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Design and Simulation of Closed Loop Controlled Buck Converter FEDPMBLDC Drive System

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Abstract – This work deals with the design and simulation of buck converter inverter fed PMBLDC drive system. Permanent Magnet Brushless DC Motor (PMBLDC) is one of the best electrical drives that has increasing popularity due to their high efficiency, reliability, good dynamic response and very low maintenance. This develops the interest of preparing an ideal PMBLDC motor and its associated Drive System in a simple and lucid manner. In this paper the drive system is proposed with a buck converter topology. Where it has the advantages of reduced switching losses, low inductor power loss, reduced ripple by using a LC-filter, which in turn makes the DC link voltage stable. The design and simulation of the PMBLDC motor is done using the software package 'matlab/simulink'. The operation principle of the buck converter fed drive system is analyzed and the simulation results are presented in this paper to verify the theoretical analysis.

Keywords : Buck Converter, PMBLDC Motor, Low Voltage Stress, Low Switching Loss, Matlab/Simulink.

I. Introduction

Permanent magnet brushless DC (BLDC) motor is increasingly used in automotive, industrial, and household products because of its high efficiency, high torque, ease of control, and lower maintenance [2], [7]. A BLDC motor is designed to utilize the trapezoidal back EMF with square wave currents to generate the constant torque. A conventional BLDC motor drive is generally implemented via a six-switch, three phase inverter [4] and three Hall-effect position sensors that provide six commutation points for each electrical cycle. Cost minimization is the key factor in an especially fractional horse-power BLDC motor drive for home applications. It is usually achieved by elimination of the drive components such as power switches and sensors. Therefore, effective algorithms should be designed for the desired performance and the relevant drive system which in turn controls the motor for all its defined applications with high efficiency, as well as good in maintaining the speed for variable torque. The mathematical modeling of DC to DC converter is given by Luo [1], [3].

II. PMBLDC Motor

The brushless DC motor is actually a permanent magnet AC motor whose torque-current characteristics mimic the DC motor. Instead of commutating the armature current using brushes, electronic commutation is used. Having the armature on the stator makes it easy to conduct heat away from the windings, and if desired, having cooling arrangement for the armature windings is much easier as compared to a DC motor. A BLDC is a modified PMSM with the modification being that the back-emfis trapezoidal instead of being sinusoidal as in the case of PMSM[5]. The position of the rotor can be sensed by the hall effect position sensors, namely Hall_A, Hall_B, and Hall_C, each having a lag of 120º with respect to the earlier one. Three Hall position sensors are used to determine the position of the rotor field.

Since the BLDC motor is easy to control, it is the motor of choice in many applications that require precise control of speed [6], [8]. The BLDC motor model can be described as the electromagnetic torque, where,

T_{em} is linearly proportional to the armature current i_a. i.e.,

$T_{em} = K_T i_a$, where K_T is the torque constant.

The back-emf in a BLDC motor is linearly proportional to the rotational speed of the shaft. The back-emf is proportional to the speed of the motor and its direction is given by Flemings right hand rule. Considering that in a magnetic field of intensity B, a conductor of length l on the edge of a rotor having radius r is rotating at an angular velocity of ω radians per second. Then the speed of the conductor is given by:

vel = ω x r.

The emf e generated in that conductor is given by:

$e = \omega rBl$.

Conventionally, the number of conductors in an electrical machine is given by Z, and if the number of conductors in series is $\frac{Z}{2}$, the series back-emf is given by e as

$$e = \omega_m rBl \frac{Z}{2}$$

In terms of the magnetic flux,

$$e = K_E \omega_m \quad (1)$$

where K_E is the back emf constant.

