International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

PMSM Field Oriented Control using Svpwm for Control Moment Gyroscope (CMG)

Sumitra.K
PG Scholar
Department of EEE
MBCET-Kerala

Mr. M. Suresh
Scientist/Engineer(SF)
IISU
VSSC,Vattiyoorkavu

Prof .M. K. Giridharan
Dean(Academics)
Department of EEE
MBCET -Kerala

Abstract— **In space flight analysis it is very important to know the position and motion of the satellite. CMG(Control moment Gyroscope) are nowadays used in small satellites .The CMG depends on two motors for operation. One is a brushless DC motor(BLDC) which is used to spin the momentum wheel and the other one is a stepper motor used to gimbal the momentum wheel around an axis which is perpendicular to the spin axis. The objective of this thesis is to improve torque smoothness in CMG. For this BLDC motor is replaced with Permanent Magnet synchronous Motor(PMSM). The main disadvantage of BLDC motor is torque ripples which induce torque pulsations that deteriorate the performance of drives particularly at low speeds. In order to minimize harmonics the PWM technique used here is Space Vector Pulse Width Modulation(SVPWM). FOC(Field Oriented Control) is used to control the PMSM in order to achieve high performance control characteristics.FOC controlled PMSM drive provides better dynamic response and lesser torque ripples. The closed loop control of the PMSM drive using FOC and SVPWM is simulated in MATLAB SIMULINK.**

Keywords*—Permanent Magnet Synchronous Motor(PMSM), Space Vector Modulation(SVPWM), Field Oriented Control(FOC), Control moment Gyroscope(CMG)***

I. INTRODUCTION

In space flight analysis it is very important to know the position and motion of the satellite. Satellites are required to have more rapid rotational movement and agility than before in order to provide multi-target pointing and tracking capability. CMG(Control moment Gyroscope) increases the agility of a satellite by enabling it to do rapid pointing manoeuvre. Future earth imaging satellites would rather move spacecraft body rapidly rather than to sweep only the imaging system from side to side which will provide high resolution images .

CMG uses two motors for operation. BLDC motor to spin the momentum wheel and stepper motor to gimbal the momentum wheel. The microcontroller (C8051F041) receives control data via RS232 from a PC, implements it and then send control commands to BLDC motor controller and Stepper motor controller. A Hewlett packard optical encoder is used for high accuracy speed feedback to the microcontroller.

BLDC motor controller has all the necessary functions for driving a BLDC motor and directly controls the three phase drive stage which connects to the motor. The stepper motor controller receives command signals from the microcontroller such as clock pulse, direction and inhibit. It has its own full bridge drivers to drive the stepper motor. A current control loop runs internal to ensure a smoother motor current.

The proposed system uses PMSM instead of BLDC. Permanent magnet ac motor drives are used in high performance applications. The general characteristics are compactness, high efficiency, smooth torque, low noise, fast dynamic response. Field oriented control of PMSM is used along with Space vector modulation for reducing torque ripples in CMG.

Vector controlled PMSM drive provides better dynamic response and lesser torque ripples[10]. Vector control is used to control the PMSM in order to achieve high performance control characteristics. In AC machines, the stator and rotor fields are not orthogonal to each other. The only current that can be controlled is the stator current.

Field Oriented Control is the technique used to achieve the decoupled control of torque and flux.FOC scheme not only decouples the torque and flux which makes faster response but also makes control task easy[1]. FOC is carried out to control the space vector of magnetic flux, current and voltage of machines in order to achieve the precise torque. The aim of the FOC method is to control the magnetic field and torque by controlling the d and q components of the stator currents or consequently the fluxes.

SVPWM refers to a special switching sequence which generate less harmonic distortion in the output voltages applied to the phases of an AC motor. It provides more efficient use of supply voltage. It has superior characteristic like easy digital realization. The objective of SVPWM is to approximate the reference voltage vector Vref using the eight switching patterns. Sinusoidal commutation technique is used here where all the three coils are excited at any given point of time.

