A

PROJECT REPORT ON

# Fuzzy PID Controller Design of Actuator System

DONE IN

DEFENCERESEARCH&DEVELOPMENTLABORATORY

Under guidance of

SHREE MURALI MOHAN GADE SC-'F'

SUBMITTED BY

JAGANNATH KURUBA

# BONAFIDE CERTIFICATE

Certified that the report on 01 July 2019(Fuzzy PID Controller Design of Actuator System) is a proof of successful completion of Industrial Training Phase–I programme undergone by Jagannath Kuruba (RA1711003011104) in the company Defence Research and Development Laboratory located at Kanchanbagh,Hyderabad during the period 01 June 2019 to 01 July 2019.

Murali Mohan Gade
Signature of the
Industrial Training In-charge

# ACKNOWLEDGEMENT

We like to share our sincere gratitude to all those who help us in completion of this project. During the work we faced many challenges due to our lack of knowledge and experience but the people help us to get over from all the difficulties and in final completion of our idea.

We would like to thank SHREE Murali Mohan Gade Sir for his governance and guidance, because of which our whole team was able to learn the minute aspects of a project work.

With great pleasure, I would like to thank D.R.D.L for giving me an opportunity to undertake the summer internship. I am having a great learning curve from this internship and I would like to express my sincere gratitude to my supervisor i.e. SHREE Murali Mohan Gade. who is mentoring me throughout this internship.

JAGANNATH KURUBA-RA1711003011104

# RUBRICS FOR EVALUATION

| S. No | Marks Split up | Maximum marks | Marks Obtained |
|---|---|---|---|
| 1 | Report Preparation | 50 | |
| 2 | Presentation | 25 | |
| 3 | Quiz and Viva | 25 | |
| | Total | 100 | |

Signature of the Staff

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Letter .No. DRDL/DP&R/HRD/PROJECT/2019 Dated: 01 July 2019

## CERTIFICATE

This is to certify that **Mr. Jagannath Kuruba** student of **B.Tech. 2nd year Dept. Of Computer Science Engineering** (Roll No.RA1711003011104) of **SRM Institute of Science & Technology**, SRM Nagar, Kattankulathur, has undergone the Mini Project work during period for one month from **01 June 2019 to 01 July 2019** Defence Research & Development Laboratory (DRDL), Kanchanbagh, Hyderabad. He has successfully completed the Mini Project work under the guidance of **Shri. Murali Mohan Gade, Scientist 'F'**. His Project title was "**Fuzzy PID Controller Design of Actuator System**".

During his Project work period for one month, he was found to be sincere & hard working. His performance is found satisfactory.

**(Dr. K. NAGESWARA RAO)**
**Scientist 'G',**
**Director, Planning & Resources**

**MURALI MOHAN GADE,**
**Scientist 'F'**
**DOS**
**DRDL**

# PROJECT BACKGROUND

Conventional proportional integral derivative (PID) controller is widely used in many industrial applications due to its simplicity in structure and ease to design. However, it is difficult to achieve the desired control performance in the presence of unknown nonlinearities, time delays, disturbances as well as change in system parameters. In order to achieve desired performance fuzzy logic control is particularly appropriate, since it allows making use of the operator's intelligence to automatic control.

Fuzzy Logic is a technology used for developing intelligent control and information systems. It is used for controlling a process that is too nonlinear or too ill-understood to use conventional control designs. It enables control engineers to easily implement control strategies used by human operators. Tuning is important parameter for the best performance of the PID controllers.

PID controllers can be tuned in a variety of ways including hand-tuning, Ziegler-Nichols tuning, Cohen- Coons tuning, loop sharing and pole placement. but these have their own limitations. a fuzzy proportional integral derivative (PID) controller is proposed which can be tuned by carrying the tuning rules from PID domain to fuzzy domain.

As a nonlinear controller can control a nonlinear process more efficiently, fuzzy controller can provide better performance in terms of rise time and smaller overshoot. The proposed controller is evaluated using some simulations. The simulation results show that both the transitory performance and the steady state performance are better than that of conventional PID controller.

# TABLE OF CONTENTS

# ABSTRACT

In order to solve the second-order simplified model of servo system, the feedback controller of the servo system is designed by using the traditional PID control method. Based on this, in order to realize the better adjustment of PID parameters, the fuzzy rules of PID parameters with error and error derivative are established, and the rule matrix is established to realize the fuzzy adjustment of PID parameters. At last, through the detailed numerical simulation analysis, the correctness of the proposed scheme is verified.

In the missile flight control system, the servo circuit as the implementing agency is the important component to manipulate the missile maneuver flight and achieve precision strike, so the stability control of servo circuit is the guarantee for missile's overall military performance. At present PID control method is widely used for the control of servo circuit. However, due to the non-linearity of the missile flight motion and the complicated and variable environmental factors, the control object has a very strong uncertainty, and the traditional PID cannot be used to control the real-time parameters as the servo load changes, so a controller with better robustness and higher control accuracy is needed. Based on the traditional PID control method, this paper designs the fuzzy PID control algorithm by using the fuzzy theory, which is proved to have a higher control quality.

# 1.INTRODUCTION

A control system manages, commands, directs, or regulates the behaviour of other devices or systems using control loops. It can range from a single home heating controller using a thermostat controlling a domestic boiler to large Industrial control systems which are used for controlling processes or machines.

For continuously modulated control, a feedback controller is used to automatically control a process or operation. The control system compares the value or status of the process variable (PV) being controlled with the desired value or setpoint (SP), and applies the difference as a control signal to bring the process variable output of the plant to the same value as the setpoint.

# 2.GUIDANCE SYSTEM

A guidance system is a virtual or physical device, or a group of devices implementing a guidance process used for controlling the movement of a ship, aircraft, missile, rocket, satellite, or any other moving object. Guidance is the process of calculating the changes in position, velocity, attitude, and/or rotation rates of a moving object required to follow a certain trajectory and/or attitude profile based on information about the object's state of motion.

A guidance system is usually part of a Guidance, navigation and control system, whereas navigation refers to the systems necessary to calculate the current position and orientation based on sensor data like those from compasses, GPS receivers, Loran-C, star trackers, inertial measurement units, altimeters, etc. The output of the navigation system, the navigation solution, is an input for the guidance system, among others like the environmental conditions (wind, water, temperature, etc.) and the vehicle's characteristics (i.e. mass, control system availability, control systems correlation to vector change, etc.). In general, the guidance system computes the instructions for the control system, which comprises the object's actuators (e.g., thrusters, reaction wheels, body flaps, etc.), which are able to manipulate the flight path and orientation of the object without direct or continuous human control.

# 2.1. MISSILE GUIDANCE

Missile guidance refers to a variety of methods of guiding a missile or a guided bomb to its intended target. The missile's target accuracy is a critical factor for its effectiveness. Guidance systems improve missile accuracy by improving its "Single Shot Kill Probability" (SSKP), which is part of combat survivability calculations associated with the salvo combat model.

These guidance technologies can generally be divided up into a number of categories, with the broadest categories being "active," "passive" and "preset" guidance. Missiles and guided bombs generally use similar types of guidance system, the difference between the two being that missiles are powered by an onboard engine, whereas guided bombs rely on the speed and height of the launch aircraft for propulsion.

## 2.2. QRSAM

Quick Reaction Surface-to-Air Missile (QRSAM) is a missile developed by the Defence Research and Development Organisation (DRDO) in association with Bharat Electronics Limited and Bharat Dynamics Limited for the Indian Army The missile is all-weather, all-terrain missile with electronic counter measures against jamming by aircraft radars. The missile can be mounted on a truck and is stored in a canister. QRSAM uses solid-fuel propellant and has a range of 25-30 km.

