International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

# Simulation of Buck Type Current Source Inverter fed BLDC Motor

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***Abstract*—DC supply to the BLDC motor has to be transmitted as a variable voltage or current to the motor using voltage source or current source inverter. In this paper a comparative simulation study between voltage source, current source and buck type converter fed BLDC motor drive is done.**

***Keywords— Inverter Topologie, Buck Converter***

## I. INTRODUCTION

Brushless DC motor is a permanent magnet AC motor with trapezoidal back emf and rectangular stator currents. It is a synchronous motor with zero slip as stator and rotor magnetic field moves at same speed. 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 like PC cooling fans, DVD players, turntables, and even electric cars.

BLDC motor is powered by a DC supply. This DC voltage has to be transmitted as a variable voltage or current to the motor using an inverter. Voltage source inverter (VSI) is generally used inverter topology for feeding the motor. A bulky and costlier capacitor is used to maintain voltage of a voltage source inverter constant. Supply harmonics, reduced motor short circuit problems, motor insulation degradation & bearing failure resulting from voltage surges, unacceptable electromagnetic interference, and acoustic noise are some of the problems faced by VSI fed BLDC motor.

To eliminate most of these problems, VSI can be replaced by a current source inverter (CSI).CSI uses an inductor and three AC filter capacitors for energy storage instead of a bulky DC bus capacitor as in the case of VSI. Substantial reduction in inverter cost and volume, increased reliability, a much higher constant power-speed range and improved motor efficiency and lifetime can be achieved by the use of CSI.

In this paper, current source is implemented by buck converter to reduce the value of inductance, to improve speed and current response and to regulate the current. Buck converter provides switch mode DC-DC conversion with advantages of simplicity and low cost. Reliability and life is improved as inductor is used as energy storage element. It is applied in areas where load current remains constant irrespective of load like hoist.

## II. INVERTER TOPOLOGIES FOR BLDC MOTOR

### *A. Voltage Source Inverter*

Voltage source inverter allows a variable frequency supply to be obtained from a DC supply. Fig. 1 shows a VSI driving a motor load. Any self commutating device can be used. Generally, MOSFET is used in low voltage and low power inverters, IGBT and power transistors are used up to medium power levels and GTO and IGCT are used for high power levels. For low range power applications and to cover medium to high power applications, single phase VSIs and three phase VSIs are respectively used.

DC source voltage at input terminals is constant or input impedance is negligible or small. DC supply to the inverter is obtained from a battery or from a rectifier.

At the input terminals a large capacitor is connected to keep input DC voltage constant and to suppress harmonics fed back to the source.VSI requires only a simple diode bridge as a frond-end converter, which minimises costs, increases efficiency and reliability for the rectifier stage.

Even though a VSI is widely used, it has some barriers and limitations. Additional power converter stage increases system cost as well as reduces efficiency. Dead time must be provided to eliminate simultaneous turn on of upper and lower switches. This will cause waveform distortion and ripples.

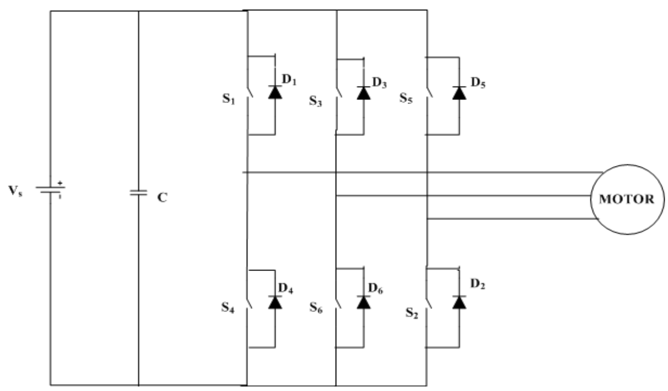


Fig. 1: VSI driving a motor load

ISSN: 2278-0181
Vol. 4 Issue 08, August-2015

Motor insulation is affected due to high dv/dt transients and if it is not checked, it may reduce the life time significantly.

### *B. Current Source Inverter*

Current source inverter is fed from a constant current source in which load current remains constant irrespective of the load on the inverter. Fig. 2 shows the current source inverter with motor load. Depending on the magnitude of load impedance, load voltage changes. When a large inductance is connected in series with a voltage source, it behaves as a current source. The large inductance maintain current constant.

