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Speed Control of BLDC Motor using Buck-Boost Converter

Shubham Rambhau Jaware[1], Atul N. Kausal[2]

PG Student [EPS], Dept. of Electrical Engineering, Dr.Sau. KGIET, Darapur, Amravati, India[1]

Assistant Professor, Dept. of Electrical Engineering, Dr.Sau. KGIET, Darapur, Amravati, India[2]

ABSTRACT: This paper presents an overview of DC–DC Converter feeding BLDCM drive with adjustable speed control for low power application. The purpose of DC–DC converter is to provide controlled DC voltage to the BLDCM drive for an uncontrolled DC output of a single-phase AC mains. In proposed system, single-phase supply is feeding to rectifier which is uncontrolled type and DC–DC Converter is used to control the voltage of DC link capacitor. The DC link capacitor is used to control the speed of BLDCM. The output of DC link capacitor fed to inverter and speed of BLDCM can be controlled by changing switching position of inverter switches. A voltage follower and current follower technique is used for operation of BLDCM under wide range of speed adjustment. There are various types of DC–DC Converter topology used for controlling of BLDCM are explained below.

KEYWORDS: Brushless Direct Current Motor (BLDCM), Discontinuous Inductor Current Mode (DICM), Power Factor Correction (PFC), Power Quality (PQ)

I. INTRODUCTION

BLDCM, are becoming more popular and find a wide variety of applications in the field of science and technology where space and weight are the key factors. Due to brushless structure, high reliability, wide speed adjustment, precise speed control and high output power density are the attractive features of BLDCM. Recently, they have been widely used in home appliances and industry for energy saving aspects but it suffers from the problems of commutation torque ripples which leads to mechanical vibration and noise. A detailed analysis on commutation torque ripple is described. It is identified that torque ripples are about 49.50 % or more than that of rated torque. BLDCM are preferred motors for a compressor of an air-conditioning system due to its features like high efficiency, wide speed range and low maintenance requirements. The operation of the compressor with the speed control results in an improved efficiency of the system while maintaining the temperature in the air-conditioned zone at the set reference consistently. Whereas, the existing air conditioners mostly have a single-phase induction motor to drive the compressor in on/off control mode. This results in increased losses due to frequent on/off operation with increased mechanical and electrical stresses on the motor, thereby poor efficiency and reduced life of the motor. Moreover, the temperature of the air conditioned zone is regulated in a hysteresis band. Therefore, improved efficiency of the Air conditioning system will certainly reduce the cost of living and energy demand to cope-up with ever-increasing power crisis. A BLDCM which is a kind of three-phase synchronous motor with permanent magnets (PMs) on the rotor and trapezoidal back EMF waveform operates on electronic commutation accomplished by solid state switches. It is powered through a three-phase voltage source inverter (VSI) which is fed from single-phase AC supply using a diode bridge rectifier (DBR) followed by smoothening DC link capacitor.

II. LITERATURE SURVEY

Reference [1] explains the power factor corrected (PFC) bridgeless (BL) modified buck–boost converter-fed brushless direct current (BLDC) motor drive as a cost-effective solution for low-power applications. An approach of speed control of the BLDC motor by controlling the dc link voltage of the voltage source inverter (VSI) is used with a single voltage sensor. This facilitates the operation of VSI at fundamental frequency switching by using the electronic commutation of the BLDC motor which offers reduced switching losses to control the dc-dc voltage between VSI and the output. Reference [2] explains power quality buck-boost converter fed permanent magnet brush less DC motor

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(PMBLDCM) drive is employed for adjustable speed operation of PMBLDCM. A single-phase, single-switch AC-DC converter topology based on non-isolated buck-boost converter is employed for power factor correction (PFC) and operated with voltage follower control in discontinuous conduction mode (DCM) operation for sensor reduction.This PFC controller ensures near unity power factor in wide speed range of the drive while restricting the total harmonic distortion (THD) in AC mains current within the specified limits of the IEC standard.

III. BRUSHLESS DC MOTOR

BLDCM are one of the motor types rapidly gaining popularity. BLDCM are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation. As the name implies, BLDCM do not use brushes for commutation; instead, they are electronically commutated. BLDCM have many advantages over brushed DC motors and induction motors. A few of them are as follows:

- High dynamic response
- High efficiency
- Long life
- Smooth operation
- Wide speed ranges
- Compact
- Minimal power loss

3.1Construction and operating principle

BLDCM are a type of synchronous motor. This means the magnetic field generated by the stator and the magnetic field generated by the rotor rotate at the same frequency. BLDCM do not experience the “slip” that is normally seen in induction motors. BLDCM comes in poly phases i.e., single-phase, two-phase and three-phase configurations. Corresponding to its type, the stator has the same number of windings. Out of these, three-phase motors are the most popular and widely used.

