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Space Vector PWM Voltage Source Inverter Fed to Permanent Magnet Synchronous Motor

Bhimrao G. Dabhade[1], Prof. P.S. Swami[2]
[1]*Govt. College Of Engineering, Aurangabad, ME Student, Station Road, Osmanpura, Aurangabad.*
[2]*Govt. College Of Engineering, Aurangabad, ME Student, Station Road, Osmanpura, Aurangabad.*

Abstract:- This paper represent the MATLAB simulation analysis of space vector pulse width modulation (SVPWM) voltage source inverter give the supply to the PMSM drive. The main Aim of this paper supply AC supply to the PMSM through VSI by using SVPWM technique. Number of PWM methods is used to generates gate pulses, but most commonly used PWM method for three phase voltage source inverter (VSI) are sinusoidal PWM (SPWM) and space vector PWM (SVPWM). Now a day SVPWM technique are used because SVPWM technique reduces the voltage and current harmonic content, increase fundamental output voltage by 15% and smooth control of PMSM. So here present modeling simulation of SVPWM inverter fed PMSM drive in MATLAB/ simulation the result of total harmonic distortion(THD) fast Fourier transformation (FFT) of current are obtained in MATLAB Simulation.

Keywords:- voltage source inverter, SVPWM, PMSM drive

I. INTRODUCTION

Now a day Permanent magnet synchronous motor are used due to his superior performance as compare to other machine, have become very popular in variable frequency drive system. In these PMSM drive system, the space vector PWM technique is widely employed to achieve grate static and dynamic performance, which is drive by the voltage source inverter using SVPWM technique, By using VSI possible to control both voltage and current applied to the permanent magnet synchronous machine drive. As a result, PWM inverter fed PMSM drive are more variable, reliable and offer wide range speed. Also it gives good efficiency and high performance as compare to other drives. The energy, which is delivered by the SVPWM inverter to the PMSM is control by the SVPWM signals applied to the gates of power switching device of inverter at different times for varying the duration to desired output voltage waveform.

A number of PWM technique are used to achieved variable voltage and frequency from a inverter to control the PMSM drives but most widely used PWM technique for 3 phase voltage source inverter are sing PWM and SVPWM Technique but to reduce harmonic content and increasing output voltage SVPWM technique is better than SPWM technique also its utilized 15% more DC link voltage. [1-2]

So using SVPWM technique for 3 phase inverter switching and output of inverter fed to the PMSM drives simulation is done in MATLAB/Simulink software.

II. VOLTAGESOURCEINVERTER

Circuit shows Voltage source inverter, which is device use to convert DC voltage to AC voltage, voltage and frequency, may be variable or fixed according to application. A voltage source inverter should have erect voltage source at the input. That is its internal impedance should ideally be zero. A large capacitor connected at the input if the input voltage is not erect, the DC voltage may be constant or variable. [1]

In voltage source inverter the power semiconductor device always remain forward biased due to DC supply voltage and there force, self-control forward or asymmetric blocking devices, such as GTO, BJT, Power MOSFET, IGBT, IGCT are suitable. A feedback diode is always connected across the device to have free reverse current flow one. Voltage source inverter has one of the most important characteristics is that the AC fabricated voltage wave cannot be effect on load parameter (4)three phase inverters are mostly used for three phase AC Drives and general purpose AC supplies fig.1 show the voltage source bridge inverter. Circuit consist of three half bridge which are mutually phase shifted by 2pi/3 angle to generates the three phase voltage source. Dc supply obtain from single phase or three phase diode rectifier and LC or C filter as shown in fig.1 they have several type of VSI such as single phase VSI and three phase VSI.(1)[2-3]

