Electrification of Automotives using BLDC Motor Drives

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Abstract: *The electrification of Automotives i.e. Electric vehicle is becoming a need in the present and it has huge scope in future. BLDC drives are gaining attention from various fields like industries and household appliances. In the process of electrification of Automotives, BLDC has become first choice of many manufacturers. This paper describes the design and implementation of BLDC motor drive using PIC microcontroller with Hall sensors. The peripheral Interface Controller (PIC) is one of the advanced microcontrollers used in present era, which helps to control the BLDC drive.*

Keywords: *BLDC drive, PIC microcontroller, Gate driver.*

I. INTRODUCTION

The advantages like high efficiency, fast dynamic performance, no excitation loss, simplified construction and high torque or per unit volume makes the BLDC motor to use in electrical machines instead of electromagnetic excitations. In the 20th century, squirrel cage motors were very popular but had disadvantage of low power factor and efficiency, whereas synchronous motors and dc commutator motors have limitations such as speed, noise, wear and EMI. This led to development of BLDC motors. [1]

Electric Vehicles (EVs) and Hybrid Electric Vehicles (HEVs) are becoming future trends in the area of transportation. Many researches in propulsion for EVs is being carried out to develop an optimum and energy efficient system. Use of BLDC motor drives is next step towards it. [2]

Reduced cost controllers for BLDC motors have more demand and many such schemes and algorithms. The cost reduction is possible in two ways; one is topological approach and second is control approach. Designer should design and implement some new algorithms. In topological approach number of switches, sensors and other peripheral circuits should be minimized. [3]

With proper approach for both control and topological, designer should give equal importance to reliability of the system. One such design for BLDC drive is introduced here with hardware.

BLDC drive

Working Principle

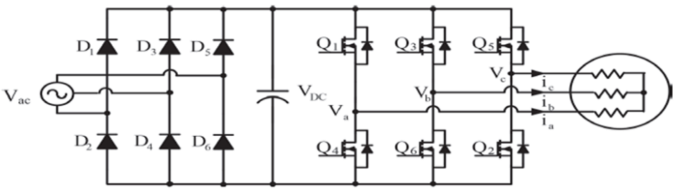

Fig.1 A typical three phase inverter used for BLDC drive

A typical three phase inverter used for BLDC drive is shown in Fig 1. It consists of a rectifier, DC link capacitor, inverter and motor. The supply maybe from a battery but mostly inverter is fed by a rectifier. Two types of conduction are possible with inverter. One is 120°conduction and another is 180°conduction. Among which 180° is preferred because it has better voltage utilization of switches. So, the output is high. Fig.2(a) shows the gating signals for 180° conduction mode and (b) shows the line to line output voltages for 180° conduction mode.

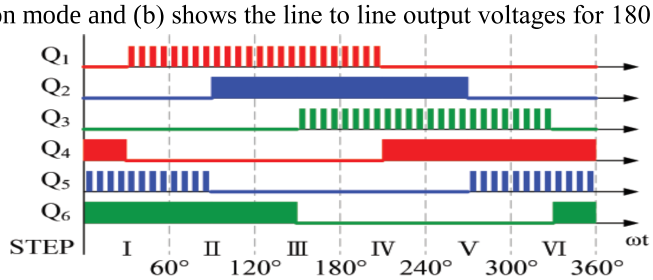

Fig.2 (a) Gating signals

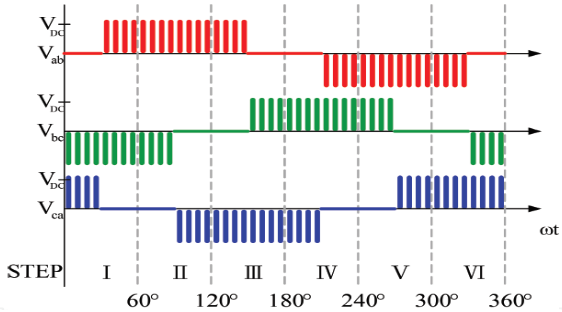

Fig.2 (b) Line-Line voltages

Mathematical equations for BLDC Motor

Before developing mathematical equations, it is assumed that stator resistance of all windings is same, mutual inductance is constant and all devices are ideal.

