Microcontroller based Speed Control of BLDC Motor with Boost Converter

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Abstract— the objective of this dissertation work is to control the speed of the brushless Permanent magnet DC motor with the help of microcontroller. Now days every industry becomes automated industry. To make the industry automation the equipment and machineries should be controlled automatically. In this work, the design is to control the BLDC motor automatically through microcontroller. So control of the machineries which involving this motor can be done accurately. By making the industrial automation production rate can be increased. BLDC machines are used in applications of vital importance such as aerospace industry, tool drives, actuators and electric vehicle propulsion system. Hence, the necessity for precise control speed is evident and obvious. In this work switches has been interfaced with microcontroller to obtain speed control with clockwise, anticlockwise and braking operation. Here the microcontroller is a flash type reprogrammable microcontroller which is already programmed with an objective. When enter the desired speed to the microcontroller, the microcontroller sends the corresponding digital signal to the drive system. The PMBLDC drive system which involves inherently an inverter controller arrangement which controls the switching speed of the MOSFET using ATMEGA16 micro controller. The motor speed is monitored by digital speedo meter. The microcontroller received measured speed signal and compared with desired entry speed. Through this way BLDC motor is controlled to our desired set speed.

Key words: Microcontroller, Boost Converter, BLDC Motor

I. INTRODUCTION

An electrical motor is defined as a mechanical transducer that converts electrical energy into mechanical energy. Electric motors are an integral part of industrial plants. Residential and commercial applications mostly use conventional motor drive technologies. Electric motors are responsible for consuming more than half of all the electrical energy used in the world. In every industry there are processes that require adjustment for normal speed. Such adjustments are usually accomplished with variable speed drive and it consists of electrical motor, power converter and controller. Typically, machines found in all appliances are single-phase induction motors or brushed dc machines which are characterized by low efficiency and high maintenance, respectively. Single-phase induction motors are less efficient because of the ohmic loss in the rotor and due to the phase angle displacement between the stator current and back electromotive force (EMF). But the above losses are less in BLDC motor due to the absence of brushes and mechanical commutation. Different methods are available for speed control of BLDC motor, like DC link variable voltage, PWM technique, etc.

In this project, PWM technique has been employed. Nowadays different PWM techniques are available, like Sinusoidal, multiple sinusoidal, 60° modulations etc. Here, sinusoidal PWM technique is used for controlling the speed of BLDC motor, because it is easy and less time consuming. This work introduces speed control of BLDC motor has been achieved through variation of duty cycle.

II. PROPOSED SYSTEM

The block diagram of proposed scheme is shown in Fig 1.

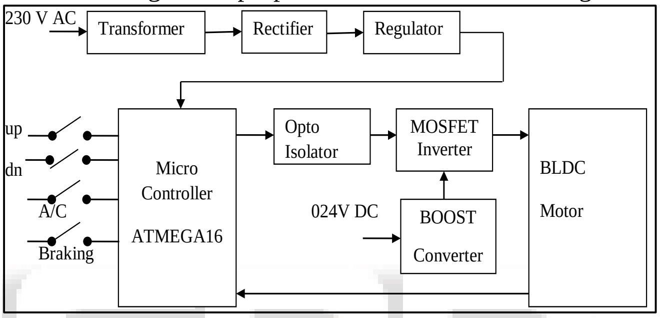

Fig. 1: Block Diagram of Proposed Dissertation Work

A. *Power Supply*

Fig 2: Power Supply

The system requires a regulated +5v supply for the semiconductors. These can be delivered from the230V domestic supply. Before applying this to the system we must step down this high voltage to an appropriate value. After that it should be rectified. To achieve +5 V DC we should regulate this. All this is run in the power supply circuitry. Power supply is used to give sufficient power to the microcontroller. A step down transformer and a bridge rectifier is used here to convert AC to DC. A regulator IC is also used here to give constant supply.7805IC is used for power supply and it is connected to the bridge rectifier. The ac supply goes to a centre tap rectifier, which converts the ac into a unidirectional voltage. The ripples in the resulting supply is filtered and smoothed by a 1000micro FD/25V capacitor. The 0.1 microfarad capacitor bypasses any high frequency noises. The resulting supply has magnitude above 17V. This voltage is given to the regulated IC 7805.This IC provides a regulated 5V positive supply at its 3rd pin. This required input for this is more than 7.5V.

