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Speed Control of Three Phase BLDC Fan Motor using Fuzzy Logic Controller

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ABSTRACT: Fans are the mostly required electrical device in day to day life. Fans with conventional DC motors which are used in industries and household operations can be utilized only for a relatively few working hours. Switched Reluctance Motors (SRM) are not preferred because of their poor noise behaviour. In present days, Brushless DC (BLDC) motors are mainly used in fan applications. BLDC motors have many advantages over brushed DC motors and induction motors. The advantages of these motors are broader speed variation, ease of speed control and less noise production. BLDC motors do not use brushes for commutation; instead, they are electronically commuted. In this paper, control strategy based on Fuzzy Logic Controller (FLC) is proposed for Four-Switch Three-Phase BLDC motor. It lowers the cost incurred for control strategy and improves its overall performance. The simulation results of the controller for BLDC motor with conventional PI and fuzzy logic are presented. Fuzzy Logic Controller overcomes the drawbacks such as steady state error, settling time and peak overshoot present in conventional PI controller.

KEYWORDS: Brushless DC motor, Four switch three phase inverter, PI controller, Fuzzy Logic Controller.

I.INTRODUCTION

BLDC motors are rapidly becoming popular in industries such as HVAC industry, medical, electric traction, automotive, aircrafts, military equipment, hard disk drive, industrial automation equipment and instrumentation because of their high efficiency, high power factor, silent operation, compact, reliability and low maintenance. A new current control algorithm for the four-switch three-phase brushless dc motor drives is suitable for low cost applications. A current reference generation scheme is developed and implemented to obtain high performance characteristics in the four-switch system, such as small torque ripple and fast dynamic speed torque response. This scheme can successfully eliminate the torque ripple during commutations, so that it can be expected that the four-switch system can be much more practically applied for the industrial application areas. A novel direct current controlled PWM scheme is designed to produce the desired dynamic and static speed–torque characteristics four-switch brushless dc motor drive. The feasibility of the four-switch converter is extended to two-phase BLDC motor drives and the six-switch converter for power factor correction and speed control. Conventional techniques for controlling of the phase current in a FSTPI brushless dc motor drive are practically effective in low speed and cannot reduce the commutation torque ripple in high speed range. A novel concept for digital control of trapezoidal BLDC motors was implemented via two different methods, namely conduction-angle control and current-mode control. Motor operation is allowed only at two operating points or states. Alternating between the two operating points results in an average operating point that produces an average operating speed. Brushless dc motors (BLDC) are non linear in nature and are affected highly by the non-linearity like load disturbance. Speed control of this motor is traditionally handled by conventional PI and PID controllers. Problems like rollover can arise in conventional PI controller due to saturation effect. A new speed control method using the acceleration feedforward compensation and using the disturbance torque estimate method improve the transition response characteristics of the system and has been a robust characteristics in the four-switch three-phase motor drive system in which the gain of speed controller cannot be made large enough. The simplification of conventional six switch inverter is the four switch inverter to control the speed of a brushless dc motor.PID controller is used for outer loop control to develop the concept of the speed control. A current control is to minimize commutation torque for the entire speed and also intelligent schemes have been used. A new methodology for designing and tuning the scaling gains of the conventional fuzzy logic controller (FLC) is based on its well-tuned linear counterpart. The

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conventional FLC with a linear rule base is very similar to its linear counterpart. The linear three-term controller has proportional, integral and/or derivative gains. Similarly, the conventional fuzzy three-term controller also has fuzzy proportional, integral and/or derivative gain. In this paper a comparison is done between the PI controller and Fuzzy Logic Controller to know which gives the better results.

II. PRINCIPLE OF BLDC MOTOR

A Brushless DC motor is defined as a permanent synchronous machine with rotor position feedback. The brushless motors are generally controlled using a three phase power semiconductor bridge. The motor requires a rotor position sensor for starting and for providing proper commutation sequence to turn on the power devices in the inverter bridge. Based on the rotor position, the power devices are commutated sequentially every 60 degrees. Instead of commutating the armature current using brushes, electronic commutation is used for this reason, it is an electronic motor. This eliminates the problems associated with the brush and the commutator arrangement, for example, sparking and wearing out of the commutator brush arrangement, thereby, making a BLDC more rugged as compared to a dc motor.

