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Fuzzy Logic Based PID Controller for a Non Linear Spherical Tank System

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***Abstract*— Non-linear process control is a difficult task in process Industries. Spherical tank level control is one among them due to the variation in cross sectional area. In this project modeling of Spherical tank system is done. The implementation of fuzzy logic controller (FLC) and Fuzzy PID for a spherical tank to control liquid level is studied. System identification of spherical tank system is done which is identified to be non-linear. Here the conventional PID controller parameters are designed based on Ziegler-Nicholas tuning method. The process is designed and implemented in Mat lab. It is observed from the result that Fuzzy based PID controller perform well in terms of less settling time, rise time and no overshoot in process output.**

***Keywords*— Fuzzy logic controller, PID controller, spherical tank, System Identification, Fuzzy PID)**

I. Introduction

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquid to be pumped and stored in the tanks, then pumped to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated. Often the tanks are so coupled together that the levels interact and this must also be controlled. Level and flow control in tanks are at the heart of all chemical engineering systems.

A real time implementation of Fuzzy logic Controller (FLC) for a spherical tank to control liquid level of the tank. Control of liquid level in a spherical tank is highly non- linear due to variation in the area of cross section of level system with change in shape .System identification of spherical tank system is done which is identified to be non- linear. Here the conventional PID controller parameters are designed based on Ziegler-Nicholas tuning method. Here we compared with Fuzzy logic controller as well as fuzzy logic based PID. The real time implementation of the process is designed and implemented in MATLAB using Simulink tool.

II. SYSTEM DISCRIPTION

A. Spherical tank system:

A sphere is a very strong structure. The even distribution of stresses on the sphere's surfaces, both internally and externally, generally means that there are no weak points. That's why a drop of water forms a spherical shape when under free fall, in short; it achieves a shape where all the resultant stresses neutralize when no external force is acting on it.[2] Moreover, they have a smaller surface area per unit volume than any other shape of vessel. This means, that the quantity of heat transferred from warmer surroundings to the liquid in the sphere, will be less than that for cylindrical or rectangular storage vessels.it is used in many applications,

- Petroleum industries
- Paper industries
- Water treatment plants
- Chemical industries, etc.

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Fig 1.1: Experimental Setup of a Spherical Tank level system

B. Block diagram:

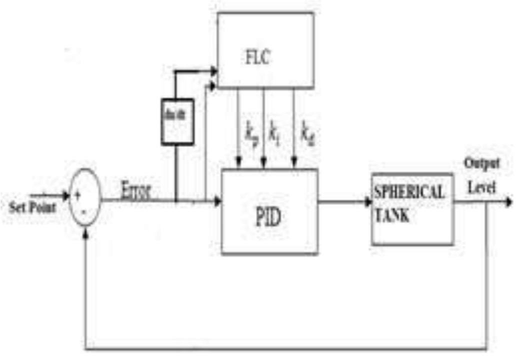

Fig. 1. Block diagram of proposed method.

After the development of fuzzy logic, an important application is to developed in Control systems and it is known as fuzzy

PID controllers. Fuzzy PID controllers may be used as controllers instead of linear PID controller in classical or modern control System applications. They are converting the error between the measured or controlled variable and the reference variable, into a command, which is applied to the actuator of a process.[4] The structure of the fuzzy PID controller is presented in Fig.2.2 In this case the derivation and integration is made at the input of the fuzzy block, on the error *e*. The fuzzy block has three input variables.

C. Process Model

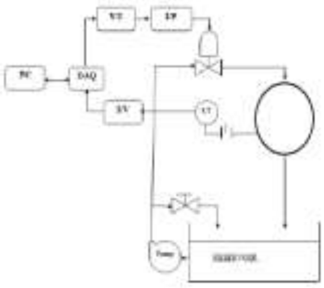

Fig. 2. Process model of proposed system

Where
LT : Level transmitter.
I/V : Current to voltage converter.
V/I : Voltage to current converter.
I/P : Current to pressure converter.
DAQ : Data acquisition card.

III. MATHEMATICAL MODELLING

The spherical tank is the process considered which is given in figure 3.

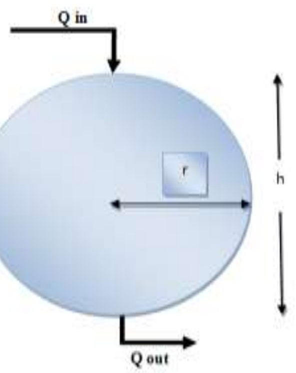

Fig .4. Conical tank.

