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# PWM Controlled Four Switch Three Phase Inverter Fed Induction Motor

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Abstract-A simplified model is employed to predict the future speed of Induction Motor. The introduced strategy is based on the emulation of the operation of the conventional six switch three-phase inverter (SSTPI). A cost effective FSTPI fed IM drive using PWM controlled technique is implemented in real time. This reduces the price of the inverter, the switching losses, and the complication of the control board for generating four PWM logic signals. The complete control schema for the FSTPI for the induction drive system is verified by simulation using MATLAB. This inverter uses four switches instead of conventional six switches; it has lesser switching losses, lower electromagnetic interference (EMI), less complexity of control algorithms, robust control and reduced circuit complexity. Simulation and experimental work are carried out and results presented to demonstrate the feasibility of the proposed approach. Simulation is carried out using MATLAB SIMULINK and in the experimental work a prototype model is built to verify the simulation results.

KEYWORDS: Four Switch Three Phase Inverter (FSTPI), Induction Motor (IM),Pulse Width Modulation (PWM), Total Harmonic Distortion (THD), Peripheral Interface Controller (PIC)

## I-INTRODUCTION:

AC induction motors are very popular in variable-speed drives, and they are medium construction complexity, multiple fields in stator, cage on rotor, high reliability (no brush wear), medium efficiency at low speeds, high efficiency at high speed, low cost per horse power and easy to reverse the speed of motor. The induction motors are widespread used in industries over the years due to their relative cheapness, low maintenance, and high reliability. A large number of induction-motor control strategies have been investigated. By tradition, 6-switch 3-phase inverters have been widely used for variable speed IM drives. The last work on FSTPI for IM drives investigated the performance of a 4-switch, 3-phase inverter fed cost effective induction motor in real time, which has been implemented by vector control initially and then by some other techniques as well .A standard three-phase voltage source inverter utilizes three legs SSTPI with a pair of complementary power switches per phase. A reduced switch count voltage source inverter FSTPI uses only two legs, with four switches. Several articles report on FSTPI structure regarding inverter performance and switch control. 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.

## II-PROPOSED TOPOLOGY:

In the simulation work, the three phase half bridge rectifier converts AC power to DC. The DC power is fed to FSTPI. The FSTPI converts the DC power to controlled 3-phase AC power. The 3-phase induction motor is driven by the FSTPI. The controlled PWM pulses are fed to the gate of MOSFETs of FSTPI.

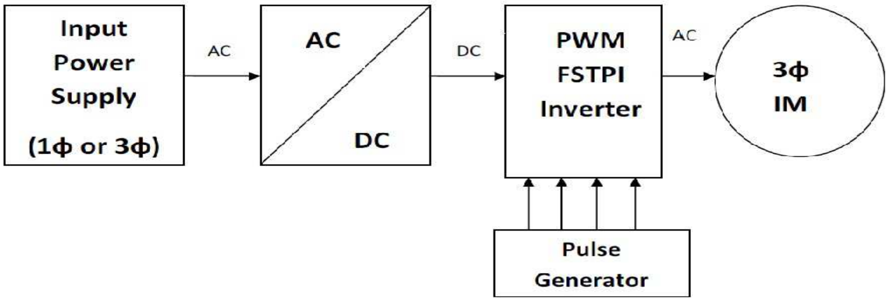



***Fig 1*** Block diagram of FSTPI

## III-PRINCIPLE OF FSTPI OPERATION:

The power circuit of the FSTPI fed IM drive is shown in Figure 6.1.1. The circuit consists of 4-switches $S_1$, $S_2$, $S_3$ and $S_4$ and split capacitors $C_1$ and $C_2$. The 3-phase AC input, which is of fixed frequency, is rectified by the 3- bridge rectifier. The power circuit is the three-phase four-switch inverter. Two phases 'a' and 'b' are connected to the two legs of the inverter, while the third phase 'c' is connected to the centre point of the dc-link capacitors, $C_1$ and $C_2$ . The 4 power switches are denoted by the binary variables $S_1$ to $S_4$, where the binary '1' corresponds to an ON state and the binary '0' corresponds to an OFF state. The states of the upper switches ($S_1$, $S_2$) and lower switches ($S_3$, $S_4$) of a leg are complementary that is $S_3 = 1 - S_1$ and $S_4 = 1 - S_2$. The terminal voltages $V_{as}$, $V_{bs}$ and $V_{cs}$ of a 3-phase Y-connected Induction Motor can be expressed as the function of the states of the upper switches as follows:

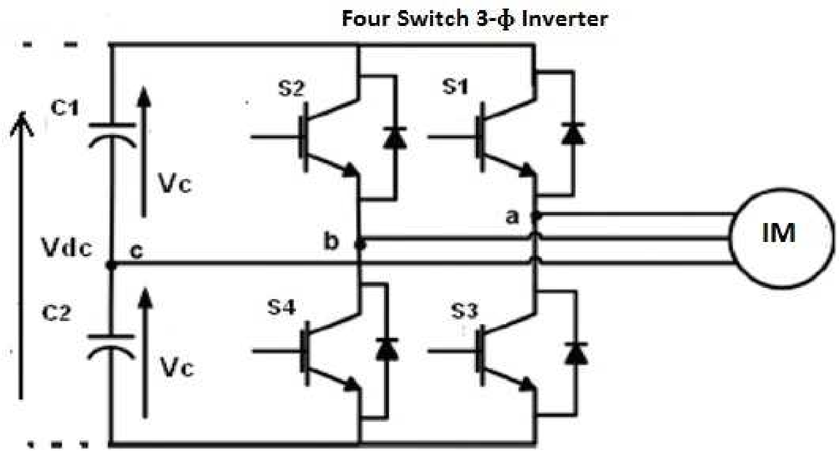



*Fig 2 Principle of FSTPI Operation*

$$Vas = \frac{Vc}{3}(4S1 - 2S2 - 1) \ldots\ldots\ldots\ldots\ldots\ldots(1)$$

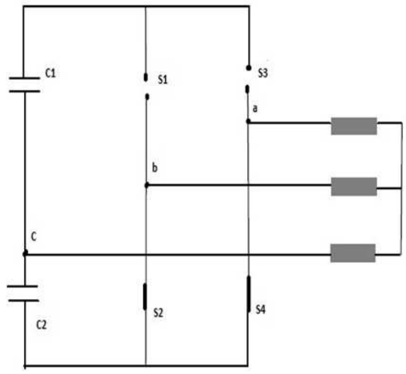
$$Vbs = \frac{Vc}{3}(-2S1 + 4S2 - 1) \ldots\ldots\ldots\ldots\ldots(2)$$

$$Vcs = \frac{Vc}{3}(-2S1 - 2S2 + 2) \ldots\ldots\ldots\ldots\ldots(3)$$

Where $V_{as}$, $V_{bs}$ and $V_{cs}$ are the inverter output voltages, $V_c$ is the voltage across the dc link capacitors, $V_{dc}$ is the voltage across the capacitors C1 and $C_2$ and also $V_{dc} = V_c/2$. S1, S2 are taken as the switching functions for the 2-switches.In matrix form the above equations can be written as:

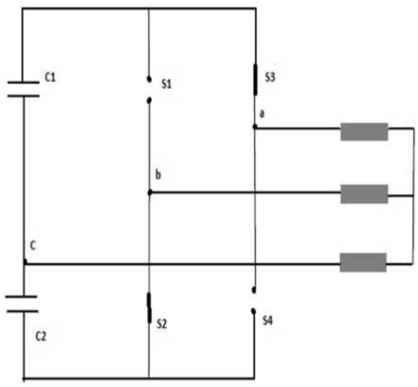
$$\begin{bmatrix} Vas \\ Vbs \\ Vcs \end{bmatrix} = \frac{Vc}{3}\begin{bmatrix} 4 & -2 \\ -2 & 4 \\ -2 & -2 \end{bmatrix}\begin{bmatrix} S1 \\ S2 \end{bmatrix} + \frac{Vc}{3}\begin{bmatrix} -1 \\ -1 \\ 2 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots(4)$$

