DSP based Control of BRUSHLESS DC Motor Drive

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Abstract- **This paper refers to the design of a motor control system required for a brushless DC motor control application. The paper work includes the design and development of the necessary hardware supported by appropriate embedded software. The BLDC motor has certain advantages over other motors such as maximum torque to weight ratio, high speed etc, but it requires an electronic commutator such as a convertor with MOSFETs/IGBTs. The MOSFETs/IGBTs need to be turned ON and OFF, in a particular sequence. This switching is controlled by a microprocessor or DSC (Digital signal controller). The dsPIC is used to control the speed of a BLDC motor drive.**

The main objective is to achieve speed control of brushless dc motor drive for industrial applications. The flexibility of the drive is increased by using the digital controller. The three phase inverter for feeding BLDC motor has been designed using MOSFET. The control algorithms are implemented using dsPIC control board, which enables single chip, cost effective, modular and increased performance solutions for BLDC drives.

The C program with MPLAB IDE software is used to program the dsPIC which generates the PWM signals. The PWM signals of all the switches are observed using CRO and the control logic is verified.

IndexTerms—BLDC motor,dsPIC,MPLABIDE

I. INTRODUCTION

Brushless Direct Current (BLDC) motors are one of the types rapidly gaining popularity, being widely used in a variety of applications in industrial automation and consumer appliances because of their higher efficiency. BLDC motors have the advantage of higher power density than other motors such as induction motors because of having no copper losses on the rotor side and they do not need mechanical commutation mechanisms as compared with DC motors, which results in compact and robust structures. Owing to these features, BLDC motors have become more popular in the applications where efficiency is a critical issue, or where spikes caused by mechanical commutation are not allowed.Generally speaking, a BLDC motor is considered to be a high performance motor that is capable of providing large amounts of torque over a vast speed range. BLDC motors are a derivative of the most commonly used DC motor, the brushed DC motor, and they share the same torque and speed performance curve characteristics. The major difference between the two is the use of brushes. BLDC motors do not have brushes (hence the name "brushless DC") and must be electronically commutated.

This paper presents the design and implementation of a DSP-based Brushless DC (BLDC) motor controller that is comparable to other more cost effective motors. This objective is met by simple design and careful component selection. To provide further cost effectiveness and ease of design a high performance 16-bitdsPIC controller is used. Sensorless control using the back EMF zero crossing technique is utilized, eliminating the need for Hall sensors thus further reducing cost and increasing reliability. The speed is varied using the pulse width modulation (PWM) technique. To verify the proposed method a prototype motor drive is constructed and tested.

II. BRUSHLESS DC MOTOR

Brushless DC motors, rather surprisingly, is a kind of permanent magnet synchronous motor. Permanent magnet synchronous motors are classified on the basis of the wave shape of their induce emf, i.e, sinusoidal and trapezoidal. The sinusoidal type is known as permanent magnet synchronous motor; the trapezoidal type goes under the name of PM Brushless DC (BLDC) machine. Permanent magnet (PM) DC brushed and brushless motors incorporate a combination of PM and electromagnetic fields to produce torque (or force) resulting in motion. This is done in the DC motor by a stator and a wound armature or rotor. Current in the DC motor is automatically switched to different windings by means of a commutator and brushes to create continuous motion.

In a **brushless motor**, the rotor incorporates the magnets, and the stator contains the windings. As the name suggests brushes are absent and hence in this case, commutation is implemented electronically with a drive amplifier that uses semiconductor switches to change current in the windings based on rotor position feedback. Commutation is the act of changing the motor phase currents at the appropriate times to produce rotational torque. In a brushed DC motor, the motor assembly contains a physical commutator which is moved by means of actual brushes in order to move the rotor. With a BLDC motor, electrical current powers a permanent magnet that causes the motor to move, so no physical commutator is necessary.In this respect, the BLDC motor is equivalent to a reversed DC commutatormotor, in which the magnet rotates while the conductors remain stationary. Therefore, BLDC motors often incorporate either internal or external position sensors to sense the actual rotor.

III. TORQUE/SPEED CHARACTERISTICS OF A BLDC MOTOR

Figure 1 shows an example of torque/speed characteristics of a BLDC motor.There are two torque parameters used to define a BLDC motor, peak torque (TP) and rated torque (TR). During continuous operations, the motor can be loaded up to the rated torque. In a BLDC motor, the torque remains constant for a speed range up to the rated speed. The motor can be run up to the maximum speed, which can be up to 150% of the rated speed, but the torque starts dropping.