ρ :density of liquid in the tank Kg/cm^3
$\rho 1$: density of liquid in the inlet stream Kg/cm^3
$\rho 2$:density of liquid in the inlet stream Kg/cm^3 V :the total volume of the spherical tank cm^3
Q_{in} : volumetric flow rate of inlet stream LPH
Q_{out} : volumetric flow rate of outlet stream LPH
R : Maximum radius of the sphere cm
r :Radius of the sphere at steady state cm
h :Maximum height of the cone cm

Using the law of conservation of mass,

$$\left[\frac{accumulation\ of\ total\ mass}{time}\right]=\left[\frac{input\ of\ total\ mass}{time}\right]-\left[\frac{output\ of\ total\ mass}{time}\right]$$

$$\frac{d(\rho v)}{dt}=\rho_2 q-\rho_2 q_0$$

Assume that the room temperature as well as the density of liquid is constant, ρ=ρ1=ρ2.

$$\frac{dv}{dt}=q-q_0$$

$$\frac{dv}{dt}=q-c\sqrt{h}$$

This equation cannot be preceded with the Laplace transform due to the presence of non-linear term **√*h*.** Where ***'c'*** is the valve constant. The obtained transfer function model is,

$$\frac{H(s)}{Q(S)}=\frac{R}{\tau s+1}$$

By system identification,

Specifications of spherical tank:
Volume : 81.6 liters
Diameter : 40 cm
Material : Stainless Steel

The transfer function of the spherical tank system obtained is

$$\frac{H(s)}{Q(S)}=\frac{0.9897}{155.38s+1}$$

IV. FUZZY LOGIC CONTROLLER DESIGN [1]

To implement fuzzy logic technique to a real application requires the following three steps:
1. Fuzzification – convert classical data or crisp data into fuzzy data or Membership Functions (MFs)
2. Fuzzy Inference Process – combine membership function with the control rules to derive the fuzzy output
3. Defuzzification – use different methods to calculate each associated output and put them into a table: the lookup table. Pick up the output from the lookup table based on the current input during an application

Table 1: FUZZY MAPPING RULES

		CHANGE IN ERROR				
		VL	L	Z	H	VH
ERROR	VL	M	P	PB	PB	PB
	L	N	M	P	PB	PB
	Z	NB	N	N	M	PB
	H	NB	NB	N	M	N
	VH	NB	NB	N	M	M

.

A. Fuzzyfication and Membership function

Here we have to select the number of input and output which we need for this process. Then we have to find out the ranges for this particular set of input and outputs [5]. After this process we should have to develop fuzzy rules according to the lookup table and arrange the membership functions shape.

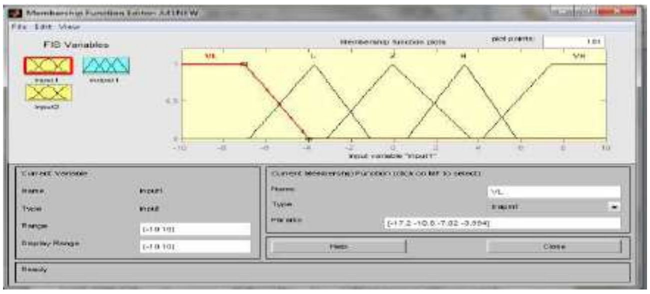

Fig.5. Membership function for error

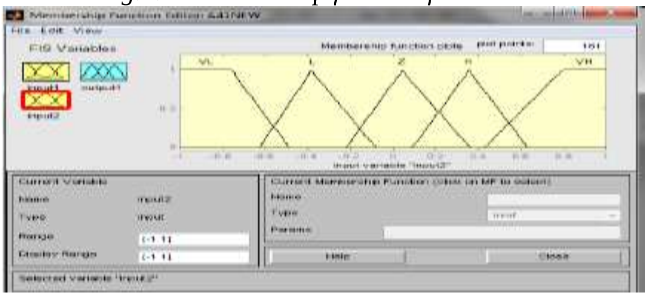

Fig.6. Membership function for change in error

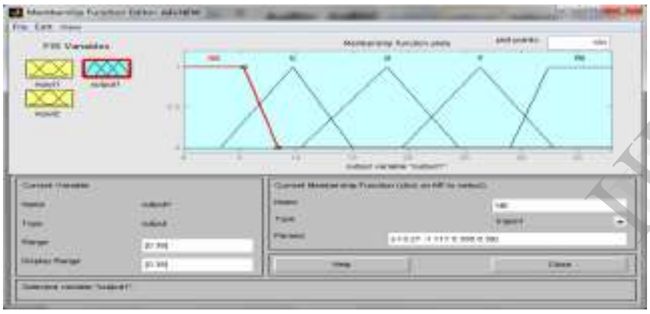

Fig.7. Membership function output

B. Zeigler-Nichols controller tuning:[3]

<u>Algorithm</u>

STEP 1

Setup open loop block diagram in MATLAB Simulink. Assign the parameters of the secondary transfer function.

STEP 2

By giving unit step input, observe the open loop response in the scope.

STEP 3

Using two-point method, Calculate time constant & time delay.

STEP 4

Using Zeigler-Nichols open loop tuning method, find the parameters of PID Controllers.

STEP 5

Observe the response of the closed loop system with the PID controller.

STEP 6

Observe the response of the PID controller.

