GRD Journal for Engineering | Volume 2 | Issue 5 | April 2017
ISSN: 2455-5703

Design of Adaptive Fuzzy PID Controller for Network Control System

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Abstract

Network control system (NCSs) are used for controlling remote plants via shared –band data communication networks. Due to some problems like communication time delay, data packet loss, network interference, signals jamming, it's difficult to achieve a satisfactory result when using the conventional control algorithm. In this paper, focusing on the above problems in Network Control Systems, a new kind of controller is designed that is the "Fuzzy PID" controller. When compared with conventional PID controller the dynamic performance of proposed "Fuzzy PID" controller is improved in terms of overshoot, settling time. This suggested design has been applied to control the speed of DC Servomotor as a remote plant using MATLAB SIMULATION. Thus the results shows that the designed controller used in this paper can increase the adaptability of the system and obtain a better control effect.
Keywords- Network Control System, PID Controller, Fuzzy Logic, DC Servomotor

I. Introduction

With the development of network technology, network control system (NCS) has been an active research hot spot in recent years. The application of network control solves many problems which traditional point-to-point control can't solve [1,]. Network control systems (NCS) are distributed systems in which the communication sensors, actuators and controllers occur through a shared band –limited digital communication network [15]. The control system constructed by network has much excellent character, such as high expansibility, flexible structure, low cost, reliability etc. But at the same time it has some drawbacks like time delay and packet loss which cannot be avoided. [2].

Some of the methods dealing with the network delay in the NCS are deterministic control [3], predictive control [6], random control [4-5], robust control [7-8] and etc. In Reference [3] deterministic control method is used, in this a cushion between controller node and sensor node is added, so that it can convert uncertain random delay into a constant delay. But this method increases the delay time virtually and it is difficult to meet the real-time demanding application. The full-order state estimator and Kalman filter are introduced in [4] to calculate the delay and suppose the probability of the system delay is known, but there is a high demand of processor due to the amount of calculation. In [7], an optimal dynamic output feedback robust control law is derived based on the Lyapunov stability theory.

Fig 1 shows the basic block diagram of network control system.

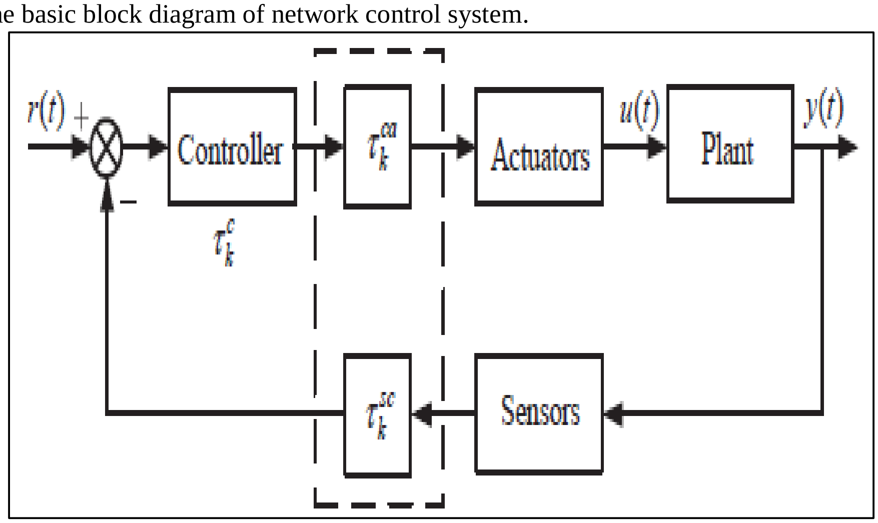

Fig. 1: Block diagram of NCS

Here: r(t) is input ,y(t) is output, τ_k^{ca} is time delay from controller to actuator. τ_k^{sc} is time delay from sensor to controller.

The paper will be organized as follows, section II describes the design and the value of transfer function of DC servomotor .Section III describes the design of controllers for (NCS).

