SPEED CONTROL OF BLDC MOTOR USING ADAPTIVE FUZZY PID CONTROLLER

A PROJECT REPORT (EEB4441)

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ABSTRACT

Brushless DC (BLDC) Motors are widely employed in a variety of industrial applications because of their high efficiency, high torque, and low volume. To accomplish the speed of the BLDC Motors, this work proposed an improved Adaptive Fuzzy PID controller. The performance of Conventional PID controllers, Fuzzy PID controllers, and Adaptive Fuzzy PID controllers are discussed in this work. Using a standard PID controller to set the parameters and achieve satisfactory control characteristics is tough. Because the Adaptive Fuzzy has the capacity to satisfy control qualities while also being simple to compute, it is a good choice. The experimental results show that an Adaptive Fuzzy PID controller outperforms both a Fuzzy PID controller and a conventional PID controller in terms of control performance. The BLDC motor was modelled, controlled, and simulated using the MATLAB/SIMULINK software suite.

Keywords—BLDC Motors, Conventional PID controller, Fuzzy PID controller, Adaptive Fuzzy PID controller, MATLAB.

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CHAPTER 1

INTRODUCTION & OBJECTIVE

1.1 PROJECT OVERVIEW

In industry, there are primarily two types of dc motors. The first is the traditional dc motor, which generates flux by passing current through the stationary field coil building made out of poles. The brushless dc motor is the second type, where the air gap is created by the permanent magnet instead of wire-wound field poles, flux is used. The BLDC (brushless DC) motor is also known as permanent magnet synchronous motor. Back EMF waveform having a trapezoidal shape.

As a result, Brushless DC motors as the name suggests do not use brushes for commutation; instead, they are commutated electronically and High-performance BLDC motor drives have recently become popular and utilized in industrial variable speed drive systems electrified cars and applications.

In practice, designing the BLDCM drive entails a lengthy procedure that includes modelling, control scheme selection, simulation, and parameter tuning. Several new control strategies for the speed control design of BLDC motors have recently been proposed. Conventional PID controller algorithm on the other hand is simple, stable, easy to alter, and has a high level of reliability. Conventional speed control system is utilized in conventional PID control. However, most industrial processes include varying degrees of nonlinearity, parameter fluctuation, and mathematical model uncertainty. Tuning PID control settings is challenging due to their lack of resilience; as a result, achieving the ideal state under field conditions in actual production is tough.

The speed regulation system of a BLDC motor is given an adaptive-fuzzy PID control. Under adaptive fuzzy PID control, the parameter can be modified in real time. An increase in the number of inputs and membership functions was required to improve the performance of the adaptive-fuzzy PID controller system, while an independent set of rules was developed for each Kp, Ki, and Kd. The controller can adapt to any change in parameter by employing a unique set of rules. In the Fuzzy PID controller, however, only a single set of rules is produced for Kp, Ki, and Kd

1.2 OBJECTIVE:

The objective of this project is to control the speed of the BLDC motor by using different controllers. The performance of Conventional PID controllers, Fuzzy PID controllers, and Adaptive Fuzzy PID controllers are discussed in this work. Using a standard PID controller to set the parameters and achieve satisfactory control characteristics is tough. Because the Adaptive Fuzzy has the capacity to satisfy control qualities while also being simple to compute, it is a good choice. The experimental results show that an Adaptive Fuzzy PID controller outperforms both a Fuzzy PID controller and a conventional PID controller in terms of control performance.

CHAPTER 2

LITERATURE SURVEY

R.Kandiban and R.Arulmozhiyal "Design of Adaptive Fuzzy PID Controller for Speed control of BLDC Motor" in International Journal of Soft Computing and Engineering (IJSCE), March 2012.

In this paper they implemented and compared the performance of Conventional PID controller, Fuzzy PID controller and Adaptive Fuzzy PID controller to control the speed of BLDC motors. It is difficult to tune the parameters and get satisfied control characteristics by using normal conventional PID controller. As the Adaptive Fuzzy has the ability to satisfied control characteristics and it is easy for computing. The experimental results verify that a Adaptive Fuzzy PID controller has better control performance than the both Fuzzy PID controller and conventional PID controller. The modeling, control and simulation of the BLDC motor have been done using the software package MATLAB/SIMULINK.

Kanaiya Bhatt, Sandip Dhoranwala and Ajay Bosamiya "Simulation of Brushless DC Motor Speed Control in Matlab" in International Journal of Advance Engineering and Research Development, December 2017.

The main objective of this paper is to control the speed of BLDC motor and displays its speed. The speed control of the BLDC motors is very essential. This proposed system provides a very precise and effective speed control system. The user can increase or decrease the speed as per the requirement and the motor will run at that exact speed. In this paper also the Simulink, modeling and controlling of BLDC motor using MATLAB/SIMULINK.

CHAPTER 3

DESIGNING &MODELLING OF BLDC MOTOR

3.1 BLOCK DIAGRAM

The complete block design of three phase BLDC motor speed control is shown in Fig3.1. The BLDC motor is controlled by two control loops. The inverter gates signals are synchronized with the electromotive forces by the inner loop. The DC bus voltage is varied in the outer loop to adjust the motor's speed. Three phase power converters with six power transistors energize two BLDC motor phases at the same time make up the driving circuitry.

