Study and Simulation of Fuzzy Logic Based Speed Control of Multi Level Inverter Fed PMBLDC Drives

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Abstract—This paper presents an analysis by which the dynamic performances of a permanent magnet brushless dc (PMBLDC) motor drive with different speed controllers can be successfully predicted. The control structure of the proposed drive system is described. The dynamics of the drive system with a classical proportional-integral (PI) and a Fuzzy-Logic (FL) speed controllers are presented. The simulation results for different parameters and operation modes of the drive system are control signals investigated and compared. The results with FL speed controller show improvement in transient response of the PMBLDC drive over conventional PI controller.

Keywords—PMBLDC motor drive, multi level inverter, PI controller, Fuzzy Controller.

I. Introduction

With the rapid development of microelectronics and power switches, most adjustable-speed drives are now realized with ac machines. Permanent Magnet Synchronous Motor (PMSM) with sinusoidal shape back-EMF and brushless DC (BLDC) motor with trapezoidal shape back-EMF drives have been extensively used in many applications, ranging from servo to traction drives due to several distinct advantages such as high power density, high efficiency, large torque to inertia ratio, and better controllability. Brushless DC motor (BLDC) fed by two-phase conduction scheme has higher power/weight, torque/current ratios and it is less expensive due to the concentrated windings which shorten the end windings compared to three-phase permanent magnet synchronous motor (PMSM) [1]- [2]. There are two methods of controlling PMBLDC motor namely sensor control and sensor less control. The latter has advantages like cost reduction, reliability, elimination of difficulty in maintaining the sensor etc. Sensor less control is highly advantageous when the motor is operated in dusty or oily environment, where cleaning and maintaining of Hall Sensors is required for proper sensing of rotor position. Sensor less method is preferred when the motor is in less accessible location. Accommodation of position sensor in motor used in compact unit such as computer hard disk may not be possible. Novel direct back emf detection for sensor less BLDC motor is given in [3]. This paper demonstrates a sensor less technique to drive a three phase brushless DC motor with a multi level voltage Inverter system using voltage control method with Hybrid Fuzzy logic control. PMBLDC motors drives are used in a wide range of commercial and residential applications such as domestic.

Many machine design and control schemes have been developed to improve the performance of BLDC motor drives. The model of motor drives has to be known in order to implement an effective control in simulation. Some simulation models based on state-space equations, Fourier series, d-q axis model, and variable sampling have been proposed for the analysis of BLDC motor drives [11-14]. Furthermore, fuzzy logic controllers (FLCs) are used to analyze BLDC motor drives in literature [15-21].

II. Fuzzy Logic Controlled BLDC Motor Drive System

The proposed control system, which contains two loops, is shown in Figure 1. The first loop is the current control loop that accomplishes torque control of BLDC motor and the second loop is the speed control loop that adjusts the speed of BLDC motor.

A. *PMBLDC Motor:-*

The three phases PMBLDC motor is operated in two-phases on fashion i.e. the two phases that produces

highest torque are energized while third phase is off. Which two phases are energized depends on the rotor position. The signals from the position sensors produce a three digit number that changes every 60°.
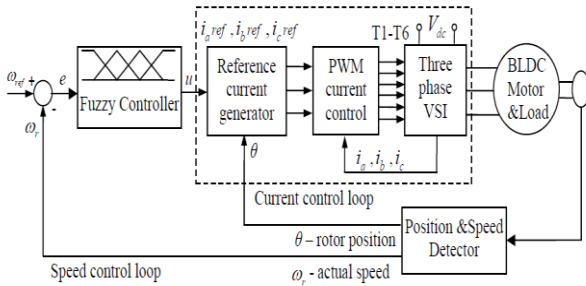

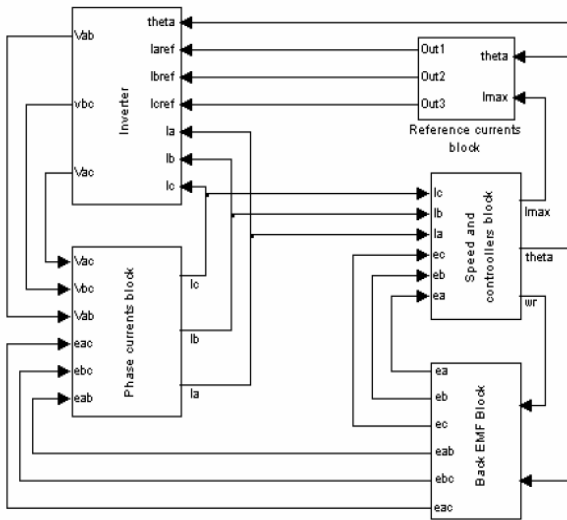Fig 1. Fuzzy Logic Based Speed Control of Multi Level Inverter Fed PMBLDC Drive

