Speed Control of Brushless DC Motor Using Different Intelligence Schemes

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Abstract - *This dissertation focuses on speed control of BLDC motor using fuzzy logic technique. The goal is determine which control strategy delivers better performance with respect to BLDC motors speed these methods are compound on the basis of output response, less rise time, less setting time and less over shoot for speed demand of dc motors excellent result. BLDC motor have many advantages than brushed DC motors and induction motor such as a better speed - torque characteristics, high dynamic response, long operating life, noiseless operation which can be considered the most dominant electric motor. Finally the performance comparison between I-controller, PI-controller and fuzzy logic controller is done. The simulations results show that fuzzy logic provide a good control of speed as compare Other Controller. FLC has minimum overshoot, minimum transient and steady state parameters, which shows its more effectiveness and efficiency of than conventional PID controller.*

Key Words: – BLDC motor, Modelling of BLDC motor, Control schemes, I-controller, PI-controller and fuzzy logic

1.INTRODUCTION

There are mainly two types of dc motors used in industry. The first one is the conventional dc motor where the flux is produced by the current through the field coil of the stationary pole structure. The second type is the brushless dc motor where the permanent magnet provides the necessary air gap flux instead of the wire-wound field poles. BLDC motor is conventionally defined as a permanent magnet synchronous motor with a trapezoidal Back EMF waveform shape. As the name implies, BLDC motors do not use brushes for commutation; instead, they are electronically commutated. Recently, high performance BLDC motor drives are widely used for variable speed drive systems of the industrial applications and electric vehicles. BLDC motors are rapidly becoming popular in industries such as Electrical appliances, HV AC 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 [1]. Brushless DC motors drives have gained widespread use in electrical drives that are rapidly gaining popularity by its utilization in various industries, such as appliances, automotive, aerospace, consumer, medical, industrial automation equipment and instrumentation and industrial drives partly as result of demand for variable speed drives because of development of power electronics devices. It gaining popularity due to their low cost, ruggedness, good dynamic response and low maintenance and are widely used in different applications this requires high torque with good speed response [2-3]. Thus this paper presents a detailed comparison of BLDC motor with I- controller, PI- controller and fuzzy logic controller. The results of these were tabulated and analysed for both the controllers. Finally the performance comparison between I- controller, PI controller and fuzzy logic controller is done.

II. Literature Review of BLDC motor

M. Daniel pradeep ,"a novel method of speed and voltage control of bldc motor" This paper presents the speed control of BLDC motor by the 3phase semiconductor bridge by the signal sensed by rotor position sensor. In the proposed method the back emf of the motor is stored in the battery and the speed of motor is sensed and is given the pi controller which drives the semiconductor thus, by this proposed method the energy consumption will be less and generated energy can be stored and reused, and it has high, long operating life, noiseless operation, and high speed range [4],

Abhishek jain, "controlling of permanent magnet brushless dc motor using instrumentation technique" The paper characterizes the controlling the permanent magnet brushless dc motor with sensor via instrumentation technique. A permanent magnet brushless dc motor is gaining popularity since its uses sensors instead of brushes and commutators. A brushless dc motor has been used in this paper since it has high efficiency, reliable and requires lower maintenance cost. Pwm technique is used for the controlling of fpga (field programmable gate array) device that calculates the duty cycle as required. The paper deals with the analyses of speed control of the brushless dc motor which can be done using pid controller [5].

Yasser ali almatheel, " speed control of dc motor using fuzzy logic controller "
Dc motor speed is controlled using pid controller and fuzzy logic controller, Pid controller requires a mathematical model of the system while fuzzy logic controller base on

experience via rule-based knowledge. Design of fuzzy logic controller requires many design decisions , for example rule base and fuzzification. The flc has two input ,one of these inputs is the speed error and the second is the change in the speed error. There are 49 fuzzy rules which are designed for the fuzzy logic controller. The center of gravity method is used for the defuzzificztion. Fuzzy logic controller uses mamdani system which employs fuzzy sets in consequent part. Pid controller chooses its parameters base on trial and error method. Pid and flc are investigated with the help of matlab / simulink package program simulation. It is founded that flc is more difficult in design comparing with pid controller, but it has an advance to be more suitable to satisfy non-linear characteristics of dc motor. The results shows that the fuzzy logic has minimum transient and steady state parameters , which shows that fic more efficiency and effectiveness than pid controller [6].