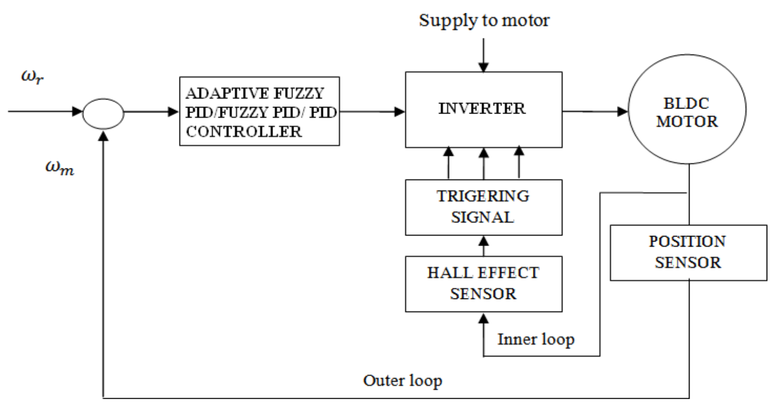

Fig3.1 Block diagram of Speed Control of BLDC Motor

Three Hall sensors located on the stator detect the rotor position, which dictates the MOSFET transistors and switching sequence. Decoder block generates signal vector of back EMF using Hall sensor information and the sign of reference current (generated by Reference current generator).

Unlike a brushed DC motor, the commutation of a BLDC motor is controlled electronically. To rotate the BLDC motor, the stator windings should be energized in a sequence. It is important to know the rotor position in order to understand which winding will be energized following the energizing sequence.

Rotor position is sensed using Hall effect sensors embedded into the stator. Most BLDC motors have three Hall sensors embedded into the stator on the non-drying end of the motor. Whenever the rotor magnetic poles pass near the Hall sensors, they give a high or low signal, indicating the N or S pole is passing near the sensors. Based on the combination of these three Hall sensor signals, the exact sequence of commutation can be determined.

For the estimation of the rotor position, the motor is equipped with three hall sensors. These hall sensors are placed every 120°. With these sensors, 6 different commutations are possible. Phase commutation depends on hall sensor values. Power supply to the coils changes when hall sensor values change. With right synchronized commutations, the torque remains nearly constant and high

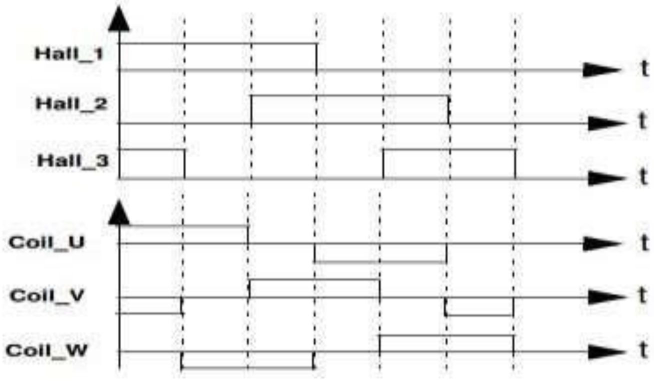

Fig3.2 BLDC Motor Hall sensor signal graph

3.2 SIMULATION MODEL DIAGRAM OF SPEED CONTROL OF BLDC MOTOR

With the help of the designed circuit parameters, the MATLAB simulation is done and results are presented here. Speeds are set at 300 rpm and load torque disturbance are applied at time t= 0.1 sec. The speed regulations are obtained at set speed and the simulation results are shown. The wave form of the back emf are shown in fig3.3. it can be seen the phasor voltages are displaced by 120 deg. The stator current waveforms are shown in fig. They are quasi sinusoidal in shape and displaced by 120 deg.