## IV-OPERATION OF FSTPI WITH DIFFERENT SWITCHING STATES



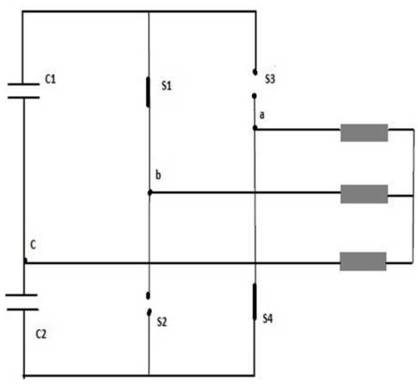

***Switching State(0,0)***

***(a)***



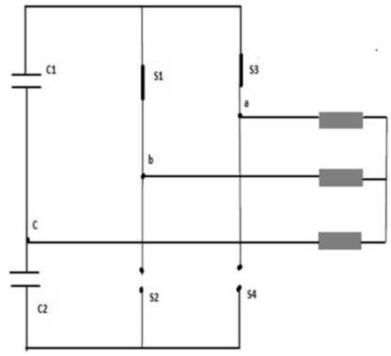

***Switching State(0,1)***

***(b)***




***Switching State(1,0)***

***(c)***




***Switching State(1,1)***

***(d)***

**Fig 3** :switching states (0,0)(0,1), (1,0),(1,1)

## V-CURRENT AND VOLTAGE EQUATIONS OF FSTPI

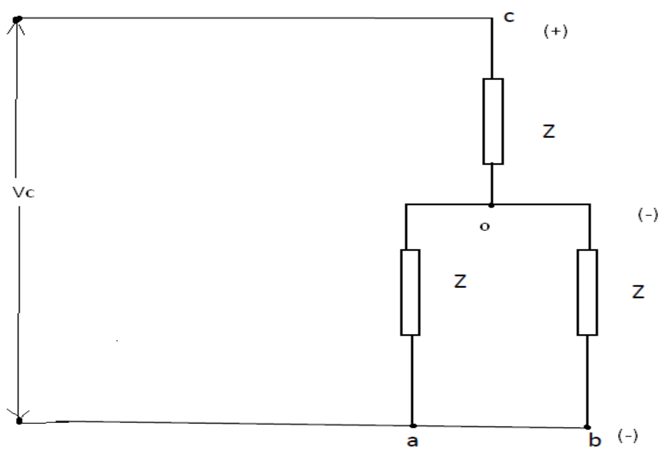



**Fig 4:** The Simplified Diagram For Switching State(0,0)

For the above mentioned line diagram, the electrical parameters are denoted as below.
The current equation is given as

$$I = \frac{Vc}{Z+\frac{Z}{2}} \text{...........(5)}$$

The above equation can be written as

$$I = \frac{2Vc}{3Z} \text{..........(6)}$$

For branch oa in the above SLD, the branch voltage can be given as

$$Voa = I * \frac{Z}{2} = Vc/3 \text{...............(7)}$$

$$Vao = -Voa = -\frac{Vc}{3} = Vbo \text{.....(8)}$$

For branch co , $Vco = I * Z = 2Vc/3$....(9)

Table 1 shows the different modes of operation and the corresponding output phase voltages of inverter, which can be derived similar to switching state(0,0).

| Switching states and output phase voltages | | | | |
|---|---|---|---|---|
| Switching states | | Output Voltages | | |
| $S_1$ | $S_2$ | $V_{as}$ | $V_{bs}$ | $V_{cs}$ |
| 0 | 0 | $-V_c/3$ | $-V_c/3$ | $2V_c/3$ |
| 0 | 1 | $-V_c$ | $V_c$ | 0 |
| 1 | 0 | $V_c$ | $-V_c$ | 0 |
| 1 | 1 | $V_c/3$ | $V_c/3$ | $-2V_c/3$ |

Table 1: Switching states and output phase voltages

## VI-SIMULATION WORK AND RESULTS

Digital computer simulation model using MATLAB-SIMULINK has been developed to test the proposed FSTPI fed IM drive block.

Simulation circuit of the FSTPI fed drive system consists of a three-phase diode bridge rectifier, a split capacitor, four switch three phase inverter and 3-phase squirrel cage Induction Motor.

