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Review on Speed Control of PMSM by using SVPWM Technique

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Abstract- -Permanent magnet synchronous motor is considered as variable speed motor due to its static and dynamic characteristics. These characteristics include high efficiency, light weight, low volume, small inertia, maintenance free and controlling of motor is also easy. In this paper includes the description of technique in which space vector pulse width modulated inverter (SVPWM) is used for the speed control of PMSM motor. Advantages of this technique are to achieve fast dynamic response with low speed ripples also dependency on motor parameters is low and high torque response. In this paper mathematical modeling of PMSM motor is done by using vector control technique in which output of inverter is obtain by SVPWM Technique. Simulation results are carried out for reference speed and torque signals given by some user define system. Simulation model is developed in MATLAB/SIMULINK to study various parameters.

Keywords - MATLAB, PMSM, SVPWM, Mathematical modeling, vector control, space vector.

I. Introduction.

Permanent magnet motors are of two types such as,
I) Brushless DC motor with trapezoidal back EMF.
II) Brushless dc motor with sinusoidal back EMF.

When PMSM motor is driven by external supply then the back EMF generated at the terminal shows sinusoidal waveform hence the PMSM is brushless motor with sinusoidal back EMF. [13] .PMSM have certain applications in AC servo system, aerospace and some military applications because of advantages of PMSM over other motors such as high efficiency, light weight, low volume, small inertia, maintenance free and ease of control as we have discussed in abstract. The main Aim of SVPWM is to produce flux vector which approaches the real gap flux circle in AC motor by controlling on-off mode and switching time of power devices in inverter .If we compare SPWM with SVPWM Technique which includes space vector approach

Following assumptions are involved such as, following assumptions are involved such as:

1) EMF having sinusoidal waveform.
2) Copper losses are negligible.
3) No saturation.

having certain advantages such as low harmonic content also reduced switching losses. SVPWM technique is easy to digitalize and can be easily implement to controllers. As industrial demand is increasing so rapidly it required high dynamic performance of motors which can be achieved with PMSM drives. Vector control of PM Machines are useful in electrical drives it overcomes almost all disadvantages of scalar control, the best advantage of vector control is that it is easy to implement in digital system.[7].

II. Permanent magnet synchronous machine model.

A. Mathematical Equations involved in machine modeling.

Mathematical model of PMSM (without considering damper winding) is developed on rotor reference frame.

The q and d axes stator flux linkage in rotor reference frames are:

$$V_q = R_s I_q + \omega_r \lambda_d + \rho . \lambda_q \quad (1)$$

$$V_d = R_s I_d - \omega_r \lambda_q + \rho . \lambda_d \quad (2)$$

Then the flux linkages are written as:

$$\lambda_q = L_q I_q \quad (3)$$

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$\lambda_d = L_d I_d + \lambda_f$ ……………………….………. (4)

Substituting these flux linkages into stator voltage equations then the stator equation:

$V_q = R_s I_q + \omega_r[L_d I_d + \lambda_f] + \rho L_q I_q$…… (5)

$V_d = R_s I_d - \omega_r L_q I_q + \rho[L_d I_d + \lambda_f]$…….... (6)

The electromagnetic torque is given by,

$T_e = (3/2)(p/2)(\lambda_d I_q - \lambda_q I_q)$ ……….... (7)

Mechanical torque is given by,

$\omega_m = \int (T_e - T_L - B\,\omega_m / J)\,dt$ ………….. (8)

Relation between mechanical torque

And electrical torque is,

$\omega_m = \omega_r (2/p)$ …………………………. (9)

Above equations are used for mathematical modeling of motor to control motor by giving some reference speed signal.

B. Park transformation and d-q modeling.

The dynamic direct- quadrature transformation is done for the analysis of motor parameters during transient and steady state condition of motor. In case of dynamic d q modeling Park transformation approach is used to convert three phase stationary AC variables in to DC variables in rotating reference frame.

