International Journal of Research Publication and Reviews, Vol 5, no 4, pp 8288-8294 April 2024

International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Smart Thermoregulation and PH Control Based on Fuzzy-Pid System with Web of Things

***Dr. K. Gaayathry* [1], *Leena R*[2], *Boomika S*[3], *Hari Varshini S*[4], *Sherene Amalia G*[5]**

[1]Assistant Professor, Department of Instrumentation and Control Engineering Saranathan College of Engineering, Tiruchirappalli-12, India.
[2,3,4,5] Instrumentation and control engineering, Saranathan College of Engineering, Tiruchirappalli, India.

ABSTRACT—

This study describes the usage of fuzzy-PID controller with Internet of Things (IoT) technologies to manage pH. Creating multiregional supervisory fuzzy PID (Proportional-Integral-Derivative) control for pH reactors is the focus of this work. The suggested work primarily focuses on two themes. The first is to suggest a fuzzy-based multiregional supervisory cascade control framework. It would make dynamics modification possible and improve system stability. The PID controller (slave loop) has been selected to be tuned by the fuzzy system (master loop). The size and cost issues that occur with using traditional methods for measuring pH would be resolved by the suggested estimation. The compatibility between LabView and the final end-user-interface (EUI) front panel have been used to provide the results that assess the supervisory fuzzy PID-based control system's performance. They ultimately lead to the conclusion that the suggested algorithms are suitable for the nonlinearities in pH reactor systems.

***Keywords*—pH, Myrio, fuzzy-PID, Labview, IOT.**

Introduction

These days, computer-based systems are used in the measurement and instrumentation fields to control and monitor process elements and devices in the field or in the laboratory. This application covers both networked computerized instrumentation systems, like the distributed control system, and standalone computerized instrumentation systems. Before reaching their current forms, advancements in instrumentation and measuring systems underwent several stages of development. The measuring and instrumentation fields have advanced greatly, but they still have certain drawbacks, such as the need for expensive and large-scale real instruments. Additionally, because the instrument is industrial oriented, its processing capabilities are limited and unable to handle new processing approaches.

As a result, the field of measurement and instrumentation experienced a shift in circumstances, leading to the creation of a new generation of instruments known as Virtual Instruments (VI). The main goal of this effort is to create a virtual pH analyzer that can take the place of the real, traditional equipment used in continuous process applications. The pH meter and pH controller were the two components of the development that were separated. The primary idea behind the creation of the virtual pH analyzer was to use an inexpensive, ordinary personal computer and software to create a strong, accurate, and versatile equipment. After obtaining the response with a PID controller, the process is once more run via a fuzzy logic controller. The outcomes are contrasted.

Fuzzy logic controllers are more flexible and produce a smoother output than PID controllers, which are more traditional and practically focused. The entire process is tracked and managed by LabVIEW (Laboratory Virtual Instrumentation Workbench) software. This research aims to provide the solution by integrating PID and fuzzy logic controllers on the two previously described processes. Because it makes it simple to interface processes with software, LabVIEW is easy to use. Programming is made easier by the use of graphical programming techniques in LabVIEW.

pH Analyser

A pH meter is essentially a high input impedance microprocessor-based electronic device that measures the voltage of an electrode that is sensitive to the concentration of hydrogen ions in relation to another electrode that displays a constant voltage. an illustration of a conventional, actual pH meter. With a memory capacity of only 100 measurements, the meter spans the spectrum from basic to sophisticated and costly laboratory instruments. Customary pH measuring device Any solution's pH is typically measured using a number of instruments, including a pH electrode and pH analyzer that are coupled to a strip chart recorder and other data gathering devices. Each of these instruments performs a specific purpose; to increase the number of functions performed, additional, potentially expensive hardware and instruments must be purchased.