Through a controlled rectifier bridge or through a diode bridge and a chopper, a fixed AC voltage is converted to DC input to current source inverter. CSIs are typically used to supply high power factor loads whose impedance either remain constant or decreases at harmonic frequencies to prevent problems either on switching or with harmonic over voltages.

CSI eliminates several problems faced by VSI.CSI uses an inductor and three filter capacitors as energy storage components instead of costly and bulky capacitor as in VSI. Reduction in inverter cost and volume, increased reliability, a much higher constant power-speed range and improved motor efficiency and lifetime are some of the advantages offered by CSI.

*Advantages*

- Any misfiring or short circuit in the inverter wouldn't cause dangerous currents since the input DC current is controlled.
- Without feedback diodes, it can handle reactive or regenerative loads.
- Wide speed control range.

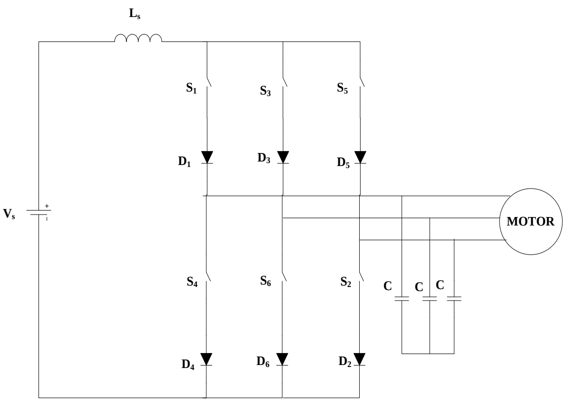


Fig. 2: CSI driving a motor load

*Disadvantages*

- To maintain current constant, large inductance is required which increases cost and size.
- High conduction loss.
- Have sluggish performance and stability problems at light loads, and high frequency.

## III. BUCK TYPE CURRENT SOURCE INVERTER FED BLDC MOTOR

The circuit diagram for Buck type CSI fed BLDC motor drive is shown in Fig. 3.Supply to the BLDC motor is given through a three phase current source inverter. From position sensors, information about the rotor position is obtained from which gating signals to the inverter switches can be provided using a commutation circuitry. Usually a current source inverter is implemented by connecting a high value of inductor in series with a voltage source. To minimize the value of inductance, to obtain a smooth speed and current characteristics and to regulate the current a buck converter is used instead of inductor. The speed of BLDC motor drive is controlled by varying the DC link current of the CSI feeding the BLDC motor. A speed control loop as well as a current control loop is employed. In speed control loop, rotor speed is compared with reference value and the resulting error is fed to a PID controller which regulates DC link current. Rotor speed error is fed to one PID controller whose output is compared with DC link current and this error is fed to another PID controller. Gating signal to the buck converter switch is provided by comparing this PID controller output with a fixed frequency fixed amplitude saw-tooth signal.

The value of buck inductor can be designed using (1) assuming the operation in continuous conduction mode.

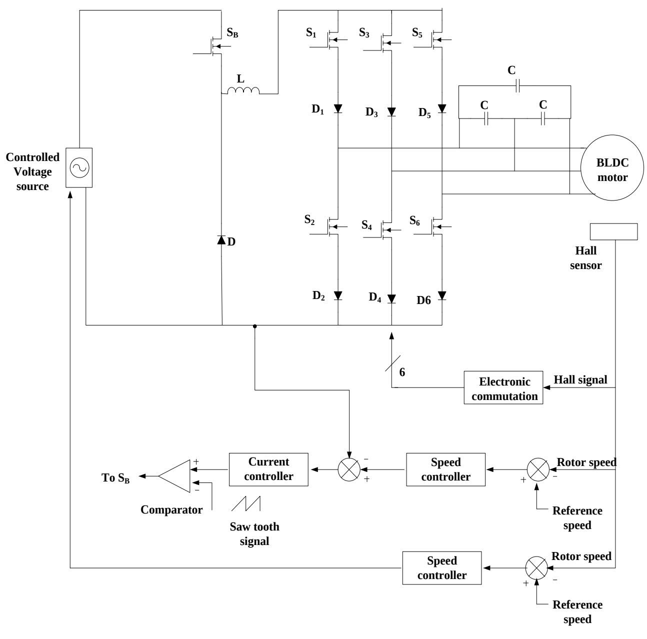


FIG. 3: BUCK TYPE CSI FED BLDC MOTOR

$$L = (V_{in,max} - V_{out})\ x\ \frac{V_{out}}{V_{in,max}}\ x\ \frac{1}{f_{sw}}\ x\ \frac{1}{LIR}\ x\ \frac{1}{I_{out}} \quad (1)$$