# 3.PID CONTROLLER

A proportional–integral–derivative controller (PID controller. or three term controller) is a control loop feedback mechanism widely used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between a desired setpoint (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted P, I, and D respectively), hence the name.

In practical terms it automatically applies accurate and responsive correction to a control function. An everyday example is the cruise control on a car, where ascending a hill would lower speed if only constant engine power is applied. The controller's PID algorithm restores the measured speed to the desired speed with minimal delay and overshoot, by increasing the power output of the engine.

The first theoretical analysis and practical application was in the field of automatic steering systems for ships, developed from the early 1920s onwards. It was then used for automatic process control in the manufacturing industry, where it was widely implemented in pneumatic, and then electronic, controllers. Today there is universal use of the PID concept in applications requiring accurate and optimised automatic control.

Figure1.PID

Pneumatic PID (three term) controller. The magnitudes of the "three terms" P, I and D are adjusted by the dials at the top.

# 3.1.DESIGN OF PID SYSTEM in Simulink (MATLAB)

A simplified model of a missile servo system can be described as a differential equation. where T is the inertial time constant, and T s 0.06, u is the control input, a y is the rotational angular velocity, y is the output. The correlation between a y and u can be described as the transfer function where S is the differential Operators in transfer Function. So, the whole servo system model can be described as follows Fig.2. Schematic diagram:

Define the error variable (e=r-y), and design the PID controller as the formula given below.

$$u = k_1 e + k_2 \dot{e} + k_3 \int edt$$

where k1, k2, k3 are the proportion, differential and integral coefficient respectively, (ė) is the derivative of error, and ∫edt is the integration of error. Generally, suppose (r) is the constant step signal, and r=5/57.3(5 degrees).

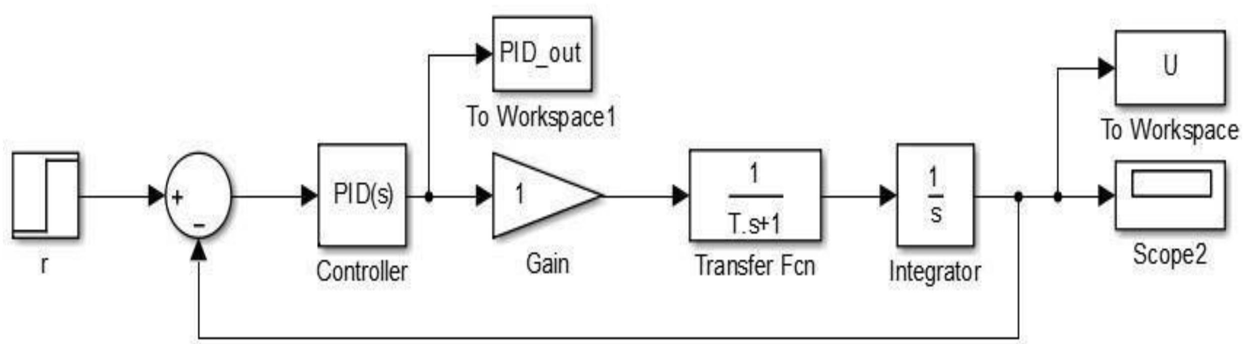


Figure2.PID Simulink model

# 3.2. SIMULATION OUTPUT

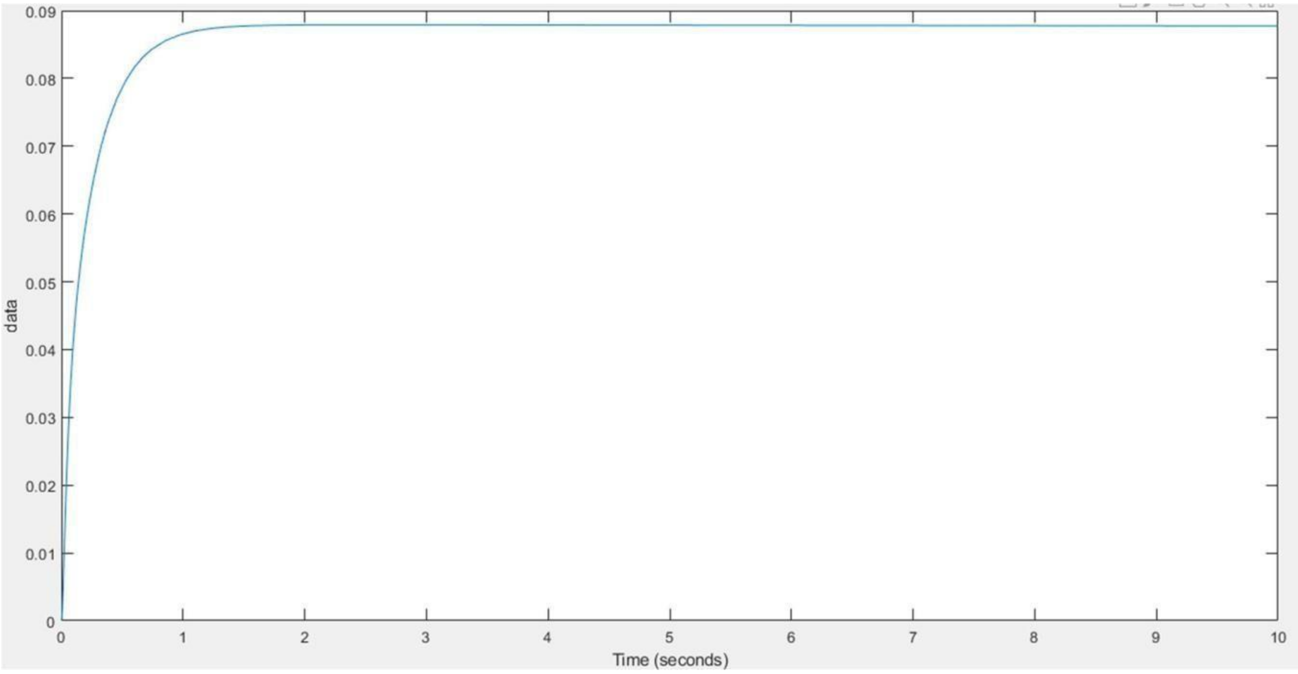


Figure3.output

The above output is achieved from using a [reference paper]1 where gains are 5, 0.2, 0.5 respectively.

