International Journal of Advanced Information in Engineering Technology (IJAIET) ISSN: 2454-6933
Vol.3, No.11, November 2016

Power Factor Correction and Power Quality Improvement Using a Bridgeless Buckboost Converter for a BLDC Motor

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***Abstract*—A bridgeless buck boost power factor correction converter which can improve the power quality of the system is introduced .This paper deals with a new system as a single stage PFC converter for PMBLDC. The VSI ensures electronic commutation to operate the PMBLDC drive. To resolve the problem of high conduction losses in cascade buck boost converter the new bridgeless buck boost converter is designed. The design, modeling and simulations are carried out in Matlab**

Keywords— Bridgeless buck boost converter; Brush less dc motor; Diode Bridge rectifier ; Power factor correction; Brush less dc

I. Introduction

THERE is a necessity to maintain high efficiency across the entire load because of various economic reasons. The buck boos PFC converter operates in both discontinuous current mode and continuous current mode. The choice of the mode of operation directly affect the cost and ratings of components.

The high voltage stress in the wide input voltage range of the adjustable electronic equipments using boost converter makes it difficult to choose the components. The PFC converters with both step up and step down topologies are capable of maintaining appropriate bus voltage. It can be seen that the maximum device voltage is always lesser than the boost PFC converter. In conventional buck boost converter there is a diode bridge rectifier and a buck boost converter. At any moment there are four Conducting semiconductors. So the conduction losses increase with increased power ratings. In the bridge less buck boost converter proposed by Wei [5] there are three conducting switches at any instant. Thus it is not a cost effective solution.

A high power buck converter is proposed by Jang[3] and a bridgeless power factor correction boost converter is proposed by Huber[4]. They can provide either buck or boost the voltage at a time and so it limits the operating range of DC link voltage control.

II. Literature Survey

Considering the distribution side in a power system Which includes household appliances such as water pumbs, blowers, mixers , fans, efficiency and cost are the major concerns. Due to the low maintenance requirements, low Electro Magnetic Interference, high efficiency, high flux density per unit volume the use of BLDC motors are becoming common in these applications. The BLDC motors have other applications like HVAC, transportation, motion control and many industrial tools. The sparking and wear and tear of brushes and commutator assembly are avoided by using the BLDC motor.

A BLDC motor which is fed by Diode Bridge Rectifier with a DC link capacitor of high value draws a peaky current which increases the THD of supply current to about 65% and the power factor to be around 0.8. The two stage power factor correction topologies that uses comparatively larger number of components have conduction losses[5] and are not cost effective.

The boost type Power Factor Correction topology has higher device voltage stress compared to Conventional buck boost converter Power factor correction topology. In Conventional Buck boost converter Power factor correction topology the inrush current problem is also reduced. The disadvantage of conventional buck boost converter is that it uses four semiconductor devices at a time. So that this topology is not cost effective though it stands superior to Boost type power factor correction converter.

Under these circumstances a new topology namely bridgeless buck boost converter is used for the purpose of driving the BLDC motor.The converter is capable of overcoming the drawbacks of the above noted topologies.

III. Methodology

The inductor currents becomes discontinuous while the Power Factor Correction converter is operating in the Discontinuous inductive current mode. The new topology is studied for a BLDC motor of 4 pole and ratings as given in table 1.

Particulars	Ratings
P_{rated}	251.32w
V_{rated}	200v
T_{rated}	1.2Nm
Rated speed	2000 rpm
Back EMF Constant K_b	78v/krpm
Torque Constant	.74Nm/A

K_t	
R_{ph}	14.56Ω
L_{ph}	25.71mH
Moment Of Inertia J	$1.3*10^{-4}$ Nm/S^2

Table 1

A converter of 350 W is designed for the above BLDC motor. The bridge less Buck boost Power Factor correction converter operation is classified into two parts.

A. Positive and negative half cycles

During the positive and negative half cycles the switches S_{w1} and S_{w2} respectively operate. In the positive half cycle the switch S_{w1}, L_{i1} and diode D_1 and D_p operate to transfer energy to DC link Capacitor C_d.

During the negative half cycle the supply voltage Switch Sw_2 inductor L_{i2} and diodes D_2 and D_n are in conducting mode.In the BL buck boost converter operating in DICM the current in inductor Li is discontinuous for certain duration in a switching period.

B. Complete Swtching cycle

The modes of operation during a complete switching cycle are as follows

Mode I

The switches S_{w1}, L_{i1} and D_p are in conducting state.The VSI discharges the DC link capacitor.

