Microcontroller Controlled BLDC Drive for Electric Vehicle

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Abstract

This paper proposes the speed control of BLDC motor for an electric vehicle. The flexibility of the drive system is increased using digital controller.The proposed algorithm has been programmed and it generates the firing pulses required to drive the MOSFETs of three phase fully controlled bridge converter. The PWM signals for driving the power inverter bridge for BLDC motor have been successfully implemented using an 8-bit microcontroller. The simulation model is developed using MATLAB/SIMULINK 7.13 environment. Simulation and experimental results verify the effective developed drive operation.

Keywords: Brushless DC (BLDC) motor, electric vehicles (EVs), SIMULINK model, microcontroller.

I. INTRODUCTION

For more than a hundred years, automobiles and other road vehicles have relied on a single technology, the internal combustion engine and on a single fuel supply, petroleum. The ever- increasing environmental concerns as well as strategic and economical considerations have prompted the search for more efficient road vehicles, possibly based on environment friendly sources located in politically stable areas. This has led to the development of electric vehicles. [1]

Currently, the vehicles are being developed with propulsion by energy of easy distribution and from different sources, such as electric power, not forgetting its easy availability in urban areas. Other advantage of using electric motors is the reduction of noise pollution. [2] The proliferation of renewable energy for electricity generation helps the development of transports with electric motors.

Since the advancement in battery technology has been relatively sluggish, compared with the power electronics area, the handicap of short range associated with EV still remains. With this technology limitation, the EV seems to be the viable alternative to the ICE automobile at the present. [7]

The interest of using microcontroller in this research as the controller came from the capability of the microcontroller to produce proper design of the control signal with flexibility. The importance of the proper design of control signals with powerful switching is to reduce the harmonics and power losses of the inverter output voltage. The potential of the Microcontroller to carry out the mathematical and logical functions allows it to imitate logic and electronics circuit. [4]

BLDC motors are very popular in a wide variety of applications. Compared with a DC motor, the BLDC motor uses an electric commutator rather than a mechanical commutator, so it is more reliable than the DC motor. In a BLDC motor, rotor magnets generate the rotor's magnetic flux, so BLDC motors achieve higher efficiency [6]. It has become possible because of their superior performance in terms of high efficiency, fast response, weight, precise and accurate control, high reliability, maintenance free operation, brushless construction and reduced size, Torque delivered to motor size is higher making it useful in applications where space & weight are critical, Thermal overload & under load protection is provided. [3, 5, 8]

Power converter in the BLDC motor drives system consists of two parts, which is a rectifier and 3-phase full bridge inverter. Control schemes for these motor drives typically a PWM waveform driving the inverter. A suitable switching technique is needed to generate Pulses to drive the power device circuit. To produce the desired output, PWM switching technique will be used to generate the pulses for power device via microcontroller. The pulses must be precisely determined and synchronized for each switching and phase sequence with the intention of avoiding glitches, delay or shoot-through phenomena during the course of switching process. Factors to be considered in designing the converter for the BLDC motor drives in order to meet the requirement includes a suitable switching technique and controlling switching angles for the BLDC motor rotation and controllable magnitude and frequency of the output voltage.

Therefore, the main idea of this project is to design microcontroller-based BLDC motor drives for electric vehicle. The performance of the converter parameter will be tested and observed based-on several PWM switching schemes.

II. BLOCK DIAGRAM OF THE CONTROL SYSTEM

The block diagram of BLDC drive system is shown in Figure 1. It consists of a three- phase inverter, position sensors, signal conditioner and a digital controller. The inverter along with the position sensor arrangement is functionally analogous to the commutator of a conventional dc motor.