Fig 2. Simulink model of BLDC motor

The trapezoidal back-EMF wave forms are modeled as a function of rotor position so that rotor position can be actively calculated according to the operation speed.
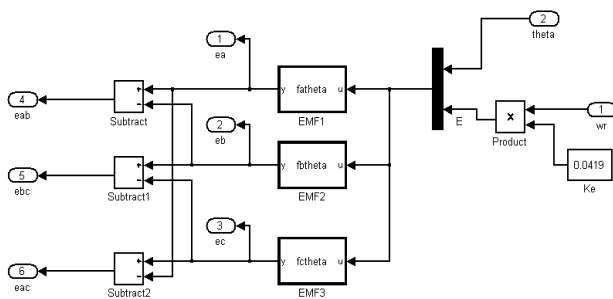

Fig 3. Simulink diagram for generating back EMF from rotor positions

Based on the rotor position, the numerical expression of the back EMF can be obtained as Equation (1), and this is implemented as shown in Figure 3. Neglecting the damping factor, the speed and torque characteristics of BLDC motor can be stated as follows:

$$\omega_m = \frac{P}{2J}\int (T_e - T_L)dt = \frac{P}{2J}\int[(T_a + T_b + T_c) - T_L]dt \quad (1)$$

B. Multi Level inverter

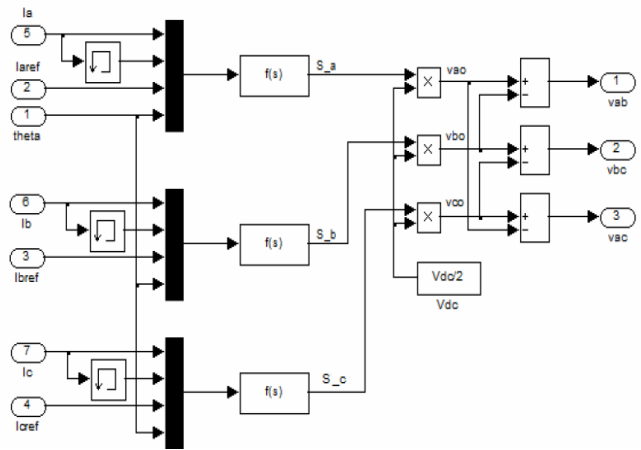In three level inverter modeling, 120 degree conduction mode is employed.

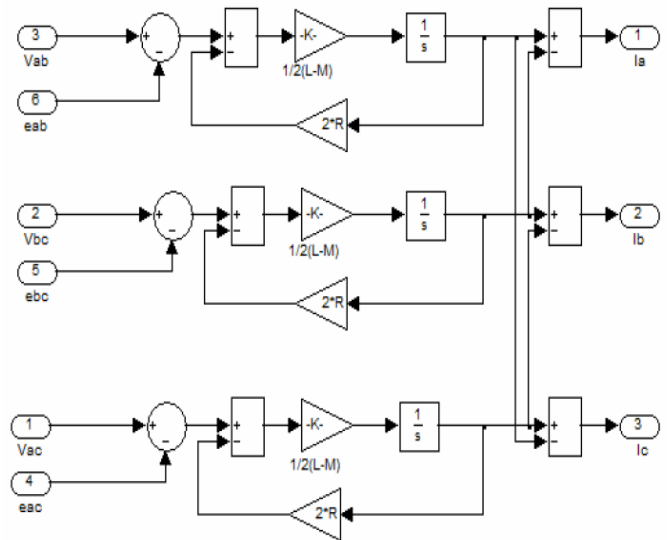Fig 4. The generation of inverter line-to-line voltages.

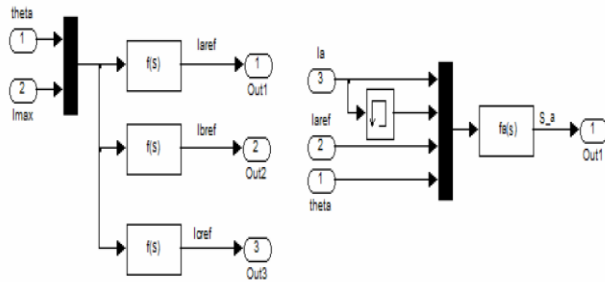Fig5. Simulink diagram for three-phase currents.

