International Journal of Applied Engineering Research ISSN 0973-4562 Volume 10, Number 17 (2015) pp 37566-37570

Simulation of Buck Converter fed PMBLDC drive using PI and Fuzzy Logic Controllers

V.Sudha
Assistant Professor, School of EEE, SASTRA University Thanjavur.
sudha@eee.sastra.edu

Dr. M.Nandhini Gayathri
Assistant Professor, School of EEE, SASTRA University Thanjavur.
nandhini.gayathri@gmail.com

ABSTRACT
Brushless Direct Current (BLDC) motors are one of the motors quickly obtaining popularity. It is used in many industry applications such as Instrumentation, Aerospace and Industrial Automation equipment. Suitable speed controllers are required in motor to achieve desired level of performance. The objective of this work is to explore and access the permanent magnet brushless DC motor drive performance controlled by speed controllers such as PI and Fuzzy logic controllers. MATLAB software is used to simulate the controllers for the PMBLDC motor drive.

Keywords: Permanent Magnet Brushless DC motor (PMBLDCM), Proportional Integral (PI) controller, Fuzzy Logic Controller (FLC)

Introduction

In many industrial applications Permanent magnet Brushless DC motors are used. It is gaining popularity due to several distinct advantages such as high torque, high efficiency and compactness. Cost reduction is one of the key factor of PMBLDC drive [1-2]. Due to the presence of brushes and commutator, conventional motors are subjected to wear and require maintenance. Commutator and brushes functions are replaced by solid state switches in BLDC motors and Permanent magnet motors. PMBLDC motors have many benefits over induction motors and brushed DC motors. They are high speed operation, responsiveness, quick acceleration, high power density and high reliability.

The aim of this work is to examine and obtain the permanent magnet brushless DC motor (PMBLDC) drive performance controlled using PI and Fuzzy logic speed controllers. MATLAB Simulink is used to simulate the controllers for the PMBLDC motor drive. PI controllers has simple control structure and easy to implement, due to the two reasons, these controllers are generally preferred in the industry to control the speed of the drive. But PI controllers need linear mathematical models and it have complication where there are limitations such as parametric variations, nonlinearity and load disturbances [6]. The drawbacks of PI controller is overcome by Fuzzy Logic Controller (FLC). The permanent magnet brushless DC motor speed controlled by Fuzzy Logic (FL) approach leads to an immune to parameter variations, load perturbations and improved dynamic behaviour of the motor drive system [4-5].

A performance of PMBLDC drive using conventional PI controller and fuzzy logic controller was compared using simulation. The simulation runs confirms the superiority of the fuzzy logic controller over PI controller**.** The manual tuning time of the classical controller was significantly reduced using fuzzy logic controller. Inspite of the easy implementation of traditional PI control, its response is not so good for non-linear systems.The improvement is remarkable when controls with Fuzzy logic are used, obtaining a better dynamic response from the system.

PMBLDC DRIVE SYSTEM

Simplified block diagram of VSI fed PMBLDC drive system is shown in figure.1. Converter is fed by dc supply and its output is given to dc link capacitor. Inverter input is fed by the dc link and its output is fed to PMBLDC motor. In this system, rotor positions are measured by using hall sensors. DC link voltage is varied to control the motor speed. Here speed controller such as conventional PI controller and Fuzzy logic controller are implemented as to control the desired speed of the drive [8-9].