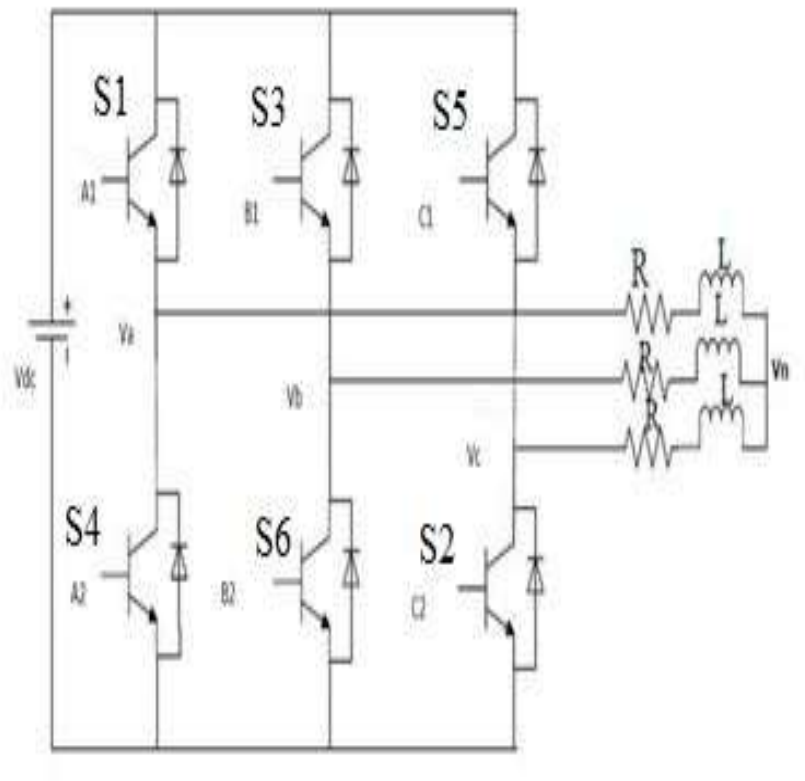

Fig.1 three phase Inverter

III. SWITCHING STATE

A three phase voltage source inverter has 2^3 =8 possible switching state as shown in fig.2 which is them 1-6 are non-zero voltage vector and two are zero voltage vector, there are six switches and 3 link six switches such as S1 to S6 the output which are control by the switching variables A1, A2, B1, B2, C1, C2. When upper switches switch on i.e. A1, B1, C1 are 1 the corresponding A2, B2, C2 is off condition means its 0. This ON and OFF condition of the upper switch S1, S3, and S5 can be used to determine the output voltage.

Table.1 switching state

Switching state	**Leg A**			**Leg B**			**Leg C**		
	S_1	S_4	V_{ao}	S_3	S_6	V_{bo}	S_5	S_2	V_{co}
1	On	Off	V_d	On	Off	V_d	On	Off	V_d
0	Off	On	0	Off	On	On	Off	On	0

As mention in the table1 when switching state1 it means than the all upper switches are ON in an inverter leg and inverter terminal voltage is V_{dc} while 0 indicates that the inverter terminal voltage is zero due to the on state of lower switches. The terminal voltage is gives,

$$V_{an} = \frac{2}{3} V_{dc} \quad 1$$

$$V_{bn} = -\,{}^{1}/_{3}\, V_{dc} \quad 2$$

$$V_{cn} = -\,{}^{1}/_{3}\, V_{dc} \quad 3$$

Similarly there are eight different combination of switching state are as follow.

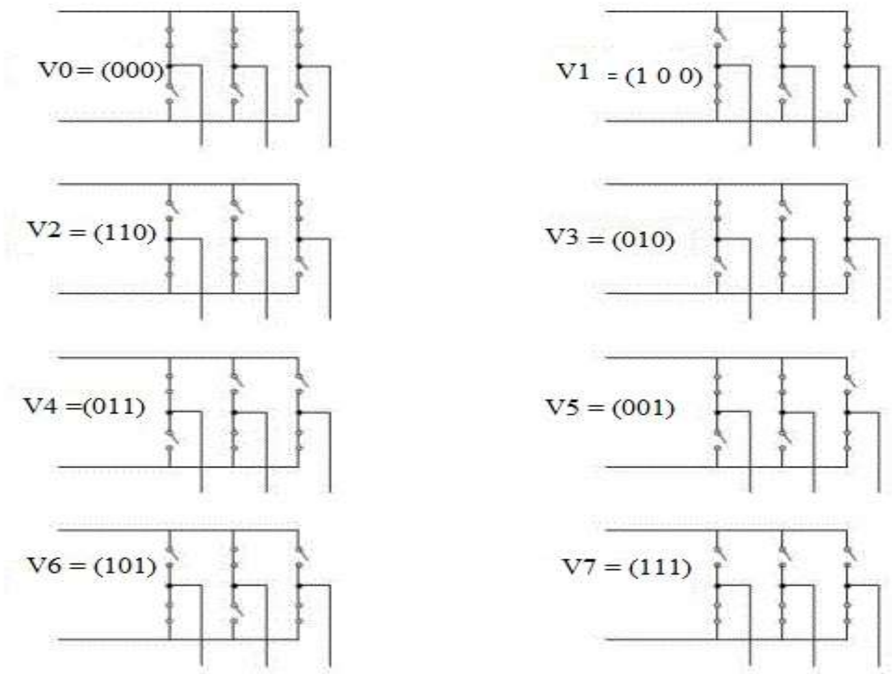

Fig.2. Switching State of SVPWM

Table 2 gives basic idea of switching states and corresponding phase to neutral voltages of an isolated neutral machine.