II. THE PROPOSED SYSTEM

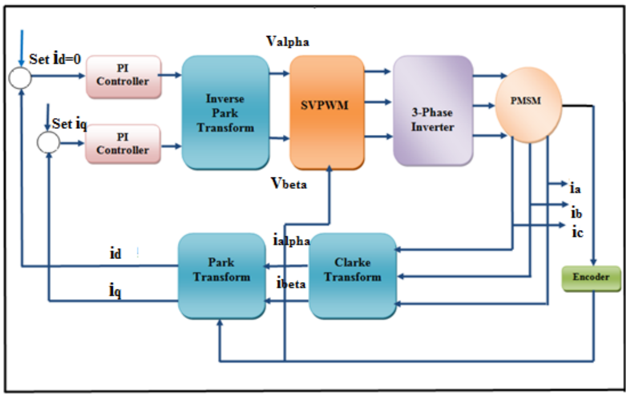

Fig.1 Field oriented control of PMSM using SVPWM

The 3-phase stator currents as well as the position are sensed from the PMSM. Since the 3-phase stator currents satisfy the relation ia+ib=ic=0 ,we need to calculate only ia and ib using clark transform. Then using park transform they are converted to id and iq values. For steady state conditions id and iq are constant. The id reference controls rotor magnetizing flux. The iq reference controls the torque output of motor.

The reference values of id and iq are given. By comparing with the actual values the error is corrected and then processed using a PI controller. The output of PI controller are the control signals Vd and Vq which is a voltage vector sent to motor. Park inverse transform can be used to calculate Valpha and Vbeta. From these values Vref vector can be calculated.

A Space Vector Pulse Width Modulation

In general the SVPWM implementation involves the sector identification, switching time calculation, switching vector determination and optimum switching pattern selection for the inverter voltage vectors. In SVPWM technique complex reference voltage is processed as a whole and avoids using separate modulator for each phase.

The interaction between three motor phases has to be considered. SVPWM generates less harmonic distortion in the output voltages and currents when compared to other PWM techniques. It actually provides a more efficient uses of the applied supply DC voltage in comparison with sinusoidal modulation techniques.

SVPWM aims to generate a voltage vector that is close to the reference circle through the various switching modes of inverter. There are total eight voltage vectors V0 to V7.Six vectors are non zero vectors are two are zero vectors. Zero vectors apply zero voltage to the load.

When an upper switch is switched ON, the corresponding lower switch connected to the same leg is switched OFF. Therefore the ON and OFF states of the upper switches S1, S3 and S5 can be used to determine the output voltage. There are eight possible switching states, i.e (0,0,0), (0,0,1), (0,1,0), (0,1,1), (1,0,0),(1,0,1), (1,1,0), (1,1,1) The inverter has six states when a voltage is applied to the motor and two states when the motor is shorted through the upper or lower switches resulting in zero volts applied to the motor.

