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Power Factor Correction Using CUK Converter by Peak Current Control Technique for PMBLDC Motor Drive

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Abstract:

This paper deals with a comparative analysis of various converter topologies for Power Factor Correction (PFC) in PMBLDCM motor drives. A power factor corrected converter is required for improving power quality at the AC mains of an inverter fed PMBLDCM motor drive. Conventionally, the PMBLDCM motor is fed by a diode bridge rectifier (DBR) which results in highly distorted supply current and a poor power factor.

A new bridgeless single-phase ac–dc Cuk derived topology has been introduced for power factor correction. This bridgeless topology uses minimum number of switches and thus reduces the less conduction losses compared with the conventional PFC rectifier. There are three Cuk derived configurations for power factor correction. In this paper, all the Cuk derived topologies are investigated and compared. The best topology is identified and recommended for PFC in PMBLDCM motor drive.

Keywords:

Power factor correction (PFC), bridgeless cuk converters, power quality, total harmonic distortion, PMBLDC drives.

1. INTRODUCTION:

PERMANENT magnet brushless DC motors (PMBLDCMs) [1, 3] are high efficiency, wide speed range and low maintenance requirements. A PMBLDCM which is a kind of three-phase synchronous motor with permanent magnets (PMs) on the rotor and trapezoidal back EMF waveform operates on electronic commutation accomplished by solid state switches.

It is powered through a three-phase voltage source inverter (VSI) which is fed from single-phase AC supply using a diode bridge rectifier (DBR) followed by smoothening DC link capacitor. The compressor exerts constant torque (i.e. rated torque) on the PMBLDCM and is operated in speed control mode to improve the efficiency of the system. Since, the back-emf of the PMBLDCM is proportional to the motor speed and the developed torque is proportional to its phase current, therefore, a constant torque is maintained by a constant current in the stator winding of the PMBLDCM whereas the speed can be controlled by varying the terminal voltage of the motor[2]. Based on this logic, a speed control scheme is proposed in this paper which uses a reference voltage at DC link proportional to the desired speed of the PMBLDC motor.

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 equipments emphasize on low harmonic contents and near unity power factor current to be drawn from AC mains by these motors. However, these two stage PFC converters have high cost and complexity in implementing two separate switch-mode converters [2], therefore a single stage converter combining the PFC and voltage regulation at DC link is more in demand.

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2. BRUSHLESS DC (BLDC):

Brushless Direct Current (BLDC) motors are one of the motor types rapidly gaining popularity. BLDC motors are used in industries such as Appliances, Automotive, Aerospace, Consumer, Medical, Industrial Automation Equipment and Instrumentation.

As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. BLDC motors have many advantages over brushed DC motors and induction motors. A few of these are:

A. POWER FACTOR IMPROVEMENT:

The low power factor is mainly due to the fact that most of the power loads are inductive and, therefore, take lagging currents. In order to improve the power factor, some device taking leading power should be connected in parallel with the load.

One of such devices can be a capacitor. The capacitor draws a leading current and partly or completely neutralizes the lagging reactive component of load current. This raises the power factor of the load.

B. TOTAL HARMONIC DISTORTION (THD):

Electrical generators try to produce electric power where the voltage waveform has only one frequency associated with it, the fundamental frequency. In the North America, this frequency is 60 Hz, or cycles per second. In European countries and other parts of the world, this frequency is usually 50 Hz.

Aircraft often uses 400 Hz as the fundamental frequency. At 60 Hz, this means that sixty times a second, the voltage waveform increases to a maximum positive value, then decreases to zero, further decreasing to a maximum negative value, and then back to zero.

3. PROPOSED SPEED CONTROL SCHEME OF PMBLDCMOTOR

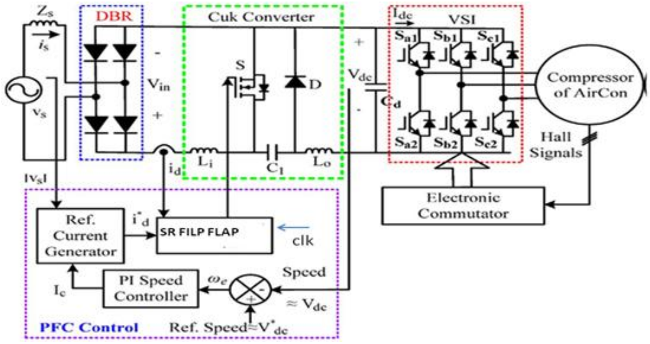

Fig.1. Control scheme of the proposed Cuk PFC converter-fed VSI-based PMBLDCMD

The proposed speed control scheme which is based on the control of the dc link voltage reference as an equivalent to the reference speed. However, the rotor position signals acquired by Hall-effect sensors are used by an electronic commutator to generate switching sequence for the VSI feeding the PMBLDC motor, and therefore, rotor position is required only at the commutation points [1]–[4].

