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Open Loop Speed Control of Brushless DC Motor

K Uday Bhargav¹, Nayana T N²

PG Student, Department of Electrical & Electronics Engineering, BNMIT, Bangalore, Karnataka, India¹

Assistant Professor, Department of Electrical & Electronics Engineering, BNMIT, Bangalore, Karnataka, India²

ABSTRACT: The Brushless Direct Current motors (BLDCM) are considered best for speed variable applications. It is more robust and has very good performance when compared to the DC motors. In this paper, an open loop speed control of three phase BLDC motor was simulated and the results were compared with the hardware implementation of the same. In open loop characteristics, the speed of the motor can be controlled (increased/decreased) by changing the pulse width (duty cycle) of the switching pulses for the inverter or by increasing or decreasing the input voltage to the motor through the inverter. The simulation of the open loop three phase BLDCM was done in MATLAB/Simulink. The speed results of the simulation and hardware for various pulse widths are shown in this paper.

KEYWORDS: Brushless Direct Current Motors (BLDCM), Speed control, Duty cycle

I. INTRODUCTION

Many industrial, commercial and domestic applications require variable speed motor drives. The DC machines have been dominating these areas in quite few years. When compared to the induction motor DC motors are little expensive but its control was made easy. But due to the presence of the brushes and the commutators in DC motors they were considered unreliable. Because of sparking of brushes and contacts they became inefficient for industrial purposes. This led to making of new brand of motors which were considered reliable and was easily controllable. These were BLDCM. The BLDCM is also considered as the stepper motor, hence the speed of the motor can be controlled in steps which can be used for many applications like robotic arm movement for industrial application, in space for projection of satellite panels, for actuators in aerospace applications, feed drives for the CNC machine and etc. The BLDC motor is type of synchronous motor that from perspective of modelling looks like a conventional DC motor having a linear relationship between voltage & rpm and current & torque. Its commutation is controlled electronically when compared to the DC motor (having brushed contacts) where commutation takes place mechanically. And in BLDC motor, the armature remains static having stator windings whereas the rotor is permanent magnet which rotates. Commutation between the stator and the rotor takes place by electronic controller which performs same distribution of power as brushed DC motor. Advantages of brushless DC motor over brushed DC motor make it useful in applications like aerospace where space and weight of the motor are critical factors.

II. PRINCIPLE & ARCHITECTURE OF BLDCM

Brushless DC motors (BLDCM) are the synchronous type of motors whose field winding is of permanent magnets. These are the motors which don't have the brushes or the commutators for passing of current or commutation. That is why these types of motors are also called electronically commutated motors. They are not operated directly instead they are operated through an inverter which switches the phases of BLDCM ON/OFF based on the position of the rotor. The switches in the inverter can work for 120° conduction mode or 180° conduction mode. The block diagram of the open loop BLDCM is shown in figure 1.

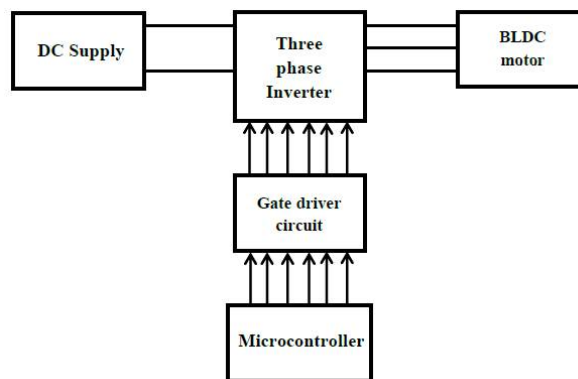


Figure 1: Block diagram of open loop BLDCM

In the above diagram shown, the pulses are generated from the Microcontroller which is given to the gate port of three phase inverter through the gate driver circuit. The inverter is powered from a DC source of 12V. The inverter drives the motor. The speed of the motor can be varied by varying the voltage to the motor.

III. MATHEMATICAL MODEL OF BLDCM IN MATLAB/SIMULINK

In an open loop control of BLDCM, the speed can be controlled only through the control of voltage. Diagram shown in Figure 2 represents the model of the open loop BLDCM in MATLAB/Simulink. The pulses are generated through a PWM pulse generator of 50%, 60% and 70% duty cycle. These are given as inputs to the base port of the IGBT three phase Inverter. The input source to the inverter is 12V. Another advantage of the BLDCM is that they can operate for low voltages such as 12v or 24v.