3.2The stator part

The stator of a BLDCM consists of stacked steel laminations with windings placed in the slots that are axially cut along the inner periphery as shown in Fig.1 Traditionally, the stator resembles that of an induction motor; however, the windings are distributed in a different manner. Most BLDCM have three stator windings connected in star fashion. Each of these windings are constructed with numerous coils interconnected to form a winding. One or more coils are placed in the slots and they are interconnected to make a winding. Each of these windings are distributed over the stator periphery to form an even numbers of poles. There are two types of stator windings variants: trapezoidal and sinusoidal motors.

3.3 The rotor part

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles. Based on the required magnetic field density in the rotor, the proper magnetic material is chosen to make the rotor. Ferrite magnets are traditionally used to make permanent magnets. As the technology advances, rare earth alloy magnets are gaining popularity. The ferrite magnets are less expensive but they have the disadvantage of low flux density for a given volume. In contrast, the alloy material has high magnetic density per volume and enables the rotor to compress further for the same torque.

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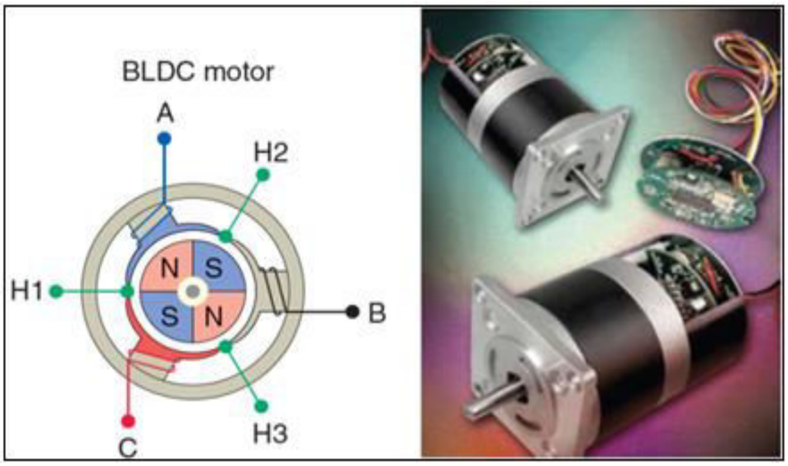

Fig. 1.Construction of BLDC motor

3.4Hall sensor

Unlike a brushed DC motor, the commutation of a BLDCM is controlled electronically. To rotate the BLDCM, the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence. Rotor position is sensed using Hall effect sensors embedded into the stator. Most BLDCM have three Hall sensors embedded into the stator on the non-driving end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

IV. TOPOLOGY OF DIFFERENT TYPES OF DC–DC CONVERTER

These DC–DC converter are classified into following types:

1. Buck (Step-down)
2. Boost (Step-up)
3. Buck–Boost (Step-up/Step-down)

1. Buck Converter

A buck converter (step-down converter) is a DC-to-DC power converter which steps down voltage (while stepping up current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) typically containing at least two semiconductors (a diode and a transistor, although modern buck converters frequently replace the diode with a second transistor used for synchronous rectification) and at least one energy storage element, a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Its name derives from the inductor that "bucks" or opposes the supply voltage. Switching converters (such as buck converters) provide much greater power efficiency as DC-to-DC converters than linear regulators, which are simpler circuits that lower voltages by dissipating power as heat, but do not step up output current. The efficiency of buck converters can be very high, often over 90%, making them useful for tasks such as converting a computer's main supply voltage, which is usually 12 V, down to lower voltages needed by USB, DRAM and the CPU, which are usually 5, 3.3 or 1.8 V.In which buck converter during on period when switch is ON, the supply terminals are connected to the load terminals. During the period Toff, when the switch is OFF, load current flows through the freewheeling diode DF.So load terminals are short circuited by DF and load voltage therefore zero during Toff. In this way, by varying the duty cycle of switch output voltage is varried. The average load voltage Eo is given by,

