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### RESEARCH ARTICLE

# A NOVEL METHOD OF SPEED AND VOLTAGE CONTROL OF BLDC MOTOR

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**ABSTRACT:** *This paper presents the speed control of BLDC motor by the 3phase semiconductor bridge by the signal sensed by rotor position sensor. In the proposed method the back emf of the motor is stored in the battery and the speed of motor is sensed and is given the PI controller which drives the semiconductor. Thus, by this proposed method the energy consumption will be less and generated energy can be stored and reused, and it has high efficiency, long operating life, noiseless operation, and high speed range.. The simulation is on the MATLAB.*

**Keywords:** *Buck Boost converter, Brushless DC motor, Hall sensor, PIC controller.*

## I. INTRODUCTION

DC motors have wide application due to their low cost, torque speed characteristics, and easy control. But the disadvantage is that wear and tear mechanism of the brush and the bulky construction. To overcome these disadvantages and the economic constraints and new standards legislated by governments place increasingly stringent requirements on electrical systems. New generations of equipment must have higher performance parameters such as better efficiency and reduced electromagnetic interference the Brushless DC (BLDC) motors are constructed. BLDC motor has increased its use in the modern technology due to their high efficiency, silent operation, compact form, high reliability due to absence of brush and commutator, low maintenance, torque to weight ratio is higher enabling it to be used in applications where space and weight are critical factor and also it eliminates the problem encountered with the brushes and the commutator. However, the problems are encountered in these motor for variable speed operation over last decades continuing technology development in power semiconductors, microprocessors, adjustable speed drivers control schemes and permanent-magnet brushless electric motor production have been combined to enable reliable, cost-effective solution for a broad range of adjustable speed applications. A brushless DC motor is a rotating electric machine with three-phase stator like that of an induction motor. The rotor has surface-mounted permanent magnets. The stator generated flux which interacts with the rotor flux, which defines the torque and the motor's speed. In the BLDC motor, the speed and position can be controlled by sensor and sensor less control. However in sensorless control, to reduce overall cost of actuating devices sensors are omitted but this needs a complex algorithm. To control the speed of the

machine using sensors the present position of the rotor is needed. The fixed gain PI controller has the limitations of being suitable only for a limited operating range around the operating point. To reduce the speed oscillation, the voltage across the motor varied which can be obtained by varying the duty cycle of PWM signal[1]. When the phase current and phase back-emf voltage are in phase the BLDC motor have the high efficiency by reduced copper and conduction losses[2]. Tozune [8] proposed a phase advancing circuit which changes the lead angle depending on the motor speed. The circuit is simple and effective for high speeds. However, it is not easy to design the proposed circuit for the entire speed range and for various demand torques. Safi [9] studied the effects of the lead angle on both the speed/torque performance and the phase current with an analytical model.

This paper the speed of the BLDC motor is controlled by the 3phase semiconductor bridge by the signal sensed by rotor position sensor. The sensed signal is given to the PIC controller which drives the converter. During motoring operation of the motor, the semiconductor acts as inverter and during the regenerative operation the semiconductor acts as rectifier and the current generated by the motor is stored in the battery.

## II. BRUSHLESS DC MOTOR

In conventional control method, the speed and the position of the motor is to be known. The sensor determines the motor speed and position and is given to the controller. The controller selects the switches of the drive of inverter for the speed control. But in this proposed method, the generative power from the rotating motor is stored back in the battery and can be used for the starting the motor.

### II.A. WORKING

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor and windings on the stator. Permanent magnets create the flux and the windings create electromagnet poles and hence the stator attracts the rotor. This is the fundamental action used in synchronous permanent magnet motors. . These offers a good compromise between control and the number of power electronic devices is required to control the stator currents. This makes the control of BLDC in all the four quadrants very vital. Fig 1.

The braking methods of a BLDC motor are similar to that of a direct current machine. Braking is nothing but stopping the machine at a desired position which has the similar importance with the starting of the motor. . If the input current is inphase with back emf, motoring torque is developed. Braking action can be achieved by generating a torque of opposite polarity (braking torque) to that of motoring torque which opposes the motion (i.e) the input current is in out of phase with back and hence the machine will work as a generator, absorbing mechanical energy from load and converting it into electrical energy.

