Speed control of a sensored Brushless DC Motor using FLC

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***Abstract*—Brushless DC motor(BLDC) are used in many industrial and domestical applications because of their high efficiency and low volume. In industrial applications, it is very necessary to control the speed of the motor. A speed control of fuzzy logic controller is proposed in this paper. The Performance of the BLDC motor are calculated by using the control characteristics like settling time, rise time, overshoot. This fuzzy logic speed control of BLDC motor was simulated using MATLAB/SIMULINK and the result obtained showed that excellent flexibility, good robustness are obtained by the proposed strategy**

Keywords— ***BLDC motor, fuzzy logic controller, Speed control, fuzzy logic controller***

I. INTRODUCTION

The conventional permanent magnet DC motor is an excellent motor to drive the system. But the DC motor have a disadvantages is frequent replacement of brushes[1]. The Brushless DC motor is often said to be a Permanent magnet synchronous motor with a shape of trapezoidal back electromotive force. The main advantage of permanent magnet Brushless DC motor is less maintenance and a longer life[2]. Due to electro mechanical properties the BLDC motor are used in aerospace, automotive, medical, instrumentation, robotics, machine tools and industrial automation equipment[3]. Proportional Integral Derivative(PID) control is one of the earlier technique used for control strategies. The main drawback of the PID controller is it needs a mathematical model[4]. This drawback is overcomed by using Fuzzy logic controller. Fuzzy logic is a method of rule based decision making used in process control. The fuzzy rules are created by human knowledge about the system. The knowledge are represented by IF-Then rules and transfer it in to the functional block. The IF part is referred as antecedent and the THEN is referred as consequent. Fuzzy logic systems can be used for advanced engineering applications such as intelligent control systems, expert systems, decision making fault detection, process diagnostics [5]. Then the tuning of fuzzy rules are done to make the system with good performance[6]. The conventional controller are used for speed control, but comparing fuzzy PID is not suitable for BLDC motor[7].

II. BLDC MOTOR STRUCTURE

The BLDC motor stator windings are similar to those in a polyphase AC motor, and the rotor has one or more permanent magnets. Brushless DC motors (BLDC) contain a powerful permanent magnet rotor and fixed stator windings. The stationary stator windings are usually three phases, which means that three separate voltages are supplied to the three different sets of windings. The structure of permanent magnet BLDC motor is shown in fig 1.

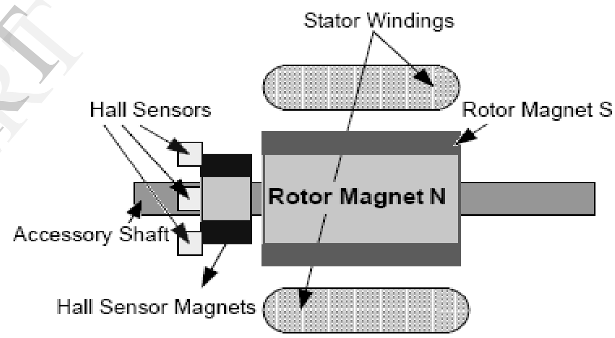

Fig 1 Structure of BLDC motor

The stator of a BLDC motor consists of stacked steel laminations with windings. Traditionally, the stator arrangements is similar that of an induction motor. Commonly BLDC motors have three stator windings connected in star fashion. All the windings separately is constructed with numerous coils interconnected to form a winding and is distributed to form an even numbers of poles. The BLDC motor has a trapezoidal back emf and its shown in fig 2.

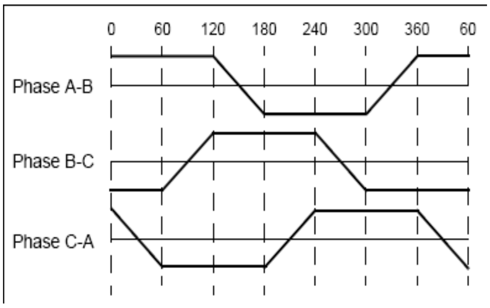

Fig 2 Trapezoidal shape of back emf

The rotor is made of permanent magnet and can vary from two to eight pole pairs with alternate North (N) and South (S) poles. The commutation of a BLDC motor is controlled electronically. To run the BLDC motor, the stator windings should be energized in a sequence. The rotor position are found by hall sensor and depends on rotor position the stator windings are energised. So that the rotor of the motor rotates continuously.