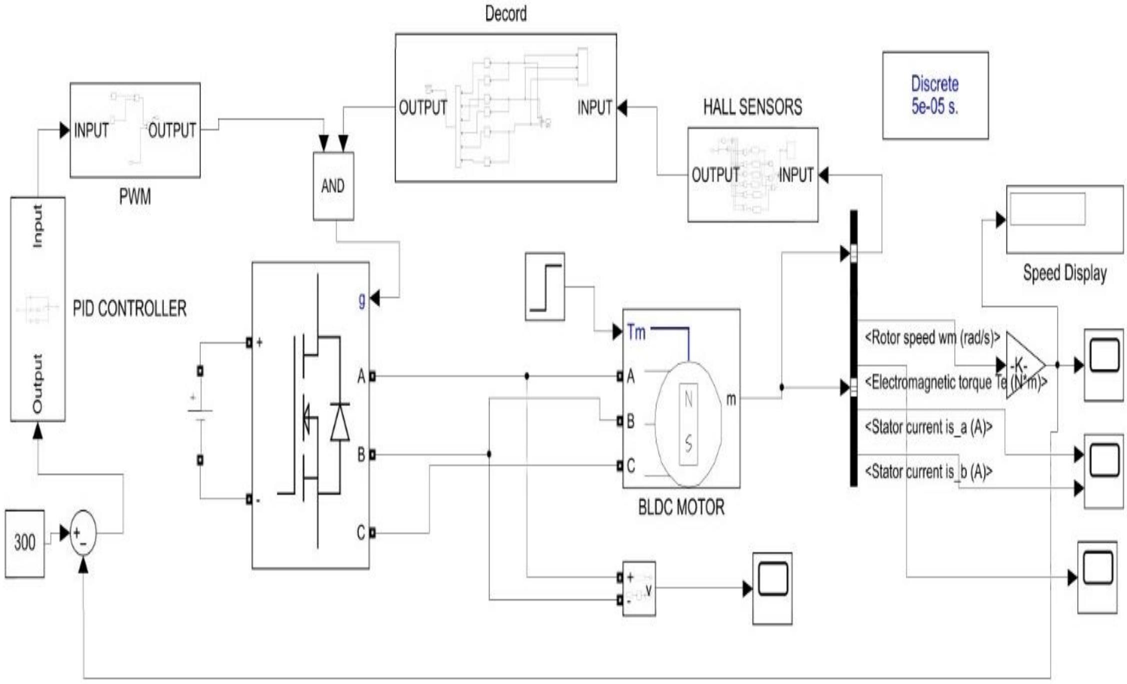

Fig3.3 Simulation Model diagram

CHAPTER 4

CONTROLLER CIRCUITS

4.1 PID CONTROLLER:

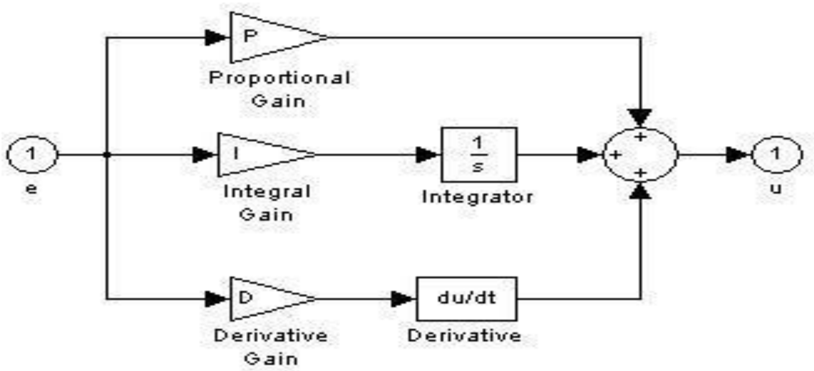

Fig4.1 Simulation Model of PID Controller

PID Controller Consider the characteristics parameters – proportional (P), integral (I), and derivative (D) controls, as applied to the diagram below in Fig.4.1, the system. 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

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

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

Where KP = Proportional gain, KI = Integral gain and KD = Derivative gain. The control u from the controller to the plant is equal to the Proportional gain (KP) times the magnitude of the error plus the Integral gain (Ki) times the integral of the error plus the Derivative gain (Kd) times the derivative of the error.

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

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

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

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

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

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. 4.2.

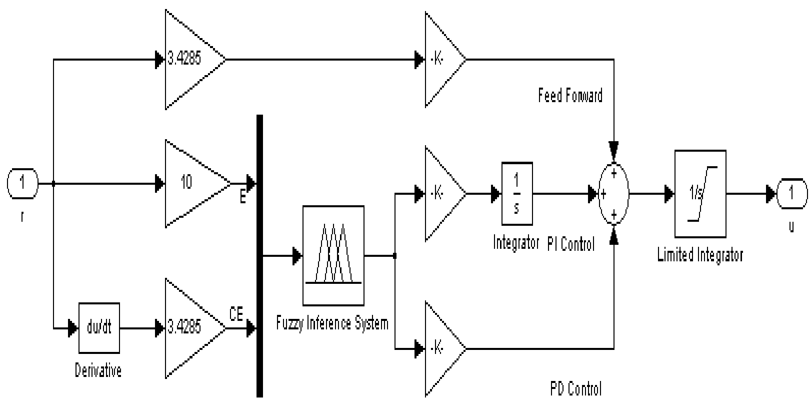

Fig4.2 Simulation Model of Fuzzy PID Controller

In Fuzzy PID controller only one output which are connected to Kp, Ki and Kd. Real interval of variables is obtained by using scaling factors which are Se, Sde and Su. The fuzzy control rule is in the form of: IF e=Ei and ce=dEj THAN UPD=UPD(i,j).

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 [-5,5] as shown in Fig4.4.

Controller Input:

Error(e):

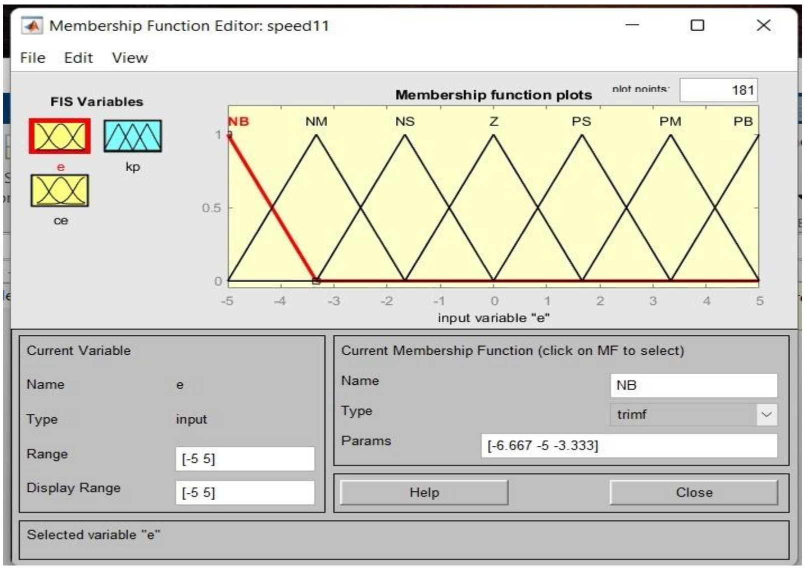

Fig4.3 Fuzzy PID Controller Error(e)

The range of the error is set to -5 to 5. The error part is differentiated into seven major parts that is given below in the fuzzy lookup table.