Section IV shows the comparative Simulation results, Section V finally conclusion closes the paper.

II. DC SERVOMOTOR DESCRIPTION

Here the DC servomotor is acting as the plant for network control system. DC servomotor is a device which converts electric energy into mechanical energy. Some of the important feature of DC servomotor is that its output shaft can be moved to specific angular position and it is also suitable for wide range speed control. [9] Fig. 2 shows the schematic representation of the DC servo motor model. Fig 3 represents the block diagram of the same. Parameters and values chosen for motor simulation can be shown at Table 1.

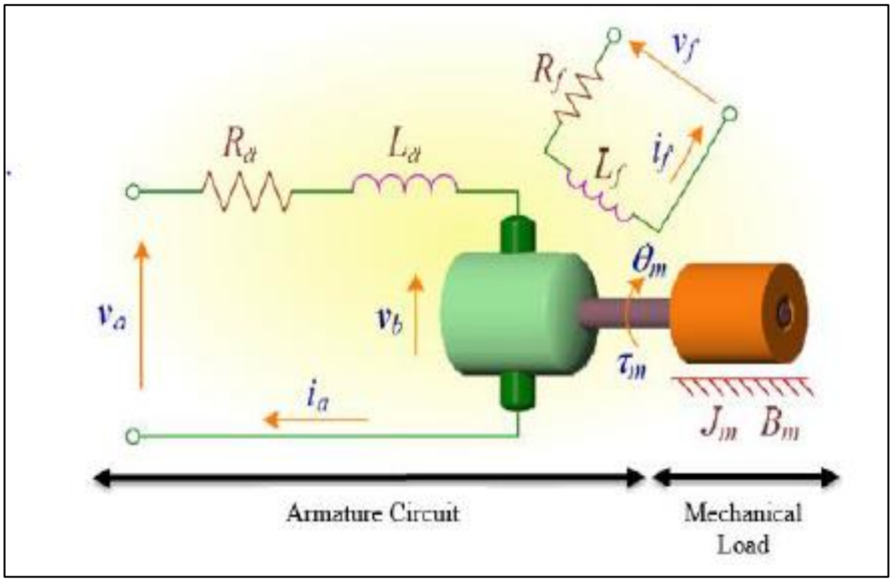

Fig. 2: Schematic Representation of the DC Servo Motor

Table 1: Dc Servomotor Parameter and Value [10]

Parameter	*Name*	*Value*
Moment of inertia	*Jm*	*0,000052 Kg.m2*
Friction coefficient	*Bm*	*0,01 N.ms*
Back EMF constant	*Kb*	*0,235 V/rad s-1*
Torque constant	*Ka*	*0,235 Nm/A*
Electric resistance	*Ra*	*2 ohm*
Electric inductance	*La*	*0.23 H*

