Control Of pH Neutralization Process Using Artificial Intelligence

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Abstract : The pH control process stays in center in a wide range of industries including wastewater treatment, biotechnology, pharmaceuticals and chemical processing. The general aim is to maintain the pH value within a liquid at a specific level. The objective of this process is to neutralize the fluid under test by regulating the reagent solution flow rate until the mixture stabilizes at set point. After analyzing the mathematical model of the process, Simulink model of the system is developing. Neutralization process is controlling by artificial intelligence technique like fuzzy logic. The performance of the fuzzy logic controller is comparing with that of conventional controller.

***Key Words*: Artificial Intelligence based Controller, Conventional Controller, FOPTD Process,Fuzzy Logic Controller, pH Neutralization Process**

I.INTRODUCTION

Studies on pH neutralization control in process industries have shown a significant increase in the last years. Control of pH is a difficult problem and has received considerable attention because it is an un avoidable part of many industries. It is one of the most challenging problems in process industries due to severe non linearity and time varying nature of titration curve. Even a small change in composition can affect titration curve, So modelling and control of pH neutralization plants are tough. The pH process is also used as benchmark for testing new control algorithms.

A perfect and simple mathematical modelling of pH process is introduced by McAvoy is a mile stone in the development of pH process [1]. Fuzzy and Neural network based models also performs well [2].CDM – PI controllers are designed for the pH control in textile industries[3]. A comparative study of ZN PI,GA PI,BFO PI controllers are available[4] .IMC based PI,PID controllers are also used to control the neutralization reaction[5] . Fractional order PI controller is a good option for the pH neutralization process [6] . Most of the papers are based on fuzzy logic controller, FLC provides good performance for the system. In some studies the set point of process also given as input [7] . But in most cases the ordinary FLC with two inputs and one output is used [8]. Hybrid fuzzy PID controllers can be used for control strong acid–strong base neutralization[9]. Here the output of fuzzy logic controller used to adjust the PID parameters.Adaptive fuzzy sliding mode control also introduced in some papers[10] . Model based controller is a good attempt for the control of both strong acid –strong base and weak acid – strong base neutralization reaction. MRAC have shown excellent control of the process[11] . Most of the papers propose MIT rule to design MRAC. There are some papers which compare the performance of MRAC and AIMC on the process [12]. Some papers describes the use of model predictive controller (MPC)[13]. Adaptive non linear control strategy also developed for the process. Studies are taking place to control the pH using robust loop shaping approach[14] .

Here section 2 provides the detailed working of system and section 3 is mathematical modelling of the system. Section 4 deals with design of controllers and 5 is performance analysis of controllers. The last section is the conclusion

II . NEUTRALIZATION PROCESS

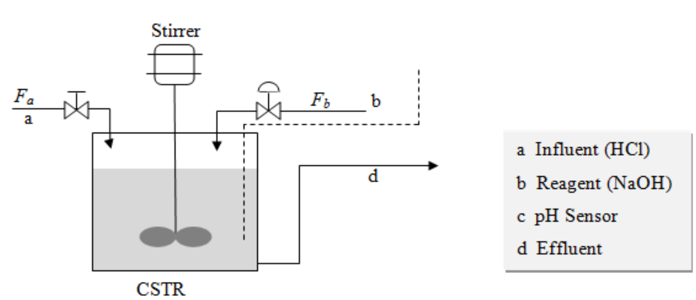

Fig: 1-pH Neutralization Process

The pH neutralization system The system consists of a CSTR with 2 input streams. One is influent stream (acidic) with the concentration (Conc.)a moles/L and flow rate of Fa L/min another is reagent stream with concentration (Conc.)b moles/L and flow rate of Fb L/min. The objective of this process is to neutralize the inlet fluid from the input stream by regulating the reagent solution flow rate Fb until the mixture stabilizes at pH equal to 7 or between the specified. The volume in the tank is constant and equal to V.

III. MATHEMATICAL MODELLING

pH is defined as the negative logarithm of hydronium ion[H+] (or hydrogen ion) concentration . It is given by:

$$pH = -\log[H^+] \quad (1)$$

The chemical reaction between the two solutions (Strong Acid Strong Base system) taking place in the CSTR

$$H^+ + Cl^- + Na^+ + OH^- = H_2O + Na^+ + Cl^- \quad (2)$$

Thus, the ionic concentration of [Na^+] and [Cl^-] in effluent stream would be related to the flows F_a, F_b and feed concentration of HCl & NaOH entering the tank .Hence the mass balance equation is given by:

$$V\frac{d}{dt}[Cl^-] = [Cl^-]\,F_a - [Cl^-]\,(F_a + F_b) \quad (3)$$

$$V\frac{d}{dt}[Na^+] = [Na^+]\,F_b - [Na^+]\,(F_a + F_b) \quad (4)$$

The concentration must also satisfy the electro neutrality equation

$$[Na^+] + [H^+] = [Cl^-] + [OH^-] \quad (5)$$

Dissociation equation for water at equilibrium at 25^0C

$$[H^+]\,[OH^-] = K_w = 10^{-14} \quad (6)$$

From (3.5) we can write

$$[H^+] - [OH^-] = [Cl^-] - [Na^+] \quad (7)$$

Let

$$X = [H^+] - [OH^-] \quad (8)$$

Therefore from (6) and (8)

$$[H^+] = \frac{X}{2}\left[\sqrt{1 + \frac{4K_w}{X^2}} - 1\right] \quad (9)$$

From equation (3) and (4)

$$V\frac{d}{dt}[\,[Cl^-]-[Na^+]] = [Cl^-]\,F_a - [Na^+]\,F_b - X\,F \quad (10)$$

Where $F = F_a + F_b$

From (7) and (8)

$$V\frac{d}{dt}X = [Cl^-]\,F_a - [Na^+]\,F_b - X\,F \quad (11)$$

The equations (1),(9),(11) corresponds to pH neutralization model. Using this equations we find out a first order plus time delay transfer function for the process.

