

An Efficient Single Stage PFC CUK Converter Based PMBLDC Motor Drive

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Abstract - The use of permanent-magnet brushless dc motor (BLDC) in low-power appliances is increasing because of its features of high efficiency, wide speed range, and low maintenance. This project deals with a power factor correction (PFC) based Cuk converter fed brushless DC motor (BLDC) 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 voltage source inverter (VSI) which uses a low frequency switching of VSI (electronic commutation of BLDC motor) for low switching losses. A diode bridge rectifier (DBR) followed by a Cuk converter working in discontinuous conduction mode (DCM) is used for control DC link voltage with unity power factor at AC mains. Nowadays, PMBLDC has become more advantageous than induction motor. This rare earth PM not only improves the steady state performance of the motor but also its power density (output power to mass ratio), dynamic performance and also its quality. Also, the cost of rare earth permanent magnet also decreasing day by day hence is making these motors highly popular. Due to the improvement in the semiconductors field, the control of the brushless motor is easy with effective cost and also the drive is operated in wide speed ranges with good efficiency. In PMBLDC the power losses are at stator side, where the heat is easily transferred from the ribbed frame. Considerable improvement in dynamic performance of BLDC motor drive is achieved since low inertia at the rotor and due to air gap magnetic flux density is high and current limitations are speed independent.

Keywords: Single Stage, PFC, Cuk Converter, PMBLDC, Motor Drive.

I. INTRODUCTION

The PMBLDCM drive, fed from a single-phase AC mains through a diode bridge rectifier (DBR) followed by a DC link capacitor, suffers from power quality (PQ) disturbances such as poor power factor (PF), increased total harmonic distortion (THD) of current at input AC mains and its high crest factor (CF). It is mainly due to uncontrolled charging of the DC link capacitor which results in a pulsed

current waveform having a peak value higher than the amplitude of the fundamental input current at AC mains. Moreover, the PQ standards for low power equipment's such as IEC 61000-3-2, emphasize on low harmonic contents and near unity power factor current to be drawn from AC mains by these motors.

Therefore, use of a power factor correction (PFC) topology amongst various available topologies is almost inevitable for a PMBLDCM drive. Most of the existing systems use a boost converter for PFC as the front-end converter and an isolated DC-DC converter to produce desired output voltage constituting a two-stage PFC drive. The DC-DC converter used in the second stage is usually a fly back or forward converter for low power applications and a full-bridge converter for higher power applications. However, these two stage PFC converters have high cost and complexity in implementing two separate switch-mode converters, therefore a single stage converter combining the PFC and voltage regulation at DC link is more in demand. The single-stage PFC converters operate with only one controller to regulate the DC link voltage along with the power factor correction. The absence of a second controller has a greater impact on the performance of single-stage PFC converters and requires a design to operate over a much wider range of operating conditions.

For the proposed voltage controlled drive, a half-bridge buck DC-DC converter is selected because of its high power handling capacity as compared to the single switch converters. Moreover, it has switching losses comparable to the single switch converters as only one switch is in operation at any instant of time. It can be operated as a single-stage power factor corrected (PFC) converter when connected between the VSI and the DBR fed from single-phase AC mains, besides controlling the voltage at DC link for the desired speed of the Air-Con compressor. A detailed modeling, design and performance evaluation of the proposed drive are presented for an air conditioner compressor driven by a PMBLDC motor of 1.5 kW, 1500 rpm rating.

The applications of PMBLDC motors are increasing in the day to day life because of its features like low

maintenance, high efficiency, and wide speed range. Brushless DC electric motor (BLDC motors) also known as electronically commutated motors, they are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

II. EXISTING SYSTEM

In this system a PMBLDC Motor drive is fed from a single-phase ac supply via a diode bridge rectifier (DBR) followed by a capacitor at dc link. The capacitor draws current in short pulses. This will generate harmonics and yield poor PF, resulting in poor power quality. Drive is supplied via diode bridge rectifier and a capacitor. But the capacitor draws pulsating currents which results in harmonics due to an uncontrolled charging of the dc link capacitor. So PFC converters are implemented in front of the dc link capacitor for PFC correction.

2.1 Drawbacks

- There is no dynamic response.
- High Total harmonic Distortion (THD).

