



SPEED CONTROL OF BLDC MOTOR USING PID CONTROLLER AND FUZZY PID CONTROLLER

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Abstract: BLDC motors are extremely well known and are supplanting brush less motors in various applications. Since the BLDC motor does not require commutator and because of its predominant electrical and mechanical attributes and its capacity to work in dangerous conditions it is more dependable than the DC motor. Generally likewise, drive conduct is measured with the assistance of Back Emf detecting. Since the BLDC motor does not require commutator and because of its prevalent electrical and mechanical qualities and its capacity to work in dangerous conditions it is more solid than the DC motor. Customarily, three-stage inverters are for the most part used to control these motors, requiring a rotor position sensor for beginning and for giving the best possible compensation arrangement to stator windings. The impediments of motor control framework are expanded cost and size of the motor, and need extraordinary mechanical plan for mounting the sensors with a specific end goal to control the BLDC motor, a Fuzzy PID controller is planned as the controller of the BLDC motor. The test results check that a Fuzzy PID controller has preferable control execution over the ordinary PID controller. The displaying, control and recreation of the BLDC motor have been done utilizing the product bundle MATLAB/SIMULINK.

Keywords – Fuzzy PID controller, BLDC motor drives, Speed Estimation, back-EMF. PID Controller

1. INTRODUCTION

For as long as two decades a few Asian nations, for example, Japan, which have been under weight from high energy costs, have actualized variable pace PM motor drives for energy sparing applications, for example, aeration and cooling systems and iceboxes [1]. Then again, the U.S.A. has continued utilizing modest actuation motor drives, which have around 10% lower productivity than customizable PM motor drives for energy sparing applications. Hence as of late, the expansion in energy costs goads higher requests of variable rate PM motor drives. Likewise, late fast multiplication of motor crashes into the car business, in view of half and half drives, produces a genuine interest for high effective PM motor drives, and this was the start of enthusiasm for BLDC motors. BLDC motors, additionally called Permanent Magnet DC Synchronous motors, are one of the motor sorts that have all the more quickly picked up prominence, basically as a result of their better attributes and execution [2]. These motors are utilized as a part of an incredible measure of mechanical segments on the grounds that their engineering is appropriate for any wellbeing basic applications. The brushless DC motor is a synchronous electric motor that, from a demonstrating point of view, looks precisely like a DC motor, having a straight relationship amongst current and torque, voltage and rpm. It is an electronically controlled replacement framework, rather than having a mechanical compensation, which is commonplace of brushed motors. Also, the electromagnets don't move, the perpetual magnets pivot and the armature stays static. This gets around the issue of how to exchange current to a moving armature. With a specific end goal to do this, the brush-framework/commutator gathering is supplanted by an astute electronic controller, which plays out the same force dispersion as a brushed DC motor [3]. BLDC motors have numerous focal points over brushed DC motors and prompting motors, for example, a superior velocity versus torque qualities, high element reaction, high effectiveness and unwavering quality, long working life (no brush disintegration), silent operation, higher pace reaches and lessening of electromagnetic obstruction (EMI). In the investigation, the motor pace is kept steady and the heap is differing from zero to top torque. The motor pace holding steady under fluctuating burden condition is an alluring way to deal with control the motor under shifting burden condition. By utilizing this methodology, PID controller is utilized in this framework to beat the undesirable undershoot of motor velocity because of fluctuating burden sway at certain strange conditions. The proposed framework model utilizing PID control plan, is composed on Mat lab and reenactments performed on Simulink stage. In this paper, the pace control procedure of independently energized DC motor under differing load condition is given reenactments. The DC motor model is produced and Mat lab recreation has been done under exasperating burden conditions on Simulink stage. Fuzzy PID controller is utilized in this control framework keeping in mind the end goal to get craved reaction of the framework. The operation and tuning principles of fuzzy PID controller, PID controller is likewise talked about. Toward the end, test result is exhibited and talked about.

