ISSN (Print) : 0974-6846
Indian Journal of Science and Technology, *Vol 9(12), DOI: 10.17485/ijst/2016/v9i12/89940, March 2016* ISSN (Online) : 0974-5645

Designing of PID Controllers for pH Neutralization Process

S. Sakthiya Ram[1*], D. Dinesh Kumar[1] and B. Meenakshipriya[2]

[1]Department of Electronics and Instrumentation Engineering, St. Joseph's College of Engineering, Chennai – 600119, Tamil Nadu, India; sakthiyaram92@gmail.com, dhineshmani@yahoo.co.in
[2]Department of Mechatronics Engineering, Kongu Engineering College, Erode – 638052, Tamil Nadu India; bmp@kongu.ac.in

Abstract

Objective: To design PID controller with different tuning methods for pH Neutralization process. **Methods:** Controlling of pH in neutral region is an important process as small change in input gives the huge change in the output. The PID controller is designed using three different tuning methods like Marlin method, Smith et al. method and Branica et al. method. The performance analysis is done for PID controllers in Acid, Neutral and Base region by keeping set point in 5, 7 and 12. **Findings:** From the simulation result it is found that Branica et al. method is better when compared to the other two methods. **Applications/Improvements:** pH Neutralization process is more important in waste water treatment, pharmaceuticals, food production etc.

Keywords: Nonlinear Process, pH Neutralization Process, PID Controller

1. Introduction

Now a days in textile industrial process, very large number of useless water comes out as pollutants, in which some of them are costly and difficult to treat. Characteristics of this type of waste water may change significantly based on industries. The most important scope of waste water treatment plant is to control effectiveness of this harmful waste water. The most important characteristics of this waste water were that the pH value, proper control of pH value is necessary. Waste comes from the textile industries is rarely neutral. This waste water has to be neutralized before discharge or reuse[1,2]. Acid is a substance which ionizes in water in order to give hydroxide ion, while base is the substance which ionize in water and give hydroxyl ion. Here strong acid (HCl) made to react with the strong base (NaOH) for maintaining of pH value at neutral, acid and base region. Controlling of pH in neutral region is an important process as small change in input gives the huge change in the output. The pH value has to be controlled for minus or plus 1 value of 7 to get the required controlling of pH for the wastage coming out from process industries. pH above 9 and pH below 4 are considered as injurious wastage to the surroundings. pH is affected by the variation in acid and base flow. Input and Output flow affects the Level[3]. Control of pH neutralization process is more important part in following areas like waste water treatment, precipitation and electrochemistry plants, chemical and biological reaction and production of pharmaceuticals, fermentation and food production[4].

2. pH Neutralization Process

The initial stage of the work is to define the goal or the required specification, for the developed system at the end of the modelling process. This is to develop a pH process system which is adequate in terms of the intended application that is to design an improved form of the controller. It is decided that the simulation model has to be represent the behaviour of the pH neutralization process with sufficient accuracy in terms of transient performance and steady state that commonly gives a basis for control system design. A general way of deriving dynamic equation for pH neutralization process in

** Author for correspondence*

Continuous Stirred Tank Reactors was done by McAvoy in 1972. Two points have been emerged in developing a pH neutralization process that describes the nonlinearity of the process. Firstly, material balance in terms of hydrogen and hydroxyl ion concentrations would be challenging to record. They are due to dissociation of water and change in water concentration has to be noted. Second point is that material balance is performed on all atomic species and all additional equilibrium relationships[5-8]. To simplify the equations the electro neutrality principle is used. Set point filter is used to reduce the peak overshoot[9,10].