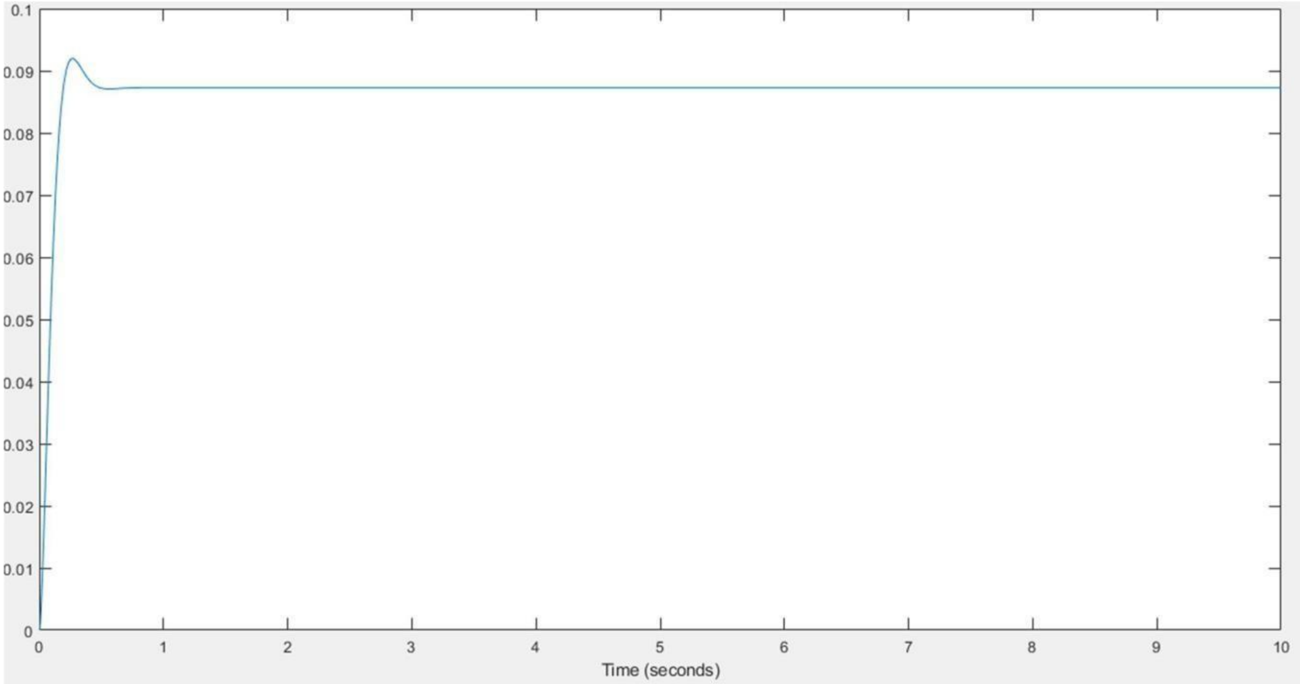


Figure4.Ideal output

We achieved the above response curve by tuning the gains as 13, 0.05, 0.2 respectively. These gains achieved a rise time less than 150ms, overshoot less than 5% and Gain margin greater than 6dB, Phase margin greater than 30 degrees.

# ANALYSIS

| Gains | Rise time | Overshoot | Settling Time |
|---|---|---|---|
| Kp ↑ | Decrease | Increase | Small Change |
| Ki ↑ | Decrease | Increase | Increase |
| Kd ↑ | Small Change | Decrease | Decrease |

# 4.FUZZY LOGIC

Fuzzy logic is a form of many-valued logic in which the truth values of variables may be any real number between 0 and 1 inclusive. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false. By contrast, in Boolean logic, the truth values of variables may only be the integer values 0 or 1.

The term fuzzy logic was introduced with the 1965 proposal of fuzzy set theory by Lotfi Zadeh.

It is based on the observation that people make decisions based on imprecise and non-numerical information, fuzzy models or sets are mathematical means of representing vagueness and imprecise information, hence the term fuzzy. These models have the capability of recognising, representing, manipulating, interpreting, and utilising data and information that are vague and lack certainty.

Fuzzy logic has been applied to many fields, from control theory to artificial intelligence.

Fuzzy Logic Controller consists of main four parts

A. Fuzzification: Fuzzification, converts each piece of input data to degrees of membership by a lookup in one or several membership functions. The fuzzification block thus matches the input data with the conditions of the rules to determine how well the condition of each rule matches that particular input instance. There is a degree of membership for each linguistic term that applies to that input variable.
B. Rule Base: The rule base consists of rules in the IF-THEN format the rules are derived from an expert's experience or from operator.

C. Inference Engine: In order to draw conclusion from the rule base inference engine employs a mechanism that can produce an output from a collection of if-then rules [8]. This is done using the compositional rule of inference.
D. Defuzzification: The resulting fuzzy sets are converted to a number that can be sent to the process as a control signal. This conversion of fuzzy values into crisp value is called defuzzification.

## FUZZIFICATION

Fuzzification is the process of changing a real scalar value into a fuzzy value. This is achieved with the different types of fuzzifiers (membership functions). Fuzzification. Fuzzy Linguistic Variables are used to represent qualities spanning a particular spectrum. Temp: {Freezing, Cool, Warm, Hot}

## DEFUZZIFICATION

Defuzzification is the process of producing a quantifiable result in Crisp logic, given fuzzy sets and corresponding membership degrees. It is the process that maps a fuzzy set to a crisp set. It is typically needed in fuzzy control systems. These will have a number of rules that transform a number of variables into a fuzzy result, that is, the result is described in terms of membership in fuzzy sets. For example, rules designed to decide how much pressure to apply might result in "Decrease Pressure (15%), Maintain Pressure (34%), Increase Pressure (72%)". Defuzzification is interpreting the membership degrees of the fuzzy sets into a specific decision or real value.

# 4.1. FUZZY CONTROL SYSTEM

A fuzzy control system is a control system based on fuzzy logic—a mathematical system that analyses analogue input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0 (true or false, respectively).

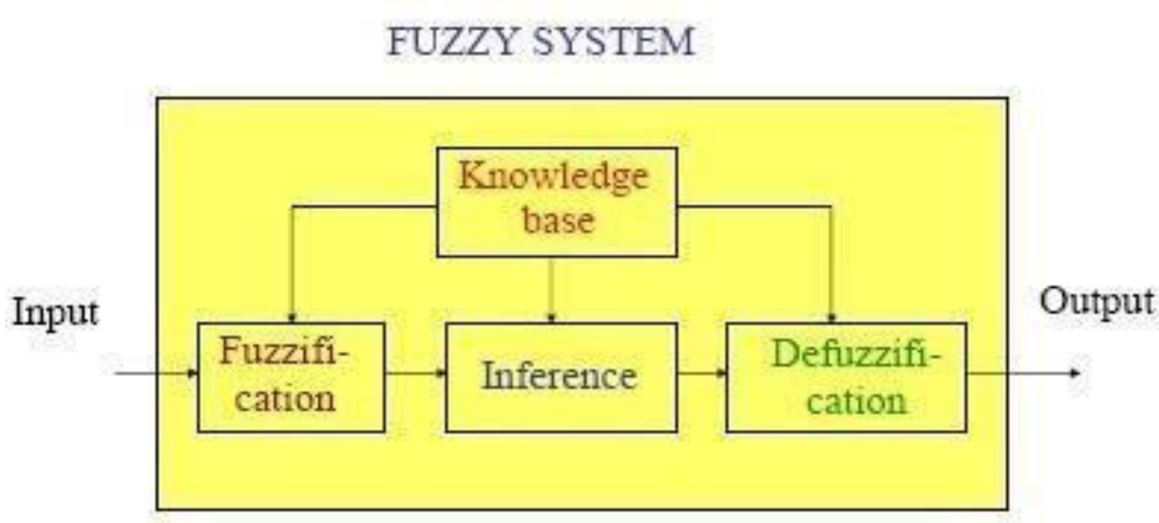


Figure5.Fuzzy system

## 4.2. DESIGN OF FUZZY CONTROL STRATEGY

The fuzzy law is established for proper PID control parameters k1, k2, k3 and picked the initial gain values as k1=5, k2=0.2, k3=0.5

Design the fuzzy system about the correlation of e and delta k, where e is the input and deltak are outputs. Definitions of fuzzy set for inputs and outputs are described as the following.

e = {NB NM ZO PM PB}

ė = {NB NM ZO PM PB}

Δk1={NB NM ZO PM PB}

Δk2={NB NM ZO PM PB}

Δk3={NB NM ZO PM PB}

The fuzzy membership function of the input and output of the fuzzy system is shown in figures.