Fig 6. a) Simulink diagram for reference currents (b) Implementation of hysteresis current control for phase A

C. *Fuzzy logic*

The block diagram showing the implementation of the Fuzzy speed controller is illustrated in Figure 7. It includes four major blocks: knowledge base, fuzzification, inference mechanism, and defuzzification. The knowledge base is composed of a data and a rule base. The data base, consisting of input and output membership functions. The rule base is made of a set of linguistic rules relating the fuzzy input variables into the desired fuzzy control actions.

A sliding mode rule base used in FLC. The fuzzy inference operation is implemented by using the 49 rules. The min-max compositional rule of inference and the center-of-gravity method have been used in defuzzifier process.

If $e1$ is NB and $e2$ is NB Then u is PB,
If $e1$ is NB and $e2$ is NM Then u is PB,
If $e1$ is NB and $e2$ is NS Then u is PM,
If $e1$ is NB and $e2$ is Z Then u is PM,
…………………………………………
and go on for all inputs.
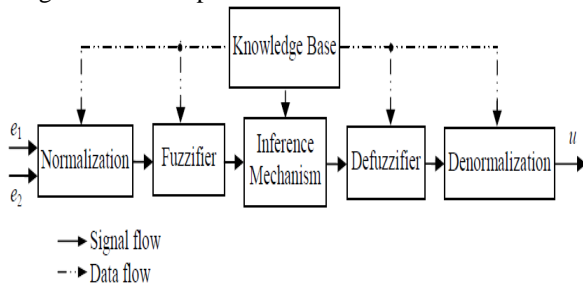
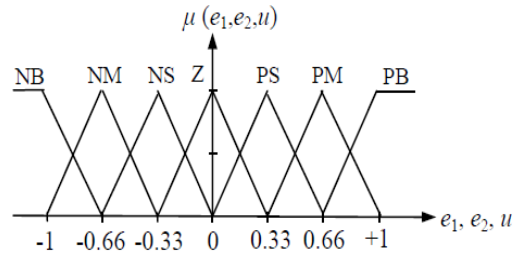Fig 7. Structure of fuzzy logic controller

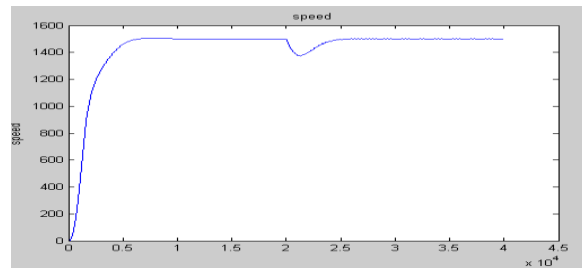Fig 8. Membership functions of fuzzy controller
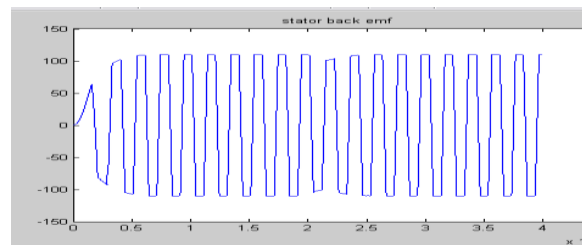
Results:-
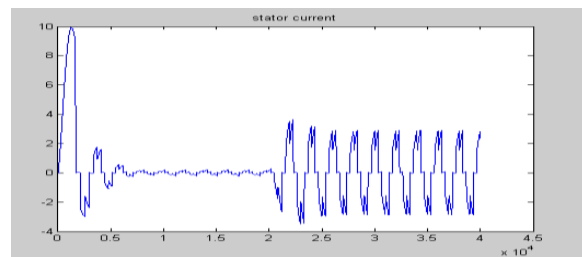

Fig 9..Speed

Fig.10.Back EMF

Fig.11.Stator Current

Conclusion

This drive can be used for variable speed applications like Electrical vehicles, Robotics etc., This Paper also presents a comparative study of fuzzy controller with conventional controller of sensor less speed control of Permanent magnet Brushless DC Motor.

Reference

[1] B.K. Bose, Power Electronics and AC Drives, Prentice Hall, Englewood Cliffs, NJ: 1986.

[2] R.Krishnan: Electric Motor Drives Modeling, Analysis and Control, Prentice Hall of India Private Limited, New Delhi, 2002, pp 578-580.

