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Reduction of Harmonics to Improve Performance of Permanent Magnet Brushless DC Motor Drive Using Cuk Converter

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Abstract:
The Presence of harmonics the input supply of permanent magnet Brushless DC Motor cause decrement of efficiency due to the power losses in higher frequency content waveform. This will also cause low power factor because of higher the harmonics which causes higher consumption of reactive power and so the overall power factor will decrease. Thus it is necessary to increase the input wave form by reducing the present harmonics. This paper deals with the cuk converter to decrease the harmonics contend in input of permanent magnet Brushless DC Motor. The Result is showing in this paper is comparatively study of wave form with and without the cuk converter based permanent magnet Brushless DC Motor.

Key words: *Air-conditioner, Cuk converter, power factor (PF) correction (PFC), permanent-magnet (PM) brushless dc motor (PMBLDCM), voltage control, voltage-source inverter (VSI).*

1.Introduction

We know that in the single phase power supply both 5^{th} and 7^{th} Harmonics are mainly present with higher magnitude and also the multiples of these harmonics with lower magnitude.

Due to the presence of these higher frequency base wave form the reactive power consumption by the circuit will increase. This increment in reactive power increase consumption causes to decrease in the power factor because power factor is the ratio of Active power to Apparent power.

If the reactive power is increase then the active power and the power factor will decreases[7].

An other disadvantage of the presence of these harmonics in the input wave form of permanent magnet Brushless DC Motor is decrease in the efficiency of the system due to the consumption of energy in these harmonics. So for these point of view the presence of harmonics must be reduced as much as possible to improve the overall performance of permanent magnet Brushless DC Motor based drive system in the reference of power factor and efficiency [5].

Permanent magnet Brushless DC Motor is basically a synchronous motor in low-power appliances which increasing because of its features of high efficiency, wide speed range, and low maintenance. It has the developed torque proportional to its phase current and its back electromotive force.

Up till now any other techniques are implemented to decrease the harmonics content in the Permanent magnet Brushless DC Motor based drive system these are BUCK converter BOOST converter and switches method. The switches method having Direct phase current control technique is in use which causes higher stress on the phase conductor. So this method is not preferable to reduce harmonics[2].

Buck converter method having working Associate with step down output voltage thus it is uses for lower voltage application. Buck converter having only inductor to provide energy storing. Other method is Boost converter having working associate with step up output than input this it is uses for up voltage application and Boost converter having only inductor to provide energy storing propose so the presence of the inductor alone does not have any action to control the inrush current from the input. Application of Cuk converter for reducing the harmonics in the Permanent magnet Brushless DC Motor Drive having advantageous on these aspects of voltage level as the cuk converter is the combination of both the Buck and Boost converters so the output and input voltage is controllable within a certain level of higher and lower value of supply voltage.

Another advantage of cuk converter is the presence of both inductor and capacitor so the inrush input current is controllable and also external filters are decrease by these cuk converter [3].

2.Method Of Reduction Of Harmonics By Cuk Converter

The Cuk dc–dc converter controls the dc link voltage using capacitive energy transfer which results in non pulsating input and output currents. The proposed PFC converter is operated at a high switching frequency for fast and effective control with additional advantage of a small size filter. For high-frequency operation, a metal–oxide–semiconductor field-effect transistor(MOSFET) is used in the proposed PFC converter, where as 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.

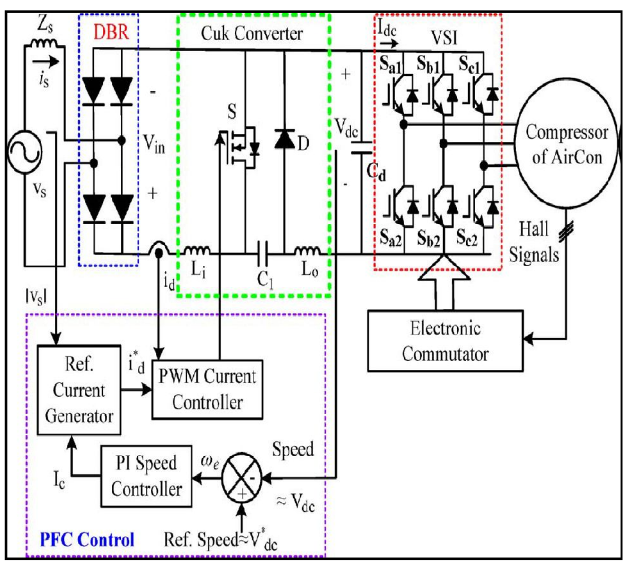

Figure 1

The PMBLDCMD is fed from a single-phase ac supply through a diode bridge rectifier (DBR) followed by a capacitor at dc link. It draws a pulsed current as shown in Fig. 1, with a peak higher than the amplitude of the fundamental input current at ac mains due to an uncontrolled charging of the dc link capacitor. This results in poor power quality (PQ) at ac mains in terms of poor power factor.[6]