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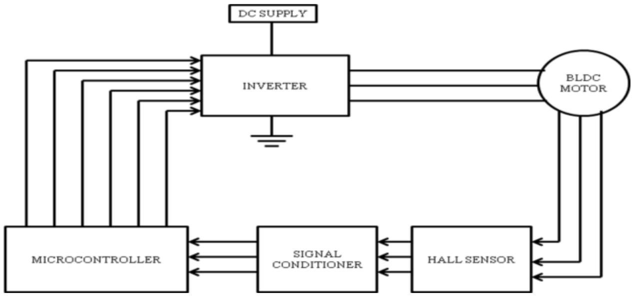

Figure 1: Block diagram of BLDC drive system

The BDLC motor detects the position of the rotor using Hall sensors. Normally Hall sensors are used for position information in brushless dc motor. Three sensors are required for position information. With three sensors, six possible commutation sequences could be obtained. For every 60 electrical degrees of rotation, one of the Hall sensors changes the state. Therefore, it takes six steps to complete an electrical cycle. The rotor of a PMBLDC motor can have any number of poles.

A digital controller can be used to provide the appropriate firing pulses to the inverter based on the position sensor information. A microcontroller can be used since it offers design flexibility that hardwired control components cannot. Table 1 shows the Sequence for rotating the motor in counter-clockwise direction when viewed from non-driving end.

Table 1: Sequence for rotating motor in clockwise direction

Hall Sensor A	Hall Sensor B	Hall Sensor C	Phase A	Phase B	Phase C
1	0	0	$+V_{DCB}$	$-V_{DCB}$	NC
1	1	0	$+V_{DCB}$	NC	$-V_{DCB}$
0	1	0	NC	$+V_{DCB}$	$-V_{DCB}$
0	1	1	$-V_{DCB}$	$+V_{DCB}$	NC
0	0	1	$-V_{DCB}$	NC	$+V_{DCB}$
1	0	1	NC	$-V_{DCB}$	$+V_{DCB}$

The BLDC motor control consists of generating DC currents in the motor phases. This control is subdivided into two independent operations: stator and rotor flux synchronization and control of the current value. Both operations are realized through the three phase inverter.

The flux synchronization is derived from the position information coming from sensors, or from sensorless techniques. From the position, the controller determines the appropriate pair of transistors which must be driven. The regulation of the current to a fixed 60 degrees reference can be realized in The Pulse Width Modulation (PWM) Mode.The supply voltage is chopped at a fixed frequency with a duty cycle depending on the current error. Therefore both the current and the rate of change of current can be controlled. The two phase supply duration is limited by the two phase commutation angles. The main advantage of the PWM strategy is that the chopping frequency is a fixed parameter; hence, acoustic and electromagnetic noises are relatively easy to filter.

A characteristic of the BLDC control is to have only one current at a time in the motor (two phases ON). Consequently, it is not necessary to put a current sensor on each phase of the motor; one sensor placed in the line inverter input makes it possible to control the current of each phase. Moreover, using this sensor on the ground line, insulated systems are not necessary, and a low cost resistor can be used. Its value is set such that it activates the integrated over-current protection when the maximum current permitted by the power board has been reached.

Each current measurement leads to a new PWM duty cycle loaded at the beginning of a PWM cycle. Note that, during Turn OFF, the shunt resistor does not have this current to sense, regardless of whether the inverter is driven in hard chopping or in soft chopping mode.

By simply varying the voltage across the motor, one can control the speed of the motor. When using PWM outputs to control the six switches of the three-phase bridge, variation of the motor voltage can be achieved easily by changing the duty cycle of the PWM signal.

III. SIMULATION & ITS RESULTS

The BLDC motor model shown in Figure 2 is simulated using MATLAB / SIMULINK software. The inputs for the motor model are three phase terminal voltages and the load torque. The motor module gives the three phase currents, speed and rotor position as output. The rotor position is used to generate the trapezoidal back emf whose amplitude is proportional to the speed. The Hall signals are also generated using the rotor position θ.

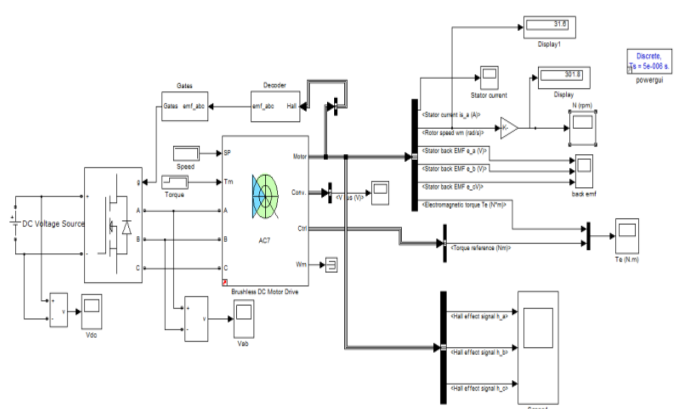

Figure 2: BLDC motor model

The simulation results of the BLDC are shown in figures 3 to 6. The three phase current I_a is shown in Figure 3, the trapezoidal back emfs E_a , E_b & E_c are shown in Figure 4. The speed is controlled by the proportional integral controller, while the current is controlled by a hysteresis controller. The speed with closed loop operation is shown in Figure 5, when

