MECHANICAL ENGINEERING FACULTY

PROJECT I

Overview and simulation comparison of variants of PID controller

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CONTENTS

1.ASSIGMENT

Overview and simulation comparison of variants of PID controller

There are various extended PID controllers, eg. PIDA using second derivation in the algorithm, FPID using non-integer operations of derivation and integration, and fuzzy PID. Make an overview and comparison of those extended PID controller. Using Matlab, Simulink, or similar software, compare their function, properties and parameter tuning methods. Focus mainly to tuning methods that do not require a model of controlled plant, however methods requiring model of controller plant are not excluded.

2. What is fractional Order PID and FOPID Tunning and comparasion with PID?

A.PID Controller

Proportional Integral Derivative (PID) Controller The PID controller is operated based on summation of three term; P-term (which operate based proportional on error), I-term (which operate based on proportional to integral on error), and D-term (which operate based on proportional to derivative on error). For this paper, all PID structures are designed in non-interacting form based on Equation 1 and it implementation in Simulink is illustrate in Equation. 1.

$$G(s) = K_p + \frac{K_i}{s} + K_d s \quad (1)$$

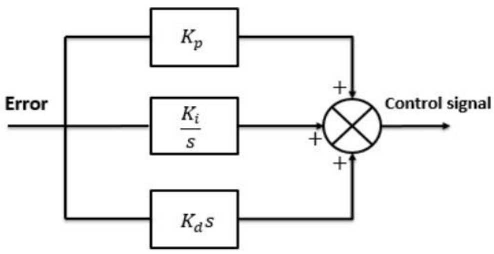

Fig.1. PID controller [1]

B. Fractional-order PID (FOPID) Controller

Fractional order controllers are design based on principle that classical inteer if I-term and D-term in PID controller can be generalized into non-integer order operation.The FOPID is consisting of addition of λ and μ paramaeters in FOPID structure is desribed as below and illustrated in Fig.2.

1. When λ=0 and μ=0, it becomes P Controller.

2. When λ=1 and μ=0, it becomes PI Controller.
3. When λ=0 and μ=1, it becomes PD Controller.
4. When λ= l and μ=1, it becomes PID Controller.

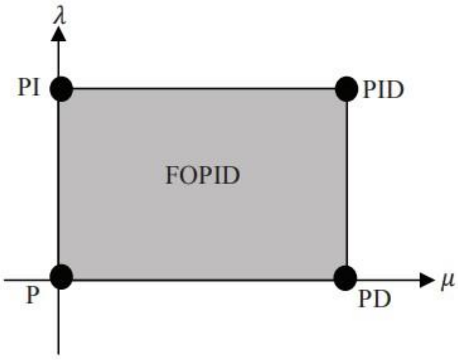

Fig.2.Effect of λ and μ in FOPID structure [2]

The s-domain equation of FOPID controller Equation 2

$$G(s) = K_p + K_i s^{-\lambda} + K_d s^{\mu} \tag{2}$$

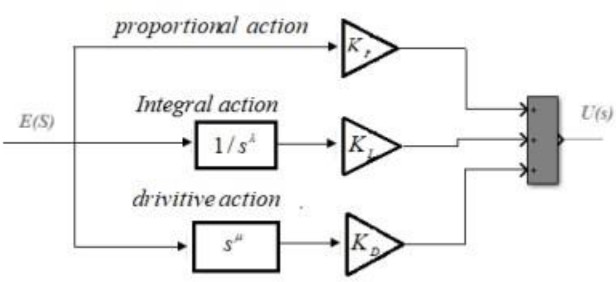

Fig.3. FOPID controller [3]

The FOPID controller is simulated to stabilize the Inverted Pendulum(IP) . FOPID controllers are used to maintain the IP. The controller is used to stabilize the angle in the x-axis direction. The FOPID controller is benchmarked with a conventional PID one to show the effectiveness of the proposed controller.

The parameters of PID controller is shown in below which is depend on trial and error tuning method and illustrates the values of λ and μ that used in the FOPID controllers, while the others parameters are taken same as the PID one for comparison purpose.

The IP parameters are selected as follows: M= 1 kg, m=0.1 kg, l =0.3m and g=9.8 m/s2 . The simulations run for 10 second before it stops.