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2. BRUSHLESS DC MOTORS

The Brushless DC motor is additionally alluded to as an electronically driven motor. There are no brushes on the rotor and the substitution is performed electronically at certain rotor positions. The stator attractive circuit is typically produced using attractive steel sheets. The stator stage windings are embedded in the spaces or it can be twisted as one loop on the attractive shaft. The polarization of the perpetual magnets and their dislodging on the rotor are picked such a route, to the point that the Back-EMF shape is trapezoidal as appeared in Figure 2. This permits the three stage voltage framework, with a rectangular shape to be utilized to make a rotational field with low torque ripples.[4]

The leading interim for every stage is 120o electrical point. The compensation stage succession resemble AB-AC-BC-BA-CA-CB, where A, B, C are the three stages. Every leading stage is called one stage. In this manner, just two stages conduct current whenever, leaving the third stage gliding. So as to deliver most extreme torque, the inverter ought to be commutated each 60o, so present is in stage with the back EMF. The recompense timing is dictated by the rotor position, which can be distinguished by position sensors. At the point when a BLDC motor pivots, every winding creates a voltage known as back Electromotive Force or back EMF, which contradicts the principle voltage supplied to the windings as indicated by Lenz's Law. The extremity of this back EMF is in inverse heading of the invigorated voltage. Back EMF depends basically on three components (an) Angular speed of the rotor, (b) Magnetic field produced by rotor magnets and (c) the quantity of turns in the stator windings

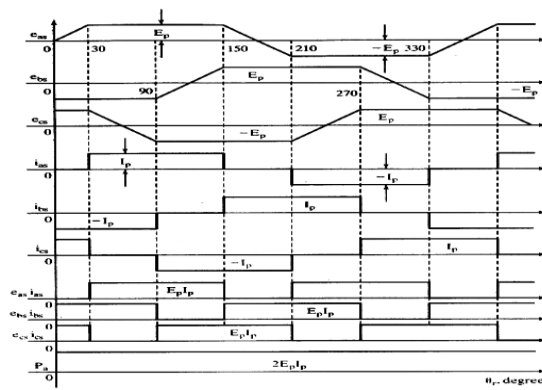


Figure.1: PM Brushless DC Motor waveforms

BLDC motors are a lower of the most usually utilized DC motor, the brushed DC motor, and they have the same torque and pace execution bend qualities. The significant distinction between the two is the utilization of brushes. BLDC motors don't have brushes (henceforth the name "brushless DC") and must be electronically commutated [5]. Replacement is the demonstration of changing the motor stage streams at the fitting times to deliver rotational torque .DC motors use mechanical commutators and brushes to accomplish the compensation .BLDC Motors use Hall Effect sensors set up of commutators.

The stators of BLDC motors are the curls, and the rotors are the changeless magnets. The stators build up the attractive fields to make the rotor pivoting .The BLDC Motor works in numerous modes (stages), however the most well-known is the 3-phase.The 3-stage has better productivity and gives very low torque. The 3phase has a decent exactness in control .The qualities conditions of BLDC motors can be represented as:

$$v_{app}(t) = L \frac{di(t)}{dt} + R \cdot i(t) + v_{app}(t) \tag{1}$$

$$v_{app}(t) = K_t \cdot \omega(t) \tag{2}$$

$$T(t) = K_t \cdot i(t) \tag{3}$$

$$T(t) = J \frac{d\omega(t)}{dt} + D \cdot \omega(t) \tag{4}$$

Where $v_{app}(t)$ is the applied voltage, $\omega(t)$ is the rotor speed,

L is the inductance of the stator, $i(t)$ is the current of the circuit, R is resistance of the stator, $v_{app}(t)$ is the back electromotive power , T is the torque of motor, D is thick coefficient , J is the snippet of dormancy , K_t is the motor torque consistent , and K_b is the back electromotive power steady.