B. *Microcontroller*

Microcontroller is the heart of this project. Microcontrollers are low-cost computers-in-a-chip. They allow electronics designers and hobbyists add intelligence and functions that mimic big computers for almost any electronic product or project. Microcontroller is programmed to generate 6driving pulses depending upon the hall sensors feedback given by the BLDC motor. In addition to that microcontroller is programmed to generate pulse width modulated pulses for speed variation of BLDC and rotates in clockwise and anticlockwise direction & braking also.

To obtain the speed control of the BLDC switches has provided to microcontroller to vary the duty cycle. The microcontroller has been programmed to generate gate pulses for the clockwise and anti-clockwise rotations as shown in table 1 & 2.

Sequence	Hall Sensor Input			Active PWMs		Phases Active		
	Hall-A	Hall-B	Hall-C			R	Y	B
1	0	0	1	Q1	Q6	$+V_{dc}$	NC	$-V_{dc}$
2	0	0	0	Q1	Q4	$+V_{dc}$	$-V_{dc}$	NC
3	1	0	0	Q4	Q5	NC	$-V_{dc}$	$+V_{dc}$
4	1	1	0	Q2	Q5	$-V_{dc}$	NC	$+V_{dc}$
5	1	1	1	Q2	Q3	$-V_{dc}$	$+V_{dc}$	NC
6	0	1	1	Q3	Q6	NC	$+V_{dc}$	$-V_{dc}$

Table 1: Sequence for rotating the motor in clockwise direction when viewed from non-driving end

Sequence	Hall Sensor Input			Active PWMs		Phases Active		
	Hall-A	Hall-B	Hall-C			R	Y	B
1	0	0	1	Q1	Q6	$+V_{dc}$	NC	$-V_{dc}$
2	0	0	0	Q1	Q4	$+V_{dc}$	$-V_{dc}$	NC
3	1	0	0	Q4	Q5	NC	$-V_{dc}$	$+V_{dc}$
4	1	1	0	Q2	Q5	$-V_{dc}$	NC	$+V_{dc}$
5	1	1	1	Q2	Q3	$-V_{dc}$	$+V_{dc}$	NC
6	0	1	1	Q3	Q6	NC	$+V_{dc}$	$-V_{dc}$

Table 2: Sequence for rotating the motor in counter-clockwise direction when viewed from non-driving end

C. Three Phase Inverter

Single-phase VSIs cover low-range power applications and three-phase VSIs cover the medium- to high-power applications. The main purpose of these topologies is to provide a three-phase voltage source, where the amplitude, phase, and frequency of the voltages should always be controllable. Although most of the applications require sinusoidal voltage waveforms (e.g., ASDs, UPSs, Var compensators), arbitrary voltages are also required in some emerging applications (e.g., active filters, voltage compensators). The standard three-phase VSI topology is shown in Fig 4.

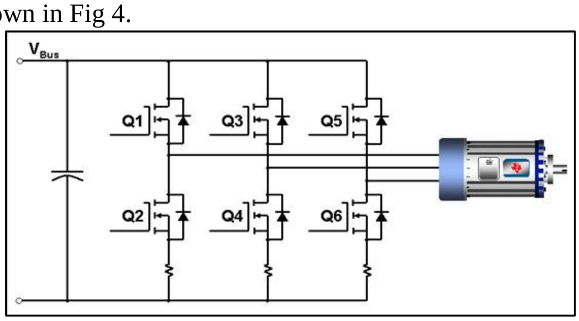

Fig. 4: three phase VSI topology

As in single-phase VSIs, the switches of any leg of the inverter (Q1and Q4, Q3 and Q6,or Q5 and Q2) cannot be switched on simultaneously because this would result in a short circuit across the dc link voltage supply. Similarly, in order to avoid undefined states in the VSI, and thus undefined ac output line voltages, the switches of any leg of the inverter cannot be switched off simultaneously as this will result in voltages that will depend upon the respective line current polarity. Of the eight valid states, two of them produce zero ac line voltages. In this case, the ac line currents freewheel through either the upper or lower components. The remaining states produce nonzero ac output voltages. In order to generate a given voltage wave-form, the inverter moves from one state to another. Thus the resulting ac output line voltages consist of discrete values of voltages that are vi, 0, and -vi. The selection of the states in order to generate the given waveform is done by the modulating technique that should ensure the use of only the valid states.

