VOLUME-2 ISSUE-3
ISSN : 2799-18

ANALYSIS OF POWER FACTOR CORRECTION FOR A VOLTAGE-CONTROLLED SWITCHED BOOST INVERTER-BASED PMBLDCM DRIVE

G.Nikhade

ABSTRACT-
This paper deals with a switched boost inverter as a single-stage power-factor-correction converter for a permanent magnet (PM) brushless dc motor (PMBLDCM) fed through a diode bridge rectifier from a single-phase ac mains. A three phase voltage-source inverter is used as an electronic commutator to operate the PMBLDCM driving an air conditioner compressor. The speed of the compressor is controlled to achieve optimum air-conditioning using a concept of the voltage control at dc link proportional to the desired speed of the PMBLDCM. The stator currents of the PMBLDCM during step change in the reference speed are controlled within the specified limits by an addition of a rate limiter in the reference dc link voltage. The proposed PMBLDCM drive PMBLDCMD) is designed and modelled, and its performance is evaluated in Matlab–Simulink environment. Simulated results are presented to demonstrate an improved power quality at ac mains of the PMBLDCMD system in a wide range of speed and input ac voltage. Test results of a developed controller are also presented to validate the design and model of the drive.

I. INTRODUCTION

Brushless DC motors have got wide applications in the field of automobile vehicle technology, hard disc drives, compressors etc because of their high starting torque, reliable operation and good efficiency. Now a days various automobile applications are satisfied by these cost effective and reliable brushless technology operated motorsThese motors are actually permanent magnet AC motors resembling the torque-current characteristics of a DC motor. It is a modified form of Permanent Magnet Synchronous motor in which the back emf is trapezoidal which is sinusoidal in case of PMSM motors. Sensor and sensor less control are employed in BLDC motors, In sensor based control, the position of the rotor is identified by the Hall sensors which are provided at 1200 apart. Since the technology is simple and highly reliable, BLDC motors are widely selecting in low power applications.

DC-DC converters are used for feeding these BLDC motor drives. Apart from the control of input voltage to the inverter driving motors, they are also performing the isolation between input and the load side. Various converter topologies are being used now a days depending on the requirements. Both bridge and bridgeless topologies are using, however the presence of diode bridge along with high value of DC link capacitor will lead to the reduction of power factor since the total harmonic distortion increases. Inverters are employed to supply power to the BLDC motor which is a three phase inverter. Voltage source inverters are most commonly using and the BLDC motor control through electronic commutation is made possible by controlling the gating sequence of inverter switches. Apart from these VSI, CSI and ZSI topologies are also employing.

Power quality issues are of great interest now adays. Most of the industrial applications are running with large power quality issues. Filters are usually provided along with these converters for the correction of power quality and thereby reducing the total harmonic distortion level.

The mode of operation of PFC converters are selected with great importance since it determines the cost and component ratings. Converters can be operated in both continuous conduction mode(CCM) and discontinuous conduction mode(DCM). DCM is mostly selecting in low power applications. This is

VOLUME-2 ISSUE-3
ISSN : 2799-18

because, for employing CCM it requires two sensors, one for sensing the inductor current and other for sensing the capacitor voltage. In DCM there requires only one sensor to detect the DC link voltage only. DC link voltage control cannot be selected in high power applications since it creates high stress on the switches

Air-conditioners (Air-Cons) constitute a considerable amount of load in AC distribution system. However, most of the existing air-conditioners are not energy efficient and thereby, provide a scope for energy conservation. Air-Cons in domestic sector are usually driven by a single-phase induction motor; the temperature in the air conditioned zone is regulated over a hysteresis band through the „on/off" control of the compressor motor. Therefore, the motor is operated only at full load (compressor „on") at nearly constant speed, i.e., rated speed, [1] because these motors achieve maximum efficiency near the rated load only. The „on/off" control provides inefficient temperature control with increased losses in the motor during frequent „on/off" operation. Efforts to improve the efficiency of the existing air-con system using new mechanical and electronic system designs have resulted in marginal improvement in system efficiency; however, the variable speed operation of the air conditioner significantly improves system efficiency [2].

Moreover, the compressor driven by a motor with speed control delivers the desired cooling capacity and maintains the room temperature effectively and efficiently. Permanent magnet brushless DC motor (PMBLDCM) drives are being employed in many variable speed applications due to their high efficiency, silent operation, compact size, high reliability, ease of control, and low maintenance requirements. It is a good option for an air conditioner compressor. PMBLDCM is operated through a threephase voltage source inverter (VSI), which is fed from single phase AC supply using a diode bridge rectifier (DBR), followed by a smoothening DC link capacitor. PMBLDCM is supplied by three-phase rectangular current blocks of 120° duration, in phase with the constant part of the back EMF waveform. These motors need rotor-position information only at the commutation points, e.g., every 60°electrical in the three-phase, requiring a simple controller for commutation [3-7].The PMBLDC motor is operated at a constant torque(i.e., rated torque) with speed control to improve energy efficiency [8]. In fact, the back-EMF of the PMBLDCM is proportional to the motor speed and the developed torque is proportional to its phase current [3-6]; 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. A new speed control scheme that uses DC link voltage proportional to the desired speed of the PMBLDC motor is used in this work. VSI control is based on the rotor position signals and used only for electronic commutation of the PMBLDC motor.

