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SPEED CONTROL AND POWER FACTOR CORRECTION IN BLDC MOTOR USING ISOLATED CUK CONVERTER

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ABSTRACT:

This paper presents Power Factor Correction (PFC) and Speed Control of BLDC motor using isolated bridgeless Cuk Converter. A variable DC link voltage of the voltage source inverter (VSI) feeding BLDC motor is used for its speed control. This allows the operation of VSI in fundamental frequency switching (FFS) to achieve an electronic commutation of BLDC motor for reduced switching losses. A bridgeless configuration of an isolated Cuk converter is derived for elimination of front end diode bridge rectifier (DBR) to reduce conduction losses in it.

KEYWORDS: PFC, BLDC, VSI, and FFS.

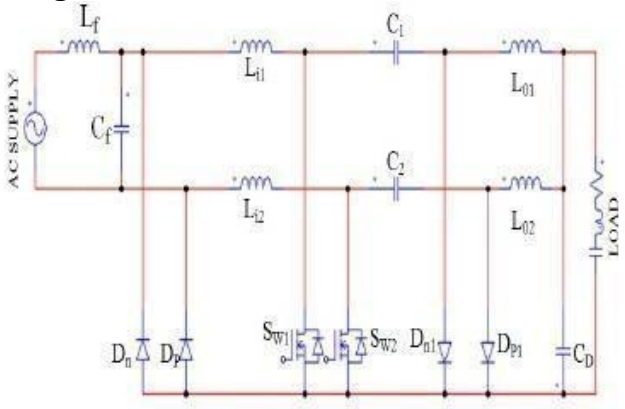
1. INTRODUCTION

The projects entitled Power Factor Correction in BLDC motor using isolated-Cuk Converter and Speed Control of BLDC Motor was carried out to reduce switching and conduction losses and develop a cost effective solution to achieve a unity power factor at AC mains for a wide range of speed control and supply voltages. This work presents a power factor correction (PFC) based bridgeless isolated Cuk converter fed brushless DC (BLDC) motor drive. A variable DC link voltage of the voltage source inverter (VSI) feeding BLDC motor is used for its speed control. This allows the operation of VSI in fundamental frequency switching (FFS) to achieve an electronic commutation of BLDC motor for reduced switching losses. A bridgeless configuration of an isolated Cuk converter is derived for elimination of front-end diode bridge rectifier (DBR) to reduce conduction losses in it. The proposed PFC based bridgeless isolated-Cuk converter is designed to operate in discontinuous inductor current mode (DICM) to achieve an inherent PFC at AC mains. The proposed drive is controlled using a single-voltage sensor to develop a cost- effective solution. The proposed drive is implemented to achieve a unity power factor at AC mains for a wide range of speed control and supply voltages.

1.1 Conventional Bridgeless Cuk Rectifier

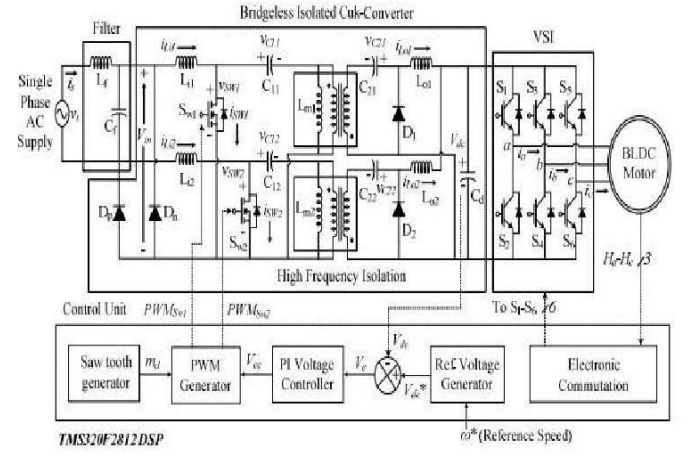
A bridgeless Cuk rectifier is used for Power factor correction (PFC) for a BLDC motor. Bridgeless Cuk converter has only two semiconductor switches in the current flowing path. During each interval of the switching cycle it result in less conduction losses and an improved thermal management compared to the conventional Cuk PFC rectifier. To achieve almost unity power factor and to reduce the input current stress, the topologies are designed to work in discontinuous conduction mode (DCM). The DCM has additional advantage such as zero-current turn-on in the power switches, zero current turn-off in the output diode. The ac-dc conversion of electric power is usually required for the BLDCM drive. It causes many current harmonics and results in poor power factor at input ac mains. This paper deals with power factor correction of BLDCM with bridgeless Cuk converter. A three phase voltage source inverter is used as an electronic commutator to operate BLDCM.