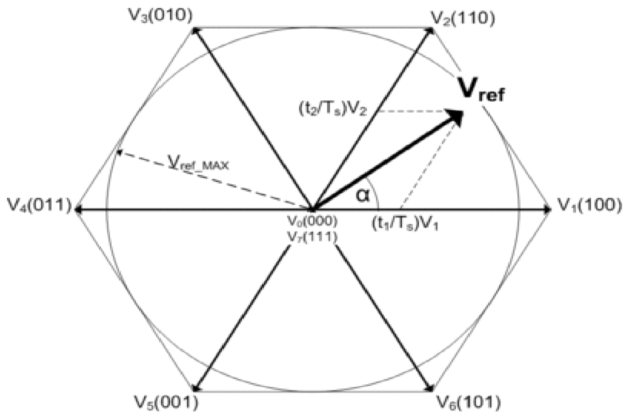

Fig 2 Space Vector Modulation

Table 1 : Switching Vectors for Inverters

Sl. No	S_1	S_3	S_5	V_{ab}	V_{bc}	V_{ca}	V_{an}	V_{bn}	V_{cn}	V_k
1	0	0	0	0	0	0	0	0	0	V_0
2	0	0	1	0	$-V_{dc}$	V_{dc}	$-V_{dc}/3$	$-V_{dc}/3$	$-2V_{dc}/3$	V_5
3	0	1	0	$-V_{dc}$	V_{dc}	0	$-V_{dc}/3$	$2V_{dc}/3$	$-V_{dc}/3$	V_3
4	0	1	1	$-V_{dc}$	0	V_{dc}	$-2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}/3$	V_4
5	1	0	0	V_{dc}	0	$-V_{dc}$	$2V_{dc}/3$	$-V_{dc}/3$	$-V_{dc}/3$	V_1
6	1	0	1	V_{dc}	$-V_{dc}$	0	$V_{dc}/3$	$-2V_{dc}/3$	$V_{dc}/3$	V_6
7	1	1	0	0	V_{dc}	$-V_{dc}$	$V_{dc}/3$	$V_{dc}/3$	$-2V_{dc}/3$	V_2
8	1	1	1	0	0	0	0	0	0	V_7

B Field Oriented Control

The main drawback of sinusoidal commutation is that the motor currents are controlled which are time variant and thus PI controllers have to operate on limited bandwidth. Hence using field oriented control the currents in a, b, c reference frame are transformed to d-q reference frame. Thus controllers are not subjected from time variant currents and voltages and limitation of controller frequency response and phase shift on motor speed and torque is eliminated. Using Field Oriented Control, current control is largely unaffected by speed of rotation of the motor[6].

In the scheme of filed oriented control motor currents and voltages obtained from the motor are transformed into d-q reference frame. Measured currents from three stator phases these currents which are now in the stator reference frame are converted into two phase using Clarke transformations which are further converted into the corresponding rotor reference frame using Park transformation. The resultant current obtained is dc which is easier for the PI controllers to operate. The obtained outputs from the PI controllers are transformed to inverse Park Transform to obtain the corresponding reference vector for the Space Vector PWM.

.

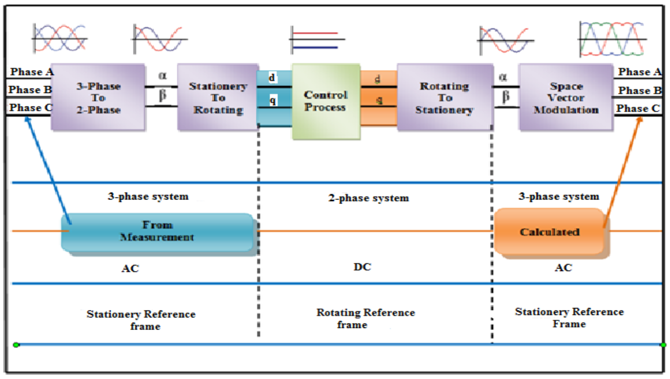

Fig.3 Field Oriented Control Scheme

The advantages of Field Oriented Control are transformation of a complex and coupled AC model into a simple linear system , independent control of torque and flux, fast dynamic response , good transient and steady state performance ,high torque and low current at start up and high Efficiency[2].

Clarke Transformation Equation

$$\begin{bmatrix} i_\alpha \\ i_\beta \\ i_0 \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \\ \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} \tag{1}$$

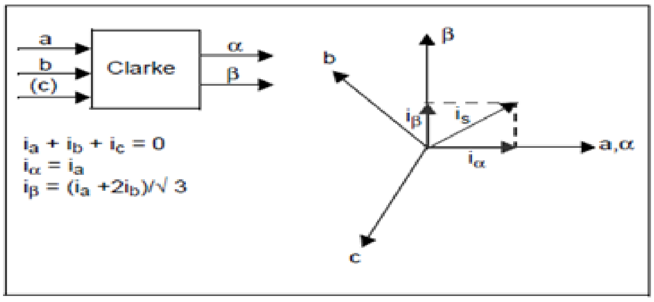

Fig.4 Clarke Transform

Park Transformation Equation

$$\begin{bmatrix} i_d \\ i_q \end{bmatrix} = \begin{bmatrix} \cos\theta & \sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} \tag{2}$$

