ABSTRACT

Speed control of a BLDC motor plays an important role in missile guidance, aircraft piloting systems, robotics, computer disc drives etc. DC motor speed control is very widely used in industries.

Many applications demand precise control of speed. Usage of conventional controllers may lead to instability of the system. Conventional control system deals with linear time-invariant single-input single-output (SISO) systems. But usually the process parameters are nonlinear and/or time variant and ill-defined. In such cases conventional control strategy fails. Automatic controllers require a precise mathematical model for the given system to be controlled. In many complex industrial processes, the construction of mathematical model is too difficult and very complex. In such situations fuzzy logic controllers (FLC) are most appropriate. In order to improve the performance of the system one has to apply FLC technique because, they give high stability, more robust control, more accuracy and higher flexibility in the design and implementation..

During the past several years, FLC's have become very popular area of research. It is a national thrust area as defined by DST and AICTE. Fuzzy logic is rapidly finding applications in the automotive, aerospace, financial transportation and consumer products industries. Fuzzy logic is a logic , which is much closer to human thinking and natural language processing. This is normally employed to control ill-defined systems (systems without mathematical model). The FLC provides means of converting a linguistic control strategy based on fuzzy or expert knowledge into an automatic control strategy. FLCs have been successfully used for various applications in various fields such

as Physics, Consumer Electronics, Industrial Controllers, Robotics, Bio-medical Instrumentation and also in Commerce, Economics and Biotechnology .

Brushless DC (BLDC) motors are penetrating in the market of home appliances, industry and defense/military, automotive applications in recent years because of their high efficiency, silent operation, compact form, reliability and low maintenance. BLDC motors are also being popularly used in radar systems antenna positioning applications for accurate detection and firing of missiles. The position of the radar antenna must be precise. Speed control of BLDC motors with conventional controllers (P, PI, PD or PID) may not be fully adequate in certain applications such as set point variations, brake application, load variation, noise interference etc. Hence, there is need for systematic design and development of FLC and integrated fuzzy logic controller (IFLC) for the speed control of BLDC motor, which is discussed in this thesis.

The design and development of BLDC motor speed control using fuzzy logic, conventional PID, auto-tuned PID controllers, multi-input single-output (MISO) FLC and auto-tuned integrated fuzzy logic controllers (AIFLCs) are discussed in present research work. In the present study ,the design and development of BLDC motor (1628T024B; servomotor from Faulhaber, Switzerland) speed control have been carried out using conventional PID controller, auto-tuned PID controller, MISO FLC and AIFLC using sophisticated hardware and software like Signal Conditioning eXtension Instrumentation Cards (SCXI), Data Acquisition (DAQ) board, LabVIEW, fuzzy logic toolkit and PID controller toolkit all from National Instruments (NI), Texas, USA. The speed control of BLDC motor is also controlled using pulse width modulation (PWM) technique using IC

UCC 3626 from Texas Instruments (TI), USA. The present study finds applications in the industries, robotics and in antenna positioning system, defense / military applications etc.

In view of the elaborate literature survey and to the best of our knowledge, Faulhaber Minimotor Swiss model BLDC motor (1628T024B) has not been subjected to speed control by fuzzy logic and integrated fuzzy logic techniques using the hardware, SCXI cards, DAQ board, LabVIEW, fuzzy logic toolkit and PID control toolkit all from NI, Austin, Texas, USA.. BLDC motor 1626T024B from Faulhaber Minimotor Switzerland is very lightweight, precise high-speed motor. They are widely used in robotic applications, when very accurate fast response, and precise speed control is necessary where conventional controllers do not meet the requirements. Hence, MISO FLC and AIFLC are designed and developed for the speed control of above-mentioned Swiss motor for the first time. Therefore, the motivation for the present work is as follows:

1. To design and develop conventional two input single output (C2ISO) FLC for the speed control of BLDC motor using SCXI cards, DAQ board, LabVIEW, fuzzy logic toolkit (from NI, USA), PWM IC UCC 3626 and an active filter.
2. To optimize fuzzification and defuzzification methods for the speed control of BLDC motor and to choose the best method for the application.
3. To optimize the sampling time on the performance of C2ISO FLC for the speed control of BLDC motor.
4. To design and develop PID and auto tuned PID controller for the speed control of BLDC motor using PID control toolkit and their comparative study.

5. To design and develop C2ISO auto tuned integrated fuzzy logic controller (AIFLC) for the speed control of BLDC motor and to compare its performance with C2ISO FLC
6. To design and develop three input single output (3ISO) FLC and AIFLC for the speed control of BLDC motor.
7. To study the performance of 3ISO AIFLC for the following parameter variations in the BLDC motor and to compare its performance with C2ISO AIFLC, 3ISO FLC and C2ISO FLC:

(a) Load variations

(b) Brake applications

(d) External disturbance (Gaussian white noise)

OUTLINE OF THE THESIS

The thesis comprises of 6 Chapters.

