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PMSM Control using Four Switch Three Phase Inverter

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Abstract—*A cost effective FSTP inverter fed PMSM drive has been developed, simulated and successfully implemented in real-time using TI TMS32OC31 DSP for a prototype 1hp motor. With no need of output filter the proposed FSTP technique provides pure three-phase sinusoidal output voltage as input to the PMSM. The variable voltage variable frequency which gives also the variable speed also. Model and experimental setup are used to validate the proposed concept, which show the effectiveness of the proposed inverter. 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 PWM 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 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.*

1. INTRODUCTION

In this we generally consist the simulation and control of permanent magnet synchronous motor through four switch inverter which is the latest one. In which we connect PMSM at the load side to control and also it gives the variable voltage variable frequency which gives us the variable speed also.

Permanent magnet synchronous motor (PMSM) is typically used for high-performance and high-efficiency motor drives. High-performance characterized by smooth rotation over the entire speed range of the motor, full control at zero speed, and fast acceleration and deceleration. To achieve such control, vector control techniques are used for PM synchronous motors. Four-switch three-phase inverter (FSTPI) is usually adopted as the topology for continuous fault-tolerant operation of a Direct Torque (DTC) system when inverter fault occurs. Due to that the FSTPI can only provide four voltage space vectors with unequal amplitude, the DTC system performance will deteriorate to a certain extent. To enhance the performance of permanent magnet synchronous motor (PMSM) drive fed by FSTPI, a sliding mode controller with the analysis and design of the controller included is proposed for the purpose of direct control the torque and stator flux linkage in this paper. Besides a nonlinear perpendicular flux observer is adopted to estimate the stator flux more accurately as well. The effectiveness of the proposed methods have been verified by simulation study, in which the torque and flux ripples have been significantly minimized and the inherent merits of fast dynamic responses of the conventional direct torque control are preserved[1-5].

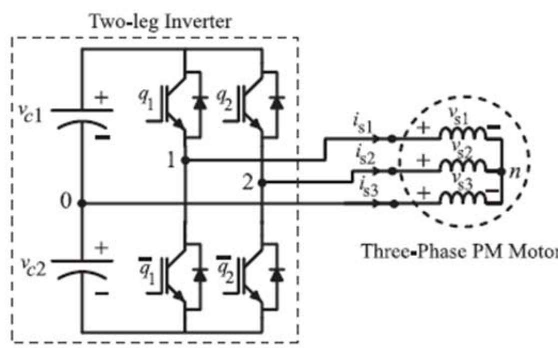


Fig. 1: Schematic diagram of Four-Switch Three-Phase Inverter Supplying a PMSM Motor .

2. THE DRIVE SYSTEM MODELING

The complete drive system modeling involves the modeling of the PMSM, inverter and the controller, which are discussed in the following subsections.

2.1 Inverter Model

Fig.1 shows the schematic diagram of Four-Switch Three-Phase Inverter, he power circuit of the PMSM fed from a four-switch three-phase (FSTP) voltage source inverter. The circuit consists of two parts; first part is a front-end rectifier powered to single-phase supply. The output dc voltage is smoothed through a two series connected capacitors. The second part of the power circuit is the FSTP inverter. The four switch inverter employs four switches and four diodes to operate **two** line-to-line voltages V_{cb}, and V_{ac}, whereas V_b, is Generated according to Kirchhoff's voltage law from a split capacitor bank. In the analysis, the inverter switches are considered as ideal switches.

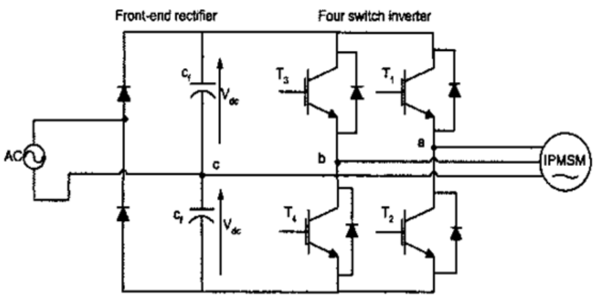


Fig. 2: PMSM fed from four switch inverter

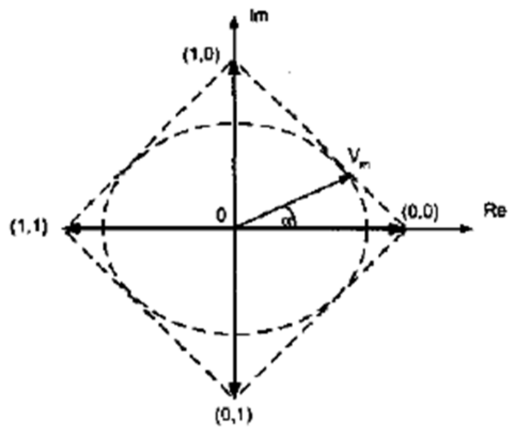


Fig. 3: Switching vector for 4-switch inverter

The phase voltages (V_a, V_b, V_c) of the motor can be written as a function of the switching logic **(**S_a**,** & S_b) of the switches and the dc-link voltage (V_{dc}) and given by:

