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Control and Monitoring of pH process using Fuzzy Based Controller

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Abstract: In today scenario Industries use different types of process variables and parameters for measurement. Among that pH is the most important parameter. These pH measurements are prominent in the industries like food & beverage, power plant, paper industries, paramedical industries etc. The smaller change in pH (amount of acid added, base solution and time) will lead to tedious effects in the process. The control of the pH process is also non-linear in nature and maintaining the pH value in the process is difficult for the desired transient response. In order to reduce problems fuzzy based system was designed and it is efficient than conventional integral controllers.

Keywords: Control of pH process, Fuzzy logic, MATLAB.

INTRODUCTION

Control of the pH neutralization process plays an important role in different chemical plants, such as chemical and biological reaction, waste water treatment, electrochemistry and precipitation plants, production of pharmaceuticals, fermentation, and food production such as in vegetable oil refining. The technology used within the process industries has changed rapidly in recent years as plant processes have become more and more complex. These changes are due to the increasing need for better product quality and requirements for the reduction of operating costs, including those associated with energy usage. Another important factor that contributes to the development of process industry technology arises from environmental legislation which not only puts significant demands on the process industries but is also constantly being revised. It is a known fact that a pH process plant is very difficult to model and control. It is often difficult to achieve a high performance and robust pH control due to their time-varying and severe nonlinear characteristics. Hence pH control is often considered a bench mark for new models and control strategies. As a result, significant new constrains have emerged which reflect directly on plant process technology. Besides, sensors and actuators applied in industrial plants are devices which contribute with nonlinearities such as dead-zones, hysteresis and backlash. In order to overcome this issue, several linear control techniques have been used in nonlinear plants.

OVERVIEW OF PROJECT

As it is known, it has the characteristics of strong non-linearity, multi constant, strong coupled time-varying and multi-input. The technology is complicated, which results in great difficulty in the course of modeling and optimization control. By manipulating control parameters, the pH level within the system can be kept within a certain range. To determine the proper control mechanism adaptive controlling schemes are used. The pH number is a measure of concentration or more precisely the activity of hydrogen ion in a solution.

pH =-log[H+]

(1)The pH was defined earlier as the measure of the acidity or the basic of a solution, and an acid was defined as the solution of pH less than 7, and the base as that solution of pH larger than 7. More specifically, the pH was controlled in a continuously stirred tank reactor (CSTR) in this experiment.The reaction being controlled was the acid-base reaction of sodium hydroxide (NaOH) and hydrochloric acid (HCL). If the pH of the process solution is maintained constantly by adding HCL to the CSTR is said to be acid control and if the pH of the process solution is maintained constantly by adding NaOH to the CSTR is said to be base control. Using process reaction curve the open loop test is done and the transfer function is obtained for both acid and base separately. Because transfer functions are need for stimulation of fuzzy controller using MATLAB.

The significance of pH control is to satisfy certain environmental requirements. This is mainly to protect life (aquatic and human) and also to prevent damage due to corrosion.

PREPARATION OF SOLUTIONS

Fluid takenfor pH process
HCL - 0.1molar concentration.
NAOH - 0.1molar concentration.
Processsolution- Distilledwater.

Preparation of 1pH of acid
pH = - log [(Amount of HCl/lit)/Molecular Weight]
= -log[3.65/36.5]
pH =1.
Preparation of 13 pH of base
pOH= -log[(Amount of NaOH/lt)/Molecular Weight]
pH =14 – pOH
=14-[-log(4.0/40)]
pH =13

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NON LINEAR CHARACTERISTICS OF pH TITRATION CURVE

The acidity of the aqueous solution which is measured with a pH sensor plays a very important role in various physical, chemical and biological processes. For example, neutralization is required for biological treatment of wastewater stream.

The control of the pH level is known as a difficult problem due to its severe non-linearity shown in Fig.1. The nonlinearity of the pH process is represented with the titration curve and is usually considered as a gain variation.

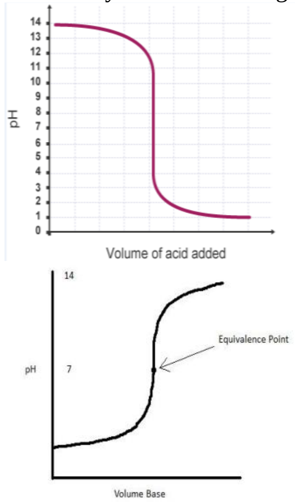

Fig.1.1 Titration curve for acid and base

The acidity measured in any solution plays very important role in any physical, chemical or biological process. Conventional controllers have poor performance or instability due to large gain variations in the controllers. This creates the necessity of a few controls that moderately controls the pH value.

ANALYSE FOR pH VARIATION

When experiments were done on taking some amount of HCL and distilled water shown in Table 3.1.

