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SIMULATION OF CUK CONVERTER FED BLDC MOTOR FOR CORRECTION OF POWER FACTOR

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ABSTRACT:

A power factor correction (PFC) based Cuk converter fed brushless DC motor (BLDC) drive is developed as a cost-effective solution for low power applications. Voltage source inverter (VSI) is used for low frequency switching (electronic commutation of BLDC motor) and low switching losses. A diode bridge rectifier (DBR) followed by a Cuk converter working in discontinuous conduction mode (DCM) is used for control of DC link voltage with unity power factor at AC mains. Performance of the PFC Cuk converter is evaluated in four different operating conditions of discontinuous and continuous conduction mode (CCM) and a comparison is made to select a best suited mode of operation. The performance of the proposed system is simulated in MATLAB/Simulink environment to validate its performance with unity power factor at AC mains.

Keywords: DCM, CCM VSI, BLDC, DBR, Cuk Converter, EMI, PFC.

1. INTRODUCTION:

Brushless Dc Motor is recommended for many low cost applications such as household application, industrial, radio controlled cars, positioning and aero modelling, Heating and ventilation etc., because of its certain characteristics including high efficiency, high torque to weight ratio, more torque per watt , increased reliability, reduced noise, longer life, elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference(EMI) etc. With no windings on the rotor, they are not subjected to any centrifugal forces, and because the windings are

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supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling purposes. The motor's internals can be entirely enclosed and protected from dust, dirt or any other foreign obstacles. The two main factors that determine the power quality of a motor are the Power Factor (PF) and the total harmonic Distortion (THD). The Power Factor determines the amount of useful power being consumed by an electrical system. The term THD is defined as the ratio of the harmonic components of voltage (or current) to the voltage (or current) of the fundamental. So the Power Factor Correction (PFC) is the best method of improving the PF by making the input to the power supply purely resistive or else due to the presence of non linear loads the input will contain phase displacement which causes harmonic distortion and thus the power factor gets degraded. The main aim of all papers is to improve the power quality according to the standards recommended ,But in the conventional schemes for example diode bridge fed Brushless Dc Motors due to the presence of huge capacitor value it draws a non sinusoidal current from the ac mains which increased the THD to 65% and power factor to 0.8.The other conventional schemes by using many of the converters fed BLDC motors like Sepic ,Buck, Boost ,Buck Boost etc. by using high frequency pulse width modulation increases the switching losses. Bridgeless configuration of these converters were also existed ,even though they reduces the switching losses ,the no of active and passive components were more which increases the complexity in designing the circuit and the overall cost.

MAIN AIM:

The aim of the work presented in the thesis is to improve the power factor and reduce the total harmonic distortion for the Class A applications (<600W and <16A) [1] by implementing power factor correction circuits employing Cuk Converter fed Brushless DC Drive for low power applications with special focus on minimal component use and better performance. Power factor Correction Circuit using Cuk Converter fed Brushless DC drive is developed. Voltage follower approach and Current multiplier approach is implemented.

MAIN OBJECTIVES OF PAPER:

- Simulation of PFC based Cuk converter fed brushless DC motor drive is implemented using Current multiplier approach in Continuous conduction mode.

- Simulation of PFC based Cuk converter fed brushless DC motor drive is implemented using Voltage Follower approach in Discontinuous conduction mode.

Comparative analysis between CCM, DICM(Li), DICM(Lo) and DCVM (V_c)

2. LITERATURE SURVEY:

1) S. B. Ozturk, Oh Yang and H. A. Toliyat, "Power Factor Correction of Direct Torque Controlled Brushless DC Motor Drive," (2007): In this technical paper they had proposed a boost PFC converter based direct torque controlled (DTC) BLDC motor drive. They have the disadvantages of using a complex control which requires large amount of sensors and higher end digital signal processor (DSP) for attaining a DTC operation with PFC at AC mains. Hence, this scheme is not suited for low-cost applications.

2) T. Y. Ho, M. S. Chen, L. H. Yang and W. L. Lin, "The Design of a high power Factor Brushless DC Motor Drive," (2012): They have proposed an active power factor correction (APFC) scheme which uses a PWM switching of VSI and hence has high switching losses.

3) C. H. Wu and Y. Y. Tzou, "Digital control strategy for efficiency optimization of a BLDC motor driver with VOPFC,"(2009): they have proposed a cascaded buck-boost converter fed BLDC motor drive, which utilizes two switches for PFC operation. This offers high switching losses in the front-end converter due to double switch and reduces the efficiency of overall system.