1.2 Bridgeless Cuk Converter fed BLDC motor Drive



2. PFC Bridgeless Isolated Converter Fed BLDC Motor Drive

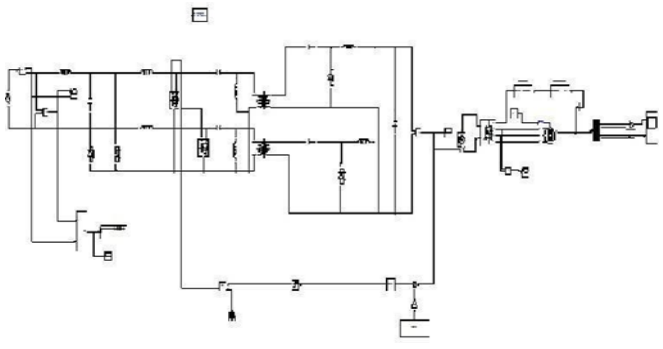
The proposed PFC bridgeless isolated-Cuk converter fed BLDC motor drive. A single-phase supply followed by a LC- filter is used to feed a bridgeless isolated Cuk converter. This maintains the required DC link voltage of the VSI and provides power factor correction at AC mains. The proposed PFC converter is designed to operate in DICM to act as an inherent power factor corrector. The DC link voltage of the VSI is controlled for adjusting the speed of the BLDC motor. The VSI feeding the BLDC motor is operated in a low frequency switching to achieve an electronic commutation of



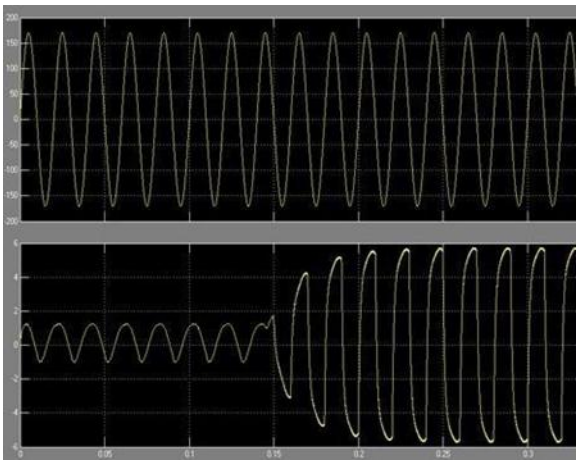
BLDC motor for reduced switching losses. The proposed Configuration uses a single voltage sensor to control the dc link voltage for speed control of BLDC motor. The proposed drive is designed and its performance is validated on a developed prototype for improved power Quality at AC mains for a wide range of speed control and supply voltages.