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additional load torque of 20% is applied at t = 0.5sec. The speed decreases momentarily, and then increases to the set reference value as depicted in the inset. The torque characteristics are shown in Figure 6.The simulation model performs satisfactorily as per the requirements.

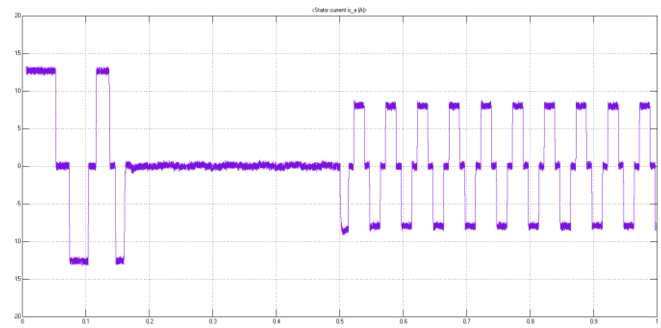

Figure 3: Three phase current ***Ia***

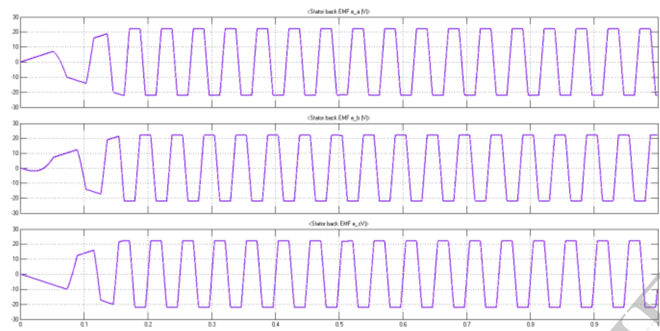

Figure 4: Trapezoidal back Emfs

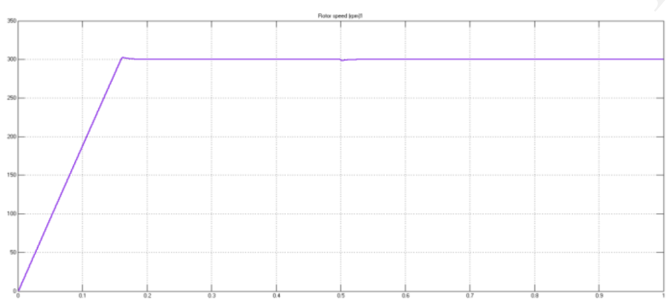

Figure 5: Speed characteristics

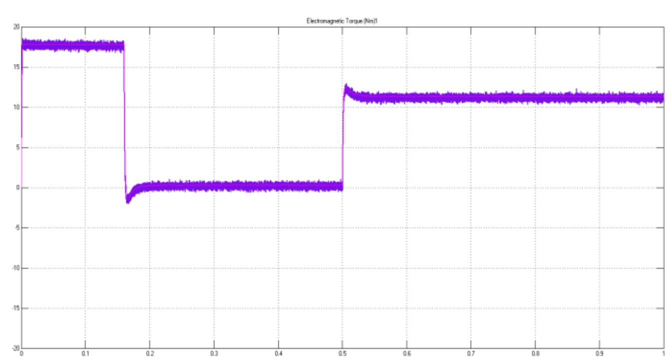

Figure 6: Torque characteristics

IV. HARDWARE & ITS RESULTS

The testing for the proposed hardware was performed with a BLDC motor whose specifications are as shown in Table 2. The output pulses from the microcontroller are fed to the driver circuit prior to driving the MOSFETs. A digital storage oscilloscope was used for storing the waveforms of torque, current, etc. The dc bus voltage of the inverter was controlled through MOSFET. The inverter circuitry includes 6 N-channel MOSFETs and their gate drives (IR2110) manufactured by International Rectifier Inc... The Figure 7 shows the half bridge driver circuit with the high sides powered by bootstrap. The MOSFETs used are IRF540 with 100V, 22A rating. To verify the results obtained through simulation, the reference of 385rpm was given to the motor.

