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INVESTIGATING THE EFFECT OF DIFFERENT SHAPES OF MEMBERSHIP FUNCTIONS IN FUZZY LOGIC USING FUZZY-PID CONTROLLED DC MOTOR

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Abstract: Conventional PID Control System has been used in the past and still today it is adequate for many industrial applications for controlling purposes. However, with a highly nonlinear plant, a time varying plant, or which has a large time delay, this controller has performed quite poorly. In this study, a kind of fuzzy self-adaptive PID controller is used. From past experiments, results have shown that the fuzzy self-adaptive PID has the strong anti-jamming, flexibility and adaptability as well as the higher control precision in speed controlling system. Using the fuzzy and simulink tools in MATLAB simulation software, we shall implement the fuzzy self-adaptive PID. A PID controller is an instrument used in industrial control applications to regulate temperature, flow, pressure, speed and other process variables. PID (proportional integral derivative) controllers use a control loop feedback mechanism to control process variables and are the most accurate and stable controllers. This has been for long the only and handy controller for control engineers. It however did not produce satisfactory results for some applications. Through extensive research, other controllers have been developed and approved for use and some are still under test. Fuzzy Logic Controller is one, already being used and has shown better results for nonlinear applications. Fuzzy logic controllers are based on fuzzy sets, that is, classes of objects in which the transition from membership to non-membership is smooth rather than abrupt. A merge of these two to form a Fuzzy-based PID controller has even shown excellent results due to the balance of the existing trade-offs between them. The main target I have is to implement the controllers in the software and to show the comparison of the results of the system using specifically triangular and gaussian membership functions. This way, we shall be able to discuss the results and make informed conclusions on when, where, and how to use these controllers best. For future research in this area, issues such as changes in dynamic loads should be put in to consideration to ensure that the model is implementable in real life situation.

Key words: Fuzzy logic, Fuzzy-PID, Membership Function, Overshoot, Rise time.

I. INTRODUCTION

In our world, we are surrounded by different machines and equipment whose speed value is crucial to us. It is therefore important to measure the speed accurately for the purpose of controlling it to the required amounts. Motors and automobiles are the most common.
Speed measurement has been an interesting topic of study and has been implemented in the past yet it's still under research. Several techniques have been developed by experts to achieve this. Controllers and algorithms have been created for this important function but none, as an individual has achieved satisfying results.
The conventional PID controller is always the first choice for control and instrumentation engineers due to the advantage of *easy design* and *easy to use*. Fuzzy Logic Controllers provide a "simple rule-based **IF X AND Y THEN Z** approach to solving a control problem rather than attempting to model a system mathematically." Fuzzy logic uses some numerical parameters in order to operate which may include the '*error*' and '*the rate of change of the error*'. The error (e) and the change rate of the error (de) are the inputs of the fuzzy logic controller. It is the output variable of the fuzzy logic that adjusts the parameters of the PID controller as shall be seen in the fuzzy-pid controller block diagram.
I have chosen to delve into this research topic to seek understanding of the effect of different shapes. I will use a Fuzzy-PID Controller, change the shapes of the membership functions then compare the different results obtained for analysis and conclusion.

II. THE PROBLEM

There have not been very precise results but 'estimations' in the area of parameter control. This, in very sensitive applications like chemical plants have caused big trouble. There is therefore dire need to have a controller that can give exact results as required. However, it is almost impossible to implement a system with zero error but I believe we can achieve a level of getting a negligible error.

III. ASSUMPTIONS

The main assumption that I will go with in my implementation is, there are no parametric variations. For the different models in test here, I will use a dc motor with constant parameters. This is to help me understand easily the effect of each model on that same motor.

IV. ORGANIZATION OF THE STUDY

I have organized this work in to four main parts. The first chapter is basically the foundation of my study. Here there is introduction, the problem statement, and assumptions as introductory information. In the second part which I have called "Literature Review", we shall tackle the subject deeper by studying the background theory around it and by studying the work that has been done before in the same line. Part three has the methodology and results obtained from the simulations. The fourth and final part has the results, analysis, and conclusion.

V. LITERATURE REVIEW

Over the years, several authors have been working on different structures of PID controllers. Zamani *et al*. proposed implementation of fractional order (FO) controller for automatic voltage regulator in which parameters of FOPID are optimized using PSO algorithm. In their work, the time domain and frequency domain criteria are taken into consideration for performance evaluation of controller and it has been found that the performance of FOPID controller is better than the PID controller.

Delavari et al. presented a fractional adaptive PID controller for a robotic manipulator in which the parameters of PID controller have been updated online and the other two parameters fractional derivative and integral are determined offline. The tracking error in fractional controller is less as compare to conventional PID controller. To attain better performance of system, the parameters of controller have to be optimized whether it is conventional controller or intelligent controller.