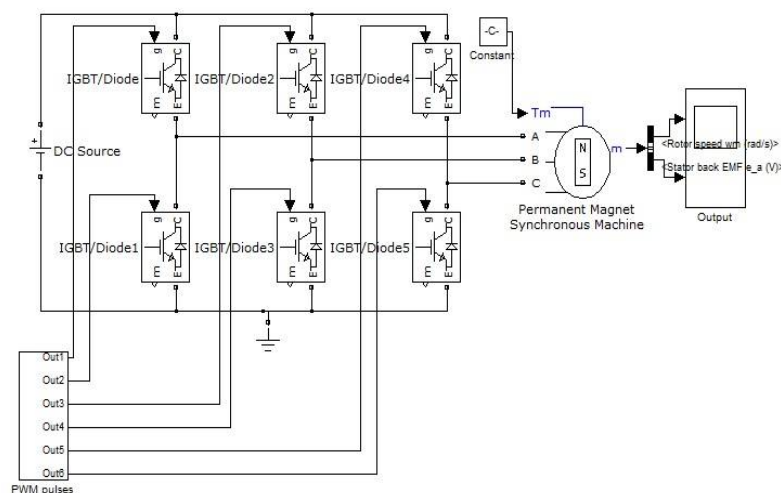


Figure 2: Simulink model of Open loop BLDCM

The BLDCM motor is driven by the PWM pulses. The system for generation of PWM pulses are shown in figure 3 which generate 40%, 50% and 60% of the duty cycles.

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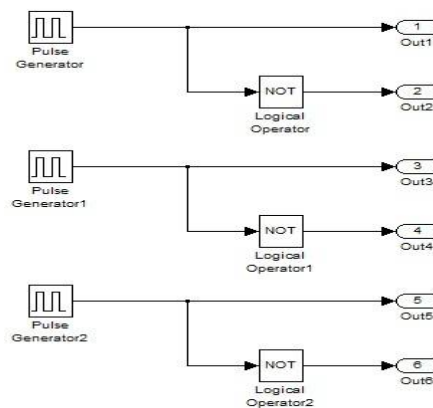


Figure 3 PWM pulses subsystem

IV. HARDWARE IMPLEMENTATION OF BLDCM

The figure 4 shows the hardware implementation of open loop control of BLDC motor which mainly consists of

- IGBT module
- BLDC motor
- Gate Driver circuit
 - Buffer
 - Isolator
 - Gate driver
- 8051 microcontroller

The gate pulses are given from the 8051 microcontroller to the gate of inverter through the gate driver circuit which consists of a buffer, isolator and a gate driver. The gate driver circuit is powered from transformer which takes the power supply of 230V ac supply and step it down to 12V. The inverter is given a 12V dc supply through a Regulated power supply/battery. The three phase inverter is connected to the BLDC motor which is a load. When the circuit is powered up the three phase inverter drives the three phase BLDC motor based on the pulses generated in 8051 microcontroller.

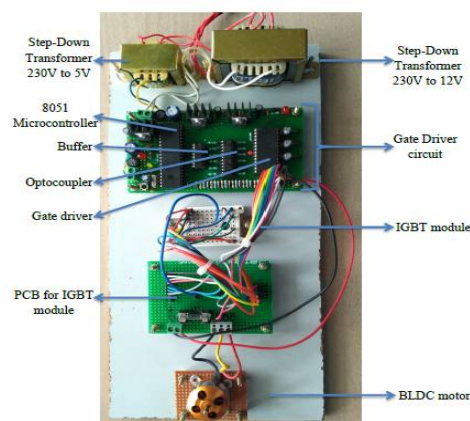


Figure 4 Open loop Hardware implementation of BLDCM

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4.1 IGBT Module

An IGBT module is a component in which the IGBT switches are structured together in a small component which can take higher voltages and higher currents. Six switches are structured into a small PCB typically of size 4x5 centimetres. IGBT module used in this was Infineon's FS35R12W1T4 having six switches and six freewheeling diodes across switches.