Table 3.1.Flow rate (ml) vs pH for acid

ACID ADDED (ml)	PROCESS FLUID pH
0	7
0.3	3.4
0.4	3
0.5	2.8
0.6	2.6
0.7	2.5
0.8	2.4
0.9	2.2
1	2.2
1.1	2.1
1.2	2.1
1.3	2.1
1.4	2.1
1.5	2
1.6	1.9
1.7	1.9
1.8	1.9
1.9	1.9
2	1.8

It can be conclude that the pH process has nonlinear characteristics as inferred in Fig.3.1.

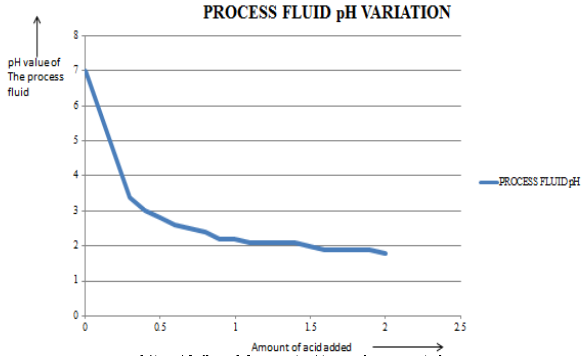

Fig.3.1 pH variation for acid

When experiments were done on taking some amount of NaOH and distilled water shown in Table 3.2.

Table 3.2Flow rate (ml)vs pH for base

BASE ADDED (ml)	PROCESS FLUID pH
0	6.7
0.1	8.4
0.2	9.2
0.3	9.4
0.4	9.5
0.5	9.7
0.6	9.8
0.7	9.9
0.8	10
0.9	10.1
1	10.2
1.1	10.2
1.2	10.3
1.3	10.3
1.3	10.3
1.4	10.3
1.5	10.4
1.6	10.4

It can be conclude that the pH processes has nonlinear characteristics as referred in Fig.3.2

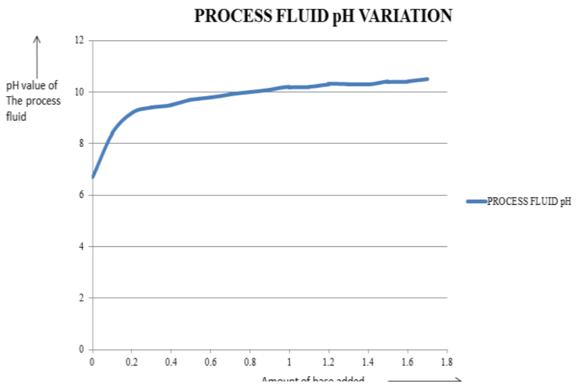

Fig.3.2pH variation for base

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BLOCK DIAGRAM

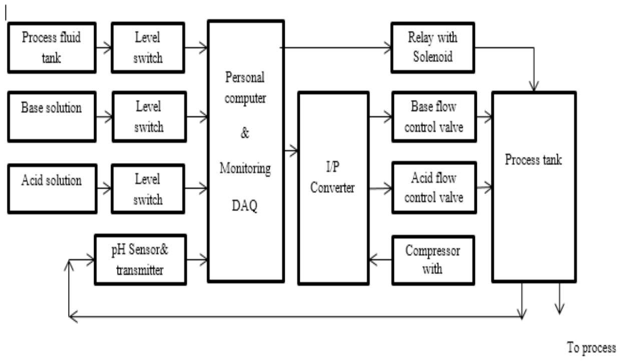

Fig.3.3Block diagram of pH process

BLOCK DIAGRAM DESCRIPTION

Solution tank

The setup consists of three solution tanks shown in Fig3.3. Each solution tank contains acid, base and water separately. Water is used only for neutralization purpose. The acid solution taken here is HCL (0.1M) and the base solution taken here is NaOH (0.1M).Level switchEach solution has its own level switch shown in Fig., when the solution from the solution tank reduces below the level switch it indicated by an alarm.

pH sensor and transmitter

pH sensor is placed inside the process tank. It is used to measure the pH value of the process solution. The pH value is showed in the display present in the setup and the transmitter transmits the pH value in terms of current shown in Fig

Personal computer and DAQ (Data AcQuisition card)

DAQ will convert analog value into digital value as well as digital value into analog value. PC can accept only digital values so DAQ will convert analog value into digital value shown in Fig.3.1.The program is built in the PC, where the percentage of valve opening can be given and the simulation graph is shown clearly. Once the valve opening is given the DAQ will convert the digital value into analog value. LabVIEW DAQ is used for this station.

I/P converter the current value is converted into pressure through I/P converter so that the control valve can move according to the percentage of valve open which is given in the PC shown in Fig.