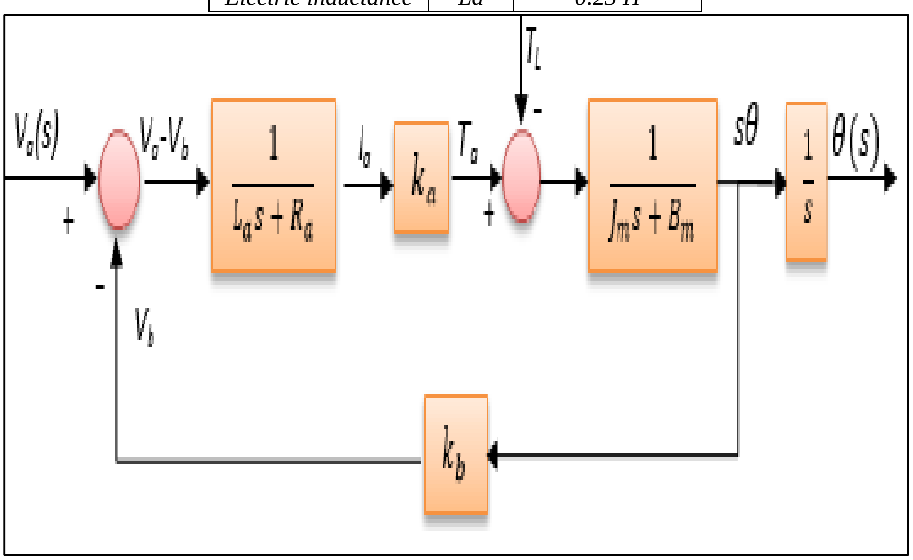

Fig. 3: Block Diagram of DC Servomotor

Including the parameters, we can get the transfer function of DC servomotor [10]:

$$G_{position}(s)=\frac{\theta(s)}{Va(s)}=\frac{19640}{s3+201s2+6290s} \qquad (1)$$

III. DESIGN OF THE CONTROLLERS

A. PID Controller

Proportional integral derivative controller (PID controller) is a control loop feedback mechanism commonly used in industrial control system. The PID controller continuously calculates an error value as a difference between measured process variable and desired set points, the controller attempts to minimize the error over time by adjustment of controlled variable, such as position of control value, a damper or the power supplied to the heating element [11]. Fig 4 shows the block diagram of PID controller.

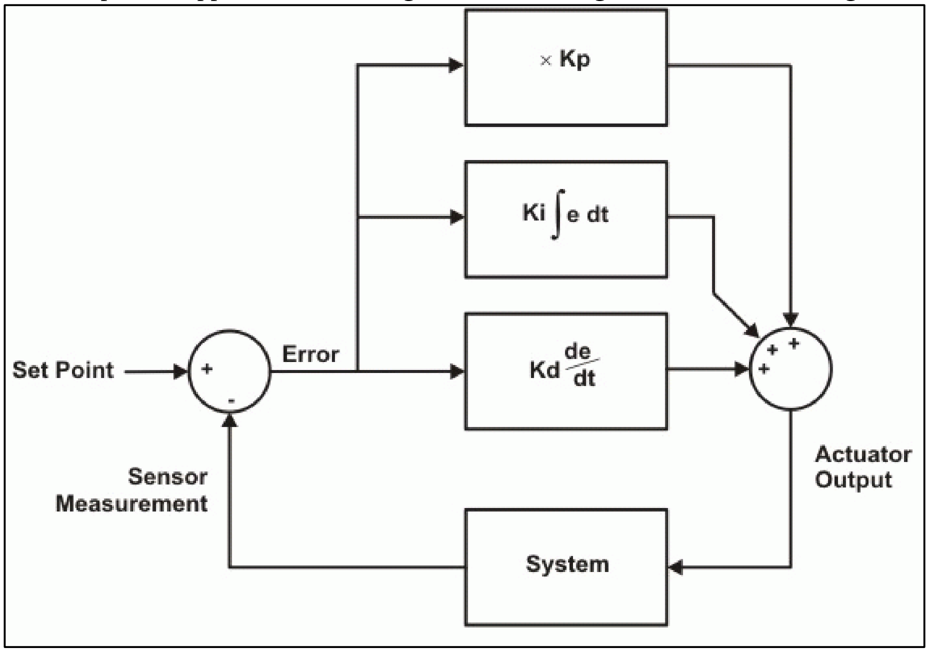

Fig. 4: Block Diagram of PID Controller

The controller parameters are: The proportional gain Kp, the integral gain Ki , integral time constant Ti , the Derivative gain Kd and derivative time constant Td.
Mathematical equation of PID controller is-

$$\text{Controller}(t) = kp\theta(t) + ki\int_0^t \theta(\tau)d\tau + kd\frac{d}{dt}\theta(t) \qquad (2)$$

When the conventional PID controller is applied to the transfer function of DC servomotor which is given in equation (1) the simulation results thus obtain is shown in figure 5.

