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Implementation of Field Orient Control for CMG Applications

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ABSTRACT: Space missions require agility that improves its efficiency and performance, agility requires fast slew rate of 1°/sec -10 °/sec, but this degrees of agility cannot be achieved by using Reaction wheels but can be achieved by Control Moment Gyros(CMG). This project work implements the usage of PMSM and Field Oriented Control to improve the performance of present reaction wheels used in Indian Remote Sensing (IRS) space crafts and upgrading Control devices from Reaction wheel to Control Moment Gyro. This project work also presents the optimized digital implementation of Field Oriented Control in ACTEL FPGA platform. Various sub modules required for FOC is also implemented in an optimized manner. Space Vector Pulse Width modulation (SVPWM),Modelling of switching interval, encoder interface is introduced. FPGA implementation and results of SVPWM are reported to realize the validity of Field Orient Control (FOC).

KEYWORDS: Control Moment Gyro, PMSM, Field Orient Control(FOC), SVPWM,BLDC

I.INTRODUCTION

Space missions require highly efficient spacecraft to perform various functions like high precision earth observation and space monitoring, commercial imaging etc. These missions require agility that improves efficiency and the agility requires fast slew rate of 1°/sec -10 °/sec, but this degrees of agility cannot be achieved by using Reaction wheels and Momentum wheels. However Control Moment Gyros(CMG) are actuators that support such slew rates. Four wheels are mounted in tetrahedral configuration in the Spacecraft.Though Reaction Wheels and Control Moment Gyro's are actuators which produce torque, the means by which they do is different. In reaction Wheels, motor is attached to a flywheel which is free to spin along the fixed spacecraft axis. Like Reaction Wheels Control Moment Gyro has a spinning flywheel controlled by brushless motor. Unlike Reaction Wheels the spin axis of a CMG can rotate with the help of a second motor placed on the Gimbal axis. By spinning Reaction wheel or CMG it is possible to tune the attitude precisely, so they are used on spacecraft's with cameras and other instruments that should be accurately pointed.

In trapezoidal Back-EMF motors, windings are trapezoidal distributed and this leads to torque ripple during motor operation. This torque ripple produces a small speed oscillation, which generates audible noise. While Permanent Magnet Synchronous Motors (PMSM) produce sinusoidal currents, which reduce the torque ripple, thus minimizing the audible noise. All the sub modules for FOC has been implemented and tested in ACTEL FPGA platform (Actel fusion FPGA-AFS600). MATLAB program was developed for validation and verification of the project. Simulation using Libero IDE for FPGA implementation was done. FOC was modelled for PMSM. Encoder Interface was developed for real-time simulation. This project presents the implementation of field orient control for gimbal control of Control Moment Gyro.

II.FIELD ORIENT CONTROL

In order to achieve better dynamic performance, a complex control scheme needs to be applied to control the PM motor. Advanced control strategies can be implemented, which uses mathematical transformations in order to decouple the torque generation and the magnetization functions in the PM motors. Such decoupled torque and magnetization control is commonly called rotor flux oriented control, or simply FOC. In order to understand the spirit of the FOC technique, start with an overview of the separately excited direct current (DC) motor. In this type of motor, the excitation for the stator and rotor is independently controlled. The goal of the FOC (also called vector control) on the synchronous and asynchronous machine is to separately control the torque producing and magnetizing the flux components. The FOC allows you to decouple the torque and the magnetizing flux components of stator current. With decoupled control of the magnetization, the torque producing component of the stator flux can now be thought of as independent torque control. To decouple the torque and flux, it is necessary to engage several mathematical transforms.

One way to understand how FOC works is to form a mental image of the coordinate reference transformation process. If you picture an AC motor operation from the perspective of the stator, you see a sinusoidal input current applied to the stator. This time variant signal generates a rotating magnetic flux. The speed of the rotor is a function of the rotating flux vector. From a stationary perspective, the stator currents and the rotating flux vector look like AC quantities.