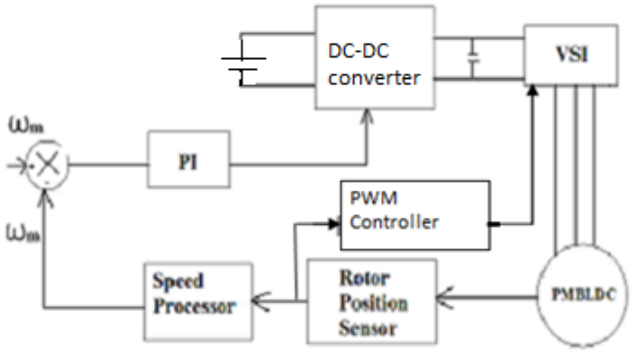


Fig.1.Block diagram of PMBLDC Motor Drive

DC-DC CONVERTER

The dc-dc converter used in the proposed system is Buck converter. It is also known as step-down converter as input voltage is always greater than average output voltage. The schematic diagram of buck converter is shown in fig.2. The

buck converter which contains dc input voltage source, switch, diode, inductor, capacitor and load resistance. During the ON state of switch, voltage source reverse biased the diode and no current flows through it. Diode is forward biased during the OFF state of the switch and voltage across the inductor is (V_L= -V_O) and current I_L decreases [3].

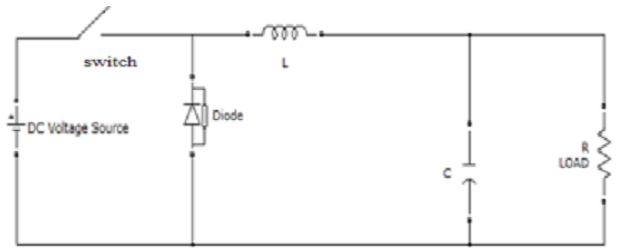


Fig.2. Schematic diagram of Buck Converter

Output voltage of the converter $V_o = V_{in} * D$

Where
V_{in} - Supply Voltage, D-Duty cycle.

Voltage Source Inverter (VSI)

Three phase inverters are used to provide variable voltage and frequency for industrial applications. Compared to single phase inverters,three phase inverter is more common. Battery or rectifier is used to provide DC supply for three phase inverters. VSI is mostly used in industrial application because it provides wide range of speed control. Two operating modes in Three phase VSI are i) 180 degree mode operation and ii) 120 degree mode operation. In 180˚ operating mode, each switch conducts for 180˚.In each cycle three switches conduct and each switch is triggered at 60˚ delay angle. By using filter, output voltage with pure sine waveform can be obtained in this mode of operation. So it is also called as a quasi-square wave mode or switched mode. In 120˚ mode operation, each switch conducts for 120˚.At any instant of time only two switches remains on. To complete one cycle of output voltage in 120˚ and 180˚ mode inverters, six steps each of 60˚ duration is needed. Compared to 180˚ mode in 120˚ operating mode, commutation is safely done. 120˚ mode of operation is used in the proposed system [3].

Performance Comparsion of PMBLDC Motor using PI and Fuzzy Logic Controller

Buck converter fed PMBLDC drive system is simulated in MATLAB platform. The speed control of the drive is achieved by using a PI & Fuzzy Logic controller and its performance are measured & compared.. Simulink model of of PMBLDCM drive using PI Controller is shown in figure 3.

PI controller

The desired speed of the drive is obtained by comparing the actual motor speed with the reference value.The resulting error is estimated by the controller on the basis of the gain values K_p and K_i. Since the PMBLDC motor is a non-linear system it is difficult to design the K_p, K_i values using the conventional design techniques available and therefore the K_p and K_i values are inputted based on trial and error method.

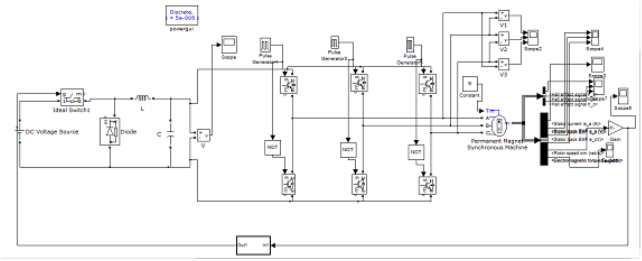


Fig.3.Simulink model of of VSI fed PMBLDCM drive using PI Controller

Simulation results ofPMBLDC drive using PI controller is shown below.