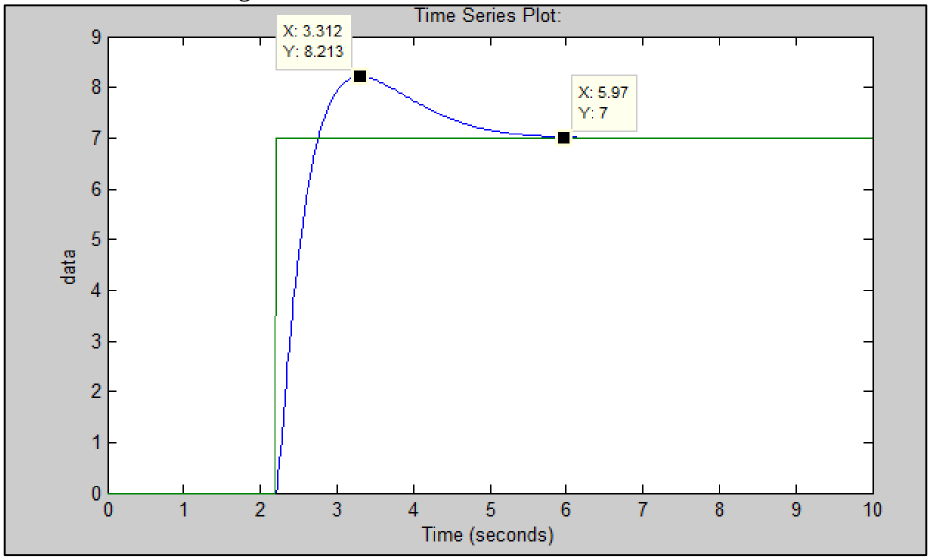

Fig. 5: Simulation Results of PID Controller

B. Fuzzy Logic Controller

Fuzzy logic controllers have logical resemblance to a human operator. It operates on the foundations of a knowledge base which in turn rely upon the various if then rules, similar to a human operator .Fuzzy logic controller is simpler as compared to other controller because there is no complex mathematical knowledge required. The FLC requires only a qualitative knowledge of the system thereby making the controller not only easy to use, but also easy to design [12].

There are basically three essential segments in fuzzy logic controller viz.

1) Fuzzification block or fuzzifier.
2) Inference system.
3) Defuzzification block or defuzzufier.

Here a Fuzzy Logic Controller (FLC) is being designed for the proposed controller. Before starting the simulation, we will design of FIS (Fuzzy Inference System) firstly by using fuzzy logic toolbox in Fig.6 and analyze the respond systems by manual reading based on the graph.