One of the salient features of the brushless dc motor is the rotor position sensors, based on the rotor position and command signals which may be a torque command, voltage command, speed command and so on the control algorithms determine the gate signal to each semiconductor in the power electronic converter. The structure of the control algorithms determines the type of the brushless dc motor of which there are two main classes voltage source based drives and current source based drives. Both voltage source and current source based drive used with permanent magnet synchronous machine with either sinusoidal or non-sinusoidal back emf waveforms. Machine with sinusoidal back emf may be controlled so as to achieve nearly constant torque. However, machine with a non sinusoidal back emf offer reduces inverter sizes and reduces losses for the same power level.

III. CONTROLLER DESCRIPTION

To control the speed of a BLDC motor the switching frequency should be controlled. Four control signals are generated by a PWM modulator and fed to the base/gate terminal of the four switches. A controller is required to process the speed error and the output is fed to the current controller. The current controller generates the signals to the four switches. The conventional PI controller and Fuzzy Logic Controller (FLC) is used for speed control and the results are compared.

A. PI CONTROLLER

In closed loop control the speed of BLDC motor can be controlled using the conventional proportional integral (PI) controller. The PI controller can regulate the duty cycle hence control the voltage applied to the BLDC motor. A reference speed is set to the BLDC motor. When there is any diversion from the reference speed then it will be given as an error signal to PI controller. PI controller will take appropriate signal on receiving of this error signal, it can increase as well as decrease the duty cycle of applied gate signal. The actual speed of BLDC motor is obtained using the speed/position encoder and is compared with the set value and the error is processed by the PI speed controller which is then used as one of the input to the current controller. The transfer function of the PI controller has the following form.

$$G_s(s) = K_p\,(1+1/T_i s) \quad (1)$$

where $T_i = K_p/K_i$ known as the integral time constants. K_p and K_i are the proportional and integral gains respectively. Here the proportional and gain values are obtained by manual tuning method.

1. Proportional gain, K_p = 2.6
2. Integral gain, K_i = 0.1

B. FUZZY LOGIC CONTROLLER

Generally the computer works with crisp logic. But the human interpretations like hot, very cold, medium, very high, very low etc can be implemented by a computer with some changes in representation of the input data. Fuzzy logic is a

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tool to represent the input data such that a computer can process them without any mathematical values. For this purpose the input data are classified to some sets which stand for the human interpretations like hot, medium, short etc. These fuzzy sets consist of a range of values called members. Each member is associated with a membership value which means percentage of that nature. The graphical representation of these sets with respect to the percentage value is called membership function. The speed control of a BLDC motor using fuzzy logic involves three steps i.e fuzzification, inference and defuzzification.

Table.1 Fuzzy Logic Membership function

CE / ERROR	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NM	NS	NS	Z
NM	NB	NM	NS	NM	NS	Z	PS
NS	NB	NM	NS	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PS	PM	PB
PM	NS	Z	PS	PM	PM	PM	PB
PB	Z	PS	PS	PM	PM	PB	PB

In practice, one or two types of membership functions are enough to solve most of the problems. Triangular and trapezoidal shapes were chosen as the membership function due its simplicity. The next step is to define the control rules. There is no specific method to design the fuzzy logic rules. The membership function is divided into seven sets: Negative Large (NL), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), and Positive Large (PL). Each fuzzy variable is a member of the subsets with a degree of membership μ varying between 0 and 1.The block diagram of the Fuzzy Logic Controller used in this system is shown in the fig 11.The BLDC motor speed signal is given to Fuzzy Logic Controller as one input and other input is reference speed. These two input signals are given to the Fuzzy Logic Controller. The measured motor speed from BLDC drive is compared with reference speed producing the error. That torque signal is generated from the Fuzzy Logic Controller. This torque signal, hall effect signals and current signals are given to the current controller as three inputs. It generates gate pulses for four-switch three-phase inverter.

