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Sensorless Speed Control of PMBLDC Motor

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ABSTRACT: This paper deals with the speed control of permanent magnet brushless dc motor (PMBLDCM) without sensor. A three-phase voltage-source inverter is used as an electronic commutator to operate the PMBLDCM. In this paper the motor's back emf is measured and it is given as commutation signal for the voltage source inverter. The proposed permanent magnet brushless dc motor (PMBLDCM) drive is designed and modelled, and its performance is evaluated in Matlab– Simulink environment. Simulated results are presented to demonstrate an improved range of speed.

KEYWORDS: Permanent-Magnet Brushless Dc Motor(PMBLDCM), sensorless control, back emf,VSI.

I. INTRODUCTION

The use of a permanent magnet (PM) brushless dc motor (PMBLDCM) in low-power appliances is increasing because of its features of high efficiency, wide speed range, and low maintenance. It is a rugged three-phase synchronous motor due to the use of PMs on the rotor. The commutation in a PMBLDCM is accomplished by solid state switches of a three-phase voltage-source inverter (VSI). This system exerts constant torque (i.e., rated torque) on the PMBLDCM while operated in speed control mode. The system with PMBLDCM has low running cost, long life, and reduced mechanical and electrical stresses compared to a single-phase induction motor operating in “on/off” mode. A PMBLDCM has the developed torque proportional to its phase current and its back electromotive force (EMF), which is proportional to the speed[1]-[4].

In order to obtain an accurate and ripple-free instantaneous torque of the BLDC motor, the rotor position information for stator current commutation must be known. The BLDC motor's electronic commutator sequentially energizes the stator coils generating a rotating electric field that ‘drags’ the rotor around with it. Efficient operation is achieved by ensuring that the coils are energized at precisely the right time. This can be done by using hall sensors mounted on the rotor[5]-[6]. Sensors work well, but add cost, increase complexity (due the additional wiring), and reduce reliability (due in part to the sensor connectors that are prone to contamination from dirt and humidity). However, the hall sensor will lose its sensing capability at the temperature above 120 °C, therefore hall sensors are not feasible in high temperature environment. For reasons of reliability, it is desirable to run the motor without position sensors – i.e., sensorless operation.

Therefore many sensorless drive solutions have been proposed to eliminate the costly and fragile position sensors for the BLDC motor. In [7]-[8] sensing three phase current waveforms for obtaining exact rotor position signals have been presented as sensorless technology. In addition, the rotor position of the BLDC motor can be identified and driven by utilizing inductance variance technique[9]-[10]. This is done by monitoring the current responses to the inductance variation on the rotor position. But they result in complex control algorithm and an increase of the system cost due to an additional current sensor.

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More over apart from speed control the torque ripple is responsible for speed oscillations. The torque pulsations in PMBLDC motors are generally resulted from the deviation from ideal conditions. It can be either related to the design factors of the motor or to the power inverter current excitation resulting in non-ideal current waveforms [11]. Consequently, the undesired torque pulsation in PMBLDC motor drives may lead to speed oscillations, resonances in mechanical portions of the drive causing acoustic noise and visible vibration patterns in high precision machines [12]. Therefore, the torque ripple minimization or elimination is a considerable issue in BLDC motor drives.

Therefore this paper presents a sensorless control scheme based on the detection of back emf and various analysis for torque ripple reduction. A combination of all three zero crossing points for the coils is used to determine the coil energizing sequence. The torque pulsations could be typically reduced by two techniques, first is by the improved motor designs and the other is by improved control schemes. And also it is able to improve both the performance and reliability of the sensorless BLDC motor drive system. For the proposed control scheme the fuzzy logic controller is used which provides robust control.

II. PROPOSED SPEED CONTROL SCHEME OF PMBLDC MOTOR

Fig.1 shows the equivalent circuit of VSI – fed PMBLDCM. A three phase full bridge circuit is to perform the electronic commutation. Commutation is the act of changing motor phase currents at appropriate times to produce rotational torque.