II. PROPOSED BRIDGELESS BUCK-BOOST CONVERTER FEEDING BLDC MOTOR DRIVE

The proposed system consisting of a bridgeless buck boost converter feeding a BLDC motor drive. The converter is operating in discontinuous inductor current mode for reducing the switching stress.An L filter is used at the input to improve the power quality. A dual buck boost converter is used in which one operating during positive half cycle and the other operating during the negative half cycle. In each of the half cycles, the DC link capacitor is continuously feeding the drive through three different modes. A voltage source inverter is used to provide alternating stator current to the motor drive. Electronic commutation is employed for controlling the switches of inverter so that the speed control of the BLDC drive can be made possible. Power factor correction is done by the voltage feedback control of the converter along with the filter operation. The switching stress will also be evaluated along

VOLUME-2 ISSUE-3
ISSN : 2799-18

with the other parameters so that the design of heat sinks can be done easily.
The circuit is operating in three modes in each of the half cycles.Lf and Cf are the filter inductance and capacitance at the input stage. SW1 and Sw2 are the switches, L1 and L2 are the inductors, D1 and D2 are the diodes in the dual buck boost converter. The inverter switches are numbered through S1 to S6 and the BLDC motor drive employed with hall effect position (Ha-Hc) sensors are also shown in the circuit.

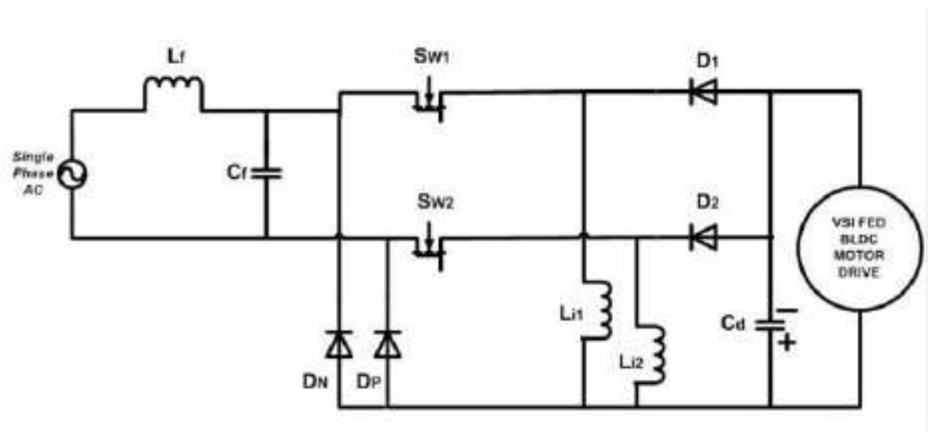

Fig 1 : Proposed Converter

III. DESIGN OF CONVERTER, FILTERPARAMETERS AND INVERTER SELECTION

The power factor corrected converter is operating in discontinuous inductor current mode such that the inductor currents Li1 and Li2 become discontinuous in a switching period. The BLDC motor used is of power 250W and the converter is designed for a rating of output power 350W. The RMS value of input voltage is 220V.

$$V_{in} = \frac{2\sqrt{2}Vs}{\pi} = \frac{2\sqrt{2}*220}{\pi} = 198V$$

The converter is designed from 50V to 200V with a nominal voltage of 100V. So the duty cycle might varies from .2016 to .5026

A) Design of input inductors Li1 and Li2

For a converter operating in crictical conduction mode the value of Inductance is given by

$$L_{i1,2} = \frac{R\,(1-d*d)}{2fs}$$

The converter operates in very low value od duty ratio. At minimum duty ratio the converter is operating at 50V and 90W power.

$$L_{i1,2} = \frac{Vdcmin * Vdcmin\ (1-d*d)}{Pmin * 2fs} = \frac{50*50\ (1-.2016*.2016)}{90*2*20000}$$

$$= 442.67\mu H$$

This can approximately be selected as 300µH. For the reliable operation in DICM mode 1/10 of this value is taken. So its value become 30µH.
B) Design of DC link capacitor Cd
For designing, the amount of second order harmonic current flowing through the capacitor should be taken into consideration.For a nominal value of 100V, thepermitted ripple in the DC link voltage can be taken of the order of 3%

VOLUME-2 ISSUE-3
ISSN : 2799-18

$$C_d = \frac{Id}{2w\Delta Vdc} = \frac{Po/Vdc}{2w\Delta Vdc} = \frac{350/10}{2*314*.03*100} = 1857.7\ \mu F$$

Therefore the nearest possible value for the DC link capacitor can be selected as 2200 ìF.