[3] J.Shao, D.Nolan, and T.Hopkins, "A Novel Direct Back EMF Detection for Sensorless Brushless DC (BLDC) Motor Drives," Applied Power Electronic Conference (APEC 2002), pp33-38.

[4]Mukesh Kumar and Bhim Singh, "Fuzzy Pre-compensated PI Controller For PMBLDC Motor Drives"@2006 IEEE.

[5]R. Somanatham, P. V. Prasad and A. D. Rajkumar, " Modeling and. Simulation of sensorless Control of PMBLDC Motor Using Zero Crossing Back E.M.F. Detection "International Symposium on Power Electronics, 2006, SPEEDAM .

[6]S.P.Natarajan, Chellamuthu and Giridharan, " Intelligent Controllers for Permanent Magnet Brushless DC Motor", India International Conference on Power Electronics,2006

[7]V M Varatharaju, B L Mathur, "Speed Control Of PMBLDC motor Using MATLAB/Simulink & Effect Of Load and Inertia Changes", International Conference on Mechanical & Electrical technology 2010

[8]Rene Zwahlen,Timothy Chang, " Feed forward speed control of Brushless DC motor with input shaping," The 33rd Annual Conference of the IEEE Industrial Electronics Society (IECON), Nov 5-8,2007.

[9]Mehdi Nasri, Hossein Nezamabadi-Pour, Malihemaghfoori, "A PSO-Based optimization of PID controller for a Linear BLDC Motor" Proc. Of World academy of Science Engg. & Tech, Vol.20, April 2007.

[10]Zhiqiang Li & Changliangxia, "Speed Control of BLDC based on CMAC & PID controller" Proc. Of 6th World congress on Intelligent Control & Automation. China, June 21-23, 2006.

[11]Yoko Amano, Toshio Tsuji, Atsushi Takahashi, Shigaoonchi, "A Sensorless Drive system for BLDC using a Digital phase-Locked Loop," Wiley periodicals Inc. vol.142 No.1pp1155-1162, 2003.

[12]Mehmet Cunkas Omer Aydoğdu "Realization of Fuzzy Logic Controlled Brushless DC Motor Drives Using MATLAB Simulink", Mathematical and Computational Applications, Vol. 15, No. 2, pp. 218-229, 2010.

[13]J. Figueroa, C. Brocart, J. Cros, and P. Viarouge, Simplified simulation methods for polyphase brushless DC motors, *Mathematics and Computers in Simulation* **63**, 209–224, 2003.

[14]C.W. Hung; C.T. Lin, and C.W. Liu, An Efficient Simulation Technique for the Variable Sampling Effect of BLDC Motor Applications, *IECON 2007*, pp. 1175– 1179, 2007.

[15]C.K. Lee and WH. Pang, A Brushless DC Motor Speed Control System Using Fuzzy Rules, *IEE Power Electronics and Variable Speed Drives*, pp.101-106, 1994.

[16]R.N. Tuncay, Z. Erenay, M. Yılmaz, and O. Ustun, Rapid Control Prototyping Approach to Fuzzy Speed Control of Brushless DC Motor, *ELECO'03, International Conference on Electrical and Electronics Engineering*, *Bursa, Turkey*, 2003.

[17]C. Xia, P. Guo, T. Shi, and M. Wang, Speed control of brushless dc motor using genetic algorithm based fuzzy controller, *Proc. of Int. Conf. on Intelligent Mechatronics and Automation,* pp.460-464, 2006.

[18]A. Rubai, A. Ofoli, and M. Castro, dSPACE DSP-Based Rapid Prototyping of Fuzzy PID Controls for High Performance Brushless Servo Drives, *IEEE Industry Applications Conference, 41st IAS Annual Meeting*, page(s):1360–1364, 2006.

[19]B. Sing, A.H.N. Reddy, and S.S. Murthy, Gain Scheduling Control of Permanent Magnet Brushless dc Motor, *IE(I) Journal-EL* 84, 52-62, 2003..

[20]B.K. Lee and M.A. Ehsani, Simplified functional model for 3-phase voltage-source inverter using switching function concept, *IEEE Trans. on Industrial Electronics* 48, 309–321, 2001.

[21]Mehmit Cunkas, Omer Aydogdn, "Realisation of Fuzzy Logic Controlled Brushless DC Motor Drives Using MATLAB Simulation" Mathematical and Computational Applications, Vol. 15, No. 2, pp. 218-229, 2010.