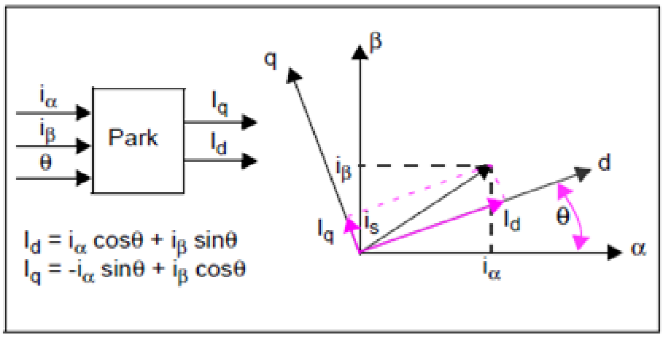

Fig.5 Park Transformation

Inverse Park transformation equation

$$\begin{bmatrix} i_\alpha \\ i_\beta \end{bmatrix} = \begin{bmatrix} \cos\theta & -\sin\theta \\ -\sin\theta & \cos\theta \end{bmatrix} \begin{bmatrix} i_d \\ i_q \end{bmatrix} \tag{3}$$

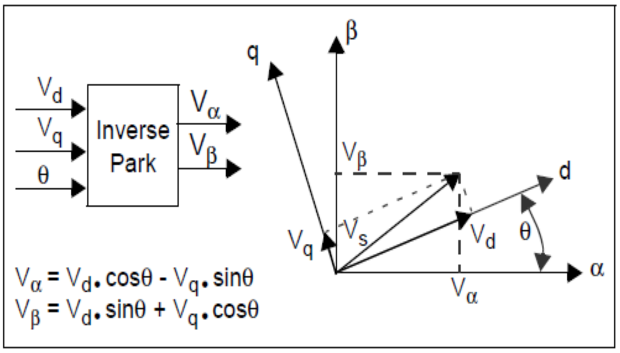

Fig.6 Inverse Park Transformation

The Clarke transformation transforms the three phase (a, b, c) signals into α, β reference frame in the stator. In order to transform the signals to the rotor reference frame Park transformation is used so as to transform the signals into rotor reference frame (d-q). Inverse park transform converts the signals back to stator reference frame (d-q to α, β).

III. Simulation Results

Simulation of Field oriented control of PMSM is done using Space Vector Modulation and the torque ripples generated are compared with that of BLDC.

Torque ripple is calculated using the formula, Torque ripple(%) = (Peak to peak torque/rated torque)*100.

The simulation results for Field oriented control of PMSM using SVPWM is shown below .