III. PROPOSED SYSTEM

The proposed PMBLDC controller scheme is based on the control of the DC link voltage reference as an equivalent to the reference speed is shown in fig 1. The rotor position signals acquired by Hall effect sensors are used by an electronic

4.1 Block Diagram

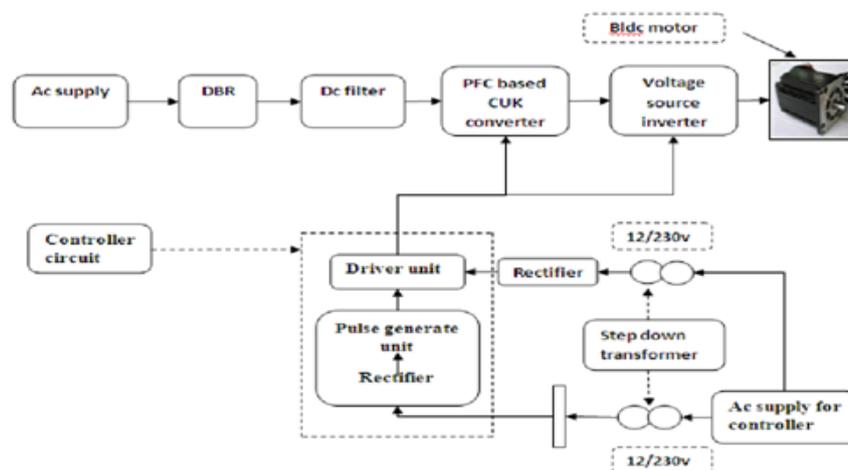


Figure 1: Block Diagram of Proposed System

commutator to generate switching sequence for the VSI feeding the PMBLDC motor, therefore, rotor-position is required only at the commutation points.

3.1 Advantages

- Facilitates the soft starting of the PMBLDC motor unlike a boost converter which habitually step-up the voltage level at its output, not ensuring the soft starting.
- Unlike a simple buck-boost converter, the Cuk converter has a continuous output current. The output inductor makes the current continuous and ripples free.
- Has ensured reasonable high power factor of the order of 0.997 in wide range of the speed as well as input AC voltage.
- Input to output DC insulation.
- Efficiency is good compared with other converters due to single switch.
- The switching loss of VSI is reduced by adopting fundamental frequency switching resulting in an additional power saving and hence an enhanced efficiency.
- Reduces the complexity and probability of slow down the system response.

IV. SYSTEM DESIGN AND METHODOLOGY

This system proposes a simple, cost effective and efficient PFC Cuk PMBLDC motor drive. Here a Cuk dc-dc converter is used as a single stage power factor correction (PFC) converter for a permanent magnet brushless DC motor (PMBLDCM) fed through a diode rectifier (DBR) from a single phase AC mains. This converter is used due to single stage requirement for dc link voltage control with unity PF at ac mains. A three phase voltage source inverter is used as an electronic commutator to operate the PMBLDCM drive.