$$Va = \frac{Vdc}{3}[4Sa - 2Sb - 1]$$

$$Vb = \frac{Vdc}{3}[-4Sb - 2Sa - 1]$$

$$Vc = \frac{Vdc}{3}[-2Sa - 2Sb + 1]$$

For a balanced capacitor voltages, the four switching combinations lead to four voltage vector as shown in Fig.3. Table I shows the different mode of operation and the Corresponding output voltage vector of the inverter.

Table 1 Inverter modes of operation

Switching function		Switch on		Output voltage vector		
Sa	**Sb**			**Va**	**Vb**	**Vc**
0	0	T2	T4	-Vdc/3	-Vdc/3	2Vdc/3
0	1	T2	T3	Vdc	Vdc	-2Vdc
1	0	T1	T4	Vdc/3	Vdc/3	-3Vdc/3
1	1	T1	T3	Vdc/3	Vdc/3	-2Vdc/3

2.2 Motor Model

The mathematical model of a PMSM drive can be described by the following equations in a synchronously rotating d-q reference frame as [6].

$$\begin{bmatrix} V\mathrm{d} \\ V\mathrm{q} \end{bmatrix} = \begin{bmatrix} R + \rho L\mathrm{d} & -P\omega rL\mathrm{q} \\ P\omega rL\mathrm{d} & R + \rho L\mathrm{q} \end{bmatrix} \begin{bmatrix} i\mathrm{d} \\ i\mathrm{q} \end{bmatrix} + \begin{bmatrix} 0 \\ P\omega r\psi f \end{bmatrix}$$

$$Te = T\mathrm{L} + J\mathrm{m}P\omega\mathrm{r} + B\mathrm{m}\omega\mathrm{r}$$

$$Te = \frac{3P}{2}(\psi f i\mathrm{q} + (L\mathrm{d} - L\mathrm{q})i\mathrm{q}i\mathrm{d})$$

2.3 Controller Model

Two independent sinusoidal band hysteresis current controllers are used to force the phases a and b currents to follow their commands [6]. These commands are generated from the vector control and speed control loops. The outputs of the controllers are in form of four logics. Those logics are used to switch on and off the inverter power switches.

3. EXPERIMENTAL SETUP

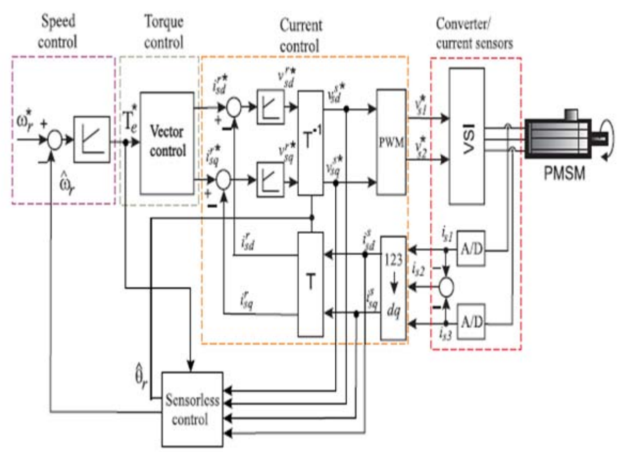


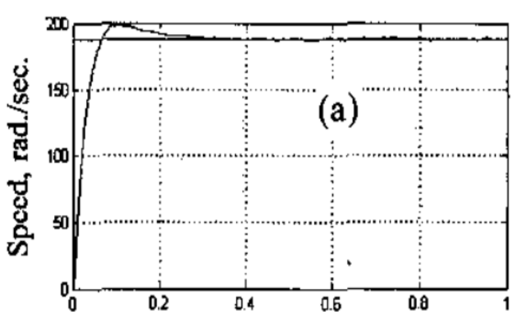
Fig. 4: Control block diagram of PMSM drive system

