DSP based Controller with Switching Loss Reduction Technique for Brushless DC Motor Drive System

K. Premalatha, D. Rajalakshmi, R. Kavitha

ABSTRACT---PMBLDC motor finds its application in various fields which includes hybrid electric vehicles, robotic applications with high precision control, fans and industries. This paper presents DSP based control with switching loss reduction technique for Permanent Magnet Brushless DC motor. Firing pulses for power switches are generated using DSP TMS320C2407 based on hall sensor feed-back. The algorithm is written in C using code composer studio to generate single mode PWM pulses and multiple PWM pulses. To reduce the switching losses three switches are turn on and turn off with single pulse and the remaining three switches are with multiple PWM pulses. The hardware is implemented and the trapezoidal stator voltage and corresponding gating signals are measured for various speed. The experimental results validate the performance of proposed system.

Keywords— PMBLDC, DSP controller, Trapezoidal PWM

I. INTRODUCTION

Permanent Magnet Brushless DC Motor (PMBLDC) is used in wide range of speed and torque control applications[1]. Permanent magnet motors like Permanent Magnet synchronous motor and PMBLDC motors are becoming more prominent now a days in electric vehicle as it has higher power density, efficiency and linear torque-speed characteristics[2]. Technological advancements in power electronic converters leads to efficient and precise control of PMBLDC motor. PMBLDC motor utilize permanent magnets for its excitation and rotor position Hall sensors are needed to perform electrical commutation[3]. DSP controller TMS320C240 have inbuilt microcontroller with peripherals essential for motor control applications[4]. The brushless dc motor with inverter operating in 120° mode is analyzed in this paper. The advantage of 120° mode of operation is larger tolerance which prevents inverter malfunction which occurs due to shoot through fault[5]. Novel inverter topology is proposed for brushless dc motor drive system with a high performance and reduced cost[6-7]. High performance digital controller for brushless dc motor using dedicated controller MC33035 and MC33039 and a prototype model is constructed and tested [8-9]. In this paper, PMBLDC motor drive system is implemented using DSP controller and its performance is analyzed. Three

semiconductor switching devices are controlled by multiple PWM and the remaining three switches are controlled with single pulse so as to reduce the switching losses.

II. PMBLDC DRIVE SYSTEM CONFIGURATION

The proposed system consists of PMBLDC motor, three phase inverter and DSP controller TMS320C240 as illustrated in fig. 1. The PMBLDC motor is equipped with three Hall effect sensors that are placed 120 degrees apart. The Hall sensor senses the rotor position to indicate which of the three phases of the motor is to be excited. The DSP control algorithm is written and the output of the controller is a sequence of gating signals pulse width modulated to drive the inverter.

Fig.1 PMBLDC motor drive system configuration

III. HARDWARE IMPLEMENTATION

The PMBLDC drive system consists of power circuit, control hardware and software. The Power circuit comprises of MOSFET IRFP450 based inverter and its associated opto-coupler, driver circuit. The control circuit consists of the power supplies, isolators and the rotor speed and position sensing circuits. Programming is performed in DSP TMS320C2407 to generate firing pulses to the inverter.

The hall effect sensor feedback from the PMBLDC motor is fed as input to the port A of the DSP processor. The TMS320C2407 processor generates the pulses required

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K.Premalatha, Associate Professor, Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India (Email: premalatha.k.eee@kct.ac.in)

D.Rajalakshmi, Associate Professor, Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India (Email: rajalakshmi.d.eee@kct.ac.in)

R.Kavitha, Associate Professor, Department of Electrical and Electronics Engineering, Kumaraguru College of Technology, Coimbatore, Tamilnadu, India (Email: kavitha.r.eee@kct.ac.in)

Fig. 2 PMBLDC Drive System using DSP MS320C2407

to drive the MOSFET. Isolation from the power circuit is provided using opto-coupler TLP250 and pulses are amplified using driver IC IR2110 and inverter output is fed to stator. Three phase bridge inverter fabricated using n-channel MOSFET is operated in 120 degree mode to provide square wave current excitation to the stator windings and is shown in fig.2. The MOSFET used is IRFP450 with ratings of 500V, 14A. A RCD snubber circuit is used for overvoltage protection. Overcurrent protection is provided by giving 5v to the shut down pin of IR2110. The output pulses from the DSP are coupled using a non-inverting hex buffer CD4050 to boost up the current. The switching states for for clockwise rotation in 120 degree mode is given in table. 1.

Table 1 Switching states for clockwise rotation in 120 degree mode

STATE	HALL SENSORS			SWITCHING DEVICE					
	H3	H2	H1	6	5	4	3	2	1
1	1	0	0	1	0	0	0	0	1
2	1	0	1	1	1	0	0	0	0
3	0	0	1	0	1	1	0	0	0
4	0	1	1	0	0	1	1	0	0
5	0	1	0	0	0	0	1	1	0
6	1	1	0	0	0	0	0	1	1

Specification of PMBLDC motor drive system

Power - ½ hp
 Stator voltage - 140V (line to line)
 Speed - 1500 rpm
 Poles - 4 made of NdFeB
 Hall position sensors - 3 nos placed 120 degrees apart

Fig. 3. Algorithm for generating pulses

The software profile developed for single pulse on mode and multiple pulse PWM mode and the algorithm is shown in fig.3. In PWM mode, action control register is configured in active high mode and the total period is loaded in period register and on time is loaded in compare register. The speed variation is obtained by varying the pulse width.

IV. RESULTS

A VSI inverter has been implemented in hardware and the Stator Voltage – Line to Line and PWM gating pulses are measured. The upper positive group switches are 1, 3, 5 controlled using PWM pulses and the lower negative group

Fig. 4 Single pulse : (a) 1,3 (b) 1,5

Fig. 5 PWM pulse : (a) 1,2 (b) 1,6

Fig.6. Stator Voltage – Line to Line voltage for speed 900 rpm

Fig. 7 Stator Voltage – Line to Line voltage for speed 540 rpm

switches 4,6,2 are controlled by single pulse mode. The waveforms of Fig.4 (a)-(b) corresponds to the single pulse mode. The waveforms of Fig.5 (a)-(b) corresponds to the PWM mode.

V. CONCLUSION

The proposed DSP based control offers reduction in switching losses and has been implemented in hardware. The algorithms are developed in DSP for single pulse mode and multiple pulse PWM mode and have been tested with MOSFET based inverter circuit. The stator voltage and PWM pulses are measured for various speed and the performance of the PMBLDC motor drive is analyzed. The combination of single pulse mode and multiple PWM mode has resulted in reduction switching losses. In future.Sensor-less techniques can be implemented as the hall position sensors are expensive and fragile components in the drive system.

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