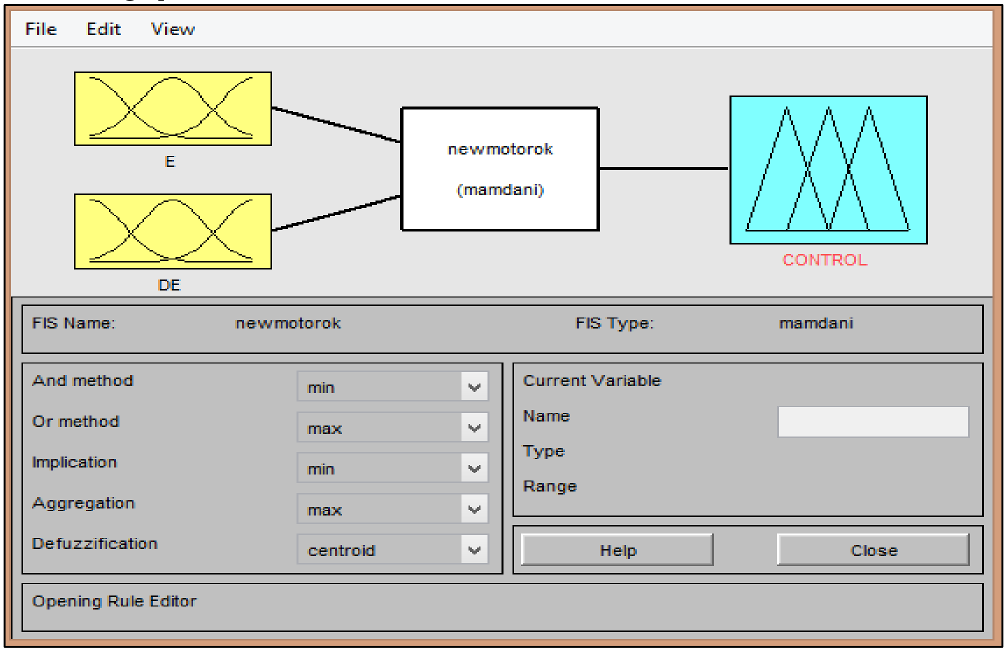

Fig. 6: The FIS Editor

Here in the proposed modal we have taken two inputs and one output. Two inputs contains error (E) and delta error (DE), one output is a CONTROL (here CONTROL is open loop gain of plant identification model) to the plant [10].

The fuzzy membership functions for the two input parameters are shown in Fig.7. And Fig.8, and the membership function for the output is shown in Fig.9.

Here for the input error (E) we have taken five membership functions, three of them are triangular and two of them are trapezoidal. The range we have taken is from (-10 10). [13] As we can see in fig 6. For error (E) as input here NL means Negative Large, NM means Negative Medium, Z means Zero, PM means Positive Medium and PL means Positive Large.

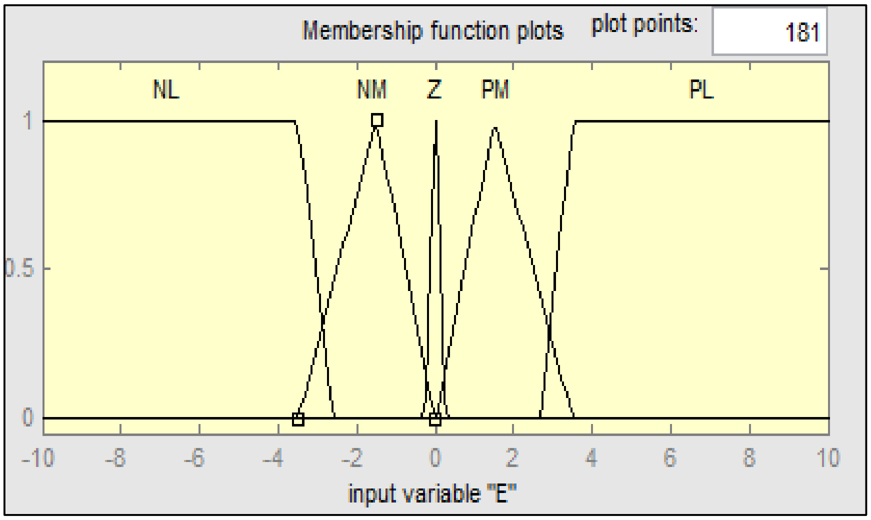

Fig. 7: Membership Functions of Error (E) as Input

For second input delta error (DE) we have taken two membership functions that are trapezoidal. And the range is (-10 10) fig 7. ,. For delta error (DE) as input, here N means Negative and P means Positive.