Using the provided parameters, we can obtain the transfer function of the inverted pendulum system as

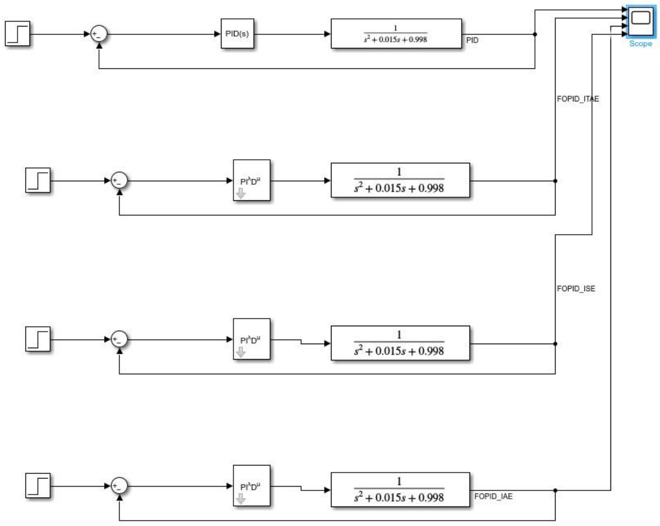

Fig.4 Matlab/Simulink FOPID and PID simulation

C.Tuning Controllers

For tunning the PID controller,PID tuner is used for detecting its parameters.

For tunning of FOPID,fomcon toolbox(FPID Optimization Tool) is used for detecting optimize parameters.Optimazation algorithm is Nelder-Meid. In FOPID controller is designed with three different performance indices, namely, the integral of time multiplied absolute error the ITAE [4], the integral of absolute error (IAE), the integral of squared error (ISE). From the results, it is shown that the FOPID controller has performed better than the PID controller and the ITAE has given the best results among the other used objective functions.

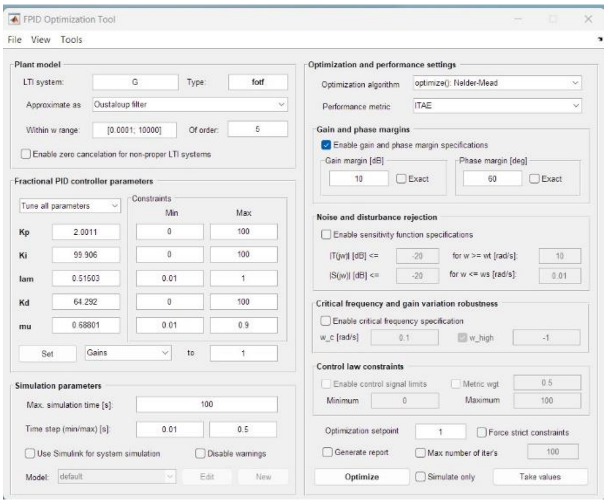

Figure 5.Fractional PID Design Tool

I. Parameters of Conventional PID controller Kp= 13.91 Ki =6.24 Kd = 6.85
II. Parameters of Conventional FOPID(ITAE) controller Kp= 5.6264 ,Ki = 25.216 Kd =23.3208 λ= 10.99889 and μ=0.69886
III. Parameters of Conventional FOPID(IAE) controller Kp= 8.4294-07 ,Ki = 51.0977 Kd =100 λ= 1 and μ=0.9
IV. Parameters of Conventional FOPID(ISE) controller Kp= 1.474e-08 ,Ki = 96.7349 Kd =100 λ= 1 and μ=0.9