IV. SIMULATION RESULTS AND INFERENCE

The MATLAB simulation model for PI controlled BLDC motor drive and fuzzy logic controlled BLDC motor drive are shown in Fig.1 and Fig.2.This simulink model consists of an inverter block, current controller, main BLDC model block and controller block. Here the performance analysis of conventional PI controller and Fuzzy Logic Controller (FLC) has been evaluated.

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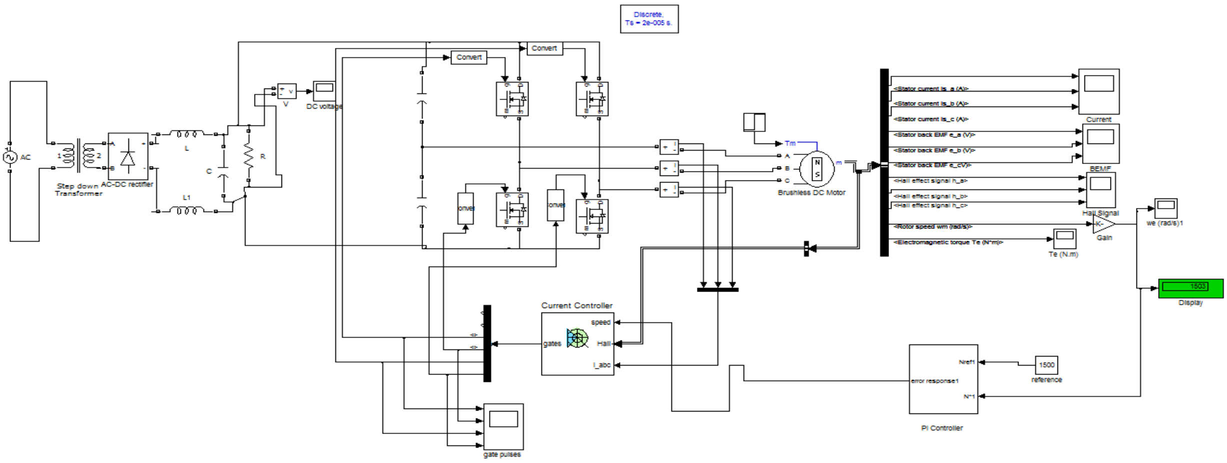

Fig. 1 Closed loop speed control using using PI controller

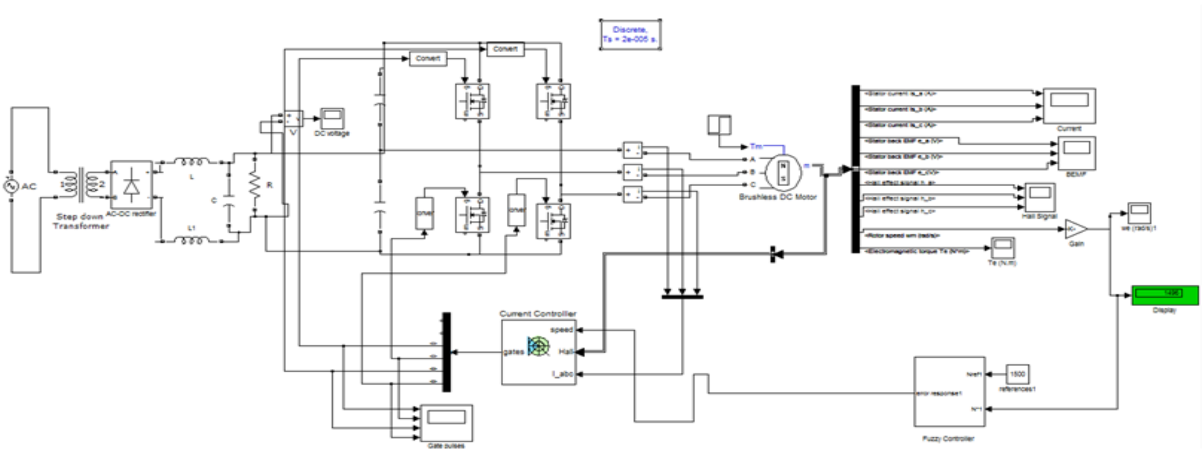

Fig. 2 Closed loop speed control using Fuzzy Logic controller

The fig.3 shows that the stator current reaches 40A and is maintained constant due to the fixed stator resistance of the winding.