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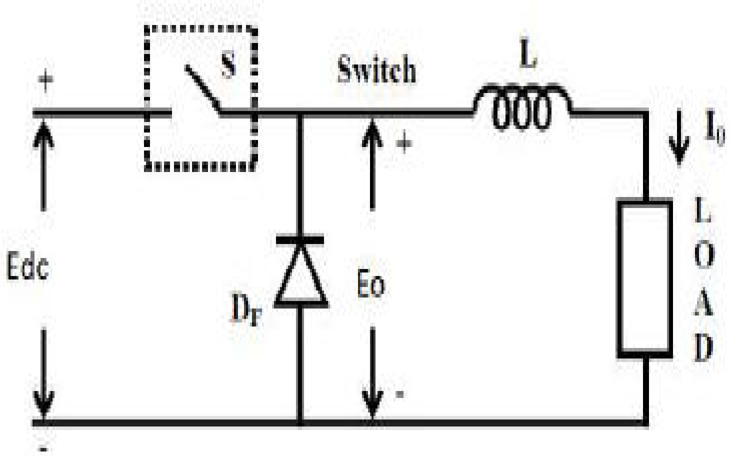

Fig. 2.Buck Converter (DC-DC)

$$Eo = Edc\frac{Ton}{Ton + Toff}$$

Where,

Ton= on time of the chopper

Toff = off time of chopper

T = Ton+Toff= chopping period

Buck converters operate in continuous mode if the current through the inductor never falls to zero during the commutation cycle. In this mode, the operating principle is described by the plots in fig. 3 In some cases, the amount of energy required by the load is too small. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle shown in fig. 4. The inductor current falling below zero results in the discharging of the output capacitor during each cycle and therefore higher switching losses. A different control technique known as pulse-frequency modulation can be used to minimize these losses.

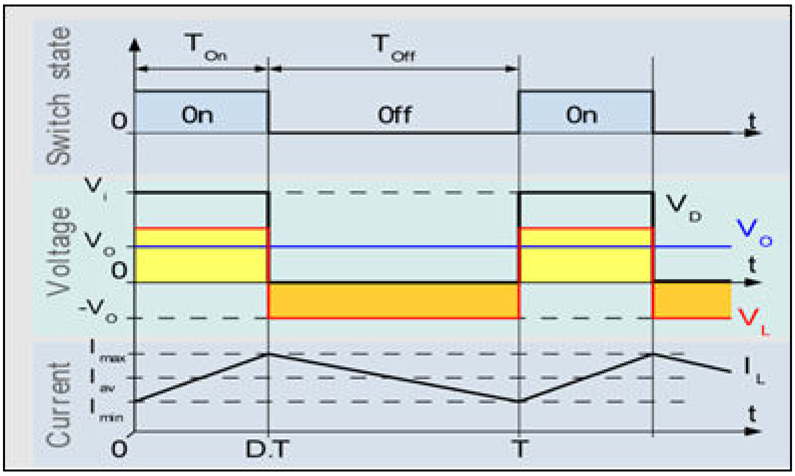

Fig. 3.Evolution with time of the voltage in an ideal buck converter operating in continuous mode

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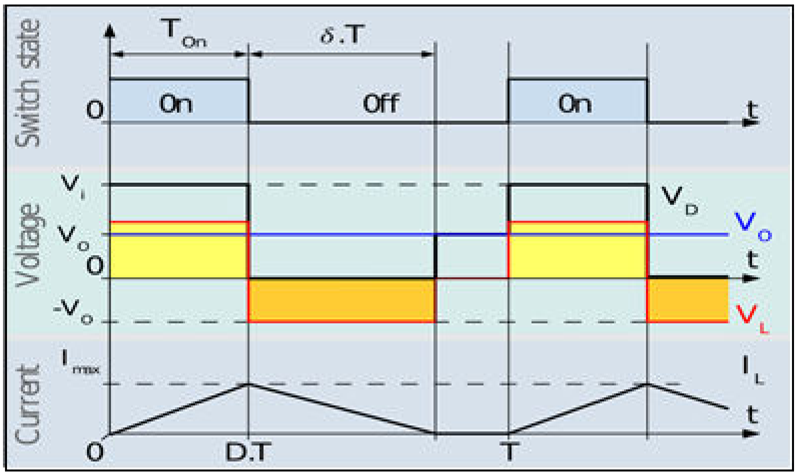

Fig. 4.Evolution of the voltages and currents with time in an ideal buck converter operating in discontinuous mode