Table 2: summary of switching states

State	ON Device	V_{an}	V_{bn}	V_{cn}	Space voltage
0	S_4 S_6 S_2	0	0	0	V_0 =(0 0 0)
1	S_1 S_6 S_2	$2/3V_{dc}$	$-1/3V_{dc}$	$-1/3V_{dc}$	V_1 =(1 0 0)
2	S_1 S_3 S_2	$1/3V_{dc}$	1/3V_{dc}	-2/3V_{dc}	V_2 =(1 1 0)
3	S_4 S_3 S_2	-1/3v_{dc}	2/3V_{dc}	-1/3V_{dc}	V_3 =(0 1 0)
4	S_4 S_3 S_5	-2/3V_{dc}	1/3V_{dc}	1/3V_{dc}	V_4 =(0 1 1)
5	S_4 S_6 S_5	-1/3V_{dc}	-1/3V_{dc}	2/3V_{dc}	V_5 =(0 0 1)
6	S_1 S_6 S_5	1/3V_{dc}	-2/3V_{dc}	1/3V_{dc}	V_6 =(1 0 1)
7	S_1 S_3 S_5	0	0	0	V_7 =(1 1 1)

The graphical derivation of V1 (1 0 0) in fig.3 shows that the vector has a value 2/3 V_{dc} and Aligned horizontal direction, similarly all six non zero vector and zero vector are equate and place as shown in fig. 3 [3-4].

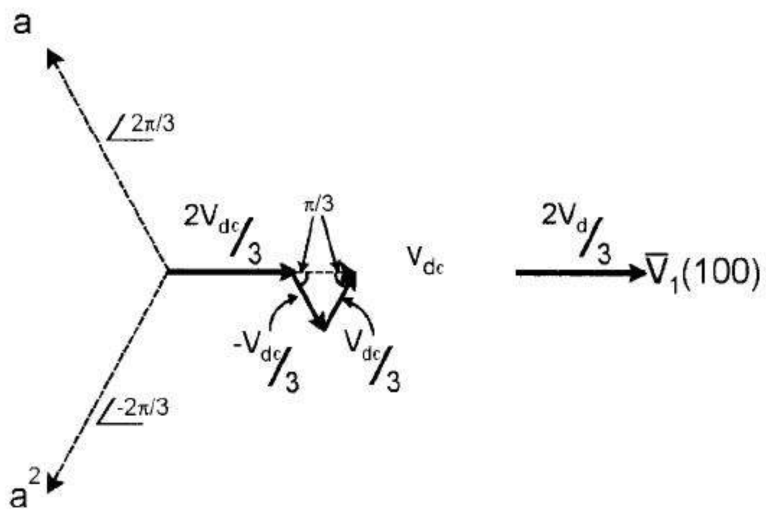

Fig.3 construction of space vector V1 (1 0 0)

IV. SPACE VECTOR PWM (SVPWM)

Space vector refers to a special switching system of the six power semiconductor devices of three phases VSI SVPWM has become very popular technique for three phase VSI in variable frequency application such as traction, PMSM, the disadvantages of SPWM and hysteresis band current control are reduced using this technique. By using interaction of the complex reference voltage vector $\ddot{V}$ with magnitude V_{ref} rotates in circular orbit with velocity ω. The direction of rotation of voltage vector is depending on phase sequence. Due to SVPWM generates less harmonic distortion as compare to SPWM. SVPWM provide a constant switching frequency and therefore easily adjust switching frequency, although SVPWM more complicated than SPWM and hysteresis band current control.[5]

The concept of a rotating space vector is very important, this idea is achieve from the rotating flux of AC motor which is used to modulating the inverter output voltage. In this technique the three phase quantities can be transformed in to equivalent two phase quantity in stator frame or rotor frame by using park transformation. From the two phase component calculate reference voltage V_{ref}. The rotating space vector is explained in the following section, considering stator reference frame. For example, if the three phase AC balance signal is as follows. (4-5)

$$V_a = V_m \sin\omega t \quad (4)$$

$$V_b = V_m \sin(\omega t - 2\tfrac{\pi}{3}) \quad (5)$$

$$V_c = V_m \sin(\omega t + \tfrac{2\pi}{3}) \quad (6)$$

$$V_{ref} = {}^{2}/_{3}\,[V_{an} + \alpha V_{bn} + \alpha^2 V_{cn}] \quad (7)$$

They produce a rotating magnetic field in air gap of the AC motor; this rotating flux component can be represented by a single rotating voltage vector. The magnitude and angle of the rotating vector can be found by the mean of clark's transformation. The representation of rotating vector in complex plane as shown in fig.4

