Simulation of a Non Inverting Buck Boost Converter Fed BLDC Motor Drive with Four Quadrant Operation

Annie Bincy C.A
IDAC, EEE department
Rajagiri School of Engineering and Technology
Kochi, Kerala, India

Salitha K
Asst. Professor, EEE department
Rajagiri School of Engineering and Technology
Kochi, Kerala, India

***Abstract*—Brushless DC motors are gaining popularity rapidly. They are widely used in industries such as appliances, traction, aerospace and instrumentation. Hence four quadrant operation of BLDC motor becomes very vital. In this paper, BLDC motor is operated in all the four quadrants of torque speed plane using a non inverting buck boost converter. Simulation of the proposed model was done in MATLAB/SIMULINK.**

Keywords—BLDC motor,non inverting converter,switching mode regulators.

I. INTRODUCTION

Permanent magnet brushless DC motors are widely used in many applications such as tractions [2], household appliances, etc because of its high efficiency, high power factor, high torque, simple control and lower maintenance. Unlike a DC motor, the brushes are eliminated in BLDC motor and windings are connected to the control circuits. Electronic commutation is used in it.BLDC motors can use either external or internal position sensors to sense the position of the rotor as the inverter phases, acting at any time must be commutated depending up on the rotor position.Sensorless methods are also used to sense the position of the rotor.

DC converters are used as switching mode regulators usually converts an unregulated voltage to a regulated DC output voltage. Single ended primary inductor conductor (SEPIC), Zeta and two switch buck boost converters are three popular non inverting converter topologies used in industrial personal computers and automotive start stop systems. When operating in buck boost mode, all three converters experience high conduction loss as well as high current stress [6].A proposal utilizing two switch buck boost converter by operating in either buck mode or boost mode can eliminate this problem.

In this paper, a non inverting buck boost converter fed BLDC motor drive with four quadrant operation is explained and simulated using MATLAB/SIMULINK.

II. FOUR QUADRANT OPERATION

There are four possible quadrants or modes of operation using a BLDC motor as shown in figure 1.

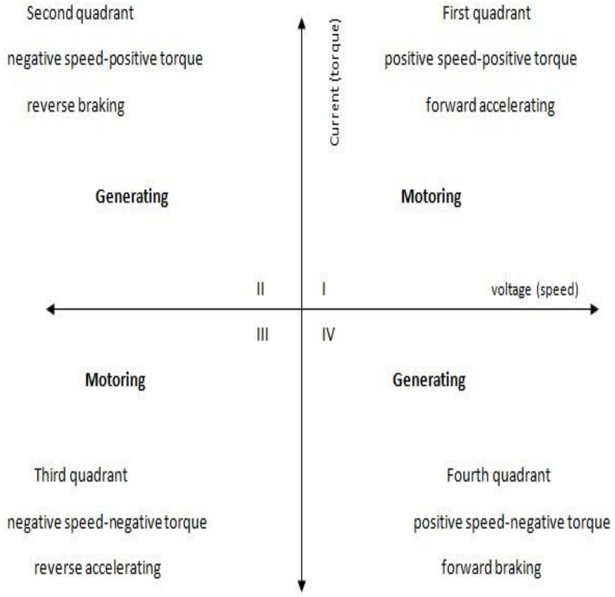

Fig. 1.Four quadrants of operation

When a BLDC motor is operating in the first and third quadrants, the supplied voltages is greater than the back emf which are forward motoring (accelerating) and reverse motoring (accelerating) modes. But the direction of current flow differs. And when the motor operates in the second and fourth quadrants, the value of back emf generated by the motor is higher than the supplied voltages which are forward braking and reverse braking modes of operation. Here also the direction of current flow is reversed.

The BLDC motor is initially run in the clockwise direction and made to rotate in the counter clockwise direction when a speed reversal command is obtained by the controller, which will bring the rotor to a standstill position [1].A continuous energisation of the main phase is done, instead of waiting for the absolute standstill position.Therefore, there is necessity for finding out the instant when the rotor of the motor is positioned for reversal. Hall effect signals are used to determine the position of the rotor and from the hall sensor outputs, we can determine whether the machine has reversed its direction.

III. PROPOSED SCHEME

Figure 2 shows the proposed scheme for a BLDC motor drive. The drive consists of a diode bridge rectifier, non inverting converter, MOSFET based voltage source inverter, PWM controller and switching logic from the hall sensor signals.