Process tank

Process solution is present in the process tank, whose pH is to be maintained and controlled shown in Fig.3.1 Process tank has pH sensor and stirrer, which continuously stirs the solution. The flow of the acid and base solution is controlled by the control valve.

PROCESS REACTION CURVE METHOD

The process reaction curve methods works by generating a process reaction curve (below) in response to a disturbance. Controller gain, integral time and derivative time can be calculated using this curve shown in Fig.8. The process reaction curve is identified by performing in an open loop step test of the process and finding model parameters for initial step.

A typical process reaction curve is generated using the following method:

- Put the controller in manual mode.
- Wait until the process value reaches steady state or as close as possible (stable and not changing) Introduce a small disturbance - The step must be big enough to see a significant change in the process value. Collect data and plot

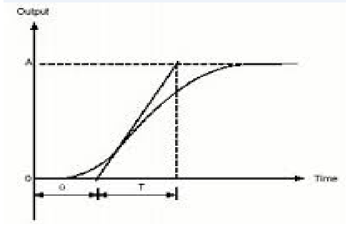

Fig.3.4 Process Reaction curve

Transfer function obtained using process reaction curve for base

Gain, K=process output/process input
K=0.04912

Time delay t_d =20 secs

Time constant $\tau = t - t_d$

τ =320

The obtained transfer function is:

$$Gp(s) = \frac{k.e^{-t_d s}}{\tau_s + 1} \quad (2)$$

$$Gp(s) = \frac{0.04912e^{-20s}}{320s + 1} \quad (3)$$

Transfer function obtained using process reaction curve for acid

Gain, K=process output/process input
K=0.07114

Time delay, t_d =20 secs

Time constant, $\tau = t - t_d$

τ =100

The obtained transfer function is:

$$Gp(s) = \frac{k.e^{-t_d s}}{\tau_s + 1} \quad (4)$$

$$Gp(s) = \frac{0.07114e^{-20s}}{100s + 1} \quad (5)$$

SIMULATION RESULTS

MATLAB BLOCK DIAGRAM

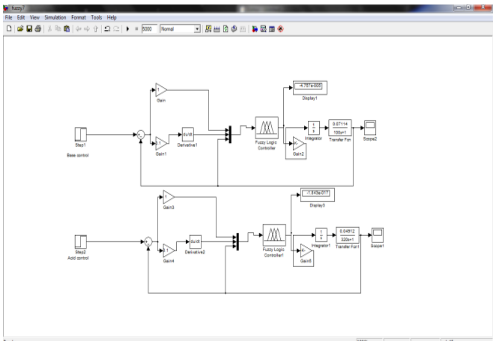

Fig.5.1MATLAB block diagram

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RESPONSE FOR ACID CONTROL

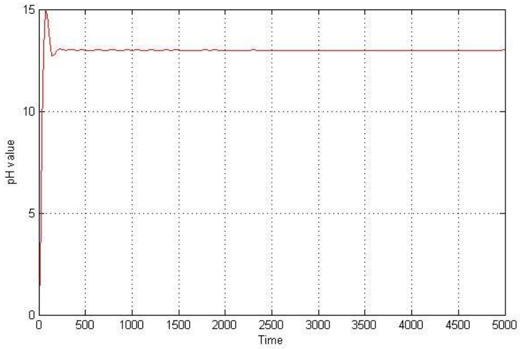

Fig.5.2MATLAB response for acid control

RESPONSE FOR BASE CONTROL

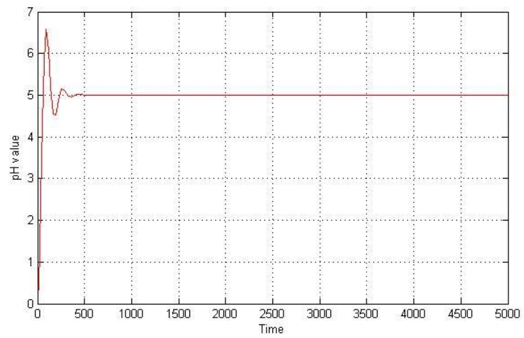

Fig.5.3MATLAB response for base control

CONCLUSION

This work is mainly aims on developing a fuzzy based control system for pH control and also to minimize the defects and the human negligence with the help of MATLAB. Unlike the other automated systems programmed using microcontrollers and PLC's, MATLAB serves the purpose of easy programming and has high flexibility.

FUTURE SCOPE

In the future, the work can be enhanced in many possible ways. Some of them are as follows:
The certain outside changes can be fed to the controller so it can also maintain the pH accurately.
More combination of MATLAB and embedded coding can be done to ensure that the system becomes fully automated and intelligent to the core
This work can be extended to design of neuro fuzzy logic controller which will be more effective.

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