Fig.2 shows the block diagram of BLDC Motor, from the characteristics equations of the BLDC motor, the transfer function of speed model is obtained:

$$\frac{\omega(s)}{v_{app}(s)} = \frac{K_t}{LJ \cdot s^2 + (LD + RJ)S + K_t K_b} \tag{5}$$

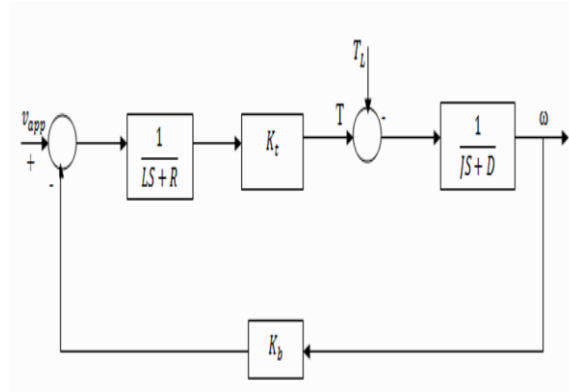


Figure.2: The block diagram of BLDC motor

The parameters of the motors used for simulation are as follows:

Table I PARAMETERS OF THE MOTOR

PARAMETERS	Values and units
R	21.2 Ω
K_t	0.1433 Vs $\square\square\square-1$
D	1*10-4Kg-m s/ rad
L	0.052 H
K_b	0.1433 Kg-m/A
J	1*10-5Kgm \square^2 /rad

3. CIRCUIT DESCRIPTIONS AND OPERATION

The complete block diagram of speed control of three phase BLDC Motor is below Fig. 3. Two control loops are used to control BLDC motor. The inner loop synchronizes the inverter gates signals with the electromotive forces. The outer loop controls the motor's speed by varying the DC bus voltage. Voltage Source Inverter circuit of BLDC Motor is shown below Fig. 4.

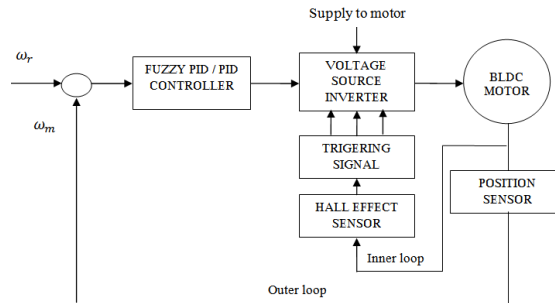


Figure.3: Block Diagram of Speed Control Of Brushless Dc Motor

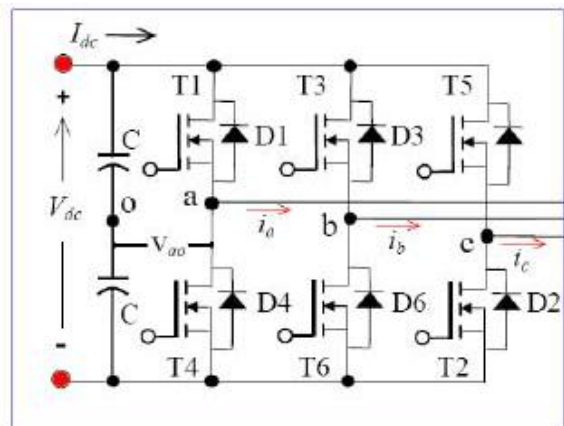


Figure.4:Voltage Source Inverter

Driving circuitry consists of three phase power convertors, which utilize six power transistors to energize two BLDC motor phases concurrently. The rotor position, which determines the switching sequence of the MOSFET transistors, is detected by means of 3 Hall sensors mounted on the stator. By using Hall sensor information and the sign of reference current (produced by Reference current generator), Decoder block generates signal vector of back EMF. The basic idea of running motor in opposite direction is by giving opposite current. Based on that, we have Table I for calculating back EMF for Clockwise of motion and the gate logic to transform electromagnetic forces to the 6 signal on the gates is given Table II.

