International Journal of Research in Advent Technology (IJRAT)
(E-ISSN: 2321-9637)
Special Issue National Conference "CONVERGENCE 2017", 09th April 2017

Speed Controlling Of PMBLDC Motor Using DC – DC Sepic Converter- A Review

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Abstract- This paper presents DC–DC Converter feeding PMBLDC Motor drive is proposed here with adjustable speed operation for low power application. DC – DC Converter provide controlled DC voltage to the PMBLDC Motor drive for an uncontrolled DC output of a single phase AC mains. In proposed system, single phase supply is feeding to uncontrolled rectifier and DC – DC Converter is used to control the voltage of DC link capacitor. Voltage of DC link capacitor is used to control the speed of DC motor. The output of DC link capacitor fed to inverter and speed of PMBLDC Motor can be controlled by changing switching pattern of inverter switches. A voltage follower and current follower technique is proposed for operation of BLDC motor under wide range of speed control. There are different types of DC – DC Converter topology used for controlling of BLDC Motor.

Index Terms- DC – DC converter, Power quality, PMBLDCM, Speed control, Voltage multiplier.

1. INTRODUCTION

The outstanding qualities of a Permanent magnet brushless DC motor (PMBLDCM) such as wide speed range, high efficiency, rugged construction and ease of control make it suitable for household application such as fan, water pump, mixers, etc.[2]. The BLDC motor not only used in household application but also these are suitable for other application such as computer disc drives, automobile starter, automobile wipers, medical equipment and many other industrial tools.The BLDC motor is also known as electronically commutated motor because an electronic commutation based on rotor position is used for controlling the speed. A BLDC motor has three phase winding on the stator and permanent magnets on the rotor.A low power PMBLDC motor is fed from a single phase AC supply through a diode bridge rectifier (DBR) followed by a DC capacitor and a voltage source inverter (VSI) which draws a pulsed current from ac mains having peaks higher than the amplitude of the fundamental input current due to uncontrolled charging of DC link capacitor.Due to draws of peak current which results in Power Quality disturbances in AC mains such as Power factor is low and increased total harmonic distortion (THD) due to these reason PFC Converter is used for improving the Power Quality at AC mains [3].

The mode of operation of PFC Converter are of two types out of which is suitable for these application is the main issue because it affects the cost and the components used in the PFC Converter. The continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are the two modes of operation amongst which the DCM is used because it requires a single voltage sensor for dc link voltage control, and inherent PFC is achieved at the ac mains, but at the cost of higher stresses on the PFC converter switch hence, DCM is preferred for low-power applications.A DC – DC Converter is connected between the VSI and the DBR fed from single phase AC supply to provide control voltage at DC link capacitor [2]. There are many DC –DC Converter topologies available such as buck, boost, buck – boost converter topology is used. The buck – boost converter topology has advantages of its simplest construction and minimum component requirement over other topologies. The buck – boost converter is designed for DCM operation for controlling the speed of BLDC motor.

2. 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)
4. Cuk Converter
5. Sepic Converter

2.1 Buck Converter

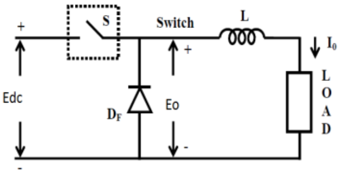

Fig-1: Buck Converter (DC-DC)

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 varied[1].

The average load voltage Eo is given by,

$$Eo = Edc\frac{Ton}{Ton+Toff} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Where,

Ton= on time of the chopper

Toff = off time of chopper

T = Ton+Toff= chopping period

2.2 Boost Converter

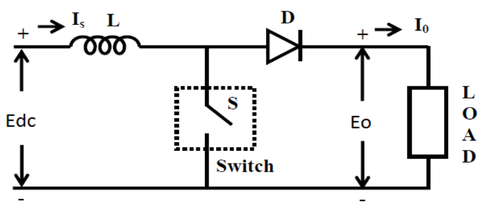

Fig-2: Boost converter (DC-DC)

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 [1]. As the current tends to decrease, polarity of the emf induced L is reversed to that shown in fig.