Chapter 1 deals with introduction to DC motors , AC motor, their advantages and disadvantages, speed control methods, permanent magnet synchronous motor, BLDC motor, its construction and working introduction of conventional PID controller and introduction to conventional FLC.

Chapter 2 deals with literature survey on fuzzy logic control, fuzzification, rule base, defuzzification, the application of PID, FLC, and IFLC for BLDC motor drives, the effect of noise/disturbances on FLC and IFLC and motivation for the present work.

Chapter 3 deals with introduction of conventional PID controller methodology for design and development of PC based PID controller for the speed control of BLDC motor. Detailed block diagram and its working, explanation of each block and methodology are discussed. This chapter gives details about design and development of

speed control of BLDC motor using PID technique and virtual instrumentation (VI) technique. The details of hardware and software used in the present study are also discussed.

Chapter 4 deals with introduction to fuzzy logic, concepts of fuzzy set theory, design and development of FLC for speed control of BLDC motor using virtual instrumentation (VI) technique. The details of hardware and software used in the present study are also discussed. The selection of number of triangular membership functions, selection of defuzzification method and effect of sampling rate on FLC are also discussed. The experimental results and discussion about fuzzification, rule base, defuzzification techniques and the effect of sampling rate for FLC speed control of BLDC motor is also outlined in this Chapter. Set point variations, load variations and braking are also discussed in this chapter. It also deals with the effect of Gaussian white noise of various amplitudes in all the proposed controllers. The effect of IIR filter on the above said controllers with noise is also discussed in this chapter.

Chapter 5 deals with. the experimental results and discussions of all the proposed controllers .

Chapter 6 deals with conclusions drawn from the present research work and its scope of future work. The references and appendix are given at the end of the thesis.

List of Author's Publications

I. Papers communicated to journals

1.Effect of Gaussian white noise on multi iput integrated fuzzy logic controller for BLDC motor Drives-Communicated to "Advances in Fuzzy sets"

2.Design and development of controller for BLDC motor using FLC and Auto Integrated FLC –communicated to International journal of Electronics, U K

II. Accepted for Presentation at the International conference

1. Sasikala[1], Rekha. B. R [1], Bharathi. Y. H[1], G. Tulsi Ramdas[2] and A. B. Kulkarni[1*]
   "Multi-input Fuzzy Logic Controller for BLDC motor Drives"- To be presented at the International conference on Industrial and Information systems (ICIIS) to be held at , Srilanka 8-11 august 2007

2. Sasikala[1], Rekha. B. R [1], Bharathi. Y. H[1], G. Tulsi Ramdas[2] and A. B. Kulkarni[1*]
   "Multi-input Fuzzy Logic Controller at International power Engineering Conference (IPEC)2007 to be held at Singapore

3. M. Sasikala[1], Rekha. B. R [1], Bharathi. Y. H[1], G. Tulsi Ramdas[2] and A. B. Kulkarni[1*]
   -Design and development of controller for BLDC motor using PID and Auto PID to be presented at the International Conference on Modeling and Simulation Coimbatore, 27-29 August 2007.

II. Papers presented in National conferences

1. Sasikala M, Bharathi. Y. H., Rekha. B. R., P. Bhaskar, C. S. Parvathi and A. B. Kulkarni, "Study of speed control of RCI BLDC motor using virtual instrumentation LabVIEW", Proceedings of 31st National Symposium on Instrumentation, Gwalior, Oct. 12-15, 2006, paper. 132
2. Sasikala. M, Bharathi. Y. H., Rekha. B. R., Bhaskar, C. S. Parvathi and A. B. Kulkarni, "PWM based speed control of BLDC motor using virtual

Material Science, Gulbarga University, Gulbarga, January 27-28, 2007, pp. 78.

3. Sasikala. M, Bharathi. Y. H., Rekha. B. R., Bhaskar, C. S. Parvathi and A. B. Kulkarni, Design and development of controller for BLDC motor using PID and Auto PID controllers-

4. Bharathi. Y. H., Rekha. B. R., Sasikala. M, Laxmikant R., Bhaskar, C. S. Parvathi and A. B. Kulkarni, "Virtual instrumentation based DC motor speed control system", Proceedings of National Conference on Advances in Material Science, Gulbarga University, Gulbarga, January 27-28, 2007, pp. 40.

* 5. Rekha. B. R., Bharathi. Y. H., Sasikala. M, Laxmikant R., Bhaskar, C. S. Parvathi and A. B. Kulkarni, "Speed control of BLDC motor using PWM Technique based on virtual instrumentation", Proceedings of National Conference on Advances in Material Science, Gulbarga University, Gulbarga, January 27-28, 2007, pp. 77.

* 6. Rekha. B. R., Bharathi. Y. H., Sasikala. M, Bhaskar, C. S. Parvathi and A. B. Kulkarni, "Study of PID controller for BLDC motor Speed control using virtual instrumentation LabVIEW", Proceedings of 31st National Symposium on Instrumentation, Gwalior, Oct. 12-15, 2006, paper. 38.