The reactor vessel used here has a volume of 5L and can be emptied by a draining pipe that can be controlled by a valve. The temperature and working pressure, at which the reactor used, will be depending on the design, size and nature of the material that has been used for manufacturing. Since every material will be tending to change its strength according to the variation in temperature, any pressure ratings have to be given in terms of the temperature at which it is applicable. Here 350-bar pressure-rated reactor vessel is selected, 400-bar pressure rated special positive displacement dosing pumps and 140-bar pressure rated special pH probe for real-time experiments. The communication among them is established using software called Delphi 6 software which is installed on a Personal Computer[11]. The Multiport Industrial Serial Server SE5008/SE5016 in the system is equipped with popular serial communication ports RS232, RS485, and RS422. It acts as a gateway between ethernet (TCP/IP) and serial communication ports. It also allows most of the serial devices to be joined to a new or existing ethernet network. The simulation model of the system used is shown in Figure 1.

The pneumatic pressure building technique is used to keep pressure that is inside the vessel at an elevated value in the environmental CSTR system by a solenoid valve.

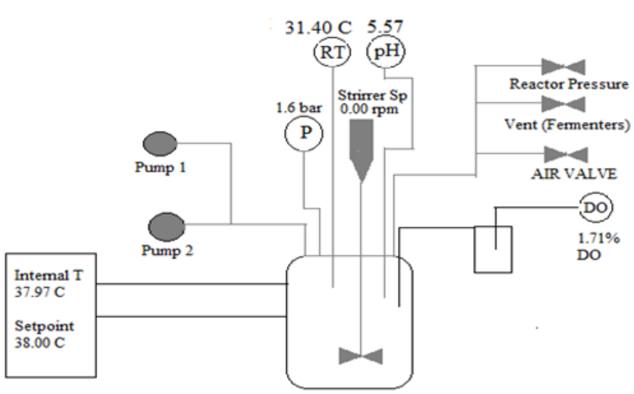

Figure 1. Diagram of simulation model for the system.

In order to maintain the pressure the CSTR is always kept closed. A special high-pressure pump called 400-bar pressure-rated positive displacement pump at the rate of 1 ml/min is used to send Acid/base to the vessel. The added Acid/base is mixed well using a hermetically sealed magnetic stirrer that will be rotated at a speed of 300 rpm. Special type of pH probe is used to measure the pH inside the setup and it should be able to withstand in the elevated pressure. In this experiment, strong acid (HCl) and strong base (NaOH) of 1 molarity is prepared and used to conduct real-time experiments[12]. The model parameters of the system and pH probe details are given in Tables 1 and 2.

Table 1. Model parameters of the system

Name	Value
Number of fermenter vessel	1
Volume of Fermenter vessel	5 L
Working pressure	Up to 350 bar
Working temperature	30 C
Reactor material construction	Corrosion 316 atainless steel with PTFE inner coating
Sterilization	Steam Sterlization

Table 2. pH probe details

Name	Value
Sensitivity of the probe in voltage	mV
Resolution of the probe	0.001
Range	0-14
Pressure rating	Maximum 140 bar

Considering the delay factors, system is modeled as FOPDT system, whose general transfer function model is given below,

$$G(s) = \frac{Ke^{-\tau_d s}}{\tau s + 1}$$

The transfer function model of the system obtained from the open-loop response is

$$G(s) = \frac{0.276e^{-5.005s}}{3.2s + 1}$$

3. PID Controller

PID controller is the combination of P controller, I controller and D controller. It is given by

$$Z = K_p e(t) + K_i \int e(t) + K_d \frac{de}{dt}$$

It gives a quick response and stability due to P and it has the ability to eliminate the offset due to I. it also have the ability to reduce peak error and provide faster recovery due to D. The advantage of using this controller is, it gives a control action which is very close to an expert human operator[13-16].

