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AN EXPERIMENTAL INVESTIGATION OF PFC BLDC MOTOR DRIVE USING BRIDGELESS CUK DERIVED CONVERTER

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Abstract

BLDC Motor Drives are finding greater role in low and medium power applications owing to their electronic commutation feature and superior performance. These drives combined with the usage of power electronic based converters, poses a severe challenge to the power quality with the most common problem being distorted supply current and low power factor. In order to overcome this problem, it is proposed to employ a Bridgeless Cuk Type III Converter, which has an inherent feature of providing Power Factor Correction, smooth variation of DC link voltage, current flow through a less number of switches. This proposed method has been analyzed using both Simulink Model and suitable hardware setup. The comparative analysis of simulation and hardware results indicates satisfactory performance of the proposed model in terms of power factor improvement and smooth speed control.

Keywords: BLDC, CUK Converter, PFC, Harmonics, Bridgeless topology.

1. Introduction

The increase in usage of power electronic based ac and dc drives for commercial, household and industrial applications, have resulted in serious power quality considerations. BLDC Motor Drives have become more common for many low and medium power applications, because of its electronic commutation feature.

Diode Bridge Rectifiers (DBR) are usually used to feed BLDC motors combined with a DC link capacitor, which leads to highly distorted input current and poor power factor. This harmonic contribution by DBR challenges the various international power quality standards like IEC 61000-3-2. Hence the alternative for this DBR has explored for years, to reduce the harmonics and improve the power factor [1].

In order to obtain improved power quality at the AC mains, a power factor corrected converter can be used for an inverter fed BLDC motor drive. This brings an improvement in the rectifier power density and also noise emission reduction through soft switching techniques. The boost converters are conventionally employed as front end rectifiers, but it demands an isolation transformer or an additional converter, for low voltage applications, in order to step down the voltage. SEPIC converters can be used, but it has the disadvantage of discontinuous output current with high torque ripple.

The concept of bridgeless topologies can be used to overcome these drawbacks, as it eliminates the need for a diode bridge at the input. One such topology is a single phase AC-DC PFC rectifiers based on SEPIC and CUK logic. The presence of only two switches during each conduction and switching cycle, results in less conduction losses and improved thermal management. Active PFC is mostly preferred, as it makes the load to behave resistive, thereby providing a near-unity load power factor and negligible input current harmonics [2].

A new speed control strategy by converting the reference speed as an DC link voltage and employing with a CUK PFC converter has been proposed in [3]. In this, the speed of PMBLDCM has been found proportional to DC link voltage, causing a smooth speed control. The rate limiter introduced in the reference DC link voltage reduces the motor current within the permissible value during transients.

Among the various bridgeless topologies, the bridgeless CUK converter has the unique advantage of providing inherent protection against inrush current at starting, reduced current ripple and electromagnetic interference along with Discontinuous Conduction Mode (DCM) and easy implementation of transformer isolation. This setup is more preferred for power quality improvement in BLDCM[4].

In [5], Ching-Tsai Pan and Emily Fang has proposed a robust and accurate controller by employing PLL (Phase Locked Loop)-assisted IM control method. The compact and economic feature of BLDC Motor drive is achieved, by properly integrating the motor current sensing scheme along with the pulse width modulation control. This also improves the current regulation value. In contrast to the conventional induction motor based industrial blower applications, this proposed method provides higher efficiency with reduced weight and volume is also The mechanical noise caused due to vibrations can also be reduced with the nature of uniform armature current waveforms.

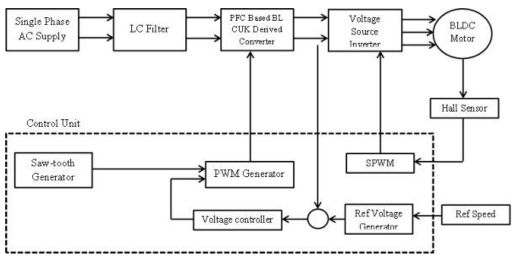

Fig. 1. Proposed Block Diagram

2. Proposed Simulink Model

The bridgeless Cuk derived converter is a combination of two dc-dc converters, one for each half line period (T/2) of the input voltage. There are one or two semiconductor switches in the current flowing path.

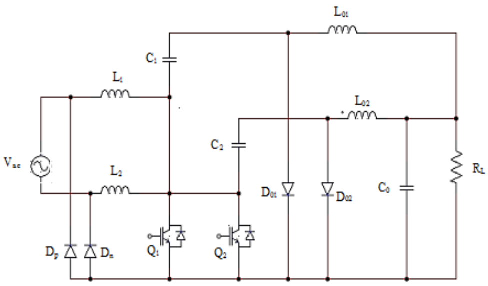

Fig. 2. Type III Cuk Converter

Current stresses in the active and passive switches are auxiliary reduced. Circuit efficiency is improved as compared to conventional Cuk rectifier. They do not suffer from high common mode noise problem and common mode emission performance is similar to that of conventional PFC topologies.

The Simulink model of the type-III Cuk converter is developed using MATLAB software is shown in Fig. 3. The circuit is operated in open loop operation. The input side voltage and current is taken as input and it is converted into corresponding real and reactive power and the power factor is calculated with the help of math operator blocks.

