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# Power Factor Corrected Bridgeless Buck–Boost Converter-Fed with Adjustable-Speed BLDC Motor Drive

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## ABSTRACT:

This paper presents a power factor corrected (PFC) bridgeless (BL) 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. A BL configuration of the buck-boost converter is proposed which offers the elimination of the diode bridge rectifier, thus reducing the conduction losses associated with it. A PFC BL buck-boost converter is designed to operate in discontinuous inductor current mode (DICM) to provide an inherent PFC at ac mains. The performance of the proposed drive is evaluated over a wide range of speed control and varying supply voltages (universal ac mains at 90-265 V) with improved power quality at ac mains. The obtained power quality indices are within the acceptable limits of international power quality standards such as the IEC 61000-3-2. The performance of the proposed drive is simulated in MATLAB/Simulink environment, and the obtained results are validated experimentally on a developed prototype of the drive.

Index Terms—Bridgeless (BL) buck-boost converter, brushless direct current (BLDC) motor, discontinuous inductor current mode (DICM), power factor corrected (PFC), power quality.

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## **INTRODUCTION:**

Efficiency and cost are the major concerns in the development of low-power motor drives targeting household applications such as fans, water pumps, blowers, mixers, etc. The use of the brushless direct current (BLDC) motor in these applications is becoming very common due to features of high efficiency, high flux density per unit volume, low maintenance requirements, and low electromagnetic interference problems.

These BLDC motors are not limited to household applications, but these are suitable for other applications such as medical equipment, transportation, HVAC, motion control, and many industrial tools. A BLDC motor has three phase windings on the stator and permanent magnets on the rotor.

The BLDC motor is also known as an electronically commutated motor because an electronic commutation based on rotor position is used rather than a mechanical commutation which has disadvantages like sparking and wear and tear of brushes and commutator assembly. Power quality problems have become important issues to be considered due to the recommended limits of harmonics in supply current by various international power quality standards such as the International Electro technical Commission (IEC) 61000-3-2. For class-A equipment (< 600 W, 16 A per phase) which includes household equipment, IEC 61000-3-restricts the harmonic current of different order such that the total harmonic distortion (THD) of the supply current should be below 19%.

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### **Existing System:**

The parameters of the BL buck–boost converter are designed such that it operates in discontinuous inductor current mode (DICM) to achieve an inherent power factor correction at ac mains. The speed control of BLDC motor is achieved by the dc link voltage control of VSI using a BL buck–boost converter. This reduces the switching losses in VSI due to the low frequency operation of VSI for the electronic commutation of the BLDC motor.

The performance of the proposed drive is evaluated for a wide range of speed control with improved power quality at ac mains. Moreover, the effect of supply voltage variation at universal ac mains is also studied to demonstrate the performance of the drive in practical supply conditions. Voltage and current stresses on the PFC converter switch are also evaluated for determining the switch rating and heat sink design. Finally, a hardware implementation of the proposed BLDC motor drive is carried out to demonstrate the feasibility of the proposed drive over a wide range of speed control with improved power quality at ac mains.

#### **Proposed System:**

The operation of the PFC BL buck boost converter is classified into two parts which include the operation during the positive and negative half cycles of supply voltage and during the complete switching cycle.

# **Operation During Positive and Negative Half Cycles** of Supply Voltage

In the proposed scheme of the BL buck boost converter, switches Sw1 and Sw2 operate for the positive and negative half cycles of the supply voltage, respectively. During the positive half cycle of the supply voltage, switch Sw1, inductor Li1, and diodes D1 and Dp are operated to transfer energy to dc link capacitor Cd as shown in Fig. 2(a)–(c). Similarly, for the negative half cycle of the supply voltage, switch Sw2, inductor Li2, and diodes D2 and Dn conduct.

## **Operation During Complete Switching Cycle**

Three modes of operation during a complete switching cycle are discussed for the positive half cycle of supply voltage as shown here in after.