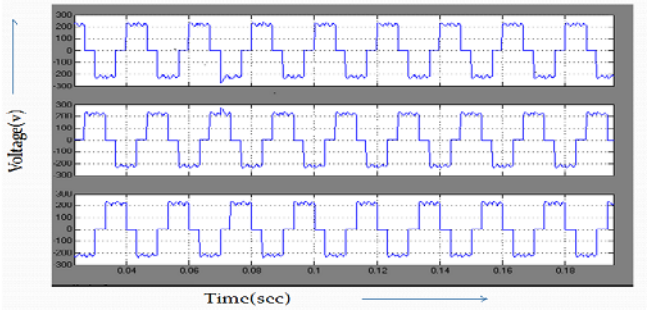


Fig. 4. Output voltage of Inverter

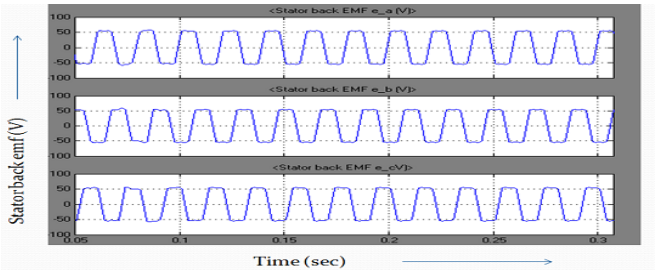


Fig.5: Stator Backemf

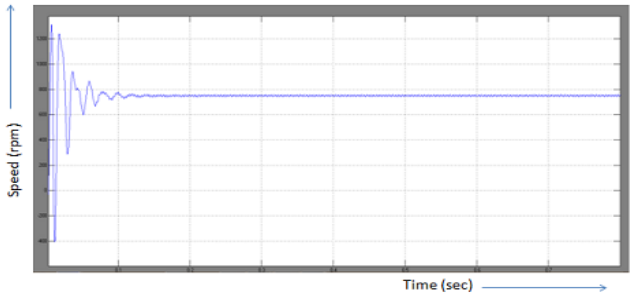


Fig.6. Speed Waveform

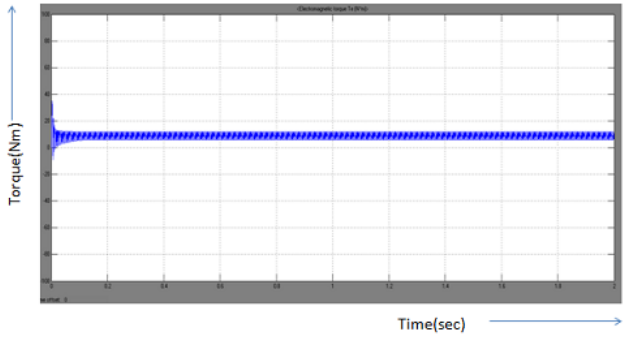


Fig.7: Torque waveform

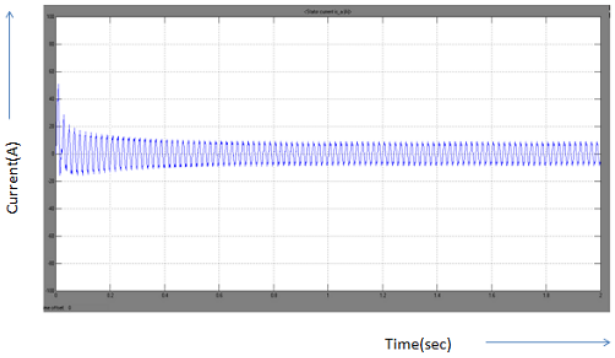


Fig.8.Stator current waveform

Table.1PI controller

Controller	Parameter	Speed	Torque
PI	Settling time(t_d)	0.15	0.04

From the simulation results its found that settling time of speed and torque of the drive using PI controller is large**.** Fuzzy logic controller is used in the proposed system in order to reduce the settling time.

