Abstract: This paper presents power factor correction based BLDC motor drive by using bridgeless luo converter. A voltage sensor is used for speed control of brushless DC motor. Power factor correction is implemented at AC mains. Electronic commutation is used to reduce switching losses.

The proposed BLDC motor drive is designed for a wide range of speed control. The proposed BLDC motor drive is with an improved power quality at AC mains. This power quality indices obtained is according to limits of IEC 61000-3-2.

“1. INTRODUCTION”

Brushless direct current motors (BLDC) are one of the advance motors used which are rapidly increasing their popularity and applications. BLDC motor has rotor with permanent magnets and stator with stacked steel laminations with windings inserted in slots. The motor has less inertia, therefore easier to start and stop. BLDC motors do not have brushes (hence the name “brushless DC”) and must be electronically commutated. BLDC motors are potentially cleaner, faster, more efficient, less noisy and more reliable. Generally a BLDC motor is considered to be a high performance motor i.e. capable of providing large amounts of torque over a vast speed range[1-3].

In the brushless DC motor, polarity reversal is performed by power transistors switching in synchronization with the rotor position. Therefore, BLDC motors often incorporate either internal or external position sensors to sense the actual rotor position or its position can also be detected without sensors. BLDC motors are used in Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation [4, 5].

A conventional BLDC motor drive consists of a front end diode bridge rectifier and a high value of DC link capacitor which draws highly distorted peak current [6]. It is rich in harmonics. Fig. 1 shows the conventional scheme of BLDC motor drive with a pulse width modulation (PWM).

These power quality indices are not acceptable under the limits of international power quality standards such as IEC 61000-3-2. These power quality indices also increase the EMI in the PFC converter.

Fig. 1 A conventional DBR fed BLDC motor drive

The conventional boost-PFC for feeding a BLDC motor drive is as shown in fig 2. This suffers from high switching loss because of high switching frequency of PWM pulses for VSI which drastically reduces the efficiency of overall system[3].

The advantages of the Luo Converter with a bridgeless configuration of the Luo converter is Explored in this paper which is used for feeding a BLDC motor as a low cost solution for low power applications.

Fig. 2 A conventional PFC based BLDC motor drive

“2. PROPOSED BLDC MOTOR DRIVE”

“A. BLDC MOTOR”

Brushless DC Motors are driven by DC voltage but current commutation is controlled by solid state switches. The commutation instants are determined by the rotor position. The rotor shaft position is sensed by a Hall Effect sensor, which
provides signals to the respective switches [1]. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating either 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. These signals are decoded by combinational logic to provide the firing signals for 120° conduction on each of the three phases [1].

The proposed power factor correction based BL-Luo converter is as shown in fig. 3. A proposed circuit consists of single phase supply with filter & BL-Luo converter which is used to feed voltage source inverter driving a BLDC motor. The BL-Luo converter acts as a power factor pre regulator.

Electronics commutation is used to reduce switching losses. This scheme is designed & performance is simulated for achieving an improved power quality at AC mains for wide range of speed control as well as supply voltage variation.

3. Operation Of PFC BL-LUO converter

The operation of proposed circuit is classified into two parts that is operation during the positive and negative half cycles of supply voltage.

“A. Operation during Positive and Negative Half Cycles”

Fig. 4 shows operation of power factor correction BL-Luo converter for both positive and negative half cycles. The bridgeless converter consist of two switches operate for a positive and negative half cycles of supply voltage. Switch Sw1, inductors Li1 and Lo1 and diodes Dp and Dp1 conduct during the positive half cycle as shown in fig. 4(a). In similar manner switch Sw2, inductors Li2 and Lo2 and diodes Dn and Dn1 conduct during the negative half cycle as shown in fig. 4(d).

“B. Operation during Complete Switching Cycle” Mode I:

When switch Sw1 is turned-on, the input side inductor (Li1) stores energy depending upon the current (iLi) flowing through it and the inductor value (Li1). The energy stored in intermediate capacitor (C1) is transferred to the DC link capacitor
(Cd) and the output side inductor (Lo1). So, the voltage across capacitor (VC1) decreases. The current in output inductor (iLo1) and the DC link voltage (Vdc) are increased.

**Mode II:**

When switch Sw1 is turned-off, the input side inductor (Li1) transfers its energy to the capacitor (C1) through diode Dp1. So, the current iLi1 decreases till it reaches zero, and the voltage across capacitor (VC1) increases. The DC link capacitor (Cd) provides the required energy to the load so the DC link voltage Vdc reduces in this mode.

**Mode III:**

No energy is left in the input inductor (Li1) i.e. current iLi1 becomes zero and enters discontinuous conduction mode of operation. The capacitor (C1) and output inductor (Lo1) are discharged so current iLo1 and voltage VC1 is reduced and DC link voltage Vdc increases in this mode of operation.