A FOC Model in Simulink

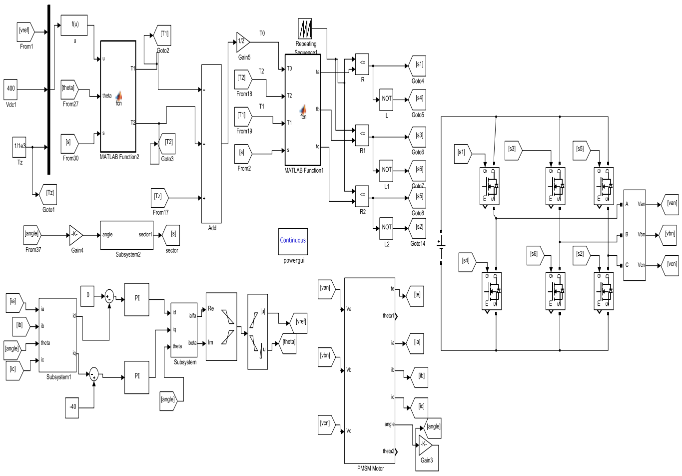

Fig.7 Simulink FOC Model

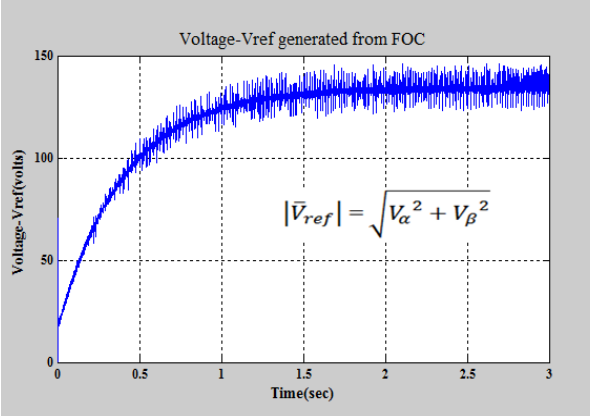

Fig.8 Vref waveform

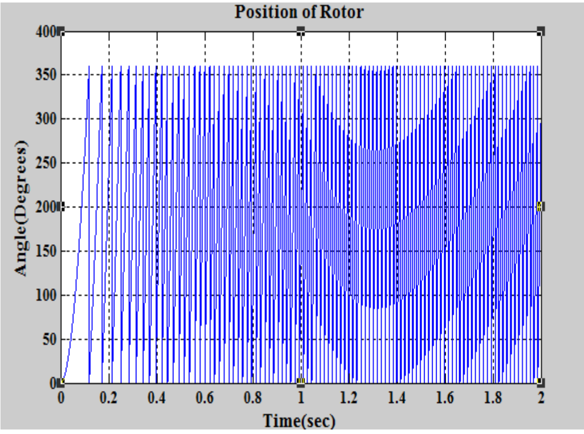

Fig.9 Waveform of Angle

B SVPWM Modeling

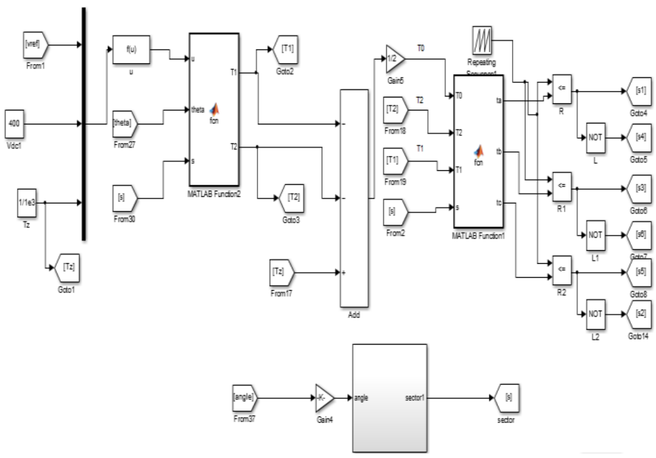

Fig.10 SVPWM Simulink Model

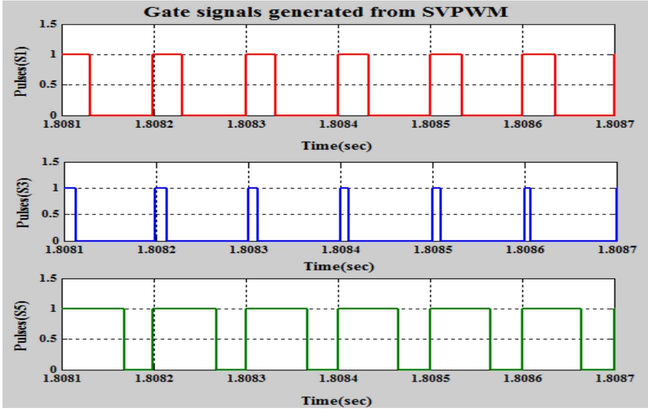

Fig.11 Gate pulses obtained from SVPWM

C Modeling of Inverter fed PMSM

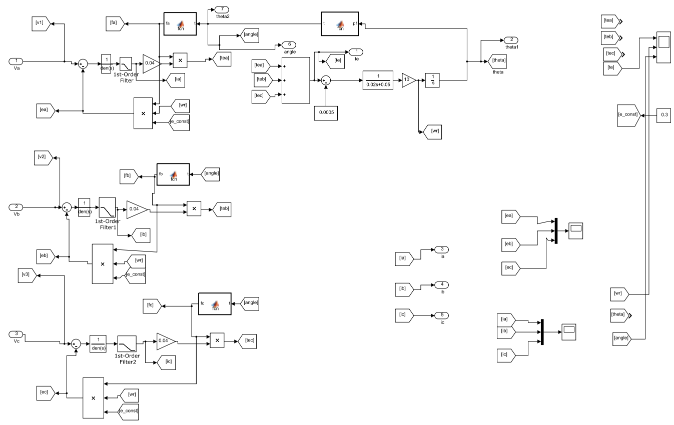