In the field of engineering, many optimization algorithms, inspired from nature and evolution, such as genetic algorithm (GA), Simulated annealing (SA), Ant colony optimization, PSO, Firefly algorithm, and Artificial bee colony have been proposed. The performance of PSO is better in terms of convergence and has less number of parameters.

In another very recent work done by Kumar *et al.* of Thapar University, Patiala India, we see their main focus being to design an FOPID controller for HEV to maintain the performance of HEV, in the presence of parametric variations and external disturbances. They combine the Particle Swarm Optimization (PSO) algorithm with FOPID to achieve their goal. The transient response which includes the stiffness of response represented by rise time (tr), the closeness of response to the desired response represented by the overshoot (Os) and the settling time (Ts), the error integral criteria includes IAE, Integral of Square Error (ISE), Integral of Time Squared Error (ITSE) were studied to get the better overall performance of the vehicle. This formed the basis of my research because this is exactly my area of interest. These are the parameters am keenly looking into controlling. Using this paper, we shall see the results achieved and through this, we shall also be able to see the results I achieve with my model.

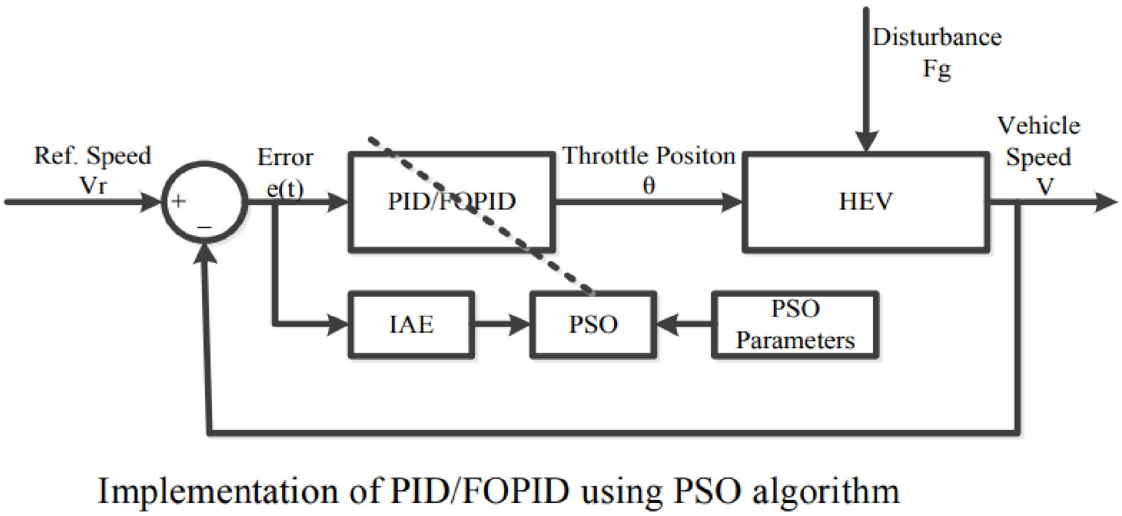
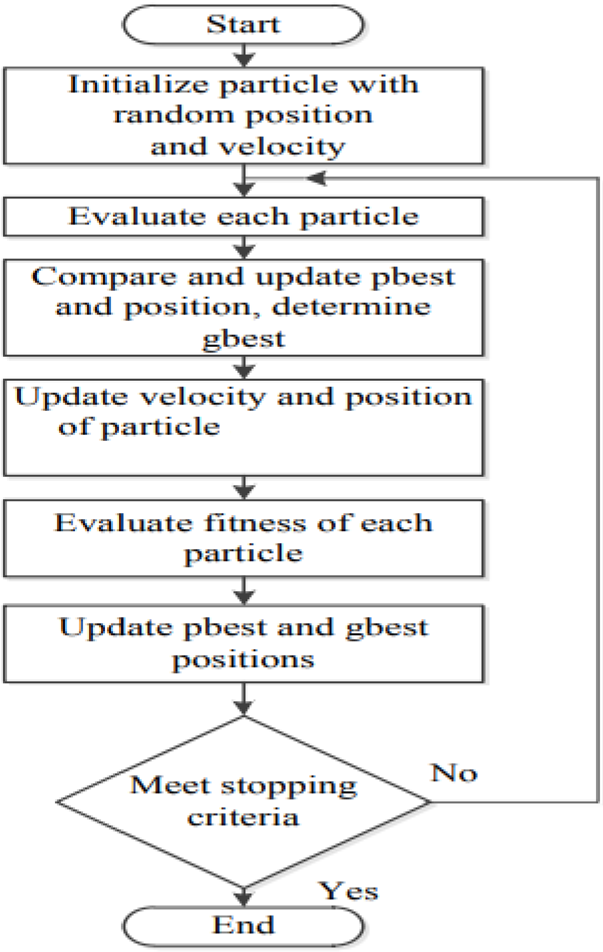