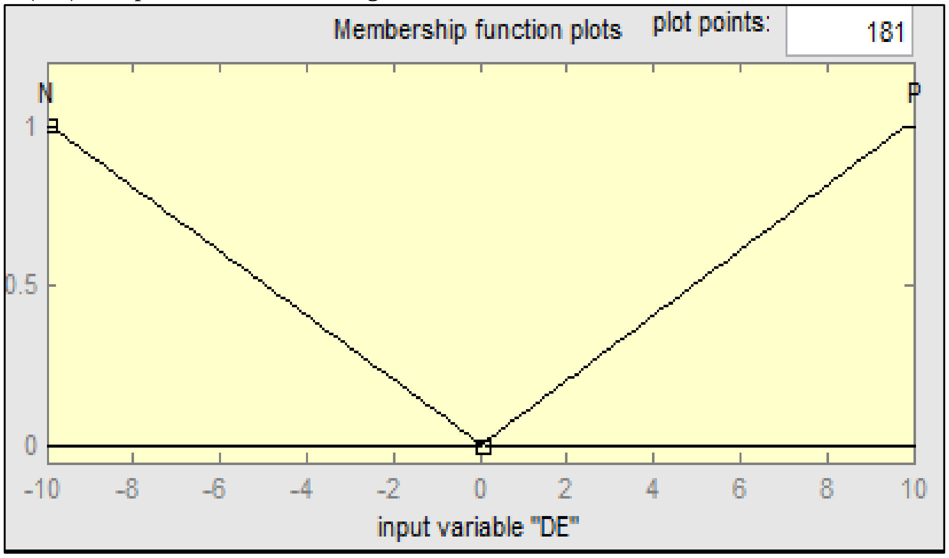

Fig. 8: Membership Functions of Delta Error (DE) as Input

For the output CONTROL again five membership functions are taken as in first input error (E). Fig 8 shows the membership functions of CONTROL as output.

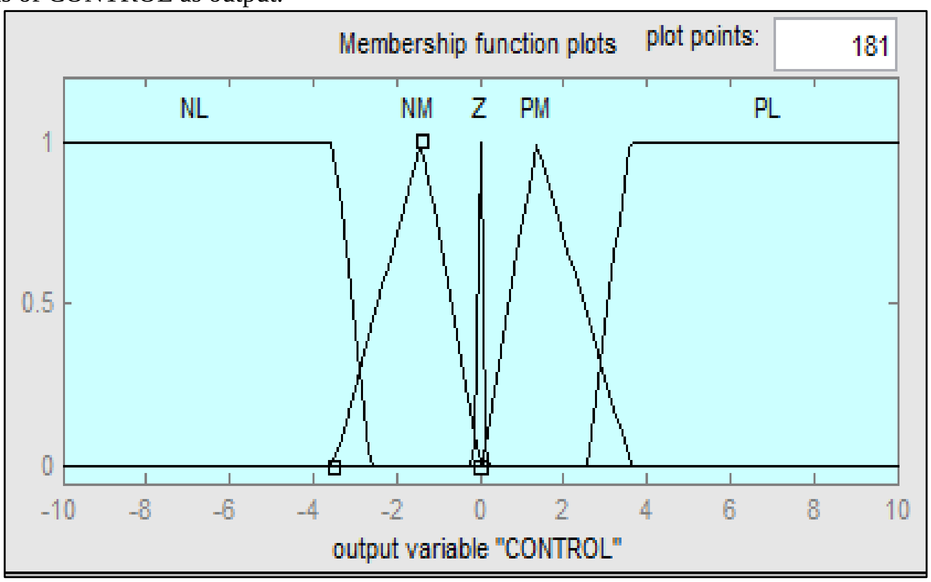

Fig. 9: Membership Functions of CONTROL as Output.

In this simulation, it is aimed to control motor speed. The knowledge base contains a set of rules which construct the decision-making logic rule [10, 14]. There are 7 rules that used at the controllers which are based on human experience and information is:

1) If E is PL then CONTROL is PL
2) If E is NL then CONTROL is NL
3) If E is Z and DE is N then CONTROL is NM
4) If E is Z and DE is P then CONTROL is PM
5) If E is Z then CONTROL is Z
6) If E is NM then CONTROL is NM
7) If E is PM then CONTROL is PM

After designing the rule, we can get the surface viewer in Fig.9 that represents the rule of FLC

