International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 03 Issue: 12 | Dec 2016 www.irjet.net p-ISSN: 2395-0072

Hybrid fuzzy Controller for conical tank process

S.Ramesh[1]

Assistant Professor, Dept. of Electronics and Instrumentation Engineering, Annamalai University, Annamalainagar,Tamilnad.

***

Abstract - *The proposed hybrid fuzzy control algorithm is designed for non-linear level process to improve the control performance better then the conventional PID controller. The conventional PID controller works well only if the mathematical model of the system could be computed. Hence it is difficult to implement the conventional PID controller for variable as well as complicated systems. But fuzzy logic control does not require any precise mathematical model and works good for complex applications also. In this paper, hybrid fuzzy P+ID controller is designed to control the chosen non-linear level process.*

Key Words: PI Controller, hybrid Fuzzy PI Controller

1.INTRODUCTION

Control of non linear process is obscure taskin the process control industries. This kind of nonlinear process exhibit many not easy control problems due to their non linear dynamic behavior, uncertain and time varying parameters. Especially,control of a level in a spherical tank is vital, because the change in shape gives rise to the non linear characteristics. An evaluation of a controller using variable transformation proposed by Anathanatrajan et.al [1] on hemi-spherical tank which shows a better response than PI controller. A simple PI controller design method has been proposed by Wang and Shao [2] that achieves high performance for a wide range of linear self regulating processes. Later in this research field, Fuzzy control is a practical alternative for a variety of challenging control applications, since it provides a convenient method for constructing nonlinear controllers via the use of heuristic information. Procyk and Mamdani [3] have discussed the advantage of Fuzzy Logic Controllers (FLC) is that it can be applied to plants that are difficult to get the mathematical model. Recently, Fuzzy logic and conventional control design methods have been combined to design a Proportional Integral Fuzzy Logic Controller (PI - FLC). Tang and Mulholland [4] have discussed about the comparison of fuzzy logic with conventional controller. To overcome these problems, in this paper the Fuzzy P+ID controller and analyze. The main idea of the study is to use a conventional D controller to stabilize a controlled object and the fuzzy proportional (P) controller to improve control performance. A design of the fuzzyP+ID controller[5][6] since this approach is used in industrial control of a plant with unknown structure or with nonlinear dynamics.

The paper is divided as follows: Section 2 shows the methodology, algorithms of hybrid fuzzy P+ID , Section 3 presents a brief description of the mathematical model of conical tank system section 4 presents the results and discussion and finally the conclusions are presented in section 5.

2. HYBRID FUZZY CONTROL

For implementing the block diagram of fuzzy P+ID controller referred Figure 4 only one supplementary parameter has to be attuned.

Consequently, the physical tuning time of the controller can be greatly reduced in comparison with a conventional fuzzy logic controller.

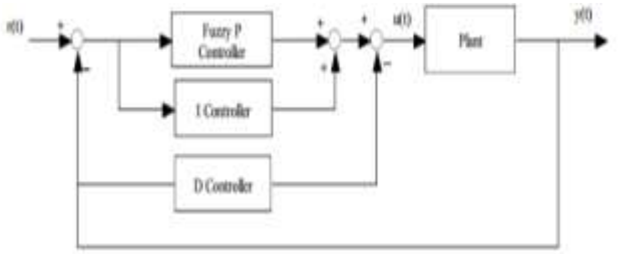


Figure-1 Structure of Hybrid Fuzzy P+ID controller

2.1 Design of Hybrid Fuzzy P+ID Controller

Design of fuzzy P+ID controller is constructed by replacing the conventional proportional term with the fuzzy one, we propose the following formula:

$$K_P = 0.6K_P(crit)$$

$$K_I = \frac{2K_P}{T(crit)}$$

$$K_D = (T+2)K_P + K_I T^2$$

For determination of their parameters. We select the parameter K_D of the derivative controller by using the sufficient stability condition [5] instead of the Ziegler and Nichols' formula. This result implies that stability of a system does not change after the conventional PID controller is replaced by the fuzzy P+ID controller without modifying any PID-type controller parameter.

The selection of the sampling period T is made in two stages: 1) during the loop design and 2) during the controller design. The observed rule [6] suggests that the sampling frequency must be from 4 to 20 times the bandwidth of the closed-loop system.

For the controller design, T should be enhanced to be greater than the sum of the error computation time, the digital analogue converter (DAC) and analogue digital converter (ADC) conversion times, and the zero-order hold delay time. The necessary conditions for selection of T is given below,

1) if T is greater, the stability regions are smaller;

2) Large T implies small cost;

3) Large T results in large conversion times of the

DAC's and ADC's (i.e., to smaller cost);

4) Small T allows good system performance in the presence of noise.