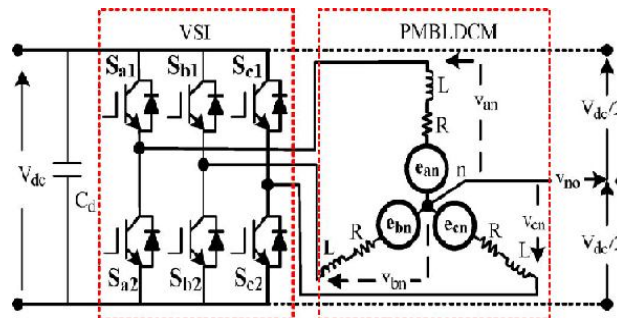


Fig. 1 Equivalent circuit of a VSI –fed PMBLDCM

The rotational speed of a BLDC motor is directly proportional to the applied voltage. Therefore to vary the rotational speed, the switches in excited pair must be pulse width modulated to produce a variable average dc voltage. The back emf signals generated in the windings are 120° out of phase to each other, but they are asynchronous with hall sensor signals.

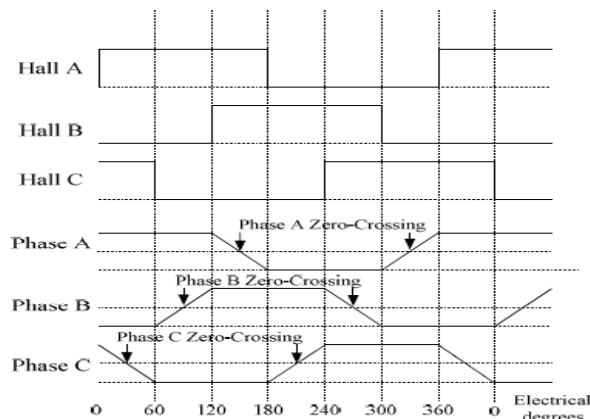


Fig. 2 Waveform of Hall sensors versus Back-EMF voltages

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Fig.2 shows the comparison of hall signals with the back emf. The back emf in three coils varies in trapezoidal form. A combination of all three zero crossing points for the coils is used to determine the coil energizing sequence. Note that there is a phase difference between an individual Hall sensor changing output in a conventional BLDC motor, and the back EMF zero crossing point for an individual coil in a sensorless unit of 30 degrees. Consequently, in a sensorless motor control circuit, after the zero crossing point is detected, a 30-degree phase lag is built into the firmware before the next action in the energizing sequence is activated.

The speed control scheme uses a fuzzy controller approach. Fuzzy logic is a form of many valued logic; it deals with reasoning that is approximate rather than fixed and exact. In contrast with traditional logic theory, where binary sets have two-valued logic true or false, fuzzy logic variables may have a truth value that ranges in degree between 0 and 1.

III. START-UP TECHNIQUE

When the motor is at standstill or very low speed, the back EMF is too small to estimate a precise rotor position. Therefore, a specific start-up process in sensorless drive systems is needed.

A. Alignment of Rotor Position

In the BLDC motor, only two phases of the three-phase stator windings are excited at any time by utilizing alternative six excited voltage vectors $V_1 - V_6$, which are sketched in Fig. 3(b).

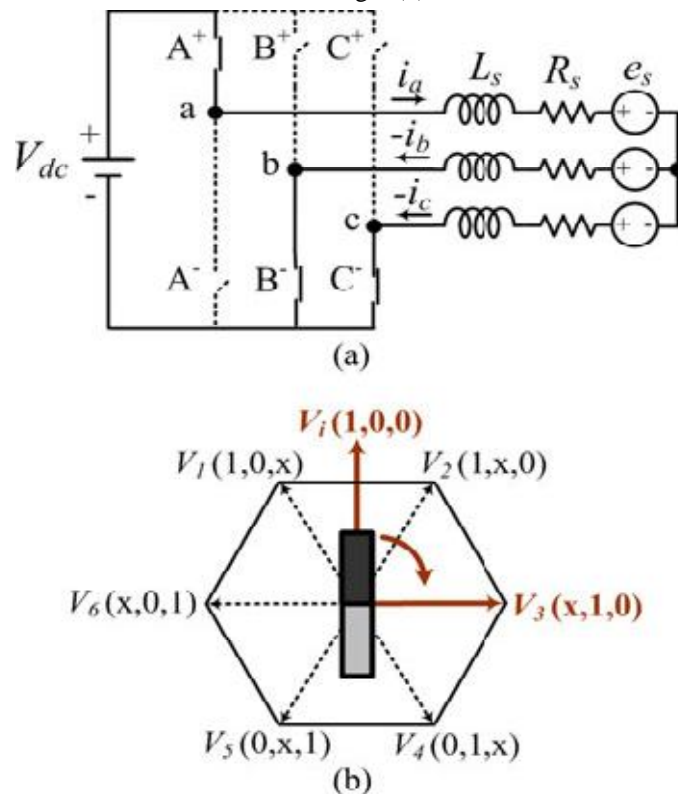


Fig. 3 Alignment of rotor position. (a) Switching states of the inverter. (b) Initial rotor position.