$$G(s) = \frac{.04912\,e^{-20s}}{320s+1} \quad (12)$$

IV.DESIGN OF FUZZY LOGIC CONTROLLER

A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data . A FLS consists of four main parts such as fuzzifier, rules, inference engine, and defuzzifier. The general architecture of a FLS is shown in Figure

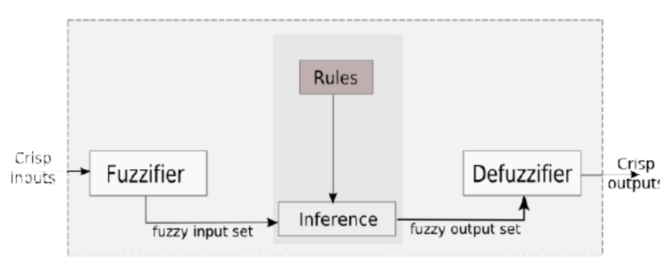

Fig 2. A Fuzzy Logic System.

Initially, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as fuzzification. Afterwards, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification step.

In this work the error and change in error of pH is taken as inputs to the fuzzy logic controller and the adjustment of flow is taken as the controller output. The error and change in error is converted into seven linguistic values namely NB, NM ,NS,ZE,PS,PM and PB. Similarly controller output is converted into seven linguistic values namely NB,NM, NS,ZE,PS,PM and PB. Triangular membership function is selected and the elements of each of the term sets are mapped on to the domain of corresponding linguistic variables. The membership functions for error change in error and controller output is shown in the figure.

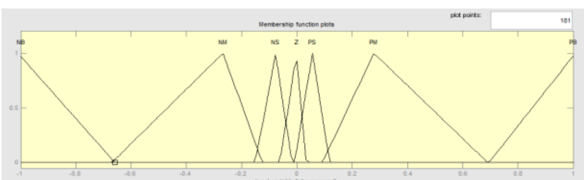

Fig 3.Membership function of error and change in error

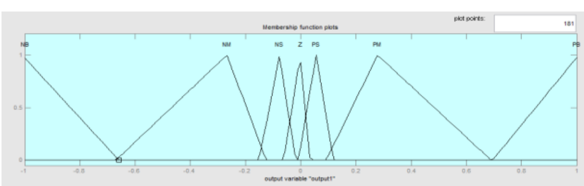

Fig 4.Membership function of controller output

ce(t) / e(t)	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	ZE	PS	PM	PL	PL	PL	PL

Table 1 :Rule Base of fuzzy logic controller

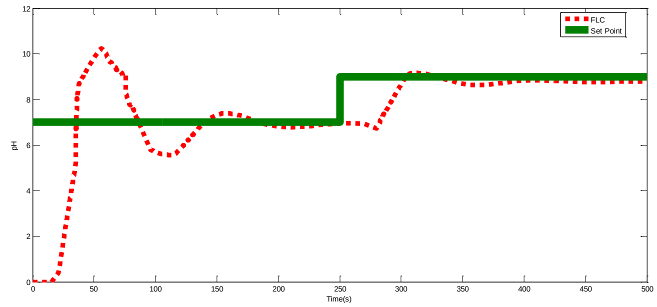

Fig 5.Servo Response of the fuzzy logic controller

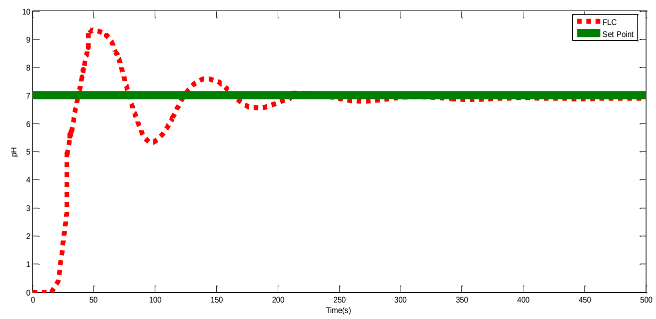

Fig 6.Regulatory Response of the fuzzy logic controller

V.COMPARISON OF FLC WITH CONVENTIONAL PI CONTROLLER

The performance of FLC can be evaluated using performance indices like Integral Square error (ISE) and Integral Absolute Error (IAE). A control system is considered optimal when it minimizes the above integrals.

Performance of FLC is compared with that of ZN PI controller with parameters K_p=293.1596 and K_i=4.3978.

Performance Indices	Servo Response		Regulatory Response	
	ZN PI	FLC	ZN PI	FLC
IAE	705	653.7	541.9	437.3
ISE	2522	1875	2314	1707

Table:2. Comparison of Controller

From the table we can see FLC have minimum value for performance indices

VI. CONCLUSION

This work clearly shows the potential advantages of using AI based controller for pH neutralization system. The comparison of the two controllers reveals that fuzzy logic controller performs well for the system.

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