Fuzzy Logic Controller

The Fuzzy Logic is the superset of conventional logic (Boolean).It operates similar to humans (decisions based on conditions).It operates on a bunch of If-Then statements. Dynamic behaviour of the motor drive system is improved using Fuzzy Logic approach.The Fuzzy Logic is immune to parametric variations and load perturbations.Three basic blocks of Fuzzy logic controller are fuzzification, inference system and defuzzification and its shown in figure 9.Mamdani inference is used as the fuzzy inference method. It has two inputs which are error & change in error and one output. The term fuzzification means the input of FLC that is input variable converted into basis of linguistic values. The IF-THEN rules constitutes the inference system and the term conversion of linguistic values into input variables are termed as defuzzification [7-10].

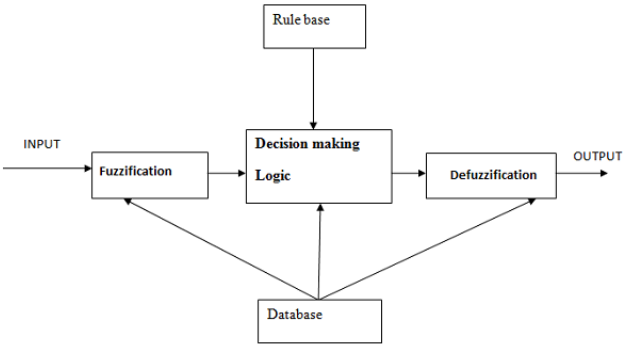


Fig.9.Block diagram of Fuzzy logic system

The rule base table has 49 rules constructed for fuzzy controller and gives the change of the output in terms of two inputs. The change of error (ΔE) and (E) error are inputs. The inference can be written as "IF A and B THEN C", such that the rule can be formed using fuzzy table. The rule tables are designed from Negative to Positive range of values.

Rule Base

Table 2. Fuzzy Logic Rules

Error/ Change of error	NB	NM	NS	Z	PS	PM	PB
NB	PB	PB	PB	PB	PM	PS	NS
NM	PB	PB	PB	PM	PS	Z	NM
NS	PB	PB	PM	PS	Z	NS	NB
Z	PB	PM	PS	Z	NS	NM	NB
PS	PM	PS	Z	NS	NM	NB	NB
PM	PS	Z	NS	NM	NB	NB	NB
PB	Z	NS	NM	NB	NB	NB	NB

Closed loop control of buck converter fed PMBLDC motor drive using fuzzy logic controller

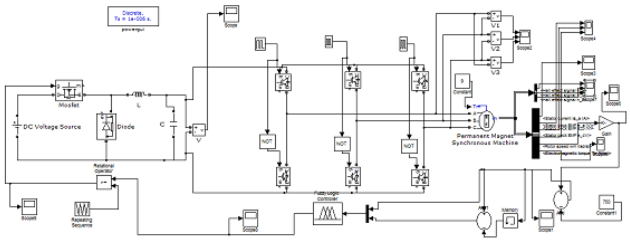


Figure 9: Simulink model of VSI fed PMBLDC drive using Fuzzy logic controller

The MATLAB schematic of buck converter fed PMBLDC motor drive using fuzzy controller is shown in Fig 9.By defining fuzzy membership functions and rule base the speed is controlled. The various responses of the motor are observed - speed, stator, current, electromagnetic-torque and electromotive force.Simulation results of the proposed system using fuzzy logic controller is given below.

