SPEED CONTROL OF PMSM BY USING DSVM -DTC TECHNIQUE

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Abstract- **The Direct Torque Control (DTC) requires low computational power when implemented digitally for AC drives. The DTC possess good dynamic performance but shows quite poor performance in steady-state since the crude voltage selection criteria give rise to high ripple levels in stator current, flux linkage and torque. To reduce the problems with DTC the discrete space vector modulation method is proposed for DTC by applying more vectors in one interval. In this paper, after a brief review of the primary concept of DTC technique, a new scheme of DSVM DTC for PMSM is proposed with a new set of switching tables. Simulation on the proposed scheme is carried out and compared with basic DTC scheme.**

Keywords— ***DTC, PMSM, DSVMDTC***

I. INTRODUCTION

The permanent magnet synchronous motor (PMSM) has found wide applications because its advantages like high power density, high efficiency etc. A very widely used drive strategy for PMSM is the field oriented control (FOC). There are some disadvantages with FOC like high dependence on motor parameters. To reduce these problems, a new control strategy developed known as the direct torque control (DTC) and the direct self control (DSC). The basic idea of DTC for induction motor is to control the torque and flux linkage by selecting the voltage space vectors properly, which is based on the relationship between the slip frequency and torque.

It has been proven that the DTC scheme for induction motors could be modified for PMSM drive. Since it does not require any current regulator, coordinate transformation and PWM signal generator, the DTC scheme has the advantages of simplicity, good dynamic performance, and insensitivity to motor parameters except the stator winding resistance.

Compared with the FOC, the major drawback of the DTC method is the large ripples of torque and flux linkage. The switching state of the inverter is updated only once in every sampling interval. The inverter keeps the same state until the output of the hysteresis controller changes state, resulting in relatively large torque and flux ripples. Another unwanted feature is the non-constant inverter switching frequency, which changes with the rotor speed, load torque and bandwidth of the two hysteresis controllers. In the past few years, many attempts were carried out to overcome these problems.

Fixed switching frequency and reduction of torque ripple could be obtained by calculation of the stator flux vector variation required to exactly compensate the flux and torque errors. The control system should be able to generate any voltage vector, implying the use of space vector modulation (SVM) which complicates the control scheme. On the other hand, a discrete SVM (DSVM) method was proposed to improve the DTC scheme, which replaces the simple switching table by several switching tables, to apply a combination of three voltage vectors in the same sampling period. The torque and flux ripple could be reduced with small calculation cost although the switching frequency of inverter is still variable.

In this paper, the DSVM DTC of PMSM is reviewed and the choice of null-vectors and the vector selection sequence are modified to improve the performance and reduce the inverter switching loss. Comparisons of the basic DTC and the improved DSVM DTC schemes are made based on the system performance and switching loss. The proposed scheme is tested by using MATLAB/SIMULINK and the results show improvements in both steady state and dynamic performance..

II. MODELLING OF PMSM

The voltage (v) over each stator winding is the sum of the resistive voltage drop (ir) and the voltage induced from the time varying flux linkage ($d\lambda/dt$)

$$V_a = r_a i_a + \frac{d}{dt}\lambda_a$$

$$V_b = r_b i_b + \frac{d}{dt}\lambda_b$$

$$V_c = r_c i_c + \frac{d}{dt}\lambda_c$$

Where $r_a = r_b = r_c = r_s$

In matrix form

$$V_{abc} = R_s i_{abc} + \frac{d}{dt}\lambda_{abc} = \begin{bmatrix} r_s & 0 & 0 \\ 0 & r_s & 0 \\ 0 & 0 & r_s \end{bmatrix}\begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt}\begin{bmatrix} \lambda_a \\ \lambda_b \\ \lambda_c \end{bmatrix}$$

Flux linkage in a linear magnetic circuit is the product of inductance and current.

$$\lambda_{abc} = L_s i_{abc} + \lambda_m$$

Stator voltage equations are converted to arbitrary frame

$$V_{qd0} = R_s i_{qd0} + \omega_T \begin{bmatrix} \lambda_d \\ -\lambda_q \\ 0 \end{bmatrix} + \frac{d}{dt}\lambda_{qd0}$$