That is why the current can flow into only two of the three windings and commutated every 60° of electrical angle. At standstill, the initial rotor position is aligned into one of these six positions that are determined by the six excited voltage vectors to energize two phases of the BLDC motor. As it is well known, the deviation of these voltage vectors is every 60° of electrical angle. The stator flux is not orthogonal to the rotor flux generated by the permanent-magnet at the beginning of the start-up point if the conventional alignment method is used. Thus, the initial motor torque cannot

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obtain the maximum value at this time. Also, the stator winding incurs a high uncontrollable current by means of the fixed dc power supply and motor parameters. This might damage the stator winding of the motor if the active time for aligning a rotor position is too long [11-14].

The conventional start-up method reveals some unexpected drawbacks that might degrade the performance of the BLDC motor. To overcome these restrictions, a simple start-up method not only to achieve the maximum starting motor torque but also to control the stator current is proposed. The principle of this technique can be remarkable as explained in Fig. 3. The current path and position of the initial voltage vector V_i are shown in Fig. 3(a) and (b), respectively. Unlike the case in the conventional method where only two stator windings are excited, all three stator windings are energized in the case of the proposed start-up scheme by using a specific initial voltage vector $V_i(1,0,0)$. As the rotor is located between voltage vector V_1 and V_2 , the voltage vector V_3 is orthogonal to V_i . It is chosen as the next applied voltage vector in order to achieve maximum starting motor torque at startup. It should be noted that the amplitude of the stator current for alignment of the rotor position can be easily adjusted by modulating the pulse width of the switching devices. Fig. 4 depicts the three-phase current responses of the BLDC motor, when turning on switch A^+ and modulating the pulse-width of the two switches B^- and C^- at the same time.

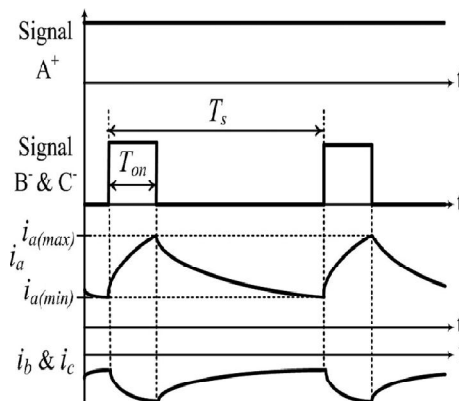


Fig. 4 Stator currents responses under alignment of rotor position.

B. Start-Up Procedure

After aligning the rotor position, the start-up procedure is considered for accelerating the BLDC motor from standstill up to a specific speed, 3000 rpm which is a minimum speed at the automotive fuel pump application. As the sensorless scheme is not self-starting, the motor should be started and can be brought to a certain speed at which the zero-crossing point of the back EMF can be detected. The $I-f$ starting method, where the current is specified and maintained constant during accelerating the motor, is proposed at the back EMF-based sensorless control of a permanent-magnet synchronous motor. The v/f starting method is used at this paper, which is suitable for the BLDC motor drive.

The open loop starting based on v/f control is accomplished by producing the rotating electric field with a specific relationship to the reference voltage in terms of a rotor speed. As the frequency is gradually increased, the rotor speed also increases. The magnitude of a reference voltage is adjusted as proportional to the rotor speed. A phase angle can be obtained from integrating the rotor speed and the pulse width of the gating signals is modulated with the reference voltage magnitude. The six PWM signals with 60° phase displacement are generated corresponding to the phase angle without any rotor position information. When the rotor speed reaches at 3000 rpm, the back EMF can be sensed to provide the rotor position information and the system is switched to the sensorless control.