Mode II

The switch S_{w1} is turned off.The stored energy in L_{i1} is discharged to the DC link capacitor.

Mode III

The inductor L_{i1} enters the discontinuous conduction. The current iLi1 is zero for the remaining switching period. No switches or diodes conduct .The energy is suppliedto the load by the DC link capacitor C_d.S o the voltage across the DC link capacitor decreases.

C. New topology of PFC Converter

The buck boost converter is designed to operate in DICM.The parameters of the BL Buck boost are so designed. By controlling the DC link voltage speed control of BLDC motor is achieved.The Perfommance of the BLDC motor is evaluated For improved power quality at AC mains.

D. Design of the proposed PFC converter

The average voltage at the input side is given as

$$Vin = \frac{2\sqrt{2}}{\Pi} Vs \qquad (1)$$

The voltage conversion ratio for a buck boost converter is given by

$$d = \frac{Vdc}{Vdc + Vin} \qquad (2)$$

Design of input inductor(L_{i1} and L_{i2})

The critical value of inductance is taken as

$$Lic = \frac{R(1-d^2)}{2fs} \qquad (3)$$

To guarantee deep DICM condition the inductance values are chosen as 1/10 th of the critical value.

DC link capacitor

The voltage ripple corresponding to the capacitor current is given by

$$\Delta Vdc = \frac{-Id\ Sin2\omega t}{2\omega Cd} \qquad (4)$$

Sin2wt is taken as one for maximum value of DC link capacitor.

$$Cd = \frac{-Id}{2\omega\ \Delta Vdc} \qquad (5)$$

ΔVdc is taken as 3% with permitted ripple in the DC link voltage.

Input filter design

The filter capacitance's maximum value is

$$Cmax = \frac{Ipeak\ tan(\theta)}{\omega L\ Vpeak} \qquad (6)$$

Where

Ipeak=Peak value of supply current

Vpeak=Peak value of supply voltage

ωL =Line frequency in rad/sec

ϑ=Displacement angle between supply voltage and supply current

The source impedance is taken as 4-5% of the base impedance.

$$Lreq = \frac{1}{4\pi^2 fc^2 Cf} - Ls \qquad (7)$$

fc is taken according to the criteria

$f_L < f_C < f_{sw}$

fc is chosen as

$$fc = \frac{fsw}{10} \qquad (8)$$

The proposed converter is designed for a BLDC motor of power rating 251w.The power converter is designed for 300w.The desired dc link voltage control is from 50v to 200v with an average value of 100v.With this the obtained value of input inductor currents are Lic=35µH, Cd=330nF.

The required value of inductance is obtained as 1.57mH approximated as 1.6mH.

E. Voltage follower approach-The front end Power factor Correction Converter

The reference DC link voltage is taken as

$Vdc^* = Kv\ \omega^*$ *(9)*

Kv=Motor's voltage constant

ω*=Reference speed

The error in voltage is found out by comparing the reference DC link voltage Vdc* with the sensed DC link voltage Vdc as

Ve(n)=Vdc(n)-Vdc(n)* *(10)*

Where n represents the n^{th} sampling instant.

The PI controller to which the error voltage signal is given generate a controlled output voltage(Vcc).

*Vcc(n)=Vcc(n-1)+Kp(Ve(n)-Ve(n-1))+Ki*Ve(n) (11)*

Where *Kp*=proportional gain

Ki=Integral gain

The PWM pulses are generated by comparing the Vcc with a high frequency saw tooth signal(*md*).

For positive half cycle

For *md*<*Vcc* Sw1 is on

For *md*≥*Vcc* Sw1is off

For negative half cycle

For *md*<*Vcc* Sw2 is on

For *md* ≥*Vcc* Sw2 is off

F. *Control of BLDC motor*

The rotor of the BLDC motor comprises of a permanent magnet and the stator has three phase windings on it.The mechanical commutation has various disadvantages like sparking and wear and tear of brushes.

Due to the electronic commutation based on rotor assembly positon BLDC motor is also known as Electronically Commutated motor.

In electronic commutation the proper switching of VSI is done such that for 120^0 a symmetrical DC current is drawn from the DC link capacitor and is symmetrically placed at the centre of each phase.