Table ii. Clockwise rotation

Hall sensor A	Hall sensor B	Hall sensor c	EMF A	EMF B	EMF C
0	0	0	0	0	0
0	0	1	0	-1	1
0	1	0	-1	1	0
0	1	1	-1	0	1
1	0	0	1	0	-1
1	0	1	1	-1	0
1	1	0	0	1	-1
1	1	1	0	0	0

Table Iii: Gate Logics

EMF A	EMF B	EMF C	Q1	Q2	Q3	Q4	Q5	Q6
0	0	0	0	0	0	0	0	0
0	-1	1	0	0	0	1	1	0
-1	1	0	0	1	1	0	0	0
-1	0	1	0	1	0	0	1	0
1	0	-1	1	0	0	0	0	1
1	-1	0	1	0	0	1	0	0
0	1	-1	0	0	1	0	0	1
0	0	0	0	0	0	0	0	0

4. CONTROLLING CIRCUIT

4.1. PID Controller

Consider the characteristics parameters – proportional (P), integral (I), and derivative (D) controls, as applied to the diagram below in Fig.5, the system,

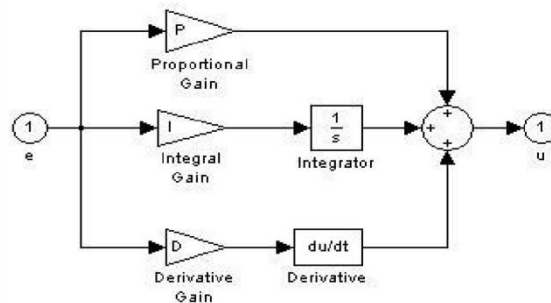


Figure. 5: Simulation model of PID Controller

A PID controller is simple three-term controller. The letter P, I and D stand for P- Proportional, I- Integral, D- Derivative. The transfer function of the most basic form of PID controller, is

$$C(S) = K_P + \frac{K_I}{S} + K_D S \quad (1)$$

$$C(S) = \frac{K_D S^2 + K_P S + K_I}{S} \quad (2)$$

Where K_P = Proportional gain, K_I = Integral gain and K_D = Derivative gain. The control u from the controller to the plant is equal to the Proportional gain (K_P) times the magnitude of the error plus the Integral gain (K_I) times the integral of the error plus the Derivative gain (K_D) times the derivative of the error.

$$u = K_p e + K_i \int e dt + K_d \frac{de}{dt} \quad (3)$$

Due to its simplicity and excellent if not optimal performance in many applications, PID controllers are used in more than 95% of closed-loop industrial processes. We are most interested in four major characteristics of the closed-loop step response. They are

Rise Time: the time it takes for the plant output Y to rise beyond 90% of the desired level for the first time.

Overshoot: how much the peak level is higher than the steady state, normalized against the steady state.

Settling Time: the time it takes for the system to converge to its steady state.

Steady-state Error: the difference between the steady-state output and the desired output.

The Values of K_p , K_i and K_d values of PID Controller is shown in below table III are obtained by using the ZN method.

Tableiv:Pidvalues

controller	K_p	K_i	K_d
PID	0.8	48	0.01

4.2. Fuzzy PID Controller

Fuzzy PID controller used in this paper is based on two inputs and one output. The overall structure of used controller is shown in Fig. 6. In Fuzzy PID controller only one output which are connected to K_p , K_i and K_d . Real interval of variables is obtained by using scaling factors which are S_e , S_{de} and S_u . The fuzzy control rule is in the form of: IF $e=E_i$ and $ce=dE_j$ THAN $UPD=UPD(i,j)$. These rules are written in a rule base look-up table which is shown in Fig. 8. The rule base structure is Mamdani type.