C) Design of input filter

A second order low pass LC filter is used to absorb the higher order harmonics in order to avoid it from the supply current. The value of capacitor is designed such that

$$C_{max} = \frac{Ipeak\ \tan(\alpha)}{\omega L*Vpeak} = \frac{350*1*\tan 1}{220*220*1.732*314} = 401.980\ nF$$

So the value of capacitor selected is 330nF.The required value of inductance is given by

$$L_{req} = L_f - L_s$$

Where Lf is the inductance of the filter and Ls is 4-5% of the base impedance.

$$L_{req} = \frac{1}{4\pi\pi*fc*fc*Cf} - 0.04*\frac{1*220*220}{314*350} = 1.57mH$$

So a low pass filter with capacitance 330nF and inductance 1.6mH is to be selected. D) Selection of Inverter for feeding BLDC drive

A voltage source inverter is selected to feed the BLDC motor drive. It is a 6 switch inverter in which three legs are used to align them as upper and lower leg switches. One switch from upper and one from lower are active at a particular instant of time. The inverter switches are gated such that the stator voltages should be within the rating of motor selected.

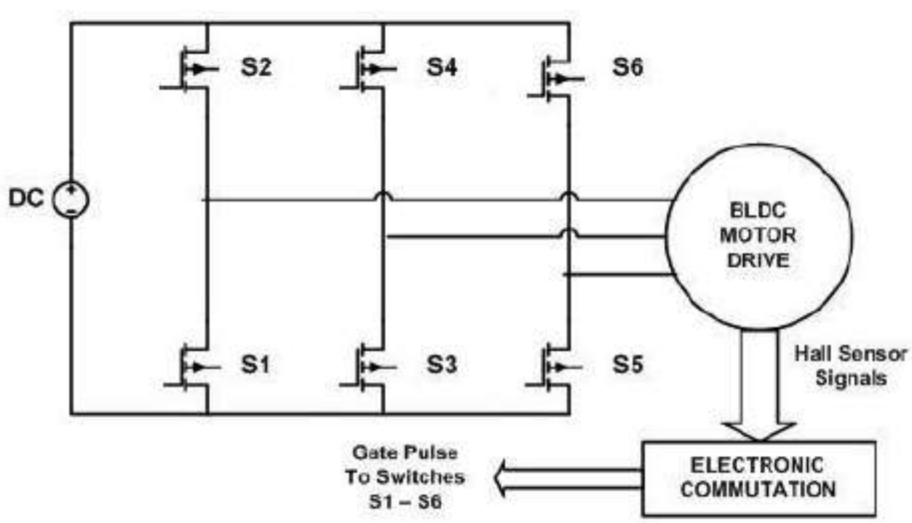

Fig 4 : Voltage Source Inverter feeding BLDC Motor

CONCLUSION

VOLUME-2 ISSUE-3
ISSN : 2799-18

The permant magnet brush less DC Motor is suitable drive for compressor of air-conditioner. Since the characteristics of PMBLDC motor with power factor corrected switched boost inverter are better than the characteristics of the single phase motors used for air conditioners. These motors suffer from the power factor and harmonic currents but the proposed voltage controlled power factor corrected switched boost inverter fed PMBLDC motor has less harmonic distortion and high power factor.

REFERENCES

[1] Ravindranath Adda, Avinash Joshi, and Santanu Mishra, "Pulse Width Modulation of Three-Phase Switched Boost Inverter" 978-1-4799-0336-8/13/$31.00 ©2013 IEEE.

[2] S. Mishra, A. Ravindranath, and A. Joshi, "Switched-boost Inverter based on Inverse Watkins-Johnson Topology," in *Proc. 3rd IEEE Energy Conversion Congress and Exposition (ECCE),* Phoenix, 2011, pp. 4208–4211.

[3] Sanjeev Singh and Bhim Singh, "A Voltage-Controlled PFC Cuk Converter- Based PMBLDCM Drive for Air-Conditioners" IEEE Transactions on Industrial Applications, Vol: 48 No:2, March/April 2012.

[4] A. Ravindranath, S. Mishra, and A. Joshi, "A PWM control strategy for switched boost inverter," in *Proc. 3rd IEEE Energy Conversion Congress and Exposition (ECCE),* Phoenix, 2011, pp. 4208–4211.

[5] T. Kenjo and S. Nagamori, *Permanent Magnet Brushless DC Motors*. Oxford, U.K.: Clarendon, 1985.

[6] T. J. Sokira and W. Jaffe, *Brushless DC Motors: Electronic Commutation and Control*. New York: Tab, 1989.

[7] J. R. Hendershort and T. J. E. Miller, *Design of Brushless PermanentMagnet Motors*. Oxford, U.K.: Clarendon, 1994.

[8] J. F. Gieras and M. Wing, *Permanent Magnet Motor Technology—Design and Application*. New York: Marcel Dekker, 2002.

[9] B. Singh, B. N. Singh, A. Chandra, K. Al Haddad, A. Pandey, and D. P. Kothari, "A review of single-phase improved power quality ac–dc converters," *IEEE Trans. Ind. Electron.*, vol. 50, no. 5, pp. 962–981, Oct. 2003.

[10] N. Mohan, M. Undeland, and W. P. Robbins, *Power Electronics: Converters, Applications and Design*. Hoboken, NJ: Wiley, 1995.