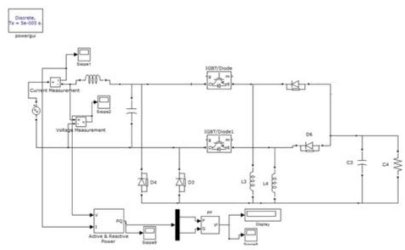

Fig. 3. Simulink Model of Type III Cuk Converter

Hardware Model

The overall hardware prototype model for type III cuk derived converter fed BLDC motor is fabricated which is shown in Fig. 4., The type III cuk derived converter is powered with the help of SMPS and the output of the cuk converter is fed to the driver circuit of the motor. The switching pulse for the converter and inverter is generated with the help of dsPIC 30F2010 microcontroller.

Fig. 4. Proposed Hardware Prototype Model

For different loading conditions the results are observed and analysed for the proposed prototype model. From the result analysis, at different variations of the speed, provides a near to unity power factor at AC main and the average output voltage in the cuk converter is less or more than the input voltage. The DC link voltage of the Cuk converter as the result is shown in Fig. 5.

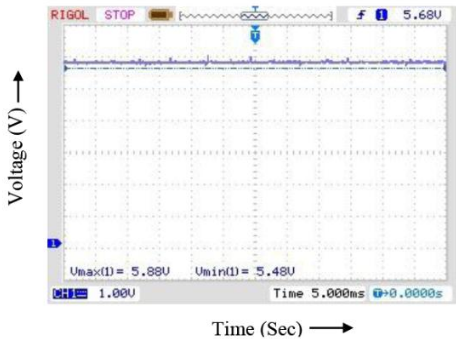

Fig. 5. Output Voltage of Cuk Converter

The Pulse-width modulation is a modulation technique that conform the width of the pulse, formally the pulse duration, based on modulator signal information. Although this modulation technique can be used to encode information for transmission, its main use is to allow the control of the power supplied to electrical devices, especially to inertial loads such as motors. The PWM signals for the upper and lower switch of the Cuk converter are shown in Fig. 6. and 7.

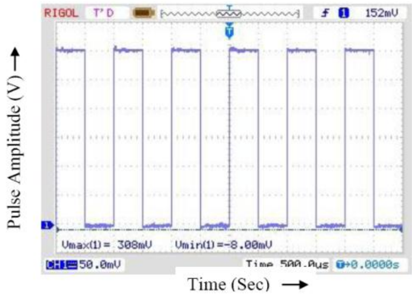

Fig. 6. Gate Pulse for MOSFET Switches (Upper)

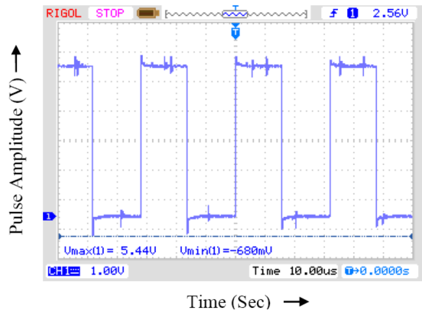

Fig. 7. Gate Pulse for MOSFET Switches (Lower)

From the drive circuit, the three phase supply is given to the BLDC motor, each phase supply is shown in Fig. 8.

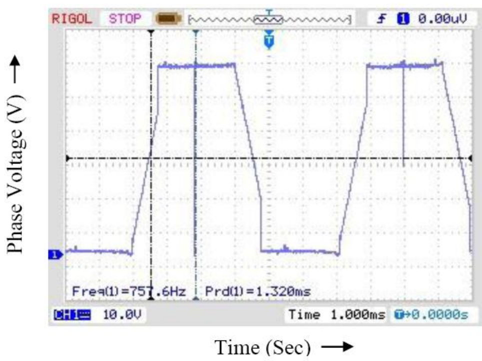

Fig. 8. Input Voltage Waveform to Motor

While the motor is working under no load condition, the current drawn from the input supply is 0.8A. The voltage is kept constant as 50V. At that time the power factor maintained as 0.998 as shown in Fig. 9.

Fig. 9. Input Power Factor Display- No Load Condition

While the motor is loaded, the current drawn from the input supply is 0.849 A. At that time the power factor maintained as 0.997 as shown in Fig. 10.

Fig. 10. Input Power Factor Display- Loading Condition

3. Conclusion

In this paper, the various types of derived Cuk converter are discussed and the Cuk Derived Type III Converter is used for the proposed drive scheme, owing to its efficiency in power factor correction. The model has been simulated with the help of MATLAB/Simulink platform for different speed ranges. The results reveal the possibility of achieving smooth speed control both during motor acceleration and deceleration, by controlling the DC link voltage. Additionally, the supply side power factor is also improved. The above results have also been experimentally validated using a 350 W/50 V 600 rpm BLDC motor powered with bridgeless Type III Cuk converter with dsPIC 30F2010 microcontroller. On loading the drive, the distortions in the supply current and voltage waveform are highly reduced along with satisfactory improvement of power factor nearer to unity.

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