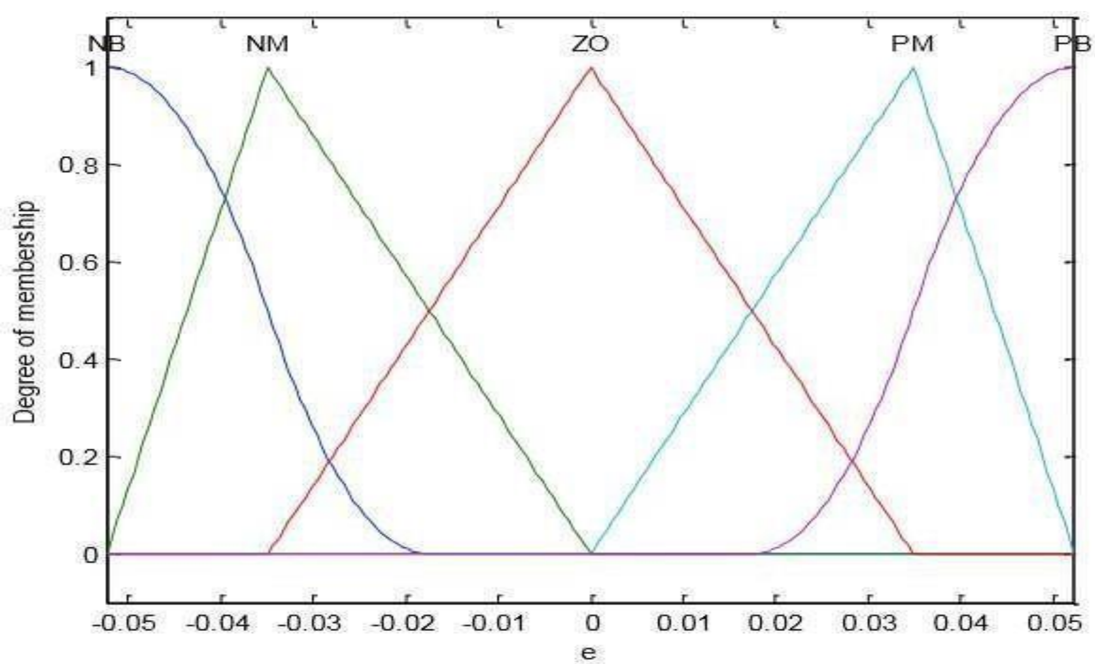


Figure6.MF_e

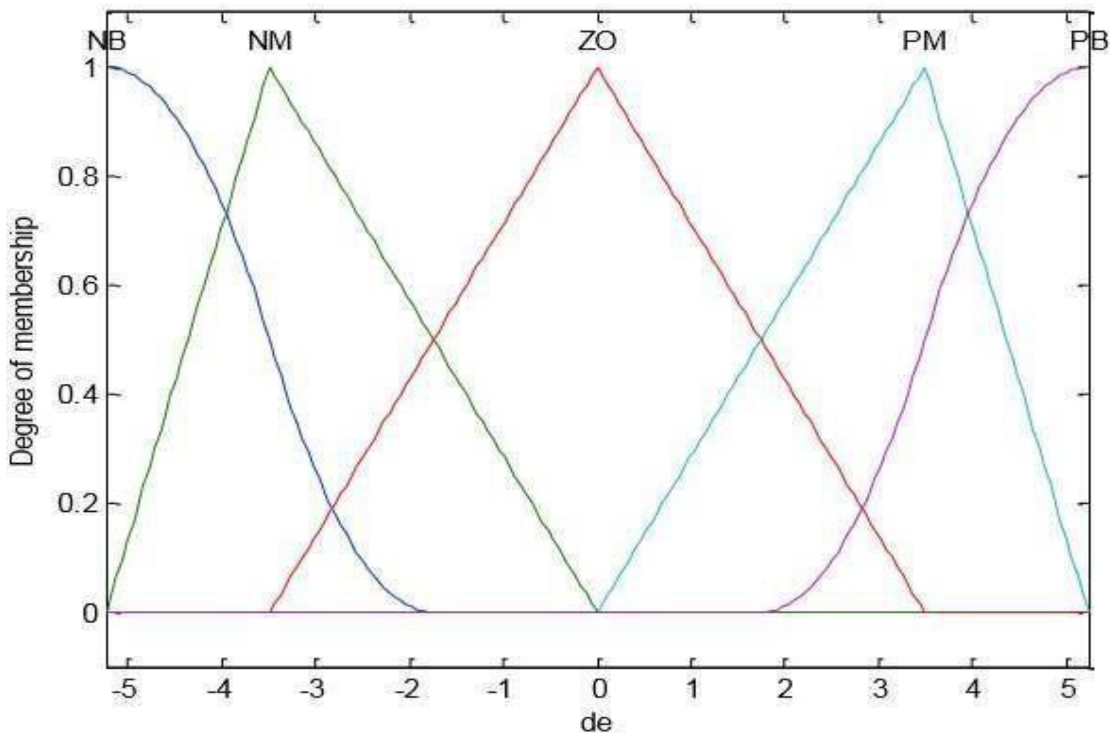


Figure7.MF_ ė

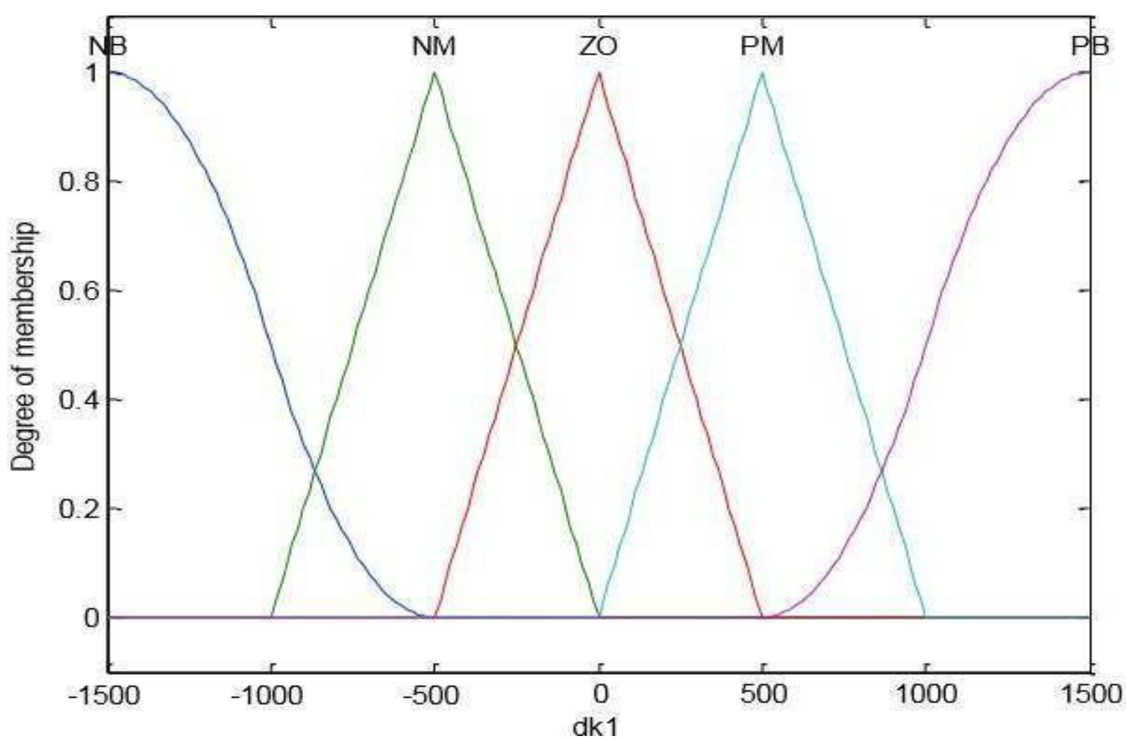


Figure8.MF_ Δk1

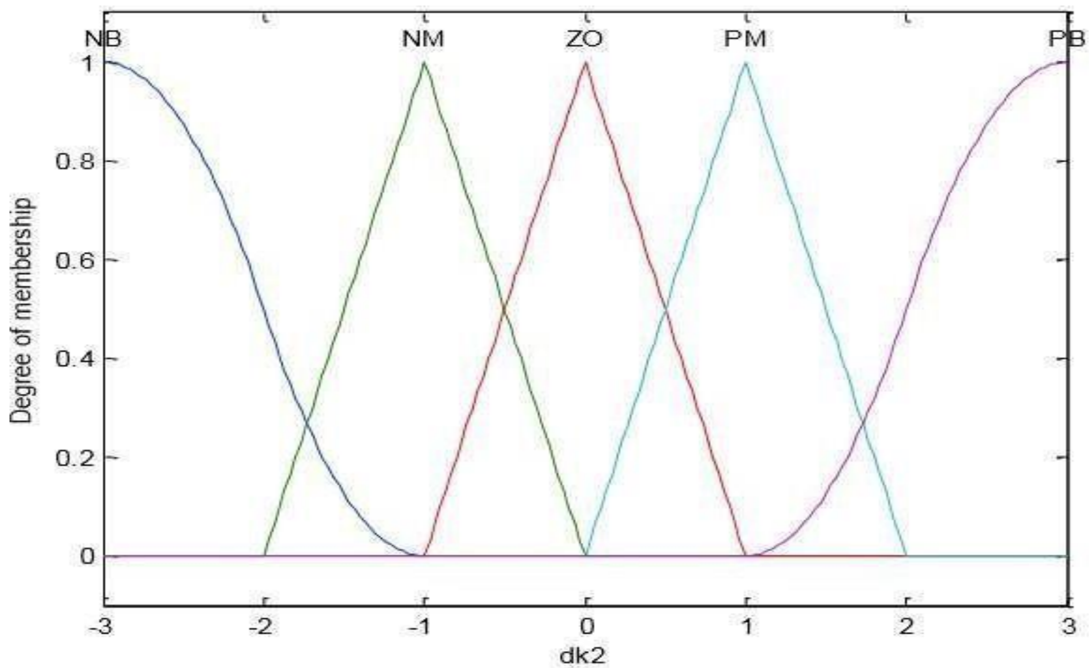


Figure9.MF_ Δk2

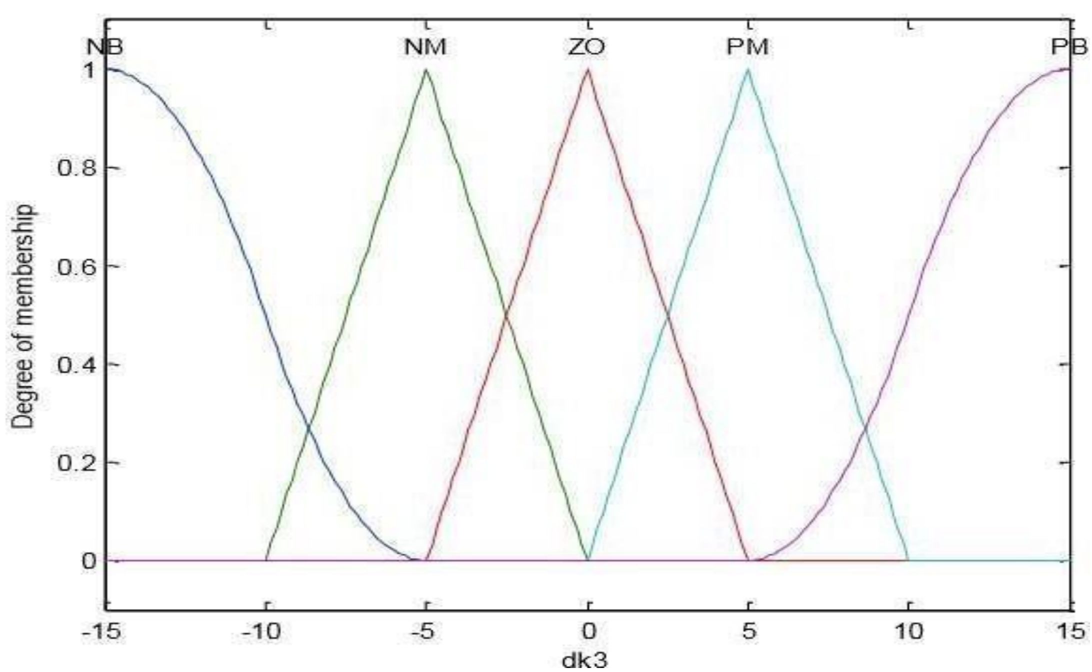


Figure10.MF_ Δk3

The fuzzy rule for Δk is set as the following.

R1: IF e is PB Then $\Delta k1$ is PB and $\Delta k2$ is PB and $\Delta k3$ is ZO.

R2: IF e is PM Then $\Delta k1$ is PM and $\Delta k2$ is PM and $\Delta k3$ is ZO.

R3: IF e is ZO Then $\Delta k1$ is ZO and $\Delta k2$ is ZO and $\Delta k3$ is ZO.

R4: IF $\dot{e}$ is PB Then $\Delta k1$ is ZO and $\Delta k2$ is ZO and $\Delta k3$ is PB.