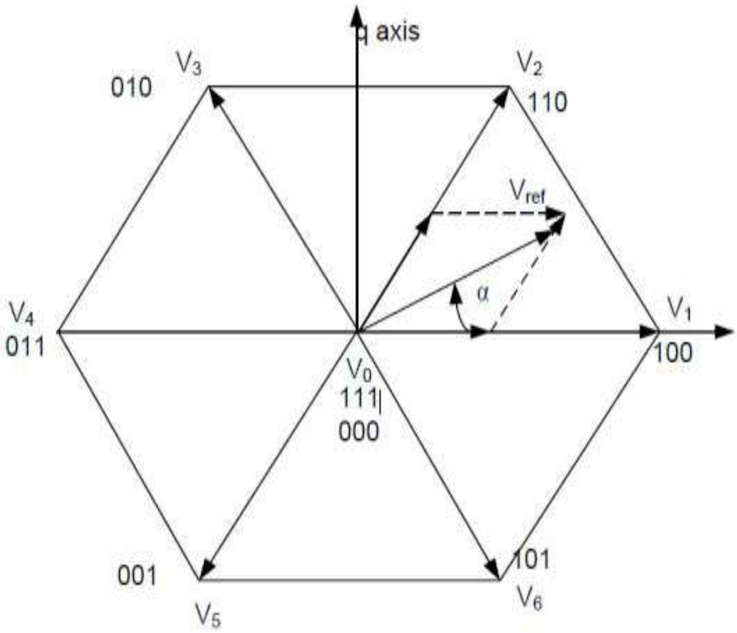

Fig.4. space vector diagrams.

V. SVPWM IMPLEMENTATION

Following steps are used to implement the space vector PWM
Step1. Determine V_d, V_q, V_{ref} and angle
Step2. Determine time duration T_1, T_2, T_0
Step3. Determine the switching time of each switches

Step1. Determine V_d, V_q, V_{ref} and angle

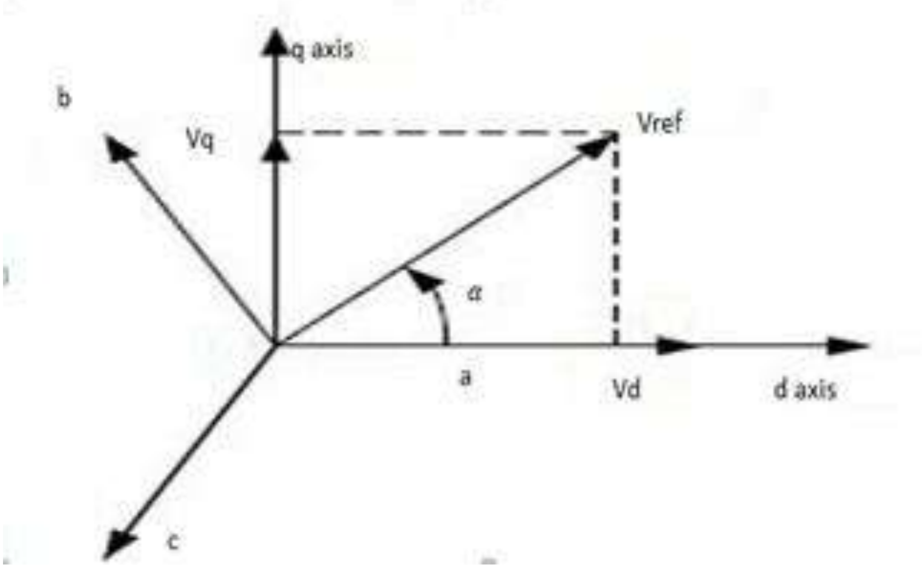

Fig.5 voltage space

Vector and its d, q axis
$V_d = V_{an} – V_{bn}*\cos60 – V_{cn}*\cos60$
$= V_{an}-1/2V_{bn}–1/2V_{cn}$ 8
$V_q = V_{bn}*\cos30 – V_{cn}*\cos30$
$=\frac{\sqrt{3}}{2}Vdc-\frac{\sqrt{3}}{2}\ Vcn$ *9*
Therefore

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \begin{bmatrix} 1 & -1/2 & -1/2 \\ 0 & -\sqrt{3}/2 & -\sqrt{3}/2 \end{bmatrix} * \begin{bmatrix} Vcn \\ Vbn \\ Vcn \end{bmatrix} \quad 10$$

$$|Vref| = \sqrt{V^2{}_d + V^2{}_q}$$

$$\alpha = \tan^{-1}\frac{V_d}{V_q} = 2\omega f_s t = \omega_s$$

Step2. Calculations time duration

The voltage vector is determined by using the tree adjacent vectors. The time of each vectors found. By using voltage time equation (12) of the vector calculation,

$$T_1V_1+T_2V_2+T_0V_0= T_sV_{ref} \quad 11$$

The magnitude and angle of adjust voltage are,

V_0=0, V_1 = 2/3V_{dc}*e^{j0},V_2= 2/3V_{dc}*$e^{jpi/3}$

So voltage equation become is

$$T_1(2/3V_{dc}*e^{j0})+T2(2/3V_{dc}*e^{jpi/3})+T_0(0)=T_sV_{ref} \quad 12$$

Therefore,

Real: $T_1\,(2/3V_{dc}*cos0) + T_2\,(2/3V_{dc}*cospi/3)=V_{ref}*sin\alpha$ 13

Im: $T_1\,(2/3V_{dc}*sin0) + T_2\,(2/3V_{dc}*sinpi/3) = T_sV_{ref}*sin\alpha$ 14

And $T_1+T_2+T_0=T_s$ 15

By solving Equation 13,14and 15 we get

T_1=T_s*K*$\left(\sin\frac{\pi}{3}-\alpha\right)$/sin$\pi/3$ 16

T_2=T_s*K*$\frac{\sin\alpha}{\sin\pi/3}$ 17

And T0=Ts-T1-T218

Similarly remaining switching time duration can be deterned.

