



# A REVIEW ON PFC CONVERTER TOPOLOGIES FOR BLDC MOTOR DRIVE USED IN FAN

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**Abstract:** This review paper presents a comprehensive analysis of Power Factor Correction (PFC) converter topologies employed in Brushless Direct Current (BLDC) motor drives used in ceiling fan. It explores the significance of PFC converter in enhancing power quality and efficiency in BLDC motor drive systems and gives an overview on various PFC converter configurations, including isolated and non-isolated converter topologies, and control techniques used to drive motor and to power the circuit. The review evaluates the performance of these PFC converter topologies in terms of power factor, Total Harmonic Distortion (THD), efficiency, and control complexity. This concise analysis gives an overview on different topologies of PFC converter for BLDC motor drive in fan application.

**Index Terms -** Brushless Direct Current motor (BLDC), Power Factor, Total Harmonic Distortion (THD).

## I. INTRODUCTION

Brushless Direct Current (BLDC) motors have revolutionized various industries by offering distinct advantages over traditional motor technologies. Unlike their other commercial motors like brushed DC motors and induction motors, BLDC motors have gained widespread adoption due to their unique attributes. These motors find application in an array of fields such as in electric and hybrid vehicles, where their efficiency and compact size contribute to improved fuel economy and reduced emissions, robotics, automotive, aerospace, and HVAC systems. BLDC motors are also finding its place of usage in household appliances some of them are ceiling fan, air conditioners, refrigerators, mixer etc.

The shift from conventional induction motors to Brushless Direct Current (BLDC) motors in ceiling fans signifies a remarkable advancement in fan technology. Traditional ceiling fans have long relied on induction motors, which have proven effective over time. However, the introduction of BLDC motor technology has sparked a fundamental revolution in the operation of ceiling fans and the advantages they provide to consumers. (Lenin et al., 2021)

BLDC motors have become popular in the ceiling fan industry because of their superior energy efficiency compared to traditional induction motors. They are designed to use less electrical power while providing the same to better airflow, making them an eco-friendly and cost-effective option for home appliances.

BLDC motors are renowned for their efficiency, durability, and low maintenance due to the absence of brushes and commutators. They utilize electronic commutation based on rotor position, avoiding issues like sparking and noise. Their precise speed and torque control make them suitable for high-precision applications, and their compact design suits various industries and environments. BLDC motors operate through electromagnetism, with key components including the motor, power converter, position sensors, and a controller with advanced algorithms to precisely manage speed and torque.

In BLDC motor drive systems, maintaining a constant DC link voltage through a 3-phase voltage source inverter (VSI) is crucial for electronic commutation. However, using an uncontrolled diode bridge rectifier (DBR) with a high-value DC link capacitor connected to single-phase AC mains results in highly distorted supply current with a low power factor, which does not comply with international power quality standards such as IEEE standard IEC 61000-3-2. According to this In Class-D equipment, includes devices with lower power consumption, such as consumer electronics, personal computers, and smaller office equipment to have quality standards to uphold a power factor (PF) exceeding 0.9 while limiting the Total Harmonic Distortion (THD) to below 5% (B. Singh & Bist, 2016), (B. Singh & Bist, 2012).

To address these issues, power factor correction (PFC) converters are introduced to achieve a unity power factor at the AC mains. These PFC converters draw a sinusoidal supply current in phase with the supply voltage while ensuring the DC link voltage remains stable, even in the face of load variations and supply voltage fluctuations. The paper focuses on reviewing various PFC converters used to drive BLDC fan.

## II. CLASSIFICATION OF CONVERTER TOPOLOGIES REVIEWED

Power Factor Correction (PFC) converter topologies can be categorized based on their suitability for Brushless Direct Current (BLDC) motor drive applications. Here PFC converters can be divided into two primary categories: bridge PFC converters and bridgeless PFC converters.

**Bridge PFC Converter:** In a bridge PFC converter, the initial step involves utilizing an input bridge rectifier to rectify the AC input voltage sourced from the mains. Following this rectification process, the converter typically employs a Boost or a similar topology to enhance power factor and diminish Total Harmonic Distortion (THD) within the current waveform.

**Bridgeless PFC Converter:** In contrast, a bridgeless PFC converter does not have an input bridge rectifier. Instead, it adopts an altered circuit configuration, which minimizes conduction losses and directly enhances power factor from the AC input.