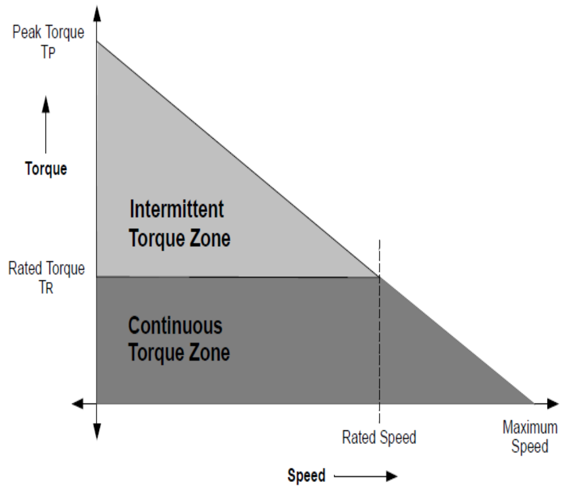

Fig.1: Torque /speed characteristics of a BLDC motor

Applications that have frequent starts and stops and frequent reversals of rotation with load on the motor, demand more torque than the rated torque. This requirement comes for a brief period, especially when the motor starts from a standstill and during acceleration. During this period, extra torque is required to overcome the inertia of the load and the rotor itself. The motor can deliver a higher torque, maximum up to peak torque, as long as it follows the speed torque curve.

IV. SENSORLESS CONTROL OF BLDC MOTOR

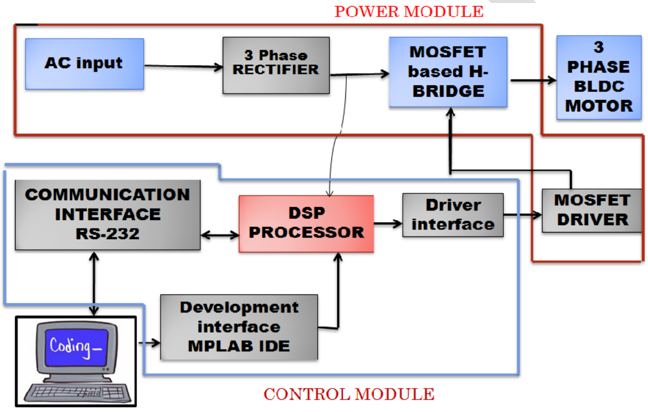

Fig.2: Block Diagram of sensorless Control

Figure 2 shows how the sensorless control of the BLDC motor can be obtained. The input AC supply is first converted into DC by rectification. The DC voltage is fed to the Inverter to energies the stator of the BLDC motor. The control signals are provided by the dsPIC according to the zero crossing detection of the back emf. The position information is available at the zero crossing of each phase. Based on the zero crossing detector circuit output the dsPIC decides the switch that has to be turned ON in the inverter.

The detection of the back e.m.f is done by using a separate back e.m.f detection circuit. At the first stage the back e.m.f is detected and it will be given to the zero crossing detection stage where the zero crossing of each and every phase is obtained and based on this the motor will be controlled to the required speed.

A. Power module

Figure 3 shows the power supply used in the present work. The single phase AC supply is given to the single phase rectifier circuit which converts incoming 230 volts AC to 315 volts DC, this 315 volts DC is reduced to 12V and 5V DC by a switching regulator 8 PIN IC (LNK306P)
Two voltage regulators (LT1117 IC) are used to get 3.3V from 12V DC supply in order to operate dsPIC controller chip.

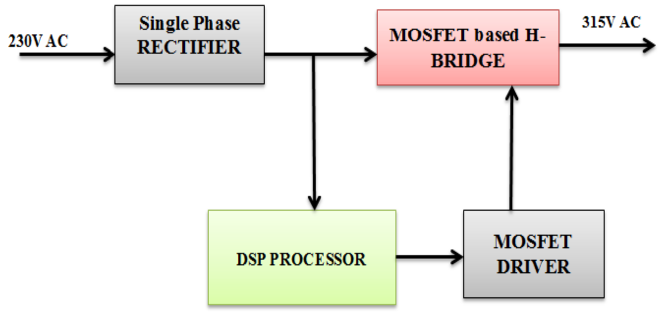

Fig.3: power module block diagram

The PWM signals generated by the controller chip is given to the Hex inverter buffer which functions as a NOT-gate with an operating voltage of 0 t0 5VDC, then the PWM signals are given to the MOSFET based H-bridge through the HEX MOSFET DRIVER (IR2133 IC). The output of the inverter is fed to the three phase BLDC motor.

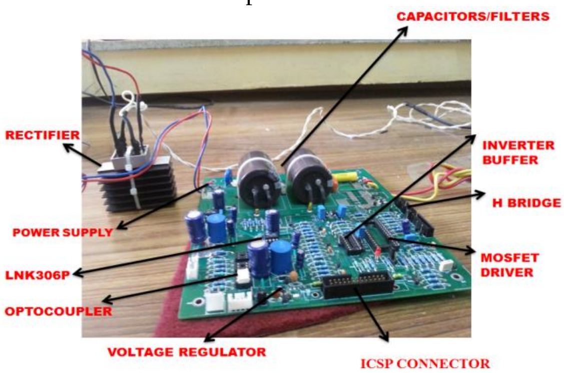

Fig.4: Picture of power module

B. Control Module

All control and driving functions shall be implemented at this level. In this work Microchip's dsPIC33Fj128MC706A digital signal controller is used. Microchip's dsPIC33FJ128MC706A digital signalcontrollers place unprecedented performance in the hands of 16-bit MCU designers. The dsPIC DSC has the "heart" of a 16-bit MCU with robust peripherals and fast interrupt handling capability and the "brain" of a DSP that manages highcomputation activities, creating the optimum single-chip solution for embedded control of three-phase BLDC motor.