Voltage equations used to convert phase voltage from V_{abc} to V_{dq0} variables in rotating reference frame.

$$\begin{bmatrix} V_q \\ V_d \\ V_0 \end{bmatrix} = \begin{bmatrix} \cos\theta_r & \cos(\theta_r - 120) & \cos(\theta_r + 120) \\ \sin\theta_r & \sin(\theta_r - 120) & \sin(\theta_r + 120) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

…… (10)

Above equation can be implemented in simulink as follows:

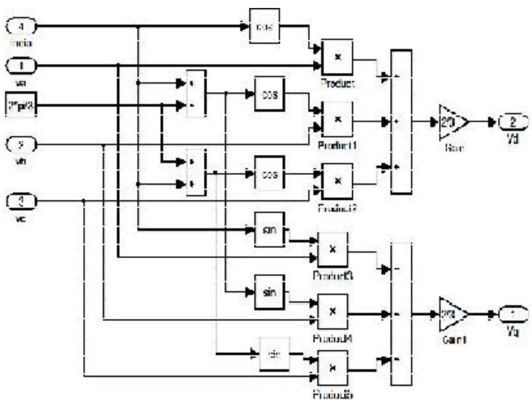

Figure. 1 Generation of V_q and V_d by using mathematical blocks.

$$\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} \cos\theta_r & \sin\theta_r & 1 \\ \cos(\theta_r - 120) & \sin(\theta_r - 120) & 1 \\ \cos(\theta_r + 120) & \sin(\theta_r + 120) & 1 \end{bmatrix} \begin{bmatrix} V_q \\ V_d \\ V_0 \end{bmatrix}$$

……… (11)

Above equation can be implemented in simulink as follows:

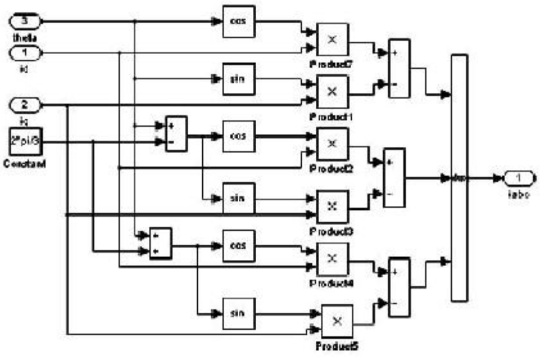

Figure. 2 Generation of Va V_b Vc Using mathematical blocks.

C. Proposed machine model with vector control using SVPWM technique.

Speed controller which is used is classical PI controller which produce reference q axis component. Park transformation is used to produce d component which is compare with the reference value and produce d axis component. Following figure represents basic block of proposed PMSM with SVPWM technique.

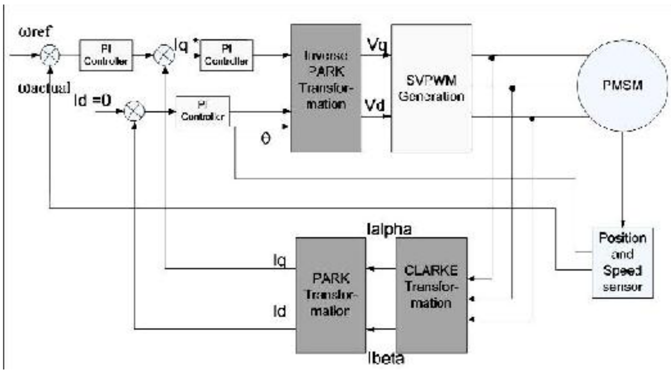

Figure. 3 Block diagram of vector controlled PMSM with SVPWM.

III. Space vector pulse width modulation technique.

Space vector pulse width modulation inverter contains six switches (IGBT Transistor) which

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form three phase three leg bridge inverter. Inverter is supplied by continuous DC voltage as a input and output is controlled by SVPWM technique applied to inverter.

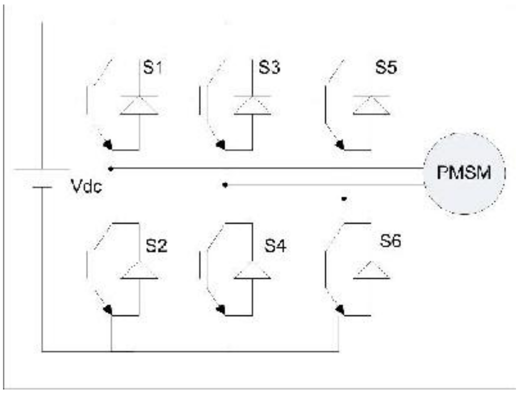

Figure. 4 Typical Three Phase VSI employing SVPWM technique.