Change in Error(ce):

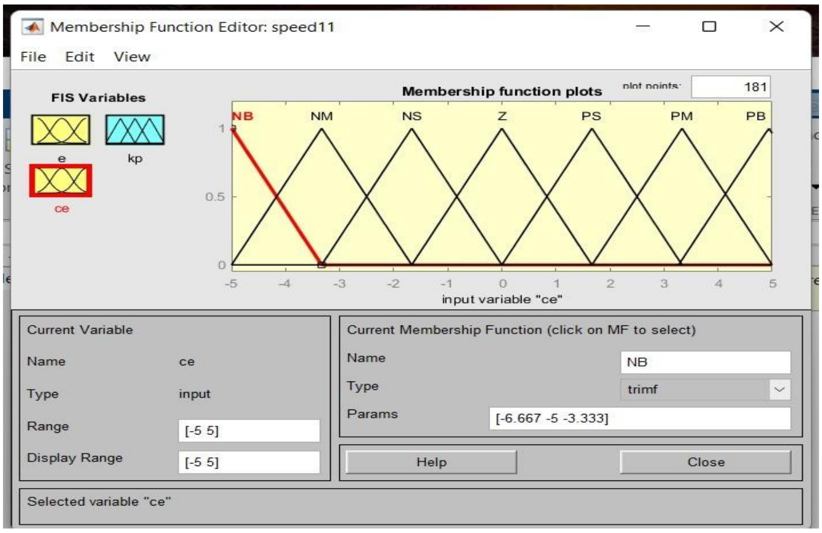

Fig4.4 Fuzzy PID controller Change in Error(ce)

Controller Output:

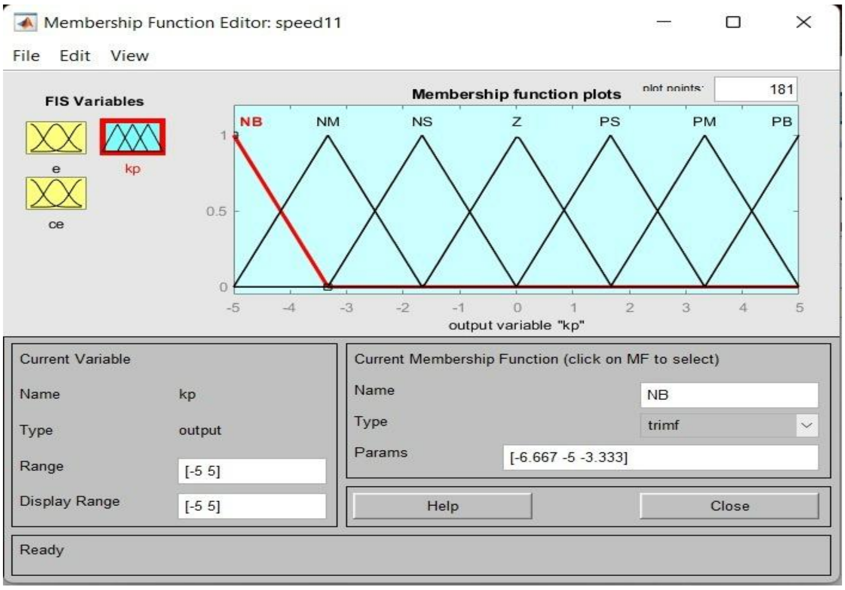

Fig4.5 Membership Function of Kp Output

E \ CE	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

Tab 4.1 Fuzzy Lookup Table

Control action:

The following is the control action taken by the controller in the simulation. There are two types of viewer in the matlab.

Surface viewer:

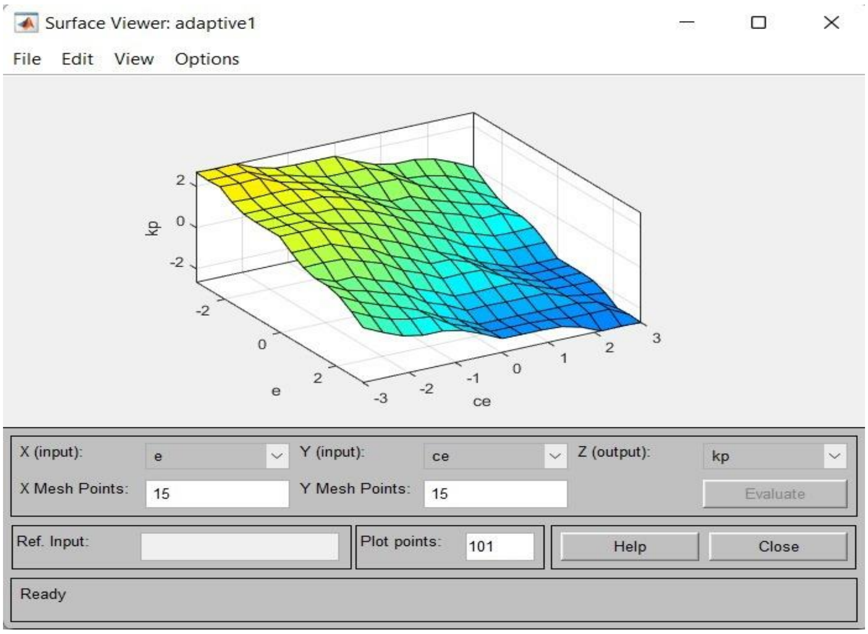

Fig4.6 Surface Viewer for Kp

Rule Viewer:

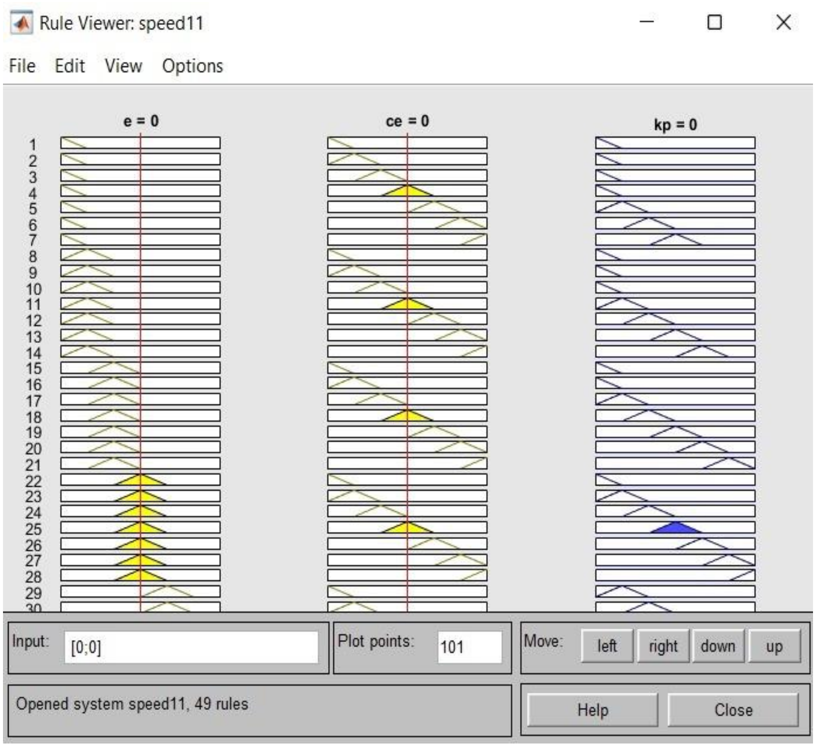

Fig4.7 Rule Viewer for Kp

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 4.1. 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.

4.3 ADAPTIVE FUZZY PID CONTROLLER:

Adaptive Fuzzy PID controller used in this paper is based on two input and three output. The overall structure of used controller is shown in Fig. 5. In Fuzzy PID controller have three outputs which are Kp, Ki and Kd.

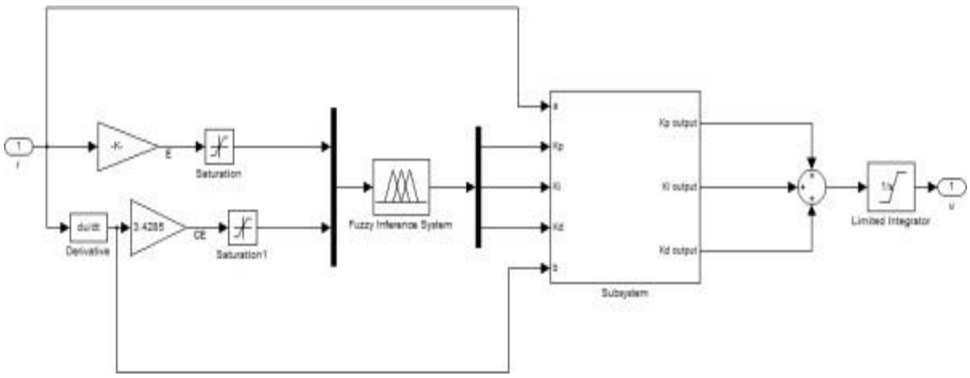

Fig4.8 Simulation Model of Adaptive Fuzzy PID Controller

Error speed (E) and Change in error speed (CE) as fuzzy control input and fuzzy outputs are ΔKp, ΔKi, Δkd.

$$\Delta Kp = Kp.\Delta Kp1 \quad (4)$$

$$\Delta Ki = Ki.\Delta Kp1 \quad (5)$$

$$\Delta Kd = Kd.\Delta Kp1 \quad (6)$$

A linguistic variable which implies inputs and output have been classified as: NB, NM, NS, Z, PS, PM, PB. Inputs normalized in the interval of [-2,2] and output ΔKp interval [-3,3], ΔKp interval [-1,1] and ΔKp interval [-5,5]. The output membership of ΔKp fuzzy set is shown fig4.9.