S.thamizmani , "design of fuzzy pid controller for brushless dc motor This brushless dc motors are widely used for many industrial applications because of their high efficiency, high torque and low volume. This paper proposed a improved fuzzy pid controller to control speed of brushless dc motor. The proposed controller is called proportional–integral–derivative controller and fuzzy proportional–integral– derivative controller. This paper provides an overview of performance conventional pid controller and fuzzy pid controller. It is difficult to tune the parameters and get satisfied control characteristics by using normal conventional pid controller. As the fuzzy has the ability to satisfied control characteristics and it is easy for computing, in order to control the bldc motor, a fuzzy pid controller is designed as the controller of the bldc motor [7].

In 2015 Nikita Tiwari, Prof. RiteshDiwan "Speed Control of Brushless DC Motor using Fuzzy and Neuro Fuzzy"
In this article the DC drive systems are often used in many industrial applications such as robotics, actuation and manipulators. The purpose of this paper is to control the speed of Brushless DC motor by using Fuzzy logic controller (FLC) and Neuro-fuzzy controller in MATLAB / SIMULINK model. The scopes includes the modelling and simulation of Brushless DC motor, application of fuzzy logic controller to actual DC motor. This paper is going to present the new capacity of assessing speed and control of the Brushless DC motor. By utilizing the Neuro fuzzy controller, the rate can be tuned until it get like the desired output that a user wants [8].

In 2015 Maloth Purnalal1, Sunil kumar T K2 "Development Of Mathematical Model And Speed Control Of Bldc Motor "
In this article the electronically commutated Brushless DC motors are enormously used in many industrial applications which increases the need for design of efficient control strategy for these noiseless motors. This paper deals with a closed loop speed control of BLDC motor and performance of the BLDC motor is simulated. The duty ratio is regulated by PI controller, which governs the duty cycle of the PWM pulses applied to the switches of the inverter to run the motor at steady state speed [9].

III.BLDC MOTOR

The BLDC motor is an AC synchronous motor with permanent magnets on the rotor (moving part) and windings on the stator. Permanent magnets create the rotor flux. The energized stator windings create electromagnet poles. The rotor is attracted by the energized stator phase, generating a rotation. . A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commentator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commentator system.

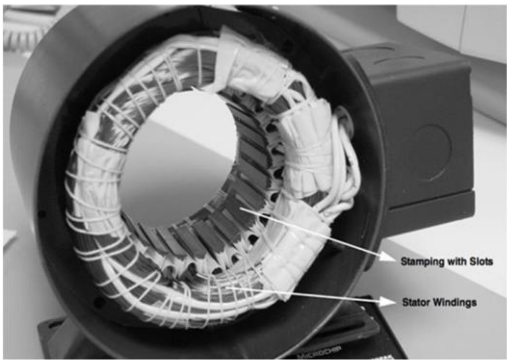

Fig - 1 Brushless motor

A. Brushless vs. brushed motors Brushed DC motors have been in commercial use since 1886.Brushless motors, on the other hand, did not become commercially viable until 1962. Brushed DC motors develop a maximum torque when stationary, linearly decreasing as velocity increases. Some limitations of brushed motors can be overcome by brushless motors; they include higher efficiency and a lower susceptibility to mechanical wear. These benefits come at the cost of potentially less rugged, more complex, and more expensive control electronics. A typical brushless motor has permanent magnets which rotate around a fixed armature, eliminating problems associated with connecting current to the moving armature. An electronic controller replaces the brush/commutator assembly of the brushed DC motor, which continually switches the phase to the windings to keep the motor turning. The controller performs similar timed power distribution by using a solid-state circuit rather than the brush/commutator system. Brushless motors offer several advantages over brushed DC motors, including more torque per weight, more torque per watt (increased efficiency), increased reliability, reduced noise, longer lifetime (no brush and commutator erosion), elimination of ionizing sparks from the commutator, and overall reduction of electromagnetic interference (EMI). With no windings on the rotor, they are not subjected to centrifugal forces, and because the windings are supported by the housing, they can be cooled by conduction, requiring no airflow inside the motor for cooling. This in turn means that the motor's internals can be entirely enclosed and protected from dirt or other foreign matter [10].