Generation of output voltage in SVPWM technique is based upon vector selection based on switching vectors. Combination of switching states are as follows: (000), (100), (110), (010), (011), (001), (101) and (111) [7].

The first and last state does not resemble for flow of current and line to line voltage is zero. Remaining six stages resembles for the voltage output fed to motor. There are possibly eight combinations to on and off upper three power switches as shown in table below:

Sector	I	II	III	IV	V	VI
N	3	1	5	4	6	2

Voltage Vectors.	Switching Vectors.			Line to Line Voltage		
V0	a	b	c	Vab	Vbc	Vca
V1	0	0	0	0	0	0
V2	1	0	0	1	0	-1
V3	0	1	0	-1	1	0
V4	0	1	1	-1	0	1
V5	0	0	1	0	-1	1
V6	1	0	1	1	-1	0
V7	1	1	1	0	0	0

Table No. -01 Switching vectors and voltage vectors with line to line voltage.

Maximum phase voltage produced with the given DC link under six step operations is as follows:

$V_{six\text{-}step} = 2V_{dc}/\pi$ …………………….… (12)

Maximum phase voltage produced with the given DC link with conventional sinusoidal modulation is:

$V_{sin\text{-}pwm} = V_{dc}/2$ ……………………….. (13)

Voltage obtains with SVPWM Technique Is:

$V_{SVPWM} = V_{dc}/\sqrt{3}$ ……………………… (14)

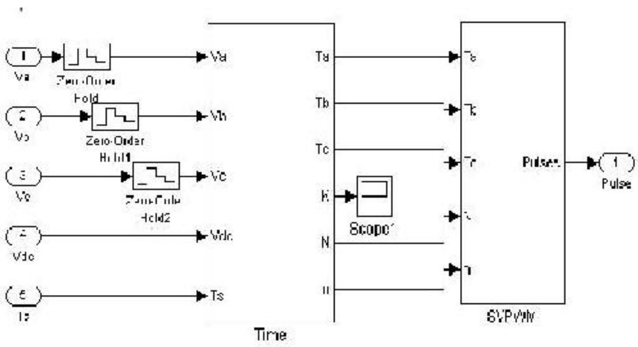

Figure. 5 Implementation Of SVPWM in Simulink.

Sector Judgment Model [11] Using the expression of voltage vector in the β coordinate for control implementation, as follows:

$V\beta > 0, A = 1$ ……….…………….. (15)

$3V\alpha\text{-}V\beta > 0, B = 1$ ……………….. (16)

$\sqrt{3}V\alpha+V\beta < 0\ C = 1$....................... (17)

Therefore Sectors can be decided as:

$N = A+2B+4C$ …………………….. (18)

Table No.02 Sector selections .

The calculation of dwelling time required for the generation of phase current is obtained by Vref and Ta and Tb.

Ta = the dwelling time required for voltage stay in state Va.

Tb = the dwelling time required for the voltage state Vb.

T0 = the dwelling time for the voltage state V0 and V7–effective voltage vector [11] as indicated in Fig.6 [13].

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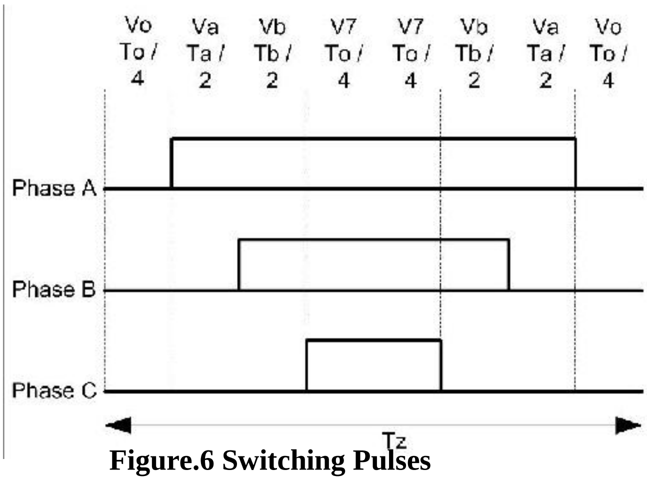

Figure.6 Switching Pulses

MATLAB – Simulink implementation of vector control based speed control of PMSM using SVPWM technique.

