The Scientific Temper (2023) Vol. 14 (4): 1557-1562
E-ISSN: 2231-6396, ISSN: 0976-8653
Doi: 10.58414/SCIENTIFICTEMPER.2023.14.4.71
https://scientifictemper.com/

RESEARCH ARTICLE

Power quality improvement in BLDC motor drive using PFC converter

Rama Rao J.V.G.[1], Raja Gopal A.N.V.J.[2], Ponnaganti S. Prasad[2], Illa V. Ram[2], Muthuvel B.[2*]

Abstract

The use of brushless DC motors (BLDC) in low-power appliances is increasing because of their features of high efficiency, wide speed range, and low maintenance. This project deals with a power factor correction (PFC) based BL Landsman converter-fed brushless DC motor drive as a cost-effective solution for low-power applications. The speed of the BLDC motor is controlled by varying the DC-link voltage of the voltage supply electrical converter feeding the BLDC motor drive. A low-frequency switch of the VSI is used for achieving the electronic commutation of the BLDC motor for reduced switch losses. The PFC-based letter of the alphabet device is designed to control in discontinuous inductance current mode; therefore utilizing a voltage follower approach which needs one voltage sensing element for DC-link voltage management and PFC operation. The projected drive is meant to control a large variety of speed management with improved power quality at AC mains. The performance of the projected drive is valid with experimental results obtained on a developed epitome of a PFC device. This manuscript deals with the configuration of a power factor correction converter feeding a drive of brushless DC motors for medium and low-power equipment. The DC link voltage of the drive system is maintained by a single DC voltage actuator. Two control converters for the BLDC motor drive have been implemented. The control strategy is based on a PFC-Landsman converter-fed BLDC motor drive. Comparison has been made in PI controller-based converter in terms of minimizing ripple and improving the power factor of BLDC motor drive. The proposed work has been implemented under MATLAB/Simulink environment

Keywords: PFC converter, Power quality improvement, Brushless direct current motor drive, Ripple current minimization, Power factor correction.

Introduction

The proposed paper gives information to improve the power factor of permanent magnet brushless DC motor (PMBLDC). Mainly in ventilating systems to achieve the below, which is difficult in the conventional system. Achieve steady and smooth speed control to maintain a constant room temperature. Minimize the harmonics in the power system due to the continuous switching of millions of ventilating systems and main higher efficiency. (Puttaswamy *et al*, 1995). The ventilating system is energy energy-conserving application that normally uses single-phase induction motors for driving compressors and fans. The efficiency is between 70-80%. The PMBLDC motors have high efficiency for the compressor application. In the actual system permanent magnet, the brushless DC motor is replacing the single-phase induction motor used in air conditioners for driving compressors and fans for its low power utilization (Singh *et al*, 2003; Singh *et al*, 2011). A brushless CSC converter and modified zeta converter fed Brushless direct current motor with P.F correction have been proposed (Bist & Singh, 2014; Singh & Bist, 2015).

This paper presents the design and implementation of a fuzzy controller for achieving the improved performance of a brushless DC servomotor drive. The performance of fuzzy and PID controller-based BLDC servomotor drives is investigated under different operating conditions such as a change in reference speed, parameter variations, load disturbance, etc. This paper deals with a CUK DC-DC converter as a single-stage power factor correction converter for a permanent-magnet brushless DC motor fed through a

[1]BVC Institute of Technology & Science, Amalapuram, Andhra Pradesh, India.

[2]Department of Electrical and Electronics Engineering, BVC Institute of Technology & Science, Amalapuram, Andhra Pradesh, India.

***Corresponding Author:** Muthuvel B., Department of Electrical and Electronics Engineering, BVC Institute of Technology & Science, Amalapuram, Andhra Pradesh, India, E-Mail: muthuvel.bmv7@yahoo.co.in

How to cite this article: Rao, R.J.V.G., Gopal, R.A.N.V.J., Prasad, P.S., Ram, I.V., Muthuvel, B. (2023). Power quality improvement in BLDC motor drive using PFC converter. The Scientific Temper, **14**(4):1557-1562.

