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AN INTELLIGENT CONTROLLER DESIGNING FOR pH NEUTRALIZATION PROCESS

Chandra Shekhar[1], Mr.S.K.Sharma[2]

[1,2]*Chemical Engineering Department, DCRUST Murthal, (India)*

ABSTRACT

The control of pH is very important in the chemical industry, poses a more difficult problem because of inherent nonlinearities and frequently changing process dynamics. pH maintain in the effluent water is important factor for discharging effluent water in environment. In this paper SISO stable system with dead time is considered for pH neutralization. Continuous stirred mixing tank system used to neutralize pH of effluent water. Steady of the process consider in two cases as Regulatory and Servo problem. An intelligent controller which is fuzzy controller design for PI/PID by two different interface mechanism, Conventional P/PI/PID controllers are also designed using different tuning methods in both consider cases. The performance analysis (Time domain, Robustness analysis) of both fuzzy and conventional controllers is done in both cases. Comparison of these controllers on the basis of analysis and controller performance gives best controller for process.

Keywords: FPI, FPID, P controller, pH, PI controller, PID controller, Tuning.

I. INTRODUCTION

The most important characteristics of waste water is the pH value, proper control of pH value is necessary for discharging waste water in environment. This waste water has to be neutralized before discharge or reuse. It provides the optimum condition of environment for microorganism activity between pH 6.5 and 7.5 and the right water discharge to the public sewage as mandated by the Department of Environment of between pH 5 and 9 (Environmental Quality Act, 1974). Wastewater of pH below 4.5 and above 9 may greatly reduce the activity of the microorganisms which treat the water and may not support their life at all.

In this paper Hydrogen chloric Acid (HCL = 3.01) used in wastewater treatment facilities to control alkalinity. Sodium Hydro Oxide (NaOH = 10.98) base used to maintain pH of system in base region. A proper and simple mathematical modeling for pH neutralization in Continuous Stirred Tank Reactors was done by McAvoy in 1972 in developing a pH neutralization process. In pH neutralization process two cases are considered Servo and Regulatory problems. There after a tidy mathematical modeling of pH neutralization tank system [1] [8]. We find a first order stable system transfer function. The transfer function model of the system obtained from the open-loop response.

Here, Fuzzy controller and conventional controller both are designed. Comparison of both controllers performance by different tuning methods, Mamdani [14] [15], Takagi-Sugano [14] [15] in Fuzzy controller and Ziegler-Nicolson [5], Cohen-Coan [4], and Marlin [6] [9], Smith et al. [6] [9], Branica et al. [6] [9] on the basis of Time domain analysis, Robustness analysis. All works in this paper were performed using MATLAB 7.8 (2009). For finding the best controller which gives better robustness and higher stability for the process system.

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II. CONVENTIONAL CONTROLLERS [7]

P controller is designated by,

$$G(s)=K_P$$

PI controller is designated by,

$$G(s)=K_P(1+\frac{1}{\tau_I s})$$

PID controller is designated by,

$$G(s)=K_P(1+\frac{1}{\tau_I s}+\tau_D s)$$

Where, K_P =Proportional Gain, τ_I =Integral Time Constant, τ_D =Derivative Time Constant

For the best performance of the system, there is need of adjusting these three parameters called controller tuning.

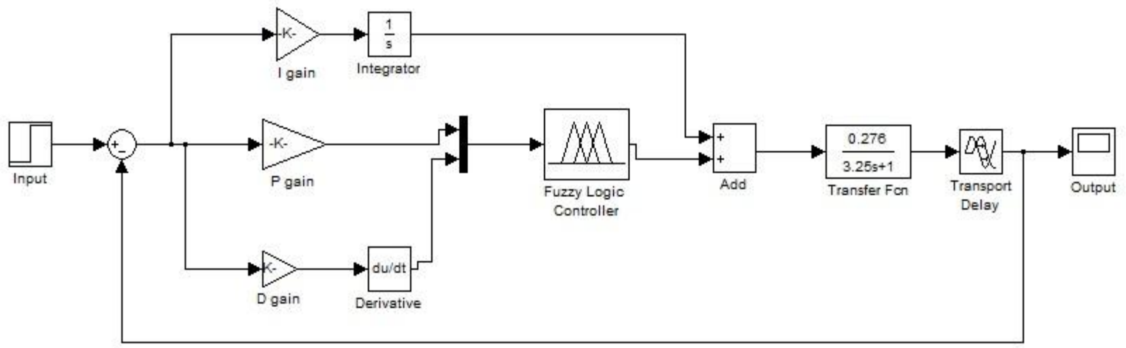

Fig.1 Fuzzy PID Diagram

III. SIMULATIONS

All simulations in this paper were performed using MATLAB 7.8 (control system design and simulation software). There example consider for pH neutralization system for studying the different controllers performance in both considered cases. Step input of 7 for regulatory response and step input of 5 for servo response are given for process.