The Theory of pH Measurement

An electrode can be used to measure the pH of the fluid. The Nernst equation, which describes how an electrode creates a potential that yields a voltage output proportional to pH value, can be used to explain the behavior of the electrode. The following equation explains how temperature affects the pH electrode's voltage output.

$$v = v_0 + (1.98 \times 10^{-4}) T_k pH \qquad (1)$$

(where Tk is the recorded temperature in Kelvin, v0 is the intersect point value, and v is the total measured voltage in millivolts. The measurement of pH is significantly impacted by temperature. primarily, how electrode slope is affected by temperature. Furthermore, the variation in the temperature coefficient affects the substance that the sensor is measuring. The pH electrode is impacted by the Nernst slope variation with temperature.

Model of pH Reactor

It has been examined how the pH value, a master process variable, and the base streams, a controlled variable, relate logarithmically. Three operational zones—two linear ranges and one nonlinear range—are separated by this relation. Its primary goals are to change the pH control's close-loop response and expand its operating range.

In our instance, the strong acid (HCL) in the titration procedure under consideration has a constant flow value of [2 mL/sec] and a concentration of [0.95 mol/L]. The strong base (NaOH) flow at a concentration of [1.9 mol/L] will be the variable that is adjusted. At this point, the following formula would be used to determine pH.

$$\mathrm{pH} = \log_{10}\left[\frac{-\left(kQ_aC_a/\left(Q_a+Q_b\right)-Q_bC_b/\left(Q_a+Q_b\right)\right)+\sqrt{\left(kQ_aC_a/\left(Q_a+Q_b\right)-Q_bC_b/\left(Q_a+Q_b\right)\right)^2-4\left(10^{-14}\right)(-1)}}{2\left(10^{-14}\right)}\right], \qquad (1)$$

where V is the volume, k is a constant that varies with acid strength, and Ca, Cb are the concentration values of acid and base, respectively, in the outlet stream. Qa, Qb are the volumetric flow rates of acid and base, respectively. For our particular strong acid-strong base system, k = 1.

Proposed System

Using the MyRio controller, fuzzy controller, PID controller, LabVIEW software, and CSTR tank, this project enables pH monitoring and control. This method aims to provide efficientpH management by attempting to modify the difference between the measured temperature, various types of solutions, and the expected set point. The entire process will be monitored via the Internet of Things (IOT).

System Design

Fig. 1. Block Diagram of the System

As it can be seen from the block diagram, Three inputs—the auxiliary variable, the pH value error (e), and the change in error (de)—are fed into the fuzzy system, which outputs three different values: the proportional gain (Kp), the integral gain (Ki), and the derivative gain (Kd). Qb is the modified variable that shows the base flow, and U is the control action.

Three divided titration regions are served by the suggested control system. These three areas were selected in accordance with the base flow rate Qb value, which controls the reactor's pH level. The variables can only be evaluated qualitatively and imprecisely because they are linguistic values in and of themselves. As a result, a method is required to explain these ambiguous values. One of the best instruments for processing linguistic data is the fuzzy set.

Methodology

The pH measuring and control system phases comprise the two stages of the development of the virtual pH analyzer. While the pH control system phase consists of components for data processing and control signal generation, the pH measurement phase consists of two components: data acquisition and data presentation. An apparatus that measures the pH of an input solution and regulates the addition of a neutralizing agent (on demand) to keep the output solution at pH 7, or within acceptable bounds, is known as a pH control system. It functions like a continual titration. Applications involving continuous processes are typically best suited for the ON/OFF control approach.

This system uses a pH sensor to monitor the solution's pH in the reaction tank. The pH analyzer is then used to compare this measured signal to the intended value. The signal to the actuator regulating the addition of reagent is always set in one of two positions: fully open (ON) or fully closed (OFF), thanks to an analyzer that offers an ON/OFF control system. On the other hand, this causes fast cycling and may harm the last control element. Thus, it is necessary to have an ON/OFF controller with upper and lower hysteresis limitations. These boundaries will keep the last control element "ON" for an extended period of time, resulting in seamless functioning devoid of frequent cycling. When the process variable changes, the parameters automatically adapt to the new situation, resulting in the desired result.