The electronic commutation for clockwise rotation of a rotor is as follows.

Table I Commutation logic sequence

Hall sensor A	**Hall sensor B**	**Hall sensor C**	**Q1**	**Q2**	**Q3**	**Q4**	**Q5**	**Q6**
0	0	0	0	0	0	0	0	0
0	0	1	0	0	0	1	1	0
0	1	0	0	1	1	0	0	0
0	1	1	0	1	0	0	1	0
1	0	0	1	0	0	0	0	1
1	0	1	1	0	0	1	0	0
1	1	0	0	0	1	0	0	1
1	1	1	0	0	0	0	0	0

III. SPEED CONTROL OF A BLDC MOTOR

The block diagram for a speed control of Brushless dc motor is shown in the fig 3. The reference speed is set to any desired value.

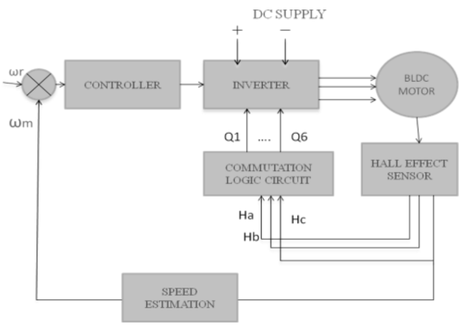

Fig 3 Block Diagram For Speed Control Of BLDC Motor

A closed loop control system is one in which control action is dependent on the output. The control system maintains the speed of a motor. The system performs this task continuously by sensing the speed and adjusting a load to maintain a speed of a motor. The set point is denoted as ω_r . Feedback gives the information about the present condition of the process. This feedback value is compared with a desired condition to produce a proper control action on the process. Information is continuously feedback to the control circuit in response to control action.The hall effect sensor are used to sense the rotor position of a motor. The sensed hall signal are fed back to the commutation logic and to the inverter. The speed estimation is used to calculate the speed of a motor and its compared with the ω_r . The error of ω_r and ω_m is given to a controller and a control action is performed.

IV. STRUCTURE OF FUZZY LOGIC CONTROL

The fuzzy logic structure of a BLDC motor is shown in Fig 4. The difference between reference speed and actual speed is given to the Fuzzy controller. The fuzzy controller consists of fuzzifier, inference engine, rule base and defuzzifier. According to the process function, the rules are written in the rule base block.

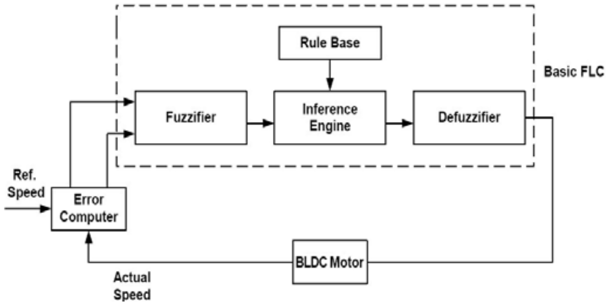

Fig 4 Structure of fuzzy controller

A. Fuzzifier

Fuzzification is a process in which the inputs are classified to corresponding linguistic terms. It means adding uncertainty by design to crisp sets or to sets that are fuzzy already. This process convert a crisp value into a fuzzy one by two ways namely fuzzy singleton and fuzzy set. Singleton method of fuzzification is used in implementation when there seems to be no noise[5]. Fig 5 shows the singleton method.

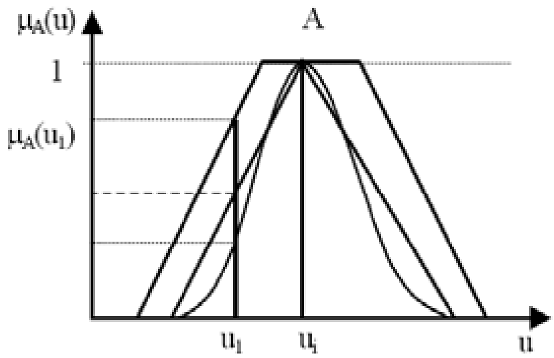

Fig 5 Singleton method

B. Rule base

IF-THEN rule are most commonly used to formulate the condition statement. The fuzzy rules are consists of two components, one is IF also referred as antecedent and an another is THEN also referred as consequent[8]. The basic structure of IF-THEN rule is as follows,

IF <antecedent> THEN <consequent>

C. Inference engine

A fuzzy system is represented by input and output linguistic variables, linguistic terms and fuzzy rules. A fuzzy inference is used for evaluating the fuzzy system i.e it computes output value from the input value. It consists of fuzzification, defuzzification and fuzzy rules.