Fig.1: showing block diagram for PID/FOPID with PSO



Flow chart of PSO algorithm

Fig.2: showing the flowchart for PSO algorithm

Through simulations, many graphs of comparison of different arrangements were plotted. There were clear differences with insights from the implementations. Of interest to me are the specific parameters recorded in the two tables below to show how the models performed in parametric variations:

TRANSIENT RESPONSE AND ERROR INTEGRAL CRITERIA COMPARISON

Performance Parameters	Controller				
	PID	**PID-ZN**	**FOPID**	**PSO-PID**	**PSO-FOPID**
ISE(m/sec)	85.11	66.92	56.79	37.25	25.89
IAE(m/sec)	10.77	8.09	6.16	4.69	3.15
ITSE(m/sec)	29.33	16.39	7.70	3.89	2.15
O_s(%)	30	28.5	17	2	1
t_r(sec)	0.397	0.329	0.310	0.279	0.227
t_s(sec)	1.73	1.64	1.21	0.35	0.22

Fig.4: showing results of different controllers

COMPARISON OF PID AND FOPID FOR PARAMETRIC VARIATIONS

Parametric variation		μ= 0.012, α= 0.01, m =800		μ=0.01, α=0.04, m =1200	
Performance Parameters	Controller	PID	FOPID	PID	FOPID
ISE(m/sec)		25.94	25.94	40.41	28.51
IAE(m/sec)		4.69	3.17	5.05	3.45
ITSE(m/sec)		3.88	2.85	4.49	2.48
O_s(%)		1.9	1	4.5	3
t_r(sec)		0.27	0.22	0.26	0.21
t_s(sec)		0.32	0.22	0.34	0.23

Fig.5: showing different results under parametric variations

The performance of PSO tuned PID and FOPID has been compared in terms of IAE, ISE, ITSE, overshoot, rise time and settling time. The FOPID controller offered the better transient and steady state response as compared to integer order PID controller. FOPID offers more flexibility as it requires five parameters to be tuned as compared to conventional PID controller which requires three parameters to be tuned.

VI. METHODOLOGY

FUZZY LOGIC MODEL

Implementing of fuzzy logic, I have two input variables and one output. The *error* and the *change in error* are my two inputs in to the controller while the output is labeled as *F-output* to mean ‘fuzzy output’.