Table 2: BLDC motor specification

Type of motor	**BLDC MOTOR**
Stator voltage	48v
Power rating	250watts
Speed	385rpm
No. of poles	46
Copper wire size	0.51mm in diameter
No. of copper wires used	7 parallel wires
No. of turns	8
Degree	60°
Position sensors	3 Hall sensors

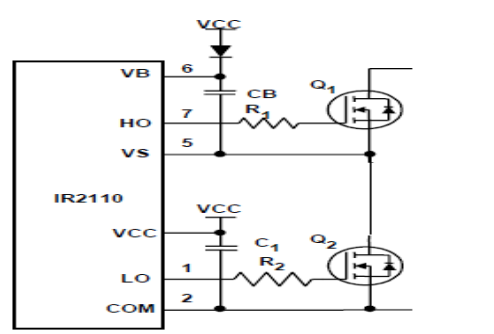

Figure 7: Half bridge driver circuit

The pulses generated from the microcontroller control circuit to drive the MOSFETs are as shown in Figure 8 and these pulses are fed to 48V, 250W BLDC motor. The complete hardware set up is as shown in Figure 9.

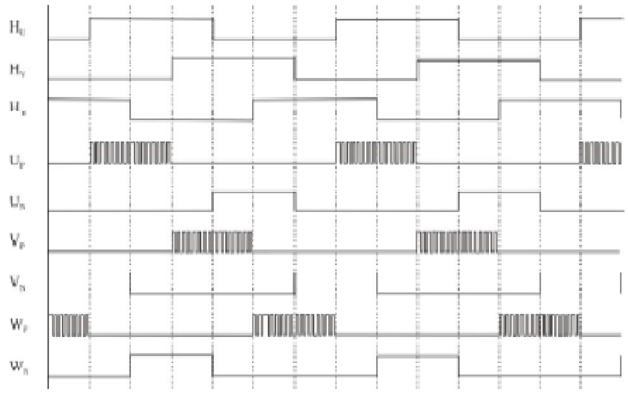

Figure 8: Pulses to drive the MOSFETs

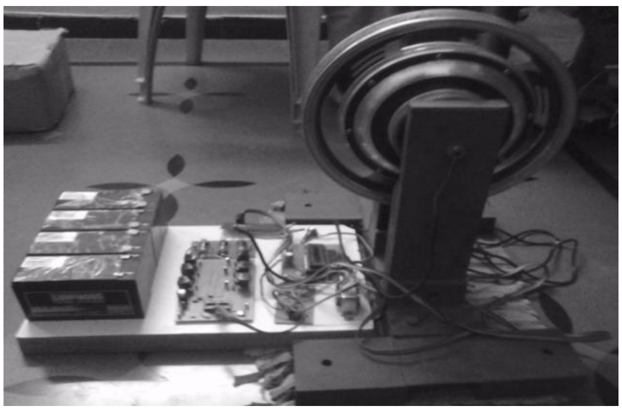

Figure 9: The complete hardware set up

V. CONCLUSION

The proposed algorithm has been programmed and it generates the firing pulses required to drive the MOSFETs of three phase fully controlled bridge converter. The generated PWM signals for driving the power inverter bridge for BLDC motor have been successfully implemented using an 8-bit microcontroller and fed to the MOSFETs of three phase fully controlled bridge converter driven by IR2110 driver circuit. The output from the converter is fed to the three phase stator winding of 48V, 250 W, 385 rpm BLDC motor and the motor is found to run at constant speed which is set by the external potentiometer connected to the microcontroller circuit. The program is found to be efficient and the results with the designed hardware are promising. The developed control and power board functions properly and satisfies the application requirements. Simulation and experimental results verify the effective developed drive operation.

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