For the aim of real-time monitoring, the microcontroller and IOT module will be attached.

A. Fuzzy Logic System

Rules, membership functions, and linguistic variables are a fuzzy system's three main parts. The basic steps involved in developing fuzzy logic control are as follows:

- Figuring out the variables that are input and output.
- Giving each fuzzy subset produced by dividing the time between each input and output a linguistic label.
- Determining the fuzzy subsets' membership functions.
- Calculating how fuzzy the "input fuzzy subsets" and "output fuzzy subsets," which together comprise the Rule Base,.
- You can understand the rules by using operators like fuzzy "AND" and "OR."
- In fuzzy systems, many rules may function concurrently, albeit to varying degrees of intensity.
- Transforming processed, imprecise data into accurate data suitable for instantaneous applications.

Proportional Integral Derivative System

Proportional–Integral–Derivative controllers, or PID controllers for short, are a common mechanism in industrial control systems and other applications requiring constantly modulated control. Let's dissect its basic functioning:

$$u(t) = K_p e(t) + K_I \int_0^t e(t)dt + K_d \frac{de(t)}{dt}$$

Where,

K_p is the proportional gain

K_I is the Integral gain

K_d is the Derivative gain

1. Proportional (P) Term: The present error between a measured process variable (PV) and a desired setpoint (SP) determines the P term. A gain factor K_p is used by the control output to react proportionately when the error is large.
2. Integrated (I) Term: Throughout time, the I term accumulates the cumulative mistake. By modifying the control variable (e.g., opening a control valve) in accordance with the integral of the error, it helps avoid steady-state errors. The integral term is crucial to preserving precision and stability in the control loop.
3. Derivative (D) Term: This term takes the error's rate of change into account. It assists in preventing oscillations and overshoot by projecting future error trends. The controller enhances responsiveness by modifying the control variable in accordance with the derivative of the error.
4. Combined Action: Using the proportional, integral, and derivative terms as a basis for correction, the PID controller continually determines the error value. Its objective is to reduce the error over time by carefully modifying the control variable.

Temperature Sensor

Resistance temperature detectors work by establishing a connection between the RTD element's resistance and temperature. The resistance of the pure material used to create the RTD element has been tested and recorded at different temperatures. A material's temperature is determined by the expected change in resistance that it experiences as a function of temperature. This time, the material is platinum. A platinum resistance temperature detector (RTD) Pt100's resistance is normally 100 Ω at 0°C. Resistance has a positive slope that increases with temperature (resistance increases as temperature increases).

Internet of Things

An real physical network of objects, such as vehicles, appliances, and other goods, with sensors, software, and network connectivity integrated into them is referred to as the "Internet of Things" (IoT). These devices use real-time sensors incorporated into their environment to continuously monitor temperature levels.

The data collected by these sensors is sent to a centralized monitoring platform via cloud computing.

1. IoT Components for Temperature Control Systems:
   - The temperature is monitored using a fuzzy logic system called ThingSpeak.
   - The MyRio and IOT module are connected to provide the data.
2. How It Functions:
   - Set a temperature setpoint and hysteresis to ensure a consistent temperature range.
   - Create a LABVIEW VI and add components to read palette data from ThingSpeak.
   - Enter the channel ID and API key to configure the ThingSpeak connection.
   - Attach the IOT device's output data to the VI's input.
   - After executing the VI, the application will receive the data to be monitored.

Multiple Input Single Output Process

A. MISO

Combining many manipulated variables and one control variable, a many Input Single Output (MISO) system is a control mechanism. For instance, the temperature of the reactor feed can be evaluated, and the coolant flow rate can be changed (a disturbance). The temperature of the reactor is affected by these two.