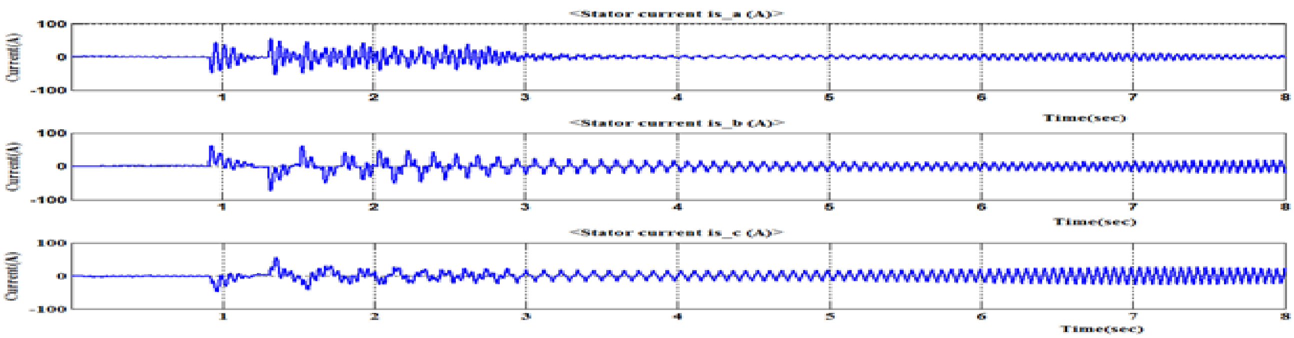

Fig.3 Stator Current waveform

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The stator voltage reaches 8V. Since the motor used here is the BLDC the back EMF should be trapezoidal as shown in fig.4.The fig.5 shows the electromagnetic torque of BLDC motor reaches steady state at 3.8 sec and maintained constant with little torque pulsation. The fig.6 shows the rotor speed overshoot is maximum in 1900 rpm and then settles at 1500 rpm and is maintained constant. There is peak overshoot and the settling time is 3.8 sec.