Stator voltage expressed in the rotor reference frame then

$$V_q = R_S i_q + \omega_r \lambda_d + \frac{d\lambda_q}{dt}$$

$$V_d = R_S i_d - \omega_r \lambda_q + \frac{d\lambda_d}{dt}$$

$$\lambda_d = L_d i_d + \lambda_M$$

$$\lambda_q = L_q i_q$$

The electromagnetic torque can be expressed as

$$T_e = \frac{3P}{4}(\lambda_d i_q - \lambda_q i_d) \quad .$$

III. DIRECT TORQUE CONTROL

Fig.1(a) illustrates the block diagram of the basic DTC scheme. The principle of Direct Torque Control (DTC) is to directly select voltage vectors according to the difference between reference and actual value of torque and flux linkage. Torque and flux errors are compared in hysteresis comparators. Depending on the comparators a voltage vector is selected from a table.

Advantages of the DTC are low complexity and that it only need to use of one motor parameter, the stator resistance. No pulse width modulation is needed; instead one of the six VSI voltage vectors is applied during the whole sample period. All calculations are done in a stationary reference frame which does not involve the explicit knowledge of rotor position. Still, for a synchronous motor, rotor position must be known at start-up. Voltage selection criteria give rise to high ripple levels in stator current, flux linkage and torque.

Its simplicity makes it possible to execute every computational cycle in a short time period and use a high sample frequency. For every doubling in sample frequency, the ripple will approximately halve. The problem is that the power switches used in the inverter impose a limit for the maximum sample frequency.

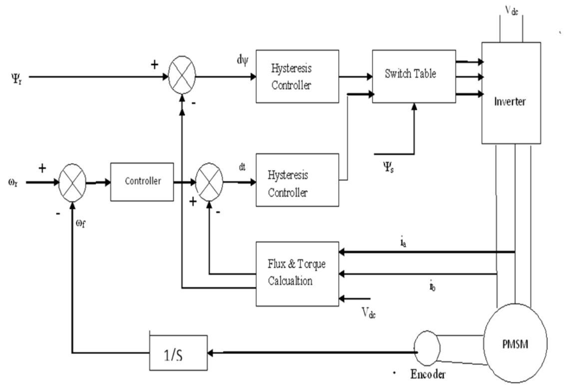

Fig. 1 Block Diagram of basic DTC scheme

The phase plane is divided, when the PMSM is fed by two-level voltage inverter with eight sequences of the output voltage vector, into six sectors.

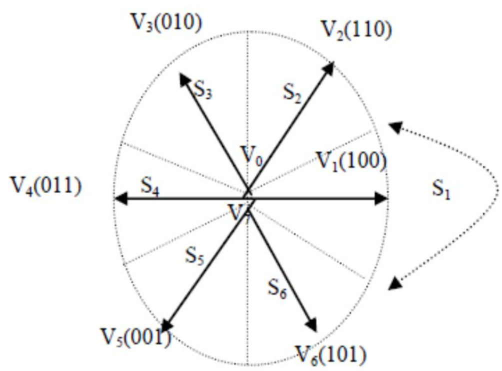

Fig. 2 *Stator vectors of tensions delivered by a two level voltage inverter*

When the flux is in a sector (i), the control of flux and torque can be ensured by the appropriate vector tension, which depends on the flux position in the reference frame, the variation desired for the module of flux and torque and the direction of flux rotation:

TABLE I
SELECTION OF VECTOR TABLE

	$\emptyset_s$Increase, $T_e$increase	$\emptyset_s$Increase, $T_e$decrese	$\emptyset_s$decrease, T_e increase	$\emptyset_s$decrease, $T_e$decrease
Vector tension selected	V_{i+1}	V_{i-1}	V_{i+2}	V_{i-2}

IV. PROPOSED SCHEME

The motor operation status of DSVM could be classified based on the torque error value and the emf, which is related to the rotor speed when the resistance loss is negligible; the torque is maintained at its actual value if the applied voltage vector effect coincides with the induced emf. If the feedback torque is close to the reference value a voltage space vector indicating approximately the emf should be chosen. The space vectors close to the emf are used for small torque error corrections. Same as the basic DTC scheme, the inverter switching frequency in the DSVM DTC system is non-constant. More vectors are applied in one sampling cycle. Theoretically, there could be more switching times in one sampling period. To minimize this, another vector selection algorithm is developed.