Implementation of fuzzy rules

Sets of variables linked by fuzzily defined logic make up a fuzzy system. A fuzzy controller makes use of pre-established rules to govern a fuzzy system according to the input variables' current values. Three primary components comprise a fuzzy system: rules, membership functions, and linguistic variables. Terminologies and Variables in Language The terms used to represent the input and output variables of the system that requires regulation are known as linguistic variables. There are often an odd number of linguistic terms in linguistic variables, with a middle term and symmetric terms at either end. There is a predicted value range for each linguistic variable. The words "cold," "moderate," and "hot" may be included in the variables for both the expected and actual temperatures. It is possible to find the terms "off," "low," and "high" in the linguistic variable heater setting. For Membership Intentions Numerical functions known as membership functions are used to represent linguistic notions. The level of membership of linguistic variables within their linguistic terms is represented by a membership function. The membership degree is a continuous scale where 0 represents 0% membership and 1 represents 100% membership. The Ÿ-type (triangular shape), Π-type (trapezoidal shape), singleton-type (vertical line form), Sigmoid-type (wave shape), and Gaussian-type (bell shape) membership functions are among the various varieties that are available.

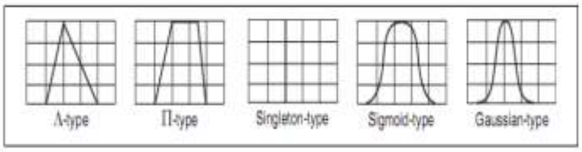


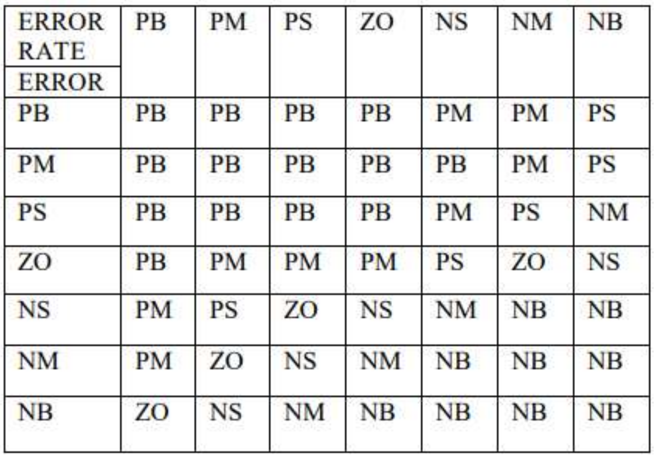
Fig.2. Different types of shapes in the fuzzy graph

Fuzzy Rule Implementation

A. Rule Description

The Table of Basic Rules Based on their linguistic language, rules convert the relationships between the linguistic variables in the input and output into words. The following formula defines the total number N of feasible rules for a fuzzy system: N is equal to p1 × p2 ×. For the input linguistic variable n, the number of linguistic phrases is represented by × pn. The following equation defines the total number N of feasible rules if all input linguistic variables have the same number of linguistic terms: N is equal to p^m, where m is the total number of input linguistic variables and p is the number of linguistic phrases for each input linguistic variable. It could be helpful to plot a rule base as a matrix in order to spot inconsistencies, such as conflicting rules. On the other hand, relatively modest rule bases get the greatest results when matrix plotting a rule basis. It is challenging to find discrepancies in large rule bases. By using cascaded fuzzy systems, large rule bases in fuzzy systems with many controller inputs can be avoided.

B. Rules Table



ERROR RATE ERROR	PB	PM	PS	ZO	NS	NM	NB
PB	PB	PB	PB	PB	PM	PM	PS
PM	PB	PB	PB	PB	PB	PM	PS
PS	PB	PB	PB	PB	PM	PS	NM
ZO	PB	PM	PM	PM	PS	ZO	NS
NS	PM	PS	ZO	NS	NM	NB	NB
NM	PM	ZO	NS	NM	NB	NB	NB
NB	ZO	NS	NM	NB	NB	NB	NB

Developing Fuzzy Logic Controller With PID Controller

A. Objective of the fuzzy and PID in our Paper

For the most part, traditional control methods need you to have a mathematical model of the system you want to regulate. However, many physical systems are difficult or impossible to model mathematically. In addition, many processes are too complicated or nonlinear to be handled by traditional techniques. If a control strategy can be qualitatively characterized, fuzzy logic can be used to create a fuzzy controller that approximates a heuristic rule-of-thumb method. The fuzzy controller uses the matching input linguistic words and rule base to decide the consequent linguistic terms of the output linguistic variables after fuzzifying the input values of a fuzzy system. The process is given stability and quick responsiveness via the PID controller. It also contributes to lowering energy costs.

