Implementation of BL-PFC Converter Fed BLDC Motor Drive for Application less than 800 W

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Abstract: This article analyses the performance of a PFC SEPIC-fed BLDC motor drive for low-power applications. The BLDC motor's speed is regulated by changing the DC connection voltage of the VSI that supplies the BLDC motor. The VSI feeding BLDC motor is used to electronically commutate the BLDC motor, which works at a low frequency to minimise switching losses. A bridgeless design of a single-ended primary-inductor converter is proposed that eliminates the need for a diode bridge rectifier. A PFC-based SEPIC is intended to operate in a discontinuous inductor current mode, with a single voltage sensor, to achieve inherent power factor correction at the AC mains. The converter proposed here has a low conduction loss, a low harmonic content, and a power factor that approaches unity. Simulate the circuit by connecting the output voltage to a resistive load. The recommended drive's output is tested experimentally on a built prototype. At the AC mains, improved power quality is achieved under all conditions, and thus the obtained power quality indices are obtained. MATLAB-Simulink is used for all simulation work.

Keywords: BLDC Motor, PFC Converter, Matlab, SEPIC

1. Introduction

The last decade has seen dramatic change in industries, with induction motors being phased out and replaced by brushless DC motors. The rotor of an AC induction motor does not include any magnets; instead, it contains a series of laminations and windings. Although the majority of AC induction motors operate directly from AC power without the use of a controller, if variable speed operation is needed, a VFD must be mounted between the AC power and the motor. This VFD modulates the motor's speed by modulating the frequency with which the motor is powered. Even with a variable frequency drive mounted, some industrial induction motors have a small speed range. Furthermore, they are unsuitable for delivering the rated torque at extremely low speeds. A BLDC motor, on the other hand, replaces the rotor's windings with a set of permanent magnets. These magnets generate an enticing field that interacts with the stator field to generate force. A three-phase voltage source inverter is needed to accomplish electronic commutation of BLDC motors based on the location of the rotor as sensed by Hall-effect position sensors[1].
Converters with enhanced power efficiency are used to correct the power factor of alternating current mains. The literature has identified a variety of non-isolated and isolated PFC converter configurations for improving the power quality of alternating current mains [7]. The sensing specifications associated with the PFC converter's mode of operation are largely responsible for the cost of these PFC converters. There are two modes of operation for a PFC converter: continuous conduction and discontinuous conduction. The continuous conduction mode of operation of a PFC converter reduces the stress on the PFC converter switches while still allowing for supply voltage sensing. A PFC converter operating in DCM, on the other hand, requires only a single voltage sensor to regulate the DC connection voltage, and inherent power factor correction is accomplished at the AC mains, but at the cost of increased stress on the PFC converter switches. As a result, applications requiring low power are limited to this mode of operation. This paper will therefore be focused on the design and implementation of a bridgeless SEPIC for feeding a low-power BLDC motor drive. A PFC-based BLDC drive has been suggested using brushless SEPI Cs [4]; however, the configuration uses a BL-SEPIC as described in this configuration and work is limited to simulation studies [2]. As a result, this research provides experimental validation for BL-SEPIC, a low-power household application that uses a single low-side driver to power a BLDC motor drive.

2. Literature review

Chen, Y., et al., 2013. A brushless dc (BLDC) motor replaces the mechanical commutator and A dc brush motor's brush gear is connected to an electrical commutating unit. A permanent magnet can be found on the rotor (PM). A motor with a broader speed range and a lower maintenance requirements than a brushless DC motor, is more powerful than an inlet motor. The engine works similarly with a DC brush engine, since the BLDC motor's back electric force may have a trapezoidal wavelength. [1]

V. Bist., et al. The brushless DC engine is called a three-phase synchronous motor with three phase windings on the stator and permanent magnets on the rotor. A three-phase voltage source inverter is required to achieve an electronical switching of the BLDC motor based on the positioning of the rotor sensed by Hall-Effect position sensors. The controller supplies current pulses to the motor windings and thus controls the motor's speed and torque. This control system eliminates the need for the commutator (brushes) used in a large number of traditional electric motors. [3]

Jang, Y., et al., 2011. Brushless DC motors are constructed with wound wire coils and a two-pole electromagnet armature. The commutator, which is a mechanical rotary switch, reverses the current's directionality twice every cycle. This allows current to flow through the armature, causing the electromagnet's poles to wave against the permanent magnets on the motor's exterior. As the poles of the electromagnet in the armature touch the poles of the permanent magnet, the commutator reverses the polarity of the electromagnet in the armature. [5]

Fardoun, A., et al., 2018. Brushless DC motors emerged in the 1960s with the advent of solid state electronics. Brushless PM DC motors did not enter the industry until the 1970s. The delay was caused by the creation of not only PMs with high energy, and electrical controllers that can substitute mechanical switching with electronic switching. [6]

3. Proposed system

The proposed system evaluates the effectiveness of a low-power PFC SEPIC-fed BLDC motor drive. The speed of the BLDC motor is controlled by changing the VSI connection voltage for the BLDC motor. The VSI feeding motor BLDC is used to switch the BLDC motor electronically, which works at low frequencies to reduce switching losses. The bridge-free layout of a single-end primary inductor converter removes the need for a bridge rectifier. A SEPIC based on PFC is expected to act with such an independent voltage sensor in an interruptive inductor current mode to accomplish innate power factor on the AC mains. The converter proposed in Figure.1 has a low driving loss, a good dynamic
content, and a nearing unity power factor. Simulate the circuit with resistive load connecting the output voltage. The recommended drive output is tested on a built-in prototype experimentally. At the AC pipeline, increased performance is measured under all conditions, thus acquiring the results of power quality indices.