In DTC system has mentioned asymmetry in torque behaviour because of speed induced voltage. The DSVM calculates this voltage and use it to choose an appropriate voltage vector. The operating range from zero speed up to where induced voltage equals the applied voltage vectors is divided into three region; Low, Medium and High as shown in Fig 3.

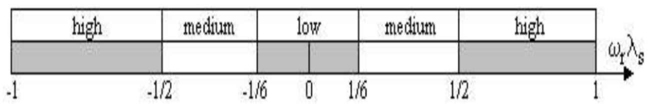

Fig 3. Speed voltage regions, [p.u]

The voltage induced is

$$\omega_r \begin{bmatrix} \lambda_d \\ -\lambda_q \end{bmatrix}$$

But only its value is used, so calculated voltage is

$$V_s = \omega_r \lambda_s$$

The fallowing figure shows the voltage vector obtained using DSVM technique.

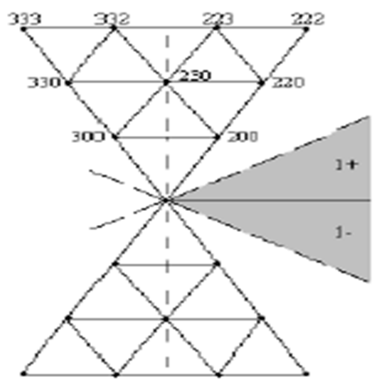

Fig. 4 Voltage vectors obtained by using DSVM

Several switching tables are carried out depending on the value of emf voltage or rotor speed. Table 2 is a set of switching tables for DSVM DTC method when the stator flux is in sector 1 for different speed region.

TABLE II

NEW SWITCHING TABLE OF DSVMDTC FOR SECTOR 1

Speed	Sector	Flux	Torque -2	Torque -1	Torque 0	Torque +1	Torque +2
Low	1	-1	555	500	000	300	333
		+1	666	600	000	200	222
Medium	1	-1	555	000	300	330	333
		+1	666	000	200	220	222
High	1-	-1	555	300	230	332	333
		+1	666	200	220	222	222
	1+	-1	555	300	330	333	333
		+1	666	200	220	223	222

Fig5. shows the block diagram of proposed scheme. Most of the blocks found in the DSVM system are the same as those found in the DTC system and the differences are discussed in figure which is similar to basic DTC

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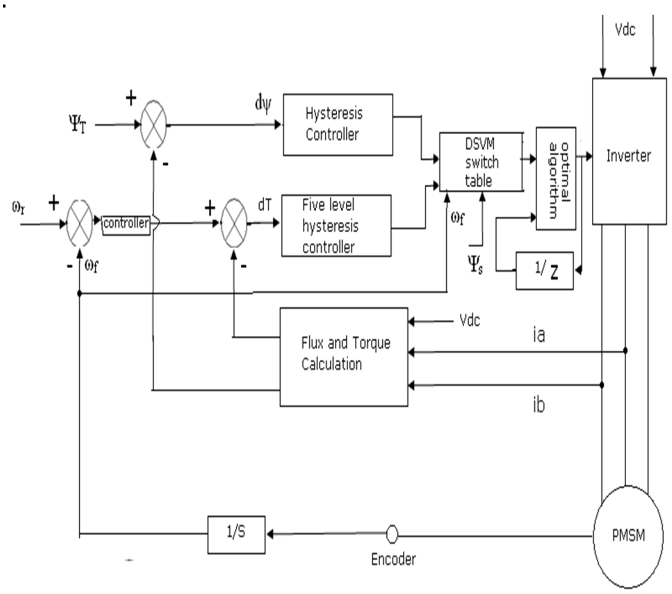

Fig. 5 Block diagram of improved DSVM DTC scheme

V. SIMULATION RESULTS

Simulation is carried out for proposed scheme and basic DTC scheme and comparison is made between them

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Fallowing simulation results shows that by using proposed scheme the steady state performance of system is proposed scheme is good when compared with basic DTC scheme.