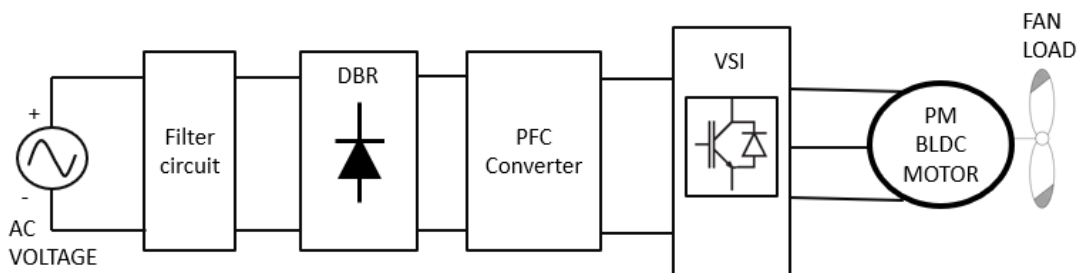


Figure 1 Block diagram of BLDC motor fed PFC converter and Diode Bridge Rectifier

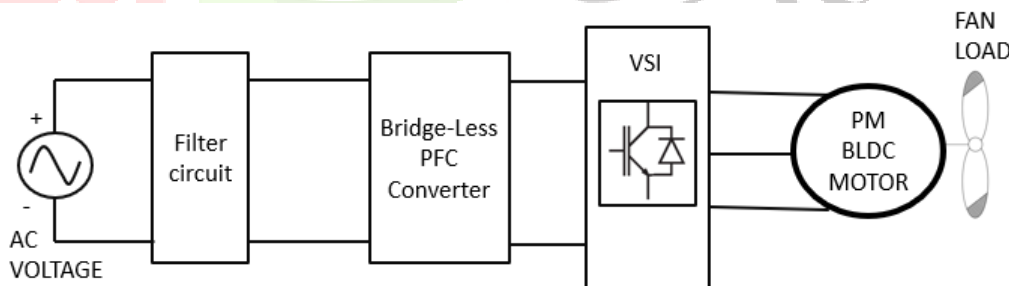


Figure 2 Block diagram of BLDC motor fed Bridge-Less PFC converter

Bridge and bridgeless PFC converters can both be useful in BLDC motor driving applications however, the choice will depend on the particular needs and limitations imposed by the system's design. In general Bridge PFC converter are used commonly in industrial motor drives, to improve power factor and reduce THD for efficient motor operation, there are also found in Uninterruptible Power Supplies (UPS) for power quality improvement and reduce harmonics, LED lighting systems, consumer electronics, like audio amplifiers.

The Bridgeless PFC converter are found in EV and PHEV battery chargers to achieve higher efficiency, faster charging times, and improved power factor correction, Solar Inverters also uses them to increase efficiency and power quality in converting DC power from solar panels to AC power for grid injection, and home appliances, such as air conditioners and refrigerators.

### III. BRIDGE - POWER FACTOR CORRECTION CONVERTER

(Manglik et al., 2016) In this paper the authors proposed, a low-cost PMBLDC based ceiling fan drive with single voltage sensor. The proposed drive consists of single phase uncontrolled diode bridge rectifier, its output given to buck – boost DC-DC converter and followed by VSI to drive BLDC motor. In this paper PFC buck – boost converter is designed for 120 V DC link voltage. The control technique employed in this paper to regulate the BLDC fan speed involves varying the DC link voltage using a PWM controller, which is fed by a PI controller. Electronic commutation of the VSI to drive the motor is achieved by utilizing the Hall sensor signal. The proposed converter operation is compared with commercially available one and this gives 12 percentage reduced power consumption with improved power factor. This PFC converter maintains a power factor of within 0.7 – 0.94 values.

(B. Singh & Bist, 2012) The paper explains a single-stage Zeta converter designed for both, DC link voltage control of diode rectifier and power factor correction. The Zeta converter operates in the Discontinuous Inductor Current Mode (DICM) and employs a voltage follower approach, enabling precise control of the DC link voltage. Furthermore, the proposed system eliminates the requirement for Hall Effect position sensors by employing sensorless control for the BLDC motor. This not only simplifies the setup but also reduces both complexity and costs associated with it. The proposed system attains a broad spectrum of speed control while maintaining a high-power factor and enhancing power quality at the power supply. It effectively keeps the Total Harmonic Distortion (THD) of the supply current under 5%, a value significantly lower than the international power quality standards.

