 1. For low and medium power applications, fully controlled or self commutated switches are used. For high power applications thyristor with proper commutation circuits or GTO can be used. For 180 degree conduction each transistor conducts for 180 degree. The sequence of firing is: 123, 234, 345, 456, 561, 612. The gating signals are shifted from each other by 60 degrees. For 120 degree conduction mode, each transistor conducts for 120 degree. The sequence of firing is: 61, 12, 23, 34, 45, 56, 61. The gating signals are shifted from each other by 60 degrees.

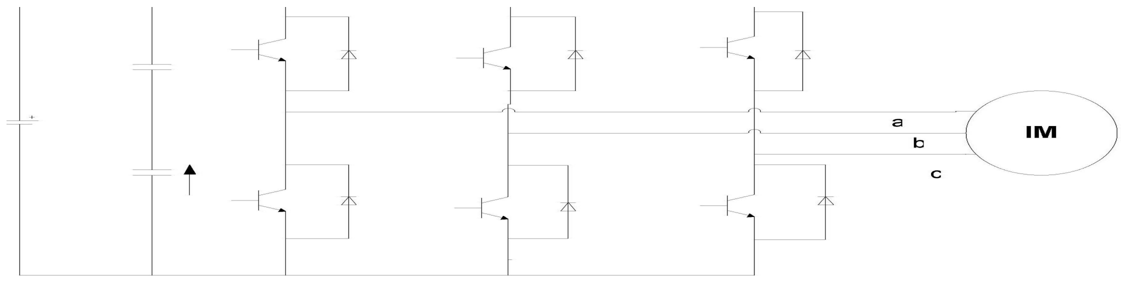


*Fig.l. Six-Switch Three-Phase Inverter Fed 1M*

**Four Switch Three-Phase Inverter**

This paper consists of a three-phase AC supply, three-phase Diode bridge Rectifier, three-phase four switch inverter, threephase Induction Motor. The AC power supply is rectified to DC by using a three-phase diode bridge rectifier. A voltage source FSTPI, consisting of four switches and two dc-link capacitors, is used to convert the DC voltage to the controlled AC voltage. The output of FSTPI is fed to three-phase induction motor. In this analysis, the inverter switches are considered as ideal switches. The output voltages are defined by the gating signals of the two leg switches and by V dc. (dc-link voltage). The following phase voltage equations of the motor can be written as a function of the switching logic of the switches and Vdc:

Va =Vdc /3[4Sa-2Sb-l]
Vb =V dc/3[4Sb-2Sa-l]
Vc =V dc/3[ -2Sa-2Sb+ 1]
where, Va, Vb, Vc are inverter output voltages; Vdc is voltage across the dc link capacitors; Sa, Sb is switching function for each phase leg

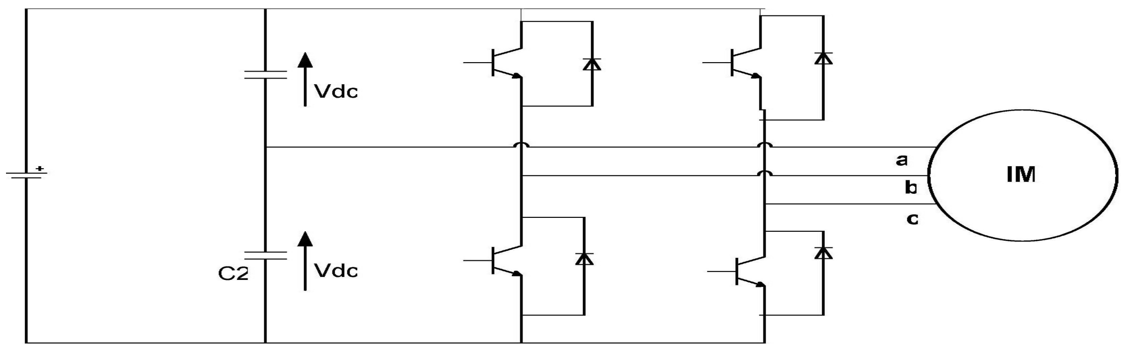


*Fig.2.Four-Switeh Three-Phase Inverter Fed 1M*

The utilization of an induction motor, with its windings connected in delta is studied here as an alternative to reduce the dc-link voltage used, in respect to the Wye connection