The mathematical model of PMSM which is discussed above uses VSI inverter implemented with SVPWM technique to deliver its input.

MATLAB Simulink implementation Of proposed strategy as follows:

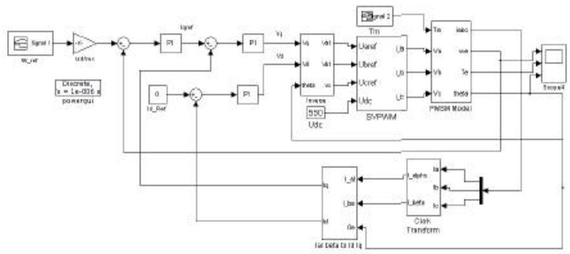

Figure.7 The MATLAB Simulation implementation of motor.

Motor Parameters:

IV. Result.

The Simulation of vector controlled PMSM drive is carried out by using MATLAB. Model is simulated by using reference signals. Fig. a shows simulation carried out for reference speed which gives the comparison in reference and actual speed.

Results obtain from the simulation are as stated as follows:

In fig 9 Simulation results carried out for reference speed are shown also comparison between reference speed and actual speed can be observed from the figure.

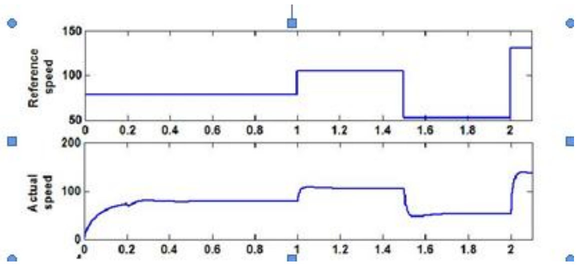

Figure. 8 comparison of reference speed and actual speed.

Fig. b shows comparison of reference and actual torque, except some points where speed suddenly changed graph of actual and reference torque is same nearly same.

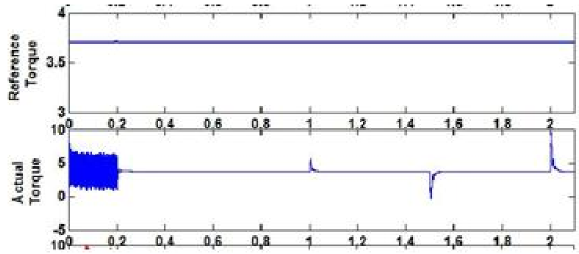

Figure.9 comparison of reference torque and actual torque.

Fig. c shows current flowing through three phase stator winding. Current is in sinusoidal nature and having very low distortion.

Sr. No	Parameter Names	Values
1	Stator Resistance Rs (Rd, Rq)	1.4 Ω
2	d-axis Inductance Ld	0.0066 H
3	q-axis Inductance Lq	0.0058 H
4	Permanent Magnet Flux Ψaf	0.11546
5	Rated Speed ωr	1015 r.p.m.
6	No of Poles p	6
7	Moment of Inertia J	0.001176
8	Damping Coefficient B	0.00038818

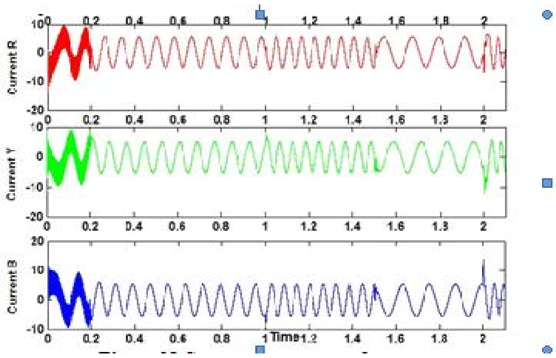

Fig. 10 stator current waveform.

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