Step3. Determine switching time of each switch.

Following figure shows the switching time each switch of an inverter system

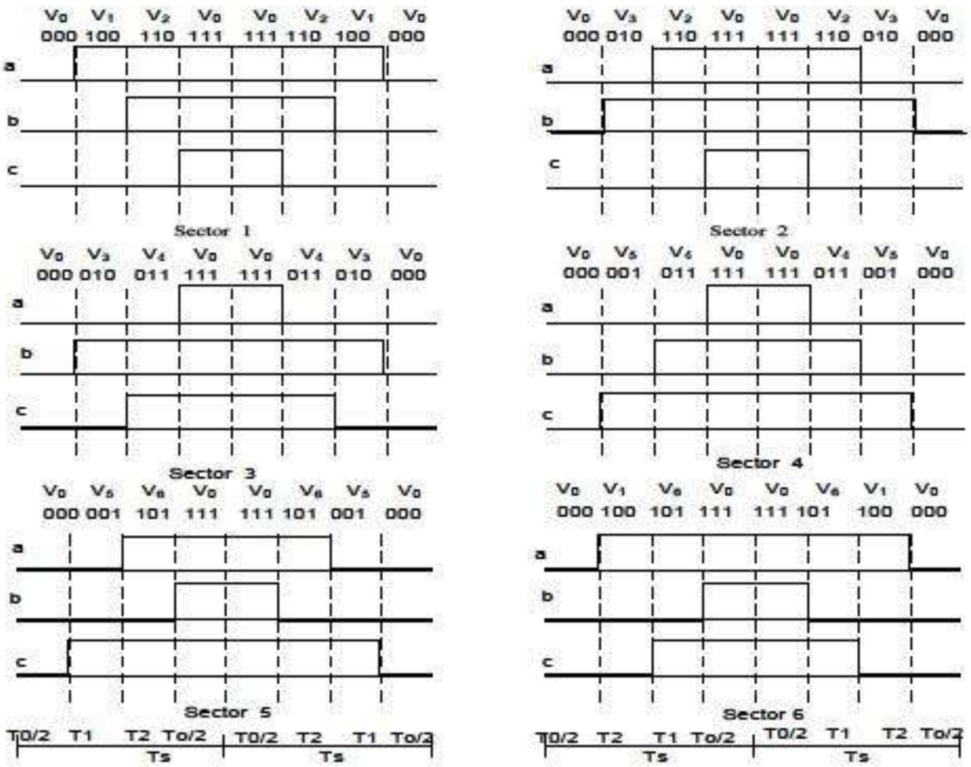

Fig.6.switching time of switches

On the basis of fig.6 the switching time at each sector is summarized in table 3 and it will be help to modulate the simulation model. Table show the six sector and time calculation of each switch. This can be easily calculated using above switching states.[6-7]

Table 3. Sector & time calculation

Sector	Upper switch	Lower Switch
1	S1 = T1 + T2 + T0/2 S3 = T2 + T0/2 S5 = T0/2	S4 = T0/2 S6 = T1 + T0/2 S2 = T1+T2 + T0/2
2	S1 = T1 + T0/2 S3 = T1 + T2 + T0/2 S5 = T0/2	S4 = T2 + T0/2 S6 = T0/2 S2 = T1+ T2+ T0/2
3	S1 = T0/2 S3 = T1 + T2 + T0/2 S5 = T2 +T0/2	S4 =T1+ T2 + T0/2 S6 = T0/2 S2 = T1 + T0/2
4	S1 = T0/2 S3 = T1 + T0/2 S5 = T1 + T2 + T0/2	S4 T1+T2+ T0/2 S6 = T2 +T0/2 S2 = T0/2
5	S1 = T2 + T0/2 S3 = T0/2 S5 = T1 + T2 + T0/2	S4 = T1 +T0/2 S6 = T1+T2 + T0/2 S2 = T0/2
6	S1 = T1 +T2 + T0/2 S3 = T0/2 S5 = T1 + T0/2	S4 = T0/2 S6 = T1+T2 + T0/2 S2 = T2 + T0/2