Fig 6(a) & 6(b) shows that steady state performance of speed of BDTC & DSVM-DTC for PMSM at speed 100rpm respectively.

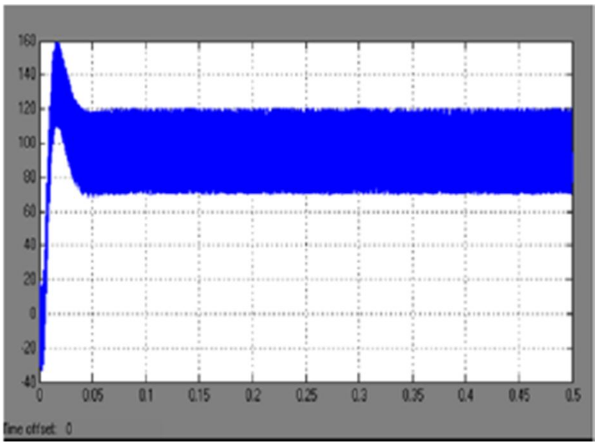

Fig. 6(a) steady state performance of speed of BDTC PMSM

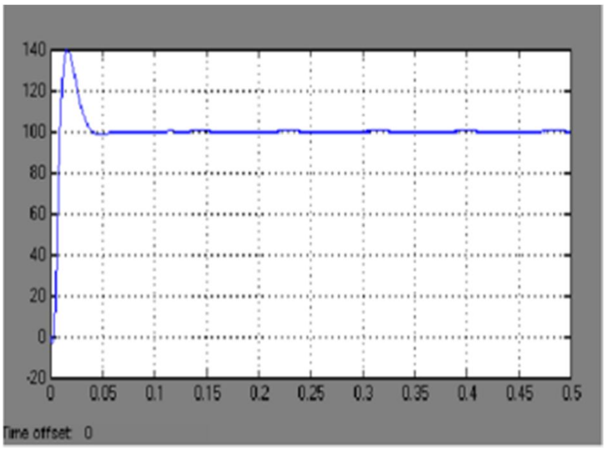

Fig. 6(b) steady state performance of speed of DSVM-DTC PMSM

Fig 7(a) & 7(b) shows that steady state performance of Torque of BDTC & DSVM-DTC for PMSM at speed 100rpm respectively

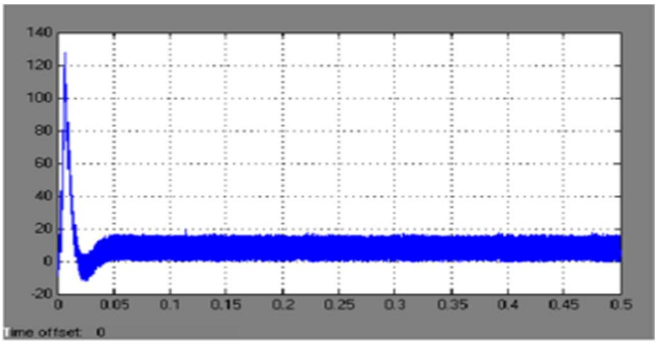

Fig. 7(a) steady state performance of torque of BDTC PMSM

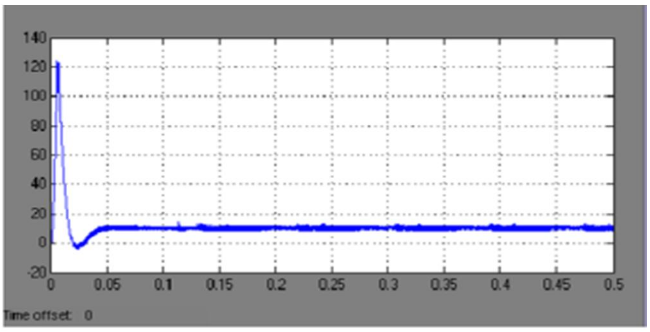

Fig. 7(b) steady state performance of torque of DSVM-DTC PMSM

Fallowing simulation results shows that by using proposed scheme the dynamic performance of system is proposed scheme is good when compared with basic DTC scheme.