Output Waveforms:

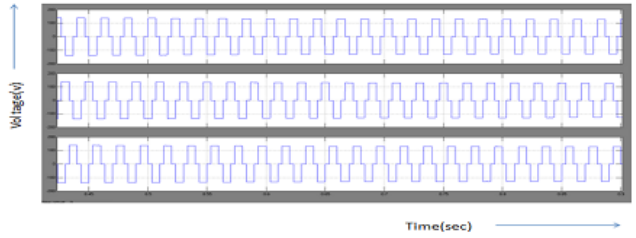


Fig.10. Output voltage of Inverter

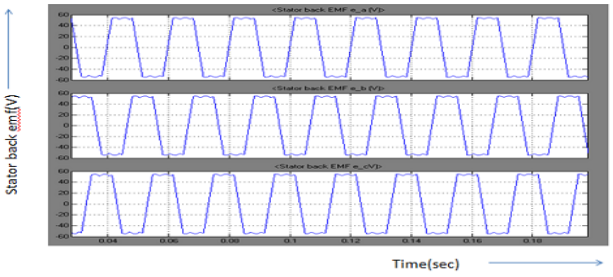


Fig.11.Stator Backemf

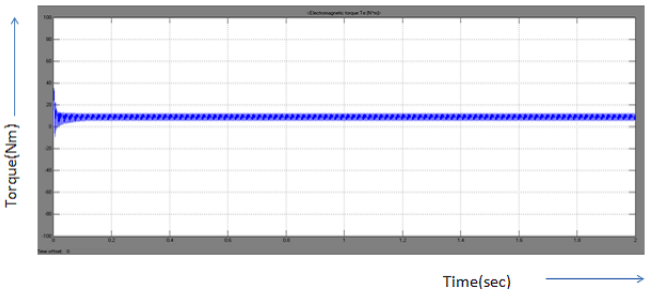


Fig.11. Torque

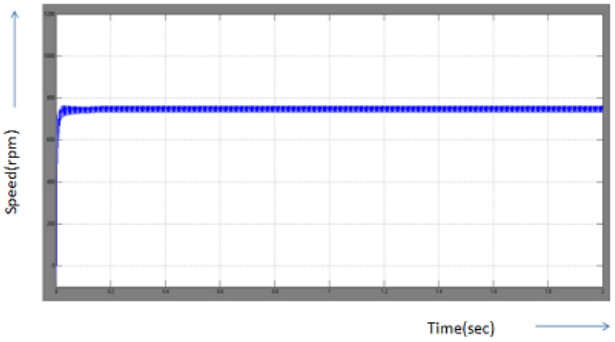


Fig.12. Speed

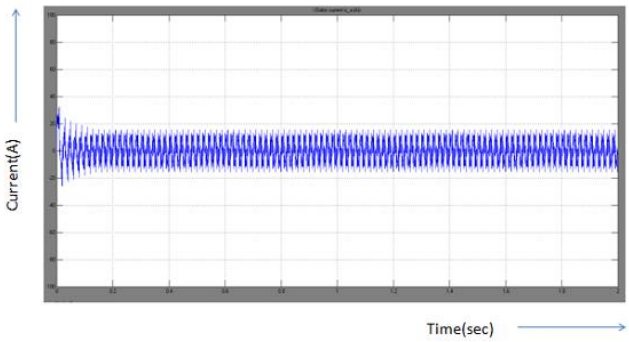
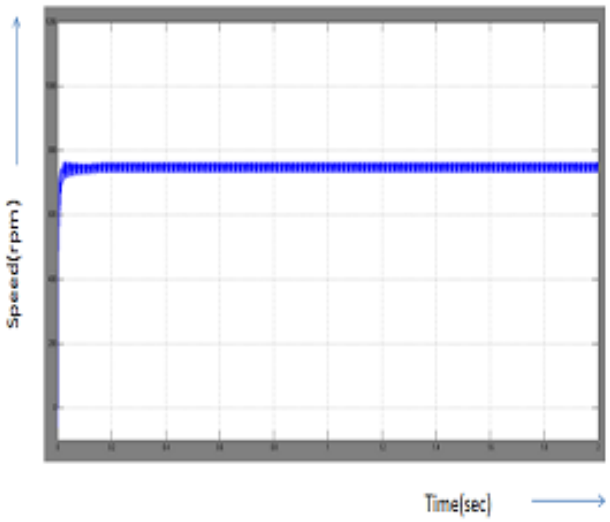