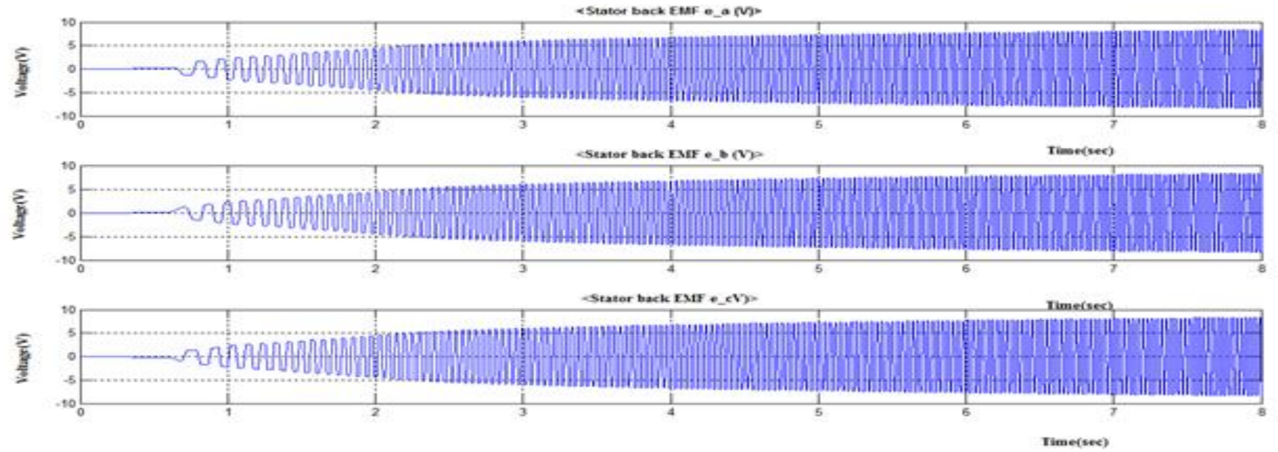

Fig.4 Stator Back EMF

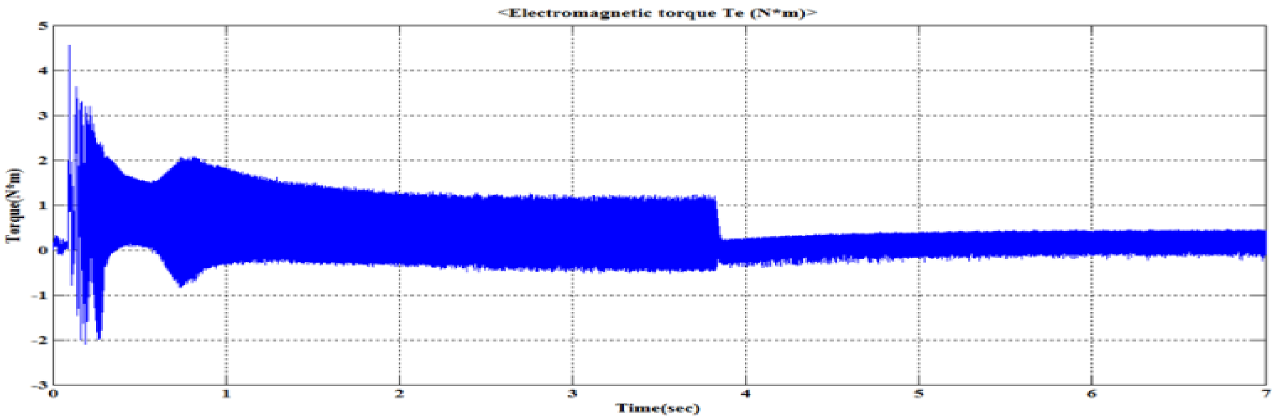

Fig.5 Torque waveform

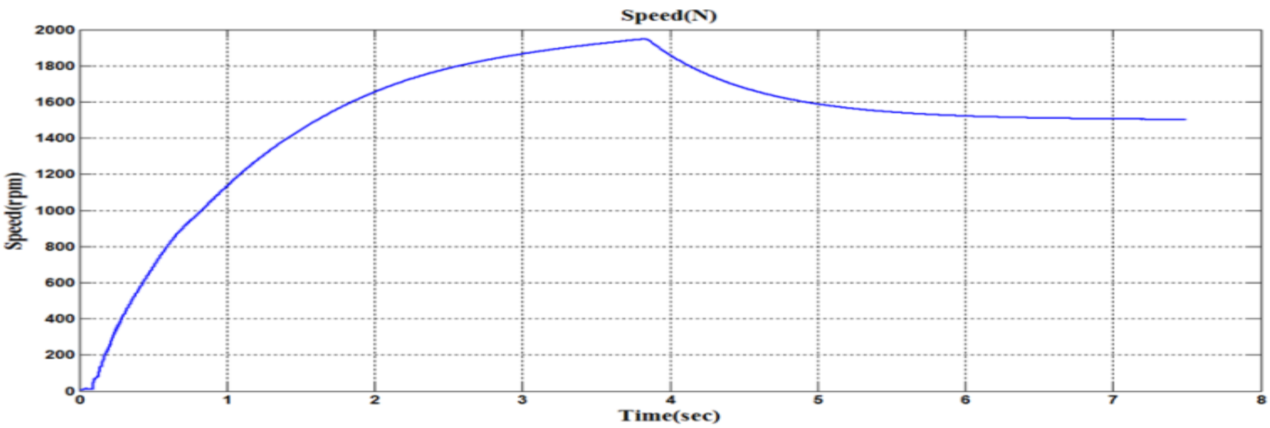

Fig.6 Speed response

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The fig.7 shows the stator current waveform. It reaches 20A and is maintained constant due to the fixed stator resistance of the winding. The stator voltage reaches 5V. Since the motor used here is the BLDC the back EMF should be trapezoidal as shown in fig.8. The electromagnetic torque reaches steady state at 1.5 sec and maintained constant with little torque pulsation.