In a similar way, for negative half cycle of supply voltage the inductor’s Li2 and Lo2, diode Dn1 and capacitor C2 conduct to achieve a desired operation.

**“4. Design of power factor correction BL-Luo Converter”**

The power factor correction BL-Luo converter is designed to operate in discontinuous inductor current mode (DICM) to acts as a power factor preregulator.

Power factor correction converter is designed to control DC link voltage from 50V (Vdcmin) to 200V (Vdcmax). The output power corresponding Vdcmin is taken as 50W (Pmin).

The average input voltage (Vin) at the input of filter is [23],

\[ V_{in} = \frac{2\sqrt{2}V_{peak}}{\pi} = \frac{2\sqrt{2} \times 220}{\pi} = 198V \]  

The relation between the input and output voltages for BL-Luo converter is [23],

\[ d = \frac{V_{dc}}{V_{in} + V_{dc}} \]  

The values of intermediate capacitors that is C1 & C2 are selected as 0.44µf.

The value of output inductors (Lo1 & Lo2) is calculated as[17],

\[ L_{o1,2} = \frac{d_{max} I_{o}}{16f_{S} C_{in} (\Delta_{o}/2)} \]  

The value of Cd is as follows[9],

\[ C_{d} = \frac{I_{o}}{2\omega_{L} \Delta V_{dc,min}} \]

L-C filter is designed to avoid the high current ripple in supply system[25].

\[ C_{max} = \frac{I_{peak}}{2\omega_{L} V_{peak}} \tan(\Theta) \]  

Where,  

\[ V_{peak}, I_{peak} = \text{Peak value of supply voltage and supply current} \]

\[ \Theta = \text{Displacement angle between supply voltage and supply current} \]

\[ L_{f} = L_{req} - L_{s} \Rightarrow \frac{1}{4\pi^2 f_{c}^2 C_{f}} \]  

“5. Control of power factor correction BL-Luo converter fed BLDC Motor drive”

The control of converter is classified in two parts,

A. Control of front End power factor correction converter

A reference DC link voltage (Vdc*) is generated as follows,

\[ V_{dc}^* = k_{v} \omega_{o}^* \]  

Where,  

\[ K_{v} = \text{Motor voltage constant} \]

\[ W^* = \text{Reference Speed} \]

Reference DC link voltage

\[ V_{dc}^* = k_{v} \omega_{o}^* \]  

Where,  

\[ K_{v} = \text{Motor voltage constant} \]

\[ W^* = \text{Reference Speed} \]

Reference DC link voltage (Vdc*) is compared with sensed DC link voltage (Vdc) to generate voltage error signal (Ve).

\[ V_{e}(k) = V_{dc}^*(k) - V_{dc}(k) \]

The voltage signal (Ve) is given to the PI controller.

B. Control of BLDC motor using Electronic Commutation

An electronic commutation of the BLDC motor performs proper switching of voltage source inverter. The symmetrical DC current is drawn from DC link capacitor at 120° & placed symmetrically at each phase. Rotor position at each 60° is sensed by hall effect sensor. The switching state of both switches is as shown in fig.

**Fig. 4 A VSI feeding a BLDC motor**
The magnitude of line current $i_{ab}$ is dependent on DC link voltage ($V_{dc}$), back emfs ($e_{an}$ & $e_{bn}$), resistance ($R_a$ & $R_b$) and self and mutual inductances ($L_a$, $L_b$ & $M$) of stator windings.

Table shows the switching states of voltage source inverter which feeds to a BLDC motor.

<table>
<thead>
<tr>
<th>Switching States</th>
<th>$e_{an}$</th>
<th>$e_{bn}$</th>
<th>$R_a$</th>
<th>$R_b$</th>
</tr>
</thead>
<tbody>
<tr>
<td>NA</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
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<td>0-60</td>
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<td>0</td>
<td>1</td>
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<td>60-120</td>
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<td>0</td>
<td>0</td>
<td>1</td>
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<td>180-240</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>240-300</td>
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<td>0</td>
<td>0</td>
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</tr>
<tr>
<td>300-360</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
</tbody>
</table>

“6. Hardware validation of the proposed power factor correction BL-Luo converter fed BLDC motor drive”

Obtained results of the proposed BLDC motor drive are discussed as follows:

“Fig. 5 Test results of proposed BLDC motor drive”

“3. CONCLUSION”

In this paper, A power factor correction based BL-Luo converter fed BLDC motor drive is proposed for wide range of speeds as well as supply voltage. A single voltage sensor is used for speed control of BLDC motor. An electronic commutation is used which utilized for reduced switching losses. The PFC BL-Luo converter has been designed to act as power factor pre regulator. The proposed BLDC motor drive has been designed and performance is simulated in proteus to achieve an improved power quality over wide range of speed control.

The performance has been verified experimentally on a developed hardware. A satisfactory performance of proposed drive has been achieved and it is recommended as a solution for low power application.

REFERENCES