Braking during forward motoring is called Forward braking while it is in reverse rotation is called Reverse braking. In Speed-Torque plane, forward braking will result in second quadrant operation where as reverse braking results in fourth quadrant operation. The electromagnetic torque developed is

$$T_e = (e * i) / \omega_a \text{ (N-m)}$$

In regenerative mode, all switches are turned off and the current can flow back through the freewheeling diodes. In regenerative braking, instead of wasting the power in external resistance the power generated during retardation is fed back towards the source i.e., the motor works as a generator developing a negative torque which opposes the motion and the generated energy is supplied to the source. For the generated energy to be supplied to the source two conditions should be satisfied

- i) back emf should be greater than supply voltage ( $E > V$ ) for all speeds
- ii) Current has to reverse its direction

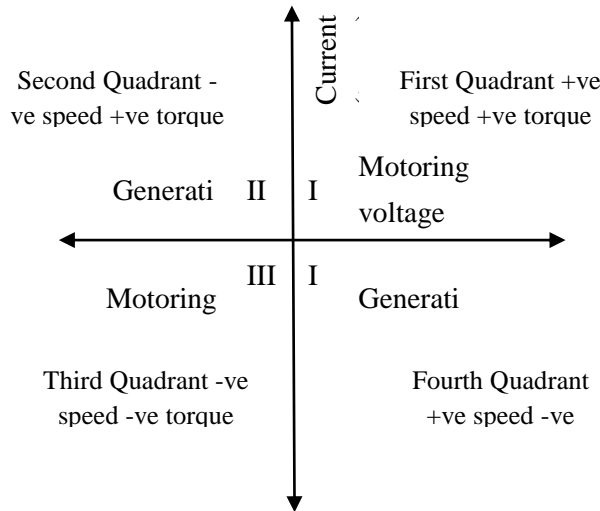


Fig 1: Four Quadrants of operation

**II.B. MODELING OF BLDC MOTOR**

In volage equation of BLDC motor becomes

$$\begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ab} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (1)$$

It is assumed that Resistance are equal in all the windings.

$$L_{aa} = L_{bb} = L_{cc} = L \quad (2)$$

$$L_{ab} = L_{bc} = L_{ca} = L_{ac} = L_{cb} = L_{ba} = M \quad (3)$$

Thus the eqn (1) becomes

$$\begin{bmatrix} v_{as} \\ v_{bs} \\ v_{cs} \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \frac{d}{dt} \begin{bmatrix} L - M & 0 & 0 \\ 0 & L - M & 0 \\ 0 & 0 & L - M \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix} \quad (4)$$

The electromagnetic torque developed is

$$T_e = \frac{e_a i_a + e_b i_b + e_c i_c}{\omega_m} \text{ (N-m)} \quad (5)$$

**II.C. DESIGN OF BLDC MOTOR**

This terminology defines the shape of the back-emf of the synchronous motor. The increased efficiency and reliability that a brushless motor offers, along with its low weight and small size, make this type of motor the perfect choice for a wide range of applications. Find the brushless motor that’s ideal for your project today. The design specification of BLDC motor is shown in table1

Table 1. Specification of BLDC motor

1	Product type	Brushless DC motor
2	Rated speed	3000rpm
3	Rated voltage	12V
4	Rated torque	60 Nm
5	Current at rated speed	2.300A

6	Number of poles	14
7	Weight	160

### III. HALL SENSORS

A Hall Effect sensor is a transducer that varies its output voltage in response to a magnetic field. Hall Effect sensors are used for proximity switching, positioning, speed detection, and current sensing applications. With a known magnetic field, its distance from the Hall plate can be determined. Using groups of sensors, the relative position of the magnet can be deduced. A Hall sensor is combined with circuitry that allows the device to act in a digital (on/off) mode, and may be called a switch in this configuration. Hall sensors are commonly used to time the speed of wheels and shafts, such as for internal combustion engine ignition timing, tachometers and anti-lock braking systems.