Where LIR is the inductor current ratio expressed as a percentage of $I_{out}$. The value of LIR represents a trade off between efficiency and load transient response. An LIR = 0.3 represents a good trade off between the two.

## IV. SIMULATION STUDIES

### *A. Voltage source inverter fed BLDC motor*

Simulation diagram for voltage source inverter fed BLDC motor is shown in Fig. 4.A 300 V supply is given and a load of magnitude 1 is applied at 0.5 sec. Simulated waveforms for voltage source inverter fed BLDC motor is shown in Fig. 5.Rotor speed slowly rises and reaches a value of 510 rad/s at 2.5s. On application of load torque, speed suddenly decreases to a value 456rad/s.

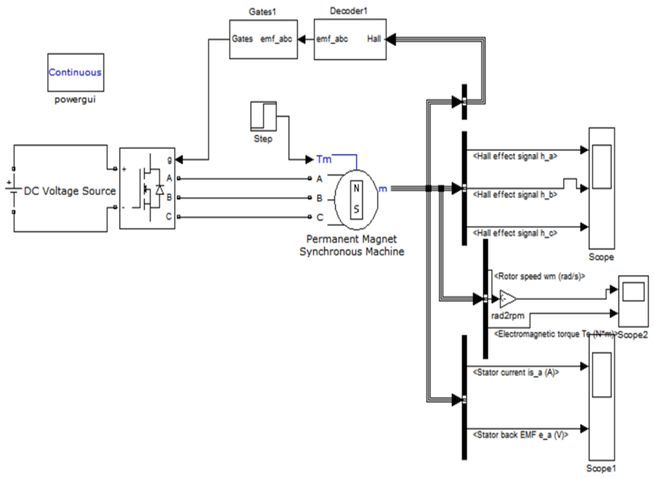


Fig. 4: Voltage source inverter fed BLDC motor

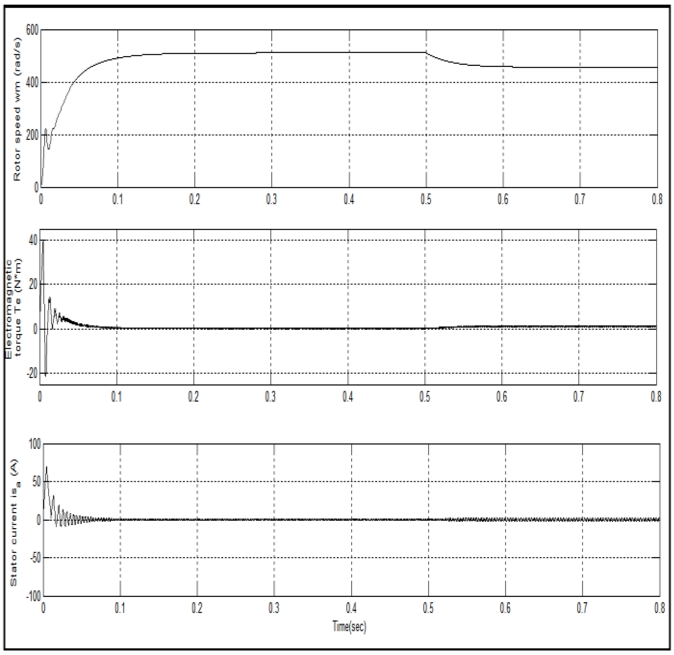

Fig. 5: Simulated waveforms for voltage source inverter fed BLDC motor

### *B. Current source inverter fed BLDC motor*

Simulation diagram for current source inverter BLDC motor is shown in Fig. 6. A 300 V supply is given and a load of magnitude 1 is applied at 0.5 sec. Simulated waveforms for current source inverter BLDC motor is shown in Fig. 7.Rotor speed rises to a high value of 600rad/s initially, then decreases and reach a stable value of 415 rad/s by 0.4 s. But due to application of load speed reduces to 407 rad/s.