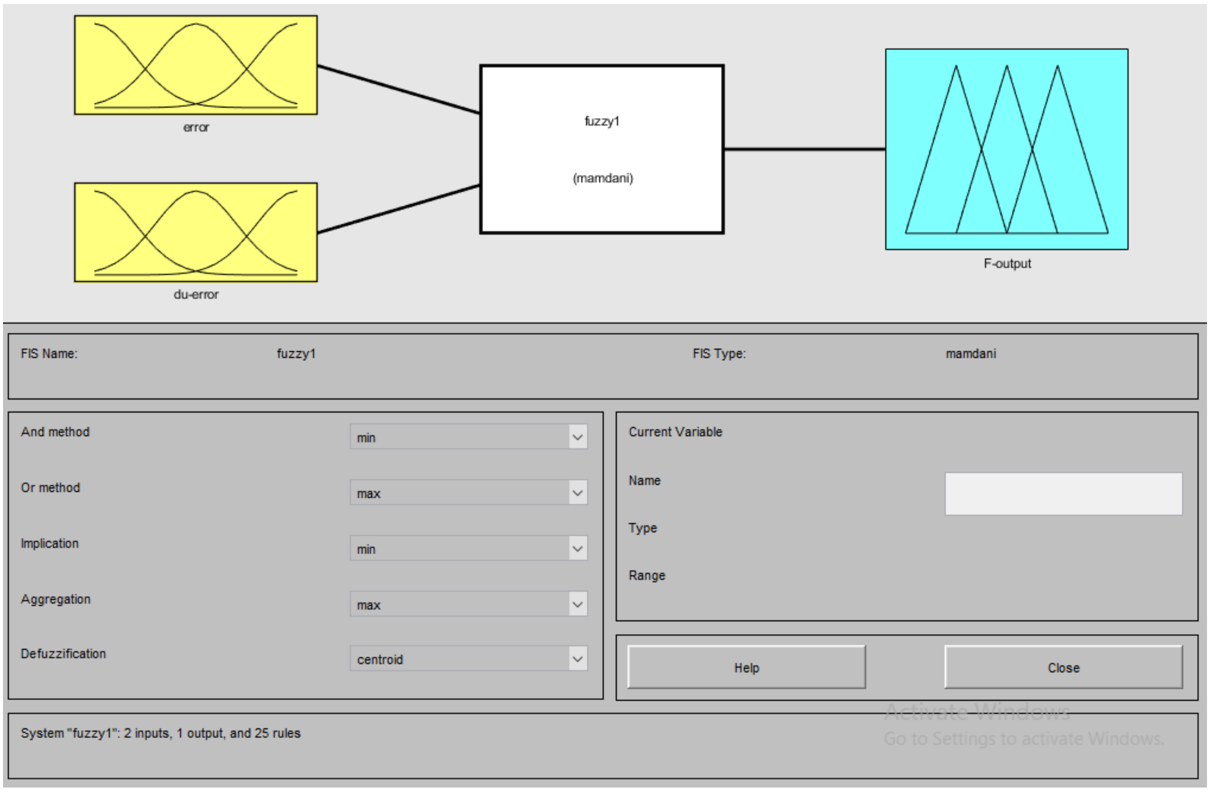


Fig.6: showing the implementation of fuzzy logic

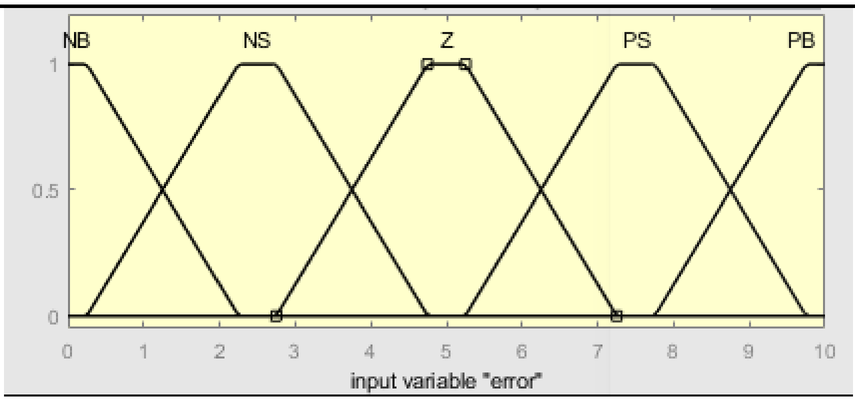


Fig. 7: Showing membership functions for error input

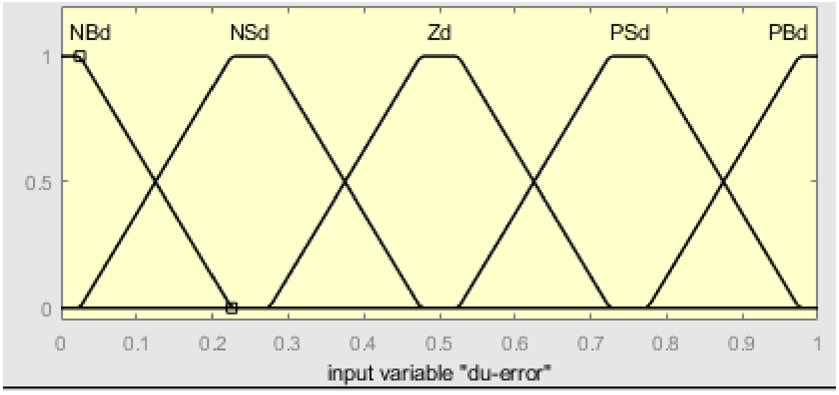


Fig. 8: Showing membership functions for du-error input

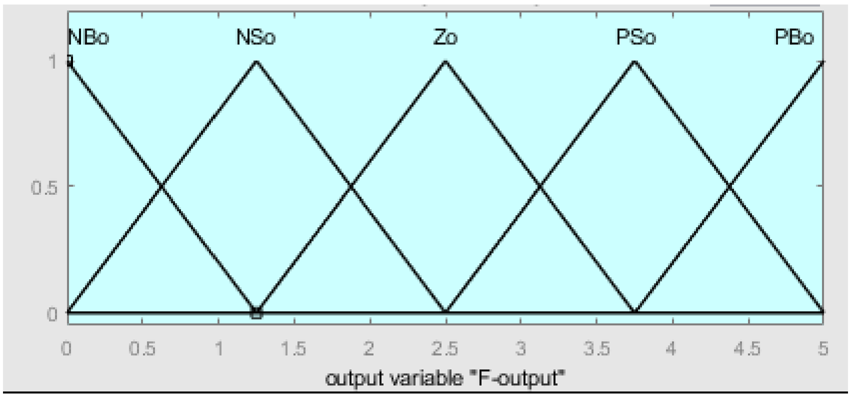


Fig. 9: Showing membership functions for F-output

Table 1: Showing the fuzzy rules

du/dt error / error	PB	PS	Z	NS	NB
NB	Z	NS	NB	NB	NB
NS	PS	Z	NS	NS	NS
Z	PB	PS	Z	NS	NB
PS	PS	PS	PS	Z	NS
PB	PB	PS	PB	PS	Z

The linguistic variables which implies input have been categorised as: NB(Negative Big), NS (Negative Small), Z (zero), PS (Positive Small), and PB (Positive Big). The fuzzy rules are extracted from fundamental knowledge and human experience about the process. These rules contain the input /output relationship that defines control strategy. In this examination, I have formulated 25 fuzzy set rules represented in the table above, from the five membership set functions.