R5: IF $\dot{e}$ is PM Then $\Delta k1$ is ZO and $\Delta k2$ is ZO and $\Delta k3$ is PM.

R6: IF $\dot{e}$ is ZO Then $\Delta k1$ is ZO and $\Delta k2$ is ZO and $\Delta k3$ is ZO.

Set the rule matrix as the following.

```
Rulelist1= [5 5 5 5 5 1 1;
            5 4 5 5 4 1 1;
            5 3 5 5 3 1 1;
            4 5 4 4 5 1 1;
            4 4 4 4 4 1 1;
            4 3 4 4 3 1 1;
            3 5 3 3 5 1 1;
            3 4 3 3 4 1 1;
            3 3 3 3 3 1 1];
```

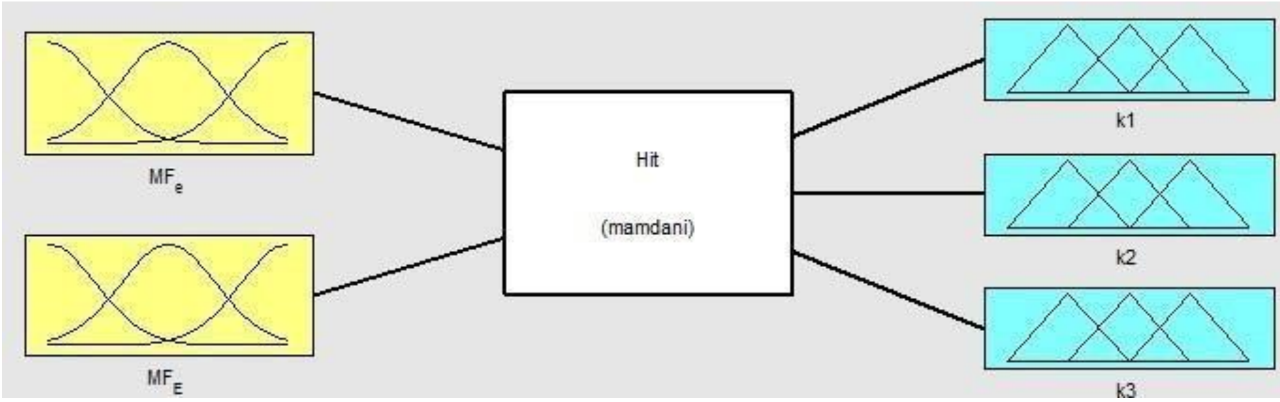


Figure11.mamdani

Using MATLAB Simulink, we created a Fuzzy Interface System with all the rules, input and output Membership functions and also set the rule matrix as Rulelist1 as mentioned above.