4) T. Gopalarathnam and H. A. Toliyat, "A new topology for unipolar brushless DC motor drive with high power factor,"(2003): They have proposed a single ended primary inductance converter (SEPIC) as a front end converter for PFC with DC link voltage control approach, but utilizes a PWM switching of VSI which has high switching losses.

5) Bridgeless configurations of PFC buck-boost, Cuk, SEPIC and Zeta converters have been proposed in (V. Bist and B. Singh, "An Adjustable Speed PFC Bridgeless Buck-Boost Converter Fed BLDC Motor Drive",(2014), B. Singh and V. Bist, "An Improved Power Quality Bridgeless Cuk Converter Fed BLDC Motor Drive for Air Conditioning System",(2013), B. Singh and V. Bist, "Power Quality Improvement in PFC Bridgeless SEPIC Fed BLDC Motor Drive",(2013), V. Bist and B. Singh, "A Reduced Sensor PFC BL-Zeta Converter Based VSI Fed BLDC Motor Drive",(2013).

6) T. J. Sokira and W. Jaffe, Brushless DC Motors: Electronic Commutation and Control, Tab Books, USA, (1989) And H. A. Toliyat and S. Campbell, *DSP-based Electromechanical Motion Control* (2004) : They presented that the motor is also referred as electronically commutated motor (ECM) since an electronic commutation based on the Hall-Effect rotor position signals is used rather than a mechanical commutation.

3. METHODOLOGY

The conventional scheme of a BLDC motor fed by a diode bridge rectifier (DBR) and a high value of dc-link capacitor draws a nonsinusoidal current, from ac mains which is rich in harmonics such that the THD of supply current is as high as 65%, which results in PF as low as 0.8 . Hence, single-phase power factor correction (PFC) converters are used to attain a unity PF at ac mains. These converters have gained attention due to single-stage requirement for dc-link voltage control with unity PF at ac mains. It also has low component count as compared to a multistage converter and therefore offers reduced losses .Conventional schemes of PFC converter-fed BLDC motor drive utilize an approach of constant dc-link voltage of the VSI and controlling the speed by controlling the duty ratio of high frequency pulse width modulation (PWM) signals. The losses of VSI in such type of configuration are

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considerable since switching losses depend on the square of switching frequency (Psw loss ∝f2S). Ozturk et al. Have proposed a boost PFC converter-based direct torque controlled (DTC) BLDC motor drive. They have the disadvantages of using a complex control which requires large amount of sensors and higher end digital signal processor (DSP) for attaining a DTC operation with PFC at ac mains. Hence, this scheme is not suited for low-cost applications. These configurations offer reduced losses in the front-end converter but at the cost of high number of passive and active components. Selection of operating mode of the front-end converter is a trade off between the allowed stresses on PFC switch and cost of the overall system. Continuous conduction mode (CCM) and discontinuous conduction mode (DCM) are the two different modes of operation in which a front-end converter is designed to operate .Avoltage follower approach is one of the control techniques which is used for a PFC converter operating in the DCM. This voltage follower technique requires a single voltage sensor for controlling the dc-link voltage with a unity PF. Therefore, voltage follower control has an advantage over a current multiplier control of requiring a single voltage sensor. This makes the control of voltage follower a simple way to achieve PFC and dc-link voltage control, but at the cost of high stress on PFC converter switch. On the other hand, the current multiplier approach offers low stresses on the PFC switch, but requires three sensors for PFC and dc-link voltage control. Depending on design parameters, either approach may force the converter to operate in the DCM or CCM. In this study, a BLDC motor drive fed by a PFC Cuk converter operating in four modes/control combinations is investigated for operation over a wide speed range with unity PF at ac mains. These include a CCM with current multiplier control, and three DCM techniques with voltage follower control.

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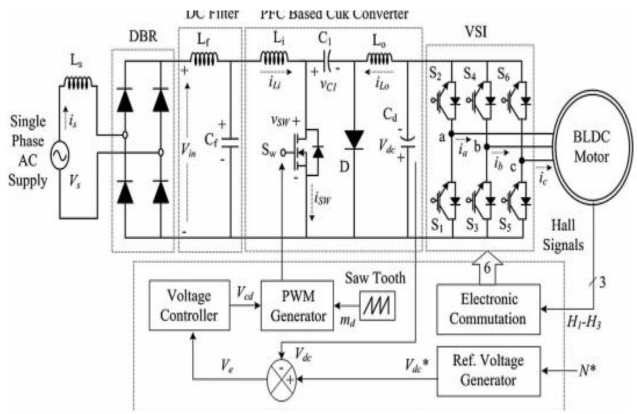

Fig.3.1. Proposed model.