D. Defuzzifier

Defuzzification is the inverse process of a fuzzification i.e the output linguistic terms are converted into crisp values according to their degree of fulfillment (DOF). There are many types of deffuzification. The types of defuzzification are as follows.

- Centroid of area (COA)
- Bisector of area (BOA)
- Mean of maximum (MOM)
- Smallest of maximum (SOM)
- Largest of maximum (LOM

In this most commonly used defuzzification method is Centroid of Area.

V. SPECIFICATION OF BLDC MOTOR

Many type of BLDC motor are available in the market. Here the BLDC motor with the Model HD92C4-64 is used for controlling the speed of a motor. The specification of HD92C4-64 BLDC motor is as follows.

Table II Motor parameters

BLDCM model	HD92C4-64T
Maximum motor emf	380V
Maximum Speed	6000 rpm
Maximum current	12.2A
Terminal resistance phase to phase	10.4 Ω
Terminal Inductance phase to phase	43mH
Mechanical time constant	3.5ms
Torque constant	0.61 Nm/A
Rotor inertia	1.3Kg cm^2

VI. CONTROLLER DESIGN

The fuzzy controller is a non linear process. The BLDC motor performance is nonlinear in nature. So the Fuzzy controller is best suited technique for speed control of a BLDC motor. The input of fuzzifier is error (e) and change in error(ce). The linguistic variable includes input and output variable is classified as Negative medium(NM), Negative big(NB), Negative small(NS), zero(Z), Positive small(PS), Positive medium(PM),Positive Big(PB). Transfer function of BLDCM is found by mathematical modeling.[9].
The input are normalized in the range of[-3,3] and the output are in the range of [-6,6]. The fuzzy rules are tabulated in Table III.

Table III Table of Fuzzy Rules

E/CE	**NB**	**NM**	**NS**	**Z**	**PS**	**PM**	**PB**
NB	NB	NM	NB	NB	NM	NS	Z
NM	NB	NB	NM	NM	NS	Z	PS
NS	NB	NB	NM	NS	Z	PS	PM
Z	NB	NM	NS	Z	PS	PM	PB
PS	NM	NS	Z	PS	PM	PB	PB
PM	NB	Z	PM	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

The membership function of the output are shown in fig 6.

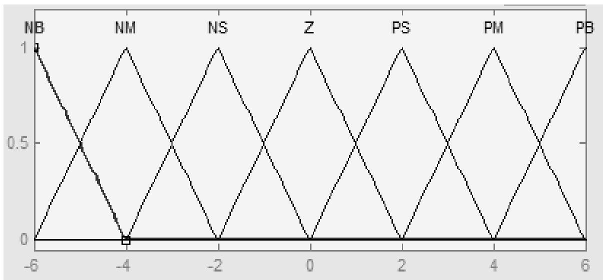

Fig 6 Output membership function

VII. SIMULATION RESULTS

The simulation result of a speed control of BLDC motor is shown in fig 7. The output has a better control characteristics than the PID controller. In this simulation, no load is considered.

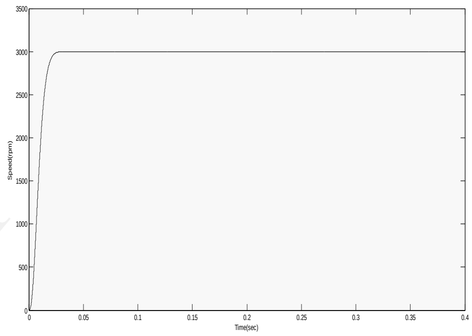

Fig 7 Simulation of Fuzzy controller

The control characteristics of the speed control of fuzzy controller for BLDC motor is given in Table IV

Table IV Controller characteristics

Controller	Rise time (sec)	Settling time (sec)	Overshoot (rpm)
Fuzzy	0.0025	0.003	-

VIII. CONCLUSION

This paper presents a simulation results of Fuzzy controller for the speed control of BLDC motor. The fuzzy controller maintains the speed of a motor for a given speed. The control characteristics are very good than comparing with PID controller. Some of other adaptive techniques Artificial neural network and ANFIS could be use as the future work.

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