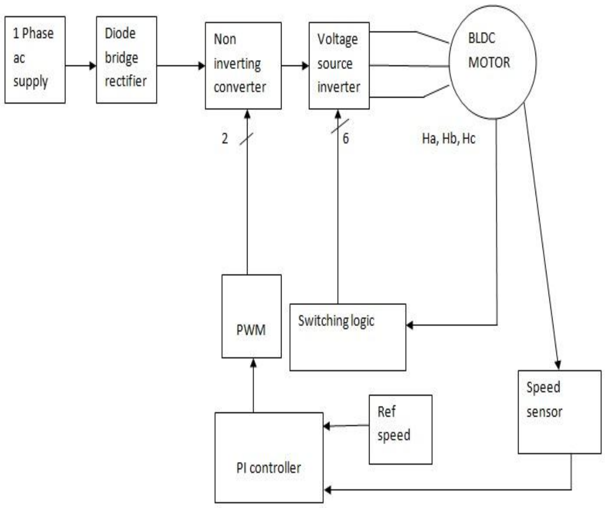

Fig. 2.Proposed scheme

A. Non inverting converter

The two switch buck boost converter is used as the non inverting converter which is a cascaded combination of buck converter followed by a boost converter. It uses two active switches for its operation. The design is same as that of the inverting buck boost converter topology [5].Due to this design, this converter can work as buck, boost and buck boost converters.

- Buck mode of operation

Figure 3 shows the circuit diagram of two switch non inverting converter for buck mode of operation. Switch S2 remains always off and diode D2 is always on. Switch S1 and diode D2 form the buck switch leg.

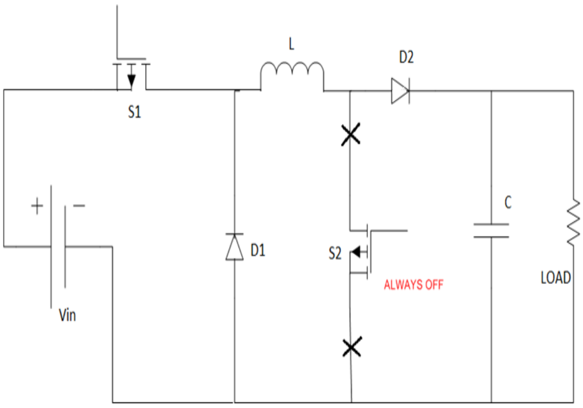

Fig. 3.Buck mode of operation of non inverting converter

- Boost mode of operation

Boost mode of operation of the two switch non inverting converter is given by the figure 4.In this, switch S1 remains on always and diode D1 is always off. Switch S2 and diode D2 form the boost switch leg.

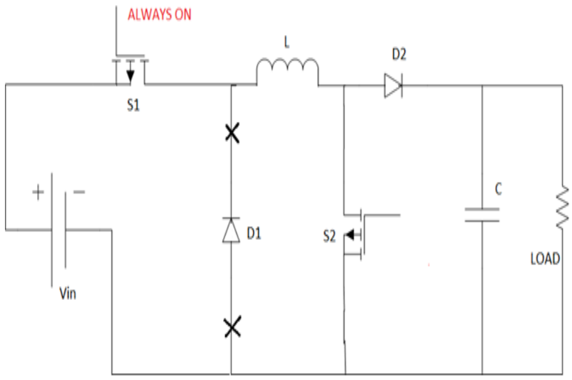

Fig. 4.Boost mode of operation of non inverting converter

- Buck-Boost mode of operation

When PWM is given to both switches S1 and S2 of the non inverting converter, buck boost mode of operation is obtained. But switching losses and conduction losses are increased due to the operation of two switches simultaneously and control complexity also increases. Hence this mode of operation is not used.

Table 1.briefly explains the switching pattern and complexity levels for buck, boost, and buck boost mode of operations.

TABLE 1.SWITCHING PATTERN FOR MODE OF OPERATIONS

Sl. No.	Switch (S1)	Switch (S2)	Mode of operation	Complexity
1.	PWM	OFF	BUCK	Simple
2.	ON	PWM	BOOST	Simple
3.	PWM	PWM	BUCK BOOST	Moderate

B. BLDC motor drive

BLDC motor is fed by a voltage source inverter. Hall Effect sensors are embedded into the stator of BLDC motors which senses the rotor position at every instant. From the Hall Effect signals, appropriate switching logic is determined for providing firing pulses for the switches in voltage source inverter.

