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PID And Fuzzy Control of BLDC Motor

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ABSTRACT: Brushless DC (BLDC) Motors are broadly utilized as a part of enterprises on account of their high productivity and high torque. This paper proposed PID and Fuzzy controller to control the speed of BLDC Motor. This paper gives a diagram of PID controller and Fuzzy controller. PID controllers are lacking to control the speed of BLDC engine as it gives high overshoot in the reaction. S o for the better execution, canny controlle r, for example, Fuzzy is utilized. Fluffy can fulfilled control attributes and it is simple for figuring. The trial comes about confirm that Fuzzy has preferred control execution over the PID controller. The demonstrating, control and impacts are concentrated through PC reenactment utilizing MATLAB/S IMULINK tool kit.

KEYWORDS*:* BLDC, FLC, GGM, PID Controller

I. INTRODUCTION

Regular DC engines [8] are exceedingly proficient and their qualities make them reasonable for use as servomotors. In any case, their exclusive disadvantage is that they require a commutator and brushes which are liable to wear and require upkeep. At the point when the elements of commutator and brushes were executed by strong state switches, support free engines were figured it out. These engines are presently known as brushless dc engines.

Plan of the BLDCM drive includes a mind boggling procedure, for example, displaying, control plot determination, recreation and parameters tuning and so forth. To accomplish coveted level of execution the engine requires appropriate speed controllers. Speed control of BLDC Motors is for the most part done utilizing relative essential Derivative (PID) controller. Ordinary PID controllers are broadly utilized as a part of the business as it has basic control structure and simple to actualize however these controllers are inadequate to control the speed of BLDC engine as it gives high overshoot in the reaction.

Fluffy rationale control offers a change in the nature of the speed reaction. A large portion of these controllers utilize scientific models and are touchy to parametric varieties. These controllers are characteristically strong to load unsettling influences. Moreover, fluffy rationale controllers can be effectively actualized Unlike ordinary brushed sort DC engine, wherein the brushes reach commutator on the rotor in order to shape an electric way between a DC electric source and rotor armature windings BLDC engine utilizes electrical substitution with changeless magnet rotor and a stator with a grouping of curls.

Brushless DC engines (BLDC) have been an abundantly centered region for various engine producers as these engines are progressively the favored decision in numerous applications, particularly in the field of engine control innovation. BLDC engines are better than brushed DC engines from numerous points of view, for example, capacity to work at high speeds, high effectiveness, and better warmth dispersal. They are a vital piece of current drive innovation, most normally utilized for activating drives, machine apparatuses, electric impetus, apply autonomy, PC peripherals and furthermore for electrical power era. With the advancement of sensorless innovation other than computerized control, these engines turn out to be so powerful as far as aggregate framework cost, size and unwavering quality.

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II. MATHEMATICAL MODELING OF BLDC MOTOR

A. Transfer Function

Transfer Function derived by the mathematical modeling [4],

$$G(s) = \frac{1/k_e}{\tau_m \tau_e s^2 + \tau_m s + 1}$$

Where,

$\tau_m =$ Mechanical time constant
$\tau_e =$ Electrical time constant

R = Terminal resistance phase to phase

L = Terminal inductance phase to phase

J = Rotor inertia
k_e = Back emf constant (V-sec/rad)
k_t = Torque constant (Nm/A)

B. Specifications of BLDC Motor[12]

Parameters	Values
Nominal Voltage	9 V
Terminal Resistance phase to phase	1.25 Ω
Terminal Inductance phase to phase	0.32 mH
Torque Constant	10.4 mNm/A
Mechanical Time Constant	60.5 ms
Rotor Inertia	52.3 gcm^2

C. Model of BLDC Motor

Final Transfer Function,

$$G(s) = \frac{32.0816}{5.1624 * 10^{-6} s^2 + 0.0605 s + 1}$$

III. CONTROL SCHEMES

A. PID Controller

Corresponding Integral-Derivative (PID)[7] control is the most well-known control calculation utilized as a part of industry and has been all around acknowledged in modern control. As the name proposes, PID controller calculation includes three separate steady parameters and is likewise now and again called three-term control: relative, fundamental and subordinate. The fundamental point of the PID controller is to detect the sensor flag and assesses the coveted yield by figuring the corresponding, indispensable and subsidiary reactions and summing those three segments to produce the yield. More often than not, framework is influenced by the actuator yield as well as by the outside variables which are called as the unsettling influences. PID controller is typically intended to dispense with the impacts of the aggravations. Figure 1 demonstrates the run of the mill square graph of the PID controller.