There are many methods to tune PID controller. Here three methods have been chosen among various methods[17]. They are

Marlin method: Marlin (1995) proposed the Min IAE tuning method for PID controller.

$$K_c = \frac{0.65}{K_m}$$

$$T_i = 0.65 * \tau_m$$

$$T_i = 0.10 * \tau_m$$

Smith et al. Method: Smith and Corripio proposed a method in 1997 for PID controller. The condition of this method is given as $0.1 \leq \frac{\tau_m}{T_m} \leq 1.5$.

$$K_c = \frac{T_m}{K_m \tau_m}$$

$$T_i = T_m$$

$$T_d = 0.5 * \tau_m$$

Branica et al. Method: Branica et al. proposed a method in 2002 for PID controller

$$K_c = \frac{1}{K_m}\left(0.338 + 0.623\frac{T_m}{\tau_m}\right)$$

$$T_i = 1.228\tau_m\left(\frac{\tau_m}{T_m}\right)^{-0.480}$$

$$T_d = 0.231\tau_m\left(\frac{\tau_m}{T_m}\right)^{-0.120}$$

The block diagram of PID controller is shown in Figure 2

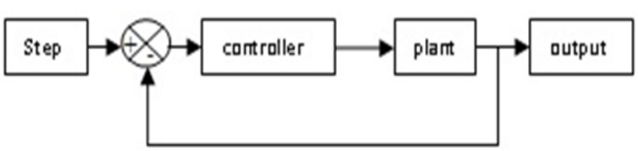

Figure 2. Block diagram of PID controller.

The tuning parameters of the controller are given in Table 3.

Table 3. Tuning Parameter of PID Controller

Tuning Method	K_p	K_i	K_d
Marlin Method	2.355	0.7246	1.1786
Smith et al. Method	2.316	0.7230	5.707
Branica et al. Method	2.66	0.537	2.912

4. Comparison Results of PID Controller

Fine tuning of PID controller is done and the comparison between the various PID controllers designed using various methods are performed. The servo response of PID controller in acid region is shown in Figure 3 and in neutral region is shown in Figure 4 and for Base region is shown in Figure 5. The time domain and error indices are listed in the Table 4 and Table 5 respectively.

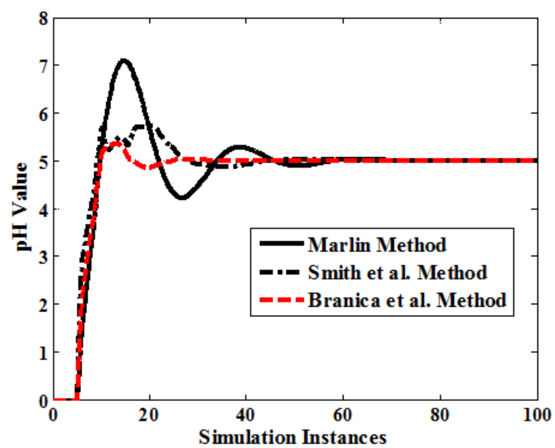

Figure 3. Servo response of PID controllers in acid region.

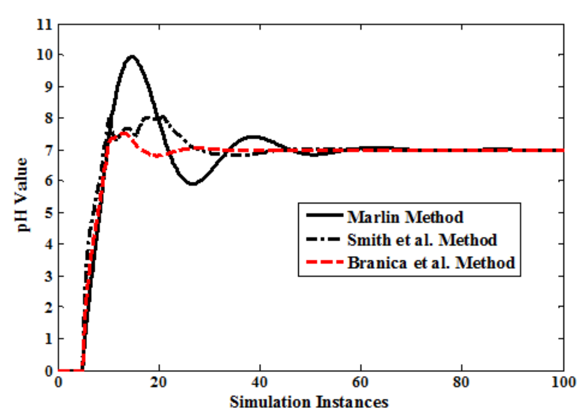

Figure 4. Servo response of PID controllers in neutral region.

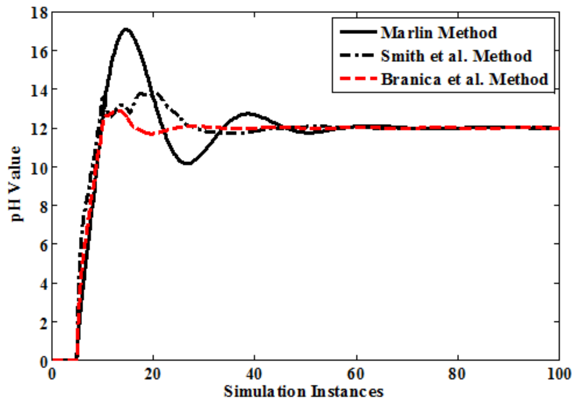

Figure 5. Servo response of PID controllers in base region.

