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Power Factor Correction and Power Quality Improvement in BLDC Motor Drive Using Sepic Converter

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Abstract:
This project design SEPIC DC-DC converter feeding a BLDC motor drive as a cost effective solution for low power applications. In proposed circuit the single phase supply is fed to uncontrolled bridge rectifier. The output of bridge rectifier is fed to a Sepic DC-DC converter which is used to control the voltage of DC link capacitor which feds the Voltage Source Inverter. The BLDC motor is fed from Voltage Source Inverter. Voltage of a DC link capacitor of SEPIC converter is controlled to achieve the speed control of BLDC motor. A MATLAB Simulation will used to simulate the developed model to achieve a wide range of speed control.

Keywords: BLDC motor, SEPIC converter, Power Factor Correction (PFC), Power Quality (PQ), motor drive, converter, DC motor, efficiency, power factor, reactive power

INTRODUCTION

The project aims to improve power quality and correct the power factor in a BLDC motor drive system by utilizing a SEPIC (Single Ended Power Factor Correction) converter. This is a crucial problem because traditional BLDC motor drives often introduce harmonics and distort the power, impacting overall power quality and system efficiency. The proposed solution addresses this by incorporating a SEPIC converter to ensure a unity power factor and reduce harmonic distortion.

The fundamental qualities of a permanent magnet brushless DC motor (PMBLDCM) such as wide speed range, high efficiency, rugged construction and ease of control make it suitable for air-conditioning compressor application. A low power PMBLDC motor is fed from a single phase AC supply through a diode bridge rectifier (DBR) followed by a DC capacitor and a voltage source inverter (VSI). This PMBLDCM drive draws a pulsed current from AC mains having peaks higher than the amplitude of the fundamental input current due to uncontrolled charging of DC link capacitor. This result in power quality disturbances at input AC mains such as poor power factor, increased total harmonic distortion (THD) and high crest factor (CF) etc. these PQ disturbances are undesirable and should be within limits as imposed by the standard IEC 61000-3-2 for the drives in low power range. High torque and low power applications mostly prefer low voltage PMBLDCMs operated at constant current. Such applications require the DC link voltage lower than the average output of a DBR fed from a single-phase AC mains.

A DC-DC converter is connected between the VSI and the DBR fed from single phase AC supply to provide controlled voltage at DC link capacitor. There are many DC –DC converter topologies available such as buck, boost, buck-boost, cuk, sepik converter amongst which the cuk converter topology is used

in this work. It provides controlled DC voltage to the PMBLDCM drive from an uncontrolled DC output of a single phase AC mains fed DBR while improving the PQ at AC mains [6].
The buck-boost converter topology has advantages of its simplest construction and minimum component requirement over other topologies.. The buck-boost converter is designed for DCM operation to result in reduced sensor requirement with the desired speed control.

Objectives:

- The SEPIC converter is a type of DC-DC converter that can step-up or step-down voltage while maintaining a positive voltage gain. It's chosen for this project due to its ability to effectively address the power factor correction challenges in BLDC motor drives, particularly its ability to provide a stable and efficient power conversion while improving power quality.
- The project focuses on improving the power factor and power quality of a BLDC motor drive system, a type of electrical motor widely used in various applications like electric vehicles, industrial robots, and more. The overarching goal is to demonstrate how the incorporation of a SEPIC converter into a BLDC motor drive can effectively improve the power factor, enhance power quality, and increase the overall efficiency and reliability of the system.

Literature Review:

1. **Sanjeev Singh and Bhim Singh, "Voltage Controlled PFC SEPIC Converter fed PMBLDCM Drive for an Air-Conditioner"IEEE.**

This paper explains a sepic DC-DC converter as a single-stage converter for a permanent magnet brushless DC motor. PMBLDCM fed through a diode bridge rectifier (DBR) from single-phase AC mains. The PMBLDCM has been driving an air conditioner compressor. The speed of the compressor is controlled to achieve optimum air-conditioning using a concept of the voltage control at DC link proportional to the desired speed of the PMBLDCM [1].

2. **Simonetti, D. S L; Sebastian, J.; dos Reis, F.S.; Uceda, J., "Design criteria for SEPIC and Cuk converters as power factor preregulators in discontinuous conduction mode,"**

This paper gives details of Power Factor Preregulators (PFP) which are used to improve input current waveform of off-line power supplies. There are two major approaches in implementing control circuits in PFP: the multiplier approach and the voltage-follower approach. The simplest one is the voltage-follower approach because only one loop control is required. SEPIC and CUK converters present a great advantage over boost and fly-back topologies. Therefore, SEPIC and CUK converters in DCM seem to be good choices to use as PFP. [2]

3. **Singh, B.; Singh, B.N.; Chandra, A; Al-Haddad, K.; Pandey, A; Kothari, D.P., "A review of single-phase improved power quality AC-DC converters"**