(S. Singh & Singh, 2012) In this paper the authors presented a PFC converter for speed control drive of BLDC motor employed in air-conditioning systems whereas, it can also be used in fans with BLDC motor. A conventional Cuk PFC converter is stated in the paper. Speed control scheme used in this paper to operate BLDC motor, is based on controlling the dc link voltage as an equivalent to the reference speed using a PI controller to generate PWM signal for PFC converter switches. Hall effect sensors are used to obtain rotor position signals only required at the commutation points, which are subsequently utilized by an electronic commutator to generate a switching sequence for VSI that power the PMBLDC motor. Cuk PFC converter provides near unity Power Factor (PF) in a wide range of speeds and input voltages, which is in conformity with the International Standard IEC 61000-3-2, for wide voltage input the THD value is less than 5.5%.

(Kumar et al., 2020c) In this paper authors presents a single switch boost-flyback PFC converter for a BLDC motor drive used in a ceiling fan, designed to achieve low voltage stress and inherent unity power factor at the input mains. The PWM signals for PFC converter are obtained as normal stated before the reference voltage is generated based on the speed of the BLDC motor ceiling fan, while the feedback voltage is sourced from the auxiliary winding of the high-frequency transformer fed to PI controller which gives the control voltage. Motor commutation are carried out using Hall sensors. In single switch boost-flyback PFC converter THD is from 6% to 2% and PF is above 0.9.

(Kumar et al., 2020b) This paper presents an isolated configuration of the Zeta PFC converter, similar to the previously observed Zeta PFC converter (B. Singh & Bist, 2012). The isolated converter topology provides several advantages, including improved power quality with reduced electromagnetic interference at the input, lower power consumption, simplified control techniques, decreased stress on switches, and reduced conduction loss. The control techniques used here is hall sensors based for electronic commutation of BLDC motor, the DC link voltage of the AC-DC converter being adjusted to manage motor speed. The Total Harmonic Distortion (THD) remains consistently below 5.5% and maintains a nearly unity power factor even when the supply voltage varies from 90V to 270V. It is noteworthy that the THD of the proposed isolated zeta PFC converter ceiling fan aligns with the requirements of the IEC 61000-3-2 standard.

(Khan et al., 2021) The paper proposes an isolated PFC Cuk converter with integrated magnetics. In this design, the integrated magnetics structure enables the same core to share, two inductors and transformer windings onto a single core. This proposed isolated configuration of Cuk converter with integrated magnetics in the paper provide significant benefits neglecting high frequency ripples in power supply and low torque ripple in BLDC motor. The performance of the proposed PFC converter shows a reduced motor torque ripple to 2.14%, with a power factor of 0.999 and a THD of 4.72% at full load, converter operates in continuous conduction mode.

(Kumar & Singh, 2020a) In this paper a sensorless BLDC motor consist of an AC-DC Power Factor Correction (PFC) converter, and Voltage Source Inverter (VSI). The  $S^4$  BL (Single Switch and Single Stage Boost-Luo) PFC converter topology integrates both boost and Luo converters, functioning in Discontinuous Conduction Inductor Mode (DCIM) is presented in this paper. Additionally, it incorporates a high-frequency isolation transformer to provide feedback control of the PFC converter's output voltage. The PWM signals are

generated by Voltage follower control technique for AC-DC PFC converter. The sensorless control of a BLDC motor ceiling fan involves sensing line voltages, filtering them, and using virtual Hall-Effect signals to generate switching pulses for the VSI at the fundamental frequency, while the line current depends on various factors such as DC link voltage, motor back EMF, stator winding resistance, and inductance, in S<sup>4</sup> BL PFC Converter THD is from 7% to 3% and PF is above 0.9.