Table 4. Time domain specification

Tuning Method	Region	Rise time	Settling time	Peak Over shoot
Branica et al. Method	Acid	4.2	32.7	0.321
	Neutral	4.7	33.5	0.458
	Base	4.9	33.8	0.77
Smith et al. Method	Acid	3.7	48.1	0.749
	Neutral	3.9	52.7	1.04
	Base	4.2	61.2	1.78
Marlin Method	Acid	4.4	69.4	2.046
	Neutral	4.7	73.8	2.87
	Base	4.9	78.1	4.92

Table 5. Error indices

Controllers	Region	IAE	ISE	ITAE
Branica et al. Method	Acid	37.81	146.3	163.4
	Neutral	51.38	289.6	229.2
	Base	88.09	871.7	393.5
Smith et al. Method	Acid	41.2	145.6	313.9
	Neutral	57.66	285.3	438.8
	Base	96.85	838.5	753.3
Marlin Method	Acid	59.91	187.6	688.7
	Neutral	83.88	367.6	964.2
	Base	143.8	1080.6	1653.2

The regulatory response of the controller in acid region is shown in Figure 6 and response in Neutral region is shown in Figure 7 and response in base region is shown in Figure 8.

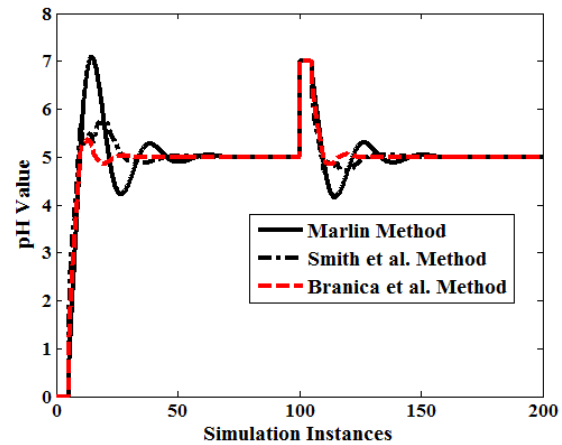

Figure 6. Regulatory Response of PID controllers in Acid Region.

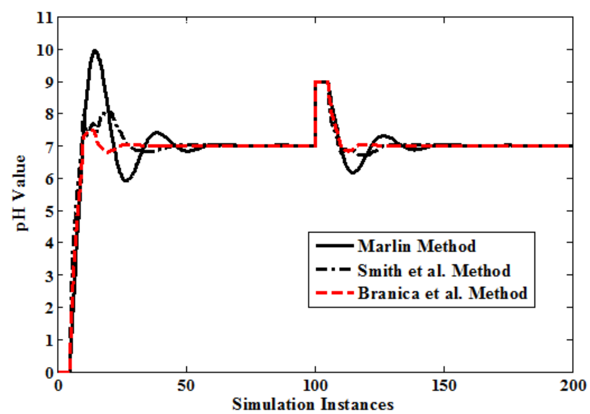

Figure 7. Regulatory Response of PID controllers in Neutral Region.

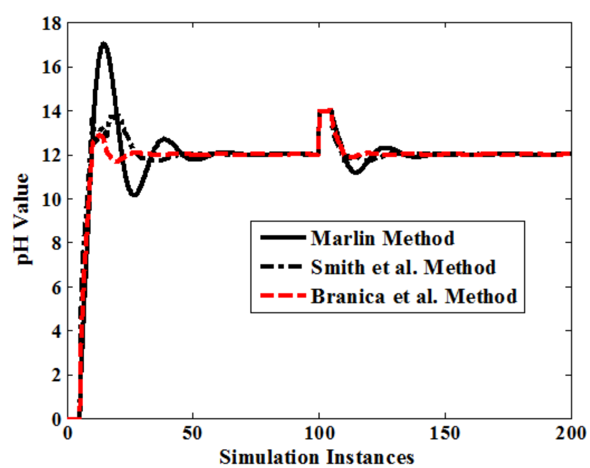

Figure 8. Regulatory Response of PID controllers in base region.