2.2 Membership function

The membership function used by fuzzy controller is triangular membership function. The fuzzy subset are Negative Big, Negative small, Zero, Positive small, and Positive Big respectively termed as NB, NS, ZO, PS, PB.

The quantization factor and the scaling factor play an important role in the performance of the fuzzy controller. The control rules are framed to achieve the best performance of the fuzzy controller. These rules are given in the tables 1.

Table-1 Fuzzy control rule

E \ CE	**NB**	**NS**	**ZO**	**PS**	**PB**
NB	PS	PS	ZO	PB	PB
NS	NS	NS	NS	NS	PS
ZO	NB	NS	NS	PS	PS
PS	NS	NS	NS	PS	PS
PB	PS	ZO	ZO	PB	PB

Using this control rules flow.fis is created. This control rules are framed using the fuzzy logic toolbox available in MATLAB. The above said membership function with the mentioned fuzzy subsets and the control rules form the fuzzy controller. This .fis file is called in the simulink environment and the connection is established between them. The inference engine used here is the Mamdani inference engine.

2.3 Rule Surface viewer of the Fuzzy Controller

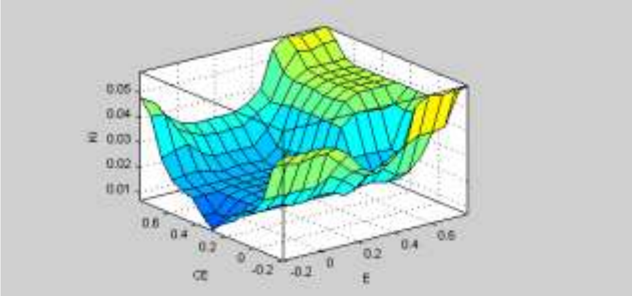


Figure-2 Surface view

Based on the established fuzzy rules, the surface view is shown in Figure 2.

3. PROCESS

The Figure-3 shows the experimental setup which consists of a conical process tank, a pneumatic control valve , a storage tank , a pump, an I/P converter, a differential pressure level transmitter, VMAT interfacing card and I/V & V/I converter. Water from storage tank is pumped continuously to the conical tank through a pneumatic control valve. A differential pressure level transmitter (DPLT) measures the level by sensing the difference in pressure between the bottom of the conical tank and the vent. The DPLT then transmits a current signal (4-20mA) to the I/V converter. The output of the I/V converter (1-5V) is given to the VMAT interfacing hardware consisting of multifunction high speed ADC and DAC. The onboard data converters of the VMAT can be directly linked with the Simulink tool of MATLAB thus forming a complete close loop system. The signal from the PC is transmitted to I/P converter through V/I converter. The output from I/P converter is the pressured air in the range 3-15 psi for actuating the control valve, which regulates the flow of liquid into the conical tank.

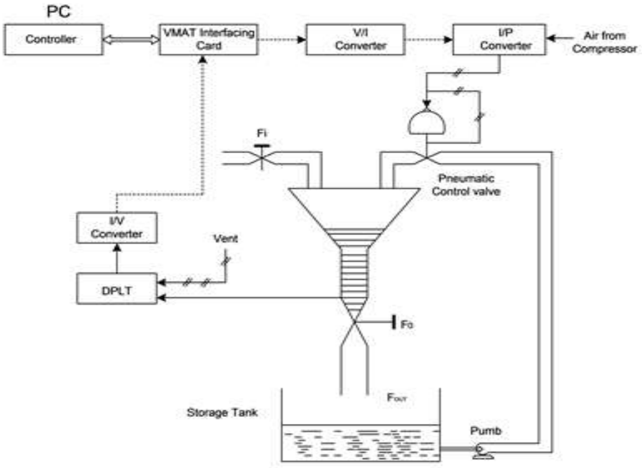


Figure-3 Functional block diagram of a conical tank level process

3.1 Description of the conical tank level process

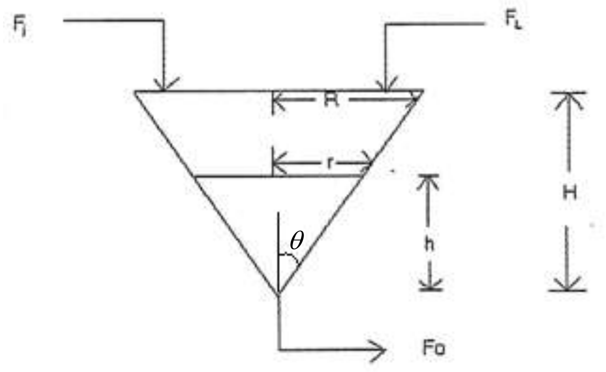
The tank is made up of stainless steel body and is mounted over a stand vertically. Water enters the tank from the top and leaves the bottom to the storage tank.The System specifications of the tank are as follows:

Table-2 System Specifications of Conical tank

PART NAME	DETAILS
Conical tank	Stainless steel body, height– 65 cm, Top diameter–33.5 cm Bottom diameter – 3.5 cm
Differential Pressure Level Transmitter	Capacitance type, Range 2.5-250mbar, output 4-20 mA
Pump	Centrifugal 0.5 HP
Control Valve	Size ¼ Pneumatic actuated Type: Air to open, Input 3-15PSI
Rota meter	Range 0-460 LPH
Pressure gauge	Range 0-30 PSI
Compressor	20 PSI

3.2 Mathematical Model Of The Conical Tank Level Process

Here F_i is the inlet flow rate to the tank, F_0 be the outlet flow rate from the tank, F_L be the disturbance applied to the tank.



Figfigure-4 Diagram of Conical Tank

F_i – Inlet flow rate to the tank (m^3 / min)

F_0- Outlet flow rate from the tank (m^3 / min)

Fl- Load applied to the tank (1pm)

H - Height of the conical tank (m)

h - Height of the liquid level in the tank at any time 't' (m)

R- Top radius of the conical tank (m)r - Radius of the conical vessel at a particular level of height h(m)

A -Area of the conical tank (m^2)

The nominal operating level h is given by

$$F_{in} - F_{out} = A(h)\frac{dh}{dt} \quad (1)$$

$$tan\theta = \frac{R}{H} \quad (2)$$

At any level (h) $tan\theta = \frac{r}{h}$ (3)

Equating (2) and (3) $\frac{R}{H} = \frac{r}{h}$

$$r = \frac{Rh}{H} \quad (4)$$

Cross sectional area of the tank at any level(h)is

$$A(h) = \pi r^2 \quad (5)$$

Substitute (4) in (5)

$$A(h) = \frac{\pi R^2 h^2}{H^2} \quad (6)$$

Also $F_{out} = b\sqrt{h}$ (7)

Substituting (7) in (1)

$$F_{in} - b\sqrt{h} = A(h)\frac{dh}{dt} \quad (8)$$

$$\frac{dh}{dt} = \frac{Fin - b\sqrt{h}}{\pi R^2 h^2 / H^2} \quad (9)$$

From equation (8)

$$F_{in} - \frac{Uh}{2h} = A(h)\frac{dh}{dt} \quad (10)$$

Where

$U = b\sqrt{h}$ =Nominal value of outflow rate

Hence the transfer function of the above system is

$$\frac{h(s)}{Fin(s)} = \frac{k}{\tau s + 1} \quad (11)$$

Where

h and U are nominal values of PV and MV from equation (11)

Time constant of the level process $\tau = \frac{2hA(h)}{U}$

The gain constant of the level process k $=\frac{2h}{U}$

In order to find the open loop response, the step input of 2.0v is applied to the ADC input in simulink tool of MATLAB platform directly with the fixed inflow rate and outflow rate. For the given step input the system attains the steady state at 15cm. After that a step increment from 2.0v to 2.25v is given and various readings are noted till the process becomes stable at different regions in the conical tank. The experimental data are approximated to be a FOPDT model, the model parameters of the transfer functions for the above mentioned are tabulated in Table 3.

Table-3 Transfer Function Model of the Conical Tank Level Process for various operating region

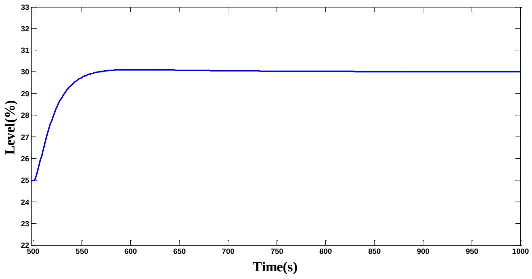
Input ADC Voltage	**Level in cm**	**Transfer Function Model**
2.0v to 2.25v	15 – 30	$\frac{5.415\, e^{-10s}}{3000s+1}$
2.25v to 2.50v	30 – 38	$\frac{2.999\, e^{-35s}}{3500s+1}$
2.5v to 2.75v	38 – 42	$\frac{1.705\, e^{-40s}}{4000s+1}$

4. RESULTS AND DISCUSSION

For comparison purpose, both the conventional PID as well as the proposed hybrid fuzzy P+ID control scheme has been simulated for various set points using MATLAB and the results are displayed in the figures 5 and 6. The simulation results clearly show that the Hybrid fuzzy P+ID controller possesses no overshoot and fast response as compare to the conventional PID controller.