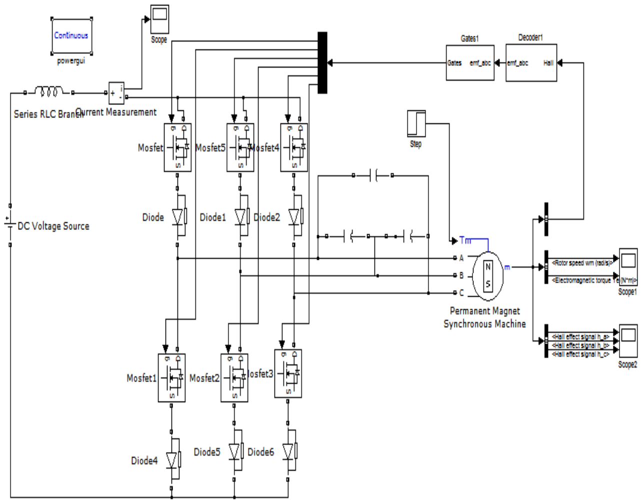


Fig. 6: Voltage source inverter fed BLDC motor

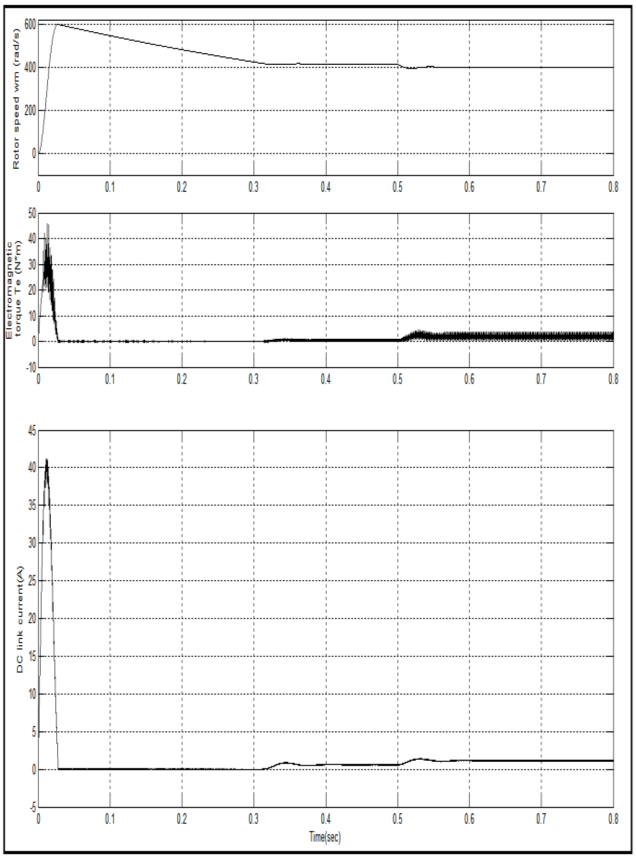

Fig. 7: Simulated waveforms for current source inverter fed BLDC motor

### *C. Buck type current source inverter fed BLDC motor*

Simulation diagram for Buck type current source inverter fed BLDC motor is shown in Fig. 8.Load torque was given as step input with magnitude 1 at 0.5 sec.

Value of inductor is selected by using (1).Assuming, $V_{in, max}$=1.66x10e5V, $V_{out}$=250V, $f_{sw}$=25kHz, $I_{out, max}$=1.65 A, we get the value of inductance as 20mH.