Doi: 10.58414/SCIENTIFICTEMPER.2023.14.4.71

Source of support: Nil

Conflict of interest: None.

Received: 25/10/2023 **Accepted:** 14/11/2023 **Published** : 27/12/2023

diode bridge rectifier from single-phase AC mains. Also, it deals with a power factor correction using a CUK converter-fed brushless DC motor drive as a cost-effective solution for low-power applications. The speed of the BLDC motor is controlled by varying the DC bus voltage of a voltage source inverter which uses a low-frequency switching of VSI for low switching losses. In this paper, a single-stage AC/DC power electronic converter is proposed to efficiently manage the energy harvested from electromagnetic micro-scale and medium-scale generators with low voltage outputs (Sokira, 1989; Gieras *et al*, 2002; Xia, 2012). The proposed topology combines a boost converter and a buck-boost converter to condition the positive and negative half portions of the input AC voltage, respectively.

Introduction to Converters

Introduction

A Brushless DC motor is a perfect motor for low and medium-power applications as a result of its high potency, high energy density, high torque/inertia quantitative relation, low maintenance demand, and a good variety of speed management. It's a section electric motor with three-phase windings on the stator coil and permanent magnets on the rotor.

Existing system

An approach of speed management of BLDC motor by dominant the DC link voltage mistreatment single voltage detector is planned. The BL-Zeta converter operative in DCM mistreatment AN approach of voltage follower is taken into account for the twin operation of PFC and DC link voltage management. AN electronic commutation of the BLDC motor is used leading to low-frequency change operation of the VSI for reducing the change losses (Bist & Singh, 2014; Singh & Bist, 2015).

Moreover, to attain AN improved efficiency, a BL converter topology is employed for reducing the physical phenomenon losses in a very DBR. Figure 1 shows the PFC converter-based BLDC motor and Figure 2 shows the Star-connected BLDC motor.

Moreover, the performance of the planned drive is additionally studied for variable provide voltage to demonstrate its behavior in sensible provide systems. The stresses on the switches are examined to pick switches and

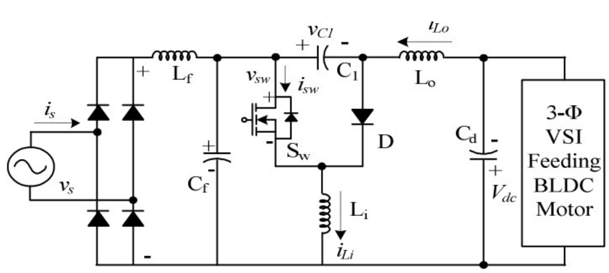

Figure 1: BLDC Motor fed PFC converter

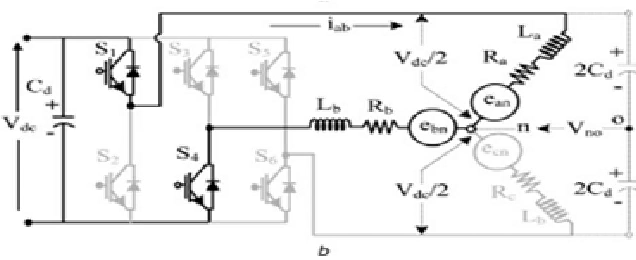

Figure 2: Star-connected BLDC Motor

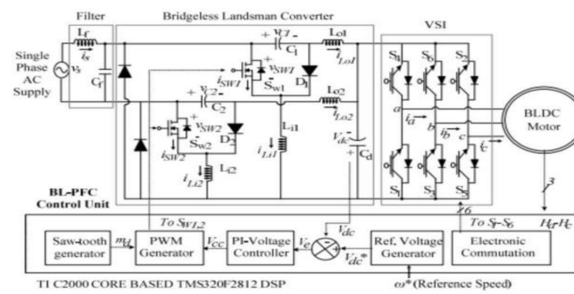

Figure 3: Landsman converter

warmth sinks that additionally illustrate the practicability of developing the planned BL-Zeta converter-fed BLDC motor drive (Singh & Bist, 2015).

