Semiconductor Optoelectronics
ISSN: 1001-5868

BUCK-BOOST CONVERTER WITH ANN FOR BRUSHLESS DC MOTOR TORQUE RIPPLE REDUCTION

Shahuraj S. Sable[1], **Dr. Ashok kumar Jhala** [2]
Research Scholar[1], Associate Professor[2]
Electrical Dept., BHABHA University, BHOPAL, MP, India.
Shahurajs@gmail.com , akjhala.35@gmail.com

Abstract

In this study, a buck-boost converter that is utilized to reduce the commutation torque ripples in permanent magnet brushless DC motors that is coupled between the input DC source and three phase bridge inverter is described. By regulating the phase current that is not conducting commutation, which determines torque throughout the commutation period, torque ripple can be reduced. Moreover, compared to the typical conduction period, a higher DC link voltage is required at commutation time period. The Buck-boost converter operates in boost mode in commutation period for stepping up the DC voltage to the inverter. A simple mode switching circuit is employed to amend the output modes of the Buck-boost converter in normal and commutation time intervals. Simulation studies of this topology are carried out in MATLAB environment.

Key Words: Buck-boost, Converter, Commutation, Torque Ripple, BLDC drive & Pulse Width Modulation (PWM)

Introduction

In the sphere of science and technology, where weight and space are important considerations, brushless DCm Drive are becoming more common and have a wide range of uses. The appealing characteristics of BLDC machines include their straightforward construction, great dependability, broad speed range, accurate control, and high power density. For energy-saving purposes, they have recently become widely used in household appliances and industry [1] [2]. However, it has issues with commutation torque ripples that cause physical vibration and noise. Because of this, BLDCM isn't really performing well. [3] Gives a thorough investigation of commutation torque ripple. There, it is noted that torque ripples have a 50% or more output than typical torque. By keeping the non-commutating current each phase constant during the commutation period, it can be reduced to a minimum. To maintain stable non-commutating phase current during the commutation period, various PWM approaches are used [4] [5]. According to the speed ranges, two phase PWM systems are typically employed during the commutation stage. The recurring switching of the modulation schemes by speed oscillation, however, may decrease the system stability as the motor works nearer to the switching state of the low and high speed ranges. The modulator design [6], it shows PWM are modulated just for the non-commutating phase, is made simpler by the two-phase modulation technique for both the commutation as well as regular conduction stages. While machine runs at a fast speed, especially at the rated condition, PWM scheme is ineffective to minimize the ripple because of the limiting DC input signal of the inverter. Torque ripple reduced using PWM approach in the low speed range. To increase voltage of inverter during the commutation period, DC to DC converters [7] [9] are built into the inverter's front end. This method successfully reduces commutation ripple at faster ranges. The introduction of a Z-source network in [7] explains how to adjust the inverter fire through period to keep non-commutating current per phase consistent during the commutation period and so achieve the required DC voltage feed to the inverter. Yet, the DC input voltage of the inverter is greater than the Input power voltage both during commutation and usual conduction periods. The [Single Ended Primary Inductor] Converter [8] is used to power the BLDCM and obtain the necessary voltage for the commutation period in order to reduce ripples.

Buck-boost employed in this study to supply the voltage needed by the PMBLDCM throughout the commutation time interval. The inverter's PWM chopping is used to efficiently control the DC link voltage. The torque ripples in PMBLDCM can be successfully reduced by this configuration and control method, especially at greater speeds ranges. The strengths and weaknesses of the suggested approach in comparison to the conventional PI / ANN controllers are demonstrated using simulation data. Because of its great power density and simplicity of control, permanent magnet brushless Electric motors (PMBLDC) are used extensively in a variety of industrial settings. The most common method for controlling these motors is 3 phase power semiconductor bridge. Rotor position sensors are necessary for the inverter bridge's starting process as well as for delivering the correct commutation sequence to switch on the power devices.