3. SIMULATION EXPERIMENT AND RESULT:

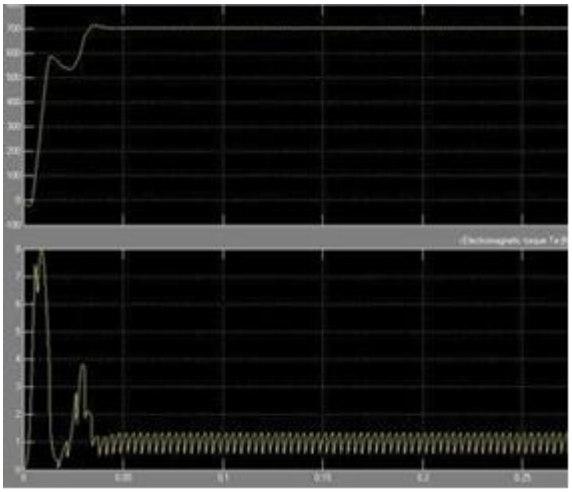
A new configuration of bridgeless isolated-Cuk converter fed BLDC motor drive has been proposed for low power household appliances. The speed control of BLDC motor has been achieved by controlling the DC link voltage of VSI feeding BLDC motor. This has facilitated the operation of VSI in low frequency switching mode for reducing the switching losses associated with it. This bridgeless isolated- Cuk converter has been designed for the elimination of diode bridge rectifier at the front-end for reducing the conduction Losses in the front -end converter.



Input voltage and current



Output (Speed and torque) for 700 rpm



Power factor : (700 rpm)

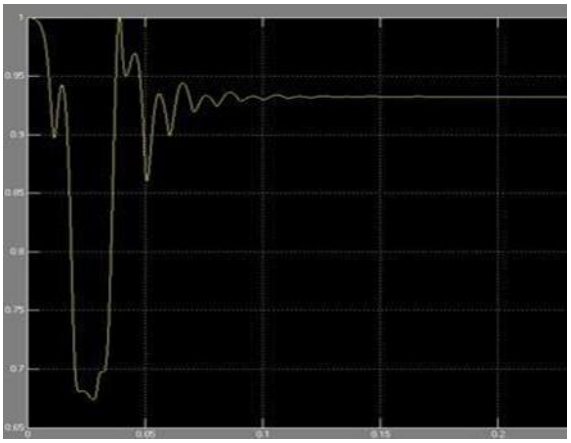


TABLE 1

COMPARISON OF PROPOSED BRIDGELESS ISOLATED-CUK CONVERTER WITH EXISTING CONFIGURATION

Configuration	No of Devices					T/2	SB	Isol	Drv. Cmp
	S	D	L	C	T				
BL-Buck [20]	2	4	2	2	10	5	No	No	Isol.
BL-Boost* [21]	2	4	1	1	8	5	No	No	LS
BL-Buck-Boost [22]	2	4	2	1	9	5	Yes	No	LS
BL-Cuk T-1 [23]	2	3	3	3	11	7	Yes	No	LS
BL-Cuk T-2 [23]	2	2	3	4	11	11	Yes	No	Isol.
BL-Cuk T-3 [23, 24]	2	4	4	3	13	7	Yes	No	LS
BL-Cuk [25]	2	3	2	2	9	7	Yes	No	H/L
BL-Cuk [26]	2	2	3	3	10	7	Yes	No	Isol.
BL-SEPIC [27]	2	3	2	2	9	7	Yes	No	H/L
BL-Zeta [28]	2	4	4	3	13	7	Yes	No	LS
BL-CSC [29]	2	4	2	3	11	6	Yes	No	LS
BL-Flyback [30]#	2	4	2	1	9	5	Yes	Yes	Isol.
BL-Flyback [31]#	2	4	2	1	9	5	Yes	Yes	LS
BL-Flyback [32]#	2	2	1	1	6	5	Yes	Yes	Isol.
BL-Isol Cuk [33]#	4	0	3	3	10	10	Yes	Yes	Isol.
BL-Isol SEPIC [36]#	2	2	3	3	10	7	Yes	Yes	Isol.
BL-Isol SEPIC [37]#	4	3	3	3	13	11	Yes	Yes	Isol.
BL-Isol, Zeta [38]#	2	3	2	2	9	7	Yes	Yes	Isol.
Proposed #	2	4	6	5	17	9	Yes	Yes	LS

S-Switches, D-Diodes, L–Magnetic Components (*Coupled Inductors, # High Frequency Transformer), C-Capacitors, T-Total components, T/2 - Devices conducing in half cycle of supply voltage, SB – Suitability to variable voltage applications, Isol. - High frequency isolation (Galvanic isolation), Drv. Cmp.- Gate Driver Complexity: Isol. - Isolated Gate Driver, LS - Low Side Gate Driver, H/L- High and Low Side Gate Driver