The Hall sensor are used in brushless DC electric motors to detect the position of the permanent magnet. In the pictured wheel with two equally spaced magnets, the voltage from the sensor will peak twice for each revolution. This arrangement is commonly used to regulate the speed of disc drives

#### HALL EFFECT

The Hall effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and a magnetic field perpendicular to the current. The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current

#### III.B. WORKING

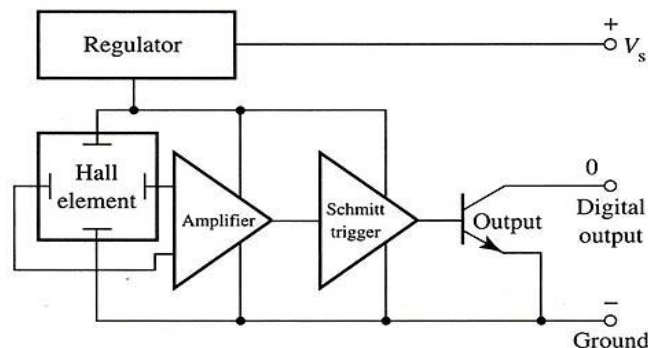


Fig 2. Working of rotor position sensor

From the figure notice that sensor are three-wire sensor. This means that two wires, the + V, and the ground provide dc voltage for the power supply portion of the sensor. Terminal 0 and ground are used as the output terminals for the sensor. Since this is a three-wire sensor, the ground terminal is part of the power supply and part of the output circuit. The power supply uses a voltage regulator to provide the initial current for the Hall-effect element and voltage for the op amp. The small sensor terminals are connected to the op amp input terminals. When a magnetic field is sensed, a small voltage is sent to the op amp and the output of the op amp is sent to a Schmitt trigger and then to the base of an NPN transistor. When the base of the transistor is biased, it will go into saturation and current will flow through its emitter-collector circuit to provide a digital (on/off) output signal. In the current-sinking circuit, notice that the transistor provides a path to ground when the transistor is biased to saturation.

#### IV. PIC CONTROLLER

Table 2: Specification of rotor sensor

<b>Supply</b>	8 - 30 Vdc @ 5 mA
<b>Voltage :</b>	0.06 – 4.95 V typical (2.5 V at
<b>Pulse Out:</b>	zero field strength)
<b>Frequency</b>	
<b>Range:</b>	0 Hz - 30 kHz
<b>Air Gap:</b>	Depends on field strength (up to 1.0" @ 3000 Gauss)
<b>Temperature Ranges:</b>	<b>2TE:</b> -40° to 221° F (-40° to 105° C)
<b>Thread Length:</b>	<b>3TE:</b> -40° to 300° F (-40° to 150° C)
<b>Thread Sizes:</b>	1.0" - 6.0" (25-152mm)
	5/8, 3/4, M16, M18

#### V. BUCK BOOST CONVERTER

The electric power can be converted from one form to another by the power electronic devices. The buck boost converter is the combination of buck and the boost converter (i.e) step down and step up converter fig 10. The basic working of the buck–boost converter is when the converter is in ON state the input voltage source is directly connected to the inductor(L) and it conducts for 0 to  $\delta T$  hence the current flows in inductance, this results in accumulating energy in the inductor and the capacitor supplies energy to the load, and when the converter is in OFF state for  $\delta T$  to T , the inductor is connected to the load and hence the inductance current decreases And the capacitor gets charged.

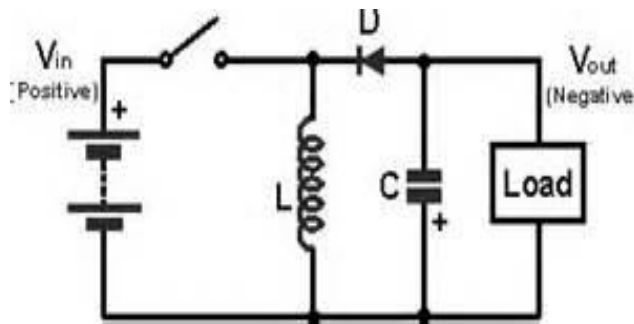


Fig 10: Basic block diagram of Buck-Boost converter

The characteristics of the buck–boost converter are mainly:

- Polarity of the output voltage is opposite to that of the input hence called as inverting regulator.
- The output voltage can vary continuously from 0 to  $-\infty$  (for an ideal converter).