Landsman converter

A power factor correction (PFC) based Landsman converter in bridgeless configuration feeding a brushless DC motor drive is proposed for low-power household appliances as shown in Figure 3. The speed of BLDCM is controlled by varying the DC bus voltage of the voltage source inverter feeding to a BLDCM.

Mode I (t1 < t < t2): once the switch (Sw) is turned 'off', the energy holds on within the input and the output inductors (Li and Lo) start discharging to the intermediate condenser (C1) and also the DC-link condenser (Cd). The diode (D) starts conducting during this mode of operation. Hence, the voltage across the intermediate condenser (vC1) and dc-link voltage will increase during this mode of operation. Mode II (t2 < t < t3): this can be the discontinuous physical phenomenon mode of operation, that is, the presence of an input electrical device (iLi) reaches zero and becomes negative. The DC-link condenser provides the specified energy to the VSI feeding BLDC motor; thence the dc-link voltage (Vdc) starts decreasing during this mode of operation.

Control of PFC-based fed sensorless BLDC motor drive

The PFC converter and the sensorless BLDC motor drive are modeled for the proposed drive scheme. The control scheme of the PFC converter consists of the following three blocks A. Reference voltage generator the speed of the BLDC motor is proportional to the DC link voltage of the VSI, hence a reference voltage generator is required to produce an equivalent voltage corresponding to the particular reference speed of the BLDC motor. The error voltage Ve at any instant of time k is as;

$Ve(k) = Vdc^*(k) - Vdc(k)$ and

the output Vc(k) of the PI controller is given by,

$Vc(k) = Vc(k-1) + Kp.(Ve(k) - Ve(k-1)) + Ki.Ve(k)$

where Kp is the proportional gain and Ki fed BLDC MOTOR drive with voltage follower approach for fan application (Hendershot & Miller, 2010).

DC to DC converter

In electronics engineering, a DC-to-DC converter is a circuit that converts a source of direct current from one voltage to another. It is a class of power converter.

DC-to-DC converters are important in portable electronic devices such as cellular phones and laptop computers, which are supplied with power from batteries. *2.6*

Switched mode conversion

Electronic switch-mode DC-to-DC converters are available to convert one DC voltage level to another. The various topologies of the DC-to-DC converter can generate voltages higher, lower, higher, and lower or negative of the input voltage; their names are Buck, Boost, Buck-boost, and Cuk converter. DC-to-DC converters are now available as integrated circuits needing minimal extra components to build a complete converter. DC-to-DC converters are also available as complete hybrid circuits, ready for use within an electronic device (Kenjo & Nagamori, 2005).

Landsman converter

The buck, boost, and buck-boost converters all transfer energy between inputs and output using the inductor, analysis is based on voltage balance across the inductor. Figures 4, 5 & 6 show the operation of the landsman converter.

If we assume that the current through the inductors is essentially a ripple we can examine the charge balance for the capacitor C1. For the transistor ON the circuit becomes"ON-STATE" and the current in C1 is I_{L1}. When the transistor is OFF, the diode conducts and the current in C1 becomes I_{L2}. "OFF-STATE" Since the steady state assumes no net capacitor voltage rise, the net current is zero.

Introduction to Inverters

DC/AC converters (inverters)

Two common types of DC/AC converters are single-phase inverters and three-phase inverters. Input is from an AC source and the output is desired to be a sinusoidal voltage or current with a zero DC component. Figures 7 & 8 show the single-phase bridge inverter and its output waveform.