The suggested neural network controller's performance is contrasted with that of the related fuzzy PI controller and traditional PI controller. The recommended speed regulation technique for brushless dc motors, which are thought to be a non- linear dynamic complex system, is demonstrated using simulation results to highlight its strengths and weaknesses. Software called MATLAB/Simulink was employed to simulate the suggested model.

Modeling of Drive

In terms of electrical constants, the stator windings of a motor can be described as,

$$\begin{bmatrix} v_{an} \\ v_{bn} \\ v_{cn} \end{bmatrix} = \begin{bmatrix} R_s & 0 & 0 \\ 0 & R_s & 0 \\ 0 & 0 & R_s \end{bmatrix} \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + p \begin{bmatrix} L_{aa} & L_{ab} & L_{ac} \\ L_{ba} & L_{bb} & L_{bc} \\ L_{ca} & L_{cb} & L_{cc} \end{bmatrix} . \begin{bmatrix} i_a \\ i_b \\ i_c \end{bmatrix} + \begin{bmatrix} e_a \\ e_b \\ e_c \end{bmatrix}$$

On the basis of Kirchoff's principles, the current for each phase in a balanced three-phase system,

$ia + ib + ic = 0$ & $ic = -(ia + ib)$

Assume that the inductances of on self & mutual are equivalent. Consequently, the inductance matrix utilised in the model can be expressed as The following modified equations are used to remove design problems from the modal by applying the voltage supplied for the current generations v_{ab} and v_{bc} by substituting the value of ic from above matrix solution .

$V_{ab} = r [i_a - i_b] + l [d [i_a- i_b] / dt] + e_a- e_b$ 1

$V_{bc} = r [i_a- 2i_b] + l [d [i_a- 2i_b] / dt] + e_b- e_c$ 2

The system has to know the position of the rotor, and the drive needs to know six discrete positions. For activating the three stator phases, this equates to every 60^0 electrical. It means that every 60^0 electrical pulses, one pulse is needed to either switch on or off one phase. The functions $f_a[\theta]$, $f_b[\theta]$, & $f_c[\theta]$of the trapezoidal-induced EMFs, which have the same pattern as with peak amplitude - or + 1 and are separated from one another by 120^0 .

In BLDC, instantaneous back emf is expressed as seen in the equation below.

$E_a= f_a [\theta] k_a * \omega$..3

$E_b= f_b [\theta] k_b * \omega$..4

$E_c= f_c [\theta] k_c * \omega$..5

The electric power P_e that creates the electric torque T_e is not entirely produced by the input voltages.

$T_e = [e_a i_a + e_b i_b + e_c i_c] / \omega$..6

Study of Commutation Torque Ripples in Pmbldcm

Terms $e_a * i_a$, $e_b * i_b$ and $e_c * i_c$ must be held constant at a specific speed in order to create an electromagnetic torque that is free of ripples. For this use, a rectangular form in phase current that is precisely in phase in the corresponding back EMF is preferred. Phase currents, however, have finite rise/fall duration and a trapezoidal pattern rather than the anticipated rectangular shape. The torque during commutation is directly impacted by the variations in phase slopes, both incoming and outgoing. Think about how current switches from one phase to another. Analytically, phase 'a' to phase 'b' current commutation is thoroughly addressed here.

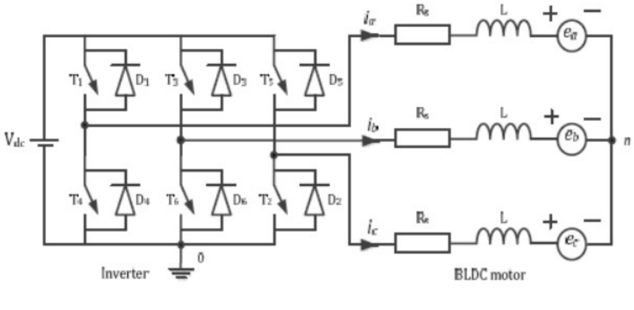


Figure 1.convertor with motor unit

Before Commutation T_1 and T_2 are conducting. From above diagram drive system and the current path T_1 to first branch to third branch to T_2 and finally negative terminal of the source under this condition Assume that back EMFs in the three phases are equal and $i_a = -i_c = I$ and $i_b = 0$ so the under this situation

$$Vdc = Rs\, ia + L * \left(\frac{dia}{dt}\right) + E + V\mathrm{no} \quad \text{And} \quad 0 = Rs\ \ i\,c + L * \left(\frac{dic}{dt}\right) - E + Vno$$