4. CONTROL OF BLDC MOTOR

Electronic commutation of the BLDC motor includes proper switching of the VSI in such a way that a symmetrical DC current is drawn from the DC link capacitor for 120 and is placed symmetrically at Centre of back-EMF of each phase. A Hall-Effect position sensor is used to sense the rotor position on a span of 60 is required for electronic commutation of the BLDC motor. As shown in Fig, when two switches of the VSI i.e. S1 and S4 are in conducting states, a line current iab is drawn from the DC link capacitor which magnitude depends on the applied DC link voltage (Vdc), back EMF's (ean and ebn), resistances (Ra and Rb) and self and mutual inductance (La, Lb and M) of stator windings. This current produces an electromagnetic torque (Te) which in-turn increases the speed of the BLDC motor

5. CONTROL OF FRONT-END PFC CONVERTER

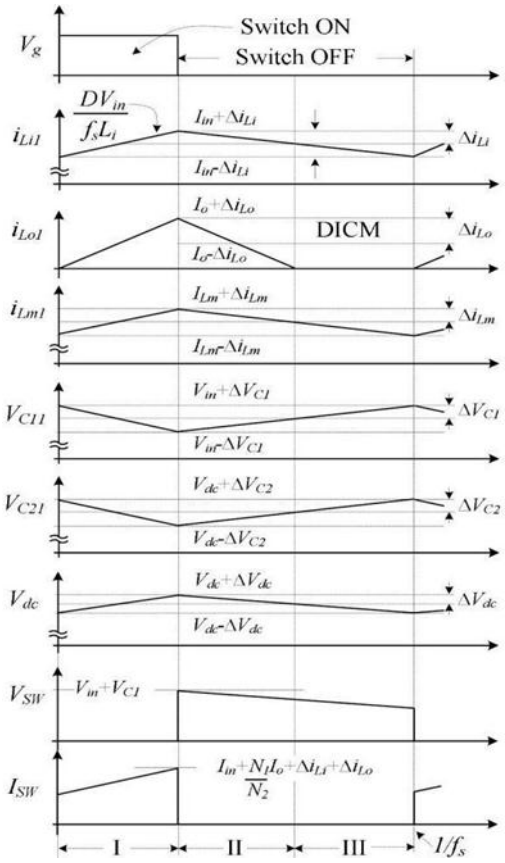
A voltage follower approach is used for the control of PFC based bridgeless isolated-Cuk converter operating in DICM. This control scheme consists of a reference voltage generator, voltage error generator, voltage controller and a PWM generator. A 'Reference Voltage Generator' generates a reference voltage Vdc* by multiplying the reference speed (ω*) with the motor's voltage constant (kv) as,

$$V_{e}(k)=V_{dc}(k)^{*}-V_{dc}(k),\ V_{dc}^{*}=k_{v}\omega^{*}$$

6. CONCLUSIONS

A new configuration of bridgeless isolated-Cuk converter fed BLDC motor drive has been proposed for low power household appliances. The speed control of BLDC motor has been achieved by controlling the DC link voltage of VSI feeding BLDC motor. This has facilitated the operation of VSI in low frequency switching mode for reducing the switching losses associated with it. This bridgeless isolated-Cuk converter has been designed for the elimination of diode bridge rectifier at the front-end for reducing the conduction losses in the front-end converter. This PFC converter has been operated in DICM for DC link voltage control and inherent power factor correction is achieved at the AC mains. A prototype of proposed drive has been implemented using a DSP. Satisfactory test results for proposed bridgeless isolated-Cuk-converter fed BLDC motor has been evaluated for its operation over complete speed range. Moreover, the performance of proposed drive is also evaluated for operation at wide range of supply voltages. The obtained power quality indices have been found within the limits of power quality standards such as IEC 61000-3-2. .

WAVEFORM OF PROPOSED CONVERTER IN COMPLETE SWITCHING CYCLE



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BIOGRAPHICS

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