COMPARATIVE ANALYSIS OF P/PI/PID CONTROLLERS FOR pH NEUTRALIZATION PROCESS

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ABSTRACT

pH Neutralization process is very important in waste water treatment, pharmaceuticals, food production plant etc. 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. Controlling of pH in neutral region is an important process as small change in input gives the huge change in the output of the process.In this paper P/PI/PID controllers are designed using different tuning methods like Zeigler-Nicolson method (Z-L)[5], Cohen-Coan method (C-C)[4], Tayrus-Luyben method (T-L)[3], Marlin method[6][9], Smith et al. method[6][9] and Branica et al. method[6][9]. Theperformance analysis of P/PI/PID controllers is done in Neutral region by keeping set point 7, which gives best condition for controller system. Result seeing of every method by particular separate graph and then for comparison a common graph construct of process response of pH system.

Keywords: Dead Time, Ph, P Controller, PI Controller, PID Controller, Tuning.

I. INTRODUCTION

Most of chemical and biological processes have pH control loops. pH control play an important role for product quality as well as environmental compliance. The extraordinary range ability and sensitivity of pH as a concentration measurement poses exceptional challenges in many aspects of pH design and implementation. Wastewater neutralization plays an important part in a wastewater treatment process. 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.

Since last of years, Hydrogen chloride (HCL) acid was used in wastewater treatment facilities to control alkalinity. HCL acid can be difficult to apply and control. Correcting the pH of alkaline wastewater is usually required either for discharge to sewer, in preparation to further biological, physical/chemical treatment or direct discharge to the environment. Strong acids such as hydrochloric acid have traditionally been used to neutralize alkaline waste streams prior to discharge. NaOH base used to maintain pH of system in base region.A general way of deriving dynamic equation for pH neutralization process inContinuous Stirred Tank Reactors was done by McAvoy in 1972. In developing a pH neutralization process,two points have been emerged that describes the nonlinearity of the process. First, material balance in terms of hydrogen and hydroxyl ion concentrations, and Second,material balance is performed on all atomic species and all additional equilibrium relationships.

In this paper comparison of P/PI/PID controllers tuning methods, Ziegler-Nicolson (1942) method [5], Cohen-Coan method(1953)[4], Tayrus-Luyben method (1958)[3], and Marlin method (1995)[6][9], Smith et al. method(1997)[6][9],Branica et al. method (2002)[6][9]have been done using MATLAB. For finding the best controller tuning method which gives better and higher stability for the process system.

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.

Considered example, (S.S.Ram-B.Meenakhshipriya, 2016) [6] [9]

$$G(s) = \frac{0.276e^{-0.5005s}}{3.2s+1}$$

By comparing standard FOPDT system get,

K_P =0.276, τ =3.2, θ =0.5005

II.GENERALISED FORM OF 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 action, τ_D =Derivative action.

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

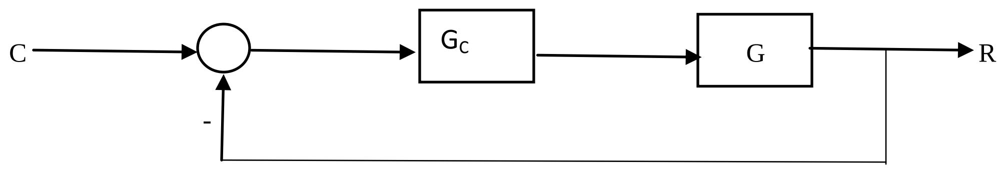


Fig.1 A Classical Feedback Diagram

III. SIMULATIONS

All simulations in this paper were performed using MATLAB 4.0 (control system design and simulation software) (Shahian & Hassul, 1993)[2]. There example considerpH neutralization system for studying the controllers tuning methods and result of each method is shown below separately, comparison of each method given in graph in form output of the process. Unit step change are consider for regulatory problems.

Example,

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

$$G(s)=\frac{0.276e^{-0.5005s}}{3.2s+1}$$ (Step input of magnitude 7 at t=50, 100 sec given for the process)

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

For P controller,

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

Table 1

For PI controller,

S.No.	Method	K_C	τ_I
1	Ziegler – Nicolson	18.636	1.667
2	Cohen-Coan	21.15	1.2574
3	Tayrus-Luyben	12.8125	4.4

Table 2

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	Tayrus-Luyben	18.6364	4.4	0.3174
4	Marlin	2.355	1.38	1.1786
5	Smith et al.	2.316	1.3831	1.707
6	Branica et al.	2.66	1.8621	2.912

Table 3

IV. ROBUSTNESS ANALYSIS

For P Controller,

S.No.	Method	IAE	ISE	ITAE
1	Ziegler – Nicolson	56.95	88.95	1316
2	Cohen-Coan	24.37	77.94	1136

Table 3

For PI Controller,

S.No.	Method	IAE	ISE	ITAE
1	Ziegler – Nicolson	16.16	39.81	133.8
2	Cohen-Coan	20.65	42.82	239.3
3	Tayrus-Luyben	8.401	42.19	8.148

Table 4

For PID Controller,

S.No.	Method	IAE	ISE	ITAE
1	Ziegler-Nicolson	27.32	44.87	539.1
2	Cohen-Coan	33.7	75.33	557.4
3	Tayrus-Luyben	8.058	36.59	11.17
4	Marlin	26.15	107.4	96.54
5	Smith et al.	26.79	101.3	117.7
6	Branica et al.	27.16	110.1	106.8

Table 5

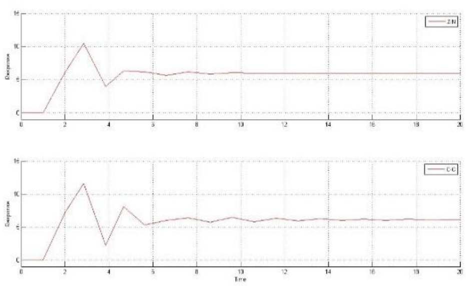
V. SIMULATION RESULTS

Figure 2 and 3 shows controller performance of P controller by each considered method and comparison of these method for pH system.