#### IV. BRIDGELESS - POWER FACTOR CORRECTION CONVERTER

(Kumar et al., 2020a) The paper introduces a converter for ceiling fan powered by a bridgeless isolated PFC SEPIC converter, operating in DC link voltage of 48V. This fan showcases superior power quality and reduced power consumption compared to traditional counterparts. This topology consists of several key components, including an Electromagnetic Interference (EMI) filter, a high-frequency isolation transformer, a Voltage Source Inverter, and a PMSBLDC motor. Operating in discontinuous inductor current mode, the primary focus of the paper lies in the design of the bridgeless isolated PFC SEPIC converter and its control technique, employing a simple voltage follower. The isolated converter topology offers advantages such as low electromagnetic interference, less power consumption, simple control technique, less switch stress, and reduced conduction losses.

(Kumar & Singh, 2020b) This paper presents the design of a single-stage bridgeless flyback converter intended for driving a sensorless brushless DC motor in a ceiling fan. The PFC converter in this design operates in the discontinuous mode (DCM) and employs a dual flyback configuration, which helps minimize conduction losses and ensures good power quality parameters at the AC mains. Furthermore, the system utilizes an auxiliary winding voltage to manage input voltage fluctuations and regulate the PFC converter's output voltage, known as the DC link voltage. This voltage control mechanism allows for precise control of the ceiling fan speed. The THD value is from 6% to 2% and the power factor is maintained above 0.9 the converter power quality under varying AC source voltage ( 70 V – 270 V ) is also observed.

The below tabulation provides comparison on different topologies of PFC converter based on number of components

| S. No.                          | PFC Converter                                  | DBR diodes | PFC converter |    |   |   |     | Filter circuit |   |
|---------------------------------|------------------------------------------------|------------|---------------|----|---|---|-----|----------------|---|
|                                 |                                                |            | D             | SW | L | C | TXF | L              | C |
| <b>Bridged PFC converter</b>    |                                                |            |               |    |   |   |     |                |   |
| 1.                              | Non – isolated buck-boost converter            | 4          | 1             | 1  | 1 | 1 | 0   | 1              | 1 |
| 2.                              | Non – isolated zeta converter                  | 4          | 1             | 1  | 3 | 3 | 0   | 0              | 0 |
| 3.                              | Non – isolated cuk converter                   | 4          | 1             | 1  | 2 | 1 | 0   | 0              | 0 |
| 4.                              | Isolated single switch boost-flyback converter | 4          | 4             | 1  | 2 | 4 | 1   | 1              | 1 |
| 5.                              | Isolated zeta converter                        | 4          | 1             | 1  | 1 | 2 | 1   | 1              | 1 |
| 6.                              | Isolated cuk converter                         | 4          | 1             | 1  | 2 | 4 | 1   | 0              | 0 |
| 7.                              | Isolated Single Switch Boost-Luo Converter     | 4          | 4             | 1  | 2 | 4 | 2   | 1              | 1 |
| <b>Bridgeless PFC converter</b> |                                                |            |               |    |   |   |     |                |   |
| 8.                              | Isolated SEPIC converter                       | 0          | 2             | 2  | 1 | 2 | 2   | 1              | 1 |
| 9.                              | Isolated flyback converter                     | 0          | 4             | 2  | 2 | 2 | 2   | 1              | 1 |

Table 1 PFC Converters Reviewed

D – diode SW – Switches L – Inductor C – Capacitor TXF – Transformer

### V. BLDC MOTOR CONTROL TECHNIQUES

From the above review the commonly employed BLDC motor control technique for speed and PWM generation for Voltage Source Inverter (VSI) to commutate the BLDC motor is either using sensor or sensor-less control.

#### 5.1 Sensor based BLDC Motor Control

Utilizes Hall-effect sensors or other position sensors mounted on the motor to detect rotor position. Provides precise control, minimizing torque ripple, and ensuring reliable starting. Advantages include accuracy and smooth operation, but it increases system complexity and can be sensitive to sensor faults. [5],[12]