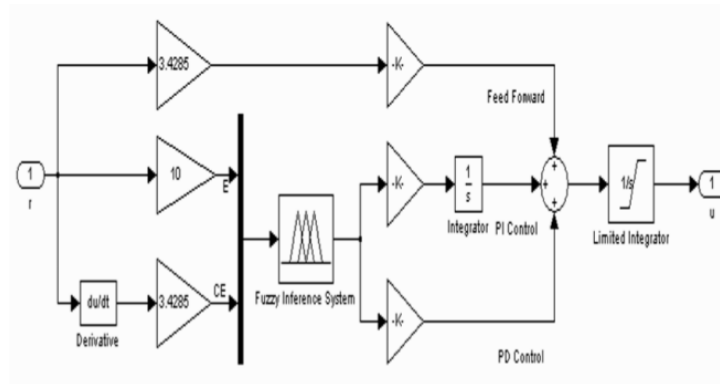


Figure 6:Simulation of Fuzzy PID Controller

FLC has two inputs and one output. These are error (e), error change (de) and control signal, respectively. A linguistic variable which implies inputs and output have been classified as: NB, NM, NS, Z, PS, PM, PB. Inputs and output are all normalized in the interval of $[-3,3]$ as shown in Fig. 7.

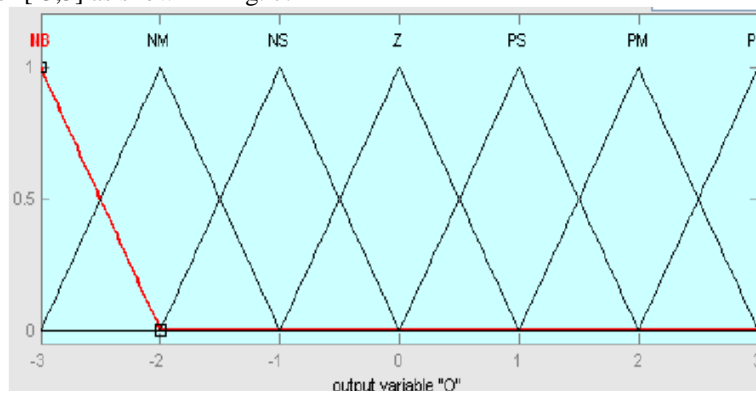


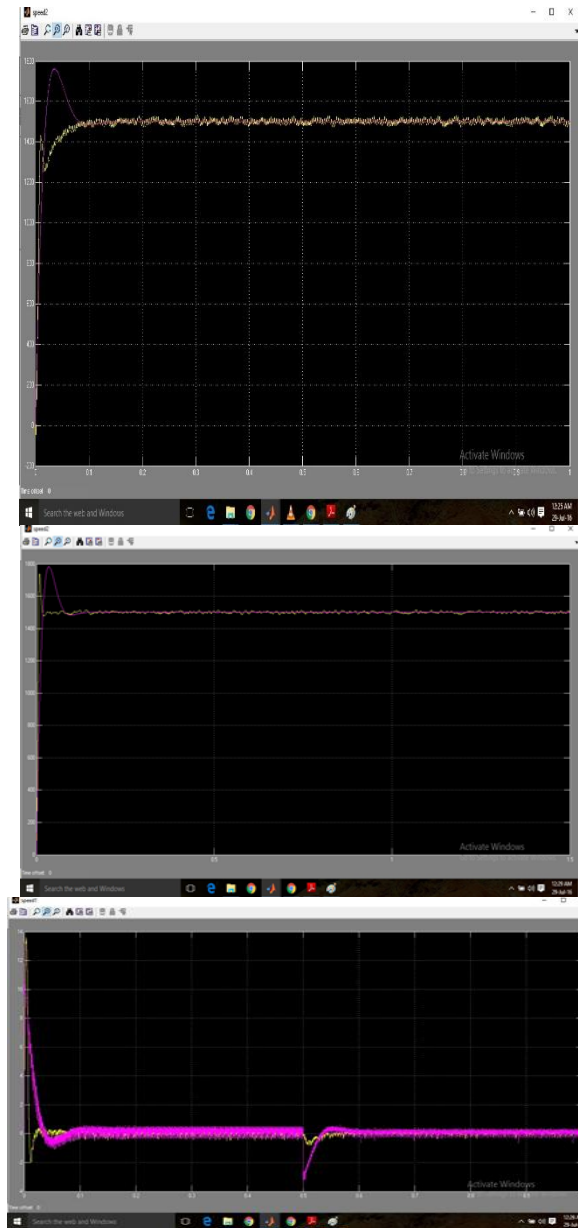
Figure 7: Membership functions of output