2. Boost Converter

In which boost converter when the switch is ON, the inductor L is connected to the supply Vs and inductor stores energy during on period Ton when the switch is Off,the inductor current is forced to flow through the diode and load for a period Toff. As the current tends to decrease, polarity of the emf induced L is reversed to that shown in fig. 5. The result voltage across the load Vo becomes

$$\mathrm{Eo} = \mathrm{Edc} + \mathrm{L}\frac{\mathrm{dis}}{\mathrm{dt}}$$

During the on period the switch is Ton the energy input to the inductor from the source is given by

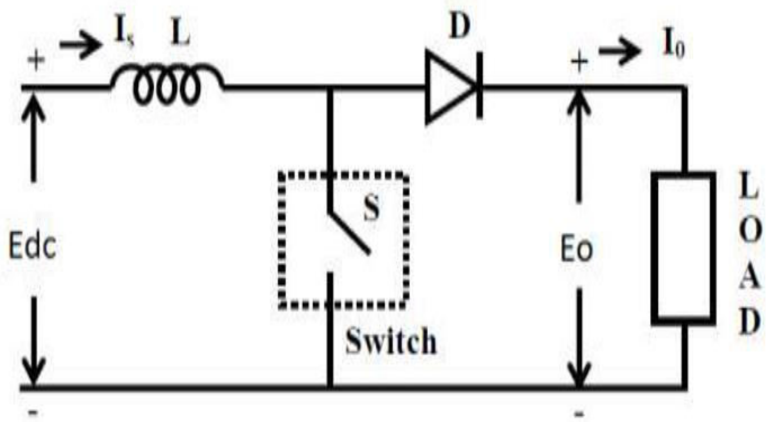

Fig. 5.Boost converter (DC-DC)

Wi =Edc Is T on

Wo=(Eo-Edc) is Toff

Edc is Ton= (Eo-Edc) is Toff

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$$Eo = Edc\frac{Ton + Toff}{Toff}$$

$$Eo = Edc\frac{T}{T - Ton} \text{ but } \frac{Ton}{T} = k$$

$$Eo = \frac{Edc}{1 - k}$$

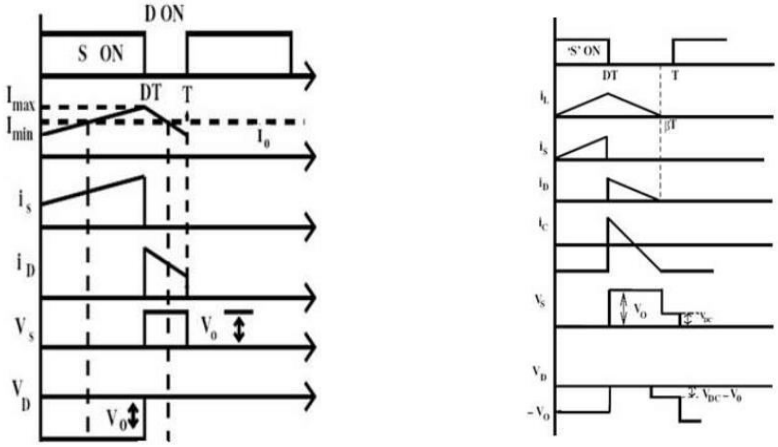

Fig. 6.(a)Continuous conduction mode.(b)Discontinuous conduction mode

3. Buck-Boost Converter

The buck–boost converter is a type of DC-to-DC converter that has an output voltage magnitude that is either greater than or less than the input voltage magnitude. It is equivalent to a flyback converter using a single inductor instead of a transformer. Two different topologies are called buck–boost converter. Both of them can produce a range of output voltages, ranging from much larger (in absolute magnitude) than the input voltage, down to almost zero. In the inverting topology, the output voltage is of the opposite polarity than the input. This is a switched-mode power supply with a similar circuit topology to the boost converter and the buck converter. The output voltage is adjustable based on the duty cycle of the switching transistor. One possible drawback of this converter is that the switch does not have a terminal at ground; this complicates the driving circuitry. However, this drawback is of no consequence if the power supply is isolated from the load circuit.