*Mode I:* In this mode, switch Sw1 conducts to charge the inductor Li1; hence, an inductor current *i*Li1 increases in this mode as shown in Fig. 2(a). Diode Dpcompletes the input side circuitry, whereas the dc link capacitor Cd is discharged by the VSI-fed BLDC motor

# DESIGN OF PFC BL BUCK–BOOST CONVERTER

A PFC BL buck-boost converter is designed to operate in DICM such that the current in inductors *Li*1 and *Li*2 becomes discontinuous in a switching period. For a BLDC of power rating 251 W (complete specifications of the BLDC motor are given in the Appendix), a power converter of 350 W (*Po*) is The proposed converter is designed for dc link voltage control from 50 V (*V*dc min) to 200 V (*V*dcmax) with a nominal value (*V*dc des) of 100 V; hence, the minimum and the maximum duty ratio (*d*min and *d*max) corresponding to *V*dc min and *V*dc max are calculated as 0.2016 and 0.5025, respectively



Fig. 5. Operation of a VSI-fed BLDC motor when switches  $S_1$  and  $S_4$  are conducting.

# SIMULATED PERFORMANCE OF PROPOSED BLDC MOTOR DRIVE

The performance of the proposed BLDC motor drive is simulated in MATLAB/Simulink environment using the Sim Power System toolbox. The performance International Journal & Magazine of Engineering, Technology, Management and Research

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evaluation of the proposed drive is categorized in terms of the performance of the BLDC motor and BL buck-boost converter and the achieved power quality indices obtained at ac mains. The parameters associated with the BLDC motor such as speed (N), electromagnetic torque (Te), and stator current (ia) are analyzed for the proper functioning of the BLDC motor. Parameters such as supply voltage (Vs), supply current (is), dc link voltage (Vdc), inductor's currents (iLi1, iLi2), switch voltages (Vsw1, Vsw2), and switch currents (isw1, isw2) of the PFC BL buck-boost converter are evaluated to demonstrate its proper functioning.

#### **Steady-State Performance**

The steady-state behavior of the proposed BLDC motor drive for two cycles of supply voltage at rated condition (rated dc link voltage of 200 V) is shown in Fig. 6. The discontinuous inductor currents (*i*Li1 and *i*Li2) are obtained, confirming the DICM operation of the BL buck boost converter. The performance of the proposed BLDC motor drive at speed control by varying dc link voltage from 50 to 200 V is tabulated in Table III. The harmonic spectra of the supply current at rated and light load conditions, i.e., dc link voltages of 200 and 50 V, are also shown in Fig. 7(a) and (b), respectively, which shows that the THD of supply current obtained is under the acceptable limits of IEC 61000-3-2.

# HARDWARE VALIDATION OF PROPOSED BLDC MOTOR DRIVE

A digital signal processor (DSP) based on TI-TMS320F2812 is used for the development of the proposed PFC BL buck–boost converter-fed BLDC motor drive. The necessary circuitry for isolation between DSP and gate drivers of solid state switches is developed using the opto coupler 6N136. A prefiltering and isolation circuit for the Hall-Effect sensor is also developed for sensing the Hall-effect position signals. Test results are discussed in the following sections.



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Fig. 11. (a) Variation of inductor's currents  $(i_{L\,i1}$  and  $i_{L\,i2})$  and (b) its enlarged waveforms with supply voltage and supply current.

# COMPARATIVE ANALYSIS OF DIFFERENT CONFIGURATIONS

A comparative analysis of the proposed BL buck– boost converter-fed BLDC motor drive is carried out with conventional schemes. Two conventional schemes of the DBR-fed.



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Fig. 15. Comparative analysis of (a) losses and (b) the efficiency of the conventional and the proposed configuration.

Table VII shows a comparative analysis of three different configurations of the BLDC motor drive. The evaluation is based on the control requirement, sensor requirement, and losses in the PFC converter and VSI-fed BLDC motor. The proposed scheme has shown a minimum amount of sensing requirement and cost with the highest efficiency among the three configurations, and hence, it is a recommended solution for low-power applications.

#### **CONCLUSION**

A PFC BL buck-boost converter-based VSI-fed BLDC motor drive has been proposed targeting lowpower applications. A new method of speed control has been utilized by controlling the voltage at dc bus and operating the VSI at fundamental frequency for the electronic commutation of the BLDC motor for reducing the switching losses in VSI. The front-end BL buck-boost converter has been operated in DICM for achieving an inherent power factor correction at ac mains. A satisfactory performance has been achieved for speed control and supply voltage variation with power quality indices within the acceptable limits of IEC 61000-3-2. Moreover, voltage and current stresses on the PFC switch have been evaluated for determining the practical application of the proposed scheme. Finally, an experimental prototype of the proposed drive has been developed to validate the performance of the proposed BLDC motor drive under speed control with improved power quality at ac mains. The proposed scheme has shown satisfactory

performance, and it is a recommended solution applicable to low-power BLDC motor drives.

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