Example,

The Following process considered (S.S.Ram-B.Meenakhshipriya, 2016) [6] [9],

$$G(s)=\frac{0.276e^{-0.5005s}}{3.2s+1}$$ (Simulation run time t = 0-100 sec given for the process)

On comparing with standard FOPDT system get,

K_P =0.276, τ =3.2, θ =0.5005

Table given below show the Controllers parameters value of different controllers calculated by different methods,

Conventional Controllers,

For P controller,

S.No.	Method	K_C
1.	Ziegler – Nicolson	20.5
2.	Cohen-Coan	24.37

Table 1 (P Controller Parameter)

For PI controller,

S.No.	Method	K_C	τ_I
1.	Ziegler – Nicolson	18.636	1.667
2.	Cohen-Coan	21.15	1.2574

Table 2 (PI Controller Parameters)

For PID controller,

S.No.	Method	K_C	τ_I	τ_D
1.	Ziegler – Nicolson	24.1176	1	0.25
2.	Cohen-Coan	34.1018	1.1567	0.17697
3.	Marlin	2.355	1.38	1.1786
4.	Smith et al.	2.316	1.3831	1.707
5.	Branica et al.	2.66	1.8621	2.912

Table 3 (PID Controller Parameters)

Fuzzy Controllers,

Fuzzy input and output membership function for both PI and PID controllers,

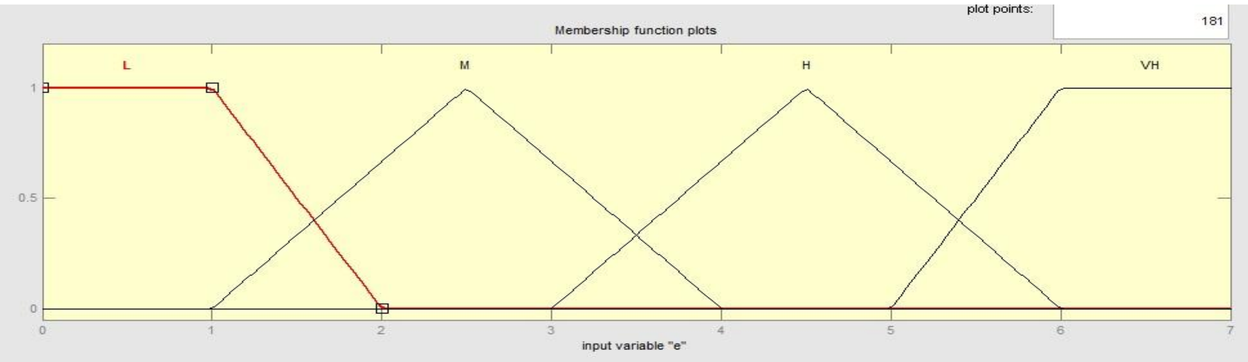

Fig. 2 I/P and O/P membership Function

For Fuzzy PI Controller,

For designing FPI controller value of proportional gain and integral gain are calculated for all methods by iterative Analysis. we can make 6*6 rules but here only 30 rules are used given above in table 4 and Min AND. Max OR operation are used with Centroid Defuzzification rule for controller designing.

$K_C = 21.15$ $\tau_I = 0.4$

Fuzzy Rules,

error	VL	L	PM	M	H	VH
Output	L	VL	VL	VL	VL	VL
	PM	PM	L	L	L	L
	M	M	M	PM	PM	PM
	H	H	H	H	M	M
	VH	VH	H	VH	VH	H

Table 4 (FPI Controller Rules)

In membership function two trapezoidal and four triangle membership relations are used. Here VL – Very Low, L –Low, PM – Positive Medium, M – Medium, H – High, VH – Very High code used on scale range.

For Fuzzy PID Controller,

For designing FPI controller value of proportional gain and integral gain are calculated for all methods by iterative Analysis. We make 4*4 rules are used for process given below in table 5 and Prod AND, Probor OR operation are used with Wtaver Defuzzification rule.