4.2 BLDC motor (BLDCM)

BLDC motor used in this paper was A2122 6T motor. The specifications of the motor are listed below in table 1.

Table 1 Specifications of BLDCM	
Number of cells	2-4 Li-Poly 4-7 NiCd
Kv	2200rpm/v
Maximum efficiency	80%
Maximum efficiency current	14-24A
No load current	1.4A@10V
Resistance	0.045Ω
Maximum current	28A
Maximum watts	300W
Poles	14

4.3 Gate Driver Circuit

This is a circuit which is used for isolation and buffering of the gate signals to the power circuit from a microcontroller. This circuit is used to drive the gate ports of the inverter through the microcontroller. It has three main components in it which are:-

- Buffer
- Isolator and
- Gate driver IC

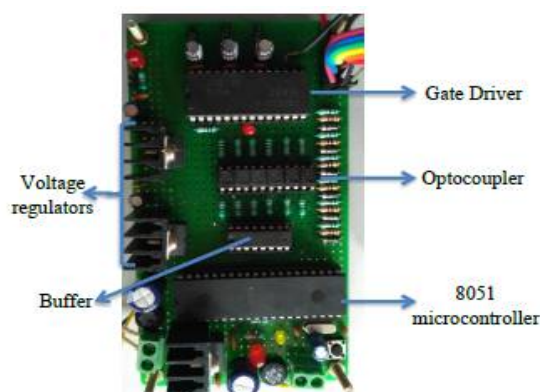


Figure 5 Gate Driver circuit for BLDCM

(a) Buffer

A buffer is a component which provides a transformation of electrical impedance from one circuit to another. The buffer component uses an op-amp in it. The main use of buffer is to generate the same signal which is given in its input irrespective of the current or the voltage changes on the load side. The buffer used in this was 4050B Hex Non-Inverting buffer.

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(b) Isolator

Optocoupler is a component which transfers the electrical signal between one circuit to another. They isolate the power circuit with the control circuit. They prevent passing of high voltages from controller circuit to power circuit which may damage the controller. The optocoupler used in this was EL817 phototransistor optocoupler.

(c) Gate Driver IC

A gate driver component is an amplifier which converts the low power input to the high power output to drive the gate port of the power transistors like IGBT/MOSFET. The output signal of the isolator/optocoupler may be of low power which has to be converted to high power so as to drive the gate port of the transistor. In this paper gate driver IR2130 was used.

4.4 8051 Microcontroller

It is a low power high performance 8 bit microcontroller having CMOS technology. It has 4k bytes of flash memory. The ATMEL 89S53 is manufactured according to the instruction set of 8051 microcontroller and can be used for industry applications. Due to the combined technology of 8-bit CPU with the in system programmable flash, the Atmel 89S53 becomes the most powerful microcontroller for providing flexible and cost reduction solutions to many industrial applications.

PWM Pulses

The pulses used in hardware implementation to drive the gate signals of inverter are PWM pulses. Pulse width modulation also known as PWM method is a technique of modulation used to encode a signal into a pulsating signal. PWM is mainly used to control the electronic devices such as switches which are connected to the dynamic loads.

V. RESULTS AND DISCUSSIONS

Simulink model Results

Figure 6(a) and 6(b) represents the Simulink results of open loop BLDCM. Figure 6(a) represents the output line to line voltage of inverter while figure 6(b) represents the switching pulses of the inverter of 50% duty cycle. The diagrams in 6(b) are represented to show the phase shift and the inversion of PWM pulses for the switches.