Now, imagine being inside the motor and running alongside the spinning rotor at the same speed as the rotating flux vector generated by the stator currents. If you were to look at the motor from this perspective during steady state conditions, the stator currents look like constant values, and the rotating flux vector is stationary. Ultimately, you want to control the stator currents to obtain the desired rotor currents (which cannot be measured directly). With coordinate reference transformation, the stator currents can be controlled like DC values using standard control loops. The torque is maximum if the stator and rotor magnetic fields are orthogonal, meaning if you are to maintain the load at 90°. If you are able to ensure this condition all the time, if you are able to orient the flux correctly, you reduce the torque ripple and ensure a better dynamic response. However, the constraint is to know the rotor position: this can be achieved with a position sensor such as incremental encoder. In brief, the goal is to maintain the rotor and stator flux in quadrature; the goal is to align the stator flux with the q axis of the rotor flux, for instance, the orthogonal to the rotor flux. To do this, the stator current component in quadrature with the rotor flux is controlled to generate the commanded torque, and the direct component is set to zero.

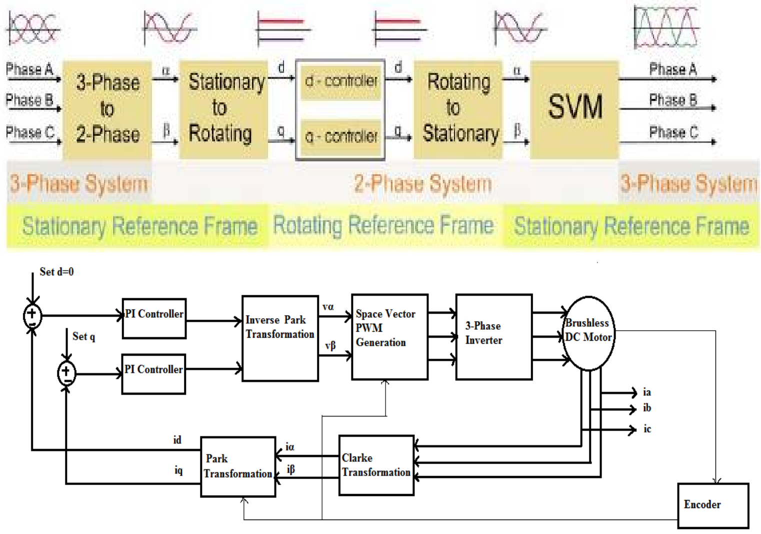

Fig:1. Field Orient Control Transformation and Scheme

The process of field oriented control involves transformation from 3-phase (a, b, c) to two phase (α, β) transformation. Since this transformation is within the stator reference frame and PI controllers can work with ease on conversion from stator to rotor reference frame. Following transformations are performed.

- Clarke's Transformation
- Park's Transformation
- Inverse Park's Transformation
- Inverse Clarke's Transformation

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- Space Vector Pulse Width Modulation

III.TEST RESULT AND ANALYSIS

In MATLAB the validity of the mathematical equation available with literature is carried out by verifying the correct sector switching sequence from sector to sector.

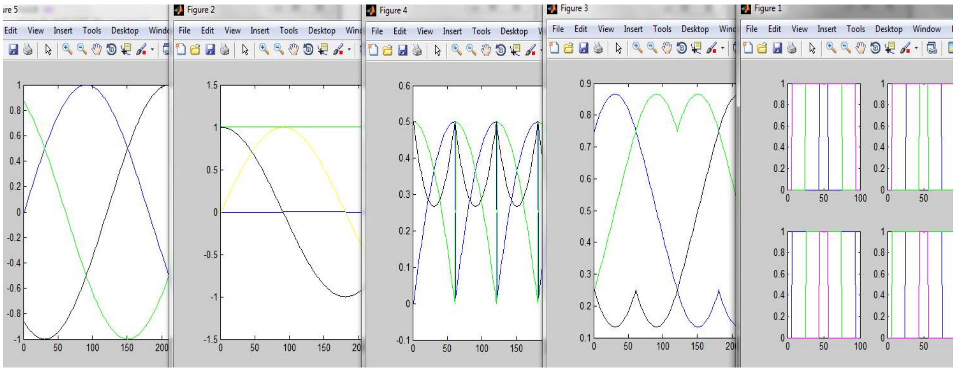

Fig.2 Wave form generated using MATLAB in sequence

Fig.2 shows the sequence through which the FOC algorithm passes.at first measured current from three phases(i_a,i_b,i_c) is converted in to two phase current in stationary frame of the stator. Then it converted in to two DC current (i_d,i_q) in the rotating frame of the rotor. Then PI is applied and covert back to the Two phase voltage waveform of the stator. Then it will be passing to the SVPWM generator and sector PWM wave forms are generated.The sector switching waveform is verified for various input amplitude.