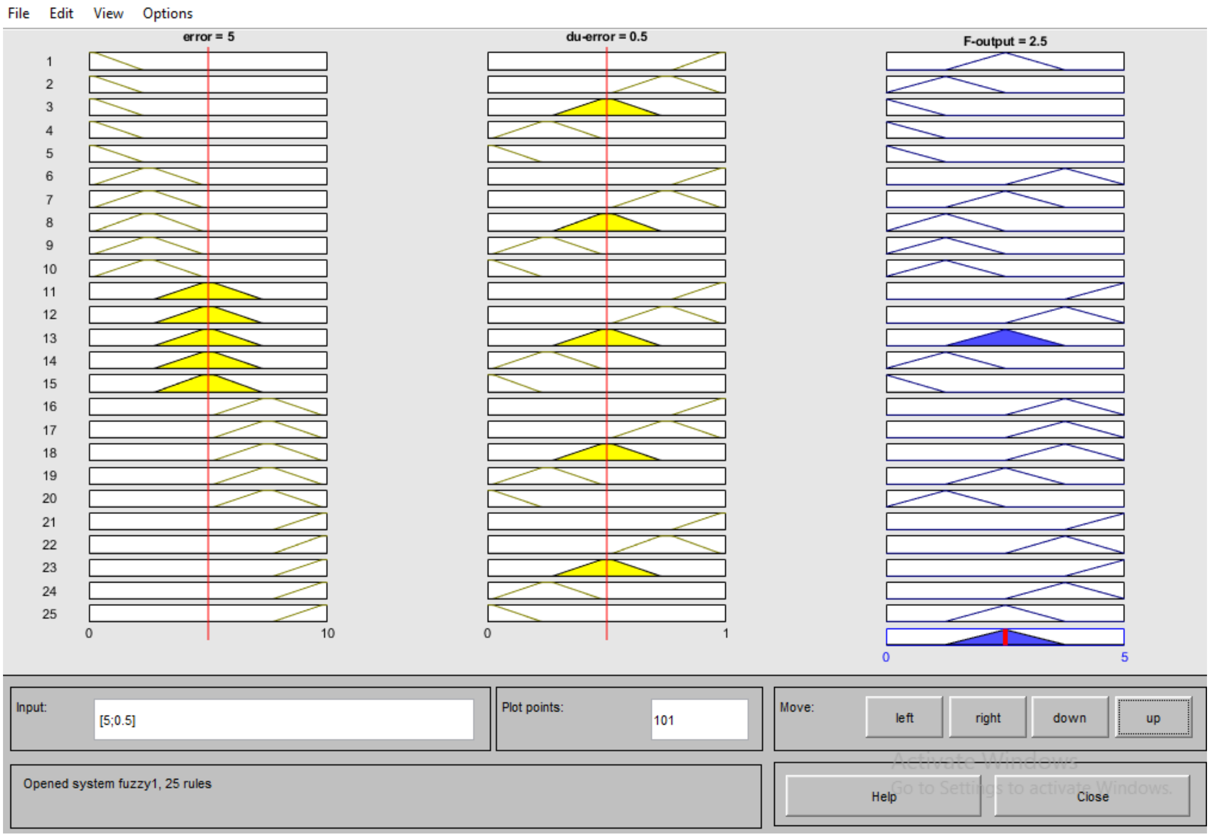


Fig.10: Showing ruleviewer

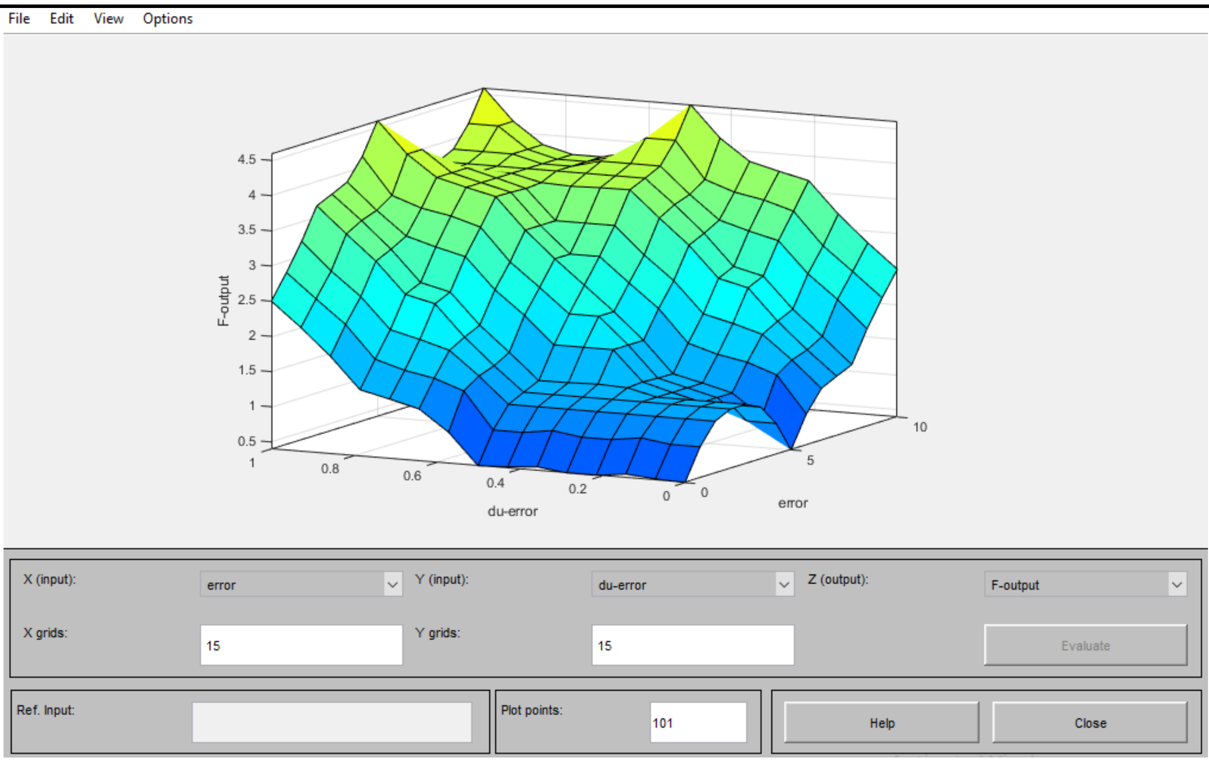


Fig. 11: showing surface viewer

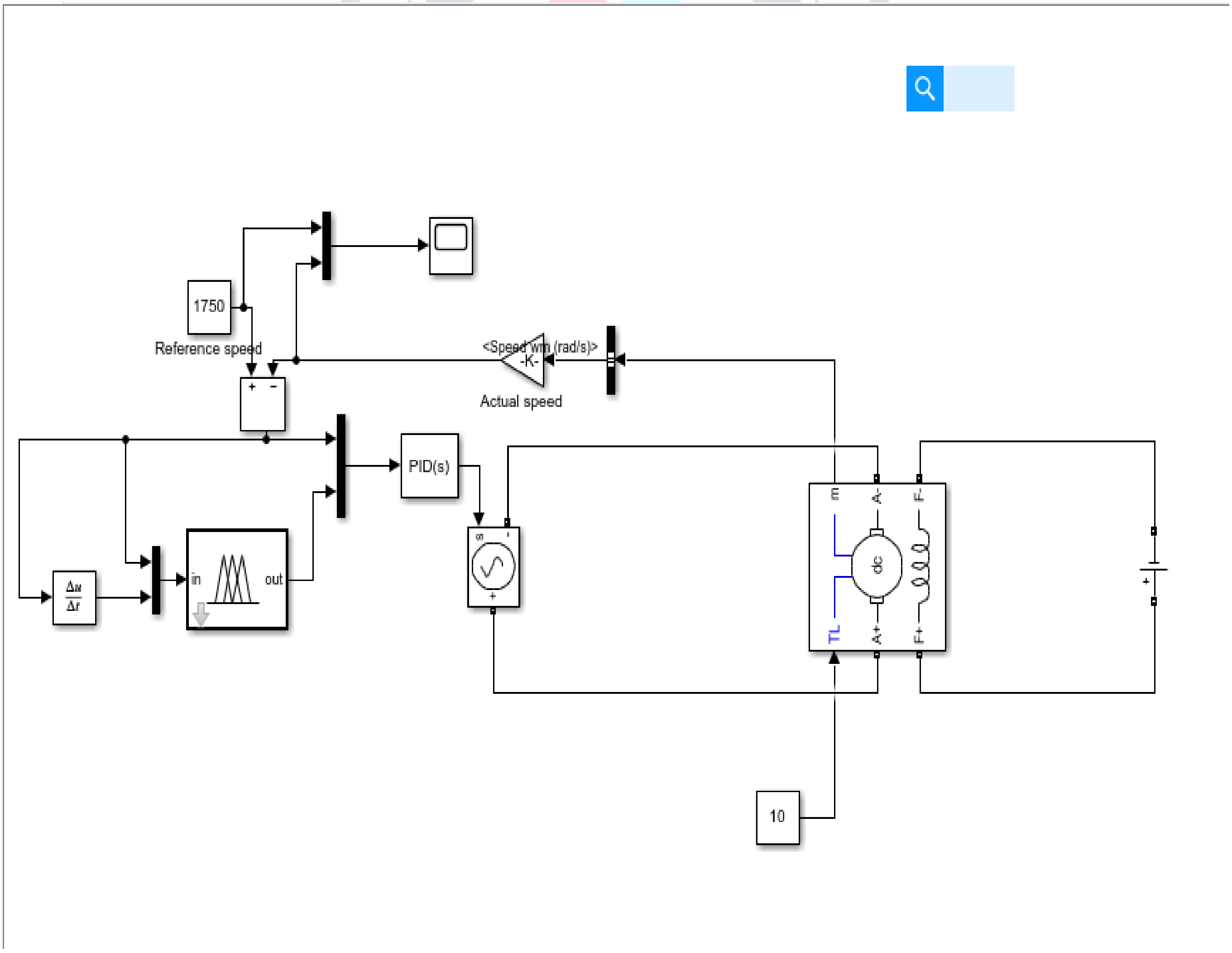


Fig.12: showing the fuzzy-pid controller block diagram

VII. SIMULATIONS RESULTS AND DISCUSSION

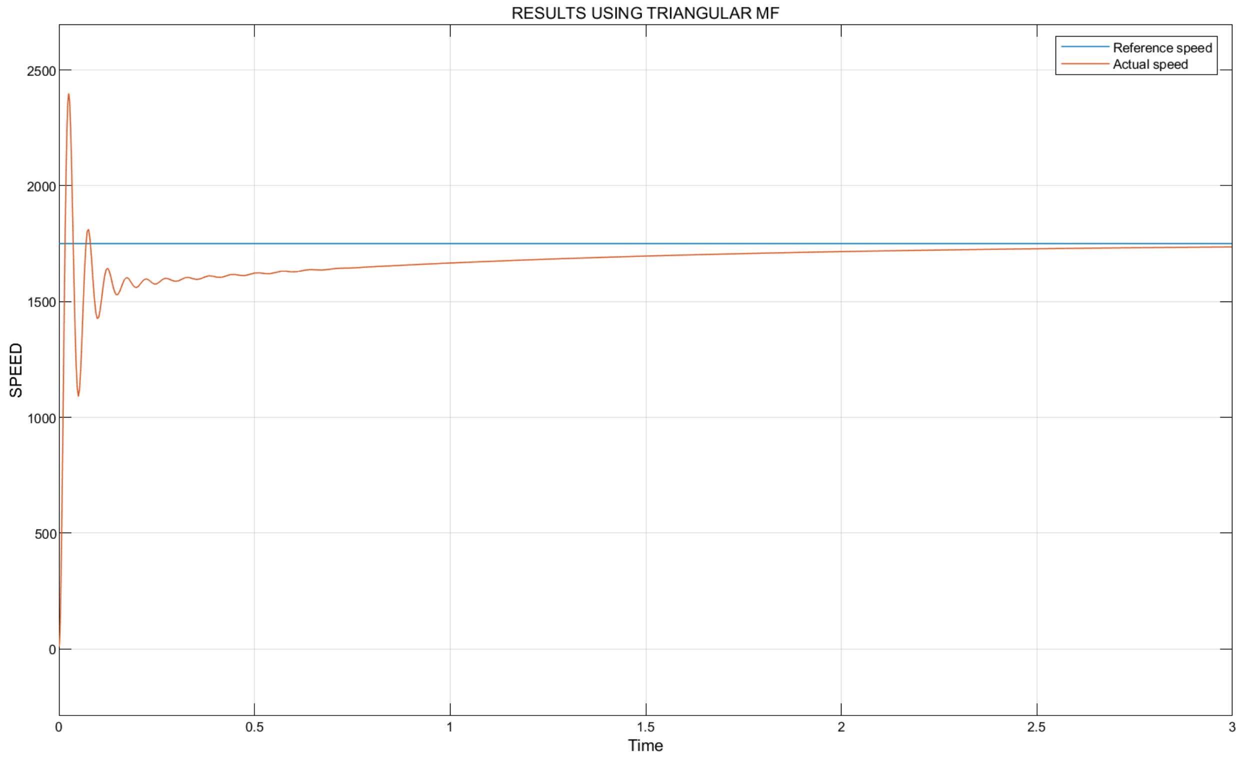


Fig.13: showing triangular membership function results

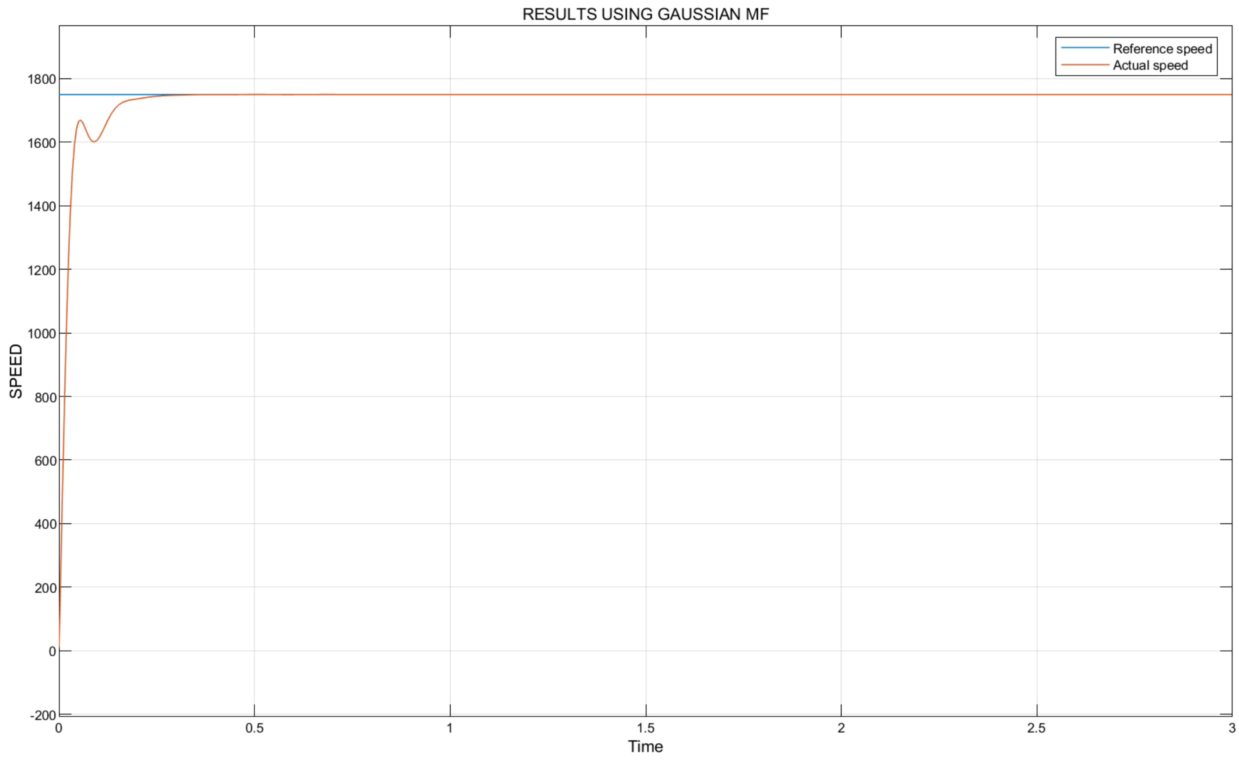


Fig.14: showing Gaussian membership function results

We have observed the results from our simulations and noted some important differences in our parameters under this study. In the conventional PID arrangement, the ***overshoot*** was at ***38.194%***. This is such a huge figure in control systems that makes it very unsuitable for a majority of applications. Overshoot is a very sensitive parameter considered in