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Power Factor and Harmonic Issues in BLDC Motor Drive System

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***Abstract*— In this topic we are discussing the harmonics and power factor issues of BLDC motor.We studies various power factor correction converters that can be adopted for eliminating the harmonics and improve the power quality of power supply. Five different type of converters used for power factor correction of a Bldc motor (zeta converter, buck converter, Cuk converter, brushless buck boost converter, Luo converter) are analysed using block diagrams. A study of these methods and comparison of the advantages, disadvantages ,applications of these techniques for power quality improvement of BLDC motor is done. Most of these converters produce desired power quality when they are operated in low power applications extension of the study can be done to develop converters that can operate efficiently in high power also without much distortion and losses.**

***Index Terms*—About four key words or phrases in alphabetical order, separated by commas.**

I. INTRODUCTION

BLDC motor has been widely used nowadays due to its complimenting features like high efficiency, high starting torque, reliability lower maintenance compared to its brushed dc motor. The BLDC (Brush Less Direct Current) motor is a commutator less electronically commutated motors. Harmonics and low power factor are the main issues of BLDC motor .The presence of 5th and 7th harmonics in input supply reduces the efficiency of BLDC motor.

A BLDC motors are powered from single-phase AC mains through a diode bridge rectifier (DBR) with smoothening DC capacitor and voltage source inverter (VSI).A conventional DBR-VSI fed BLDC motor drive with DC link capacitor draws a pulsed current from AC mains because of DC link capacitor. Since it draws a large current the AC voltage is higher than the dc link voltage. Many Power Quality (PQ) problems arise at input AC mains and they are undesirable. For class-A equipment (< 600 W, 16 A per phase) which include household equipment, IEC 61000-3-2 restricts the harmonic current of different order such that the full total harmonic distortion (THD) of the supply current must be below 19%. A BLDC motor when fed by diode bridge rectifier (DBR) and a higher value of dc link capacitor shown in fig.1 draws peaky current which can cause a THD of supply current of the order of 65% and power factor as little as 0.8.Hence, a DBR followed by way of a power factor corrected (PFC) converter is utilized for improving the quality at ac mains.

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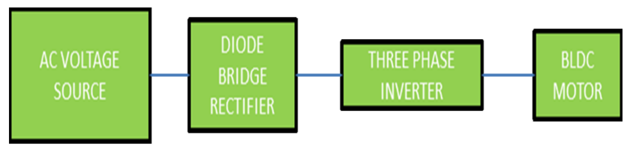

FIG.1 Conventional dbrfed vsi bldc motor

II. MODELLING OF BLDC MOTOR

As any typical three phase motors, one structure of the BLDC motor is fed by a three phase voltage source as shown in Fig 2.The source is not necessary to be sinusoidal. Square wave or other wave- shape can be applied as long as the peak voltage is not exceeded the maximum voltage limit of the motor. Similarly, the model of the armature winding for the BLDC motor is expressed as follows.

$$Va = Ria + \frac{Ldia}{dt} + ea$$
$$Vb = Rib + \frac{Ldib}{dt} + eb$$
$$Vc = Ric + \frac{Ldic}{dt} + ec$$

I_a, I_b, I_c, = *Motor input current in amperes*
e_a, e_b, e_c =*Motor back emf in volts*

where, L_a =, L_b, = L_c, =L=L_s –M

L_s = *Armature of self inductance*
M = *Mutual inductance*

$R_a = R_b = R_c = R$ =*Armature resistance in ohm*
V_a ,V_b ,V_c ,=*Terminal phase voltage in volts*

Due to the permanent magnet mounted on the rotor, its back emf is trapezoidal. The expression of back emf must be modified as expressed as follows:-

$$e\_a\ (t) = K_E \emptyset(\theta)\omega(t)$$
$$e_b(t) = K_E \emptyset\left(\theta - \frac{2\pi}{3}\right)\omega(t)$$
$$e_c(t) = K_E \emptyset\left(\theta + \frac{2\pi}{3}\right)\omega(t)$$

