CHEMICAL PROCESS CONTROL IN SUGAR MANUFACTURING UNIT

Rukkumani V.[1], Khavya S.[2], Madhumithra S.[2], Nandhini Devi B.[2]
[1]Assistant professor, Department of Electronics and Instrumentation Engineering
[2]B.E, Electronics and Instrumentation Engineering
Sri Ramakrishna Engineering College
Coimbatore, India

ABSTRACT
Neutralizing pH value of sugarcane juice is the important factor to be considered in the sugar manufacturing process since it influences the quality of white sugar. The pH neutralization process is a complicated physical-chemistry process with strong characteristics of non-linearity and time-varying property. Hence there is no optimal solution to control the varying pH without mathematical modeling. For the systems whose mathematical model would be hard to derive, any alternative method could be used. Therefore PID control and Fuzzy Logic Control was used for the control in clarifying process of sugar juice based on relevant error values of real-time sample data from sugar manufacturing unit. The pH being non-linear in nature, PID control was ineffective for steep changes. In such cases LabVIEW based fuzzy logic method was used to optimize and control the neutralized pH value in the clarifying process of sugar juice. The simulation results indicate that this method had the good control effect. This will build a good foundation for stabilising the clarifying process and enhancing the quality of the purified juice and lastly enhancing the quality of white sugar.

KEYWORDS*: pH control, Sugar manufacturing unit, LabVIEW, PID control, Fuzzy control*

I. INTRODUCTION

Clarifying and the sulphitation process are considered as important in the sugar manufacturing process. The process has the characteristics of strong non-linearity and time-varying property, the technology is still complicated and it results in great difficulty of modeling and optimization control [1]. The control strategy requires optimising several process parameters [2]. The existing technological process and equipment can't solve this problem from the root and adjust the processing parameters in real time on site. It is done to keep the optimum state of production, to improve the quality of the purified juice and mainly to maintain the colour of the crystal. Since it is a complicated process to neutralize the pH, this needs the manual regulation in the actual production process. In this process, the problem of instability of flow of sugarcane juice causes the need to control the flow of MOL and SO_2 [3]. Here the control effect using PID control is insufficiently stable, i.e. sometimes pH value is excessively high and sometimes it is excessively low and so the result is not good [4] [5].

This paper is organized as follows. In section 2, the process occurring in the clarification area of the sugar industry is explained. In section 3, the block diagram of the control process using the PID controller and the Fuzzy Logic Controller is given. In section 4, the proposed model of the control process in the sugar industry is obtained. In section 5, the experimental results showing the S-curve characteristics using the sugarcane juice and for the addition of MOL (in ml) is given. The section 6 shows the simulation results of the control action programmed in LabVIEW. Moreover, in this section, the control action taken by the fuzzy controller is displayed.

II.   PROCESS EXPLANATION

The raw sugarcane juice is separated from the bagasse, and is sent to the process of clarification and sulphitation. After which the process of crystallisation occurs. The main process of maintaining the pH process involves this sulphitation process which is considered as one of the main reasons of the whitening of the sugar crystals [2] [6].

In this process of production of sugar, the sugarcane juice with a pH range of 4.5 to 5 is taken for the process. It is then mixed with Milk Of Lime (MOL) whose pH value is approximately 12. After the addition of MOL, the pH of sugarcane juice changes to a range of 8.9 to 9. Next to the process of clarification, the process of sulphitation occurs. The main process of maintaining the pH process involves this sulphitation process which is considered as one of the main reasons of the whitening of the sugar crystals. In the sulphitation process SO_2 is added with the sugarcane juice. After the addition of this, the pH value becomes 7.3 to 7.4. The sugar juice is heated to a temperature of about 70 degree Celsius. The juice in this stage contains impurities and hence it has to be filtered. Finally the purified juice is obtained which is sent to the chemical department and the crystallization process takes place.

III.   BLOCK DIAGRAM OF THE CHEMICAL PROCESS CONTROL

The difference between the setpoint i.e., the pH value to be maintained and the feedback i.e., the current pH value is given as the input to the comparator. The comparator compares the input value with the pre-defined reference value. Based on the output of the comparator, the control is taken either by PID controller or Fuzzy Logic Controller as shown in Figure.1. The control action taken is given to the final control element which will be given to the clarifying process.
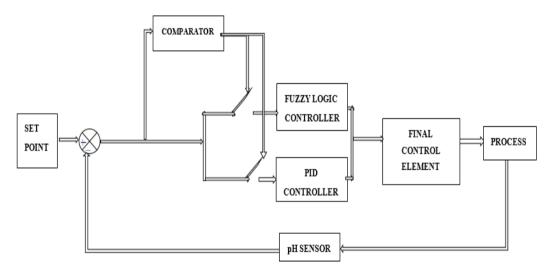

Figure.1.Block diagram of the process with controllers choosing either PID or fuzzy controller

In the absence of knowledge of the underlying process, a PID controller has historically been considered to be the best controller. By tuning the three parameters in the PID controller algorithm, the controller was believed to provide control action designed for specific process requirements. The response of the controller can be described in terms of the responsiveness of the controller to an error, the degree to which the controller overshoots the setpoint, and the degree of system oscillation [6]. This makes PID control to be used even for non-linear process.