The control block diagram of the proposed system is shown in Fig. 4. The control strategy of the system is composed by the speed control in cascade with torque and current control loops. The speed controller is a PI regulator type. The vector control block defines the reference currents of dq-axis. The reference current is obtained from the reference torque of the speed controller output. The d-axis reference current is set to be zero, thus, i defines the required torque. The stator currents are controlled by two PI-controllers in the synchronous reference frame. The reference voltages are transformed to the reference phase voltages. Based on the phase reference voltages, the reference pole voltages are calculated according to (9)-(100).The phase currents are measured and transformed back to the synchronous reference frame. The current controller gains have been designed according the pole placement criteria. The controller gains cancel the machine poles. As a result, the controller gains are determined from the desired bandwidth of the closed-loop transfer function. The same procedure is applied to define the gains of the speed controller. The measured currents and the reference voltages are used as input of the back-Emf estimator [7]. The rotor position observer provides the rotor position used in the transformations between reference frames. Besides, the estimated rotor speed is used in the speed control loop replacing the mechanical transducer. The experimental implementation of the control scheme is established according to Fig.4. The experimental set up incorporates a digital signal processor (DSP) board DSP102, which is based on 32-bit floating point DSP TI TMS320C31. The hoard is also equipped with a fixed point 16 bit TMS320P14 DSP which is used as a slave processor. In this work, the slave processor is configured to work as digital input/output subsystem. Two phase currents ia and ib are sensed by Hall-effect current sensors [8]. 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 hoard are four logic signals, which are fed to the proposed FSTP inverter through driver isolation circuits.

4. RESULT AND DISCUSSION

The simulation starting responses of the PMSM drive fed from the proposed 4-switch, 3–phase inverter. While Fig.6 shows the responses of the conventional 6-switch, 3-phase inverter based drive at identical conditions. Fig. 5(a) shows that the actual speed follows the command speed accurately without steady-state error. It is evident from Fig. 5(b) indicate almost balanced operation of the FSTP inverter. Simulated dynamic responses of the proposed drive are shown in Fig. 6(a) and 6(b) for a step change in command speed and step increase in load, respectively. These figures show that the

Proposed drive is capable of handling the dynamic disturbances.



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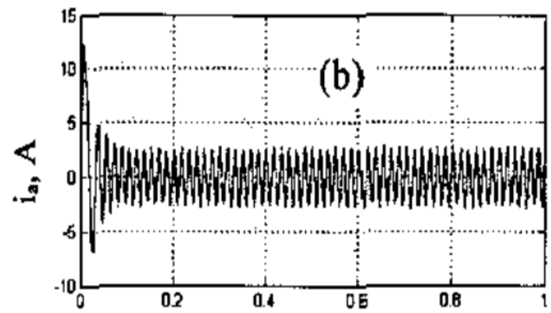

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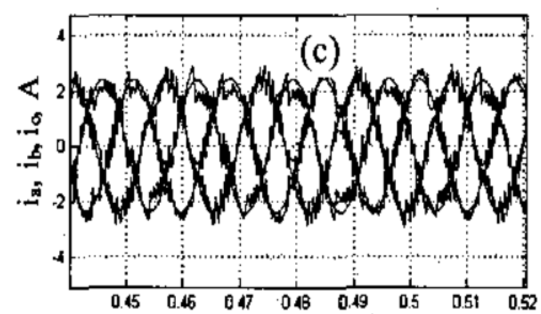

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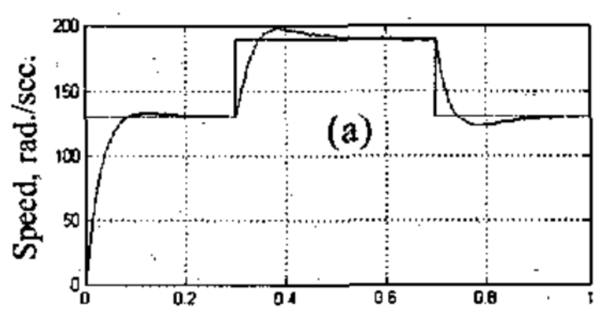
Fig. 5 Simulation starting responses of the FSTP inverter based at rated speed and load; (a) speed and (b) current.



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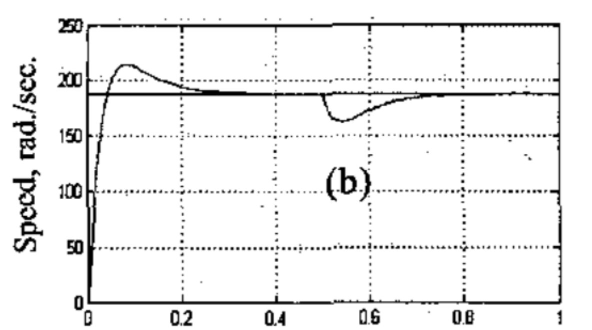

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Fig. 6 Simulation responses of the drive for: (a) step change in speed and (b) step increase in load

5. CONCLUSION

A cost effective FSTP inverter fed PMSM drive has been developed, simulated and successfully implemented in real-time using TI TMS32OC31 DSP for a prototype 1hp 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 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 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.

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