This paper tells solid-state switch-mode rectification converters have reached a matured level for improving power quality in terms of power-factor correction (PFC), reduced total harmonic distortion at input ac mains and precisely regulated dc output in buck, boost, buck–boost and multilevel modes with unidirectional and bidirectional power flow. This paper deals with a comprehensive review of improved power quality converters configurations, control approaches, design features, selection of components, other related considerations, and their suitability and selection for specific applications. [3]

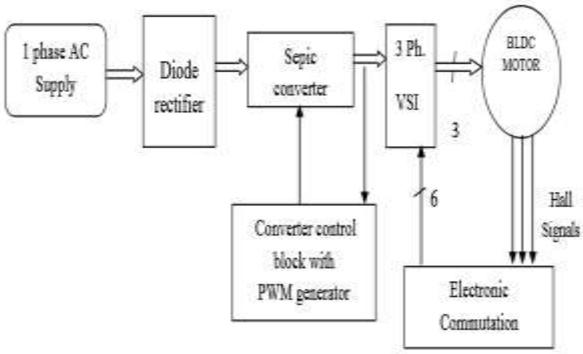
4. Bist, V.; Singh, B., "An Adjustable-Speed PFC Bridgeless Buck–Boost Converter- Fed BLDC Motor Drive.

This paper presents a buck–boost converter-fed brushless direct current (BLDC) motor drive as a cost-effective solution for low-power applications. An approach of speed control of the BLDC motor by controlling the dc link voltage of the voltage source inverter (VSI) is used with a single voltage sensor. [4]

5. Singh, S.; Singh, B., "PFC buck converter fed PMBLDCM drive for low power applications"

This paper deals with various control strategies and operating principle of a buck converter for feeding a Permanent Magnet Brushless DC Motor Drive in various modes of operation. A buck converter is operated with the current multiplier control and voltage follower control schemes for the operation of PMBLDCMD under wide range speed control. [5]

Block Diagram:



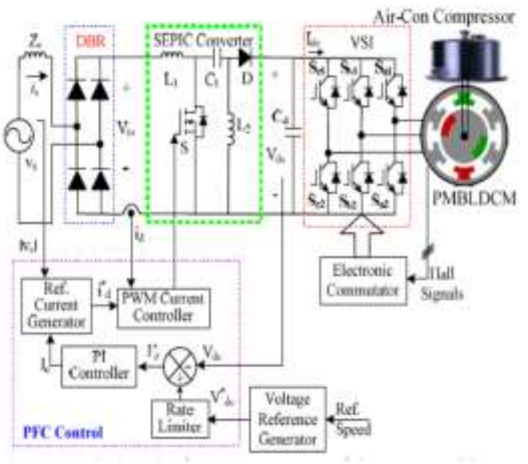
DC-DC converter feeding permanent magnet brushless motor drive is proposed here for low power application. sepic converter comes under the category of DC to DC converter. In proposed circuit single phase supply is feeding to uncontrolled rectifier and DC converter is to control the voltage of DC link capacitor. Voltage of DC link capacitors used to control the speed of BLDC motor. The output of DC link capacitor is fed to inverter and then BLDC motor to control the speed. A current multiplier technique is used to control the speed of BLDC motor.

Working:

The proposed sepic converter based PMBLDCM drive operated with current multiplier follower approach. The proposed controller is operated to maintain a constant DC link voltage with PFC action at AC mains. It has a current control loop inside the speed control loop, for continuous conduction mode (CCM) operation of the converter. The control loop processes the voltage error (Ve) between sensed DC link voltage (Vdc) and a voltage (Vdc*) equivalent to the reference speed, through a proportional-integral (PI) controller to generate modulating control signal (Ic). This signal (Ic) is multiplied with a unit template of input AC voltage to generate reference DC current (Id *) and compared with the DC current (Id) sensed after the DBR.

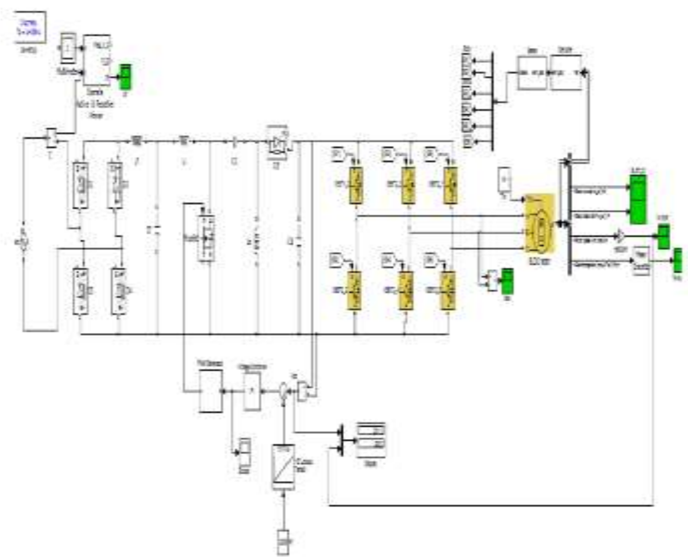
The resultant current error (Ie) is amplified and compared with saw-tooth carrier wave of fixed frequency (fs) to generate the PWM pulse for the PFC converter For the speed control, the speed signal derived from rotor position of the PMBLDCM, sensed using Hall effect sensor, is compared with a reference speed. The resultant speed error is passed through a speed controller to get the torque equivalent which is converted to an equivalent current signal using motor torque constant .