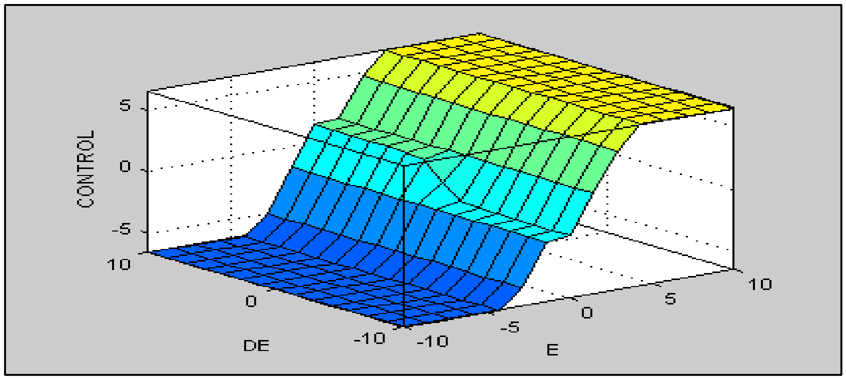

Fig. 10: 3D FLC Surface

This fuzzy rules when applied to transfer function of DC servomotor which is given in equation (1) the simulation results thus obtain is shown in figure 11.

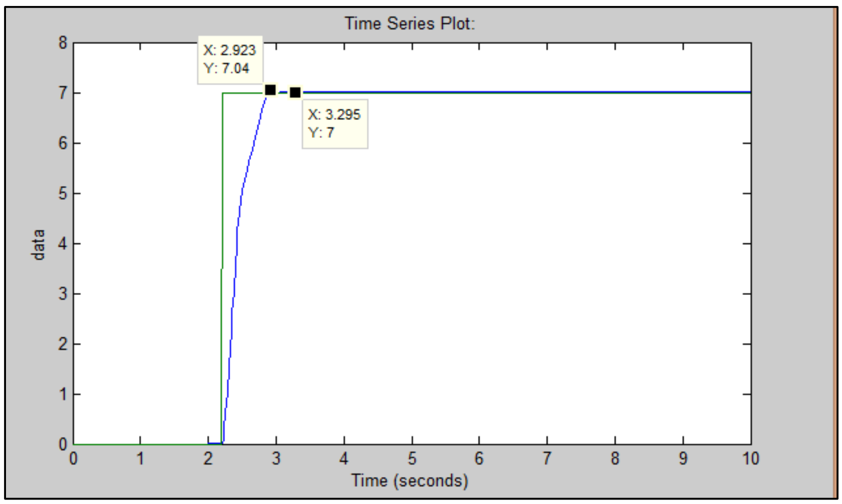

Fig. 11: Simulation Result of Fuzzy PID Controller

IV. PROPOSED CONTROLLER AND COMPARATIVE SIMULATION RESULTS

In this section we will discussed about the proposed controller. As we all know the PID controller is a Conventional controller, but PID controllers are not adaptive enough, this is the limitation of PID controller. So as to increase the effectiveness of the controller "fuzzy PID" controller is introduced, which is quite good in controlling. The structure of improved "fuzzy PID" controller is shown in the fig 12.