A common way of varying the AC voltage parameters is to introduce a third state which is called the zero state. The zero states can be obtained by closing either the upper leg switches (S1 - S3) or lower leg switches (S2 - S4). When the zero state occurs, the AC voltage of the single-phase inverter output is used to change the AC voltage parameters.

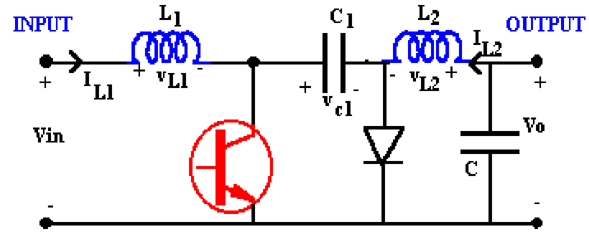

Figure 4: Converter circuit

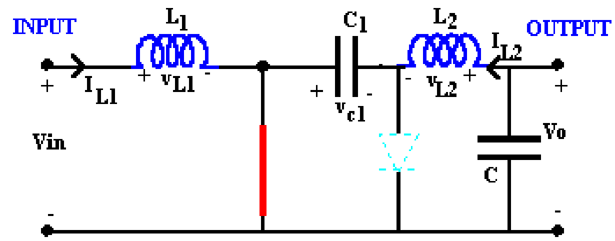

Figure 5: ON state

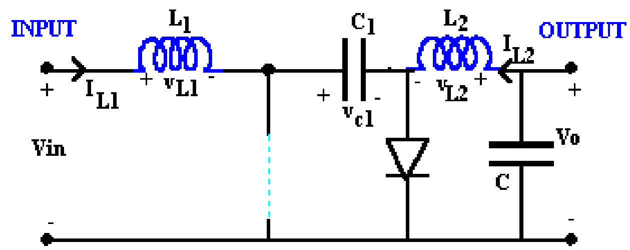

Figure 6: Off state

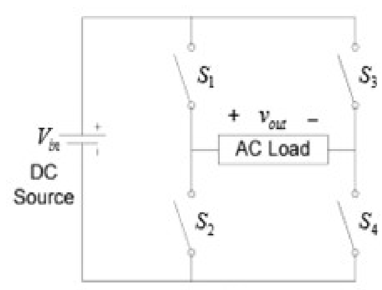

Figure 7: single phase bridge inverter

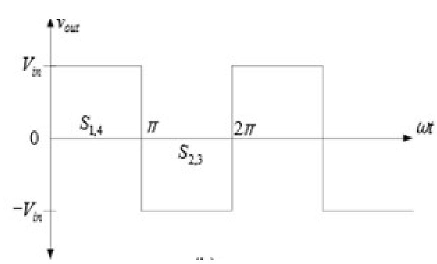

Figure 8: Output waveforms

Pi controller principle

A PI controller is an algorithm that can be implemented without resorting to any heavy control theory. Such an algorithm aims to determine the plant input (in our case the stator voltage frequency) that will make the measured output (in our case the speed of the rotor) reach the reference

Inverters (introduction)

Inverters can be broadly classified into two types based on their operation,

1. Voltage Source Inverters (VSI)
2. Current Source Inverters (CSI)

Voltage source inverters are ones in which the DC source has small or negligible impedance. In other words, VSI has a stiff DC voltage source at its input terminals. A current source inverter is fed with adjustable current from a DC source of high impedance, i.e.; from a stiff DC source. A voltage source inverter is one in which the D.C. source has a small or negligible impedance. In other words, a voltage source inverter has a stiff DC voltage source at its input terminals.

Introduction to BLDC Motor

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator (fixed part) as shown in Figure 9. Permanent magnets create the rotor flux and the energized stator windings create electromagnet poles. The rotor (equivalent to a bar magnet) is attracted by the energized stator phase as shown in figure 10. The merits of BLDC motors are high efficiency, better speed versus torque characteristics, noiseless operation, higher speed range. Table 1 shows the different speeds and their current ratings of the BLDC motor which indicates the relation between speed and current.