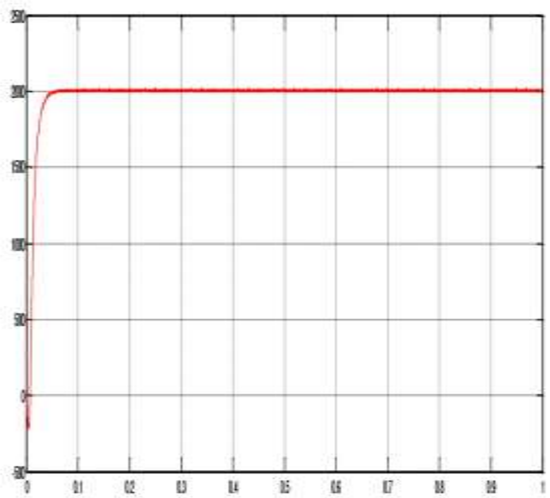
Design and Implementation



Simulation And Results

The simulation model primarily designed for the opportunity analysis of controlling the speed of BLDC, for their management in the design phase and for the study of problems that may occur due to the adopted solution. The adopted solution concerns the management solutions that can be adopted, but also the monitoring, control and command of controlling of speed DC motor. One of the advantages of Matlab software is that libraries offer a wide range of basic components for modeling the consumers. Thus, it can be modeled both single- phase or three phased consumers with different powers, nature and types (e.g.: resistive, capacitive or inductive consumers). Basic components of simulink library are: Each of these components basically modeled on studies of mathematical models and has associated specific parameters. The interfacing with Matlab libraries components was realized in order to make a thorough study of the modeled of speed control systems to the centralized operational management system. By using different types of measurement and display blocks of Matlab, voltages, currents, Inverter powers and energy flows from the system.





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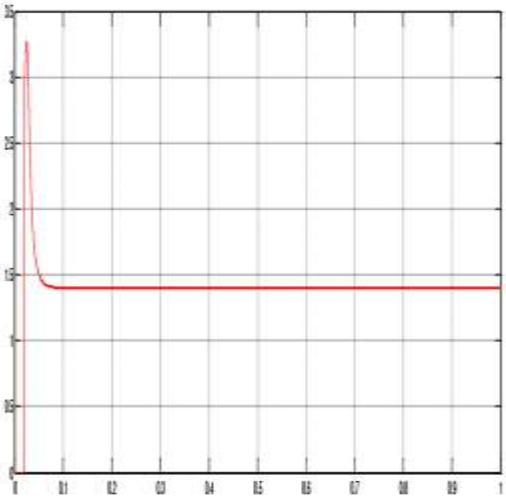

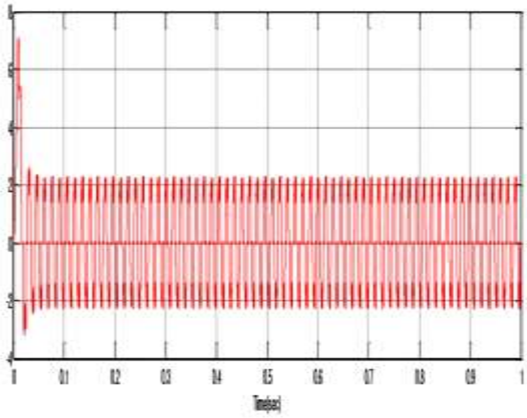

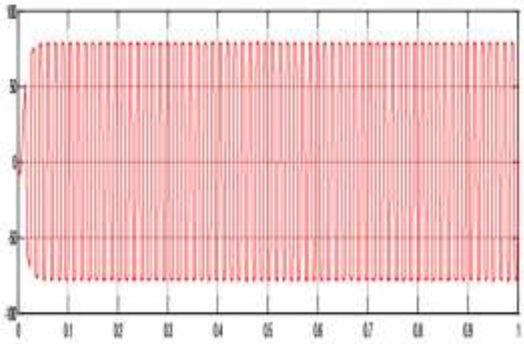

Conclusion

A simple control using a current multiplier approach has been used for voltage control of a PFC sepic converter fed BLDC motor drive. A single stage PFC converter system has been designed and validated for the speed control for a wide range of speed. The performance of the proposed drive system has also been evaluated for varying input AC voltages and smooth performance of motor is obtained. The proposed drive system has been found a suitable control technique among various adjustable speed drives for many low power applications. With help of comparison with buck converter it can be concluded that the sepic converter fed BLDC motor gives better performance.

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