electronic PCB design, sports and business fields. It greatly determines the cost and should therefore be reduced by every means possible. In the improved model, we have obtained a better result of this parameter; ***0.079%***. This is quite impressive and satisfactory. However, it comes at the expense of another parameter.

The rise time in PID controller was at ***10.105 ms*** and now it goes higher to ***34.730 ms***. In electronics field, this parameter is not as crucial as the overshoot because it cannot destroy the circuit. It is usually recommended by engineers that this trade-off between the two parameters(overshoot and rise time) be made in favour of the former. Well, since the time is in the degree of milliseconds, it may not be so big to us humans but to machines and their response.

The overshoot has been reduced by an amount of about 38 times less while the rise time has increased by an amount of about 3 times. This should tell us that this new model has done a better job in reducing or managing the overshoot and done slightly badly in terms of managing rise time. But on an average scale, it scores highly because the benefit is greater than the loss by about 35 or the benefit is about 12.67 times than the loss experienced.

VIII. CONCLUSION

The main parameters of my interest(overshoot and rise time) have been tuned by fuzzy logic approach. The results of the Fuzzy-based PID have been compared for two different types of membership functions(triangular and gaussian) and they provided insight on my study and research. Gaussian has shown to have better and satisfactory results in terms of overshoot because it is a very special parameter(but not always/in every model) because it depends with the target of the plant.

Here, a simple but robust tuning scheme with fuzzy rule-based technique is proposed for an initially designed fuzzy PID controller. The most important feature of the proposed controller is that its functioning methodology is independent of the process model. Performance of the proposed tuning strategy is validated with well-known linear and nonlinear process models. The proposed methodology is found to be quite effective to provide acceptable performance with minimum overshoot during set point tracking. Effectiveness of the proposed methodology has been justified through simulation study and real-time experimentation. In future scope, number of fuzzy rules may be increased towards further enhancement of the fuzzy PID controller.

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