Then equations for armature windings are,

$$V_a = i_a R + L\frac{di_a}{dt} + e_a \qquad \dots\dots\dots\dots(1)$$

$$V_b = i_b R + L\frac{di_b}{dt} + e_b \qquad \dots\dots\dots(2)$$

$$V_c = i_c R + L\frac{di_c}{dt} + e_c \qquad \dots\dots\dots(3)$$

Where,

Va, Vb, Vc - terminal voltages of phase a, b, and c in Volts

ia, ib, ic - stator current of phase a, b, and c in Amps

ea, eb, ec - back EMF of phase a, b, and c in Volts

The torque produced by the motor can be expressed in the following expression.

$$T_e = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega_m} \qquad \dots\dots\dots\dots\dots(4)$$

The electromagnetic torque will be counter-balanced by load torque Tl, inertia torque and friction torque and is given as:

$$T_e = T_L + J\frac{d\omega_m}{dt} + \beta\omega_m \qquad \dots\dots\dots\dots(5)$$

Block Diagram

Fig.3 shows block diagram for proposed hardware prototype. The drive is built for 24V, 26W BLDC motor.

The BLDC drive needs 24V DC as an input, for this a power supply or battery can be used. Here, a single-phase AC (230V) is stepped down to 24V and used as input to voltage source inverter.

The Pic microcontroller is programmed as per algorithm mentioned earlier.

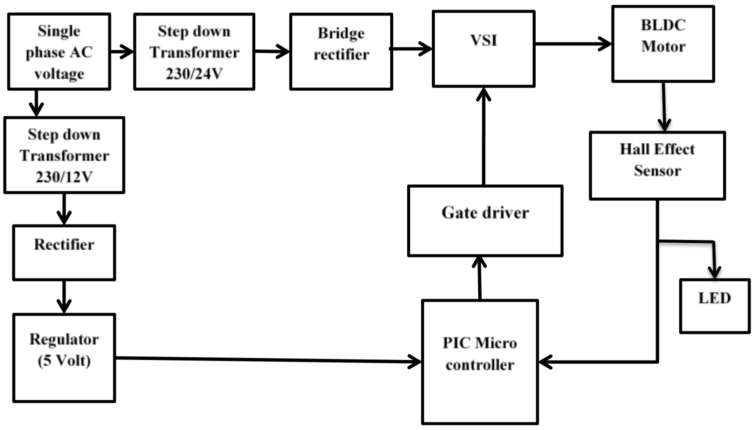

Fig.3 Block diagram of a 24V BLDC motor drive

When first sequence is energized, the microcontroller sends the signal to the driver, the driver IC plays the role of synchronization between MOSFET bridge and microcontroller.

According to the sequence the switches are turned ON and OFF. The output is given to the motor phases and motor is driven. The hall sensors give rotor position feedback to the microcontroller and next sequence is decided.

II. HARDWARE PROTOTYPE

A hardware prototype of 24V BLDC motor drive is shown in fig.4.

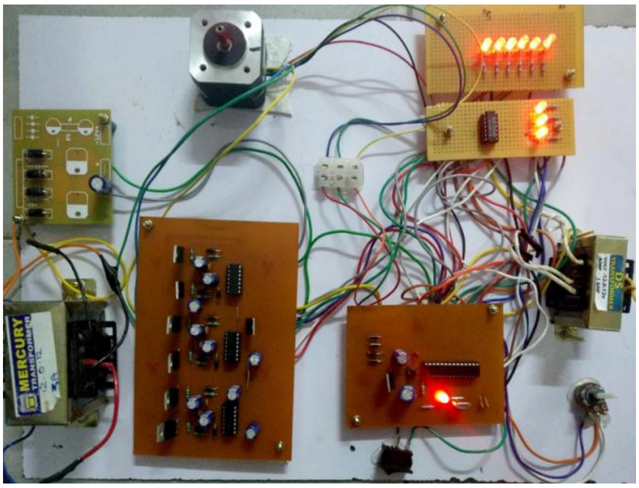

Fig.4. Hardware prototype of BLDC drive

It consists Inverter Bridge with driver IC IRS2110 as shown in fig.5, PIC16F877 microcontroller as shown in Fig.6, 6 LEDs to indicate switching sequences of MOSFET bridge and a BLDC motor having ratings of 24V, 26W, 4000RPM as shown in Fig.7.