Figure 4 and 5 shows controller performance of PI controller by each considered method and comparison of these method for pH system.

Figure 6 and 7 shows controller performance of PID controller by each considered method and comparison of these method for pH system.

For P Controller,



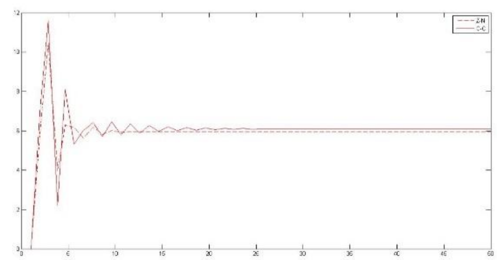
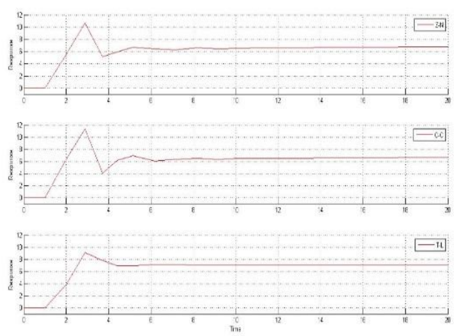


Fig.2 Fig.3

For PI Controller,



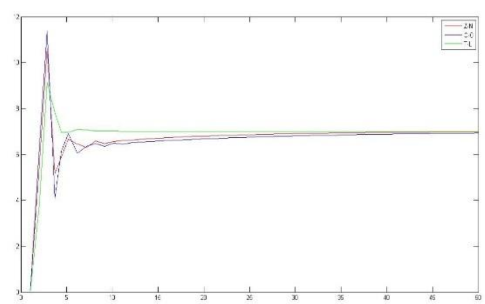
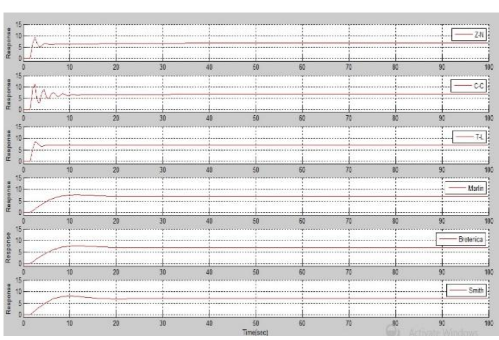


Fig.4 Fig. 5

For PID Controller,



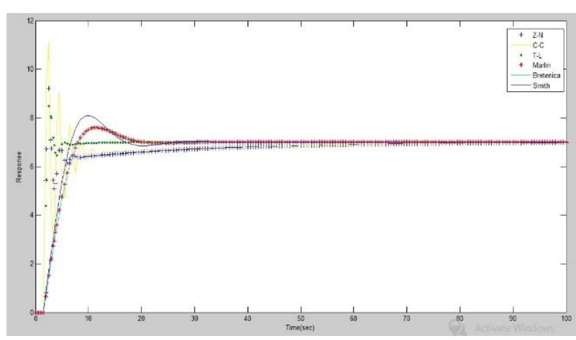


Fig. 6 Fig.7

Time Domain Analysis [10],

Controller	P Controller		PI Controller			PID Controller					
Method	Z-N	C-C	Z-N	C-C	T-L	Z-N	C-C	T-L	Marlin	Smith	Branica
Rise Time	2.27	1.9	2.32	2.2	2.65	2.06	1.85	2.231	8	8	6.46
Settling time	9.25	11.25	50	74.75	14.25	84.75	83.75	19.75	29.74	38.25	34.25

VI. RESULTS AND DISCUSSION

For controller tuning parameters are calculated, any one parameters is changed controller response is also changed, optimum values of these parameters are aim to give the better response for the process. Here P/PI/PID controllers are designed by different methods and time domain analysis shows the rise and settling time of the controller for the process. Controller with minimum rise and settling time are shows good response and better stability for the process to achieve desired response.

VII. CONCLUSION

P/PI/PID controllers are designed for pH neutralization system by different controller tuning methods. All methods are worked in direction of settling the process variable to a desired set value. In P controller IAE, ISE and ITAE are very minimum by Cohen and Coan method as compared to other controller tuning methods,this controller shows stability but not attained proper desired value.In PI controller IAE, ISE and ITAE are very minimum by Tayrus and Luyben method as compared to other controller tuning methods, this controller shows stability but more oscillation in response to attain desired value. In PID controller IAE, ISE and ITAE are very minimum by Tayrus and Luyben method as compared to other controller tuning methods. This controller shows good stability and robustness for the process without taking more oscillation to attain desired value.

VIII. ACKNOWLEDGEMENT

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