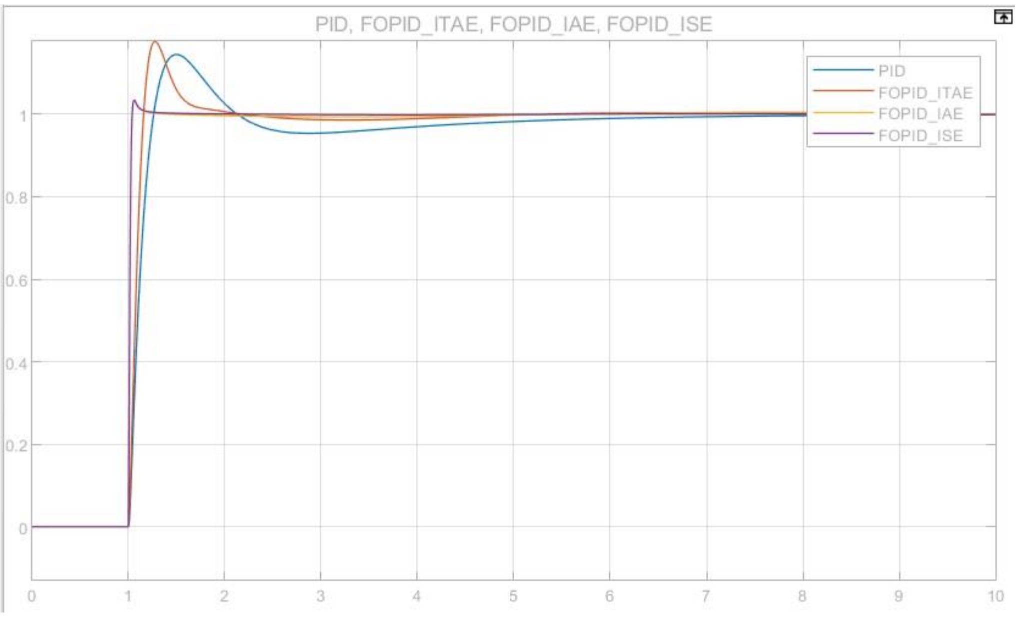

Fig.6.Angle of IP

The simulation results show that the FOPID controllers achieves faster settling time and lower overshoot than the PID controller.

Specifically, the settling time of the FOPID controllers is approximately less than 5 seconds, while the settling time of the PID controller is approximately 7 seconds.

3. How does PIDA Tune and its comparasion with PID?

A.PIDA Controller

In this study, a method is proposed to determine the parameters of Proportional Integral Derivative Acceleration (PIDA) controller, which are used in the control of higher degree systems, via Particle Swarm Optimization (PSO) algorithm. Classic controller methods may sometimes be insufficient, especially in the control of higher degree systems. In PIDA controller design, heuristic optimization algorithms, which is one of the recommended methods for these systems, provides successful results.

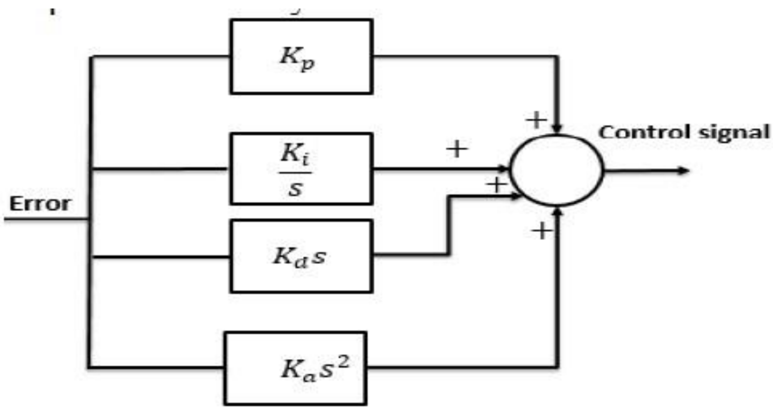

Figure 7.Block Diagram of PIDA controller [5]

B.PSO Algorith Principle

Particle Swarm Optimization (PSO) is used to solve optimization problems [6], and the solution of each optimization problem is a bird in the simulated search space called particles. Each particle is determined by an optimized function of their fitness value (fitness value) they have two parameters, position, and velocity, their initial Each iteration updates their speed and position by tracking two extreme values, the first one is the optimal solution found by the particle itself, which is called the extreme individual value; the second extreme value is the optimal value found by the whole population iteration to the current one, which is the extreme global value.

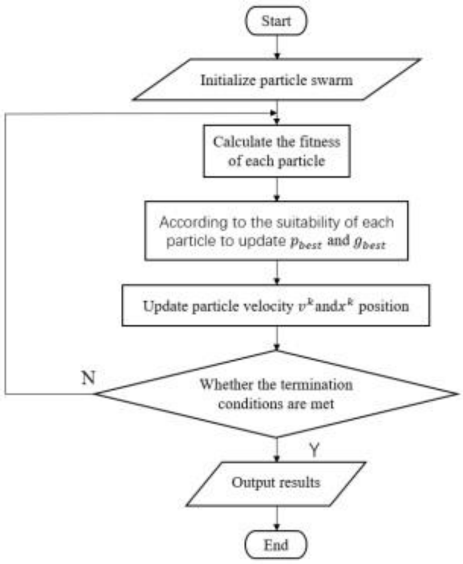

Figure 8.PSO Algorithm Flow Chart [7]