The simulation results also display the superiority of the proposed controllers adaptive ability and robustness over the conventional PID controller.

The performance index comparison for various set points to the plant models with the designed controllers is presented.



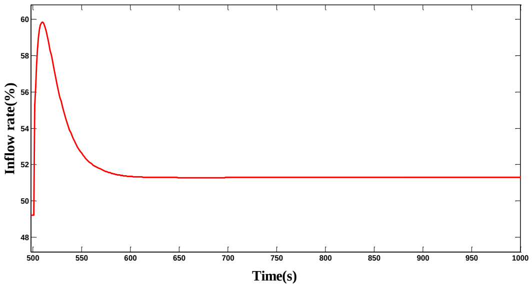


Figure.5 Simulated servo response of a CTLS with Hybrid Fuzzy PID controller for region 1. (setpoint changes from 25 to 30 %)

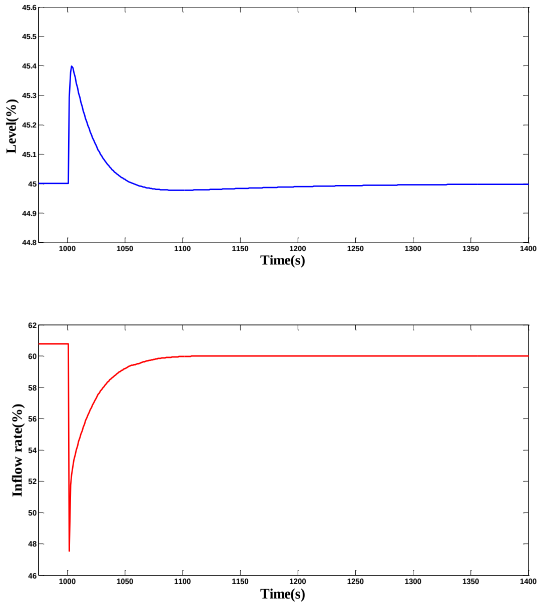


Figure.6 Regulatory response of a CTLS with Hybrid Fuzzy PID controller for 10% positive step change for region 2.

Table.4 Comparison of performance measures of Hybrid Fuzzy PID controller for set-point tracking

Set point change in level	Integral square error		Settling time(seconds)	
	PID	Hybrid Fuzzy	PID	Hybrid fuzzy
15 – 30	536.2	189.3	465	211
30 – 38	623.2	222.8	419	243
38 – 42	582.8	211.4	380	260

Table.5 Performance measures of CTLS for load disturbance in level

Operating region	Load change in level (10%)	
	Integral square error	Settling time
15 – 30	1.764	180
30 – 38	2.054	209
38 – 42	1.908	217

5. CONCLUSION

In this paper, hybrid fuzzy P+ID controller for non-linear level process has been presented. The fuzzy control combined with conventional PID controller constitutes an intelligent control, which adjusts the control parameters depending upon the error.

The various results have been presented to prove the improved performance of the Hybrid fuzzy P+ID over the conventional PID. The simulation responses for the models validated reflect the effectiveness of the hybrid fuzzy based controller in terms of performance indices. The performance indices of the proposed controller under the various error criteria exhibit its superiority over the conventional PID controller. Simulation results show the effectiveness of the proposed scheme and guarantee the good robust performance of the Hybrid fuzzy P+ID controller against disturbances and plant variations.

REFERENCES

[1] Anandanatarajan and M.Chidambaram.”Experimental evaluation of a controller using variable tansformation on a hemi-spherical tank level process”, Proceedings of National Conference NCPICD, 2005, pp. 195-200.

[2] Ya-Gang Wang, Hui-He Shao, “Optimal tuning for PIcontroller”, Automatica, vol.36, 2000,pp.147-152.

[3] T.J.Procyk, H.Mamdani, “A Linguistic self-organizing process controller”, Automatica, vol. 5, 1979,pp.15-30.

[4] K.L.Tang , R.J. Mulholland, “Comparing fuzzy logic with classical controller design” , IEEE Transaction on systems, Manan cybernetics ,vol.17, 1987,pp.1085- 1087.

[5] Wei Li,”Design of a Hybrid Fuzzy Logic Proportional Plus Conventional Integral Derivative Controller”, ieee transactions on fuzzy systems, 6(4),Nov 1998.

[6] S.Ramesh and S.Abraham lincon,”Fuzzy model Reference learning controller for nonlinear spherical Tank process”,IJETT,4(10),Oct 2013,pp.4459-4465.