Where K_E is the back emf constant and ω is the mechanical speed of the rotor. The permanent magnet also influences produced torques due to the trapezoidal flux linkage. Given that K_T is the torque constant. The resultant torque, T_E, can be obtained by the following expressions

$$T_a(t) = K_T Ø(\theta) i_a(t)$$

$$T_b(t) = K_T Ø\left(\theta - \frac{2\pi}{3}\right) i_b(t)$$

$$T_c(t) = K_T Ø\left(\theta + \frac{2\pi}{3}\right) i_c(t)$$

$$T_E(t) = T_a(t) + T_b(t) + T_c(t)$$

III. VARIOUS HARMONICS AND POWER FACTOR CORRECTION METHODS

1. PFC Zeta Converter Fed BLDC Motor

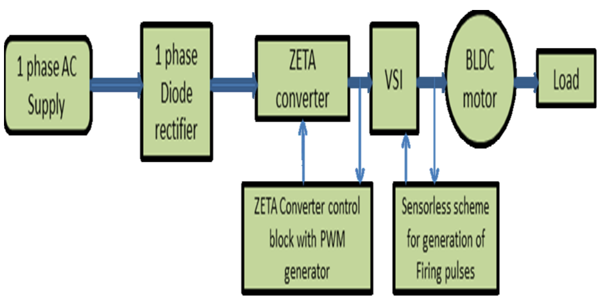

Figure 2:Block diagram of Zeta Converter

This sensorless approach is used to detect the rotor position for electronic commutation .A high frequency MOSFET of suitable rating is used in the front end converter for its high frequency operation whereas an IGBT's (Insulated Gate Bipolar Transistor) are used in the VSI for low frequency operation. The proposed scheme maintains high power factor and low THD of the AC source current while controlling rotor speed equal to the set reference speed.

A voltage follower approach is used for the control of Zeta DC-DC converter operating in DICM(Discontinuous current conduction mode). The DC link voltage is controlled by a single voltage sensor. V_{dc} (sensed DC link voltage) is compared with V_{dc}* (reference voltage) to generate an error signal which is the difference of V_{dc}* and V_{dc}.The error signal is given to a PI (Proportional Integral) controller to geta controlled output. The controlled output is compared with the high frequency saw tooth signal to generate PWM (Pulse Width Modulation) pulse for the MOSFET of the Zeta converter.

2. Power Factor Improvement using Buck Converter

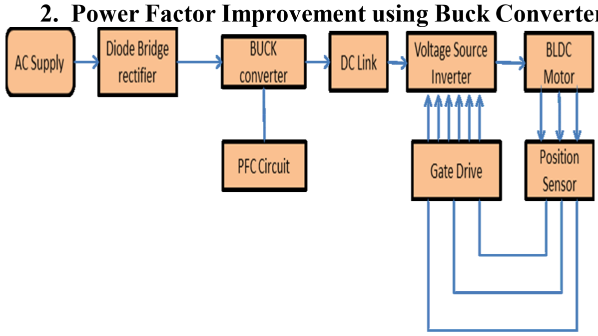

Figure 3:Block diagrm of Buck converter

The Buck DC-DC converter controls the dc link voltage. In this topology, a conventional DBR fed from single-phase AC mains. Its output is given to a DC-DC converter, and a VSI used to feed the BLDC Motor. The DC-DC converter provides a controlled DC voltage from uncontrolled DC output of DBR, while controlling the power factor through high frequency switching of the PFC switch. A Buck converter forces the drive to draw sinusoidal supply current in phase with the supply voltage. The buck PFC converter is a combination of diode rectifier and step-down current chopper. It uses input and output filters to improve its performance in terms of THD of AC mains and ripples at DC output voltage.

3. PFC Using Cuk converter

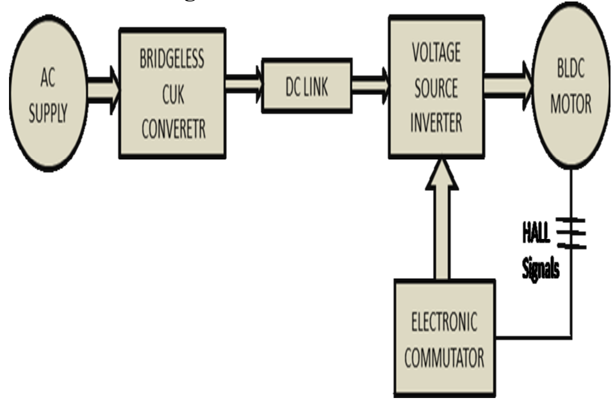

Figure 4 :-Block diagram of Cuk Converter

The bridgeless power factor correction rectifiers are shown in Fig.4. The topology is formed by connecting two DC-DC Cuk converters. There are one or two semiconductors in current flowing path. Hence, the current stresses in the active and passive switches are further reduced and the circuit efficiency is improved compared to the conventional Cuk rectifier. Here, the output voltage bus is always connected to the input AC line through the slow-recovery diodes. The bridgeless rectifiers consists of two semiconductor switches (Q1 and Q2).The two semiconductor switches can be driven by the same control circuitry.