The Cuk dc–dc converter controls the dc link voltage using capacitive energy transfer which results in non pulsating input and output currents [9]. The proposed PFC converter is operated at a high switching frequency for fast and effective control with additional advantage of a small size filter [10]. For high-frequency operation, a metal–oxide–semiconductor field-effect transistor (MOSFET) is used in the proposed PFC converter, whereas insulated gate bipolar transistors (IGBTs) are used in the VSI bridge feeding the PMBLDCM because of its operation at lower frequency compared to the PFC converter.

3.MATLAB/SIMULATION RESULTS:

Inverter output voltage is AC sine wave fed to PMBLDC motor as a taken as motor specifications are selected as per required power rating of machine [4]. The simulation diagram of conventional PMBLDC motor for without using cuk converter shown below fig.2.

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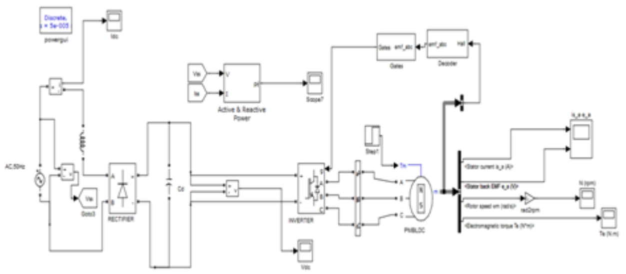

Fig.2 conventional PMBLDC motor without PFC correction MAT lab simulink model

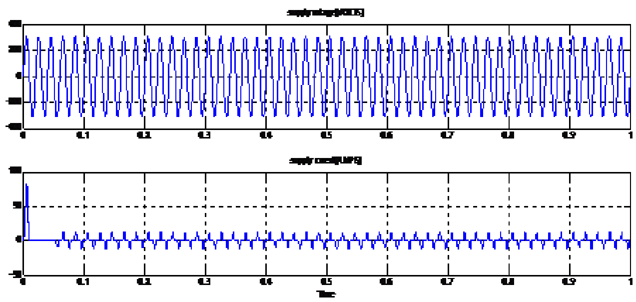

Fig.3. supply voltage and current waveforms of conventional PMBLDC motor without PFC

4. PROPOSED PFC METHOD FED TO CUK CONVERTER

The proposed scheme of PFC method is power factor correction is done by the cuk converter controlled by peak current controlled method [8]. The proposed scheme of peak current control method used to control the switching pulse of MOSFET device. Converter fed to the resistive load and the simulation diagram for proposed system fed by AC input voltage 220V, 50Hz and switching frequency of 40KHz.

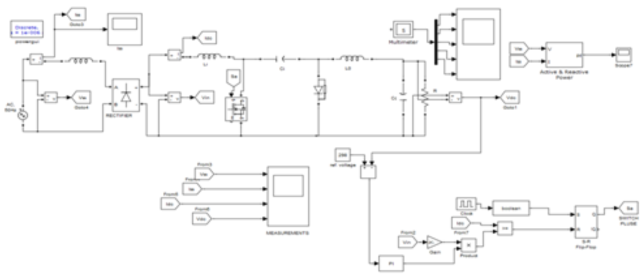

Fig.4. simulation diagram of proposed PFC converter fed to the cuk converter

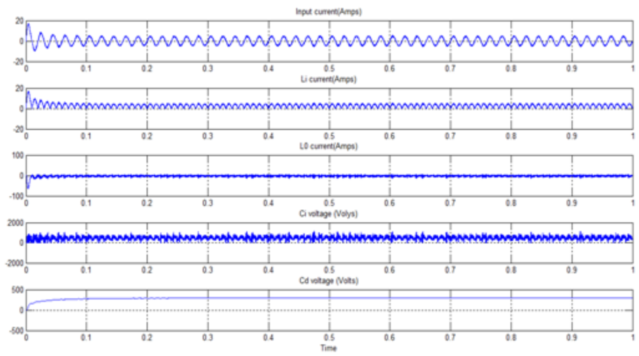

Fig.5: current waveform at input ac mains and converter parameter voltage and current for the proposed drive under steady-state condition at rated torque and 220 V ac input.

5. PROPOSED PFC METHOD FED TO CUK CONVERTER FED TO THE PMBLDC MOTOR

The proposed scheme of PFC method is power factor correction is done by the cuk converter controlled by peak current controlled method. In this cuk converter is DC-DC converter for low or high values of voltage is available in on one converter in the place of different converters[10]. Compare to other converters cuk converter gives continuous input and output current with low current ripple and due to these advantages CUK converter is best candidate for the power factor correction [6]. The simulation diagram of proposed PFC converter fed to the cuk converter for PMBLDC motor for rated speed of 1500 rpm for input voltage 220v shown below Fig.6.