And following expression of torque (Te) $= \frac{2*E*ia}{\omega m} = -\frac{2*\mathrm{E}*\mathrm{ic}}{\omega m}$

Now after commutation T_3 and T_2 are conducting. From above diagram drive system and the current path T_3 to second branch to third branch to T_2 and finally negative terminal of the source under this condition

In this situation $i_b = -i_c = I$ and $i_a = 0$ so the under this situation

$$Vdc = Rs\, ib + L * \left(\frac{dib}{dt}\right) + E + V\mathrm{no} \quad \text{And} \quad 0 = Rs\ \ i\,c + L * \left(\frac{dic}{dt}\right) - E + Vno$$

And following expression of torque (Te) $= \frac{2*E*ib}{\omega m} = -\frac{2*\mathrm{E}*\mathrm{ic}}{\omega m}$

During Commutation time D4 begins conducting when T1 is turned OFF as a result of the winding's inductance. T3 begins to conduct, and T2 keeps conducting as previously. From above diagram drive system and the current path T3 to second branch to third branch to T2 and finally negative terminal of the source and through the diode D4 (connected across T4) and first branch also having current and complete path through third branch under this condition

$$0 = Rs\, ia + L * \left(\frac{dia}{dt}\right) + E + V\mathrm{no} \quad ,$$

$$Vdc = Rs\, ib + L * \left(\frac{dib}{dt}\right) + E + V\mathrm{no} \quad \text{and} \quad 0 = Rs\ \ i\,c + L * \left(\frac{dic}{dt}\right) - E + Vno$$

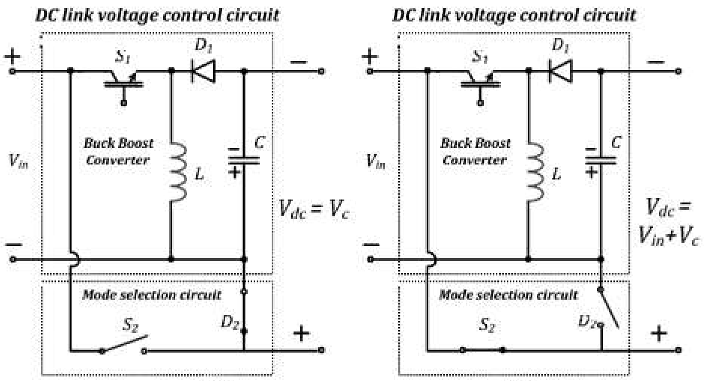
And following expression of torque (Te) $= \frac{2*E*(ia+ib)}{\omega m} = -\frac{2*\mathrm{E}*\mathrm{ic}}{\omega m}$

The research shows that the torque remains a function of just one current both before and after commutation. However, it depends on two currents (the outgoing as well as incoming phase currents) during the commutation time. This indicates that it depends on the non-commutating phase supply current. The dc link supply, back EMF, and speed of the machine all affect how quickly the current changes.

Methodology

Buck Boost topology

A mode control circuit and a Buck-boost converter make up the setup. A larger DC voltage is needed during the commutation period compared to the regular conduction time. To regulate the DC link voltage, a Buck-boost converter is installed between the DC source and the inverter [10]. To increase the input of the inverter, the mode switching circuit efficiently manages the converter's working strategy during the commutation interval. The exploded view of closed-loop regulation with this topology is shown in Fig. depicts the mode switching circuit in action as it modifies the converter's working modes.



(a) (b)

Figure 2.buck boost switching

Three hall detector signals and two currents are needed for commutation detection. The current switches from one phase to another at every growing edge of the hall signal, and the beginning and end of the commutation are determined by that. The non-commutating current has not changed during the aforementioned time.