After verification with Matlab, all sub modules required for FOC are implemented ACTEL fusion FPGA AFS600.The sub modules required are

- Main module
- CORDIC algorithm.
- Clarke transformation.
- Park transformation.
- Inverse park transformation.
- Sector calculation.
- PWM value generation.
- SVPWM generation.

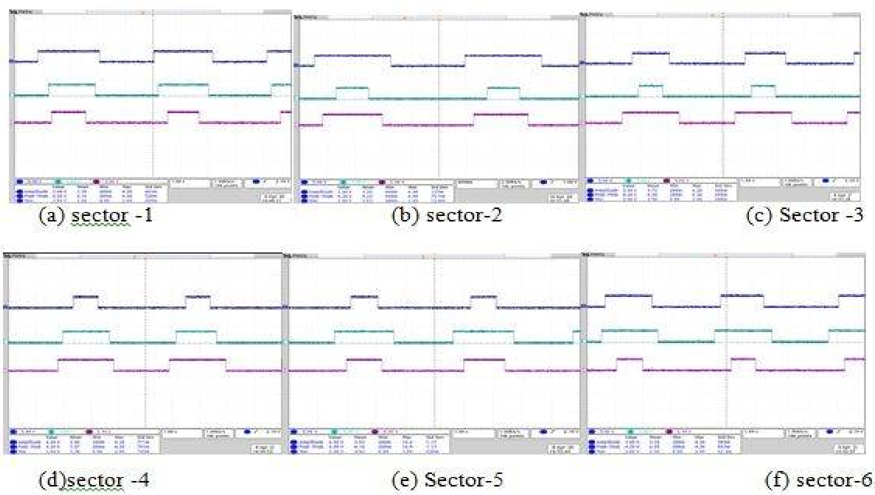

Fig:3Output of MAIN MODULE,Instantaneous sector switching waveform captured by DSO in the order of switching

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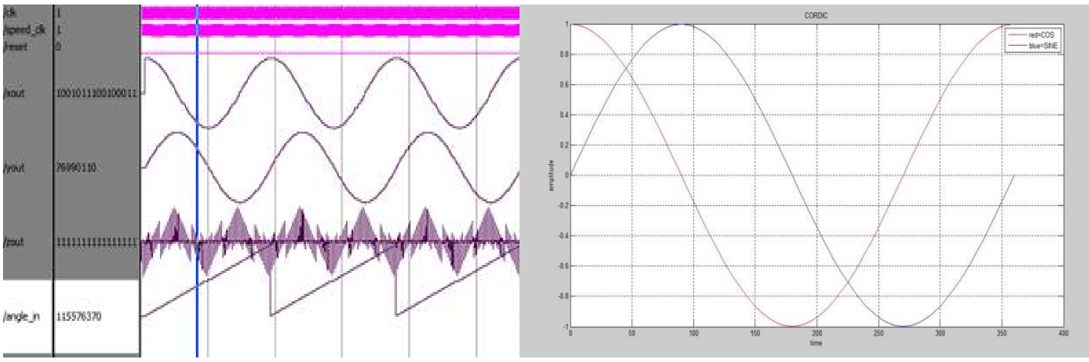
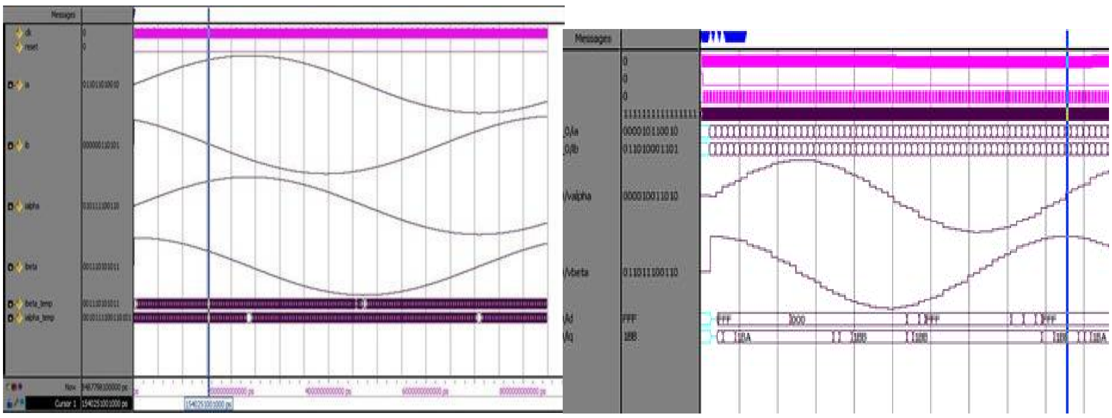