PMBLDC motors with new power converter topology are given by Krishnan and Shiyoung [4]. The four switch three phase brushless motor for low cost commercial applications is given

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by Lee [5]. The above literature does not deal with the analysis, design, modeling and simulation of the buck converter fed PMBLDC drive. This study proposes the buck converter for PMBLDC drive system. The elements of the buck converter are found using the following formulae:

$$L = \frac{vo(vi-vo)}{\Delta I.f.vi} \quad (2)$$

$$C = \frac{\Delta I}{8.f.\Delta v} \quad (3)$$

III. Simulation Results

Closed loop system is simulated using Matlab Simulink. The Simulink model of the closed loop controlled buck converter inverter fed PMBLDC drive is shown in Fig 3a. Here 48V DC is stepped down to 24V DC using a buck converter. The output of the buck converter is filtered using pi-filter. The output of the pi-filter is applied to the three phase inverter. The inverter produces three phase voltage required by the PMBLDC motor. The technical specifications of the drive systems are as follows

Input voltage : 48 V DC
Buck output voltage : 24 V DC
Pulse width to Buck MOSFET : 0.5 duty cycle (50%)
T_{off} : 50%
Pulse width (33%) to Inverter MOSFET: 120° mode of operation..

Parameters of BLDC Motor .
The inverter is a MOSFET bridge.
Stator resistance R_s : 2.8750 ohms
Stator Inductance L_s : 8.5e-3 Henrys
Flux induced by magnets : 0.175 Weber's
Back EMF Flat area : 120 degrees
Inertia : $0.8x10^{-3}$
Friction factor : $1x10^{-3}$
Pole pairs : 4
Stator windings are connected in star to an internal neutral point.

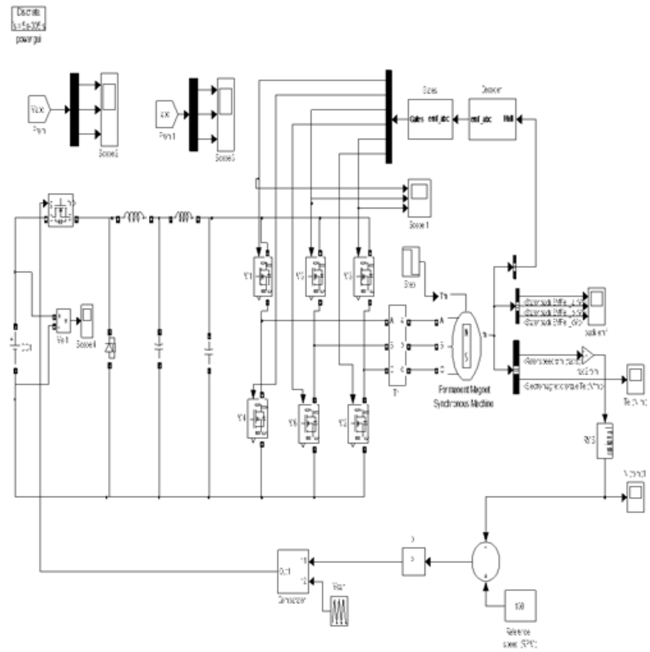
Fig 3a Simulink Diagram of Closed Loop System

The actual speed is measured and it is compared to the reference speed. The error is given to the PI Controller. The output of the PI controller is one of the inputs to the comparator. The other input is high frequency triangular wave. The output of the comparator controls the pulse width applied to the buck MOSFET. The pulses that are given to the MOSFETS 1, 3 and 5 are shown in Fig 3b.

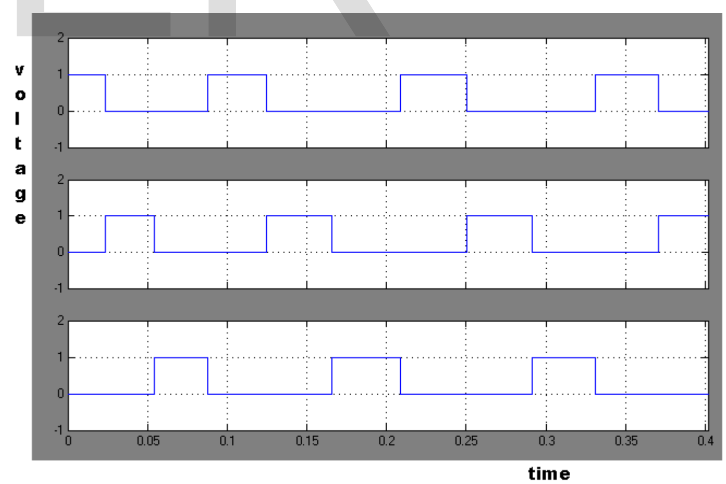

Fig 3b Triggering Pulses

D.C. input voltage is shown in Fig 3c and its value is 48 volts. Phase voltages of the three phase inverter are shown in Fig 3d. The voltages are displaced by 120°. Three phase currents drawn by the motor are shown in Fig 3e. The back emfs in the three phases are shown in Fig 3f. The response of the speed is shown in Fig 3g. The speed settles at 130 rpm, which is equal to the set value.