$K_C = 5.5$ $\tau_I = 0.4$ $\tau_D = 10$

Fuzzy Rules,

e\de	L	M	H	VH
L	L	L	M	H
M	L	M	H	H
H	L	H	H	VH
VH	L	H	VH	VH

Table 5 (FPID Controller Rules)

In membership function two trapezoidal and two triangle membership relations are used. Here, L – Low, M – Medium, H – High, VH – Very High code used on scale range.

IV. ANALYSES

Conventional Controllers,

For P Controller,

Time Domain Analysis (Sec)			
S.No.	Method	Settling Time (T_S)	
		Servo Response	Regulatory Response
1.	Zeigler – Nichols	6.4	10
2.	Cohen – Coan	7.2	15.2

Table 6 (P Controller Time Domain Analysis)

Robustness Analysis							
S.No.	Method	Servo Response			Regulatory Response		
		IAE	ISE	ITAE	IAE	ISE	ITAE
1.	Zeigler- Nichols	700	4900	35000	700	4900	35000
2.	Cohen – Coan	700	4900	35000	700	4900	35000

Table 7 (P Controller Robustness Analysis)

For PI Controller,

Time Domain Analysis (Sec)			
S.No.	Method	Settling Time (T_S)	
		Servo Response	Regulatory Response
1.	Zeigler- Nichols	48.5	74
2.	Cohen – Coan	60.5	83

Table 8 (PI Controller Time Domain Analysis)

Robustness Analysis							
S.No.	Method	Servo Response			Regulatory Response		
		IAE	ISE	ITAE	IAE	ISE	ITAE
1.	Zeigler- Nichols	700	4900	35000	218.28	439.84	1147.3
2.	Cohen – Coan	700	4900	35000	221.85	442.12	1313.6

Table 9 (PI Controller Robustness Analysis)

For PID Controller,

Time Domain Analysis (Sec)			
S.No.	Method	Settling Time (T_S)	
		Servo Response	Regulatory Response
1.	Zeigler- Nichols	35	84.75
2.	Cohen – Coan	39	83.75
3.	Marlin et al.	37	77.74
4.	Smith et al.	41	68.25
5.	Branica et al.	32	64.25

Table 10 (PID Controller Time Domain Analysis)

Robustness Analysis							
S.No.	Method	Servo Response			Regulatory Response		
		IAE	ISE	ITAE	IAE	ISE	ITAE
1.	Zeigler- Nichols	700	4900	35000	127.41	501.4	1539.1
2.	Cohen – Coan	700	4900	35000	135.79	483.36	1574.6
3.	Marlin et al.	700	4900	35000	127.18	407.5	1117.7

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4.	Smith et al.	700	4900	35000	126.8	410.2	1106.8
5.	Branica et al.	700	4900	35000	126.16	345.24	1090.57

Table 11 (PID Controller Robustness Analysis)

FUZZY Controllers,

S.No.	Method	Time Domain Analysis(Sec)			
		Fuzzy PI Controller		Fuzzy PID Controller	
		Settling Time (T_S)		Settling Time (T_S)	
		Servo Response	Regulatory Response	Servo Response	Regulatory Response
1.	Mamdani	57	62	33.6	36
2.	Takagi-Sugano	30	56	28	32

Table 12 (Fuzzy Controllers Time Domain Analysis)

For Fuzzy PI Controller,

Robustness Analysis							
S.No.	Method	Servo Response			Regulatory Response		
		IAE	ISE	ITAE	IAE	ISE	ITAE
1.	Mamdani	62.26	237.7	603.1	74.39	314.1	733.4
2.	Takagi-Sugano	51.45	177.9	457.9	60.49	262.4	661

Table 13 (FPI Controller Robustness Analysis)

For PID Controller,

Robustness Analysis							
S.No.	Method	Servo Response			Regulatory Response		
		IAE	ISE	ITAE	IAE	ISE	ITAE
1.	Mamdani	59.60	237.7	661	74.39	314.1	733.4
2.	Takagi-Sugano	41.45	150	390.7	48.6	112.9	452

Table 14 (FPID Controller Robustness Analysis)

V. SIMULATION RESULTS

Figure 3 and 4 shows Comparison of P controller performance, Figure 5 and 6 Comparison of PI controller performance, Figure 7 and 8 shows Comparison of PID controller performance, Figure 9 and 10 shows Comparison of FPI controller performance, Figure 11 and 12 shows Comparison of FPID controller performance in Regulatory and Servo response respectively by each considered method for pH neutralization system.