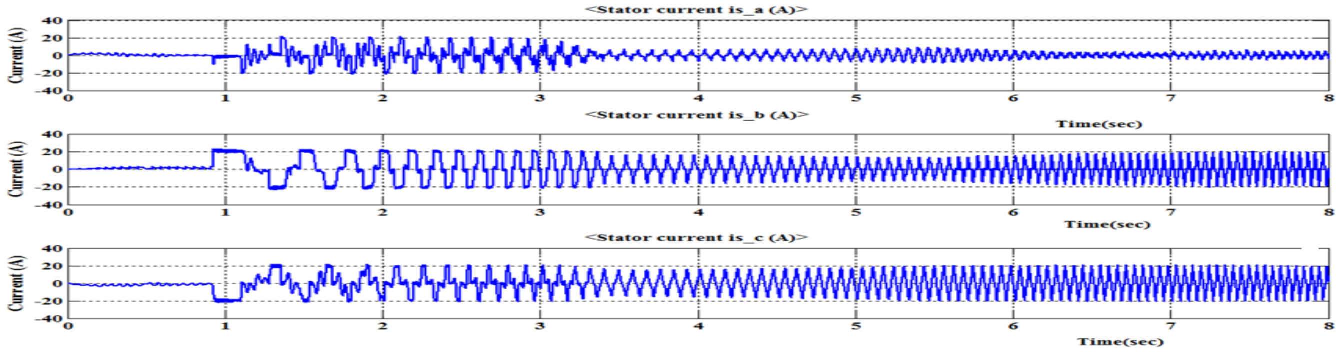

Fig.7 Stator current waveform

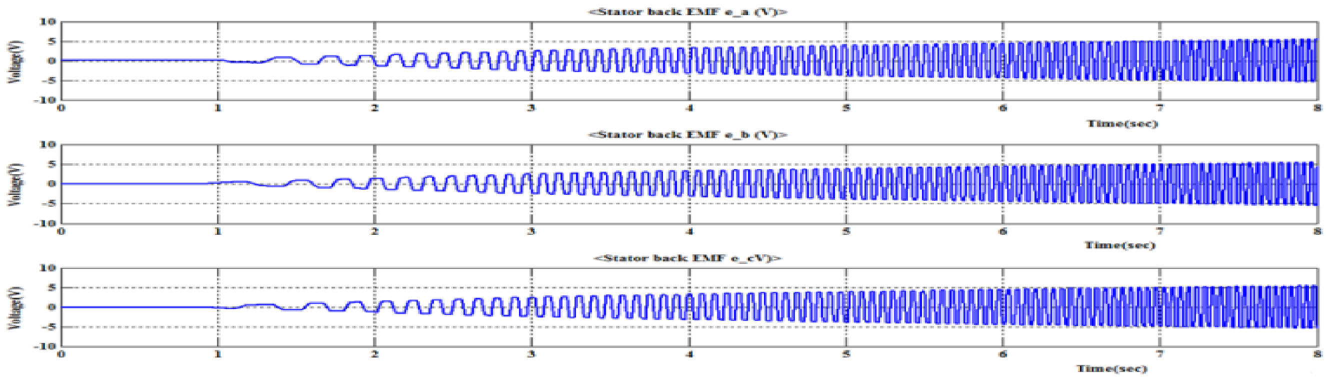

Fig.8 Stator back EMF

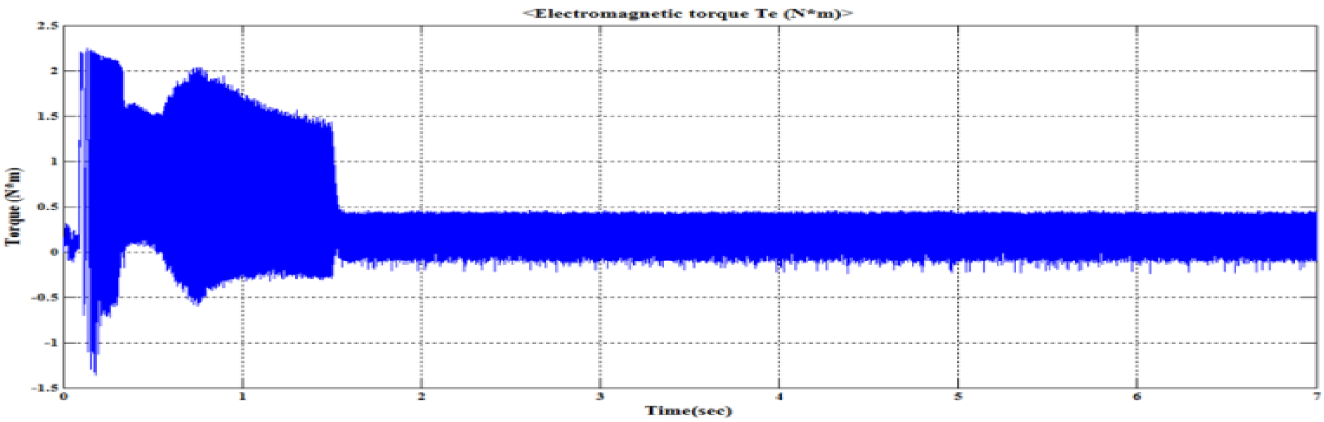

Fig.9 Torque waveform

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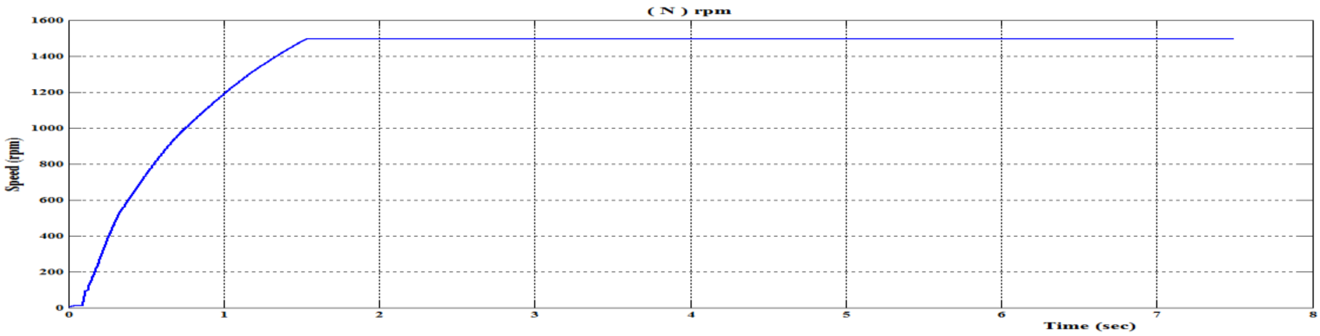

Fig.10 Speed response

Table.2 Performance parameters comparison using PI and Fuzzy Logic Controller

Condition	PI	FLC
Settling time (sec)	3.8	1.5
Steady state error	0.6	0.4
Stator current (A)	40	20
Stator voltage (V)	8	5

The fig 10 shows the rotor speed settles at 1500 rpm and is maintained constant. There is no peak overshoot and the settling time is less compared to the PI controller i.e 1.5 sec. The Fuzzy Logic Controller has less settling time and steady state error and no peak overshoot. It attains the rated speed with less ripples. Table 3 shows the comparison between the PI controller and Fuzzy Logic Controller.

V.CONCLUSION

This paper proposes a Fuzzy Logic Controller for speed control of BLDC fan motor. Three phase four switch inverter is implemented to reduce the switching loss and the system cost. Fuzzy Logic Controller is used in the design of speed controllers of the drive system and the results are compared with that of PI controller. It has been observed that the Fuzzy Logic Controller overcomes the limitations of PI controller like the overshoot in speed, thus the starting current overshoot can be reduced. The settling time and steady state error also gets minimized using Fuzzy controller. The advantages of the Fuzzy controller are that it reduces computational time, learns faster and produces lower errors than other method. By proper design a Fuzzy Logic controllers is much better than PI controllers for the speed control of BLDC motor drives.