Fig. 13. Stator Current

Comparsion of Speed waveform of PMBLDC using PI and Fuzzy logic controller:



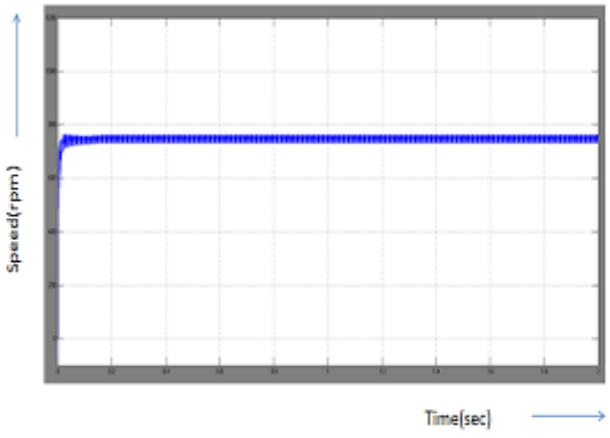


Table.3 Comparitive table

Controller	Parameter	Speed	Torque
PI CONTROLLER	Settling time(t_d)	0.15	0.04
FUZZYLOGIC CONTROLLER		0.03	0.02

Speed response of BLDC drive using PI controller and fuzzy logic controller is discussed above. Using PI controller, motor reaches the expected speed of 750 rpm with a settling time 0.15 seconds and by using FLC the motor reaches the same speed with a settling time 0.03 seconds.

CONCLUSION

The closed loop buck converter fed Permanent Magnet Brushless DC motor using PI and fuzzy controller is simulated and the results are tabulated. From the simulation results, its observed that the speed response of the BLDC drive using FLC is faster than conventional PI controller. The speed control of the PMBLDC drive using FLC provides better performances which is of immense help to industrial applications.

REFERENCES

1. Kaiwei Yao, Senior Member, IEEE, Yang Qui,Ming Xu, and Fred C.Lee, Fellow,IEEE."A novel winding-coupled Buck Converter for high frequency, High-step-down DC-DC conversion", IEEE transactions on Power electronics,Vol.2,2005.
2. S.Prakash, R.Dhanasekaran, "Interleaved buck converter fed pmbldc drive system", International journal of technology and engineering science, Vol 1(6),2013.
3. MUHAMMADH.RASHID,"PowerElectronics Handbook",second edition, Elsevier,2007.
4. Atul Kumar Dewangan, Sashai Shukla, Vinod Yadu," Speed Control of a Separately Excited DC Motor Using Fuzzy Logic Control Based on Matlab Simulation Program" International Journal of Scientific & Technology Research, Volume 1, Issue 2, March,2012.
5. Jaydeep Chakravorty, Ruchika Sharma,"Fuzzy Logic Based Method of Speed Control of DC Motor" International Journal of Emerging Technology and Advanced Engineering, Volume 3, Issue 4, April 2013.
6. S.Assly Steffy, B.Mangaiyarkarasi, S.Sherin Jasper, K.Priyanka, K.Soorya, "Analysis and Simulation of speed control of PMBLDC motor by PI controller", International Journal of Advanced Research in Computer and Communication Engineering Vol. 3, Issue 2, February 2014.
7. B.Mahesh kumar,G.Ravi and R.Chakrabarti "Sensorless speed control of Brushless DC motor with Fuzzy based Estimation" Iranian journal of electrical & computer Engg.vol.8 No.2 Summer-fall 2009.
8. C. L. Xia, Permanent Magnet Brushless DC Motor Drives and Controls,Wiley Press, Beijing, 2012.
9. I.Janpana, R.Chaisricharoenb, P. Boonyananta,"Control of the Brushless DC Motor in Combine Mode" ELSEVIER 2012.
10. T.Venkateswara Rao, B.Mahesh Babu, Power Quality Improvement in a PMBLDCM Drive Using a forward Buck Converter International Journal of Scientific and Research Publications, Volume 2, Issue 11, November 2012.