Calculate k1, k2, and k3 by integration method by given formula

$$k_1 = \Gamma_1 \int \Delta k_1 dt$$

$$k_2 = \Gamma_2 \int \Delta k_2 dt$$

# 4.3. SIMULATION OF FUZZY SYSTEM

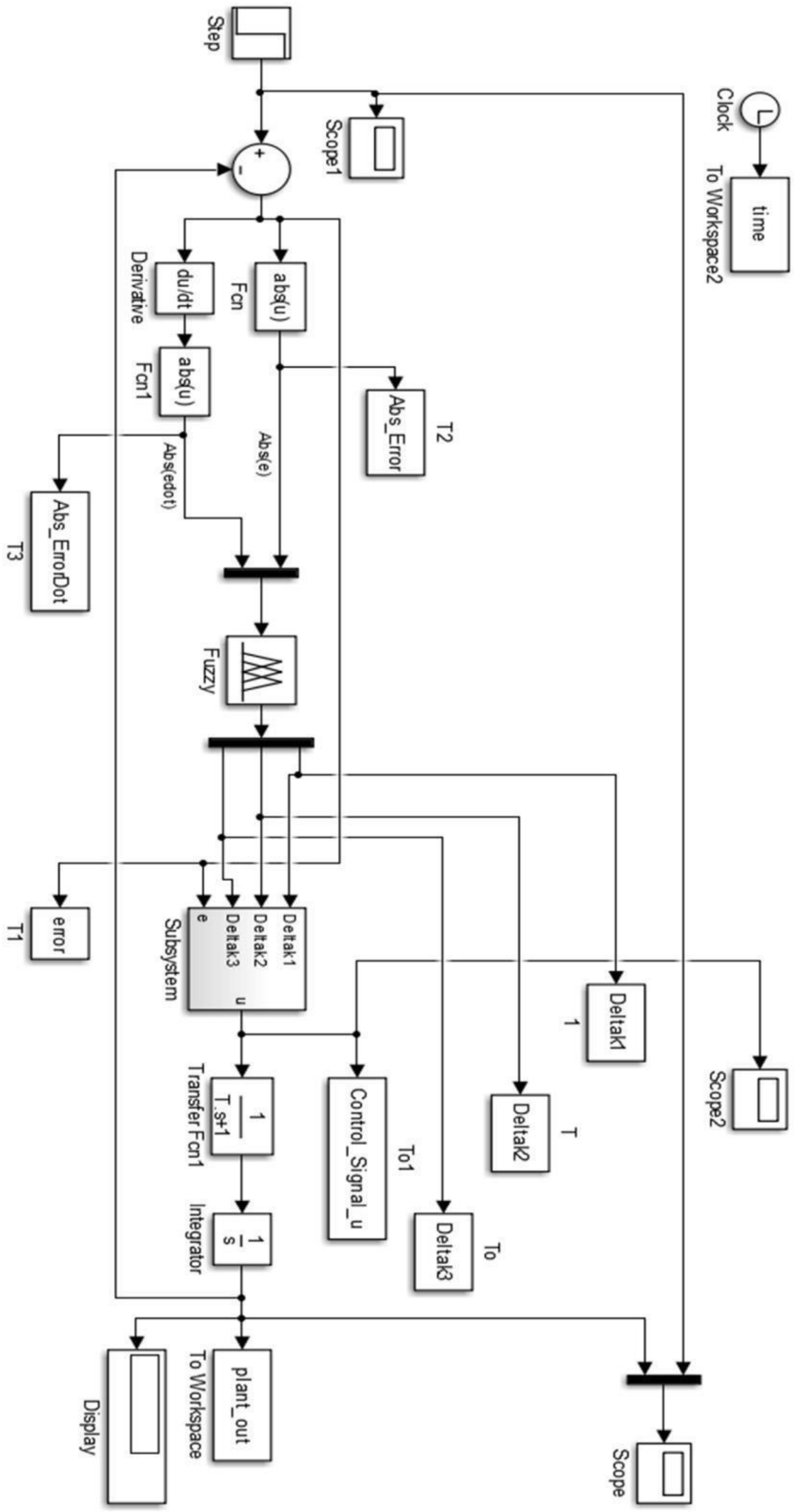


Figure12.FLC (Simulink model)