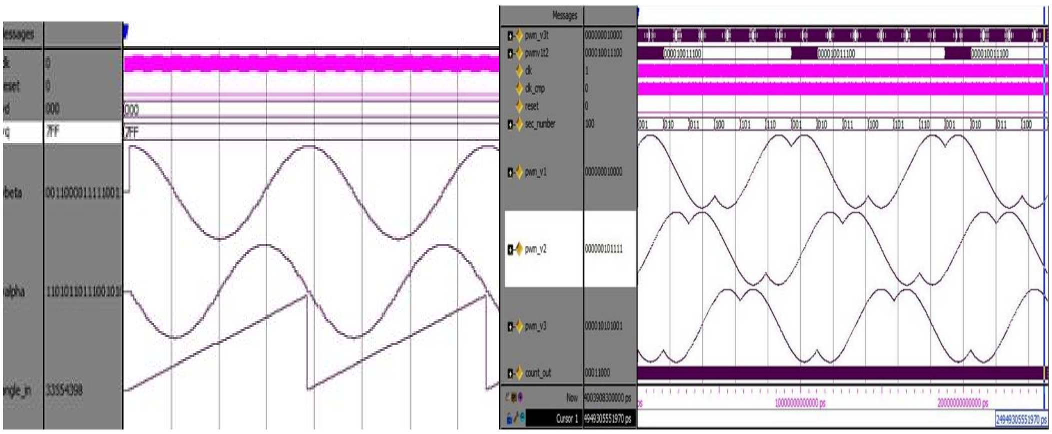
a) b)

Fig:4. CORDIC OUTPUT, Sin and cosine waveform generated in CORDIC algorithm from a) FPGA b) MATLAB



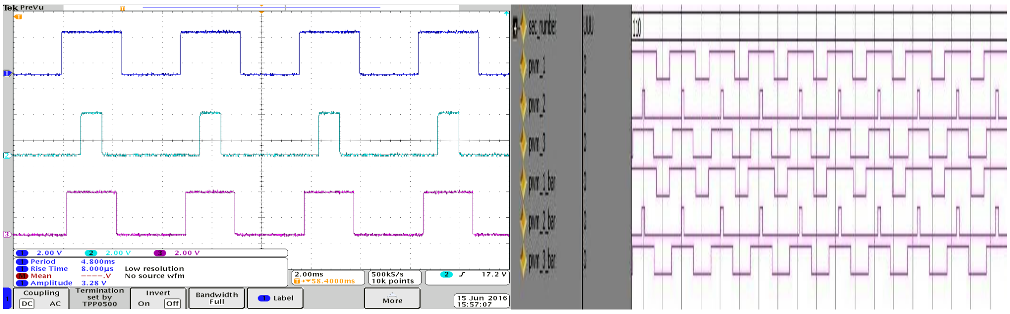
a) b)