B. Brushless DC motor and model concept

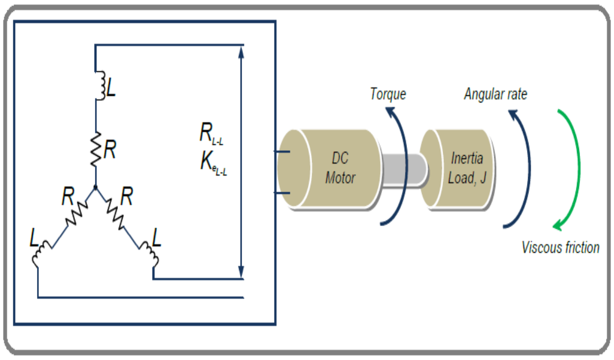

Fig . – 2 Model of Brushless DC motor

The BLDC motor operates in many modes (phases), but the most common is the 3-phase. The 3- phase has better efficiency and gives quite low torque. Though, it has some cost implications, the 3-phase has a very good precision in control. And this is needful in terms of the stator current [11].

For the mechanical time constant (with symmetrical arrangement), equation becomes

Therefore, the equation for the BLDC is

$$G(s) = \frac{\frac{1}{K_g}}{\tau_m \cdot \tau_g \, s^2 + \tau_m \cdot s + 1} \ldots\ldots\ldots\ldots (1)$$

Table 1 BLDC motor [11]

	BLDC Motor data	Unit	Value
1.	Nominal voltage	V	12.0
2.	No load speed	Rpm	4370
3.	No load current	Ma	1.51
4.	Nominal speed	Rpm	2860
5.	Nominal torque (max. continuous torque)	mNn	59.0
6.	Nominal current (max. continuous current)	A	2.14
7.	Stall torque	mNn	255
8.	Starting current	A	10.0
9.	Maximum efficiency	%	77
	Characteristics		
10.	Terminal resistance phase to phase	Ω	1.1
11.	Terminal inductance phase to phase	Mh	0.50
12.	Torque constant	MNn	24.5
13.	Speed constant	Rpm	35.4
14.	Mechanical time constant	Ms	16.6
15.	Rotor inertia	gcm2	82.5
16.	Number of phase		3

$$G(S) = \frac{14.48}{151.51 \times 10^{-6} \times 0.0161 s^2 + 0.0171 s + 1} \ldots\ldots (2)$$

IV. Fuzzy Technique and Fuzzy Controller Design

Fuzzy logic , introduced in the year 1965 by lotfiA.zadeh , is a mathematical tool for dealing with uncertainty [12]. Dr. zadeh states that the principle of complexity and imprecision are correlated, "the closer one looks at a real world problem, the fuzzier becomes its solution". Fuzzy logic offers soft computing paradigm the important concept of computing with words .it provides a technique to deal with imprecision and information granularity. The fuzzy theory provides a mechanism for representing linguistic constructs such as "high", "low", " medium", " tall", "many". In general, fuzzy Logic provides an inference structure that enables appropriate human reasoning capabilities. On the contrary, the traditional binary set theory describes crisp events, that is, events that either do or do not occur . it uses probility theory to explain if an event will occur , measuring the chance with which a given event is expected to occur. The theory of fuzzy logic is based upon the notion of relative graded membership and so are the functions of cognitive processes [14-15].

Fig – 3 Fuzzy Controller

Designing of fuzzy logic controller

In a fuzzy controller, the set of linguistic rules is the most essential part. The various linguistic variables to design rule base for output of the fuzzy logic controller are enlisted in below table. The below figure 4, figure 5, figure 6, figure 7, shows the FIS Editor Window, Fuzzy input variables "error", Fuzzy input variables "Change error" and Fuzzy output variable control of Fuzzy Logic Control.

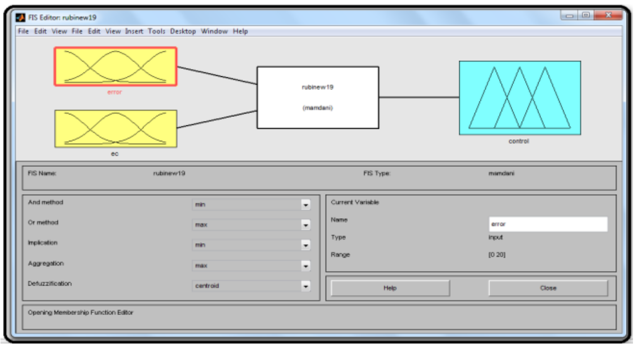

Fig.- 4 FIS editor window in MATLAB

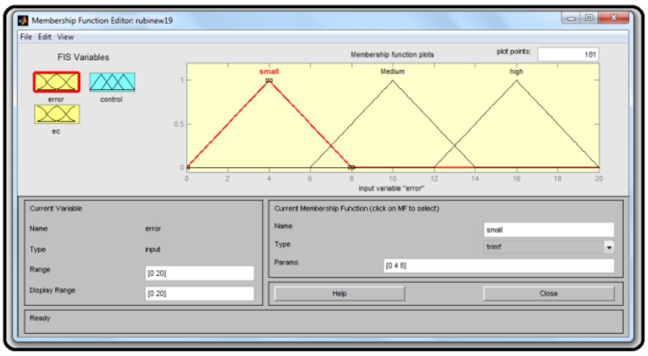

Fig - 5 Fuzzy input variables "error"