The result voltage across the load Vo becomes

$$Eo = Edc + L\frac{dis}{dt} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

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

$$Wi = Edc\ Is\ T\ on \quad \ldots\ldots\ldots\ldots\ldots(2)$$

During the Toff period when switch is off ,energy released by the inductor to the load is given by

$$Wo=(Eo-Edc)Is\ Toff \quad \ldots\ldots\ldots\ldots\ldots(3)$$

$$Edc.Is.Ton= (Eo-Edc)\ Is\ Toff \quad \ldots\ldots\ldots\ldots\ldots(4)$$

$$Eo= Edc.\frac{Ton+Toff}{Toff} \quad \ldots\ldots\ldots\ldots\ldots(5)$$

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

$$Eo=\frac{Edc}{1-k} \quad \ldots\ldots\ldots\ldots\ldots(6)$$

. *2.3 Buck-Boost Converter*

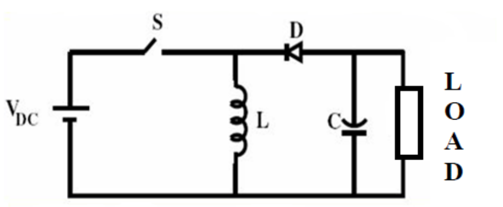

Fig-3:Buck-Boost converter (DC-DC)

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 be stepped up/down to a level greater than/less than the input voltage [1]. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

Input power (P_{in}) = output power (P_{out})

In step up mode $V_{in}<V_{out}$ 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

$V_{in}<V_{out}$ and $I_{in}>I_{out}$

In step down mode $V_{in}>V_{out}$ 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

$V_{in}>V_{out}$ and $I_{in}<I_{out}$

2.4 CUK CONVERTER

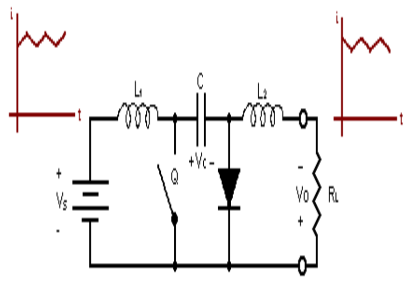

Fig.4.: Cuk Converter Circuit Representation with input and output current waveforms

The Cuk converter is named for Slobodan Cuk of the California Institute of Technology. It is the result of applying the duality principle to the buck-boost converter to use a capacitor instead of an inductor as the primary energy storage device. As a result, the DC transfer function is nominally the same as that of the Buck-Boost converter,

$V_o = DV_s/ (1-D)$

Where,

D represents the PWM duty cycle of the transistor Q.

V_s represents the source voltage.

V_o represents the output voltage.

An advantage of the Cuk converter topology is that the current pulsing occurs within the converter itself and both the input and output currents are not pulsed. Furthermore, if integrated magnetics are used, the input or output current can (theoretically) be nullified as the ripple is transferred to the other side of the converter. Because only one capacitor suffers the losses associated with (internal) current pulsing, the Cuk converter is more efficient than a filtered Buck-Boost converter.

2.5 SEPIC CONVERTER

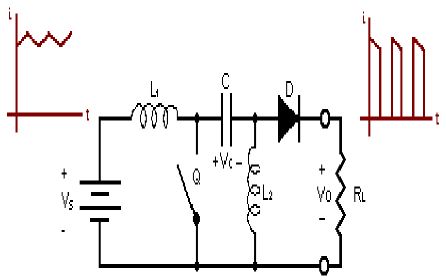

Fig. 5: SEPIC Converter Circuit Representation with input and output current waveforms

The SEPIC (Single Ended Primary Inductor Converter) is very similar to the Cuk converter, except that the secondary inductor, L_2, and the diode, D, have been swapped so that the output polarity is the same as the input polarity. This can be an advantage in certain applications, because the negative terminals of both the input and output are common. Unfortunately, this has the negative side effect of reinstating pulsed current on the output.