Fig.5. Post synthesis output of a) Clarke Transformation b) Park Transformation



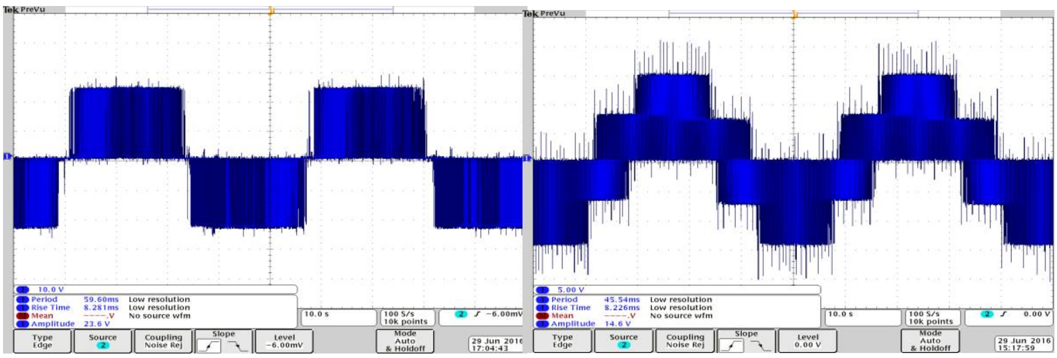
a) B)

Fig: 6. Output waveform of a) inverse park transformation b) PWM value



a) b)

Fig:7. Sector waveform of sector-2 a) captured by DSO b) in LIBERO



a) b)

Fig: 8 Hardware output a) line voltage b) Phase voltage

IV.CONCLUSION

In this project, we have developed a Field Oriented Control system for PMSM motors. This scheme aids in reaction wheels and Gimbal control of Control Moment Gyroscope (CMG) .The simulation results shows that the usage of PMSM and Field oriented control could improve the performance reaction wheels used in Indian Remote Sensing space crafts.The FPGA results shows that the usage of PMSM and Field oriented control could improve the performance of present reaction wheels used in Indian Remote Sensing space crafts and can be implemented in Control Moment Gyros.

FPGA implementation and experimental results of SVPWM are reported to realize the validity of SVPWM technique.Developed VHDL code CORDIC algorithm, forward backward Park & Clarke transformation. Developed code tested using ACTEL Fusion FPGA kit (AFS600). And using FPGA kit we obtained the expected results when connected across load. The work emphasizes digital implementation of various sub modules required for FOC in an optimized manner.This project investigates the possible usage of PMSM and Field oriented control for reaction wheels and control moment gyros.

REFERENCES

[1] T. Sebastin, G. slemon,M. Rahman "Modeling of Permanent Magnet Synchronous motor", Magnetics,*IEEE Transaction,1986*

[2] T.M Jahns,G.BKliman and T.W Neuman "Interior Permanent Magnet Synchronous motors For Adjustable Speed Drives", Industrial Application,*IEEE Transaction,1986*

[3] P.Pillay, R.Krishnan"Modeling of Permanent Magnet Synchronous motor drives," Industrial Electronics,*IEEE Transaction,1988*

[4] P.Pillay, R.Krishnan "Modeling, simulation and analysis of Permanent Magnet Synchronous motor drive"s, Industrial Application,*IEEE Transaction,1989*

[5] B.Chui,J.Zhou,Z.Ren ""Modeling and simulation of Permanent Magnet Synchronous motor drives, 2001

[6] X.T Gracia, B.Zigmund"Comparison of FOC and DTC Control strategy of a PMSM motor"

[7] MarekStulrajter,Val´eriaHrabovcov´a, MarekFranko "Permanent magnet synchronous motor control theory", 2007

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

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(An ISO 3297: 2007 Certified Organization)

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[8] PragasenPillay, and Ramu Krishnan "Application Characteristics of Permanent Magnet Synchronous and Brushless dc Motors for Servo Drives",1991

[9] M.S Merzoug and F.Naceri "Comparison of FOC and DTC for permanent magnet synchronous motor(PMSM)" , 2008

[10] Hamid Chaikhy MohamedKhafallahAbdallahSaad "Evaluation of Two Control Strategies for Induction Machine", 2011

[11] SelinOzcira and NurBekiroglu "Direct Torque Control of Permanent Magnet Synchronous Motors"

[12] Bilal Akin and Manish Bhardwajin" Sensorless field orient control of 3 phase permanent synchronous motors"

[13] "Comparative Review Of PMSM And BLDCM Based On Direct Torque Control Method",Abdul-Aziz Bello, Ibrahim Muhammad Kilishi, Muntaka Musa Bari, UsmanAbubakar, International Journal Of Scientific & Technology Research Volume 3, Issue 3, March 2014 ISSN 2277-8616