In conjunction with a PID controller, a fuzzy controller, Linguistic rules and contextual data are provided by the fuzzy controller. With this data, the PID controller may dynamically modify its parameters. The behavior of the system can be used by the fuzzy controller to adjust the PID gains. Precise control is guaranteed around the setpoint by the PID controller. The fuzzy controller facilitates the handling of nonlinearities and condition adaptation.

B. Steps in designing the fuzzy logic

- Determining the variables that are input and output.
- Giving linguistic names to every fuzzy subset that is produced for every input and output time period.
- Establishing a fuzzy subset's membership function.
- Determining the relationships between the "input fuzzy subsets" and "output fuzzy sets," which collectively comprise the Rule-Base.
- Applying fuzzy "AND" and "OR" operators to interpret the rules. Multiple rules may fire simultaneously in fuzzy systems, but at different intensities.
- Converting the processed, hazy data into clear data appropriate for practical application.

C. Steps in designing the PID

- Outlining the process's performance requirements.
- Being aware of the parameter's system dynamics.
- Selecting Proportional, Integral, and Derivative Gain as the PID Parameters.
- The crucial stage in the procedure is fine-tuning the PID controller.
- The next step will be to implement the PID Controller. Discretize the continuous-time PID controller in digital systems. To determine the control signal at each time step, use the difference equation.
- Applying the intended PID controller to the real temperature control system in order to test and validate the system. Examine the reaction and contrast it with the intended outcome. Adjust the profits as needed.

D. Sensor Integration

Take into consideration LabVIEW's data collecting features to obtain temperature readings from the attached sensors. If necessary, apply suitable signal processing techniques to guarantee precise measurement.

E. Actuator Control

To create control signals and communicate with the actuators attached to your system, use LabVIEW. To maintain the appropriate temperature, this may entail producing analog or digital control signals that operate the actuators.

F. Fuzzy Inference and PID control Implementation

Use LabVIEW to implement the PID control method and fuzzy inference mechanism. Determine the proper control actions depending on the target setpoint and the current temperature measurement by applying the fuzzy rules that were previously created. To create the final control signal, combine the PID control output and the fuzzy logic output.

G. Control Signal Generation

The control system component is designed to compare the measured pH to the target value and, if required, to turn on the pump using an ON/OFF control signal. In this work,pH is automatically controlled by a program that is designed to turn on the pump when the predetermined point is reached. The pH measurement is stabilized and the solution is adequately mixed thanks to the mixer. In this instance, the user manually activates the mixer, and it is intended to be turned off when the predetermined point is achieved.

H. Result

The comparative results of PID controller and supervisory fuzzy PID controller within the three regions of the titration curve and towards the set point tracking are presented.

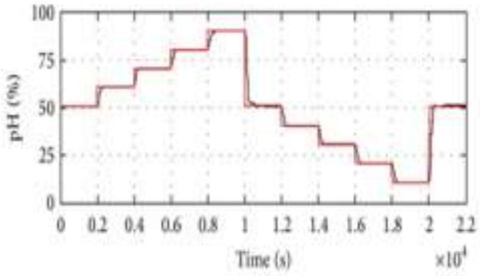


Fig.3. Supervisory fuzzy PID response process.

Performance of multiregional fuzzy PID controller in the three regions of titration curve for weak acid (Fig. 4) and also for strong acid (Fig. 5).