Duty Ratio during Commutation Period is, at the boost action of the converter, which is provided by, increases the DC link's voltage for the duration of the commute $V\ dc\ (commu.) = V_{dc} + 2 * E + 2 * I_n\ \ R_S$

The voltage of the DC link is greater than what is needed. The voltage at the connection point of the BLDCM is changed to the necessary level by employing inverter switching. The commutational duty ratio,

$$D_{\text{commu.}} = 0.5 + (4\ E + 3 * I_n * R_s / (2 * V_{dc\ (commu.)})$$

ANN Topology for drive

The controller in the AN Network control unit model is shown as a nonlinear map between inputs and outputs. The structure of the map (in the shape of network) can be used as trained to perform any type of control method, depending on a particular plant. [11]With the controller adopting the structure of an intelligent multi-layer network & the adaptable values being defined as the adjustable weights, neuro controller provides a special type of adaptive control. The principal benefits are:

- It is feasible to use any type of nonlinear mapping in a parallel system.
- Training is adaptable to any desired setting because it can be done under different working situations.

Neural nets are computer programmes that take their design cues from the biological networks of neurons seen in animal brains [12] [13].

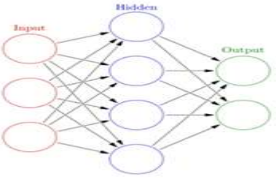


Figure 2. ANN Topology for drive

Simulation

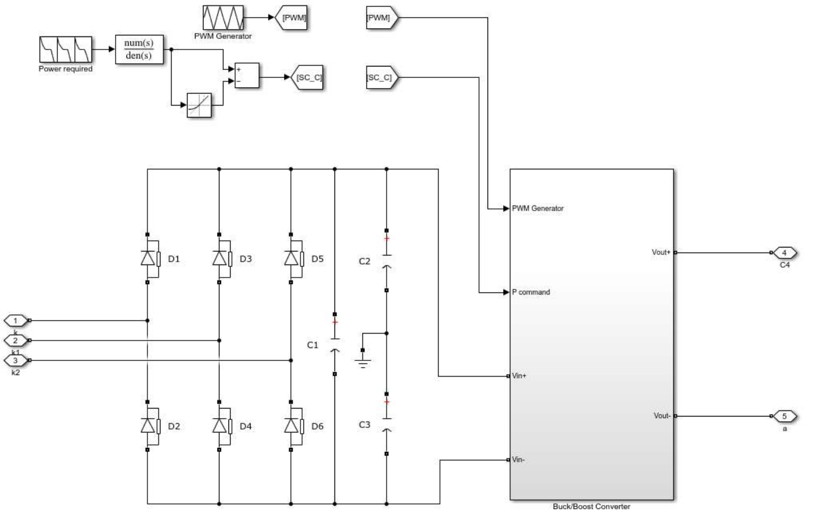


Figure 3. Motor with Buck bust circuit

In order to reduce torque ripple during commutation, outcomes from Buck boost control mechanism are shown in Fig. Ratio of torque ripple the torque ripple is significantly reduced BY Buck boost design with control approach, according to the results. Figure 5 depict the drive's dynamic behavior using a Buck-boost with ANN.