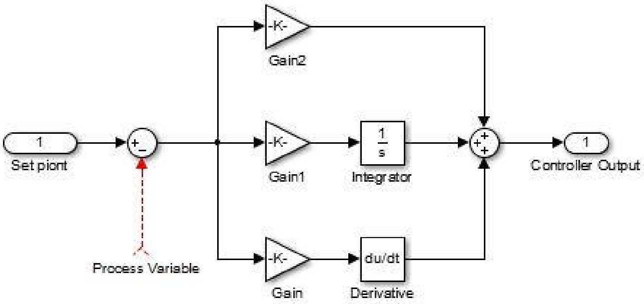

Fig. 1 : PID Block Diagram

Keeping K_P part, set T_i and T_d to infinite and zero respectively, controller gain K_C could be obtained that would sustain the oscillation output which is called the ultimate gain, K_{CU}. For proper oscillations, K_C is set to be less than K_{CU}.

$$1 + K_{CU} * G(s) = 0$$

$$G(s) = \frac{32.0816}{5.1624 * 10^{-6} s^2 + 0.0605\, s + 1}$$

$$1 + K_{CU} * \frac{32.0816}{5.1624 * 10^{-6} s^2 + 0.0605\, s + 1} = 0$$

$$5.1624 * 10^{-6} s^2 + 0.0605\, s + 1 + 32.0816 * K_{CU} = 0$$

Routh's array,

S^2	$5.1624 * 10^{-6}$	$1 + 32.0816 * K_{CU}$
S^1	0.0605	0
S^0	$1 + 32.0816 * K_{CU}$	

For no change in first column,

$$1 + 32.0816 * K_{CU} > 0$$

$$32.0816 * K_{CU} > -1$$

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Closed Loop Response:

Parameters	**Rise Time**	**Overshoot**	**Settling Time**	**S -S Error**
K_P	Decrease	Increase	Small Change	Decrease
K_I	Decrease	Increase	Increase	Eliminate
K_D	Small Change	Decrease	Decrease	No Change

PID Tuning:

There are various method for PID tuning, here two method are used to tune the PID for and the performance of system is compared

1. Trial and Error Method
2. Good Gain Method

1) Trial and Error Method

It is a trial and error method[4] but a computational stability rule is needed to set a mark for its effect. This is done by using the R-H stability rule.

R-H Criteria:

K_{CU}> - 0.03117

The above result shows that the main values of K_{CU} are greater than zero. With a trial and error tuning, the value of K_P can be set to num of the system transfer function i.e. 32.0816. The value of K_I is the inverse value of 0.03117 and the value of K_D is equal to the 0.03117.

So, from trial and error method the obtained value of PID parameters are K_P= 32.0816, K_I = 32.0821, K_D = 0.03117.

2) Good Gain Method

The Good Gain Method[10] is a simple method based on the experiments similarly to a trial and error method. It can be implemented on a simulation set up or on a real system. For tuning the parameters of PID controller, follow the steps given below.

1. Initially, set $T_i = \infty$ and $T_D = 0$ and keep increasing the value of K_P until satisfactorily stable response is obtained i.e. slight overshot and undershoot.
2. Find the value of T_{OU} i.e. the time difference between first overshoot and first undershoot of the response.
3. Calculate the value of T_i

$$T_i = 1.5 * T_{OU}$$

4. Calculate the value of T_D

$$T_D = \frac{T_i}{4}$$

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For the given system, the values of the parameters of PID controller are $K_P = 12$, $K_I = 1350.074$, $K_D = 1.851 * 10^{-4}$

The Simulink model mechanism denotes the closed loop PID controller is shown in figure 2. Here, Trial and Error method and Good Gain technique have been implemented for the tuning of PID parameters is given by.

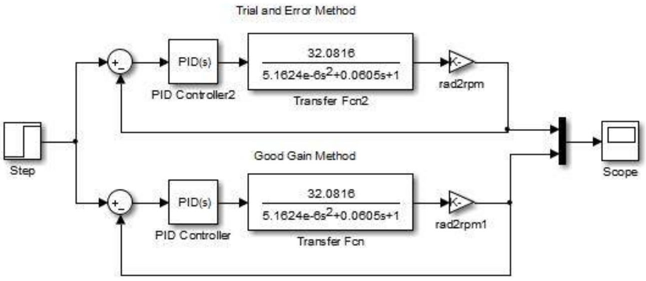

Fig. 2 : Simulink model for the closed loop PID controller

The comparison of the responses of both trial and error method and good gain method is shown in figure 3.

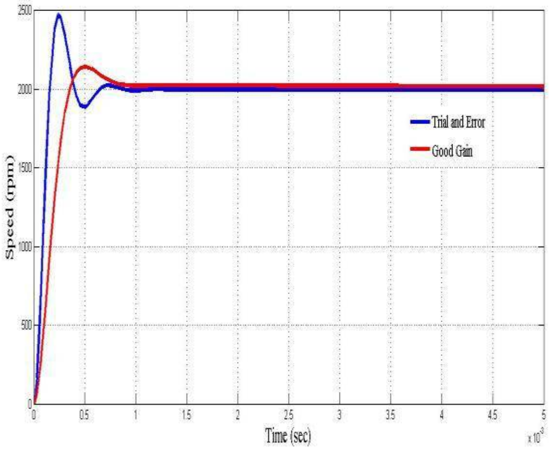

Fig. 3 : Responses of PID Controller

B. Fuzzy Logic Control

The idea of Fuzzy Logic was brought about by Prof. Lotfi A. Zadeh at the University of California at Berkley in 1965. Fluffy rationale is fundamentally a multivalued rationale that enables middle of the road qualities to be characterized between ordinary assessments like yes/no, genuine/false, and so forth. Thoughts like rather warm or quite chilly can be detailed numerically and algorithmically handled. Along these lines an endeavor is made to apply a more humanlike way of thinking in the programming of computers ("soft" computing).