Brushless DC motors (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous electric motors powered by direct-current (DC) electricity and having electronic commutation systems, rather than mechanical commutators and brushes. When a current passes through the coil wound around a soft iron core, the side of the positive pole is acted upon by an upward force, while the other side is acted upon by a downward force. According to Fleming, the forces cause a turning effect on the coil, making it rotate.

$I=(V_{applied} - V_{cemf}) / R_{armature}$.

The mechanical power produced by the motor is given by

$P=I*V_{cemf}$

Principle of BLDC motor

As an unloaded DC motor spins, it generates a backward-flowing electromotive force that resists the current being applied to the motor. In an experiment of this kind made on a motor with separately excited magnets, the following figures were obtained:

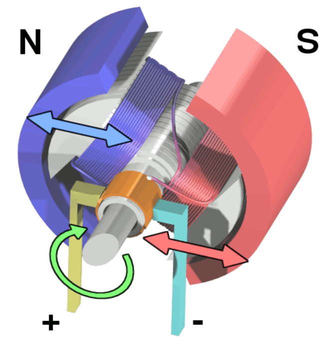

Figure 9: BLDC motor

Figure 10: Construction of BLDC motor

If the motor had been helped to run at 261.5 rpm, the current would have been reduced to zero. In the last result obtained, the current of 5.1 amperes was absorbed in driving the armature against its friction at the speed of 195 revolutions per minute. Figures 11 (a) & 11 (b) show the BLDC motor characteristics and its output waveforms.

Speed torque characteristics

Figure 11(a) & (b) shows the speed torque (N Vs T) characteristics and output (Time Vs Voltage) characteristics of the BLDC motor

Control of BLDC motor

An electronic commutation of the BLDC motor includes proper switching of VSI in such a way that a symmetrical DC is drawn from the DC link for 120° and placed symmetrically at the cente r of the back-EMF of each phase. A Hall effect position sensor is used to sense the rotor position on a span of 60°; which is required for the electronic commutation of the BLDC motor.

Modeling of the proposed PMBLDCM drive

- *Voltage reference generator:* This is used to generate a reference voltage at the DC link which is equivalent to the desired reference speed of the PMBLDCM.
- *Rate limiter:* The rate limiter introduced in the reference voltage maintains a constant voltage error (Ve) at the DC link during transient states so that the motor current (IDC) rises in a controlled manner.

Table 1: Different speeds and their current ratings

Revolutions per minute	0	50	100	160	180	195
Amperes	20	16.5	12.2	7.8	6.1	5.1

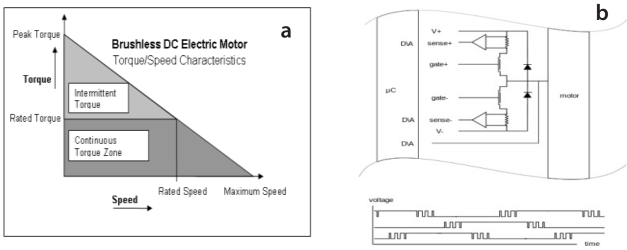

Figure 11: (a) BLDC motor characteristics (b) Outputs of BLDC Motor

- *Voltage Controller:* The voltage controller is a proportional and integral (PI) controller that tracks the error voltage between the reference voltage and sensed voltage at the DC link and generates a control signal Ic based on the Kp and Ki the proportional and integral gains of the PI controller, respectively.
- *Reference Current Generator:* The reference current at the input of the isolated zeta converter (id*) is generated using the unit template of the AC mains voltage and the output of the PI controller.
- *PWM Controller:* The PWM controller processes the current error (Δid) between the reference input current (id*) of the isolated zeta converter and the DC (id) sensed after DBR.
- *Electronic Commutators:* The electronic commutators use signals from Hall effect position sensors to generate the switching sequence for the VSI.
- *Voltage Source Inverter:* The voltage source inverter employed in the proposed PMBLDCM drive uses insulated gate bipolar transistors (IGBTs) because of its operation at a lower frequency compared to the PFC converter.