SIMULATION RESULTS:

The operation of Cuk converter in DICM (Li) is described as follows. Figs. 3.5(a)-(c) show the operation of Cuk converter in three different intervals of a switching period and Fig. 3.5(d) shows the associated waveforms in a switching period.

Interval I: When switch S_w is turned on, inductor Li stores energy while capacitor C_1 discharges through Switch S_w to transfer its energy to the DC link capacitor Cd as shown in Fig.3.5(a). Input inductor current i_{Li} increases while the voltage across the capacitor C_1 decreases as shown in Fig. 3.5(d).

Interval II: When switch S_w is turned off, then the energy stored in inductor Li is transferred to intermediate capacitor C_1 via diode D, till it is completely discharged to enter DCM operation.

Interval III: During this interval, no energy is left in input inductor Li, hence current i_{Li} becomes zero. Moreover, inductor Lo operates in continuous conduction to transfer its energy to DC link capacitor Cd.

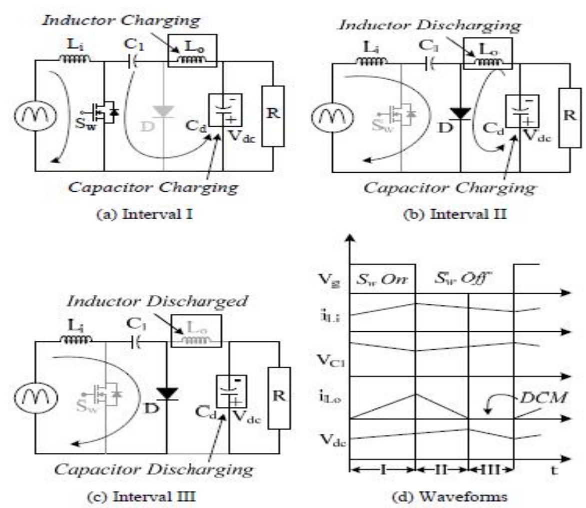

Fig.3.2. Inverter Operation.

advocated structure guarantees a much better strength top wonderful at the energy matrix as for strength variable in addition to THD. Fig. 3.3 (a) offers the THD and additionally music shape of supply present is displayed in Fig. 3.3(a), at the off opportunity that the water siphon is dealt with via

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electricity matrix as it had been. Additionally, Fig. 3.3 (b) affords the THD and songs series of is displayed in Fig. 3.3(b), on the off danger that the radiation degree is six hundred W/m2 and also persevering with to be electricity is anticipated to be sorted with the resource of the strength community. Under both problems, THD of supply modern-day is seen below 5% which satisfies the IEEE519 guiding precept. Furthermore, a team spirit power component activity is guaranteed underneath the numerous working issues.

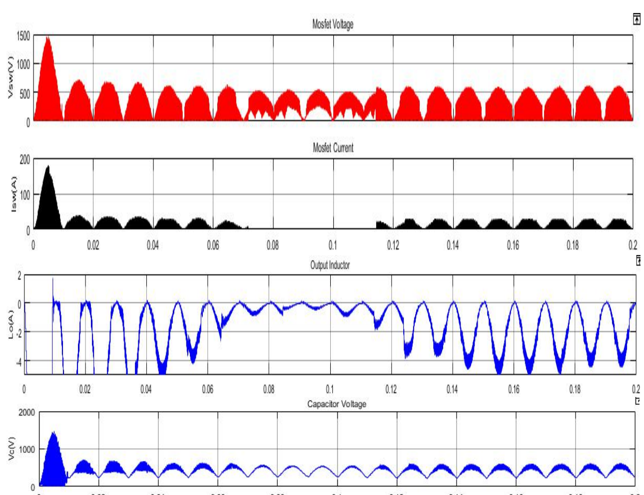

Fig.3.3. Simulation circuit outputs.

CONCLUSION

A singular section structure clever PV series based water siphoning shape utilizing a BLDC engine strain has been advised further to shown. A bi-directional power move manager of VSC has simply encouraged a whole use of assets and water siphoning with high-quality restriction irrespective of what the weather situations. A clear-cut UVT age method has been placed on adjust the strength circulation as preferred. All the strength notable viewpoints have been fulfilled consistent with the IEEE-519 preferred. The charge control of BLDC engine siphon has been completed with beside no current identifying components. A predominant recurrence changing of VSI has protected in update the effectiveness of usually framework with the aid of lowering the buying and selling tragedies. The advised arrangement has advanced as a truthful water siphoning framework, and additionally as a root of obtaining via deal of power to the software at the same time as water siphoning isn't always wanted.

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