Controller Output:

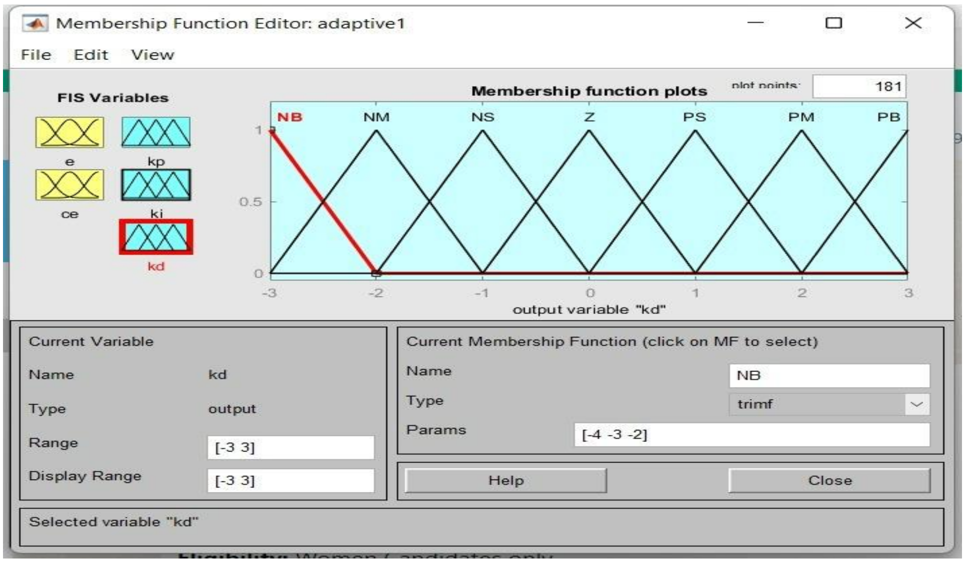

Fig4.9 *Membership Function of K_d Output*

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

Tab 4.2 Fuzzy Lookup Table

Control action:

The following is the control action taken by the controller in the simulation. There are two types of viewer in the matlab.

Surface Viewer:

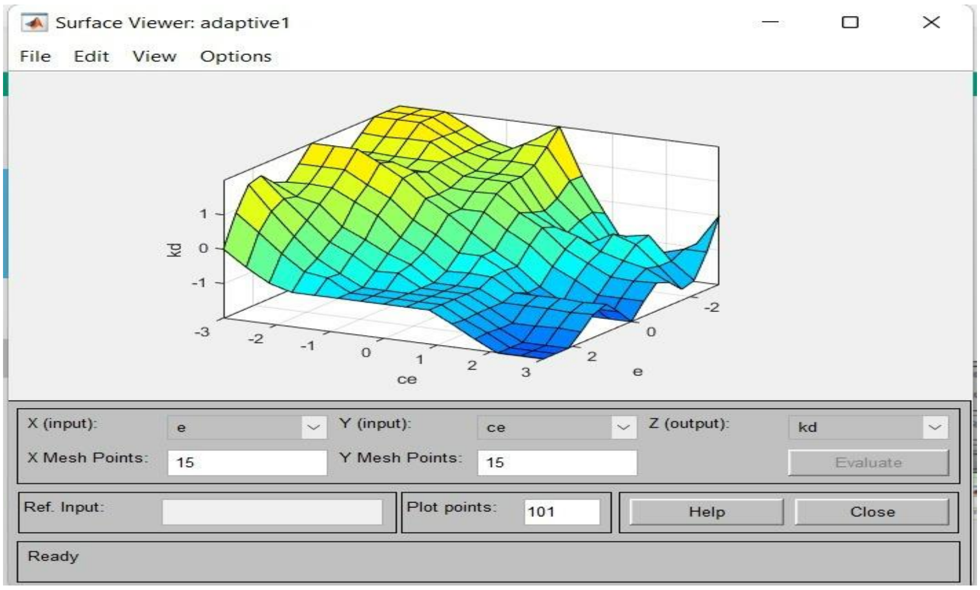

Fig4.10 *Surface Viewer for Kp*

Rule Viewer:

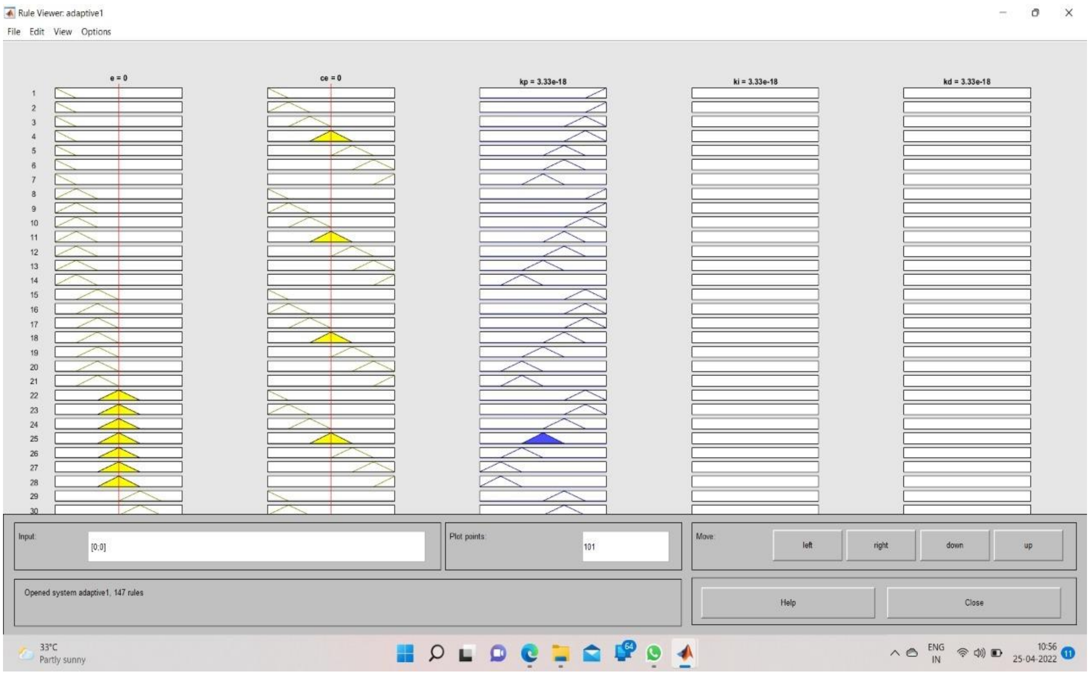

Fig4.11 Rule Viewer

This paper uses a mamdani fuzzy interference reasoning algorithm and ambiguity resolution uses center of gravity method. Then, the output of ΔKp, ΔKi, Δkd can be obtained by ambiguity resolution.