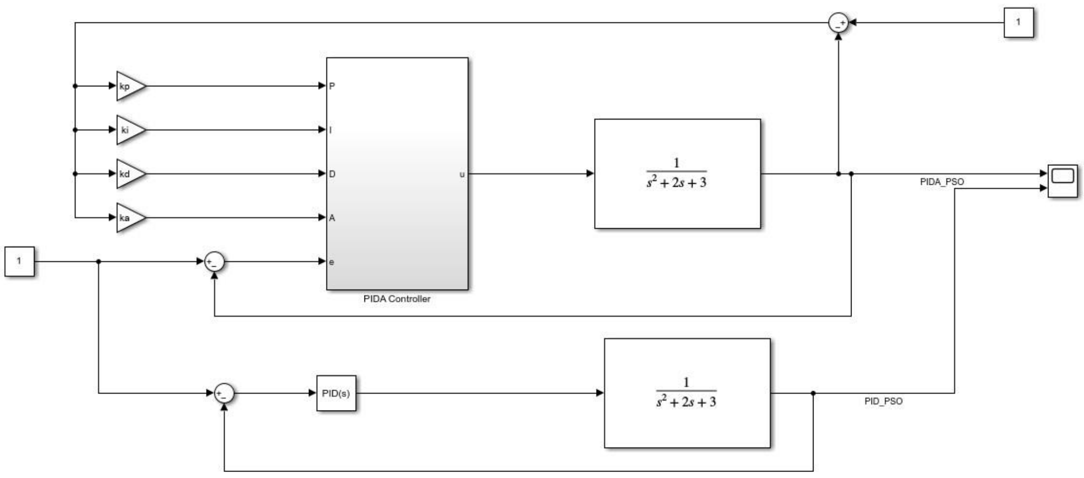

Figure 9.MATLAB/Simulink model of PIDA and PID

$$G(s) = \frac{1}{s^2+2s+3} \quad (3)$$

Transfer function of the system (3)

Figure 9 respectively the system is used two different functions, they are unit step function, sinewave function and step change input signal.

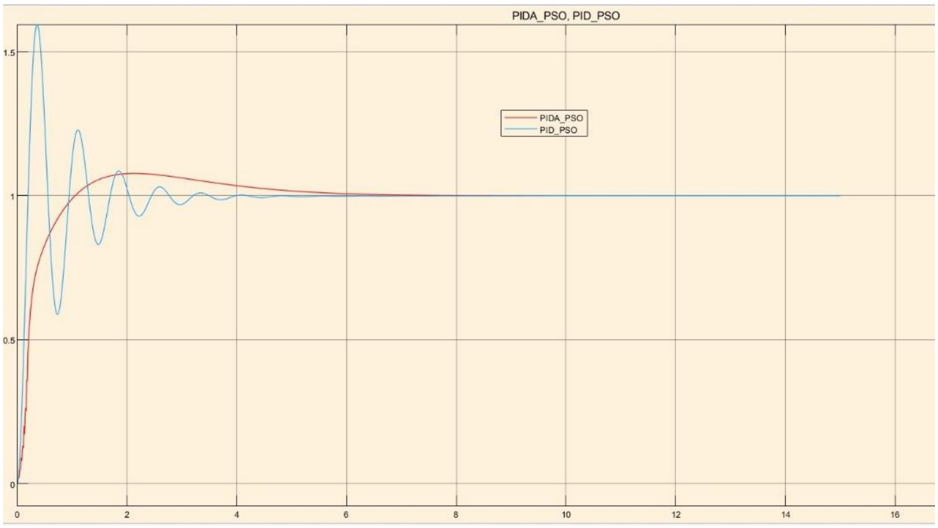

Figure 10. Step response of the system referance, PID, and PIDA controllers.

The simulation results show that the PID controllers achieves faster settling time and lower overshoot than the PIDA controller.

Specifically, the settling time of the PID controllers is approximately less than 5 seconds, while the settling time of the PIDA controller is approximately 7 seconds.

5. How does Fuzzy Controller Tunning and its comparasion with PID?

A.Fuzzy-PID Controller

Fuzzy controllers are nonlinear, it is more difficult to set the controller gains compared to proportional-integral-derivative (PID) controllers. This assignment proposes a design procedure and a tuning procedure that carries tuning rules from the PID domain over to fuzzy single-loop controllers. The idea is to start with a tuned, conventional PID controller, replace it with an equivalent linear fuzzy controller, make the fuzzy controller nonlinear, and eventually fine-tune the nonlinear fuzzy controller. This is relevant whenever a PID controller is possible or already implemented.