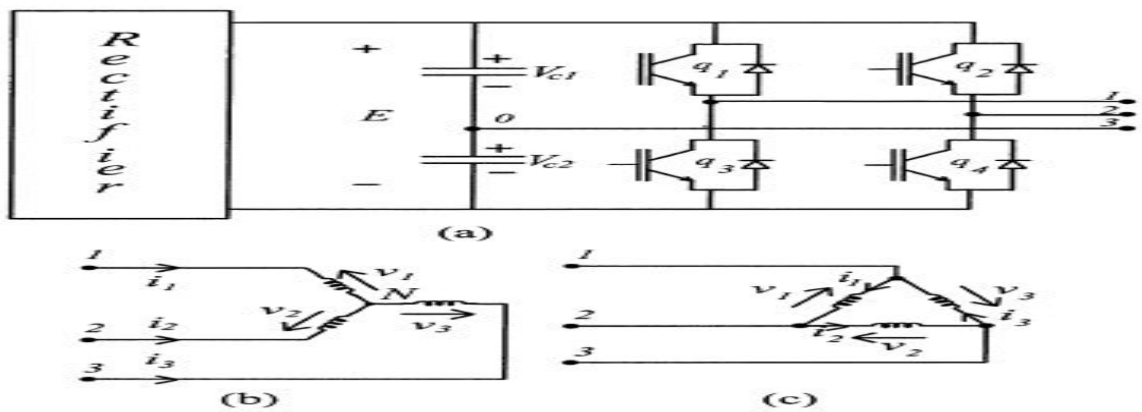


*Fig 3: AC Drive System Configuration*

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## 3. SWITCHING SYSTEM

TABLE I
INVERTER MODES OF OPERATION

| Switching function | | Switch on | | Output voltage vector | | |
|---|---|---|---|---|---|---|
| $S_a$ | $S_b$ | | | $V_a$ | $V_b$ | $V_c$ |
| 0 | 0 | $T_2$ | $T_4$ | $-V_{dc}/3$ | $-V_{dc}/3$ | $2V_{dc}/3$ |
| 0 | 1 | $T_2$ | $T_3$ | $V_{dc}$ | $V_{dc}$ | $-2V_{dc}$ |
| 1 | 0 | $T_1$ | $T_4$ | $V_{dc}/3$ | $V_{dc}/3$ | $-3V_{dc}/3$ |
| 1 | 1 | $T_1$ | $T_3$ | $V_{dc}/3$ | $V_{dc}/3$ | $-2V_{dc}/3$ |

$$\begin{bmatrix} v_{qs}^e \\ v_{ds}^e \\ 0 \\ 0 \end{bmatrix} = \begin{bmatrix} R_s + pL_s & \omega_e L_s & pL_m & \omega_e L_m \\ -\omega_e L_s & R_s + pL_s & -\omega_e L_m & pL_m \\ pL_m & (\omega_e - \omega_r)L_m & R_r + pL_r & (\omega_e - \omega_r)L_r \\ -(\omega_e - \omega_r)L_m & pL_m & (\omega_e - \omega_r)L_r & R_r + pL_r \end{bmatrix} \begin{bmatrix} i_{qs}^e \\ i_{ds}^e \\ i_{qr}^e \\ i_{dr}^e \end{bmatrix} \quad (5)$$

$$T_e = \frac{3}{2}\frac{P}{2} L_m \left( i_{qs}^e i_{dr}^e - i_{ds}^e i_{qr}^e \right) \quad (6)$$