CHAPTER 5

SIMULATION RESULTS & GRAPHS

5.1 SIMULATION RESULTS:

Fig. 7 as shown performance of the Adaptive Fuzzy PID controller, Fuzzy PID controller and Conventional PID Controller of BLDC Motor on Reference speed of 300rpm with no load condition of speed. The results show that conventional PID controller, fuzzy PID controller and fuzzy PID controller reach settling time are , 0.10 sec respectively.

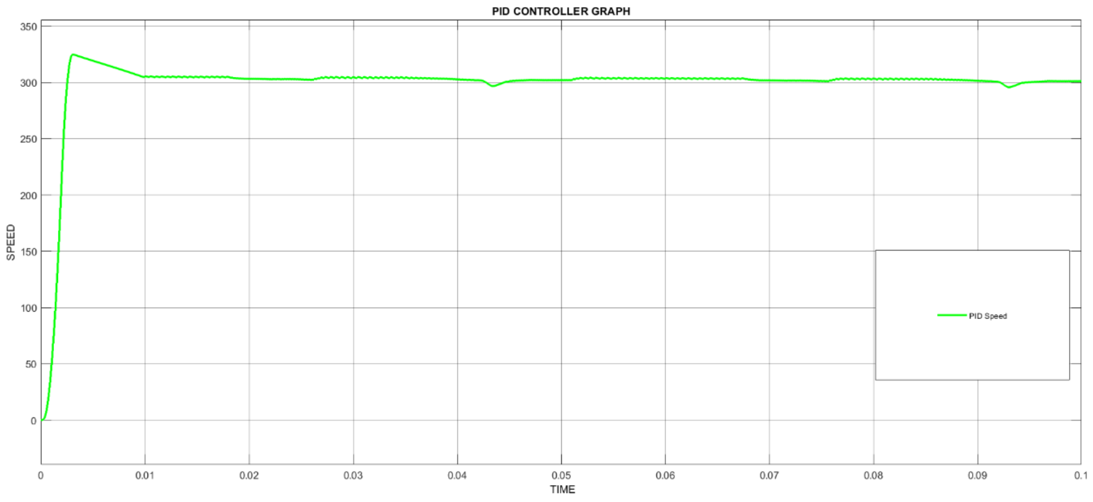

Fig5.1 PID Control Reference speed of 300 rpm with no load Speed

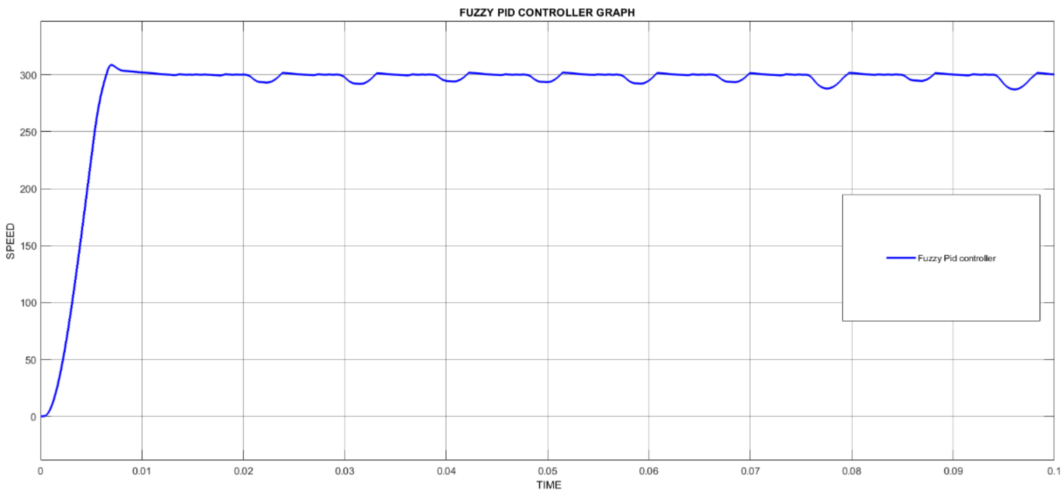

Fig5.2 Fuzzy PID Control Reference speed of 300 rpm with no load Speed

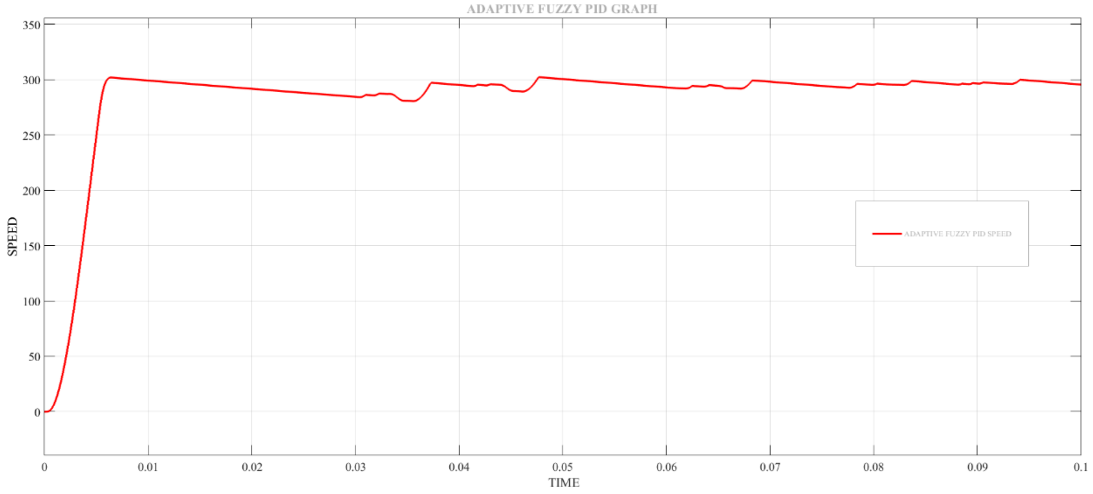

Fig5.3Adaptive Fuzzy PID Control Reference speed of 300 rpm with no load Speed

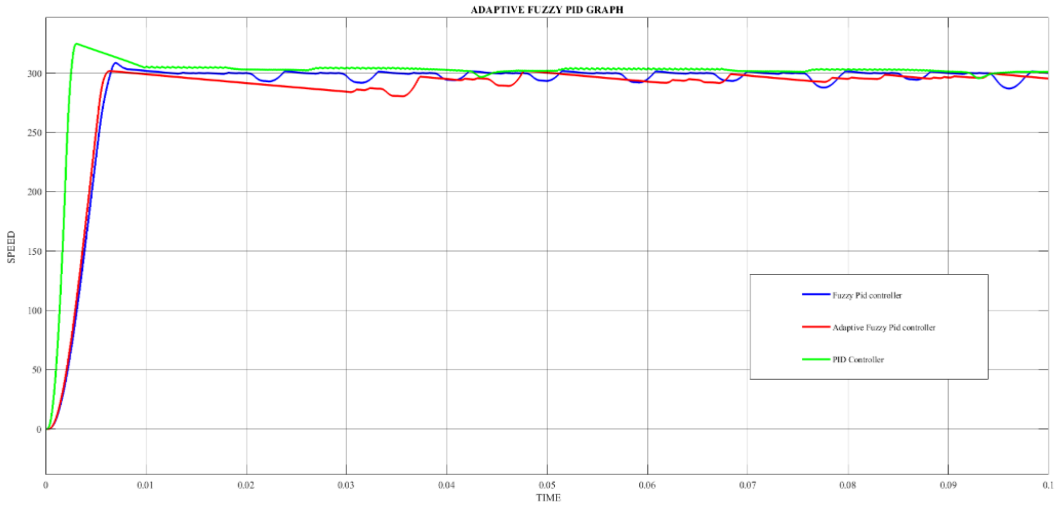

Fig5.4 Reference speed of 300 rpm with no load Speed

5.2 PERFORMANCE RESULTS:

PID CONTROLLER:

Speed	PID Controller		
	tr	***%Mp***	***ts***
300 noload	0.0202	16.53	0.35
300load	0.0206	16.60	0.35
200 – 300 noload	0.0201	16.40	0.35
200 – 300 withload	0.0205	16.60	0.35
300 - 200 noload	0.0202	16.53	0.35
300 - 200 withload	0.0206	16.60	0.35
300 load impact	0.0202	16.53	0.35

Tab 5.1Performance Result of PID Controller

FUZZY PID CONTROOLER:

Speed	Fuzzy PID Controller		
	tr	***%Mp***	***ts***
300 noload	0.0061	13.13	0.10
300load	0.0390	1.37	0.25
200 – 300 noload	0.0042	55.10	0.15