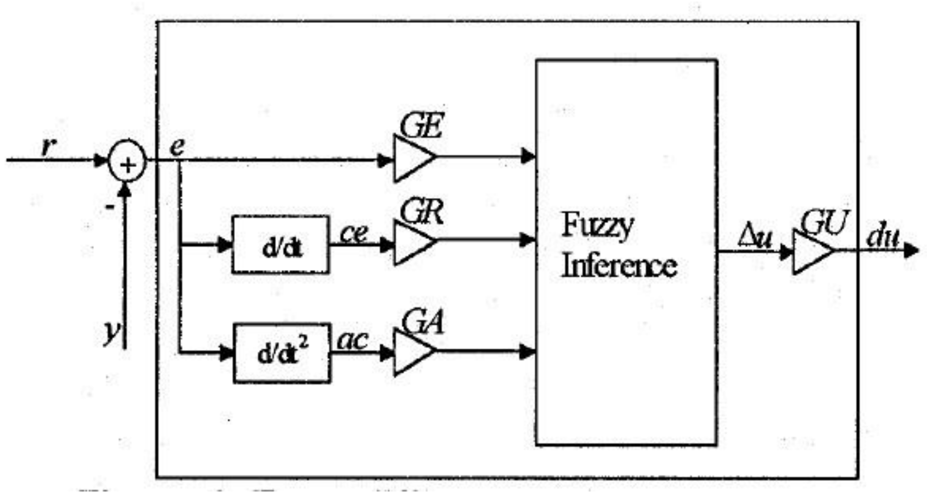

Figure 11.Fuzzy-PID controller and tuning parameters [8]

Figure 11 shows the basic diagram of an incremental Fuzzy-PID controller, where error *e* -the difference between the process output *y*, and the reference signal ***r*** **,**the error change *ce*, and the second error derivative *ac*, are the input FLC variables, and the increment of the control action Au is the FLC output. The parameters chosen to tune the FLC are the scale factors *GE*, *GR*, *GA*and *GU*, gains which weight the input and output variables respectively[10]

B. Finding parameters by Ziegler-Nichols.

Controller	Kp	Ti	Td
P	0.5Ku		
PI	0.45Ku	Tu/1.2	
PID	0.6Ku	Tu/2	Tu/8

1-Increase the proportional gain until the system oscillates; that gain is the ultimate gainK_u.

2-Read the time between peaks T_u at this setting.

3-Table gives approximate values for the controller gains.