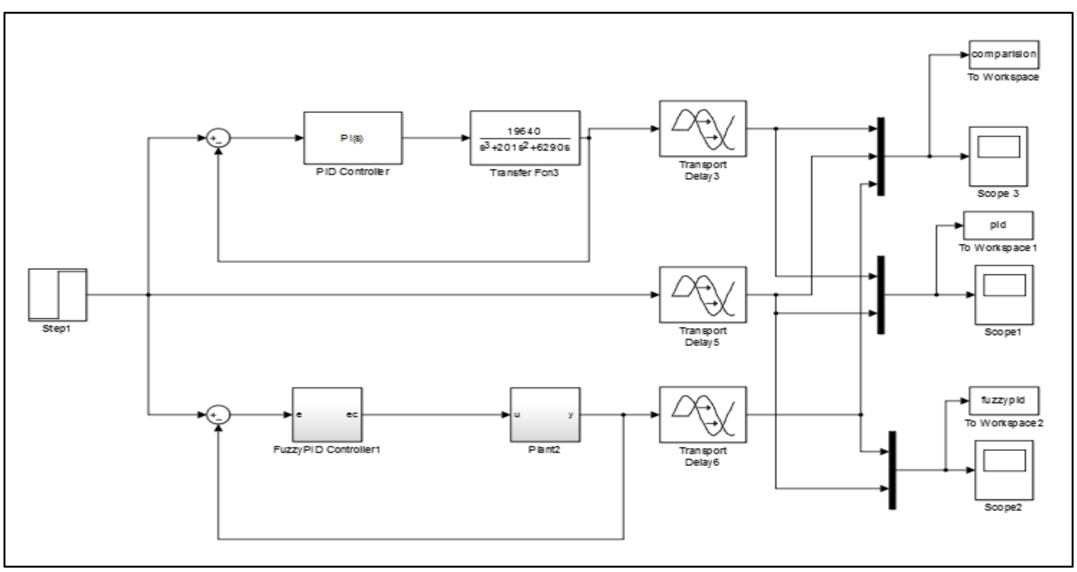

Fig. 12: Structure of the improved Fuzzy PID controller

When simulation results of PID and Fuzzy PID is compared. It is found that the "fuzzy pid" shows better results as compared to only PID controller in terms of overshoot and settling time. The simulation curves are shown in figure 13. The curve with blue colour refers only PID and the curve with red colour refer proposed "Fuzzy PID". The results can be verified from Table 1

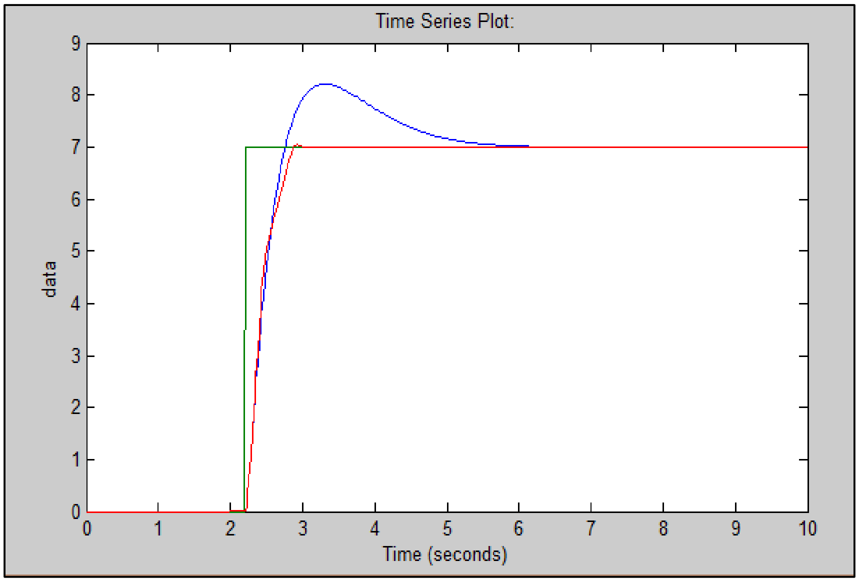

Fig. 13: Comparative Results of PID and Fuzzy PID

Table 1: Comparative Results between PID, Fuzzy PID Controller

Parameters	*PID*	*Fuzzy PID*
Overshoot	*8.213 (20.2%)*	*7.04 (1.2%)*
Settling time(sec)	*5.97*	*3.295*

V. CONCLUSION AND FUTURE SCOPE

This paper proposed a novel "Fuzzy PID" controller for the Network Control System (NCS). Fuzzy logic is used as expert system. Analysis is made under various controlling parameters like overshoot and settling and it is found that the performance of proposed "Fuzzy PID" controller is best as compared to conventional PID and . Simulation results show that the proposed controller has a better performance in terms of overshoot and settling time. Thus the proposed controller shows the best dynamic performance.

However, here in this paper we only deal with the controller designs. We know that the Network Control System has many issues such as time delay, data drop out. So how to solve the problem of time delay using compensators like Smith Predictor will be the next research direction.

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