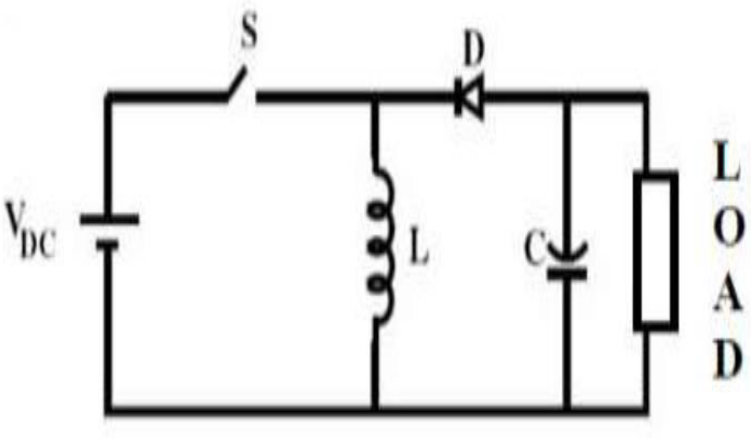

Fig. 7.Buck-Boost converter (DC-DC)

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A Buck converter is a switch mode DC to DC converter in which the output voltage can be transformed to a level less than or greater than the input voltage. The magnitude of output voltage depends on the duty cycle of the switch.It is also called as step up/step down converter. The name step up/step down converter comes from the fact that analogous to step up/step down transformer the input voltage can bestepped up/down to a level greater than/less than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit). Input power (Pin) is equal to output power (Pout). In step up mode Vin is less than Vout in a Buck-Boost converter, it follows then that the output current will be less than the input current. Therefore for a Buck-Boost converter in step up mode, Vin is less than Vout and Iin is greater than Iout. In step down mode Vin is greater than Vout in a Buck-Boost converter, it follows then that the output current will be greater than the input current. Therefore for a Buck-Boost converter in step down mode

Vin>Vout and Iin<Iout

V. PROPOSED METHODOLOGY

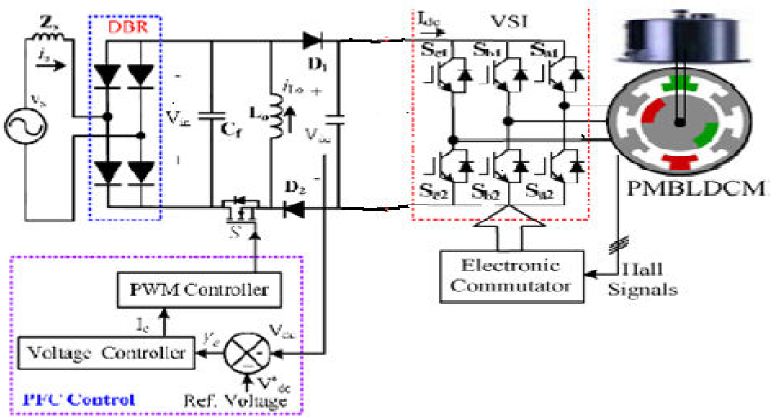

Fig. 8.DC-DC converter fed BLDCM drive with voltage follower control

The proposed buck-boost converter based BLDCM drive operated with voltage follower control. The proposed controller is operated to maintain a constant DC link voltage with PFC action at AC mains. The DC link voltage is sensed and compared with a reference voltage which results in a voltage error. This voltage error is passed through a voltage controller to give a modulating signal which is amplified and compared with saw-tooth carrier wave of fixed frequency to generate a pulse width modulated signal for the switching device of the DC-DC converter.For the speed control, the speed signal derived from rotor position of the BLDCM, sensed using Hall effect sensor is compared with a reference speed. The resultant speed error is passed through a speed controller to get the torque equivalent which is converted to an equivalent current signal using motor torque constant This current signal is multiplied with a rectangular unit template waveform which is in phase with top flat portionof motor's back EMF so that reference three-phase current of the motor are generated.These reference current are compared with the sensed motor current and current error are generated which isamplified and compared with triangular carrier waves to generate the PWM signals for the VSI switches.

VI. APPLICATIONS

The cost of the Brushless DC Motor has declined since its introduction, due to advancements in materials and design. This decrease in price, coupled with the many advantages it has over the Brush DC Motor, makes the Brushless DC Motor a popular component in many different applications

1. Heating and ventilation
2. Industrial automation

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3. Motion control
4. Positioning and actuating system
5. Aero modeling
6. Cooling fan
7. Robotics

VII. CONCLUSION

In this paper overview of controlling BLDCM using DC–DC Converter is explained. The proposed technique can be used in various low power application due to their better performance, wide range of speed control and minimum component requirement based on proposed technique and buck–boost Converter fed topology is mostly preferred to controlling of BLDCM because of smooth output of converter used.

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