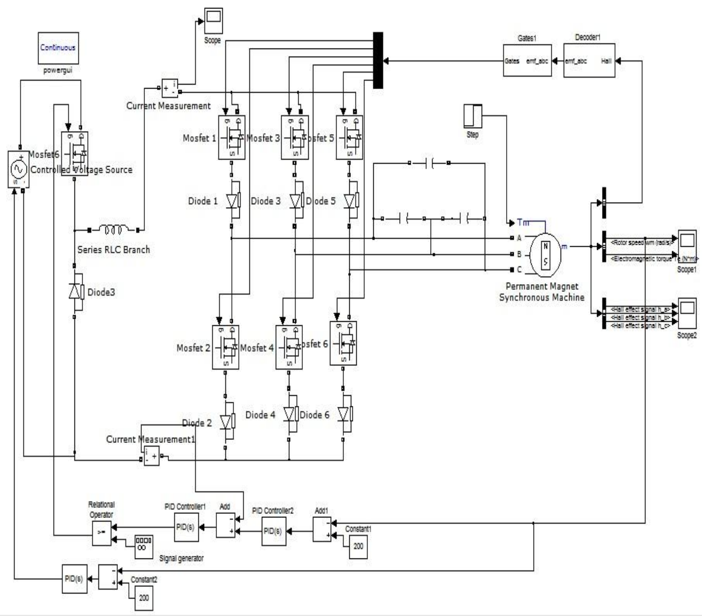


Fig. 8: Buck type current source inverter fed BLDC motor

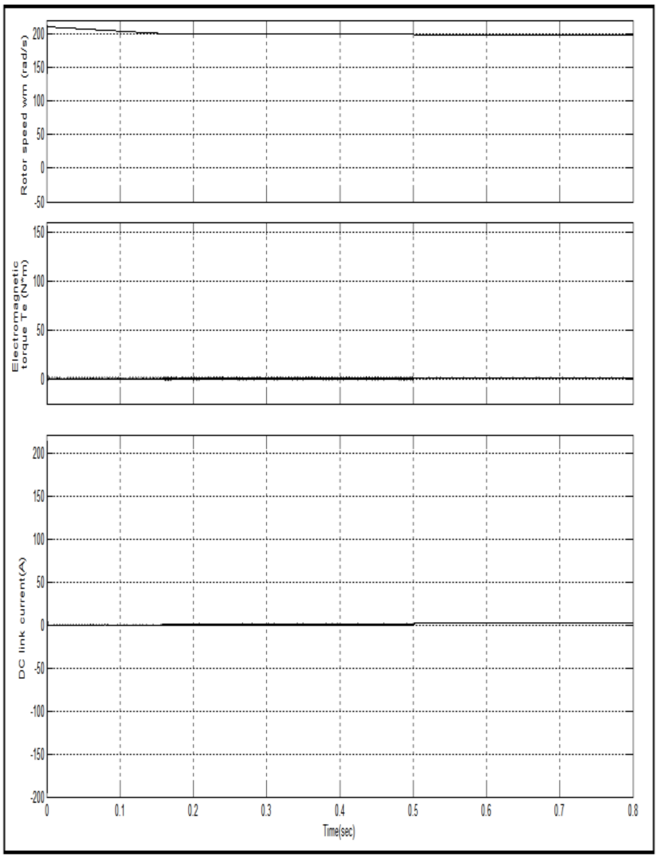


Fig. 9: Simulated waveforms of buck type current source inverter fed BLDC motor

Table 1: Simulation parameters

| | |
|---|---|
| Pole number | P = 8 |
| Buck inductor | L = 20mH |
| Buck switching frequency | $f_{tri}$ = 25 kHz |
| CSI output capacitor | C = 0.033 F |

Simulation parameters are tabulated in Table 1.Simulated waveforms for buck type current source inverter fed BLDC motor is shown in Fig. 9.Speed attains value of 200rad/s by 0.15s. DC link current is seen to be a constant at 2A.

## V. CONCLUSION

A comparative simulation study was carried out between voltage source inverter fed BLDC motor, current source inverter fed BLDC motor and buck type current source inverter fed BLDC motor.In voltage source inverter fed BLDC motor, speed waveform gradually reaches steady state value. Torque and stator current waveform shows rapid fluctuations.

In current source inverter fed BLDC motor, speed waveform gradually settles and doesn't show much variation even after load is applied. However, rapid fluctuation in torque and stator current is minimized compared to voltage source inverter fed BLDC motor. High value of inductance results in higher cost.

To minimize the value of inductance, to obtain better speed and current waveforms and to regulate current, buck type current source inverter fed BLDC motor is used.

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