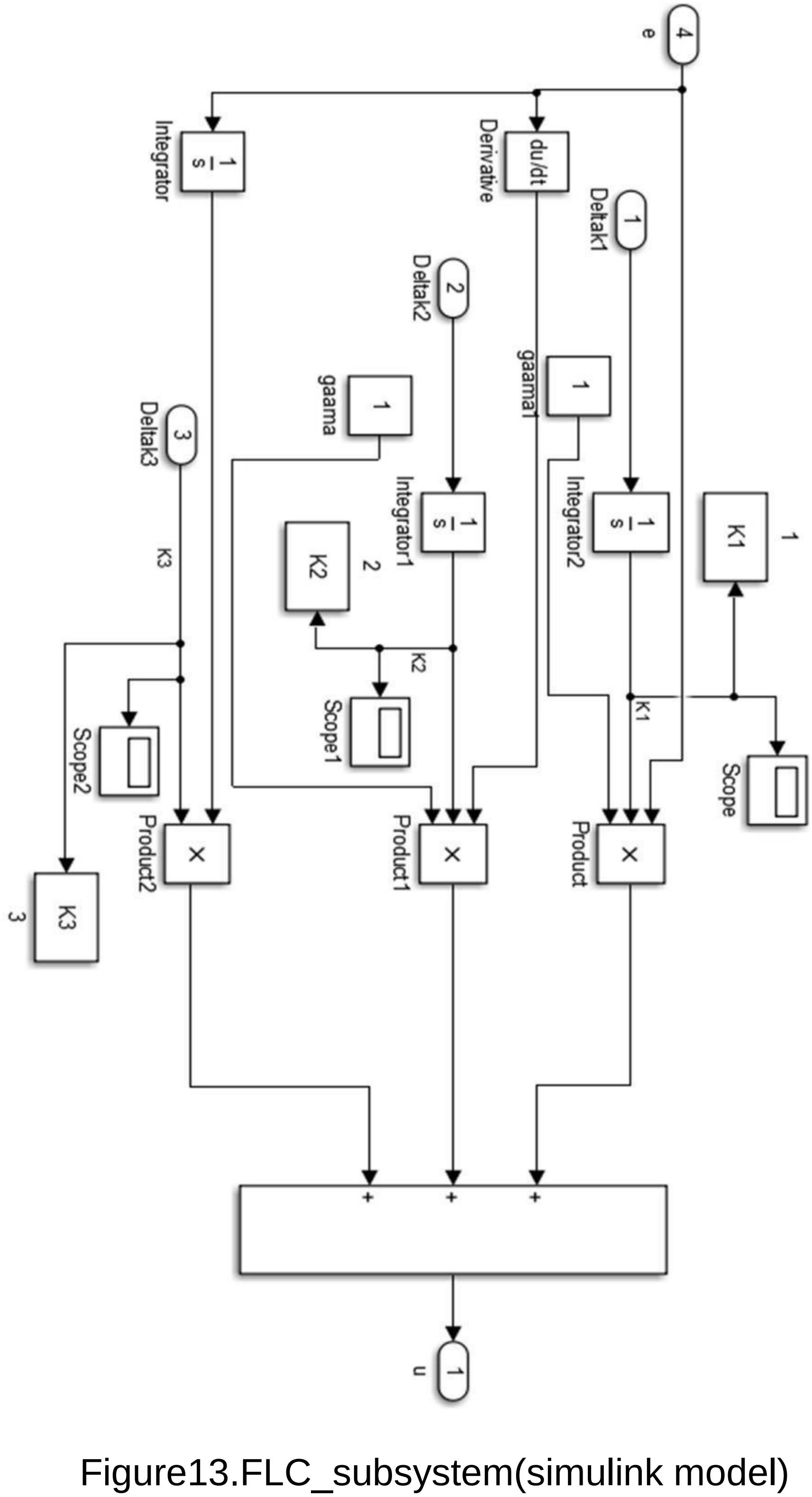


Figure13.FLC_subsystem(simulink model)

# 4.4. SIMULATION OUTPUT

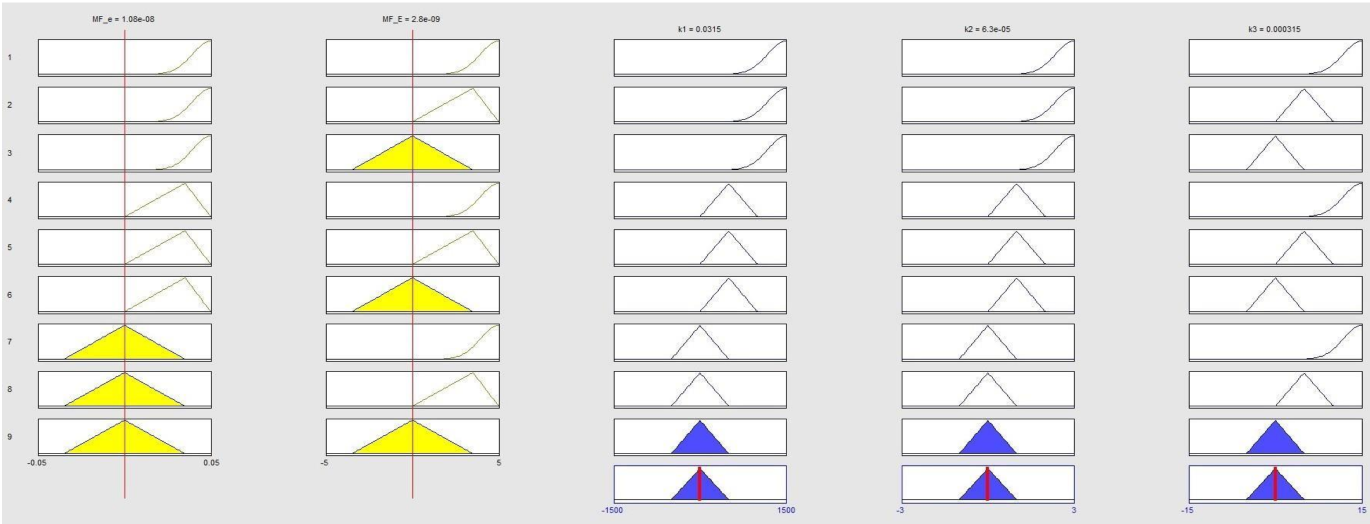


Figure14.RuleViewer

Figure14.RuleViewer is Rule viewer output after running the FLC simulink model.

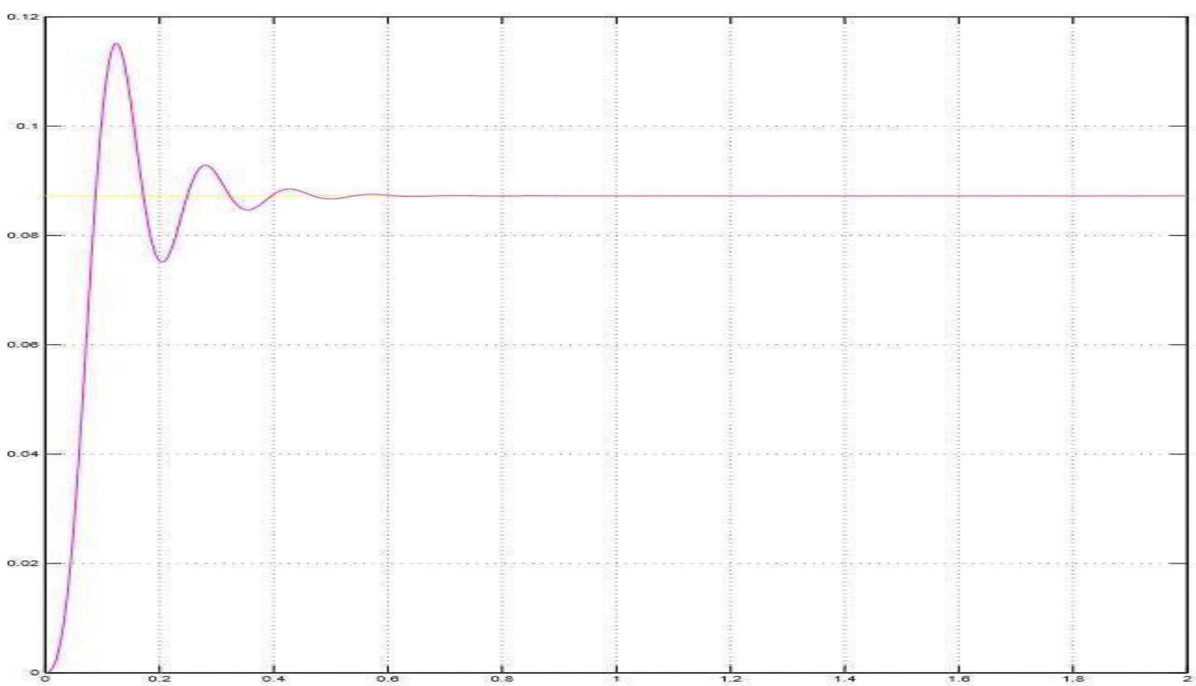


Figure15.Servo Output response curve

Figure15.Servo Output response curve is the final output response from servo circuit model.