Actual speed of the motor is sensed and compared with a reference speed and the error is given to a PI controller. The values of proportional gain (Kp) and integral gain (Ki) are determined by trial and error method.PWM method is used to generate switching signals for non inverting converter.

IV. SIMULATION

Figure 5 shows the simulation diagram for non inverting buck boost converter based BLDC motor drive with four quadrant operation. The simulation time was 2 seconds. The input was 24V.

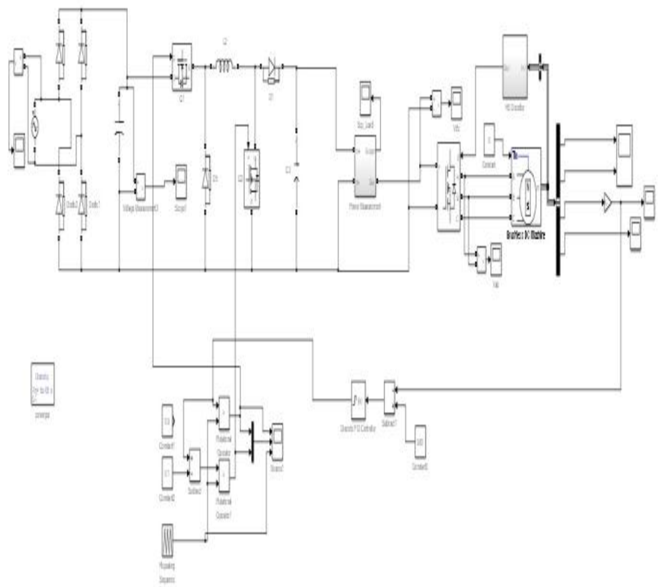

Fig. 5.Simulation diagram for non inverting buck boost converter fed BLDC motor drive with four quadrant operation

Hall signal (HS) decoder block is given in figure 6.

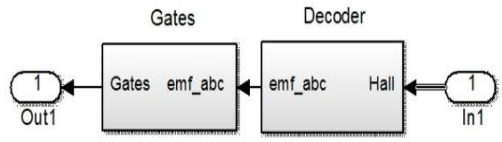

Fig. 6.HS decoder block

V. RESULTS

The results obtained after simulation in each quadrants is shown below.

A. First quadrant

At initial conditions, the motor is operated in forward motoring mode. Figure 7 shows the DC output voltage waveform from a non inverting converter.

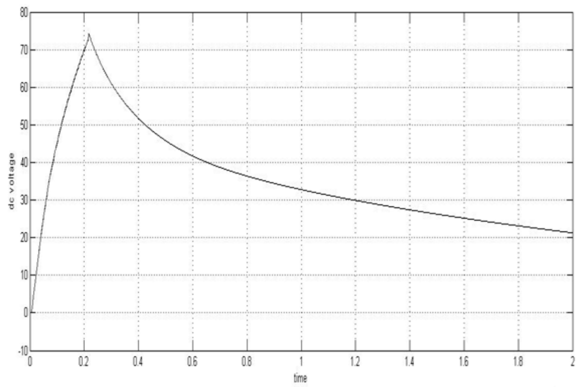

Fig. 7.DC output voltage waveform from a non inverting converter

It is seen from the graph that, for an input of 24V, boost operation is done at first and voltage is incremented to about 75V and thereafter buck operation is done.

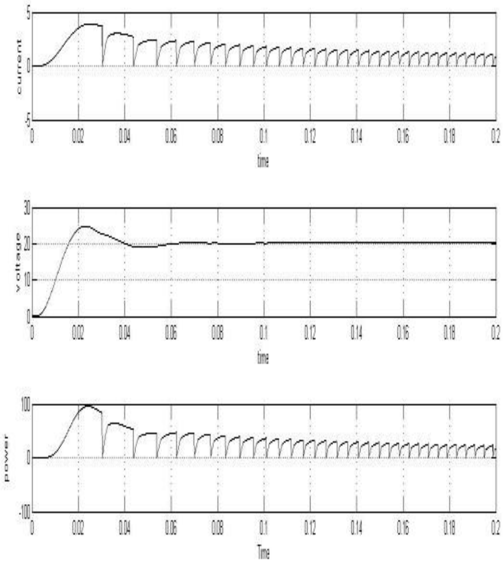

Fig. 8.Current, voltage, power waveforms

Figure 8 shows current, voltage, power waveforms respectively. It is observed that power is positive in this quadrant of operation.