**BLDC motor speed control**

The recommended Dc motor drive is a bridgeless SEPI VSI-driven BLDC motor. By adjusting the VSI DC connection voltage, the BLDC motor speed is controlled by a single voltage sensor. This allows the electronic switching of Dc motors during VSI operations at low frequency, which significantly reduces switch losses compared to the PWM. Due to the lack of DBR, bridge-less converters have low diode performance losses leading to maximum efficiency. For PF correction and voltage, a DICM front-end bridge free SEPIC can be used. High-frequency field-effect metal oxide transistors are used on the front of the rectifier for high-frequency operation. The component size is reduced. MOSFETs are used in VSI for low frequency applications. When connected to AC power supplies, the driving keeps superior PF and better efficiency levels, allowing for various variable speeds. [2].

![Block diagram of the proposed system](image)

**Figure 1**: Block diagram of the proposed system

**4. Mathematical model**

The PFC BL-SEPIC is designed to operate in discontinuous conduction mode, which means that during the switching time, the current flowing through the output inductors (Lo1 and Lo2) is interrupted. A 500W (Pmax) PFC converter will be used with the chosen BLDC motor. For a wide range of speed variations, the DC connection voltage is regulated from a low value of 50 V (Vdc min) to the rated voltage of 200 V (Vdc max), with the supply voltage varying from 170 V (Vs min) to 270 V (Vs max).

For a 3 percent permissible ripple voltage, DC connection condenser value is measured respectively at higher and lower DC connection voltages. As a consequence, the DC connection capacitor is structured to obtain minimal ripple even in the lower DC connection voltage.

\[
C_{\text{max}} = \frac{I_m}{\omega_c V_m \tan(\theta)} = \frac{[P_{\text{max}} \sqrt{2} V_s]}{\omega_c V_s} = \tan(\theta) \quad (1)
\]

Where, the angle of displacement between the fundamental portion of supply voltage and supply current is equal to one. The filter capacitor is chosen to be less than Cmax.

\[
I_q = L_f - I_s \quad (2)
\]

\[
I_{\text{req}} = \frac{1}{4\pi^2 \omega_c C_f} - 0.035 \left( \frac{1}{\omega_c} \right) \left( \frac{V_s}{P_{\text{max}}} \right) \quad (3)
\]
5. Working

![Circuit diagram of the proposed Converter](image)

The proposed method function is divided into two components, each of which corresponds to its application for a full line and a switching cycle. In this project, a bridgeless SEPIC converter fed BLDC motor is proposed. From Figure 2, The bridgeless SEPIC converter is fed an AC voltage as input. The SEPIC transforms the AC voltage from the input into DC voltage. It can be used for both buck and boost operations. If the duty cycle is less than 50%, it operates in buck mode; if the duty cycle is greater than 50%, it operates in boost mode; in the meantime, it is used for PFC. When compared to traditional buck and boost converters, it improves performance. Two inductors, an IGBT, and two capacitors are included in the circuit. The output DC bus voltage is regulated using PWM control. The three phase inverter receives this DC bus voltage. The input DC voltage is converted into AC voltage by this inverter.

The BLDC motor is supplied with this AC voltage. The hall effect sensor is used to provide PWM power to the inverter. The rotor location is determined using the Hall effect. The location of the rotor is detected by the PWM controller, which then energies the next winding in order to rotate the rotor. The speed of a BLDC motor is controlled using PI power. The service cycle of the inverter is adjusted by the PI control based on the set point and feedback.

6. Matlab simulation and result

The output voltage is connected to a resistive load, and the circuit is simulated in Matlab shown in Figure 3. The performance of the suggested drive is supported by real-world results obtained on a prototype. For all conditions, improved power quality is achieved at the AC mains from Figure 4, and thus the obtained power quality indices are achieved. MATLAB-Simulink is used for the entire simulation process. Waveform of the DC link voltage is shown in Figure 5 and the motor speed waveform is shown in Figure 6. The hardware setup image is shown in Figure 7.

![Matlab Simulink model of the proposed system](image)
Figure 4: Waveform of Input current of SEPIC PFC Converter

Figure 5: Waveform of DC link voltage output

Figure 6: Waveform of Speed of the motor
The BLDC motor’s speed has been regulated using the VSI feeding’s variable DC connection voltage. This PFC converter has been used to operate a three-phase VSI in lower frequencies switching mode, resulting in lower Losses switching. A DICM front-end was used for DC-link voltage control and power factor correction in the AC network. For speed control and supply voltage fluctuations across a wide range, the output of the proposed drive was found quite satisfactory. A framework of the system drive was built and tested, yielding satisfactory results across the entire speed range and a wide range of supply voltages. The obtained power quality indices were discovered to be within the limitations of the world power quality standard.

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