$$T_e = J_m \frac{d\omega_r}{dt} + B_m \omega_r + T_L \quad (7)$$

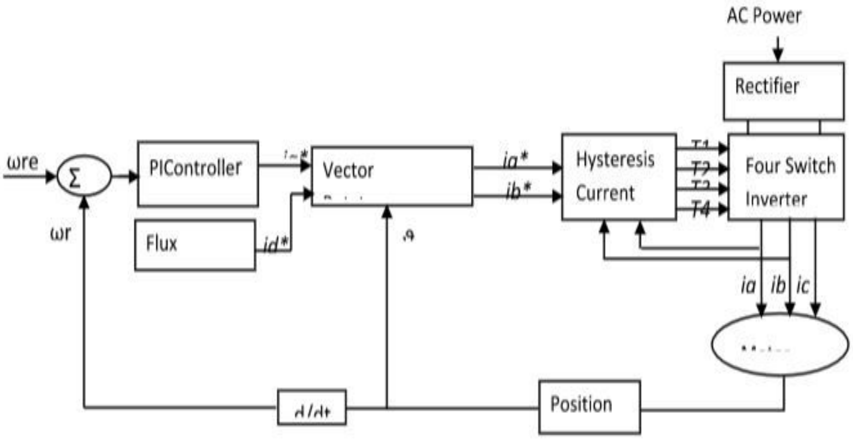


Fig 4: Block Diagram Representation

**IM Control Setup**

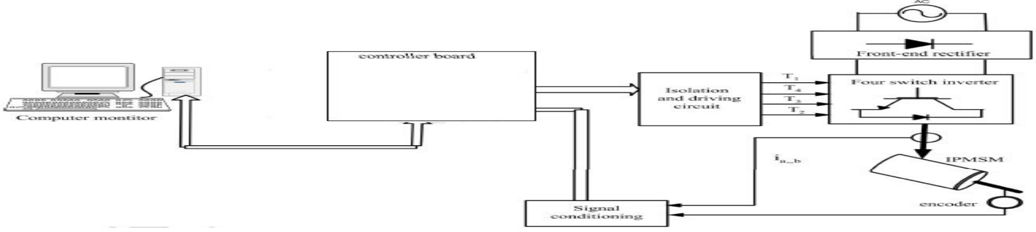


*Fig 5: Control Setup of Induction Moto*

## 4. PROPOSED CONTROL SCHEME

The proposed vector control scheme is shown in Fig. 4. The speed error is processed through a PI controller to generate the torque producing component of the stator current ($i_q^*$). The magnetizing component of the stator currents $i_d^*$ along with $i_q^*$are then used to generate the reference currents $i_a^*, i_b^*$, and $i_c^*$. The reference currents are formulated as follows:

$$i_a^* = i_d^* \cos\theta - i_q^* \sin\theta \; i_b^* = i_d^* \cos(\theta - 120^0) - i_q^* \sin(\theta - 120^0)$$

$$i_c^* = i_d^* \cos(\theta - 240^0) - i_q^* \sin(\theta - 240^0)$$

Two independent hysteresis current controller with a suitable hysteresis band are used to command the motor currents $i_a$, and $i_b$ to follow the reference currents. The hysteresis controllers also generate four switching signals which will fire the power semiconductor devices of the three phase inverter to produce the actual voltages to the motor.