The output gain curves

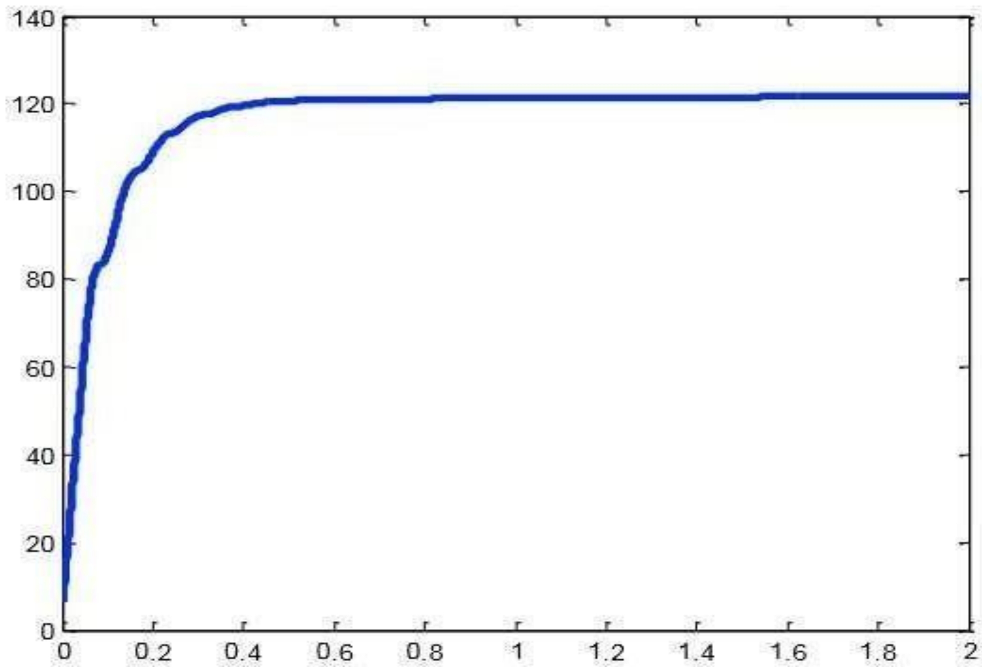


Figure16.First Gain

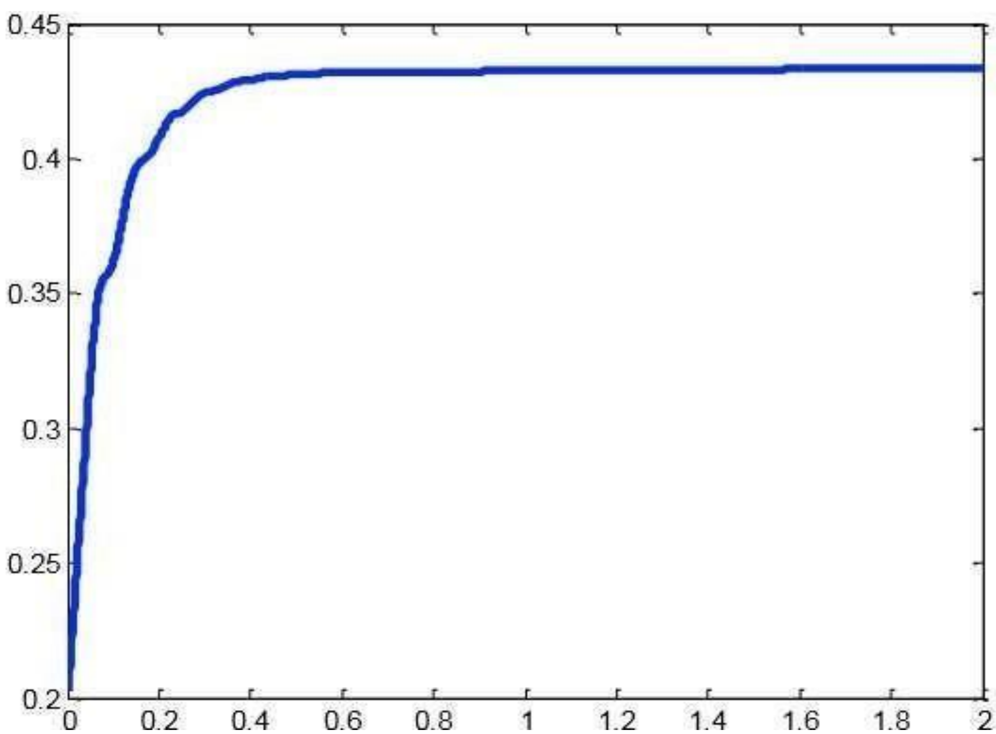


Figure17.Second Gain

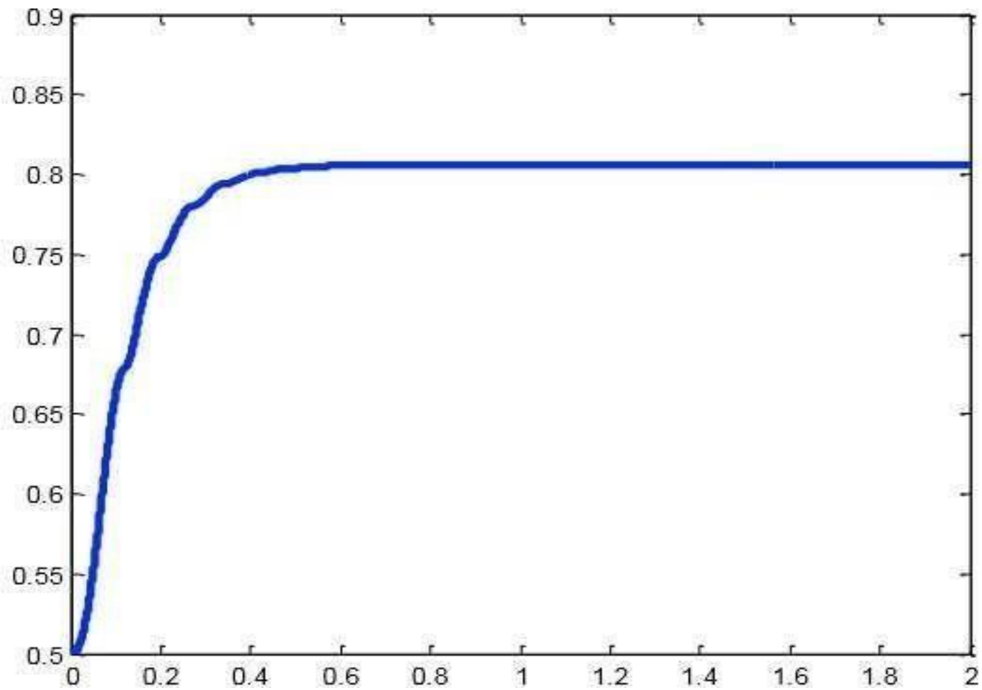


Figure18.Third Gain

Fig.15 shows the output of position of actuator system, and we can find that the speed is very quick and the rise time is near 0.1s And Fig.16 to Fig.18 shows the fuzzy adjustment of three gains, and the figures shows that the turning of fuzzy rules are reasonable, so the proposed method is right and effective, which can be applied in real engineering.

We tuned the gains so that the output curve is more stable with less overshoot and quick raise time. We changed the proportional constants so that the gains are tuned accordingly.


Figure19.ideal output

Fig.19 is achieved by tuning the proportional constants as

$\Gamma_1=2$

$\Gamma_2=8$

# 5.CONCLUSION

The results have clearly emphasized the advantages of fuzzy inference systems. A balance is obtained between both rise time and overshoot in response i.e. lesser overshoot and smaller rise time are obtained simultaneously by using Fuzzy Logic Controller.

The fuzzy PID control of servo circuit is designed and simulated. The simulation results of the three parameters in the servo circuit model show that the fuzzy PID algorithm can correct the control error caused by complex and variable noise during flight. The proposed method has good dynamic characteristics, high steady-state accuracy and robustness.

# REFERENCE


[1.] Yong Liu, Tian Lan, Yuqiang Jin and Junwei Lei, "Research on Fuzzy Controller Design of Actuator System".

[2.] Asim Ali Khan and Nishkam Rapal, "Fuzzy PID Controller: Design, Tuning and Comparison with Conventional PID Controller".

[3.] Bong Joo Kim and Chung Choo Chung, "Design of Fuzzy PID Controller for Tracking Control".

[4.] R. Ketata, D. De Geest and A.Titli, "Fuzzy controller: design, evaluation, parallel and hierarchical combination with a PID controller".

[5.] S.N. Sivanandam, S.Sumathi and S.N. Deepa, "Introduction to Fuzzy Logic using MATLAB".