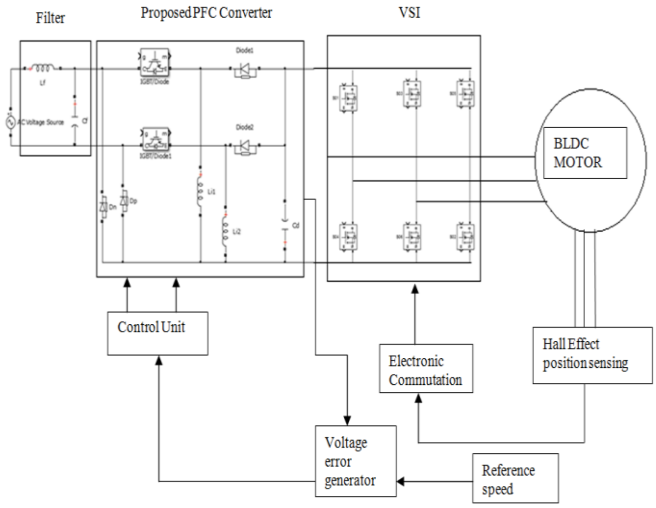

Fig.1 Proposed topology of converter

Vdc(v)	Power Factor	THD(%)	Speed(rpm)
200	.9974	6.303	1908
180	.9989	1.942	1706
160	.9983	1.417	1504
150	.9909	1.417	1504
120	.9752	10.52	1090

Table 2

IV. Experimental Results

The operational benefits of the new PFC converter is evaluated for the motor with given ratings.The power factor was found to be improved by using the new topology.Efficient power factor correction has been done using the new converter.

1. Experimental results for a DC link voltage of 200v

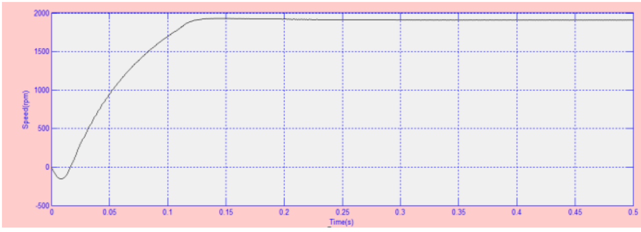

Fig.2 Speed Output

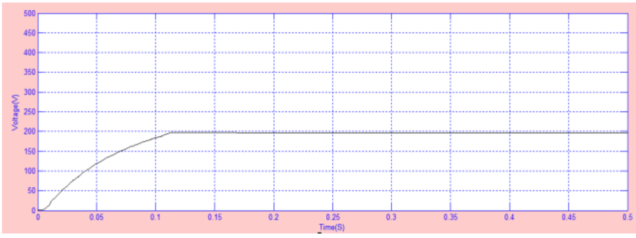

Fig 3.Converter Output voltage

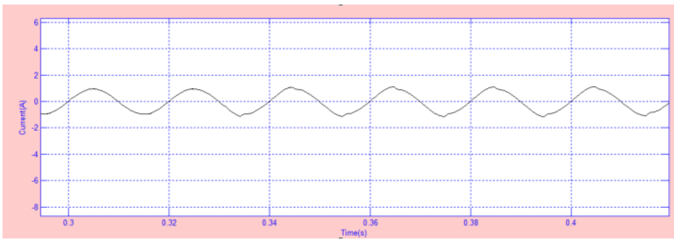

Fig 5. Source Current

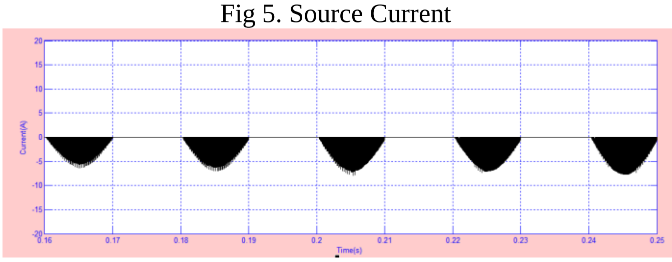

Fig 6.Current through inductor Li1

V. CONCLUSION AND FUTURE ENHANCEMENT

It has been found that the power factor has been considerably improved with the use of the new power factor correction converter. Though THD levels are satisfactory considering the IEEE standards they can still be reduced. The future works include improving the topology so as to reduce the THD level further for better usage.

VI. ACKNOWLEDGMENT

First and foremost, I offer my gratitude to God Almighty for his blessings and deliverance throughout the preparation of this paper. I am grateful to my Co Author Er. Jaison Cherian for his whole hearted support and guidance in helping me present the seminar to the best of my ability.

I hereby extend my sincere gratitude to all the staff members of the Electrical and Electronics Engineering Department for all the support given to me.

Last, but not the least, I extend my sincere thanks to my parent and friends for their valuable help and encouragement in my endeavor.

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