4.2 Circuit Diagram

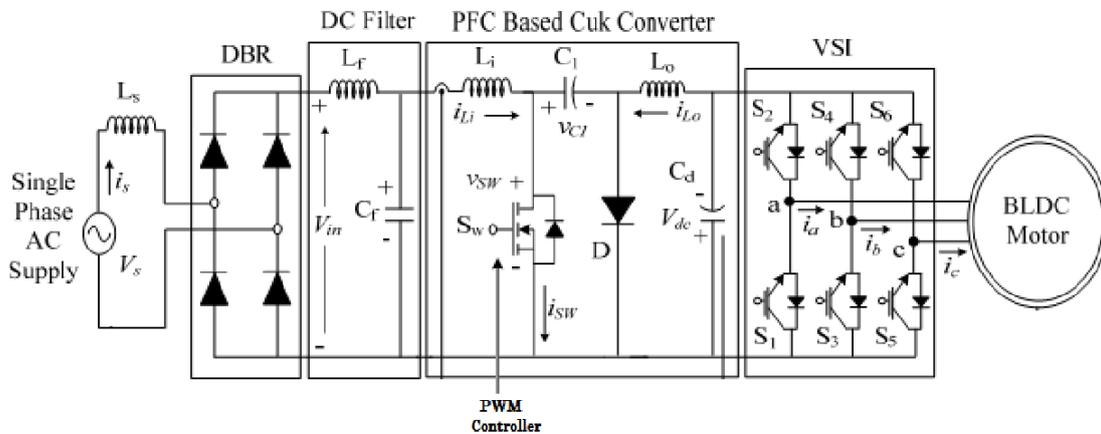


Figure 2: Circuit Diagram of Proposed System

A PMBLDCM has torque directly proportional to phase current and its back EMF, which is proportional to the speed. So, it has a constant current in its stator windings with variable voltage across its terminals maintains constant torque in a PMBLDCM under variable speed operation. However, the control of VSI is done by electronic commutation based on the rotor position signals of the PMBLDC motor.

4.3 Control Methodology

The proposed speed control scheme which is based on the control of the DC link voltage reference as an equivalent to the reference speed. An electronic commutator to generate switching sequence for the VSI feeding the PMBLDC motor, therefore, rotor-position is required only at the commutation points.

4.4 CUK PFC Stage

The Cuk DC-DC converter controls the DC link voltage using capacitive energy transfer which results in non pulsating input and output currents. The proposed PFC converter is operated at a high switching frequency for fast and effective control.

For high frequency operation, a metal oxide field effect transistor (MOSFET) is used in the proposed PFC converter, whereas, insulated gate bipolar transistors (IGBTs) are used in VSI bridge feeding PMBLDCM as switches, because of its operation at lower frequency compared to PFC converter.

4.5 Control Of PFC CUK Converter Fed BLDC Motor Drive

The control of the proposed drive system is divided into two categories of control of the PFC converter for dc link voltage control and control of three phase VSI for achieving

the electronic commutation of the BLDC motor as follows . A. Control of PFC converter The modeling of the PFC converter consists of the modeling of speed controller ,reference current generator and PWM controller as given .

4.5.1 Speed Controller

The speed controller is a PI controller which tracks the reference speed as an equivalent reference voltage .The reference voltage (V_{dc}) is obtained by multiplying the reference speed (ω) with motor's voltage constant (K_v) as

$$V_{dc}^* = k_v \omega^*$$

For k th instant of time , is the reference dc link voltage and is the voltage sensed at the dc link then the error voltage is given by

$$V_e(k) = V_{dc}^*(k) - V_{dc}(k)$$

4.5.2 Reference Current Generator

The reference current at the input of the cuk converter (I_d) is given as

$$I_d^* = I_c(k)uv_s$$

Where is the unit template of the ac mains voltage ,calculated as

$$uv_s = \frac{V_d}{V_{sm}} ; V_d = |v_s| ; v_s = V_{sm} \sin \omega t$$

Where V_{sm} and ω are the amplitude (in volts) and frequency (in radians per second) of the ac mains voltage.

4.5.3 PWM Controller

The reference input current of the cuk converter is compared with its current sensed after DBR to generate the current error. This current error is amplified by gain and compared with fixed frequency sawtooth carrier waveform to get the switching signal for the MOSFET of the PFC Cuk converter as

$$k_d \Delta i_d > m_d(t)$$

Where S denotes the switching of the MOSFET of the cuk converter.

V. RESULT AND SIMULATION OUTPUTS

The Cuk converter is a type of buck-boost converter with zero ripple current. Cuk converter can be seen as a combination of boost converter and buck converter, having one switching device and a mutual capacitor, to couple the energy.

Similar to the buck-boost converter with inverting topology, the output voltage of non-isolated Cuk converter is typically inverted, with lower or higher values with respect to the input voltage. Usually in DC converters, the inductor is used as a main energy-storage component. In cuk converter, the main energy-storage component is the capacitor. It is named after Slobodan Cuk of the California Institute of Technology, who first presented the design. The main applications of this circuit are in regulated dc power supplies, where a negative polarity output may be desired with respect to the common terminals of the input voltage and the average output is either higher or lower than the dc input voltage.