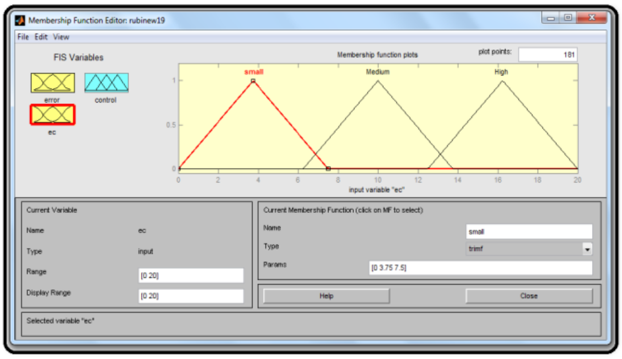

Fig- 6 Fuzzy input variables change in error

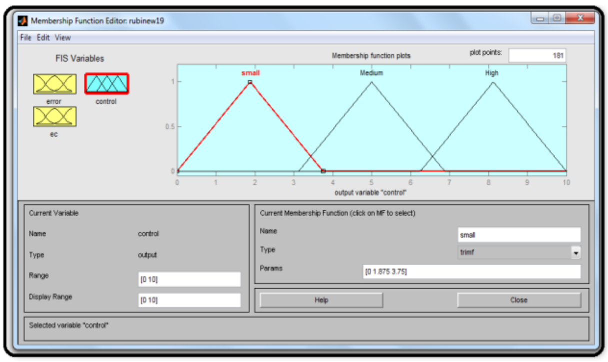

Fig - 7 Fuzzy output variable control.

Design of rules and rule viewer for speed control BLDC MOTOR Fuzzy if then rules are show below in figure 8; in this paper 9 standard rules are design for output variable is show in fig and output response show in figure 9.

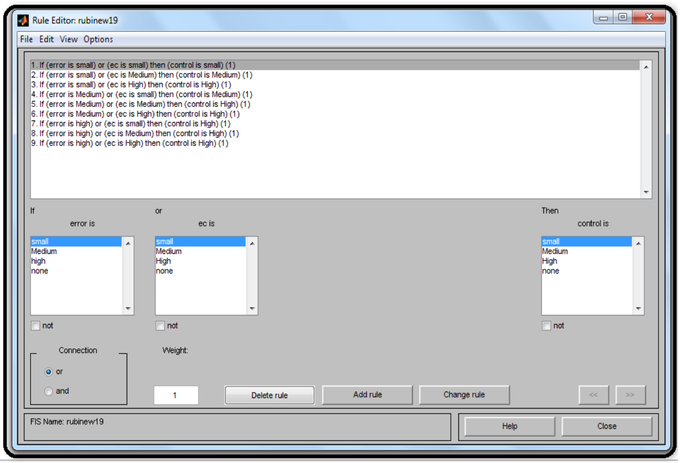

Fig- 8 membership function of the output

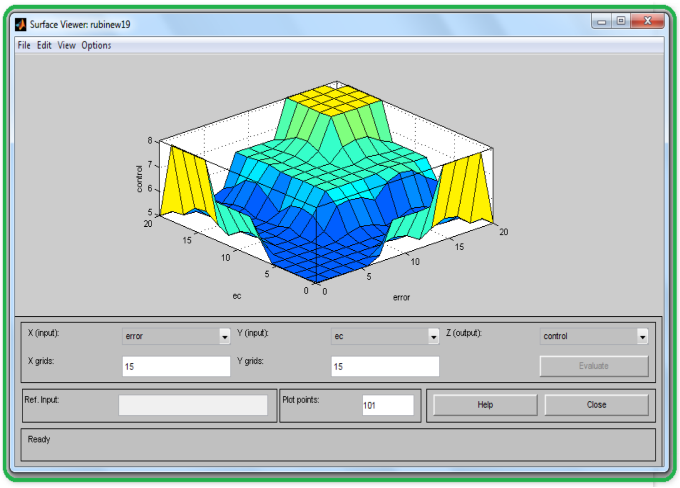

Fig.-9 surface view of output

V. SIMULATION RESULT

The simulation of the BLDC motor is done by using MATLAB/SIMULINK technical computing software package. BLDC MATLAB/SIMULINK model is given in figure 10. Its speed waveforms are analyzed. I- controller, PI- controller and fuzzy controller have been employed for speed control of BLDC motor. Through the simulations of all controllers Response show in figure 11.