VI. SIMULATION/RESULT

Block diagram of simulation model and simulation result is shown in fig.7

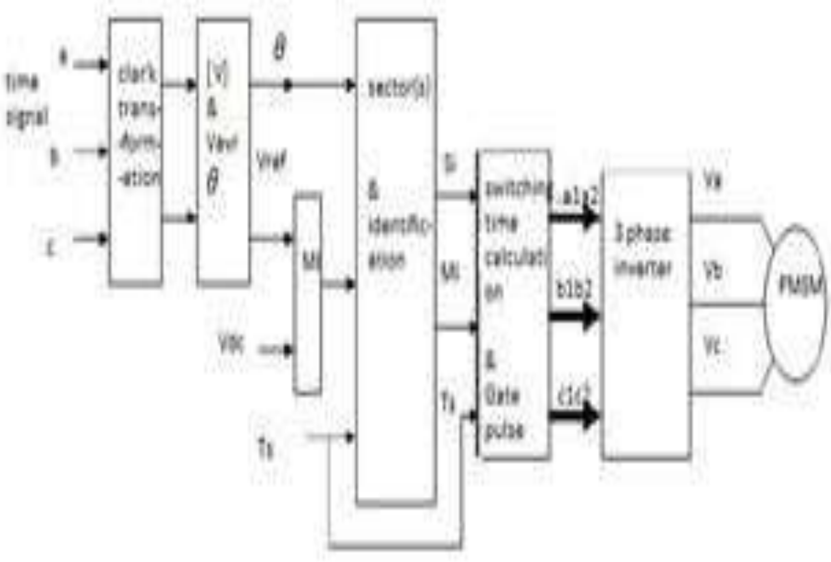

Fig.7 Simulation Block Diagram of SVPWM two level inverter with PMSM load

In this system firstly we have transfer three phase quantity in to two phase (a,b,c to α,β) by using clark's transformation than transfer in to the rotor reference frame by using park's transformation(d, q), v_{ref} , Ө, MI, and T_s help to identify the sector than calculate the switching time to produce proper gate pulse to the VSI. VSI received the DC supply and convert in to AC supply which is fed to the PMSM.

In simulation Results from FFT analysis less current harmonic produce near about 74% in rotor current and 64% in torque repletion at 4000 Hz frequency repletion will be observed and the magnitude is 2 to 3 % of fundamental frequency. At initially all the component gate transient after the time 0.1 sec. it's become stable