## 5. SIMULATION/RESULTS

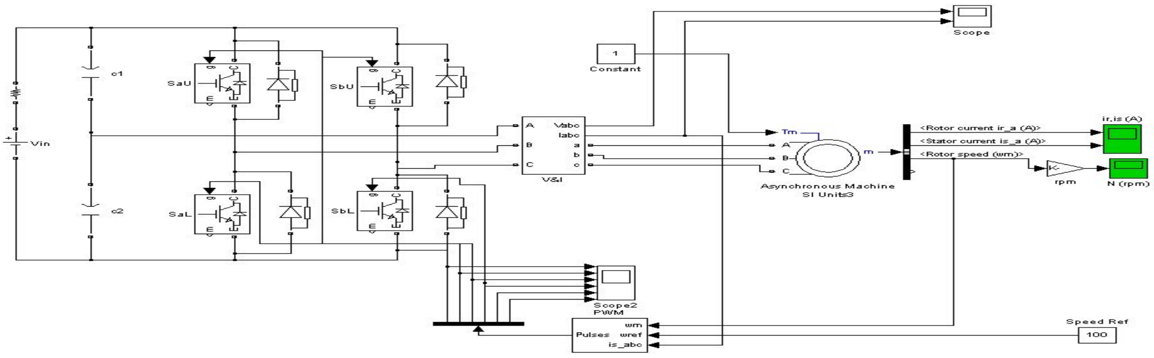


*Fig 6: Simulink Model of Generator*

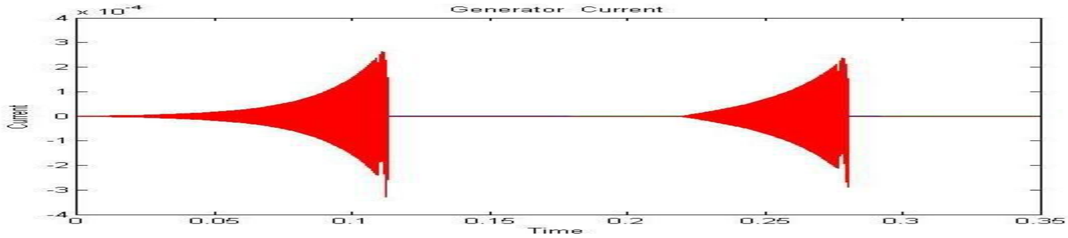


*Fig: Generator Current Vs Time*

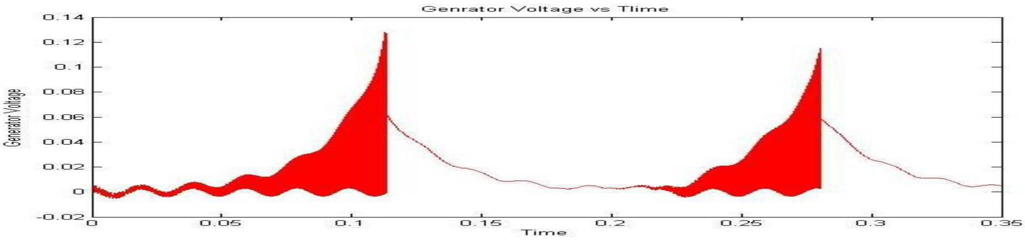


*Fig: Generator Voltage Vs Time*

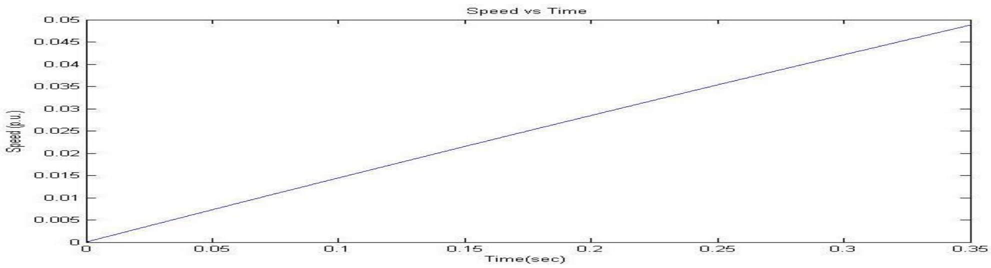


*Fig: Generator Speed Vs Time*

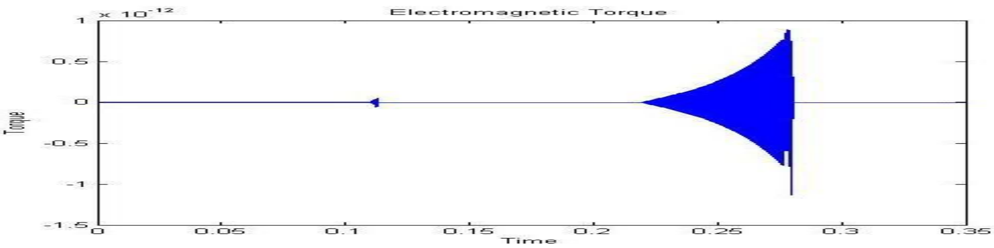


*Fig: Electromagnetic Torque Vs Time*

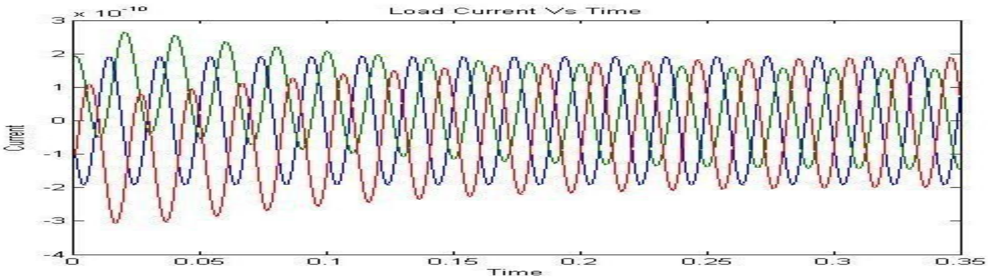


*Fig: Load current Vs Time*

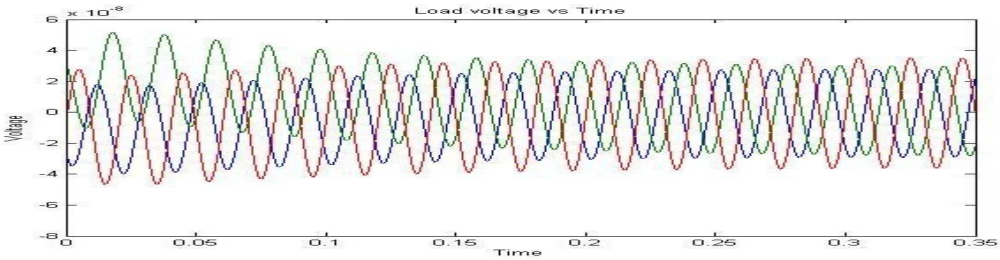


*Fig: Load Voltage Vs Time*

## 6. CONCLUSION

This paper demonstrates the simulative approach for induction motor drive with four-switch three-phase inverter. It presents suitable PWM strategy to implement the proposed drive system. The proposed approach reduces the cost of the inverter as well as the total drive system due to reduced number of switches, reduced switching losses and complexity of the control algorithm and interface circuits. A comparison of the proposed 4S3PI with a conventional 4S3PI is made with respect to the performance of Induction Motor Drive. It is analyzed in terms of THD of stator and rotor currents and speed response. However, the proposed 4S3PI based Drive suffers from unbalance in the phase currents due to DC link voltages which may cause higher speed vibrations as compared to 6S3PI

base Drive. The THD of stator and rotor currents of 4S3PI fed 1M Drive is higher in comparison to the THD of stator and rotor currents of SSTPI fed 1M Drive. The proposed 4S3PI 1M Drive is found acceptable considering its cost reduction and other advantageous features.