The PFC control scheme uses a current multiplier approachwith a current control loop inside the speed control loop for continuous-conduction-mode operation of the converter. The control loop begins with the processing of voltage error (*Ve*), obtained after the comparison of sensed dc link voltage (*V*dc) and a voltage ($V^{*}dc$) equivalent to the reference speed, through a proportional–integral (PI) controller to give the modulating control signal (*Ic*). This signal (*Ic*) is multiplied with a unit template of input ac voltage to get the reference dc current ($I^{*}d$) and compared with the dc current (*Id*) sensed after the DBR. The resultant current error (*Ie*) is amplified and compared with a saw tooth carrier wave of fixed frequency (*fs*) to generate the pulse width modulation (PWM) pulse for the Cuk converter. Its duty ratio (*D*) at a switching frequency (*fs*) controls the dc link voltage at the desired value. For the control of current to PMBLDCM through VSI during the step change of the reference voltage due to the change in the reference speed, a rate limiter is introduced[4].

3.Simulink Modelling

The Figure.2 show the simulink modelling of permanent magnet Brushless DC Motor based drive system applicable on the Air condition. This model contain Cuk converter thus the overall performance of cuk converter based system can be examine.[8]

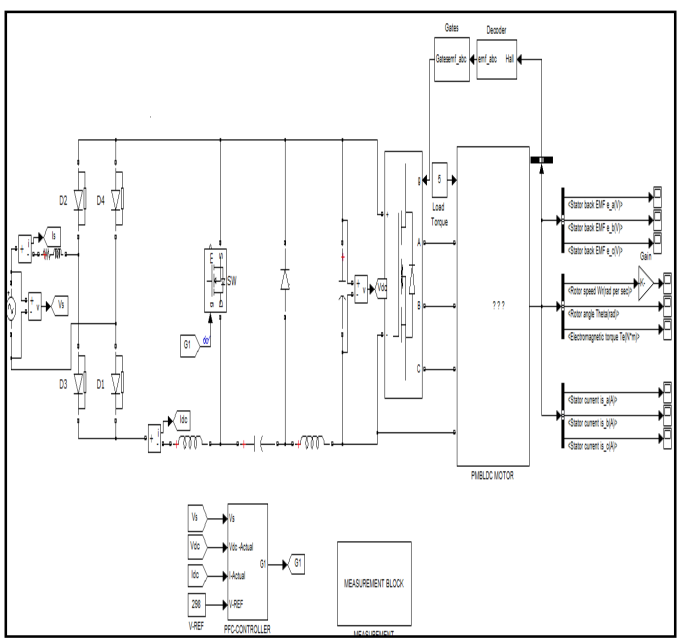

Figure 2 : PMBLDCM drive with Cuk converter

The Figure.3 show the simulink modelling of permanent magnet Brushless DC Motor based drive system applicable on the Air condition. This model is without Cuk converter thus the overall performance of cuk converter based system can be examine as the comparative study between with and without cuk converter.

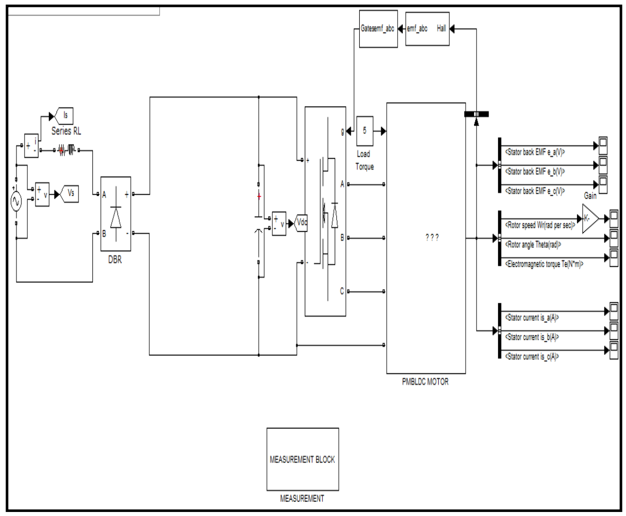

Figure 3: PMBLDCM drive without Cuk converter

4.Design Of PFC Cuk Converter-Based PMBLDCMD

The proposed PFC Cuk converter is designed for a PMBLDCMD with main considerations on the speed control of the Air-Con and PQ improvement at ac mains. The dc link voltage of the PFC converter is given as