#### V.A MODELLING OF CONVERTER

##### V.A.1 INDUCTOR SELECTION

The inductor must have high current rating. The equation of buck and boost mode is given respectively,

$$L > \frac{v_{out} \times (v_{in_{max}} - v_{out})}{k_{ind} \times f_s \times I_{out} \times v_{i_{max}}} \text{ and} \tag{6}$$

$$L > \frac{v_{in_{min}}^2 \times (v_{out} - v_{in_{min}})}{k_{ind} \times f_s \times I_{out} \times v_{out}^2} \tag{7}$$

$k_{ind}$  Co-efficient that represents the ripple current of the inductor relative to maximum output current. It varies between 0.2 to 0.4.

### V.A.2 CAPACITOR SELECTION

The input capacitor selection must be minimum value to stabilize the input voltage due to the peak current requirements of switching current. The output capacitor selection is that the value must be larger than both minimum required output capacitance of buck and boost. The equation of buck and boost mode of capacitor is given respectively,

$$C_{out_{min}} = \frac{k_{ind} \times I_{out}}{8 \times f_{sw} \times v_{out_{ripple}}} \text{ and} \tag{8}$$

$$C_{out_{min}} = \frac{I_{out} \times \delta}{f_{sw} \times v_{out_{ripple}}} \tag{9}$$

$\delta$  is the dutty cycle.

$$\delta = \frac{T_{on}}{T} \tag{10}$$

The two modes of operation of converter is continuous and discontinuous mode. When the current through the inductor never comes to zero it is continuous mode and when it comes to zero it is discontinuous mode of operation.

The average output voltage is

$$v_{o(av)} = -\frac{\delta}{1-\delta} v_s \tag{11}$$

The ripple in the output current is

$$i_{o(ripple)} = \frac{\delta}{fL} v_s \tag{12}$$

The voltage output ripple is

$$v_{o(ripple)} = \frac{\delta I_o}{fC} I_{o(av)} \tag{13}$$

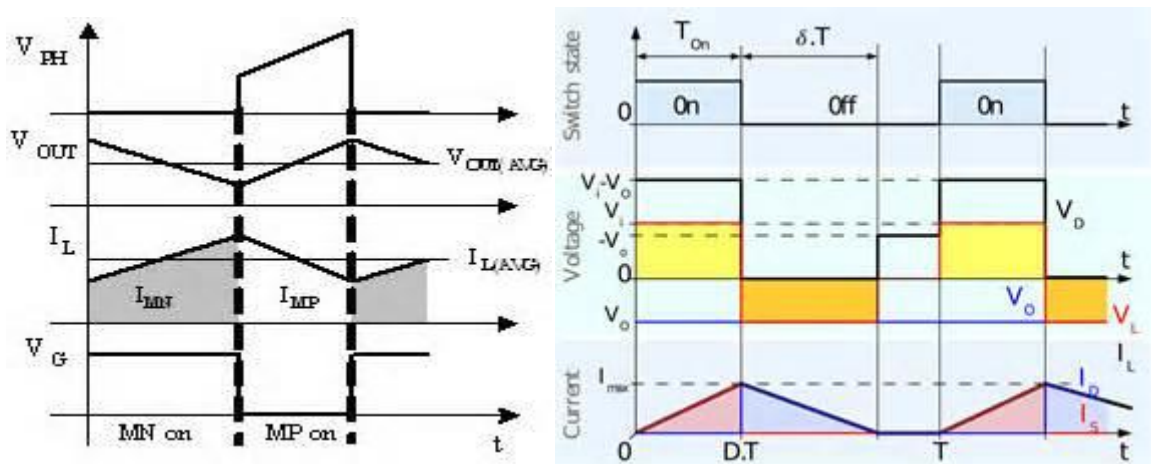


Fig 10. Waveform of Buck Boost converter.

The Buck-Boost converter is used in applications where the inverter output is required. It is high efficient and the short circuit protection can be implemented.

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