FIS contains three components [3]:

1. Fuzzifier: The fuzzifier denotes input values and determines the degree to which they belong to each of the fuzzy sets via membership functions of fuzzy logic system.

2. Rule base: The rule base contains denotes linguistic rules that are provided by experts. It is also possible to extract rules from numeric data. Once the rules have been established, the FIS can be viewed as a system that maps an input vector to an output vector.

3. Defuzzifier: The Defuzzifier takes the values from fuzzy sets via membership techniques and gives the crisp output.

Simulink model for the Fuzzy Logic controller is shown in figure 4.

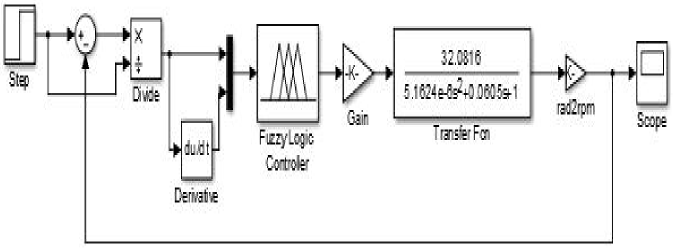

Fig. 4 : Simulink model for the Fuzzy Logic controller

The response of the Fuzzy Logic Control is shown in figure 5.

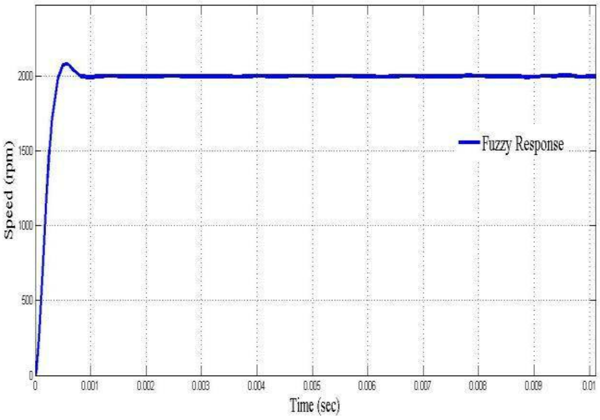

Fig. 5 : response of the Fuzzy Logic Control for speed 2000 rpm

The comparison of the responses of trial and error method, good gain method and Fuzzy Logic Control is shown in figure 6.

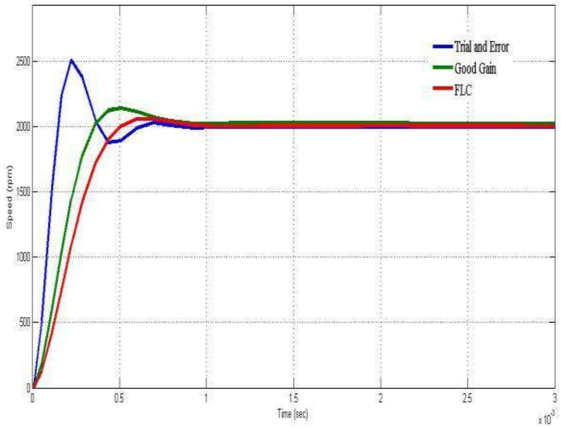

Fig. 6 : Responses of PID and FLC

IV. RESULT

The transient parameter of the system for the different tunin g parameters are obtained and shown in Table 1.

Table 1 : Transient Response for different tuning methods

Tuning Methods	Transient Parameters		
	Rise Time (ms)	**Settling Time (ms)**	**Peak Overshoot (%)**
Trial and error	0.1253	0.7632	23.5
Good Gain	0.24	3.745	7.1

From Table 1, it is clearly visible that the rise time and settling time of the system for the trial and error method is much better than good gain method but good gain method gives much less peak overshoot as compared to trial and error method.

The transient parameter of the system for the different tuning parameters and Fuzzy Logic Control are obtained and shown in Table 2.

Table 2 : Transient Response for PID and FLC

Control Schemes	**Transient Parameters**		
	Rise Time (ms)	**Settling Time (ms)**	**Peak Overshoot (%)**
Trial and error	0.1253	0.7632	23.5
Good Gain	0.24	3.745	7.1
FLC	0.339	0.6949	4.05

From Table 2, it is clearly visible that the settling time and peak Overshoot of the system for the Fuzzy Logic

V. CONCLUSION

With the help of simulation results and the information exhibited, it can be inferred that reaction of the framework is better when PID controller parameter is tuned by GGM rather than experimentation technique. The outcome likewise uncovers that the use of astute control like FLC to the framework can give a superior execution than the regular controller. Other insightful control plans can be utilized to control the framework that may bring about better execution of framework.

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