Fig.12 PMSM Simulink Model

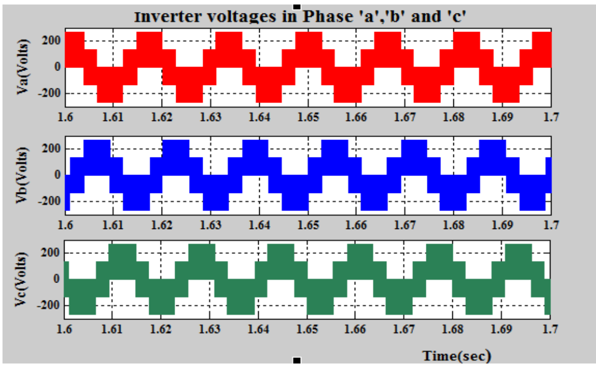

Fig.13 Inverter voltage

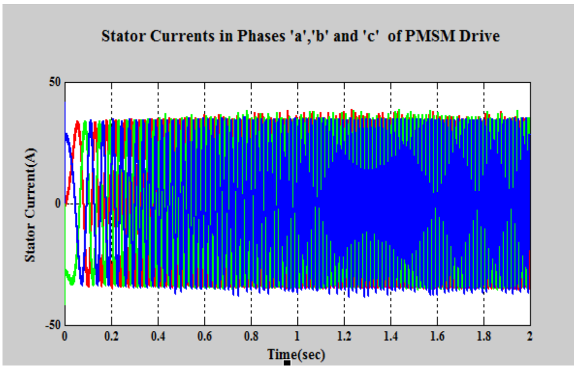

Fig.14 PMSM Stator current

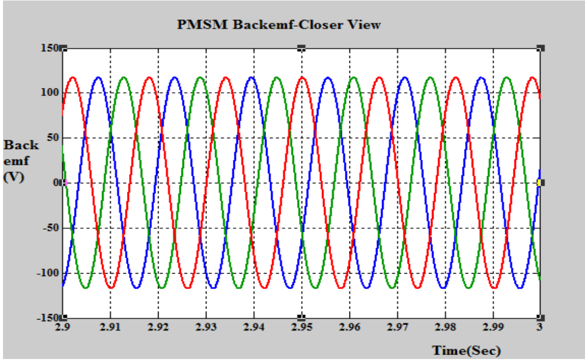

Fig.15 PMSM Backemf

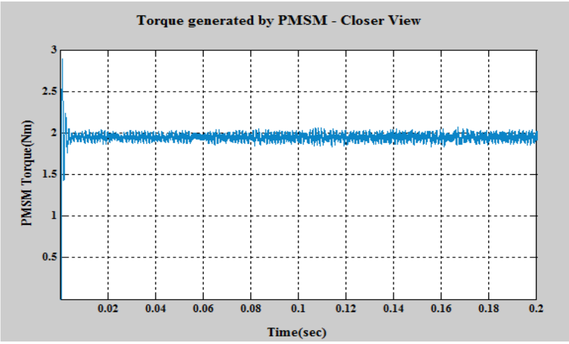

Fig.16 Torque obtained from PMSM

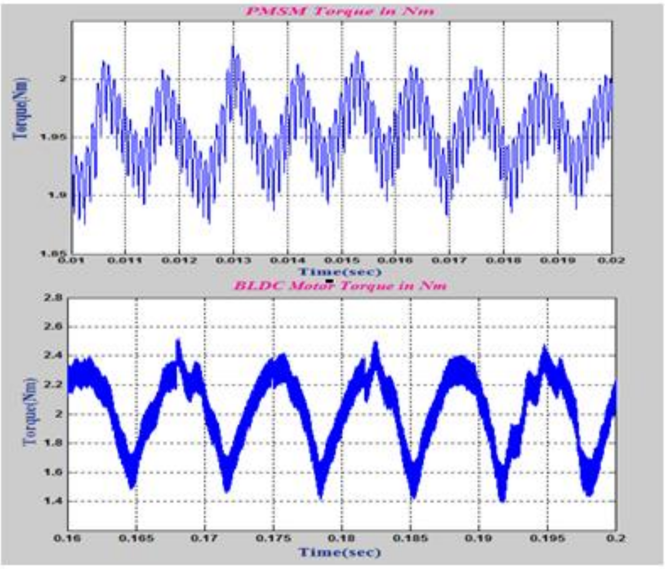

Fig.17 Torque ripple comparison

The comparative results of the Field oriented control of BLDC and PMSM are shown in Table 2