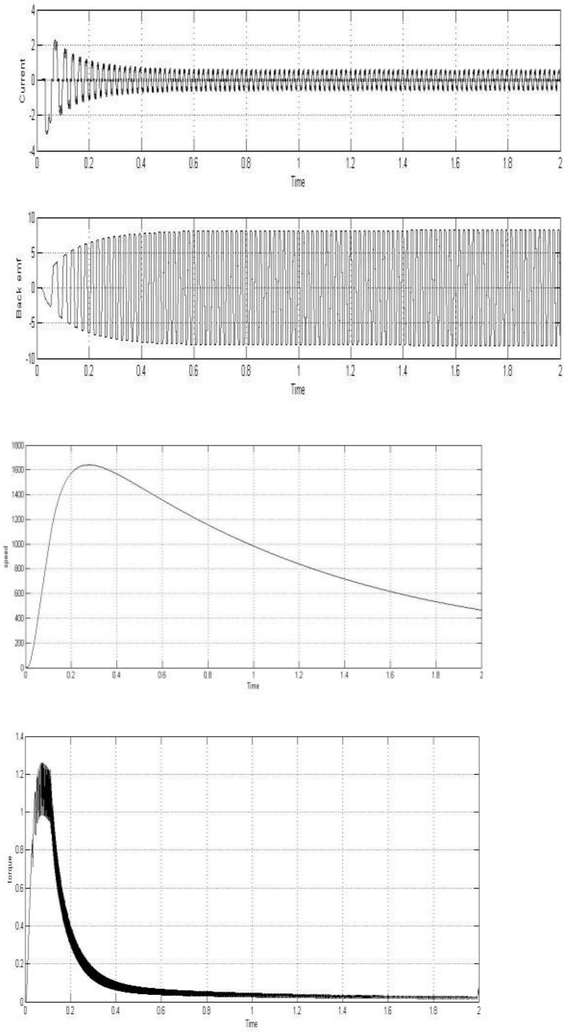

Fig. 9.Stator current, back emf, speed and torque of BLDC motor

Stator current, back emf, speed and torque of BLDC motor is given by the figure 9.Both torque and speed are positive in this quadrant.

B. Second quadrant

When a speed reversal command is given, motor undergoes braking operation in forward direction and speed tending to zero and starts rotating in the reverse direction.

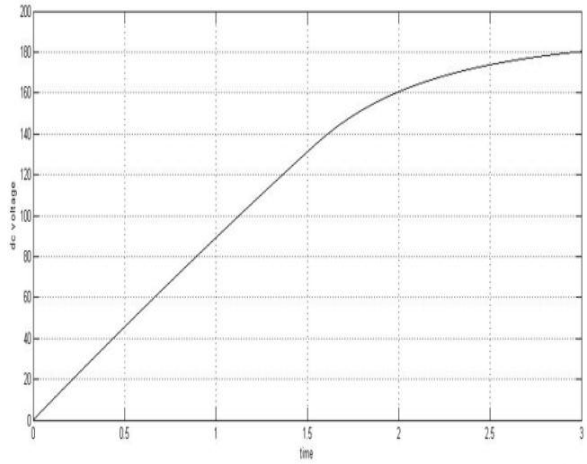

Fig. 10.DC voltage waveform

In figure 10, DC voltage, ie, voltage across the capacitor increases to 180V due to generating action of the BLDC motor. Motor acts like a generator in this quadrant.