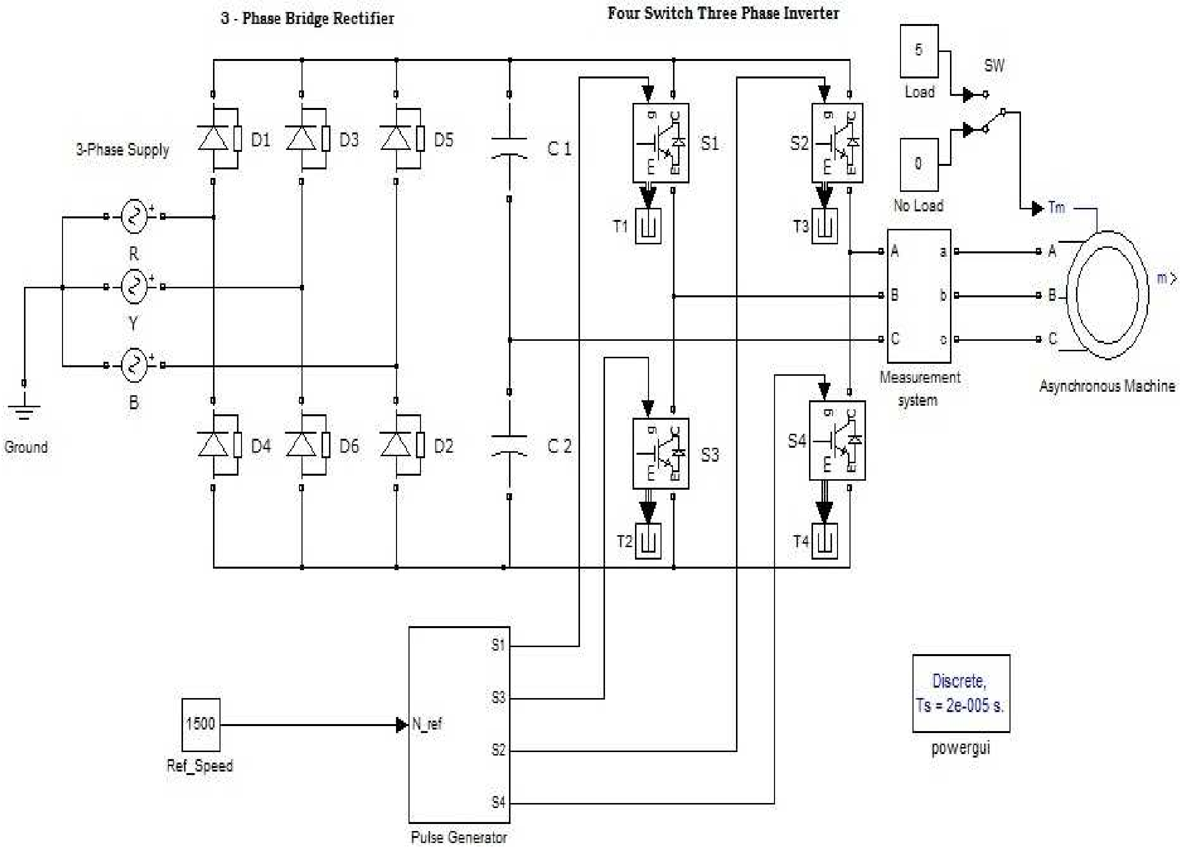



Fig 5: simulation diagram for PWM Controlled Four Switch Three Phase Inverter Fed Induction Motor