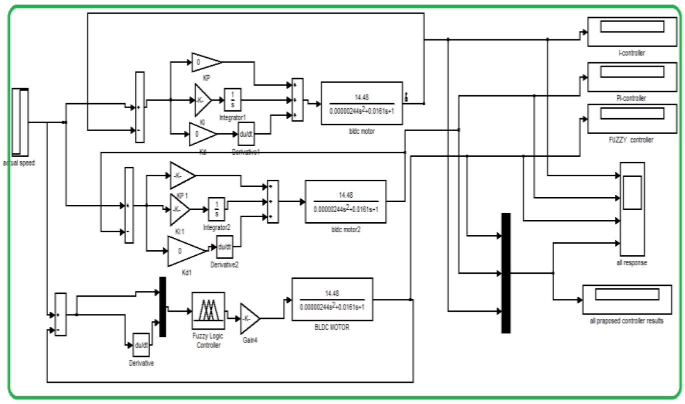

Fig - 10 Simulation model for BLDC Motor

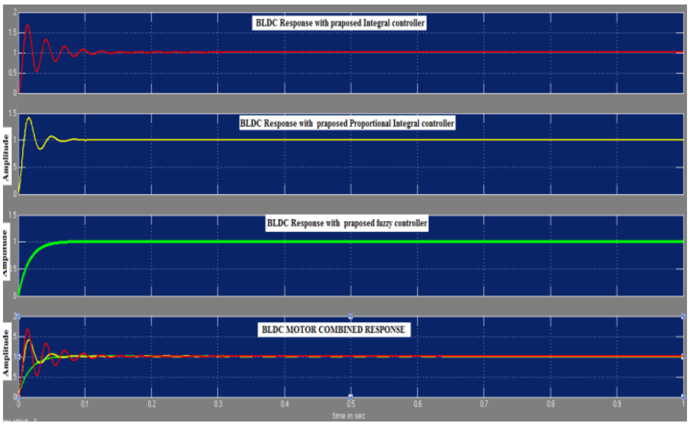

Fig - 11 Step response of system by using proposed all controllers

Comparative study with all proposed controller

In this case above shown figure 12, it can be seen that the overshoot has been considerably reduced with fuzzy logic controller. It shows that the response of the system has greatly improved on application of fuzzy controller. Table 2 It shows that the response of the system has greatly improved on fuzzy controller so proposed controller have proper performance.

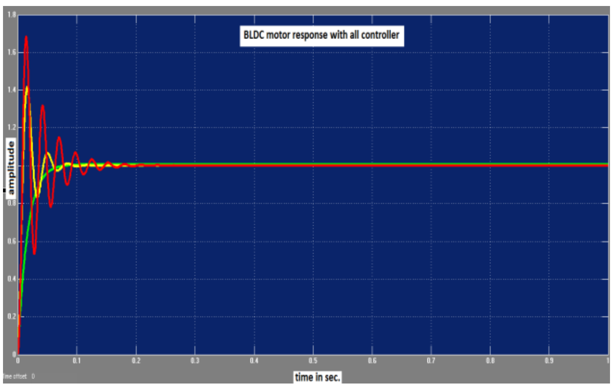

Fig - 12 combined output response of all controllers

Table 2 Comparison between the output responses for controllers

S.NO	Tuning controller	Overshoot	Settling Time	Peak time
1	Integral controller	68.2	0.141	1.68
2	Proportional Integral controller	40.8	0.0719	1.41
3	Fuzzy controller	0.0522	0.0612	1.00

VI. CONCLUSIONS

BLDC motors have many advantages over brushed DC motors and induction motors, such as a superior speed versus torque characteristics, high dynamic response, more efficiency and reliability, cheaper, longer life, quieter, higher speed ranges, and reduction of arcing. In addition, the BLDC motor has higher delivered torque to size ratio. All the above advantages make it useful in applications where space and weight are critical factors, particularly in aerospace applications. The results for different conditions have been presented and analyzed for a BLDC motor.

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BIOGRAPHIES

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