Results and Discussions

All the work was carried out in MATLAB/Simulink block set. Figure 12 shows the Landsman converter with the BLDC simulation circuit. Figure 13 shows the Hall sensor simulation circuit.

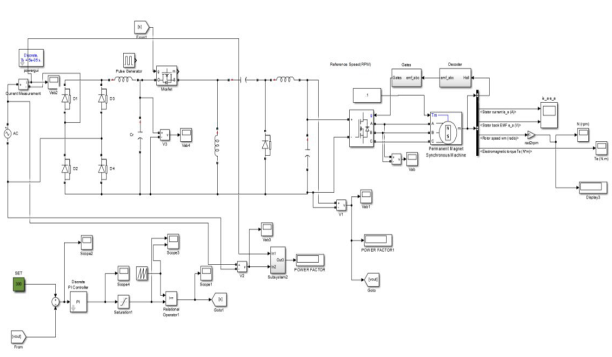

Figure 12: Landsman converter with BLDC simulation circuit

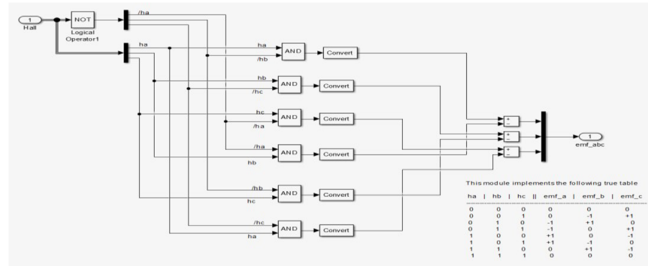

Figure 13: Hall sensor simulation circuit

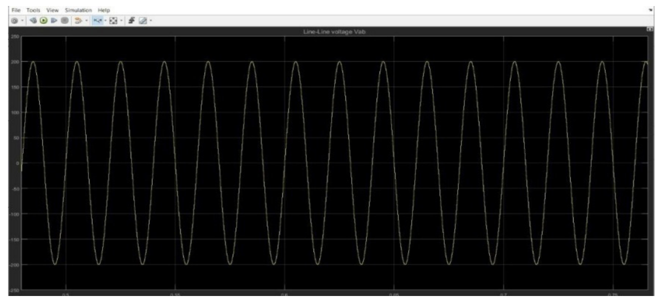

Figure 14: Input voltage of the BLDC motor

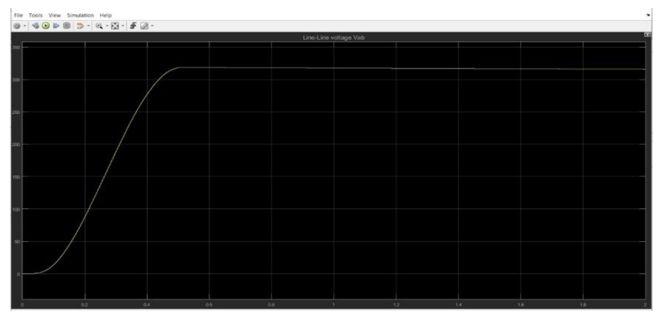

Figure 15: Output voltage of the BLDC motor

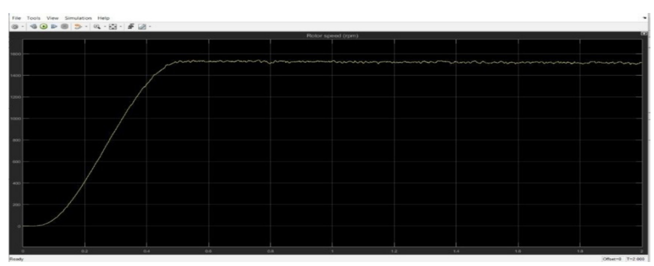

Figure 16: Rotor speed of the BLDC motor

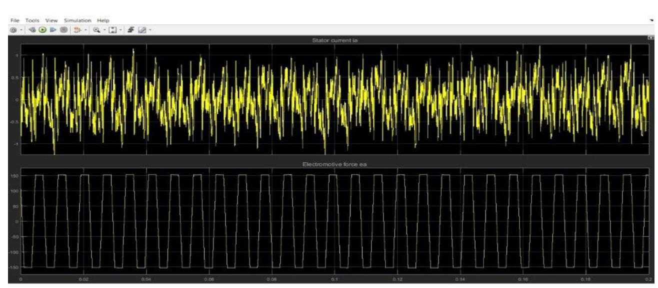

Figure 17: Stator current and EMF of the BLDC motor

Simulation results

Figure 14 shows the simulated Input voltage waveform of the BLDC Motor. Figure 15 shows the simulated output voltage waveform of the BLDC Motor. Figure 16 shows the simulated rotor speed waveform of the BLDC Motor. Figure17 shows the simulated stator current and EMF waveform of the BLDC Motor

Conclusion

A PFC zeta converter fed BLDC motor drive has been proposed for a large variety of speed management with UPF at AC mains. The speed of the BLDC motor has been controlled by varying the DC-link voltage of VSI via the PFC zeta converter. The PFC zeta converter has been designed to operate in DICM and needed a voltage follower for DC-link voltage management. One voltage detector is required for the whole drive which makes it a cost-effective answer. Moreover, low-frequency change pulses are used for electronically commutating the BLDC motor offering reduced change losses within the VSI compared with the typical theme of PWM-based switching of VSI. The projected drive has been designed to achieve associate degree improved power quality at AC mains for a wide range of speed management. The experimental results have shown agreement with the simulated results that have shown associate degree correct modeling of the projected BLDC motor drive.