5.1 PFC CUK Converter Fed PMSBLDC Motor Drive Circuit Diagram

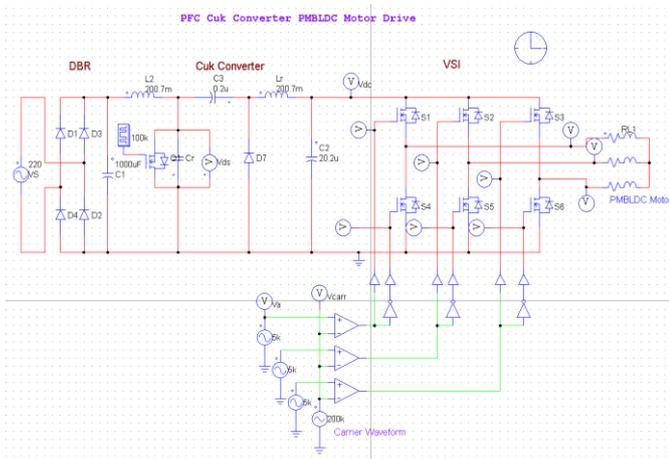


Figure 3: PFC CUK Converter Fed PMSBLDC Motor Drive Circuit Diagram

5.2 Outputs Screenshots of PSIM Simulation

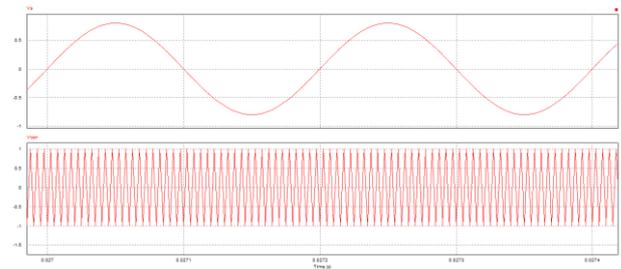


Figure 4: Carrier Generation

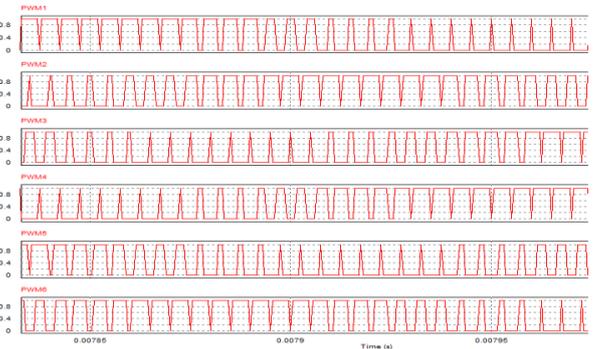


Figure 5: Gate Signals

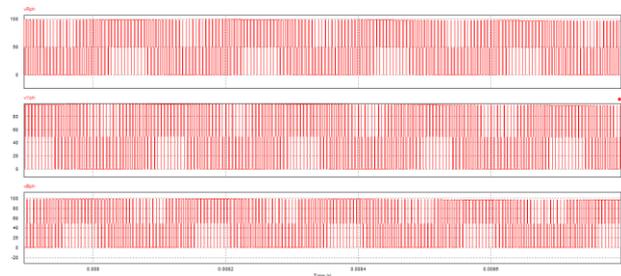


Figure 6: Three Phase Output Voltage

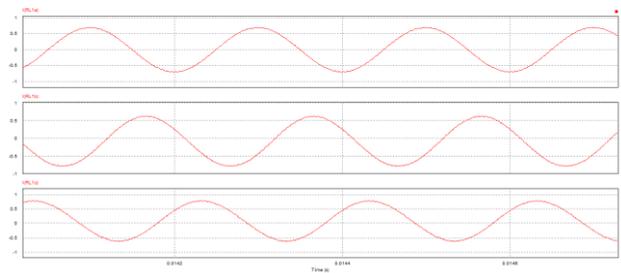


Figure 7: Three Phase Output Current

VI. CONCLUSION

A new efficient permanent magnet brushless DC motor drive has been simulated and experimentally validated, so can be used with any load to yield a good efficient working system. Initially various topologies of power factor correction circuits are evaluated and the result are confined such that the best suitable one is selected. It is analyzed that a cuk converter

has the best results and is analyzed with the PMBLDC motor drive which has unity input power factor and less conduction losses. So all together it is an efficient drive. The proposed PMBLDCMD is promising variable speed drive for air conditioning system, electric traction etc. All the problems of poor power factor, heavy inrush current, etc of can be mitigated by the proposed bridgeless Cuk PFC based PMBLDC Motor Drive. The performance of the drive has been found very good in the wide range of input AC This topology has been found suitable for the applications involving speed control at constant torque load.

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