Table.2 Comparative results of Torque Ripples

Field Oriented Control	Developed Torque	Torque Ripple Factor(%)
FOC with BLDC Drive	2.2-2.6 Nm	50
FOC with PMSM Drive	2 Nm	5

CONCLUSION

In the current setup used in CMG, BLDC motor with trapezoidal method is used. The model is simulated in Matlab which shows torque ripples from 17 to 20%.Inorder to rectify this the current system is modified with PMSM. Field oriented control of PMSM using Space Vector Modulations has been modeled and simulated in Matlab and the results obtained are compared with that of BLDC motor.The simulated results have shown that when compared to BLDC, the torque ripples are reduced to 5% in PMSM.

IV. APPENDIX

Motor Parameters
Specification Details are given below
Angular Momentum => 68 Nms at 6000 rpm
Speed => 4400 rpm
Motor Type => PMSM
Rated Torque => 2Nm
Torque constant => 0.04 Nm

REFERENCES

[1] G.Jaya Baskaran,Prof.b.Adhavan,Dr.V.Jagannathan "Torque ripple Reduction in Permanent Magnet Synchronous Motor driven by Field Oriented Control using Iterative Learning Control with Space Vector Pulse width modulation" 2013 International conference on Computer Communication and Informatics (ICCCI-2013) Jan-04-06,2013,Coimbature,India

[2] Adhavan.B, Kuppuswamy.A, Jayabaskaran.G,Jagannathan. V (2011) "Field oriented control of Permanent Magnet Synchronous Motor (PMSM) using fuzzy logic controller"', Recent Advances in Intelligent Computational Systems (RAICS), IEEE, pp.587-592.

[3] Ahn H.S, Chen Y.Q (2007), Moore K.L, "Iterative Learning Control: Brief Survey and Categorization".IEEE Transactions on Systems, Man and Cybernetics -part c:application and reviews, vo1.37, no.6, pp. I 099-1121.

[4] Bimal. K. Bose (2002), "Modem Power Electronics and AC- Drives", PHI Learning Private Limited.

[5] Favre E, Cardoletti L, Jufer M (1993),"Permanent Magnet Comprehensive Approach to Cogging Torque Suppression ", IEEE Transactions on Industry Applications, pp.1l41-1149.

[6] Gulez K, Adam A.A, Pastaci H (2008)," Torque Ripple& EMI Noise Minimization in PMSM Using Active Filter Topology & Field-Oriented Control". IEEE Transactions on Industrial Electronics, vo1.55, no.l,pp.251-257.

[7] Jahns T.M, Soong W.L (1996)," Pulsating Torque Minimisation Techniques for Permanent Magnet AC Motor Drives - a review". IEEE Transactions on Industrial Electronics, vol.43, no.2, pp.321-330.

[8] Qian.W,Panda S.K, Xu J.X, "Speed Ripple Minimization in Permanent Magnet Synchronous Motor Using Iterative Learning Control'". IEEE Transactions on Energy Conversion, vol.20, no.I, pp.53-61.

[9] R.S.Kanchan, M.R. Baiju ,K.K. Mohapatra, "Space Vector PWM signal Generation for multilevel inverters using only the sample amplitudes of the reference phase voltages" IEE Power Appl., Vol. 152, No. 2, March 2005.

[10] Panda.S.K,X,Jian-Xin,Q.Weizhe,"Review of Torque Ripple Minimization in Permanent Magnet Synchronous Motor Drives" ,IEEE Transaction on Electrical Engineering,July2008, pp.1-6