For P Controller,

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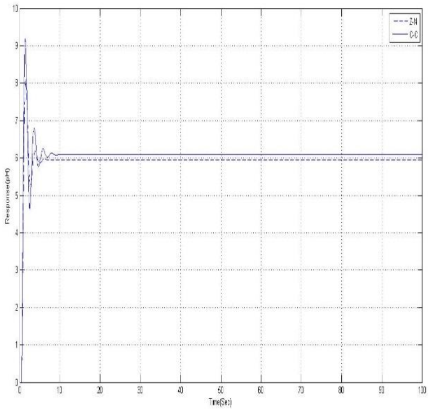


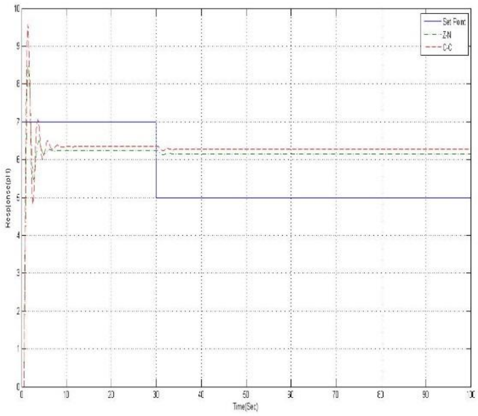
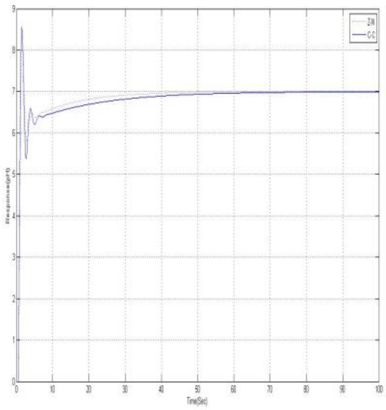


Fig. 3 (Regulatory Response of P Controller) **Fig. 4 (Servo Response of P Controller)**

For PI Controller,



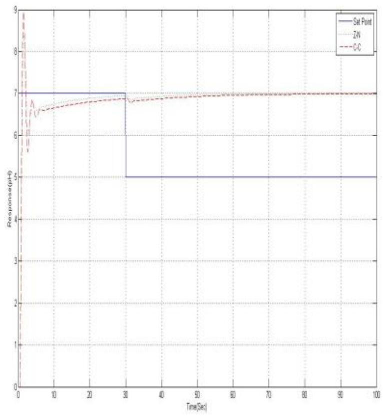
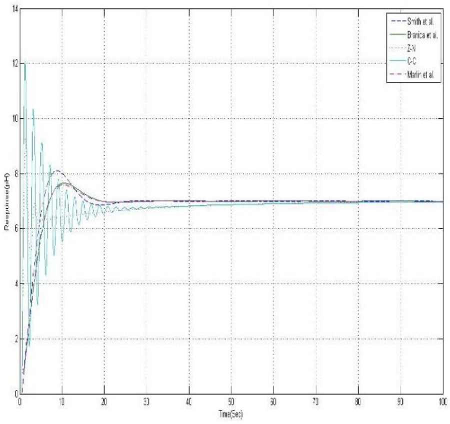


Fig. 5 (Regulatory Response of PI Controller) **Fig. 6 (Servo Response of PI Controller)**

For PID Controller,



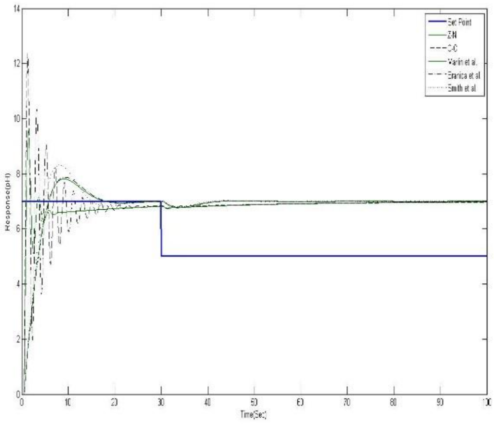


Fig. 7 (Regulatory Response of PID Controller) **Fig. 8 (Servo Response of PID Controller)**