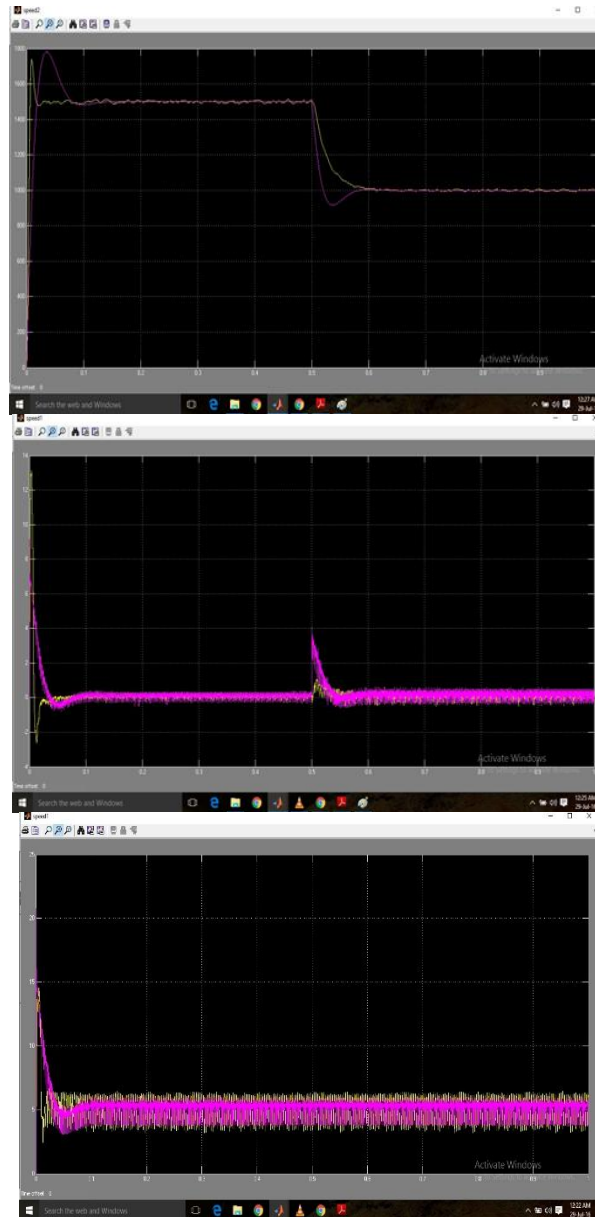
The linguistic labels used to describe the Fuzzy sets were „Negative Big“ (NB), „Negative Medium“ (NM), Negative Small“ (NS), Zero (Z), Positive Small (PS), Positive Medium (PM), Positive Big“ (PB). It is possible to assign the set of decision rules as shown in Table IV. The fuzzy rules are extracted from fundamental knowledge and human experience about the process. These rules contain the input/the output relationships that define the control strategy. Each control input has seven fuzzy sets so that there are at most 49 fuzzy rules.

Table v. Fuzzy rules

CE \ E	NB	NM	NS	Z	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	Z
NM	NB	NB	NB	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	NS	Z	PS	PM	PB	PB	PB
PB	Z	PS	PM	PB	PB	PB	PB

5. SIMULATION RESULTS





6. CONCLUSION

A performance comparison of PID Controller and fuzzy PID controller has been carried out by several simulations. The results have shown that fuzzy PID controller regulator is better than conventional PID controller under variable operating conditions such as sudden variation in load conditions. The performance of FPIDC is excellent for reducing torque ripples. The conclusion is that fuzzy regulator is found to be more robust, stable flexible and insensitive to parameter variations as compared with conventional PID Controllers.

7. REFERENCES

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