References

Puttaswamy, C. L., Bhim Singh and Singh, B.P. (1995). Investigation on the dynamic behavior of permanent magnet brushless DC motor drive, *Electric power Comp. & Sys*., **vol. 23, no. 6,** pp. 689-701.

Singh, B., Singh, B. N., Chandra, A., Al-Haddad, K., Pandey, A., and Kothari, D. P. (2003). A review of single-phase improved power quality AC-DC converters, *IEEE Trans. Ind. Electron.,* **vol. 50, no. 5**, pp. 962-981.

Singh, B., Singh, S., Chandra, A., and Al-Haddad, K. (2011). A comprehensive study of single-phase AC-DC power factor corrected converter switch high-frequency isolation", *IEEE Trans. Ind. Inf.,* **vol. 7, no. 4**, pp. 540-556, Nov. 2011.

Bist, V., and Singh, B. (2014). A reduced sensor configuration of BLDC motor drive using a PFC based modified-zeta converter*, IET Power Electron.,* **vol. 7, no. 9**, pp. 2322-2335.

Singh, B., and bist, V. (2015). *A BL-CSC converter fed BLDC motor drive with P.F correction: IEEE Transition India Electron,* **vol. 62, no. 1**, pp. 172-183, 2015

Sokira, T.J., and Jaffe, W. (1989). Brushless DC motors: electronic commutation and control' Tab Books, USA.

Gieras, J.F., and Wing, M. (2002) Permanent magnet motor technology – design and application'(Marcel Dekker Inc., New York.

Xia, C.L. (2012) 'Permanent magnet brushless DC motor drives and controls' Wiley Press, Beijing,

Kenjo, T. and Nagamori, S. (2005). Permanent magnet brushless DC motors Clarendon Press, Oxford.

Hendershot, J.R., and Miller, T.J.E. (2010) Design of brushless permanent magnet motors Clarendon Press, Oxford.