$$V_{dc} = V_{in}D/(1 - D) \qquad (1)$$

where V_{in} is the average output of the DBR for a given ac input voltage (V_s) related as

$$V_{in} = 2\sqrt{2}\,V_s/\pi. \qquad (2)$$

The Cuk converter uses a boost inductor (L_i) and a capacitor (C_1) for energy transfer. Their values are given as

$$L_i = DV_{in}/\{f_s(\Delta I_{Li})\} \qquad (3)$$

$$C_1 = DI_{dc}/\{f_s\Delta V_{C1}\} \qquad (4)$$

where ΔI_{Li} is a specified inductor current ripple, ΔV_{C1} is a specified voltage ripple in the intermediate capacitor (C_1), and I_{dc} is the current drawn by the PMBLDCM from the dc link[1].

A ripple filter is designed for ripple-free voltage at the dc link of the Cuk converter. The inductance (L_o) of the ripple filter restricts the inductor peak-to-peak ripple current (ΔILo)within a specified value for the given switching frequency (*fs*),whereas the capacitance (*Cd*) is calculated for the allowed ripple in the dc link voltage (ΔVCd) [2]. The values of the ripple filter inductor and capacitor are given as

$$Lo = (1 - D)V\mathrm{dc}/\{fs(\Delta I\mathrm{Lo})\} \qquad (5)$$

$$Cd = I\mathrm{dc}/(2\omega \Delta V\mathrm{Cd}). \qquad (6)$$

The PFC converter is designed for a base dc link voltage of Vdc = 298 V at Vs = 220 V for fs = 40 kHz, Is = 4.5 A, ΔILi = 0.45 A (10% of Idc), Idc = 3.5 A, ΔILo = 3.5 A (≈ Idc), ΔVCd = 4 V (1% of Vo), and ΔVC1 = 220 V (≈ Vs).

The design values are obtained as Li = 6.61 mH, C1 = 0.3 μF, Lo = 0.82 mH, and Cd = 1590 μF.

5.Result And Discussion

As the given figure 4, figure 5, figure 6 are showing current wave form of stator current for all separate phases phase A, phase B, and phase C, and figure7, figure 8, figure 9 are showing current wave form of stator current for all separate phases phase A, phase B, and phase C for with cuk Converter and without cuk converter respectively.