Fig 8(a) & 8(b) shows that Dynamic performance of speed of BDTC & DSVM-DTC for PMSM at speed 1000rpm.

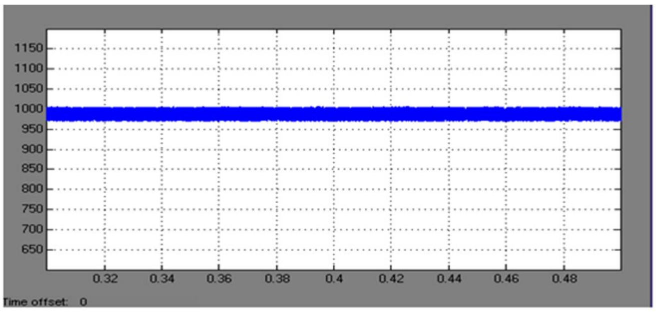

Fig. 8(a) Dynamic performance of speed of BDTC PMSM

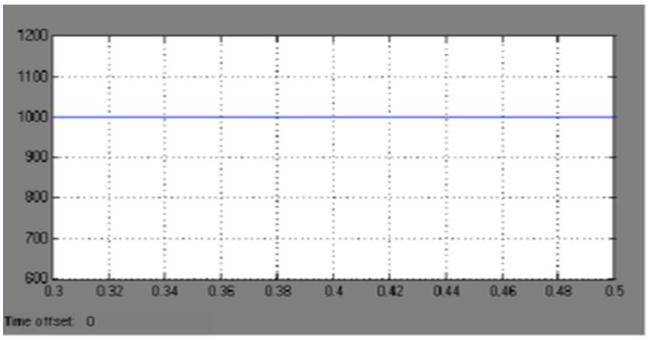

Fig. 8(b) Dynamic performance of speed of DSVM-DTC PMSM

Fig 9(a) & 9(b) shows that Dynamic performance of torque of BDTC & DSVM-DTC for PMSM at speed 1000rpm

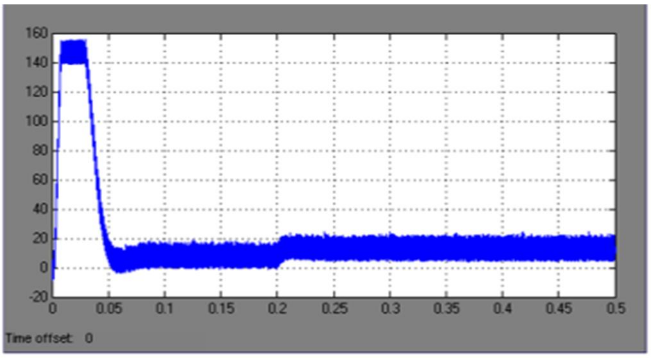

Fig. 9(a)Dynamic performance of torque of BDTC PMSM

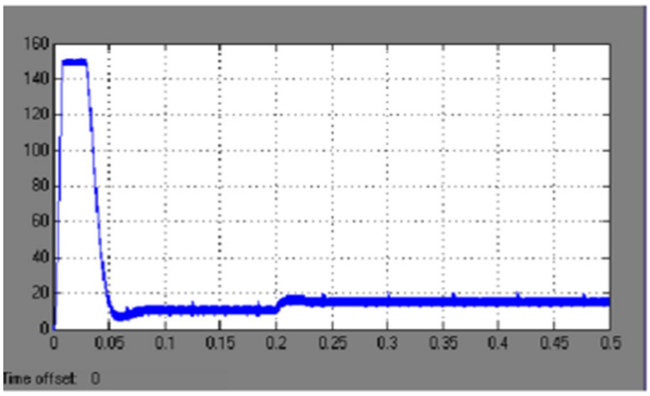

Fig. 9(b)Dynamic performance of torque of DSVM-DTC PMSM

VI. CONCLUSIONS

This paper has been presented a new technique called DSVM-DTC for speed control of PMSM. Simulation results show that the steady state and dynamic performance of motor is improved with DSVM-DTC technique when compared with DTC technique.

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