200 – 300 withload	0.0391	0.86	0.20
300 - 200 noload	0.0061	13.13	0.15
300 - 200 withload	0.039	1.37	0.25
300 load impact	0.0061	13.13	0.15

Tab5.2 Performance Result of Fuzzy PID Controller

ADAPTIVE FUZZY PID CONTROLLER:

Speed	Adaptive Fuzzy PID Controller		
	tr	***%Mp***	***ts***
300 noload	---	---	0.10
300load	---	---	0.10
200 – 300 noload	---	---	0.57
200 – 300 withload	---	---	0.59
300 – 200 noload	---	---	0.58
300 – 200 load	---	---	0.59
300 load impact	---	---	0.l0

Tab5.3 Performance Result of Adaptive Fuzzy PID Controller

From performance comparison a Fuzzy PID controller has better control performance than the conventional PID controller.

CHAPTER 6

CONCLUSION

This paper presents simulation results of conventional PID controller, Fuzzy PID controller and Adaptive Fuzzy PID controller of three phase BLDC Motor. In conventional PID control it is not necessary to change the control parameters as the reference speed changes. With results obtained from simulation, it is clear that for the same operation condition the BLDC speed control using Adaptive Fuzzy PID controller technique had better performance than the conventional PID controller and Fuzzy PID controller, mainly when the motor was working at lower and higher speeds. In addition, the motor speed to be constant when the load varies.

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