Fuzzy controllers are used to control fuzzy systems. Most traditional control algorithms require a mathematical model of the system you want to control. However, many physical systems are difficult or impossible to model mathematically. In addition, many processes are either non-linear or too complex to control with traditional strategies. However, when a control strategy is described qualitatively, fuzzy logic can be used to create a fuzzy controller that emulates a heuristic rule-of-thumb strategy [7] [8]. Fuzzy logic controller can be better used in case without mathematical modelling [9]. This makes fuzzy to be used along with PID for the control of non-linear process [10].

The voltage value corresponding to the pH of the sugarcane juice after sulphitation is taken as the measured value, whereas the control is given to the MOL valve. By adjusting the MOL flow into the process, it is possible to get the correct pH value as the end result. In this process, SO_2 flow can also be adjusted. But SO_2 shouldn't be increased greatly in the process, since it causes health hazards and is also not economic.

IV. EXPERIMENTAL SETUP

The main process is maintaining the pH of the process in the line mixing of sugarcane juice and the MOL thereby maintaining it in the final pH. This process is fed back into the DAQ through the pH sensor. The error value is controlled accordingly either in the PID controller or in the fuzzy logic controller. The corrective action is given to the final control element i.e., the pump which allows the flow of the MOL.
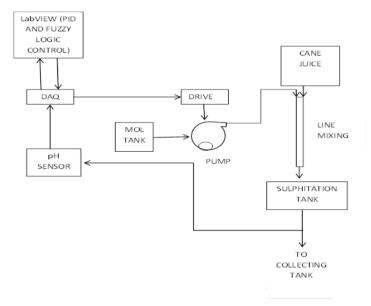

Figure.2.Block diagram of the proposed model of pH automation in the sugar manufacturing unit

The real time process is continuous in nature. Hence for certain values of error, we are using PID control algorithm and for other values, we are using LabVIEW based fuzzy logic method. The difference between the set point and the measured value of pH is given as the input to the comparator. Based on the comparator value, either the PID control algorithm or LabVIEW based fuzzy logic method is chosen. From the pH automation process, the output pH value to the sulphitation tank is expected to be of pH value 9.

The MOL and sugarcane juice is mixed up together during continuous flow through the pipe as shown in fig.2. The value of pH after the addition of MOL to the sugarcane juice should have pH value 9. After the sulphitation process, the pH should lie between 7.3 and 7.4. When the above two processes of controlling pH are automated correctly, then the final pH value of a sugar will be obtained as 7.

There occurs the need for the PID controller and the fuzzy logic controller, since for smaller values of error PID is found to be the best option at affordable rate whereas the fuzzy logic is highly sufficient for higher range of values.The value from the real-time field can be obtained by using the pH sensor. Error detector gives the output to the comparator which compares the output of the error detector with the pre-defined value. Depending upon the value of the error detector, the comparator chooses either fuzzy logic method or PID controller. This output activates the FCE which delivers the required amount of MOL to the process.

V. EXPERIMENTAL RESULTS

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

biological treatment of wastewater stream. But the control of pH level is known as a difficult problem due to its severe non-linearity. The non-linearity of a pH process is represented with the titration curve and is usually considered as a gain variation i.e., the S-curve [11].

Experimentally 50 ml of sugarcane juice is taken and the MOL is added in amounts of ml. The corresponding pH value is measured and tabulated as shown in table 1. The values show steep changes at some points and smaller changes at others. From the graph obtained, the S - Curve can be seen clearly as shown in figure.3.

Table 1. Showing the values of amount of MOL added and pH value for 50ml sample of sugarcane juice

AMOUNT OF MOL ADDED(ml)	pH VALUE
1	10.7
2	10.9
3	11.1
4	11.6
5	11.8
6	12.1

5.1 Characteristics between amount of MOL and 50ml sugar juice

The change of pH value when 1ml of MOL added to the 2ml, is 0.2. Similarly it is 0.2 ml for many other values. But at some points, a steep change more than 0.5ml is obtained. So in such cases, PID controller is used for small changes such as 0.2 pH changes and fuzzy controller for 0.5ml and more.
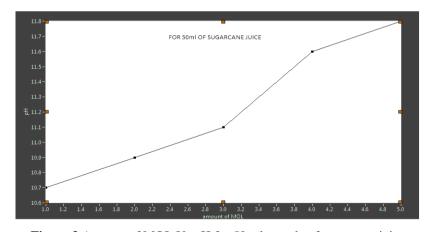

Figure 3.Amount of MOL Vs pH for 50 ml sample of sugarcane juice

Similarly 50 ml of sugarcane juice is taken and the MOL is added in amounts of ml. The corresponding pH value is measured and tabulated as shown in table 2. The values show steep changes at some points and smaller changes at others. Also from this graph the S - Curve is obtained as shown in Figure 4. This experimental results show that the pH is non-linear and produces some steep changes.