In this work an optocoupleris used to isolate the gate drive circuit and the MOSFET-based power circuit. Six MOSFETs of the power circuit are controlled bythe Pulse Width Modulation (PWM) signals generated by the control circuit. These PWM signals are required to derive avarying AC voltage from the power circuit.

Fig. 5: Picture of Control Board

C. Motor driver

The 3-phase BLDC motor is connected to a 3-phase inverter bridge as shown in Figure 6.The power inverter has 6 switches that are controlled in order to generate 3-phase AC output from the DC bus. PWM signals, generated from the dsPIC33FJ128MC706A controller chip, control these 6 MOSFET switches. Switches Q1 through Q3, which are connected to DC+, are called upper switches, Q4 through Q6, connected to DC-, are called lower switches.

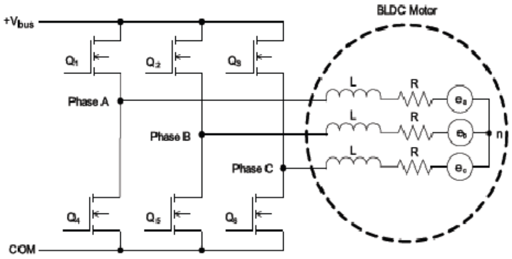

Fig.6: Three-phase full-bridge power circuit for BLDC motor drive

The amplitude of phase voltage is determined by the duty cycle of the PWM signals. While the motor is running, three out of six switches will be on at any given time, either one upper and two lower switches or one lower and two upper switches. The switching produces a rectangular shaped output waveform that is rich in harmonics. The inductive nature of the motor's stator windings filters this supplied current to produce a 3-phase sine wave with negligible harmonics. When switches are turned off, the inductive nature of the windings oppose any sudden change in direction of flow of the current until all of the energy stored in the windings is dissipated. To facilitate this, fast recovery diodes are provided across each switch. These diodes are known as freewheeling diodes.

The relationships between three-phase back-EMF, motor current, and airgap power of the BLDC motor are shown in Fig.7 The trapezoidal back-EMF (ea, b, and c) has a constant magnitude of Ep during 120 electrical degrees in both positive and negative half cycle. The air-gap power, Pa, and the electromagnetic torque are both continuous when applying motor current ia, b, and c during the same period in both half cycles.

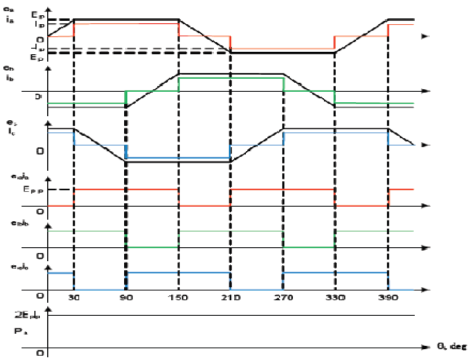

Fig.7: Relationship between back-EMF, motor current, & air-gap power for three-phase BLDC motor drive

V. RESULTS AND DISCUSSIONS

After checking the gate pulses across the power board, the pulses are fed to the inverter. The following experimental results obtained from a single phase supply.

DUTY RATIO IN %	VOLTAGE IN volts
20	160
30	170
40	175
50	180
60	195

Table 1- Tabulated Experimental results

Speed control in a BLDC involves changing the applied voltage across the motor phases. The duty cycle is set by the user in the dsPIC control board. As the duty ratio increases the voltage and the current drawn also increases. The inference made from the above tabular column is the BLDC motor can be controlled by controlling the duty ratio.

Fig.8: CRO output for 50% duty cyclewithincandecent bulb

VI. CONLUSION

In the present work, a dsPIC based speed control of Brushless DC motor was developed. C program is developed in MPLABIDE to generate the controlled PWM pulses to drive the system. The complete system was integrated and downloaded into the dsPIC controller chip. This system implemented on BLDC motor in open loop condition and controlling of speed is achieved successfully. The 64-pin dsPIC33FJ128MC706A controller is an ideal low-cost solution to control a BLDC motor drive. Its specialized hardware peripherals provide efficient motor control with limited support circuitry, reducing the cost and complexity of the motor control hardware. The implemented sensorlesscontrol technique is ideal for use in appliance, automotive and industrial application.

ACKNOWLEDGMENT

I would like to thank my project guide Dr.SanjayLakshminarayanan, Associate Professor, Dept. of EEE, MSRIT and HOD Dr. Premila Manohar, Dept. of EEE, MSRIT for their guidance and support in completion of this work.

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