Fig.5. MOSFET Bridge with driver

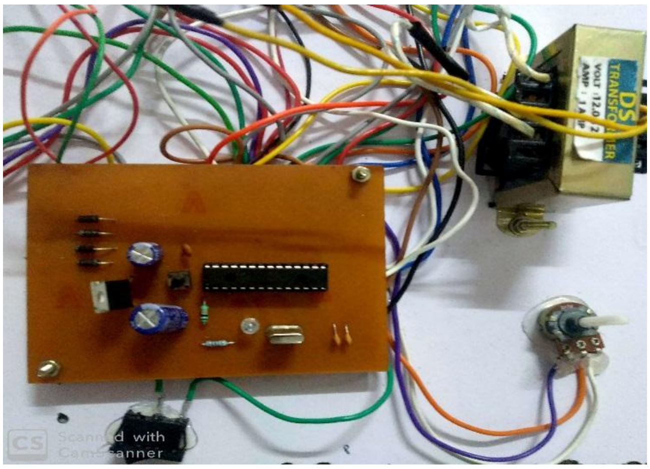

Fig.6.PIC microcontroller

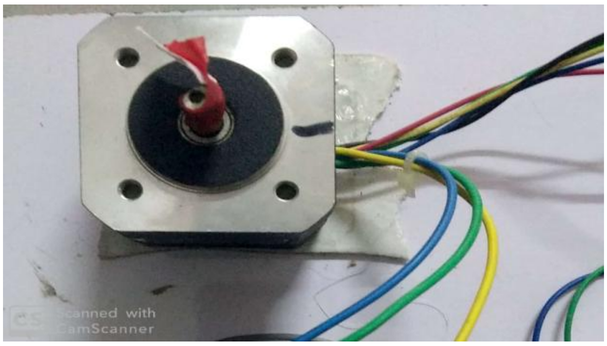

Fig.7. 24V BLDC motor

Fig.8,9,10 shows the line-to-line output voltage waveforms for Vab, Vbc, Vca respectively. Fig.11 shows the hall sensor feedback.