Proportional Mode

Kc =6.0624sec

Proportional Integral Mode

KC= 5.4562sec

Ti=3.33td sec= 87.412sec;

Ki=KC/Ti = 0.06241sec

Proportional Integral Derivative Mode

KC=1.2 T/td*KP=7.274sec

Ti=2td sec=52.5sec

Ki = KC/Ti=0.1385sec

Td=13.125sec

Kd= KC*Td sec =95.48sec

VI RESULTS AND DISCUSSION

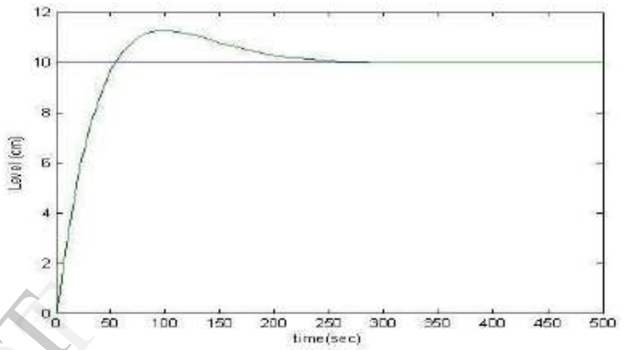

Fig.8. *Ziegler-Nichols tuning for PID mode in MATLAB*

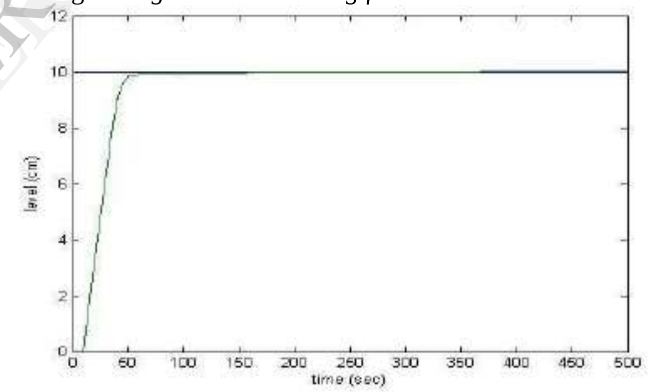

Fig.9.Response of fuzzy logic controller in MATLAB

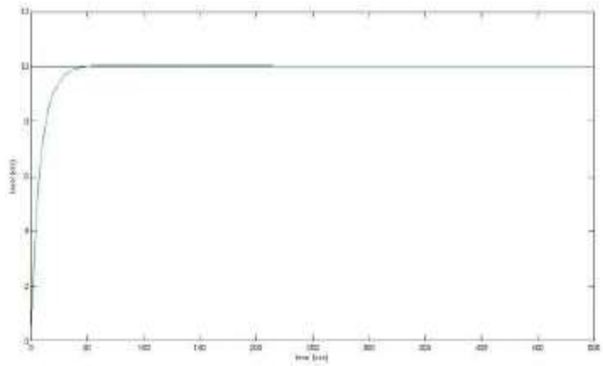

Fig.10.Response of fuzzy based PID controller in MATLAB

A Comparison:

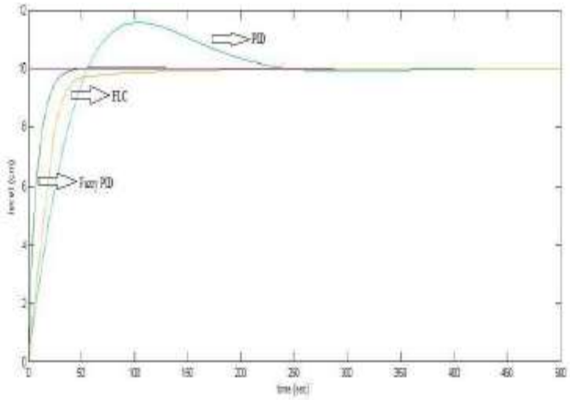

Fig.11:comparison of performance measure

Table 2: comparison of performance measures

Controller	Rise time (sec)	Settling time(sec)	Overshoot (%)
PID	**50**	**300**	**5.18**
FLC	**40**	**190**	**0**
Fuzzy based PID	**25**	**60**	**0**

The peak overshoot of the response Is zero for both fuzzy logic controller and fuzzy based PID controller which is one of the important advantage. When compare with fuzzy logic controller and conventional controllers we can able to notice that the rise time and settling time is less in FLC. Moreover that Fuzzy based PID controller gives the best performance in terms of rise time, settling time and overshoot when compared with other controllers.

VII CONCLUSION AND FUTURE WORK

The modeling of Spherical tank is done and the transfer function parameters are obtained from the modeling. The nonlinearity of the spherical tank is analyzed. The performance is tested using Matlab. Comparison with a fuzzy logic and conventional PID controller gives testimony to the effectiveness of the fuzzy logic based PID control technique in the non-linear system. The settling time, rise time and overshoot of the process using Fuzzy Logic based PID Controller shows better response than PID controller as well as ordinary FLC . It is concluded that for a nonlinear system the Fuzzy Logic Controller based PID performs well when compared to conventional controllers. The project can be extended with real time implementation of the control of level in Spherical tank using Genetic algorithm (GA) as well as Neuro Fuzzy techniques.

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