D. Boost Converter

These converters are also called as step–up converters, which steps voltage from its input to its output, hence the output voltage of boost converter is greater than the source voltage it is a class of switched mode power supply containing at least two semiconductors, and at least one energy storage element. Power for the boost converter can come from any suitable DC source, such as batteries, solar panels, rectifiers and DC generators.

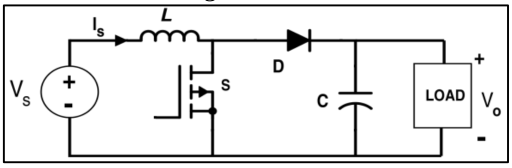

Fig. 3: Circuit diagram of Boost converter

When the converter is turned ON, the voltage across the inductor is

$$V_L = \mathrm{L}\,\frac{\mathrm{di}}{\mathrm{dt}}$$

And this gives the peak to peak ripple current in the inductor as

$$\Delta \mathrm{I} = \frac{\mathrm{V_s}}{\mathrm{L}}\mathrm{t_1}$$

The average output voltage is

$$\mathrm{V_o} = \mathrm{V_s} + \mathrm{L}\frac{\Delta \mathrm{I}}{\mathrm{t_2}} = \mathrm{V_s}\left(1 + \frac{\mathrm{t_1}}{\mathrm{t_2}}\right)$$

The principle behind the working of boost converter is that, the tendency of an inductor to resist the changes in current by creating and destroying a magnetic field. When the switch is closed (on-state), current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. When the switch is open (off-state), current will starts to decrease because of higher impedance. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity of the inductor will be reversed now, therefore both the sources will be in series causing a higher voltage to charge the capacitor through the diode D. if the switch is operating quickly, then the inductor will not discharge fully, and the load will always have a voltage greater than that of the input voltage. Also while the switch is opened, the capacitor in parallel with the load is charged to this combined voltage.

E. Isolation & Drive Circuit

The isolation and drive circuit is used to provide required gate voltage and current to MOSFET’s for switching. It provides electrical isolation between power switch and control circuit. Drive circuit amplifies control signals to level required to drive power switch. In the inverter there are six MOSFET's, so separate isolator and driver circuits are used to drive each MOSFET.

The primary function of a driver circuit is to switch a power semiconductor device from off state to on state & vice versa. The low cost drive circuit is chosen such that it minimizes the turn-on & turn-off times so that the power device spends little time in traversing the active region where instantaneous power dissipation is large. In the on-state the drive circuit must provide adequate drive power to keep the power switch in the on-state where the conduction losses are low. Very often the drive circuit must provide reverse bias to power switch control terminals to minimize turn-off times & to ensure that the device remains in the off state & is not triggered on by stray transient signals generated by switching of other power devices.

The signal processing & control circuits that generate the logic-level control signals used to turn the power switch on & off are not considered as the part of drive circuit. The driver circuit is the interface between the control circuit and the power switch.

III. Experimental Results

The speed control technique employed here is pulse width modulation (PWM) technique the duty cycle determines the speed of the motor. The desired speed can be obtained by changing the duty cycle. The PWM in microcontroller is used to control the duty cycle of DC motor.

Average voltage = D * Vin

The average voltage obtained for various duty cycles is also mentioned and as the duty cycle percentage decreases average voltage also decreases from the supply voltage. Duty cycle is defined as the percentage of time the motor is ON. Therefore, the duty cycle is given as

Duty Cycle = 100% x Pulse Width/Period

Where, Duty Cycle in (%)

Pulse Width = Time the signal is in the ON or high state (sec)

Period = Time of one cycle (sec).

The program for the closed loop control of BLDC motor operation is written in embedded C and executed in keil software. The PWM pulses generated from the microcontroller are viewed for various duty cycles.

Input Duty Cycle (%)	Output Speed (Rpm)
10	240
20	400
30	615
40	690
50	715
60	790
70	830
80	900
90	1050

Table 3: various duty cycles

IV. Conclusion

This dissertation work demonstrates the use of an efficient and low cost controller based on microcontroller programming to control the speed of BLDC motor. Due to the simplistic nature of this control, it has the potential to be implemented in a low cost application. The experimental results demonstrated the effectiveness of sinusoidal PWM technique for speed control of BLDC motor and its practical applications.

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