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IV .SIMULATION RESULTS

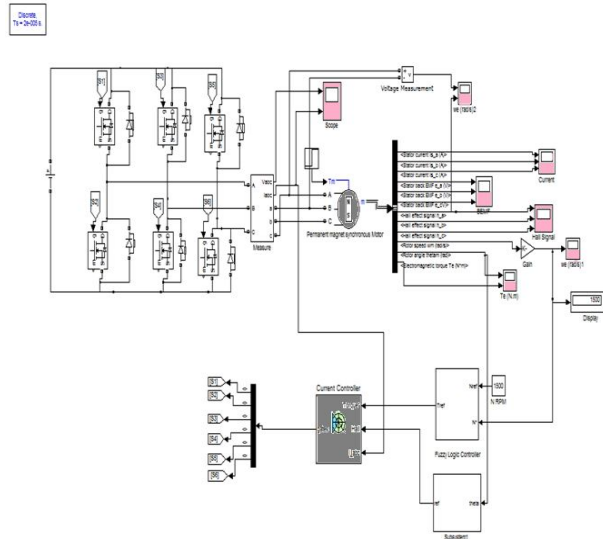


Fig. 5 Simulation Diagram

A prototype of BLDC motor has been built to validate the theoretical results as well as the simulation by using FUZZY Controller. Fig 5 shows simulation diagram of BLDC motor with FUZZY controller. Fig 6 shows the rotor angle and EMT and Fig 8 shows the BackEMF waveform for BLDC drive.

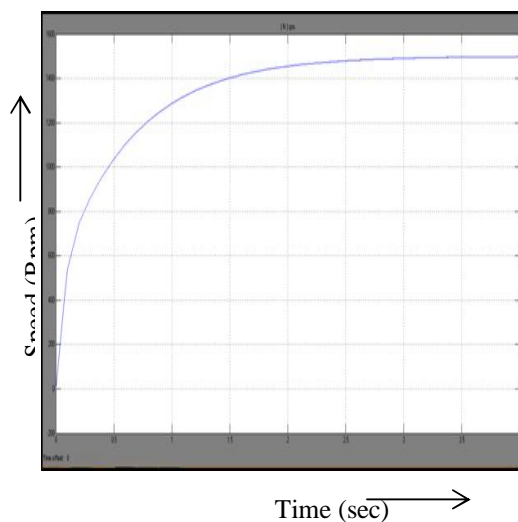


Fig .6 Rotor speed

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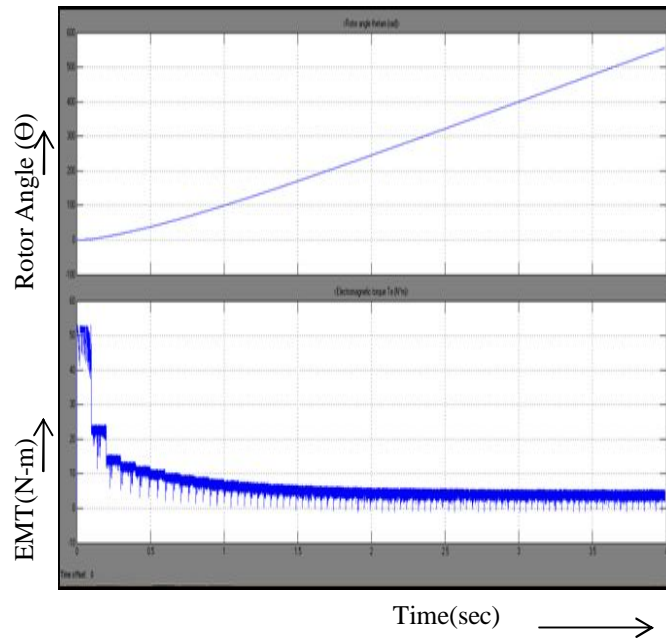


Fig.7 Rotor angle and EMT

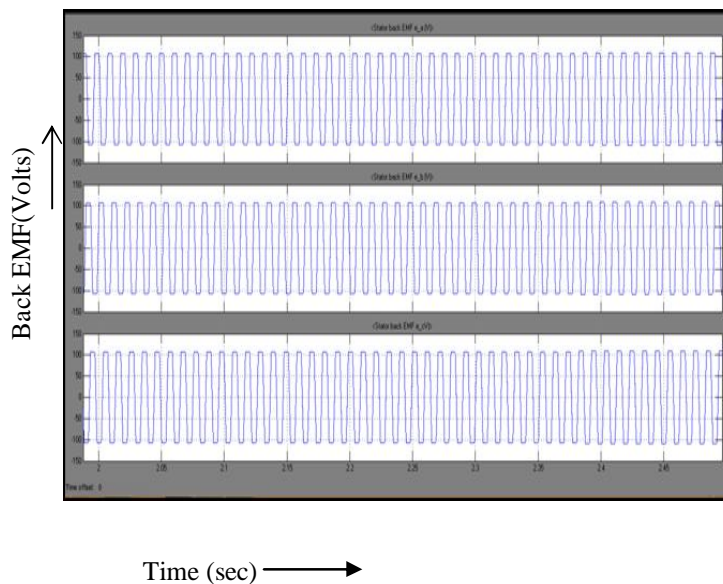


Fig .8 Back EMF waveform for BLDC drive

V. CONCLUSION

A new speed control strategy for a PMBLDC using the back emf as a commutation signal has been simulated. The PMBLDC drives are majorly used in air-conditioners, fuel pumps, printers, electric vehicles and further. These applications attain noise, vibration and efficiency problems as they use simple controllers. By implementing the

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proposed control strategy the speed oscillation and torque ripple can be recovered and can make motor run more efficient for long duration of life time.