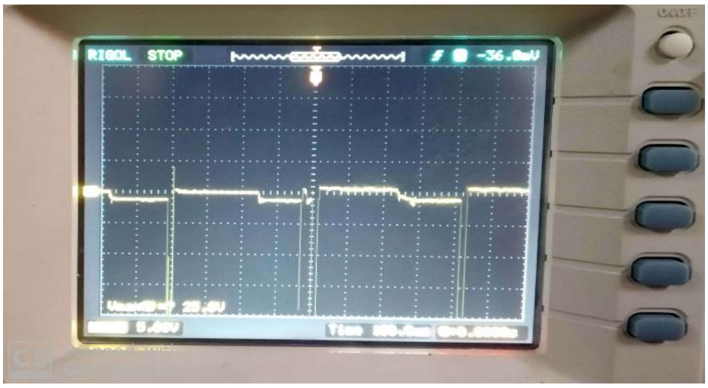

Fig.8 Line-line voltage Vab

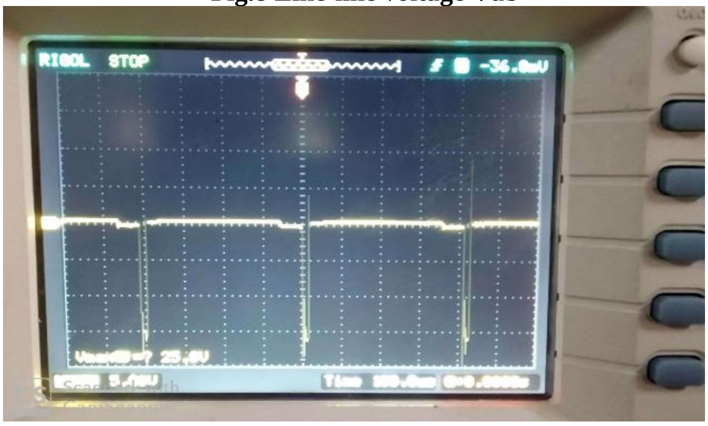

Fig.9 Line-line voltage Vbc

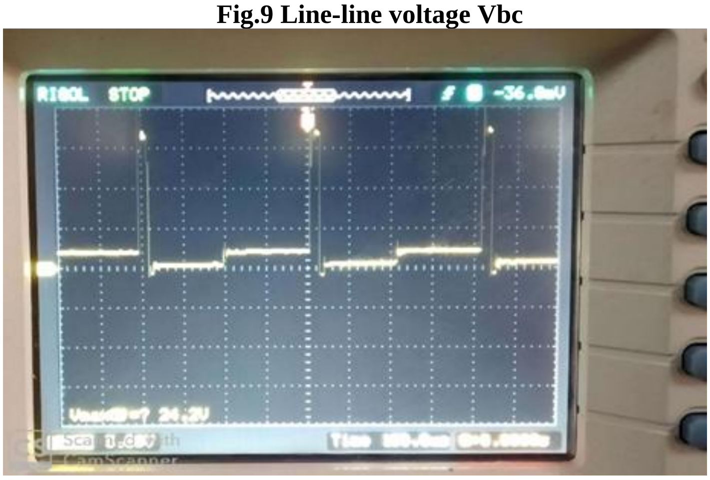

Fig.10. line-line voltage Vca

Table 1 shows the voltage between phase and respective hall sensor for all three at some fixed speed. As the speed is varied by using potentiometer, so there is no specific step sequence between two consecutive speeds. It is clear from the table that for a particular speed two voltage levels are same and low, whereas one voltage level is high all the time which is represented in the timing diagram (Fig.2b).

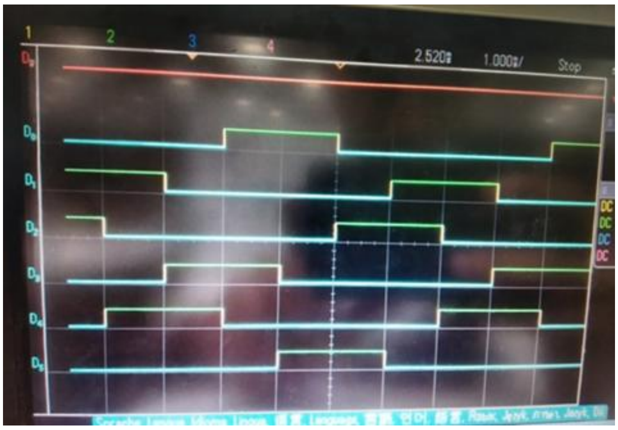

Fig.11. Hall sensor feedback

Table 1: Voltage between phase and hall feedback with variable speed

Speed in rpm	Phase A- Hall A	Phase B- Hall B	Phase C- Hall C
0	0	0	0
815	0.92V	0.51	0.50
1884	1	1.02	1.6
2590	2.58	2.66	3.16
3100	5.68	5.58	6.13
3904	11.01	11.01	11.53
4015	12.72	12.36	11.89

III. CONCLUSION

In this paper a simple and cost-effective BLDC motor drive has presented. The advantages and disadvantages mentioned here denote the significance of BLDC in various fields. A complete hardware with results is shown here. With some additional circuits like CAN communication, wake up circuits, the BLDC drive is used for electric vehicles. Thus, BLDC motor drive is one step towards the electrification of Automotives.

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