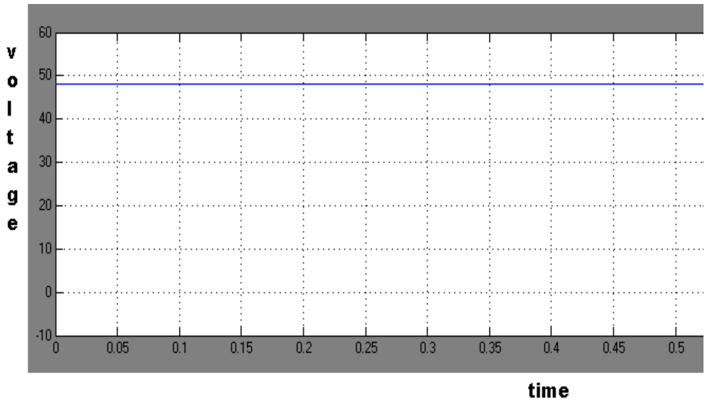

Fig 3c DC Input Voltage

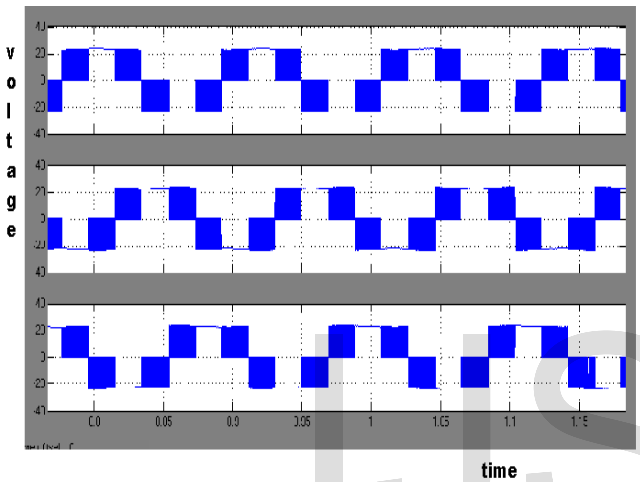

Fig 3d Phase voltages of Inverter

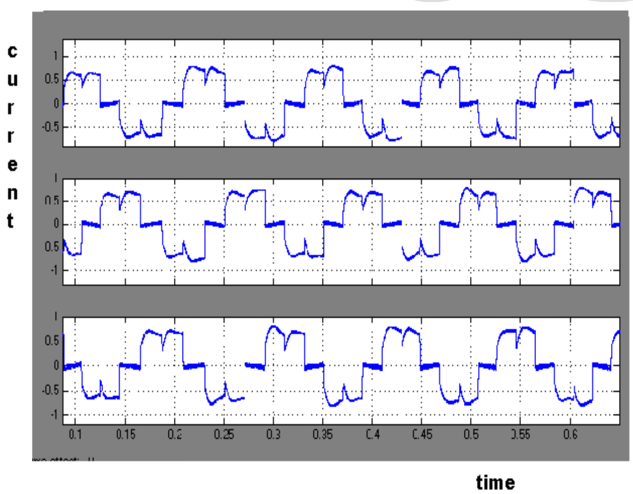

Fig 3e Output Currents of Inverter

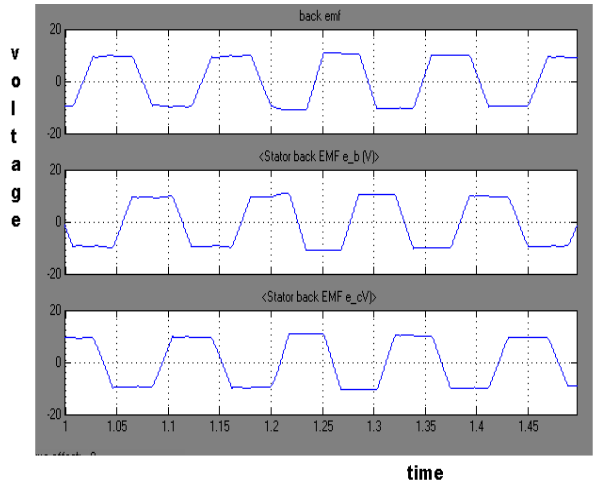

Fig 3f Back EMF Waveforms

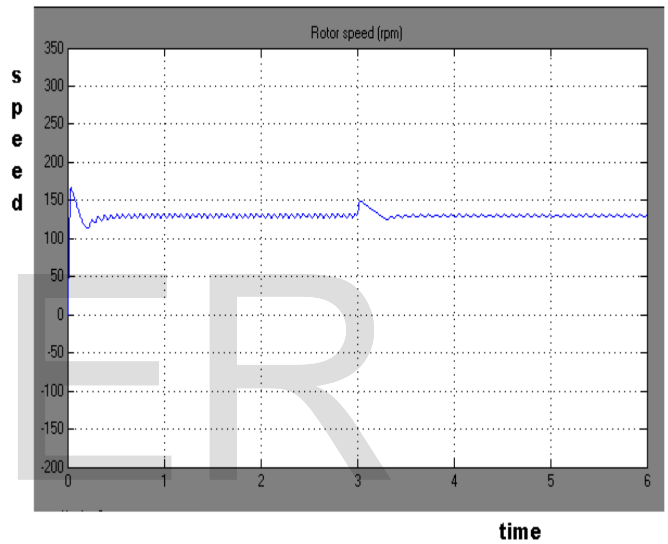

Fig 3g Rotor Speed in rpm

IV. Conclusion

Closed loop controlled PMBLDC drive system is modeled and simulated using MATLAB/SIMULINK and the above results were derived. Buck converter is designed to reduce the input voltage to the required value. LC-filter is proposed at the output of the buck converter to reduce the ripple content. This drive system has improved merits such as reduced number of switches and improved response. The scope of this paper is modeling and simulation of closed loop controlled PMBLDC drive system. Buck converter inverter fed PMBLDC motor system may be a viable alternative for low voltage rated PMBLDC motor drives. The hardware implementation is yet to be done.

References

[1] F.L.Luo, and H.Ye "Energy Factor and Mathematical modeling for power dc-dc converters", Proc Inst.Elect.Eng, Vol 152, No 2 pp. 191-198, Mar.2005.