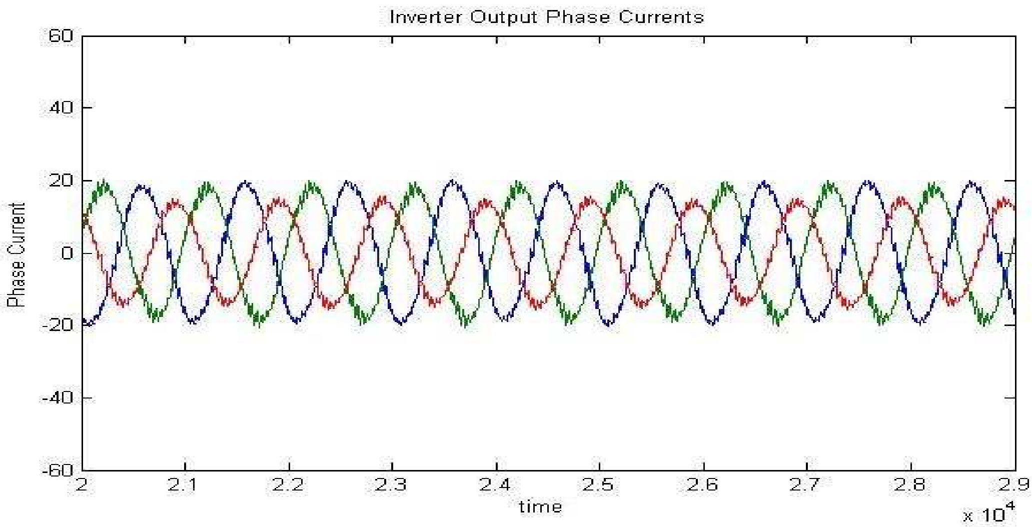



Fig 6:current wave form of the inverter output

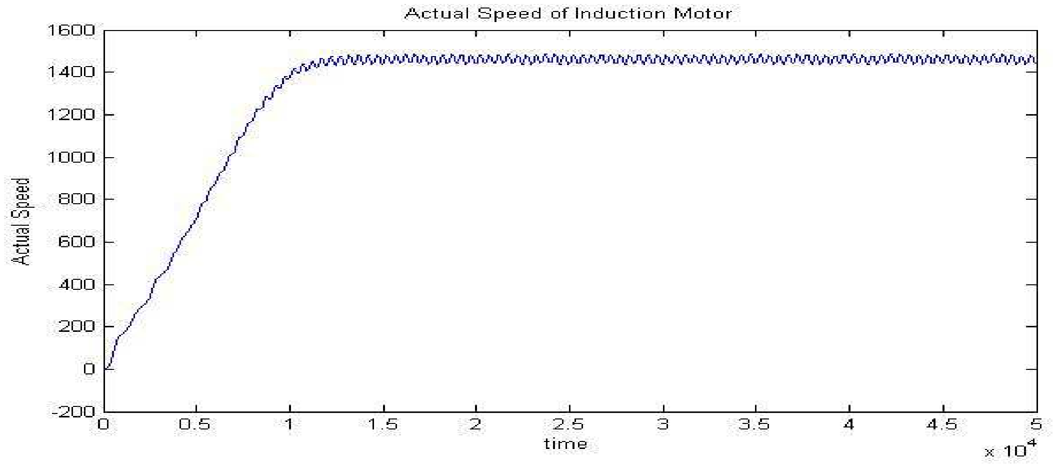



Fig 7: Actual Speed of The Induction Motor

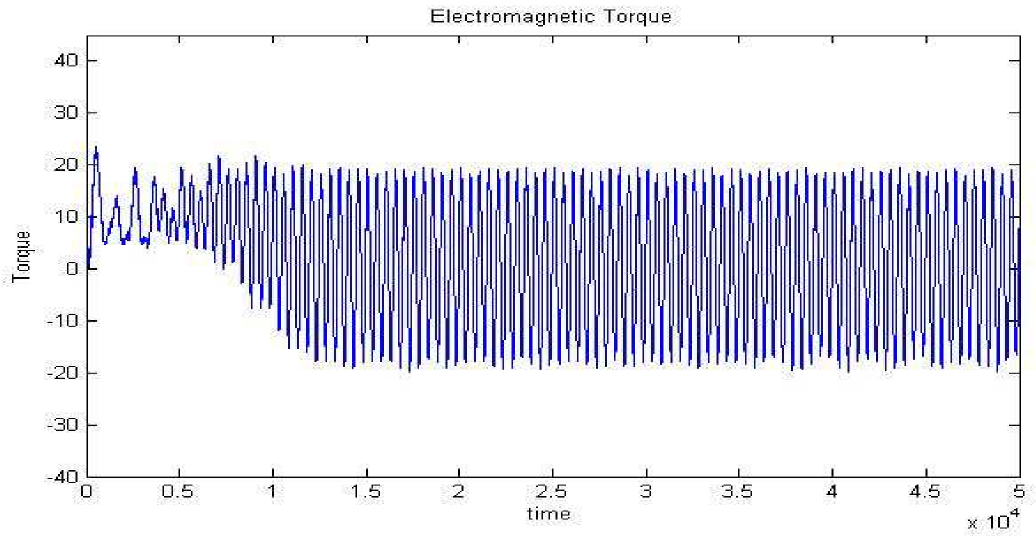



Fig 8:Electromagnetic Torque of The Induction Motor

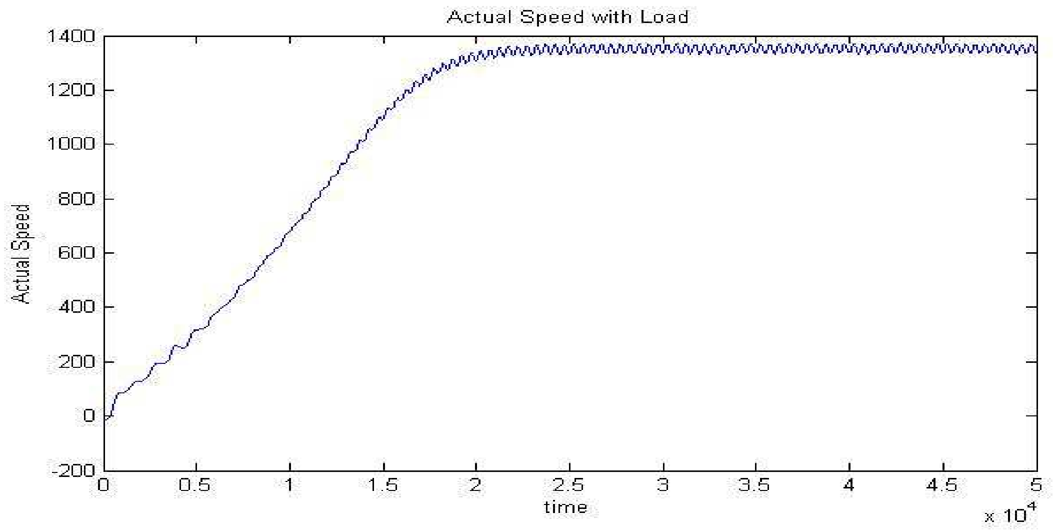



Fig 9: Actual Speed of The Induction Motor with load

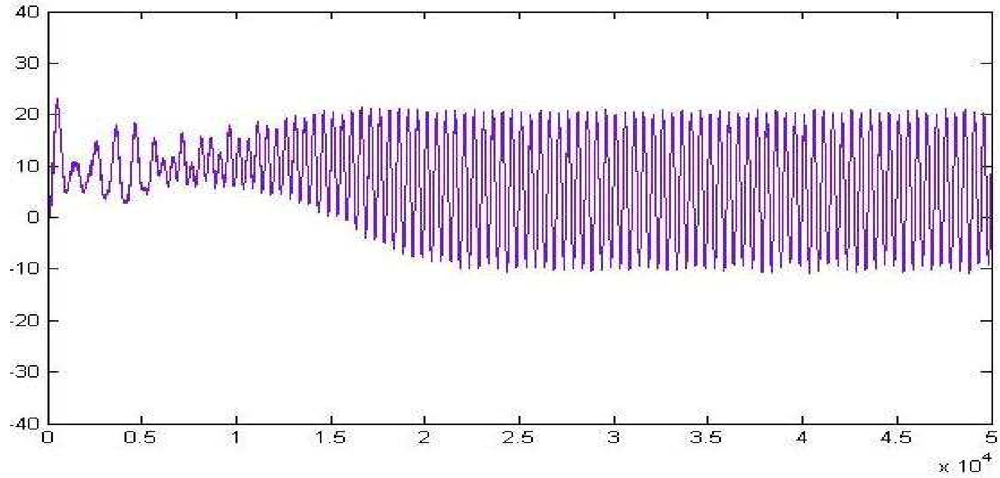



Fig 10:Electromagnetic Torque of The Induction Motor with load

## VII-CONCLUSION

A Microcontroller based PWM controlled FSTPI fed induction motor has been experimentally tested under various load conditions. It is found that the motor operates at higher speed when operated at higher frequency for same input voltage and current increases with increase in load. The same experimentations were carried out on simulation using MATLAB. The results are obtained such as the speed and torque characteristics of induction motor are found satisfactory. The simulation result shows that the dynamic response of the motor speed is fast, steady tracking has high precision, and the torque has instantaneous response characteristics, all of which are consistent with the theoretical analysis of variable frequency speed regulation. The PWM in this implementation is based on the principle of similarity between FSTPI and SSTPI (Six-Switch Three Phase Inverter). The PWM control method is utilized to gain the high performance of IM drive. Meanwhile this constructing method of simulation model is simple and convenient, which provides effective means for the realization and debugging in practical motor control system.

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