4. PFC using BL Buck-Boost converter

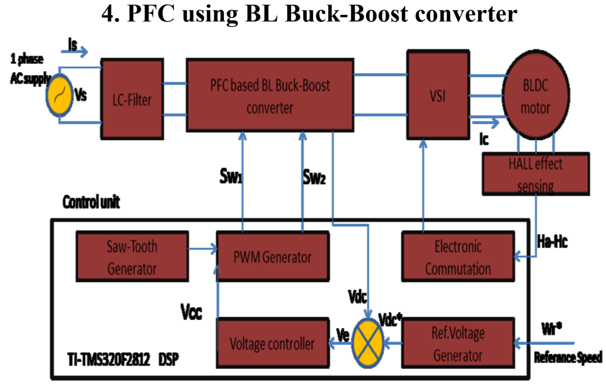

Figure 5:-Block Digram of Buck-Boost converter

A PFC based bridgeless buck-boost converter is designed in such a way to operate in Discontinuous Inductor Current Mode (DCIM), so that it provides an inherent PFC at ac mains. A Buck–boost converter configuration is most effective among various BL converter topologies for applications requiring a wide selection of dc link voltage control (i.e., bucking and boosting mode the dc bus voltage is varied for speed control and VSI is operated at fundamental frequency to achieve electronically commutated BLDC motor to reduce switching losses in VSI.

5.Power Factor Correction using Brushless Luo converters

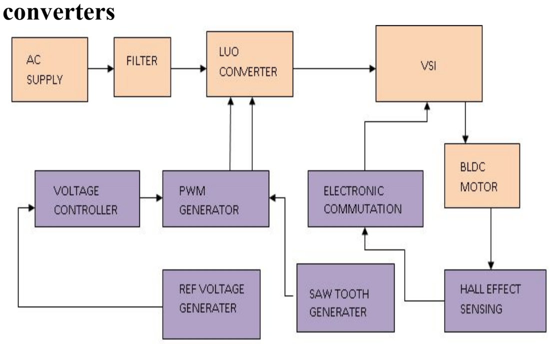

Figure 6:-Block diagram of BL-Luo converter

A power factor correction (PFC)-based bridgeless Luo (BL-Luo) converter-fed brushless dc (BLDC) motor drive. A single voltage sensor is used for the speed control of the BLDC motor and PFC at ac mains. The voltage follower control is used for a BL-Luo converter operating in discontinuous inductor current mode. The speed of the BLDC motor is controlled by an approach of variable dc-link voltage, which allows a low-frequency switching of the voltage source inverter for the electronic commutation of the BLDC motor, thus offering reduced switching losses. The proposed BLDC motor drive is designed to operate over a wide range of speed control with an improved power quality at ac mains. The power quality indices thus obtained are under the recommended limits of IEC61000-3-**2.**

IV. COMPARISON OF VARIOUS METHODS OF POWER QUALITY IMPROVEMENT IN BLDC MOTOR

METHODS	PFC using Zeta Converter	PFC using Buck Converter	PFC Using Cuk converter	PFC using BL Buck-Boost converter	PFC using BL- Luo converters
APPLICATION	Low power applications	Typically used in supplies from 10 to250w	Low-current, high-voltage.	Battery-powered systems, where the input voltage can vary widely,	Low power applications
ADVANTAGES	Low output voltage ripple, safety at the output side, and flexibility for output	Easy to implement, low noise at output low price compact design ,easy to get feed back .	Inherent power-factor correction capability and low turn-off switching loss. Soft turn-on	Higher switching frequencies possible; Since the duty ratio is always larger than 0.5 low-loss snubber circuits can be made easily	Low cost,low losses, inherent power-factor correction capability
DISADVANTAGES	LC input-filter used at first sight to reduce the harmonic	No isolation between input and output , ,the 50 Hertz or 100 HZ hum can appear at output (from ground),Step down (we can't increase the voltage within) .	Line current ripple is large, more suitable for light load	Pulsed current drawn from the source ,for larger duty ratios high conduction losses in the semiconductors	Variable DC bus is required,unable to use be in high power applications

CONCLUSION

Bldc motor are highly efficient, highly reliable motors. The rotational speed of a bldc motor can be controlled, . they have a good weight/size to power ratio and excellent acceleration performance, require little or no maintenance and generate less acoustic and electrical noise than universal (brushed) DC motors Application of Bldc motor in various fields are increasing ,the harmonics and low power factor are the major problems on Bldc motor. There are numerous methods available for rectifying these problems. Each of their application are limited and specified .Here a study of these methods is done and an analysis based on their applications and limitations is done.

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