Table 2. Showing the values of amount of MOL added and pH value for 200ml sample of sugarcane juice

AMOUNT OF MOL ADDED(ml)	pH VALUE
1	7.2
2	7.5
3	8.8
4	9.7
5	9.9
6	10.2

5.2 Characteristics between amount of MOL and 200ml sugar juice

The change of pH value when 1ml of MOL added to the 2ml, is 0.2. Similarly it is 0.2 ml and 0.3ml for many other values. But at some points, a steep change more than 0.9ml is obtained. So in such cases, PID controller is used for small changes such as 0.2 pH changes or for 0.3ml pH changes and fuzzy controller for 0.9ml and more.
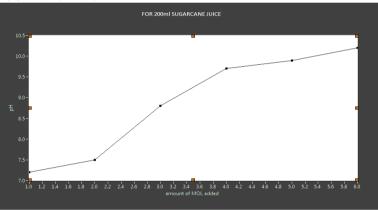

Figure 4. Amount of MOL Vs pH for 200 ml sample of sugarcane juice

From the amount of MOL added and the quantity of sample taken, the steep change in the S-curve changes and the values are obtained accordingly. In the 50ml of sugarcane juice taken, a steep change of 0.5 is obtained for 3ml of MOL, whereas for the sample of 200ml added, a steep change of 0.9 had occurred for 4ml of MOL. When experiments are done on taking some amount of sugarcane juice and MOL, we can conclude that the pH possess nonlinear characteristics as inferred above.

The difference between the set point and the feedback i.e.,the measured value from the pH sensor is calculated. The error value decides the type of control to be used, either the PID control or the fuzzy logic control in the auto mode and the PID control in the manual mode.

In the simulation, two different cases are made use of, in which, if the error value is greater than or equal to a certain value, fuzzy logic controller takes up the control action, whereas the PID controller comes into play when the error value is controllable using PID control algorithm i.e., lesser than a certain value in case of the automatic mode.

VI.   SIMULATION RESULTS

The PID tunings are formed only for the range below 0.5, and for the other higher values, it is possible to tune only with the help of the fuzzy logic controller. So, as programmed, the control action occurs as given in the LabVIEW program and is shown in the fig.5. The values inside the fuzzy logic if-then rule base are given according to the output values needed which can be obtained which ranges from the value of 4-20 mA.

In this simulation, it is programmed in such a way that in case of automatic mode, for values below 0.5, PID controller takes up the action whereas for values above 0.5, fuzzy logic control is used. After a fuzzy controller fuzzifies the input values of a fuzzy system, the fuzzy controller uses the corresponding input linguistic terms and the rule base to determine the resulting linguistic terms of the output linguistic variables.
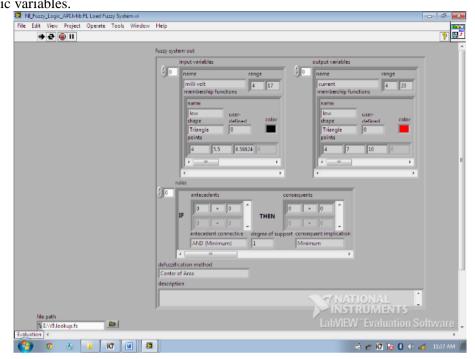

Figure 5. Front panel showing the simulation result in LabVIEW

In case of the manual mode, manual tuning and controlling is needed. In any process industry, there occurs a difficulty in start-up. So, such case needed a manual start-up.

VII.   CONCLUSION AND FUTURE EXPANSION

Thus the pH value, which is a main parameter to be considered during the manufacture of sugar is controlled using two controls namely the PID controller and the Fuzzy Logic Controller. The simulation results shows that the corrective action is taken by the above mentioned two controllers as and when they are needed. It has been found through the literature survey and the industrial study, that the use of PID controller and fuzzy logic controller could probably increase the efficiency and the feasibility of the process when used in the industry.

The same control programming in the industries could be expanded using industry suitable PLC programming. This results in the automatic control of pH and hence it reduces man power and increases the quality of sugar crystals.

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AUTHORS

V. Rukkumani was born in Coimbatore, India, in 1983. She did her bachelor of engineering in Electronics and Instrumentation Engineering from Bharathiyar University, in 2004 and master in VLSI design from Anna University, in 2009, Coimbatore. She is currently pursuing her Ph.D. in Electrical Engineering. Her research areas include VLSI design, CAD VLSI, instrumentation, sensors and measurements.

S. Khavya was born in Coimbatore, India, in 1993. She is pursuing her bachelor of engineering in Electronics and Instrumentation Engineering from Anna University, Chennai. Her research areas include industrial automation and process control.

S. Madhumithra was born in Coimbatore, India, in 1993. She is pursuing her bachelor of engineering in Electronics and Instrumentation Engineering from Anna University, Chennai. Her research areas include image processing, biomedical instrumentation and industrial automation.

B. Nandhini Devi was born in Coimbatore, India, in 1992. She is pursuing her bachelor of engineering in Electronics and Instrumentation Engineering from Anna University, Chennai. Her research areas include industrial automation and process control