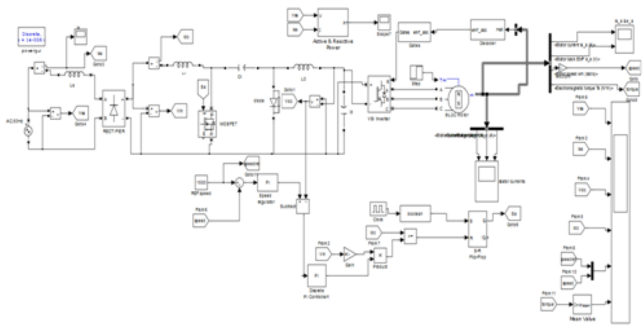

Fig.6: simulation diagram of proposed PFC converter fed to the cuk converter for PMBLDC motor for rated speed of 1500 rpm for input voltage 220V for rated torque 5.2 Nm

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The proposed method of power factor correction for PMBLDC motor will give high efficient as compare to the conventional PMBLDC motor without using cuk converter fed by a peak current control method. Form the below tabulation of speed control of PMBLDC motor values are showed. In this constant AC supply of voltage 220v fed to the motor and varying speed to motor up to the rated speed of 1500rpm. For different speeds of the PMBLDC motor, the power factor and THD values are showed

Table 1: result of proposed PFC to the PMBLDC motor

Speed(rpm)	Vs(volts)	Vdc(V)	Is(amps)	pf	THD of I(s)%	Ripple speed Max	Ripple speed Min	%Ripple
400	220	98	2.34	0.992	13.47	418	384	8.5
600	220	134	3.1	0.995	10.49	614	590	4
800	220	170	3.9	0.9972	8.2	810	790	2.5
1000	220	207	4.8	0.998	7.06	1010	990	2
1200	220	242	5.65	0.9984	6.19	1210	1190	1.66
1500	220	298	6.9	0.9992	5.36	1510	1490	1.333

The speed ripple is the ratio of difference of maximum speed variations (ripple max.) and minimum speed variation (ripple min.) to the average speed of the motor.

$$\frac{\text{Ripple speed Max} - \text{Ripple speed Min}}{\text{Avg .speed}} * 100 \qquad (1)$$

let us,

Calculate percentage ripple speed for motor for the speed at rated speed of 1500 rpm,

$$= \frac{1510 - 1490}{1500} * 100$$

$= 1.333$

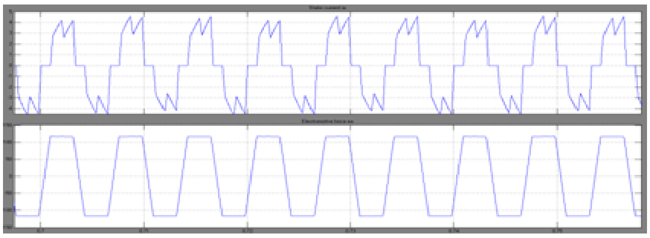

Fig. 7. Performance of the proposed PFC drive under speed control at220-V ac input. (a) Stator current and electromotive force drive at 1500 r/min.

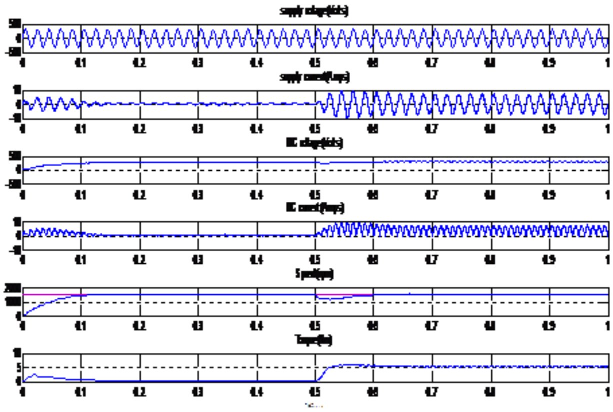

Fig. 8: transition mode speed control of PFC controlled converter fed to the PMBLDC

6. CONCLUSION:

A new speed control strategy of a PMBLDCM drive is validated for load which uses the reference speed as an equivalent reference voltage at DC link. The speed control is directly proportional to the voltage control at DC link. The rate limiter introduced in the reference voltage at DC link effectively limits the motor current within the desired value during the transient condition (starting and speed control). The additional PFC feature to the proposed drive ensures nearly unity PF in wide range of speed and input AC voltage. Moreover, power quality parameters of the proposed PMBLDCM drive are in conformity to an International standard. The proposed drive has demonstrated good speed control with energy efficient operation of the drive system in the wide range of speed and input AC voltage. The proposed drive has been found as a promising candidate for a PMBLDCM driving load in 1-2 kW power range.

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