Result

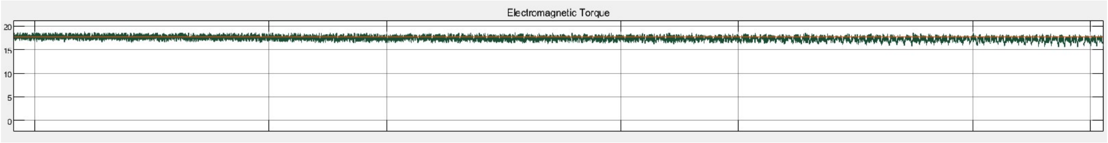


Figure 4. Toque output without Methodology

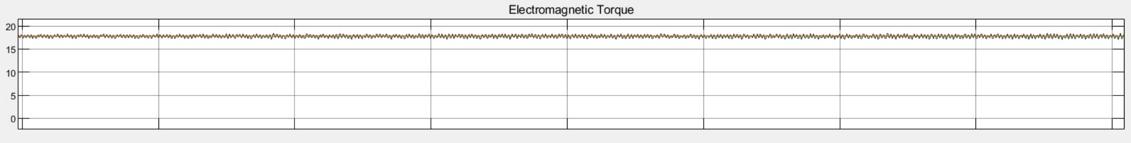


Figure 5. Toque output with Methodology

Conclusion

In this article, control strategies for BLDC motor torque ripple reduction are presented. The pulse torque excursions that deviate from ideal conditions result in the non-ideal current waveforms, which can be attributed to the converter circuit supply or the motor's design.

Reference

[1] K. Byung-taek, " Minimization of torque ripple in a BLDC motor using an improved DC link voltage control method,& quot; in Telecommunications Energy Conference, 2009. INTELEC 2009. 31st International, 2009, 1-5.

[2] B. Dunxin, " A PWM control algorithm for eliminating torque ripple caused by

stator magnetic field jump of brushless DC motors", in Intelligent Control and Automation,2008. WCICA 2008. The 7th World Congress on, 2008, 6547-6549.

[3] Z. Zhong-chao, " A novel PWM scheme to eliminate the diode freewheeling in the inactive phase in BLDC motor", Frontiers of Electrical and Electronic Engineering in China, vol. 1, 194-198, 2006.

[4] K.Naga Sujatha, K.Vaisakh; Torque Ripple Reduction in BLDC Motor Using Neural Network Controller., International Journal & Magazine Of Engineering, Technology, Management And Research Registrar of Newspapers of India(RNI) Regd No: APENG/2011/47294, December 12, 2011

[5] B. Chen, & quot; Influences of PWM mode on the current generated by BEMF of switch-off phase in control system of BLDC motor", in Electrical Machines and Systems, ICEMS 2001. Proceedings of the Fifth International Conference on, 2001, 579-582 vol.1.

[6] Hao Xiong, Huaishu Li, "Commutation torque ripple reduction in BLDC motor using PWM_ON_PWM mode," in Electrical Machines and Systems, 2009. ICEMS 2009. International Conference on, 2009, 1- 6.

[7] J. Shi and T. C. Li, “New method to eliminate commutation torque ripple of brushless DC motor with minimum commutation time,” IEEE Trans.Ind. Electron. vol. 60, no. 6, pp. 2139–2146, Jun. 2013.

[8] Y. K. Lin and Y.S. Lai, “Pulse width modulation technique for BLDCM drives to reduce commutation torque ripple without calculation of commutation time,” IEEE Trans. Ind. Appl., vol. 47, no. 4, pp. 1786–
1793,Jul/Aug. 2011.

[9] D. K. Kim, B. I. Kwon and K. W. Lee, “Commutation torque ripple reduction in a position sensorless brushless DC motor drive,” IEEE Trans.Power Electron., vol. 21, no. 6, pp. 1762–1768, Nov. 2006.

[10] T.N.Shi, Y.T. Guo, P. Song, and C.L.Xia, ‘‘A new approach of minimizing commutation torque ripple for brushless DC motor based on DC-DC converter,’’ IEEE Trans. Ind. Electron., vol. 57, no. 10, pp. 3483--
3490, Oct. 2010.

[11] V. Pushparajesh, M. Balamurugan, and N. Ramaiah, “Artificial neural network based direct torque control of four phase switched reluctance motor,” SSRN Electronic Journal, 2019.

[12] A. Kailash, Everything You need to Know about Neural Networks, Mate Labs, 2017, https://hackernoon.com/everything-you-need-to-know-about-neural-networks-8988c3ee4491.

[13] D. Lu and N. C. Kar, “Neural network based torque control of switched reluctance motor for hybrid electric vehicle propulsion at low speeds,” in Proceedings of the 2009 IEEE International Conference on Electro/Information Technology, Windsor, Canada, 2009.