3. PROPOSED METHODOLOGY

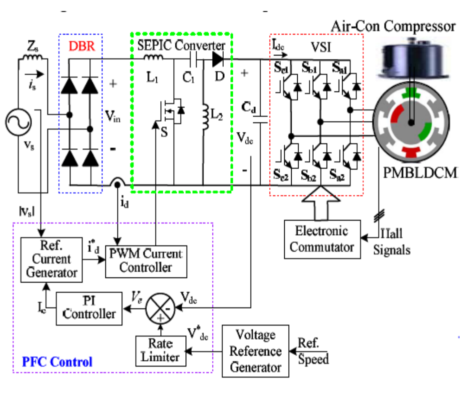

Fig-6:DC-DC converter fed PMBLDCM drive with voltage follower control

The proposed buck-boost converter based PMBLDCM 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 [3].For the speed control, the speed signal derived from rotor position of the PMBLDCM, 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 portion of motor's back EMF so that reference three phase current of the motor are generated [2] .These reference current are compared with the sensed motor current and current error are generated which is amplified and compared with triangular carrier waves to generate the PWM signals for the VSI switches Sections, sub-sections and sub-subsections are numbered in Italic. Use double spacing before all section headings and single spacing after section headings..

4. ADVANTAGES OF SEPIC CONVERTER OVER OTHER CONVERTER

1.SEPIC Converter having non-inverted output(the output voltage is of the same polarity as the input voltage)while in case of buck-boost the output voltage is of opposite polarity with respect to the input voltage.
2. It contains minimum ripples in voltage than other converter.
3. Both step up and step down voltage can be Possible
4. Smooth speed controlling of motor can achieved.

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

5.1 Heating and ventilations

Refrigeration industries to use brushless motors instead of various types of AC motors. The most significant reason to switch to a brushless motor is the dramatic reduction in power required to operate them versus a typical AC motor. While shaded-pole and permanent split capacitor motors once dominated as the fan motor of choice, many fans are now run using a brushless motor. Some fans use brushless motors also in order to increase overall system efficiency.

5.2 Motion control systems Brushless motors are commonly used as pump, fan and spindle drives in adjustable or variable speed applications. Brushless dc motors are widely used as servomotors for machine tool servo drives. Servomotors are used for mechanical displacement, positioning or precision motion control. In the past DC stepper motor were used as servomotors; however, since they are operated with open loop control they typically exhibit torque pulsations. Brushless dc motors are more suitable as servomotors since their precise motion is based upon a closed loop control system that provides tightly controlled and stable operation.

5.3 Positioning and actuation systems

Brushless motors are used in industrial positioning and actuation applications. For assembly robots, brushless stepper or servo motors are used to position a part for assembly or a tool for a manufacturing process, such as welding or painting. Brushless motors can also be used to drive linear actuators.

5.4 Aero modeling

Brushless motors are a popular motor choice for model aircraft including helicopters. Their favorable power-to-weight ratios and large range of available sizes, from under 5 gram to large motors rated at well into the kilowatt output range, have revolutionized the market for electric-powered model flight, displacing virtually all brushed electric motors. They have also encouraged a growth of simple, lightweight electric model aircraft, rather than the previous internal combustion engines powering larger and heavier models. The large power-to-weight ratio of modern batteries and brushless motors allows models to ascend vertically, rather than climb gradually. The low noise and lack of mess compared to small glow fuel internal combustion engines is another reason for their popularity.

6. CONCLUSION

In this paper overview of controlling BLDC motor 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 sepic Converter fed topology is mostly preferred to controlling of BLDC motor because of smooth output of converter.

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