[2] R.Krishnan, Electric Motor Drives, Modelling, Analysis and Control.Prentice hall of india Pvt Ltd, New Delhi, July – 2003.
[3] E.L.Muo, " Mathematical modelling for power dc-dc converters," IEEE Int. Conf. Powercon'04, Singapore, pp. 323-328, Nov 2004.

[4] Rahul Khopkar, S.M.Madani, Masoud Hajiaghajani, Hamid A.Toliyat "A Low Cost BLDC Motor Drive using Buck-Boost Converter for residential and commercial Applications" IEEE Int. Conf. on Electric Machines and Drives' IEMDC'03, Vol-2,pp-1251-1257, Jun2003.
[5] P C K Luk, C K Lee "Efficient modeling for a brushless DC motor Drive" IEEE Paper 1994.
[6] AtefSalehOthman and Al-Mashakbeh"Proportional Integral and Derivative Control of Brushless DC Motor",European Journal of Scientific Research,ISSN 1450-216X Vol.35No.2(2009),PP.198-203.
[7] R.Krishnan, Senior Member, IEEE and Shiyoung Lee "PM Brushless DC Motor Drive with a New Power-Converter Topology", IEEE Transactions on Industry applications, Vol.33.No.4,July/August 1997.
[8] Byoung-KukLee, Member; IEEE, Tae-Hyung Kim, Student Member; IEEE, and Mehrdad Ehsani, Fellow, IEEE, "On the Feasibility of Four-Switch Three Phase BLDC Motor Drives for Low Cost Commercial Applications : Topology and Control" IEEE Transactions on Power Electronics, Vol,18.No.1,January 2003.