5. Conclusion

PID controller is designed using three tuning methods and their performances are compared. It is shown graphically that the time domain specification in terms of peak overshoot and settling time are less in Branica et al. method. Error indices like Integral Absolute Error (IAE), Integral Square Error (ISE) and Integral of Time weighted Absolute Error (ITAE) of Branica et al. method is also comparatively less. From the result it is identified that Branica et al. method is better than other two tuning methods for pH Neutralization Process.

6. References

1. Meenakshipriya B, et al. Study of pH system in common effluent treatment plant. Modern Applied Science. 2008; 2(4):113–21.
2. Jacobs OLR, Hewkin PF. While C. Online computer control of pH in an industrial process. IEEE Proceedings D Control Theory and Applications. 1980; 127(4):161–8.
3. Garcia C, De Godoy RJC. Modelling and simulation of pH neutralization plant including the process instrumentation. Applications of MATLAB in Science and Engineering. 2011. p. 485–10.
4. Jose T, Antony R, Isaac S. pH Neutralization in CSTR using model reference neural network and fuzzy logic adaptive controlling schemes. International Journal of Advancements in Research and Technology. 2013; 2(1):1–6.
5. McAvoy TJ, Hsu E, Lowenthals S. Dynamics of pH in controlled stirred tank reactor. Industrial Engineering Chemistry Process Design and Development. 1972; 11(1):68–70.
6. Ibrehem AS. Mathematical model for neutralization system in Stirred tank Reactor. Bulletin of Chemical Reaction Engineering Catalysis. 2011:6(11):47–52.
7. Thirupathi K, Ponnusamy L, Kirubhagaran R, Atmaanand MA. Design and optimization of high pressure rated modified CSTR system. IEEE International Conference on Signal Processing, Computing and Control; Solan. 2013. p. 1–6.
8. Kabila V, Glan Devadhas G. Comparative analysis of PID and fuzzy PID controller performance for continuous stirred tank heater. Indian Journal of Science and Technology. 2015; 8(23):1–7.
9. Vijayan V, Panda RC. Design of PID controllers in double feedback loops for SISO systems with set-point filters. ISA Transactions. 2012; 51(4):514–21.
10. Vijayan V, Panda RC. Design of set point filter for minimizing overshoot for low order process. ISA Transactions. 2012; 51(2):271–76.
11. Kannangot J, Lakshmi P, Thirupathi K. Design of Fuzzy logic based pH controller for high-pressure-rated modified CSTR System. Artificial Intelligence and Evolutionary Algorithms in Engineering Systems. 2015. p. 803–11.
12. Dinesh Kumar D, Deepika D. Performance comparison of pH neutralization process among different tunings of conventional controllers. Applied Mechanics and Materials. 2014; 573: 260–66.
13. Sakthiya Ram S, Dinesh Kumar D, Meenakshipriya B. Designing of Controllers for pH Neutralization Process. International Journal for Research in Applied Science and Engineering Technology. 2015; 3(12):164–9.
14. Shahri ME, Balochain S, Balochian H, Zhang Y. Design of fractional- order PID controllers for Time delay Systems using different evolution algorithm. Indian journal of Science and Technology. 2014; 7(9):1307–15.
15. Poulin E, Pomerleau A. PID tuning for integrating and unstable process. IEEE Proceedings Control theory Applications, 1996; 143(5):429–35.
16. Devikumari AH, Vijayan V. decentralized PID controller design for 3x3 multivariable system using heuristic algorithms. Indian Journal of Science and Technology. 2015; 8(15):1–6.
17. O'Dwyer A. Handbook of PI and PID Controller Tuning Rules. 2nd edition, World Scientific: Singapore; 2006.