Assuming the following transfer function for our system

$$G(s) = \frac{1}{(s+1)^3}$$

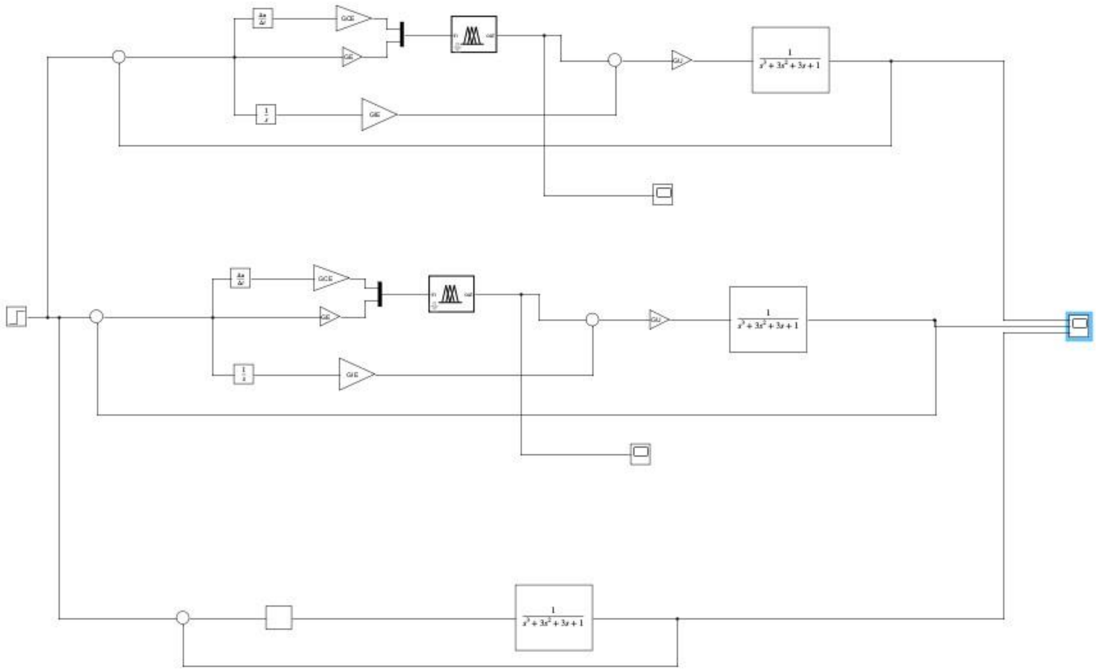

Figure 12..MATLAB/Simulink model of Fuzzy-PID and PID

After building the FIS our block diagram is built in Simulink as shown in figure 12. We have watched the output of the controller (control signal) and the overall output of the system (process output).

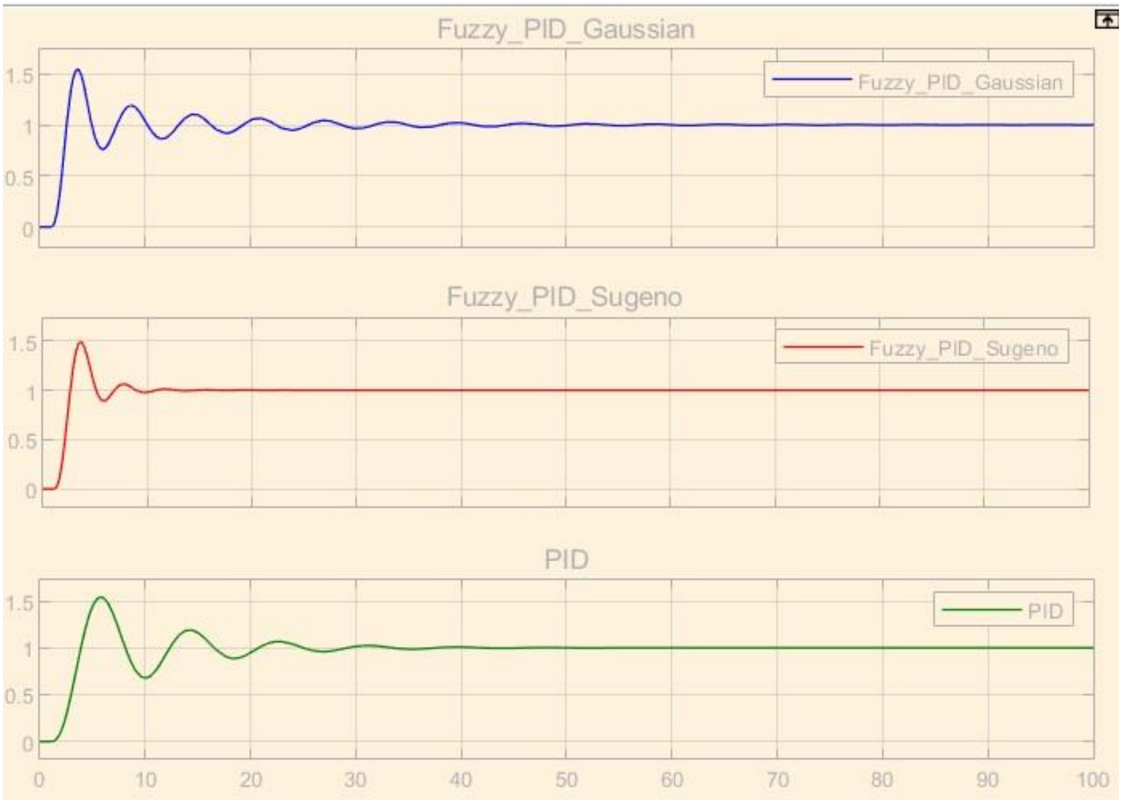

Figure 13. Step response of the system referance, PID, and PIDA controllers.

Comperasion three controllers

Time Domain Specification	PID	Fuzzy_PID_Sugeno	Fuzzy_PID_Gaus
Settling Time	40	12	75
Peak Overshot	5	4	3.75

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