For Fuzzy PI Controller,

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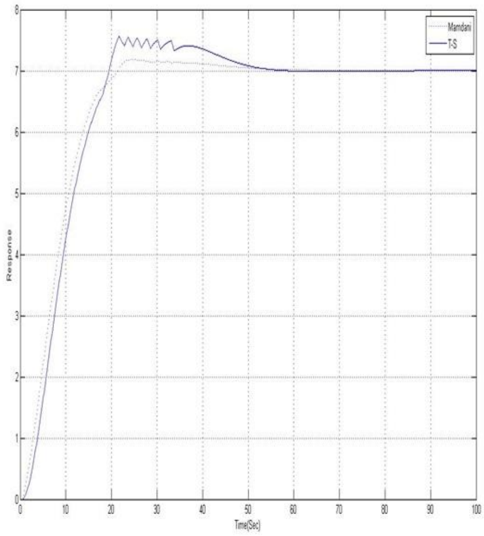


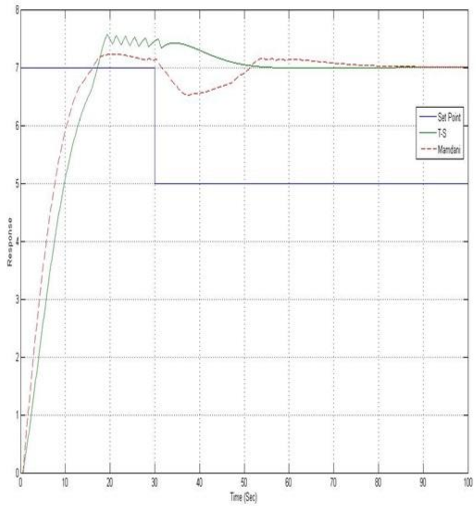
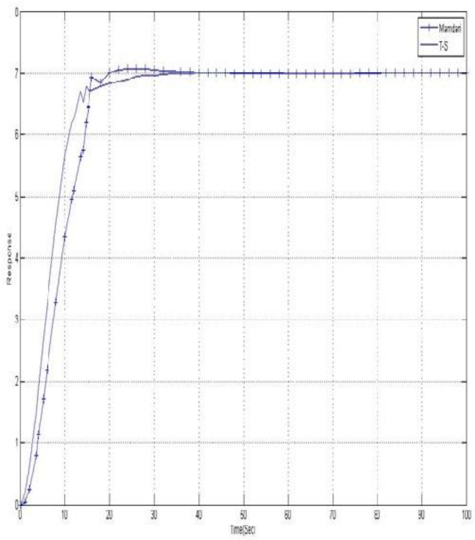


Fig. 9 (Regulatory Response of PID Controller) **Fig. 10 (Servo Response of PID Controller)**

For FPID Controller,



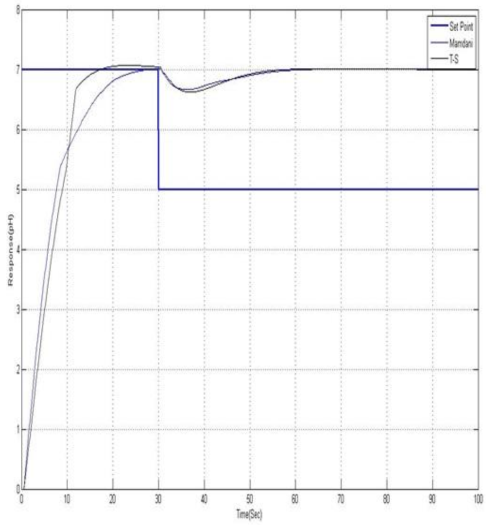


Fig. 11 (Regulatory Response of FPID Controller) **Fig. 12 (Servo Response of FPID Controller)**

VI. RESULTS AND DISCUSSION

For controller designing, parameters are calculated by different controller designing methods in both conventional and fuzzy controller, if any one parameters is changed controller response is also changed. Time domain analysis and robustness analysis gives the result for best controller of the process. Controller with

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minimum settling time are shows good response and robustness analysis shows better stability for the process to achieve desired response.

VII. CONCLUSION

Here different controller are designed for same process and its performance and different analysis shows which controller is best for this process. Two different controller, Conventional and Fuzzy both are designed in two different cases Regulatory and Servo; controller in both case generally used for controlling the process. By seeing the results of both controller above, it's easy to decided suitable controller for process. Conventional Controllers gives desired response but take too much time for stability of the process, in conventional controller only two out of three controller which are Proportional-Integral and Proportional-Integral-Derivative controller gives desired response with more oscillation. In Fuzzy controller two out of two controller which are Fuzzy Proportional-Integral, Fuzzy Proportional-Integral-Derivative controller gives desired response without taking more time and oscillation.

By the comparison of these controller we find that Fuzzy controller gives better response as compared to other controller specially Fuzzy PID controller gives spontaneous response without oscillation in the controller response. So Fuzzy PID controller is very suitable for this process.

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