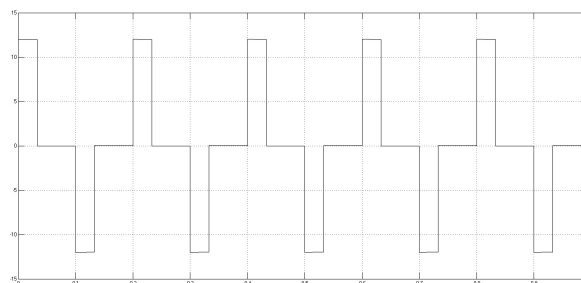


Figure 6 (a) Simulink model output (line-line) voltage of Inverter

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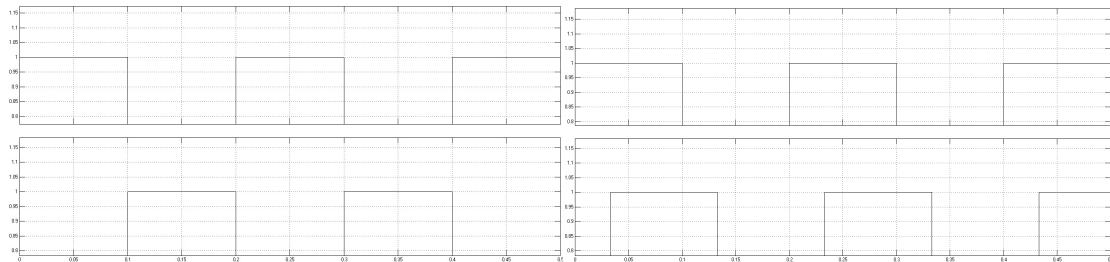


Figure 6 (b) Simulink model output PWM pulses

Hardware model results

Figure 7(a) and 7(b) represents the hardware results of the model. Figure 7(a) represents the output line to line voltage of inverter while figure 7(b) represents the switching pulses of the inverter of 50% duty cycle. The diagrams in 7(b) are represented to show the phase shift and the inversion of PWM pulses for the switches.



Figure 7 (a) Hardware model output (line-line) voltage of Inverter

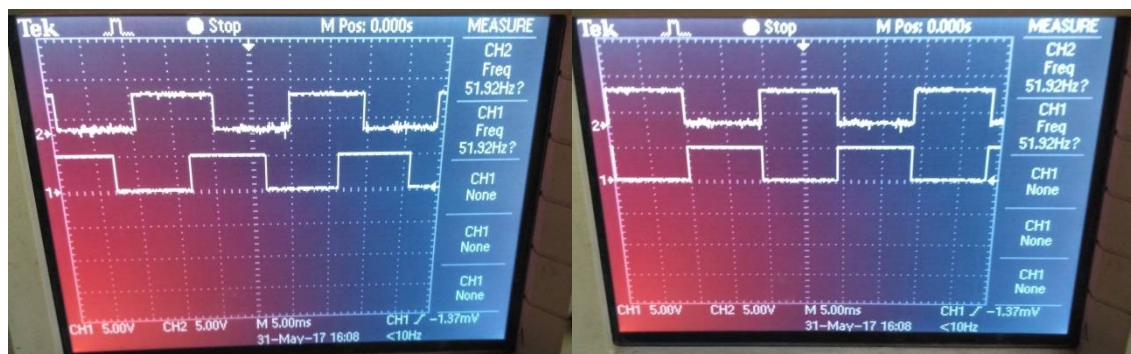


Figure 7 (b) Hardware model output PWM pulses

The table 2 presents the comparison of the open loop speed for the three phase simulated BLDCM and the hardware implementation.

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Table 2 Open loop speed comparison

Duty cycle	Speed	
	Simulation	Hardware
40%	9920	9550
50%	12950	12600
60%	15700	15440

VI. CONCLUSION

The BLDCM are considered in most of the applications because of their less weight, more speed and more power, low cost and less maintenance. In this paper, an open loop speed control of three phase BLDCM was done in MATLAB/Simulink and Hardware. The speed comparison was done for the simulated design and the hardware. It was seen from the comparison that the speed increases when the duty cycle increases (increase in voltage) and speed decreases when the duty cycle decreases (decrease in voltage). BLDCM which are stepper motors can be used in open loop speed control for the application like robotic arm movement for industrial application, can be used in space for projection of satellite panels, can be used for actuators in aerospace applications, feed drives for the CNC machine and etc.

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BIOGRAPHY



K Uday Bhargav, M Tech, 4th semester, Department of Electrical and Electronics, B N M Institute of Technology, Bangalore, Karnataka – 70



Nayana T N, Assistant Professor, Department of Electrical and Electronics, B N M Institute of Technology, Bangalore, Karnataka – 70