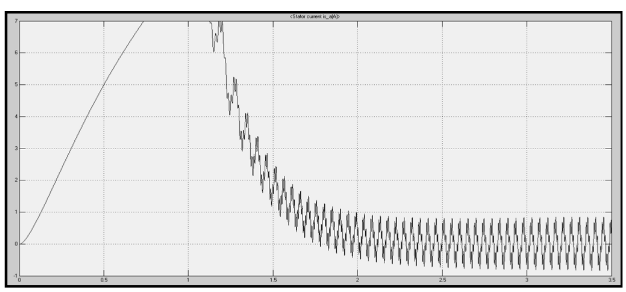

Figure 4: Phase current A with Cuk converter

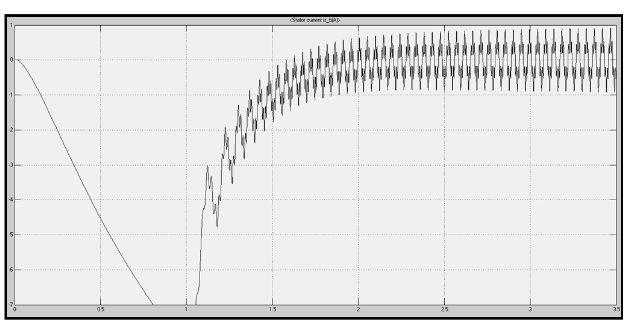

Figure 5: Phase current B with Cuk converter

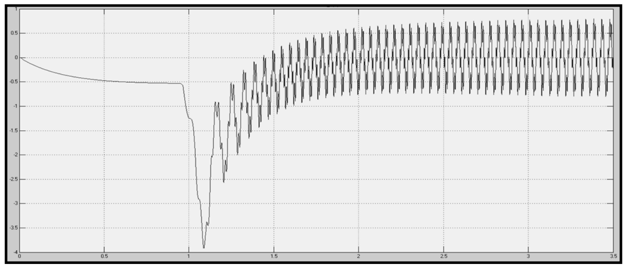

Figure 6: Phase current C with Cuk converter

As the above figure show that the distortion in fundamental wave form is reduces by apply cuk converter

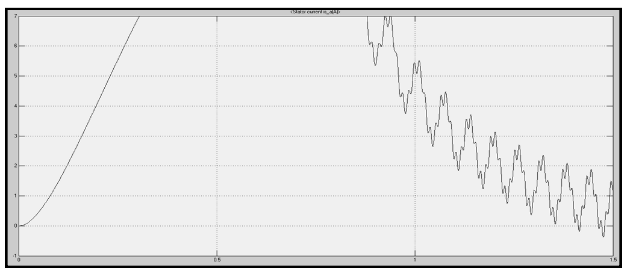

Figure 7: Phase current A without Cuk converter

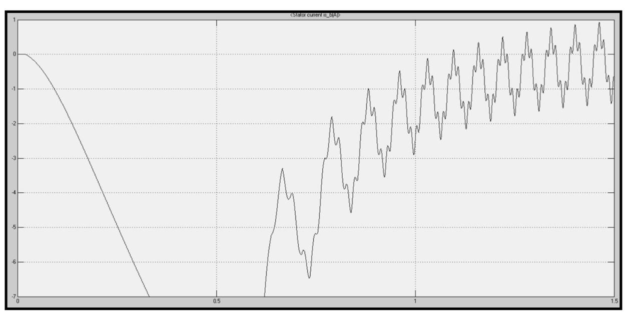

Figure 8: Phase current B without Cuk converter

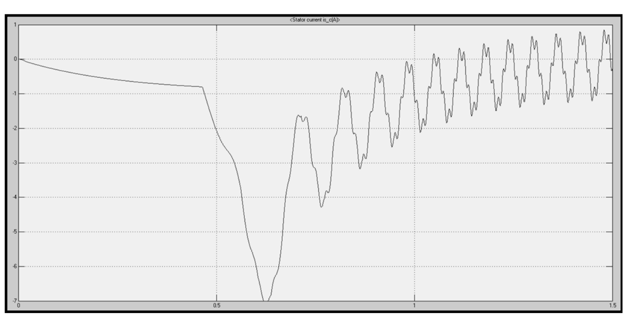

Figure 9: Phase current C without Cuk converter

With the help of the cuk converter the power quality of the system is improved and thus the power factor is increased nearly to one by reducing the harmonics. Thus it is now clear that the application of cuk converter on permanent magnet Brushless DC Motor based drive system reduce the harmonics content.

6.Conclusion

This paper describe the application of cuk converter to improve the power quality by reduction of harmonics present in the fundamental waveform. So the overall power factor is also improves. This increment in power quality causes improvement in the overall efficiency of the permanent magnet Brushless DC Motor based drive system very effectively. The speed of PMBLDCM has been found to be proportional to the dc link voltage; thereby, a smooth speed control is observed while controlling the dc link voltage. The introduction of a rate limiter in the reference dc link voltage effectively limits the motor current within the desired value during the transient conditions. All the power quality problems of poor PF, inrush current, and speed control can be reduced by the Cuk converter-based PMBLDCMD

7.Appendix

SN.	PMBLDC Parameters and Values	
	Parameter	**Value**
1.	Rated speed	1500 r/min
2.	Inductance (L+M)	9.165 mH/ph
3.	Stator Resistance(R)	3.57 Ω/ph
4.	Inertia (J)	0.068 kg $\cdot m^2$
5.	Source impedance	0/03 p.u
6.	Rated power	0.816 kw
7.	Rated torque	5.2 N m
8.	Number of poles	6
9.	Switching frequency	40 kHz
10.	Back emf constant	1.3 V · s/rad

Table 1

8.Acknowledgment

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