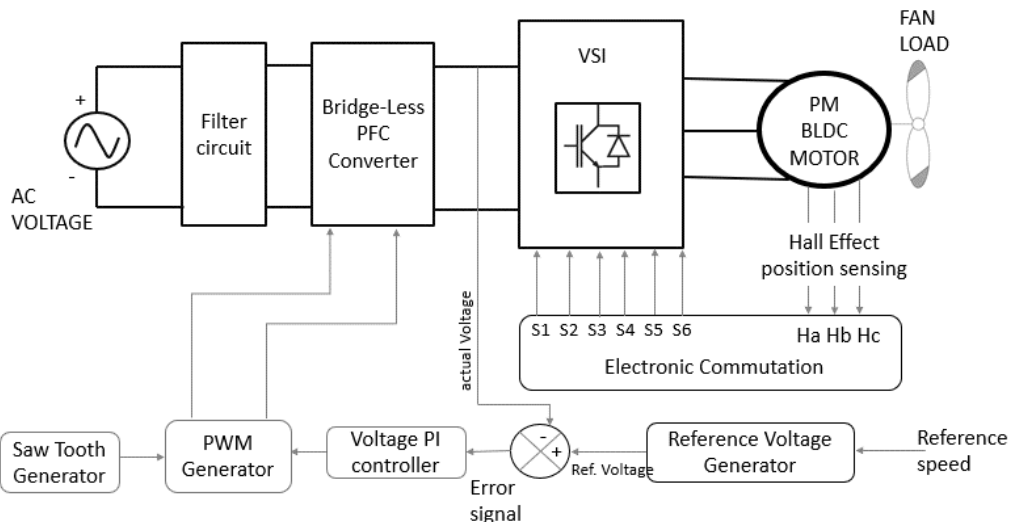


Figure 3 Sensor based BLDC motor Drive

#### 5.2 Sensor-less BLDC Motor Control

This technique does not require physical sensors on the motor but relies on other methods to estimate rotor position. It relies on monitoring the back electromotive force (EMF) generated by the motor windings as the rotor rotates within the stator's magnetic field. By detecting the zero-crossing points of the back EMF waveforms in multiple motor phases, the controller can estimate the rotor's position and adjust the motor's commutation accordingly. This estimation is made possible through advanced control algorithms, including sensor-less field-oriented control (FOC) and sensor-less direct torque control (DTC), which enhance accuracy. While sensor-less control reduces cost and enhances reliability by eliminating the need for sensors. [3], [9]

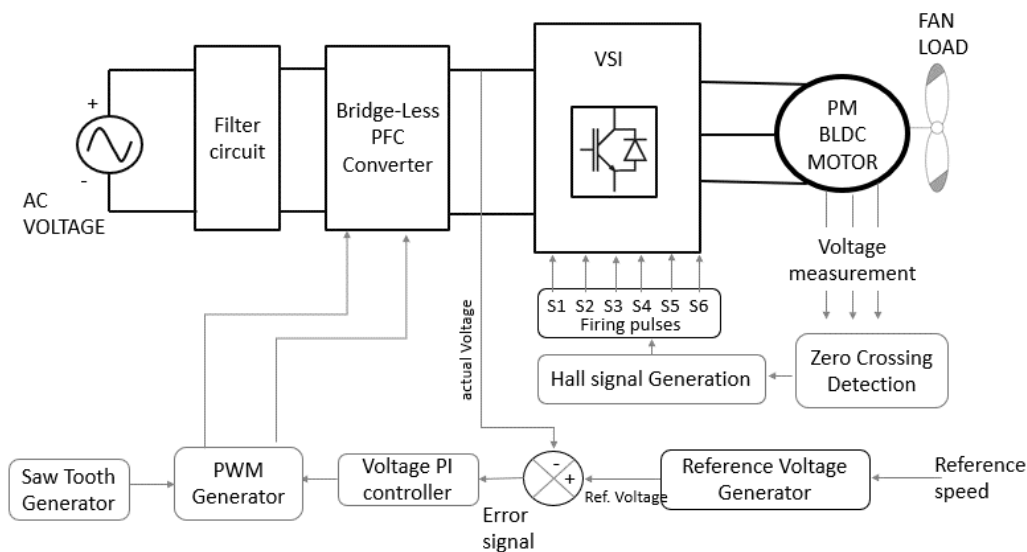


Figure 4 Sensor-Less BLDC motor Drive

## VI. CONCLUSION

This paper provides an overview on Power Factor Correction (PFC) converter topologies for BLDC motor drives in fan applications. These topologies include bridge-type and bridgeless converters, under which the converter design is categorized as non-isolated and isolated converter. PFC converters are employed for enhancing power quality by reducing total harmonic distortion (THD) and achieving near-unity power factor in fan applications. In this paper a review on converter topologies, their control techniques stated, THD and Power Factor (PF) values are observed and reviewed.

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