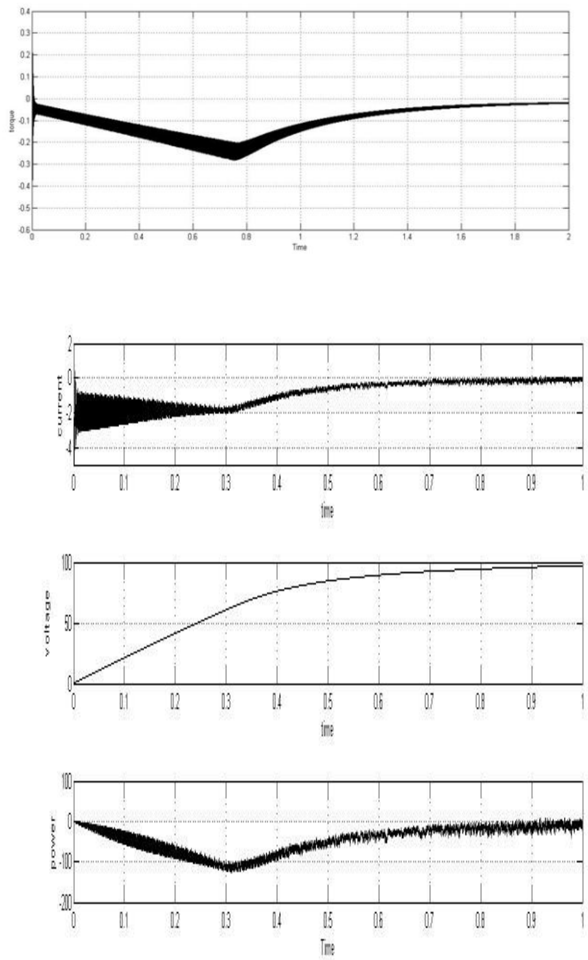

Fig. 11.Torque, current, voltage and power waveforms

Figure 11 shows the torque, current, voltage and power waveforms respectively.Current, power and torque is negative in this quadrant of operation.

C. Third quadrant

The BLDC motor will rotate in counter clockwise direction. By changing the phase sequence of the BLDC motor from ABC to BAC counter clockwise rotation is obtained.

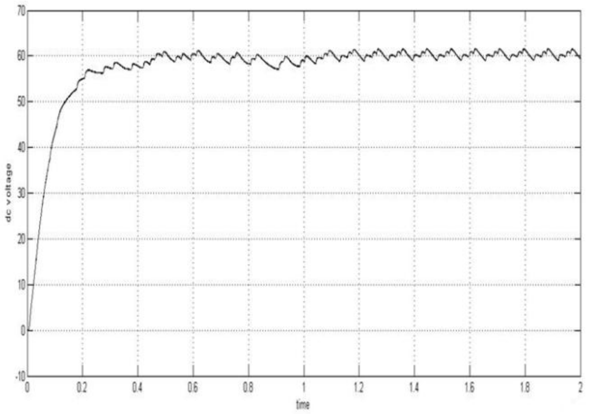

Fig. 12.DC voltage waveform

Figure 12 shows the DC voltage waveform from the converter after boost operation. Counter clockwise motoring is observed in this quadrant.

D. Fourth quadrant

In this quadrant, motor acts as a generator and rotates in the counter clockwise direction. Figure 13 shows the capacitor voltage in generation mode which is observed to be higher than in motoring mode.

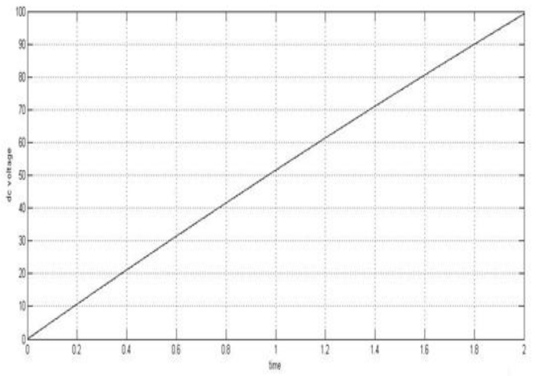

Fig. 13.DC voltage waveform

VI. CONCLUSION

The four quadrant operation of BLDC motor using a non inverting buck boost converter was modeled using MATLAB/SIMULINK.It can be concluded that, by using a two switch converter either in buck or boost mode, switching loss as well as conduction loss can be reduced as only one switch is used at a time. And also back emf in a BLDC motor is directly proportional to the speed of the rotor and field strength of the motor, which means, if the speed or field of the motor is increased, back emf is increased and vice versa. The back emf acts as a resistance and opposes the current flow so if the speed of the motor or field strength increases, back emf increases which in turn increases the resistance to the current flow to the windings and hence only less current is delivered to the motor.

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