Simulation Result

Fig.8 Inverter Line Voltages

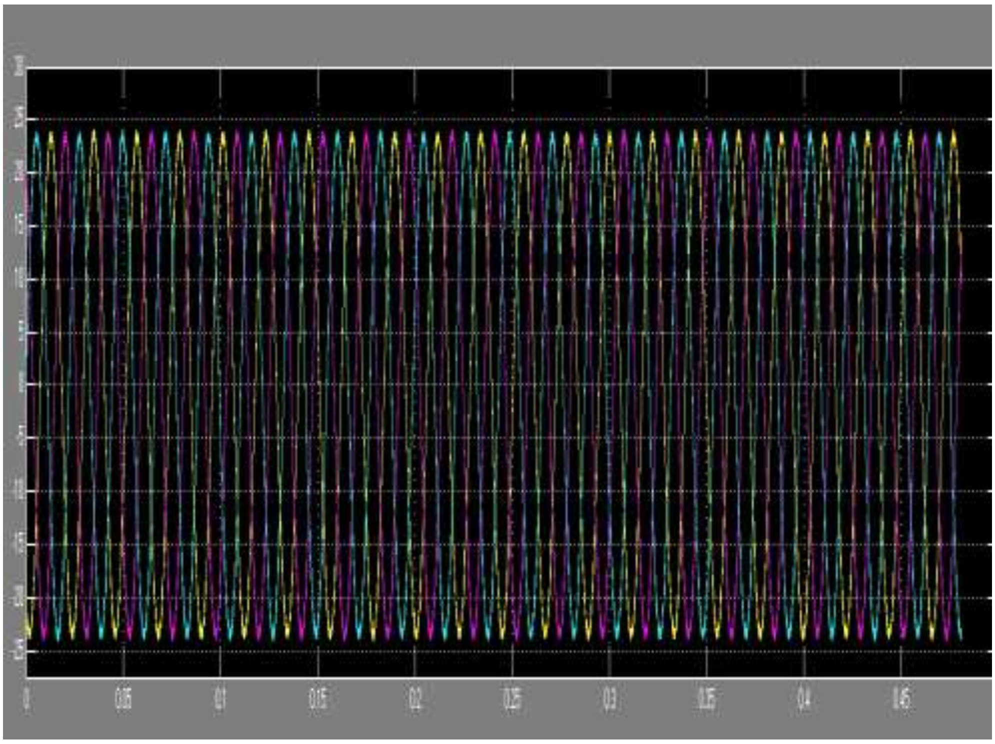

Fig. 9 Inverter Line Current

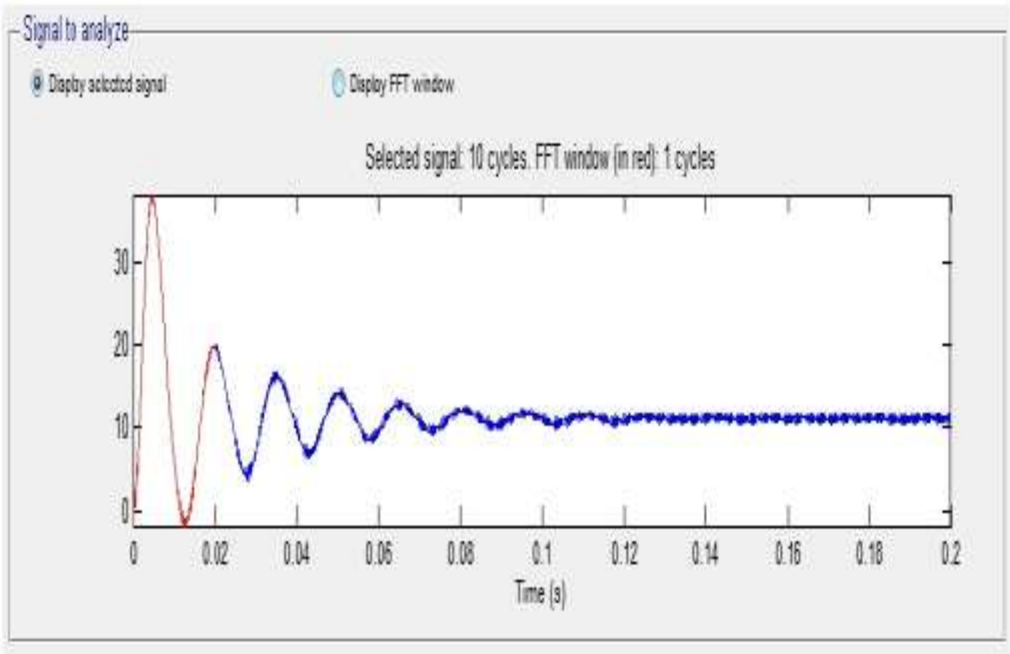

Fig.10 Rotor current

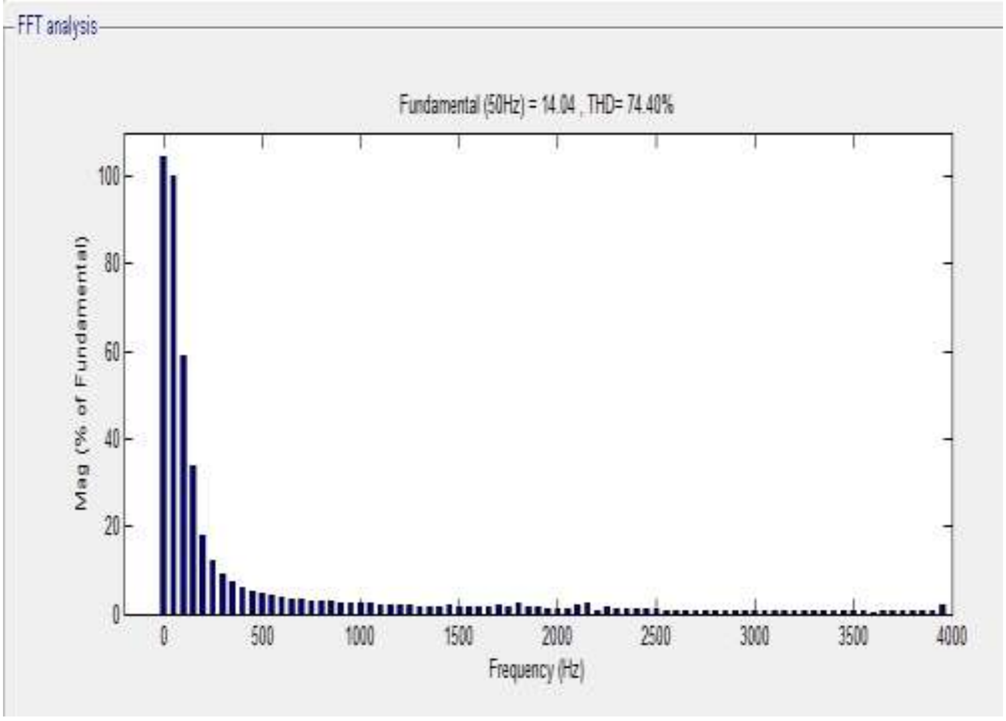

Fig.11 FFT Rotor Current

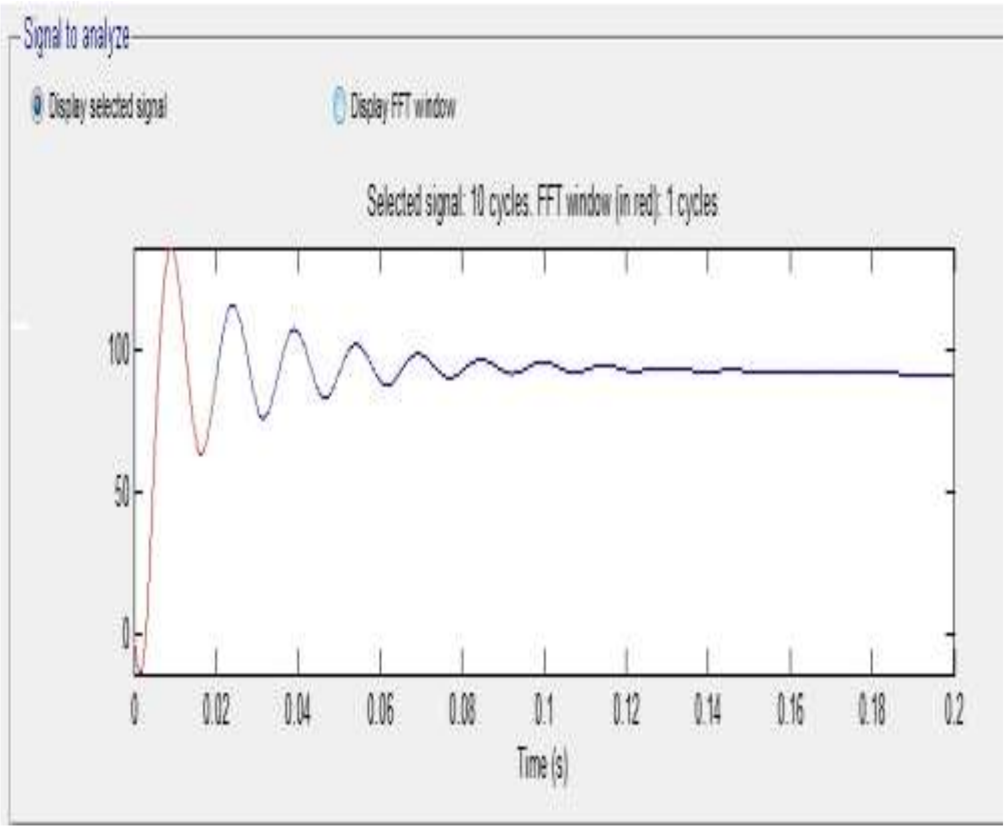

Fig.12 Rotor Speed

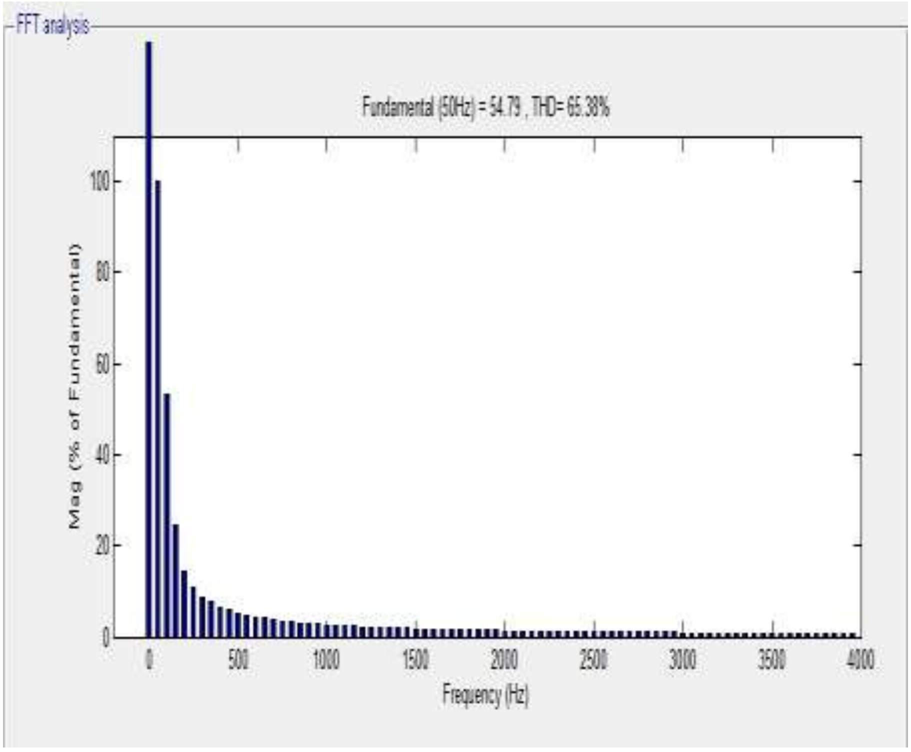

Fig.13 FFT of rotor speed

VII. CONCLUSION

By using SVPWM Inverter fed PMSM drive Modeling and then simulation is done in MATLAB/ SIMULINK 10. From simulation result of THD and FFT analysis concluded that SVPWM technique is better overall PWM technique which give less THD in Inverter current 74%, which under the permissible limit.

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