REFERENCES

[1] Pooja Agarwal, Arpita Bose , " Brushless Dc Motor Speed Control Using Proportional-Integral And Fuzzy Controller'', IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE) Volume 5, Issue 5 (May. - Jun. 2013), PP 68-78.
[2] Teck-seng low, Mohammed A.Jabbar, M.Azizur Rahman, "Permanent-Magnet Motors for Brushless Operation", IEEE Transactins on Industry Applications,vol 26,no I,January/February 1990.
[3] Teck-seng low, Mohammed A.Jabbar, M.Azizur Rahman, "Permanent-Magnet Motors for Brushles Operation", IEEE Transactions on Industry Applications,vol.26,no 1,January/February 1990.
[4] Joon-Hwan Lee, Sung-Chan Ahn, Dong-Seok Hyun, "A BLDCM Drive with Trapezoidal Back EMF Using Four-Switch Three Phase Inverter"
[5] Sang-Hyun Park, Tae-Sung Kim, Sung-Chan Ahn, Dong-Seok Hyun, "A Simple Current Control Algorithm for Torque Ripple Reduction of Brushless DC Motor Using Four-Switch Three-phase Inverter''.

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International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 6, Special Issue 2, March 2017

[6] Byoung-Kuk Lee, Tae-Hyung Kim, and Mehrdad Ehsani, "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.
[7] Abolfazl Halvaei Niasar , Abolfazl Vahedi, and Hassan Moghbelli, "Analysis and Control of Commutation Torque Ripple in Four-Switch, Three-Phase Brushless DC Motor Drive", IEEE International Conference in Industrial Technology,2006.
[8] Fernando Rodriguez and Ali Emadi, " A Novel Digital Control Technique for Brushless DC Motor Drives", IEEE Transactions on Industrial electronics, Vol. 54, No. 5, October 2007.
[9] Arundhathi Shyam, Febin Daya J.L, "A Comparative Study on the Speed Response of BLDC Motor Using Conventional PI Controller,Anti-windup PI Controller and Fuzzy Controller", 2013 International Conference on Control Communication and Computing (ICCC).
[10] Joon-Hwan Lee, Tae-Sung Kim, and Dong-Seok Hyun, "A Study for Improved of Speed Response Characteristic in Four-Switch Three-phase BLDC Motor", The 30th Annual Conference of the IEEE Industrial Electronics Society, November 2 - 6,2004, Busan. Korea.
[11] Chandru K ,Mariaraja P,Kuppuswamy A, "Speed Control of Brushless DC Motor using Four Switch Topology" International Journal of Engineering Research & Technology (IJERT),Vol. 3 Issue 2, February – 2014.
[12] Han-Xiong Li, (1997) "A Comparative Design and Tuning for Conventional Fuzzy Control", IEEE transactions on systems, man, and cybernetics – Part B: Cybernetics, Vol. 27, No. 5, October.
[13] Akhila R and Nikhil S , "A Comparative Study of Sensor and Sensor less Control of Four-Switch Inverter Fed Permanent Magnet Brushless DC Motor", International Conference on Power signals, controls and computation (EPSCICON),2012.
[14] Vinod KR and Singh Patel, A.K.Pandey, "Modeling and performance analysis of PID controlled BLDC motor and different schemes of PWM controlled BLDC motor", International Journal of Scientific and Research Publications, Volume 3, Issue 4, April 2013 ISSN 2250-3153.
[15] J.E.MuraliDhar, Dr.P.Varanasi , " A Progressive Rugged Appearance of Fuzzy Controller Fed Four-Switch BLDC Drive", High Performance Implementations and Applications (ICGHIA2014).
[16] Park. S.J, Park. H.W, Lee. M. H ,Harashima. F, " A new Approach for Minimum-Torque Ripples Maximum Efficiency Control of BLDC Motor", IEEE Trans. Ind. Electron., vol. 47, no. 1, pp. 109-114, Feb. 2000.
[17] A. Zanjade, J.W.Bakal, Ajit J. More, "Speed Control of Permanent Brushless DC Motor Using Fuzzy Logic Controller-Hardware Implementation'', International Journal Of Engineering And Computer Science *ISSN:2319-7242* Volume 2 Issue *7* (July 2013).
[18] Benjamin Wrzecionko, Andreas Looser, Johann W. Kolar, Michael Casey, 'High-Temperature (250 ◦C/ 500 ◦*F)* 19 000 min-*1* BLDC Fan for Forced Air-Cooling of Advanced Automotive Power Electronics, IEEE/ASME Transactions on mechatronics,vol.20,No.1,February 2015.