## REFERENCES

1) *'Suraj R.Karpe and P.S.Phutane, "Perfonnance of a 4-switch, 3-phase inverter fed induction motor drive system", UAREEI , vol. 2,Issue 3, March 2013.*
2) *Jaehong Kim, Kwanghee Nam and Jinseok Hong, and, "A Current Distortion Compensation Scheme for Four-Switch Inverters, " IEEE Trans. Power Electronics, vol. 24, no. 4, pp. 1032- 1040, April 2009.*
3) *C. W. Liu, C. T. Lin, and C. W. Hung, "Position sensorless control for four-switch three-phase brushless DC motor drives," IEEE Tran. Power Electronics, vol. 23, no. I, pp. 438-444, Jan. 2008.*
4) *T. S. Radwan, M. N. Uddin, and M. A. Rahman, "Fuzzy-logic-controllerbased cost-effective four-switch three-phase inverter-fed PM synchronous motor drive system," IEEE Trans. Ind. Appl., vol. 42, no.l, pp. 21-30, Jan./Feb. 2006.*
5) *Cursino Brandao Jacobina and Mauricio Beltrao de Rossiter Correa , "A General PWM Strategy for Four-Switch Three-Phase Inverters", IEEE Transactions on Power Electronics, vol. 21, no. 6, pp.1618-1627, Nov 06.*
6) *T. S. Radwan, M. Nasir Uddin and M. A. Rahman, "Perfonnance analysisof a cost-effective 4-switch 3-phase inverter fed 1M drive", Iranian JournalOf Electrical and Computer Engineering, Vol. 5, No. 2, Summer Fall 06.*
7) *A. M. N. Lima, C. B. Jacobina, E. R. C. da Silva, and R. L. A. Ribeiro, "Vector and scalar control of a four switch three phase inverter", in Proc. IEEE-lAS Annu. Meeting, 1995, pp. 2422-2429.*