REFERENCES

- [1] T. Kenjo and S. Nagamori, *Permanent Magnet Brushless DC Motor* Oxford, U.K.: Clarendon, 2005.
- [2] T. J. Sokira and W. Jaffe, *Brushless DC Motors: Electronic Commutation and Control*. New York: Tab, 2009.
- [3] J. R. Hendershort and T. J. E. Miller, *Design of Brushless Permanent- Magnet Motors*. Oxford, U.K.: Clarendon, 2004.
- [4] J. F. Gieras and M. Wing, *Permanent Magnet Motor Technology— Design and Application*. New York: Marcel Dekker, 2002.
- [5] J. Fang, X. Zhou, and G. Liu, "Instantaneous torque control of small inductance brushless DC motor," *IEEE Trans. Power Electron.*, vol. 27, no. 12, pp. 4952–4964, Dec. 2012.
- [6] J. Fang, X. Zhou, and G. Liu, "Precise accelerated torque control for small inductance brushless DC motor," *IEEE Trans. Power Electron.*, vol. 28, no. 3, pp. 1400–1412, Mar. 2013.
- [7] R.-L. Lin, M.-T. Hu, S.-C. Chen, and C.-Y. Lee, "Using phase-current sensing circuit as the position sensor for brushless DC motors without shaft position sensor," *IEEE Conf. Digital Object Identifier*, Vol. 1, pp. 215-218, Nov. 1989.
- [8] C. G. Chen, T. H. Liu, M. T. Lin, and C. A. Tai, "Position control of a sensorless synchronous reluctance motor," *IEEE Trans. Digital Object Identifier*, Vol. 51, Issue 1, pp. 15-25, Feb. 2004.
- [9] G. H. Jang, J. H. Park, and J. H. Chang, "Position detection and start-up algorithm of a rotor in a sensorless BLDC motor utilizing inductance variation," *IEE Proc., Electr. Power Appl.*, vol. 149, no. 2, pp. 137–142, 2002.
- [10] P. Champa, P. Somrasi, P. Wipasuramont, and P. Nakmahachalasint, "Initial rotor position estimation for sensorless brushless DC drives," *IEEE Trans. Ind. Appl.*, vol. 45, no. 4, pp. 1318–1324, Jul./Aug. 2009.
- [11] S. Saranraj, A. Sasipriya and M. Muruganandam, "A voltage controlled PFC SEPIC converter based PMBLDC motor drive for Air-conditioners using Fuzzy controller", *IJAIR*, Vol.3, Issue.9, 2014.
- [12] SINGH, B. : Recent Advances in Permanent Magnet Brushless DC Motors, *Sadhana – Academy Proceedings in Engineering Sciences* 22 (1997), 837–853.
- [13] S. Ramkumar and M. Muruganandam, S. Saranraj, A. Sasipriya, "A Voltage Controlled PFC SEPIC Converter Based PMBLDC Drive for Air - Conditioners Using Fuzzy Controller", *International Journal of Advanced and Innovative Research*, vol. 3, issue. 11, pp. no. 358-362, Dec. 2012.
- [14] M. Muruganandam, H. Naveena, C. S. Dhanapriya, "Evaluation of Diabetic Macular Edema From Color Retinal Images", *International Journal of Advanced and Innovative Research*, vol. 3, issue. 12, pp. no. 284-287, Dec. 2014.
- [15] J. Vinoth, T. Muthukumar, M. Muruganandam, "Implementation of Distributed Maximum Power Point Tracking for Partially Shaded PV Systems", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 4, issue. 2, pp. 702-709, Feb. 2015.
- [16] P. Ranjitha, V. Dhinesh, M. Muruganandam, "Soft Switching with Cascaded Transformers to Drive the PMDC Motor", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 4, issue. 2, pp. 787-794, Feb. 2015.
- [17] M. Saravanakumar, C. Harris Naveena, M. Muruganandam, "Bidirectional Modular Multilevel DC/DC Converter with Wide Range of Control", *International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering*, vol. 4, issue. 2, pp. 984-989, Feb. 2015.