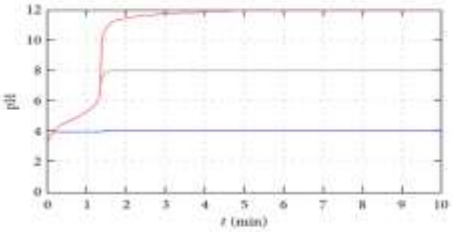


Fig. 4. Output of the system in graph

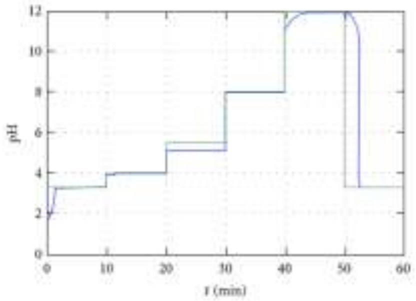


Fig. 5. Output of the system in graph

Implementation in IOT

With LabVIEW, evaluate the fuzzy-PID controller with simulated or actual pH data. Check to make sure the control system performs as anticipated and achieves the intended control goals. To enhance performance, change the PID gains, fuzzy logic, or other parameters as needed. Install the LabVIEW program on the chosen platform or system. Make sure the system can interact with the IoT platform and is correctly connected to the IoT devices. Keep an eye on the temperature control system and adjust as needed based on practical use.

Fig.6. Real-Time monitoring in IOT

Conclusion

In the purposes of this research, we have effectively used Internet of Things technology to manage pH with a fuzzy-PID controller. We have created a reliable and adaptive control mechanism that can successfully manage nonlinearities and uncertainties in the pH control system by integrating the benefits of fuzzy logic with PID control. According to the experimental findings, the accuracy, stability, and disturbance rejection of the Fuzzy-PID controller are better than those of the traditional PID controller. Users may now conveniently and efficiently monitor and control the temperature system in real time from remote places thanks to the incorporation of IoT technology. All things considered, there is a lot of promise for the fuzzy-PID controller for temperature management via IoT in a variety of settings, including residences, businesses, and other establishments where accurate temperature control is crucial.

References

Peter Harriot, “Process Control”, Tata McGraw Hill Education, 1972.

Stephanopoulus, G., “Chemical Process Control – An introduction to theory and practice”, Prentice Hall, 2nd Edition, 1984.

George, J. K. & Yuan B (1995), “Fuzzy Sets and Fuzzy Logic : Theory and Applications”, Prentice Hall, PTR, New Jersey

Chen, C. L., P. C. Chen and C. K. Chen (1993) Application of Fuzzy Adaptive Controller in Nonlinear Process Control. Chem. Eng. Comm., 123, 111-126.

Abdullah, Krsiti, Ibrahim (2012) “A review of pH neutralization process”, IEEE Trans. On Intelligent and Advanced Systems, Vol. 2, pp: 594-598.

Dr. Emad Ali, Dr. Mustafa Suliman (2000), “Experimental Set-up of pH Neutralization in CSTR with Application of PI Controller”, Research Paper

Gary W. Johnson, Richard Jennings –“LabVIEW Graphical Programming Paperback”, Aug 2006LabVIEW based Fuzzy Logic Controller for PLC

M.P. Rigobello, F. Cazzaro, G. Scutari, A. Bindoli, “Virtual Instrumentation for pH Measurement in Biological Systems”, Journal of Computer Methods and Programs in Biomedicine, vol.60, 1999, pp. 55- 64.

S. Murtadha “On-Line Control Of pH Neutralization for Wastewater Using Labview”, M.A thesis, University of Technology, Iraq, 2011.

Emerson Process Management, "Basics Of pH Control," Application Data Sheet ADS 43-001/rev. C, March 2011.

Gregory K McMillan and Robert A Cameron, Advanced pH Measurement and Control.: ISA, 2005,p.81

J. Miller, “Statistics and Chemometrics for Analytical Chemistry, 5th ed., Pearson, 2005, p. 21.

A. Bier, “Electrochemistry Theory and Practice”, Loveland: Hach, 2010, p.8.