Real-Time Fuzzy Logic Controller for Glycerin Bleaching Process

Siti Fatimah Adliah Mohd Noor
Faculty of Electrical Engineering
Universiti Teknologi MARA Malaysia
40450 Shah Alam, Selangor, Malaysia
adliah85@yahoo.com

Abstract-**In this paper the real-time temperature control system for glycerin bleaching process using Fuzzy Logic PD-Like Controller was presented. The NI Compact DAQ (NI cDAQ) and LabVIEW were used as an interfacing system for this work. 4-20mA current signal is used to control the heater of the tank. 9 Fuzzy rules were used to compare and evaluate the best and suitable set for this application. It was found that the implementation of PD-Like Controller with 9 rules is sufficient to give high performance of heating compared to PID Controller. The results show the Real-Time system is capable of controlling the Glycerin bleaching process.**

Keywords- temperature control, Fuzzy Logic Controller, interfacing system, glycerin bleaching process

I. INTRODUCTION

To maintain and control the set point temperature of a process is a difficult task. It has been known to be intrinsically challenging due to a variety of factors such as producing slow response [1-3] because of the thermal nature in the process. Furthermore, there will predictably be further lags or time delays before it reaches a steady uniform level [2], [4] following a change of an input.

In process control field, Fuzzy Logic Controller is commonly used because of its intelligence. The Fuzzy Logic Controller gives out faster response, more reliable and recovers quickly from system upsets. It also works well to uncertainties in the process variable. Fuzzy Logic Controller does not require mathematical modeling [5].

The main objective of this study is design and construction of a new fuzzy system controlled by computer. User interface system is generated with using LabView PID&FUZZY Toolkit.

This paper presents the real-time temperature control system for glycerin bleaching process by taking advantage of the modern instrumentation and measurement methods, which are already established.

In this work, the system was designed to monitor a resistance temperature detector (RTD) and maintain a constant temperature setting. The NI cDAQ and LabVIEW were used to import the data into the computer and also to control a heater.

A system was designed in such that the heater is turn ON by setting the voltage output of the terminal of the cDAQ. This voltage is sent to a solid-state relay, which switches the current 4-20mA sent to the heater.

The system performance in terms of system stability was evaluated experimentally using the Fuzzy Logic and PID controllers. The objective was to have real-time of monitoring and controlling the temperature for glycerin bleaching process.

II. GLYCERIN BLEACHING PROCESS PLANT

This study is based upon a glycerin heat bleaching process plant, which installed at Distributed Control System Laboratory (DCS) in Universiti Teknologi MARA, Malaysia. This process plant is the type of industrial instrumentation, measurement and actuation system used within the process industries.

The reactor tank is the most important part of the process plant as this is where the heat bleaching process took place and where the output measurements are taken. Figure 1.0 shows the simplified diagram of the physical arrangement of the reactor tank. The closed-loop block diagram of the temperature control system is as shown in Figure 2.0. The percent of color reduction of the glycerin is directly related to the amount of heat released inside the reactor. Therefore, the percent of color reduction can also be maintained to the desired value by controlling the temperature in the reactor. The temperature of the crude glycerin in the reactor has to keep as low as possible to minimize fatty matter increase from heating operation [6] but high enough to yield the desired final product. However, it depends on the characteristics and the quality of the crude glycerin [7]. In this study, the desired temperature level was set at 85^{o}C under suitable agitation speed.

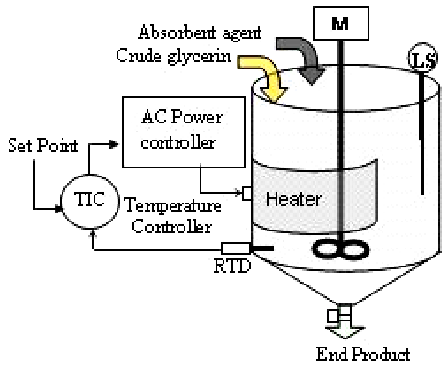


Figure 1.0: Simplified diagram of reactor tank

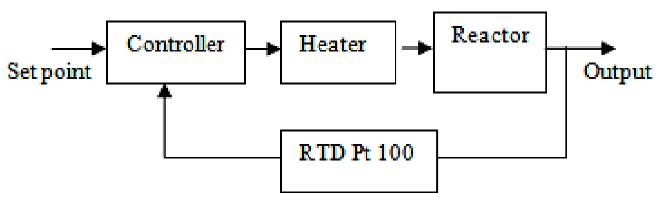


Figure 2.0: Closed-loop temperature control block diagram

III. HARDWARE DEVELOPMENT

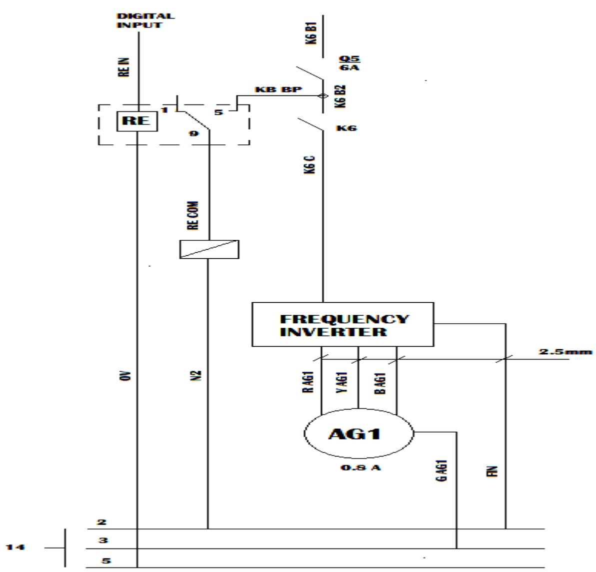


Figure 3.0: The schematic diagram of Agitator

Figure 3.0 shows that the signal of 24V was send to relay to activate the contactor. Frequency inverter was set at 8Hz in which corresponds to speed of 480 rpm.

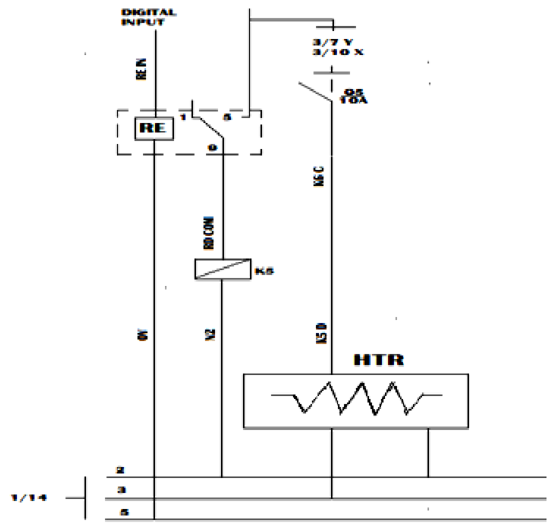


Figure 4.0: The schematic diagram of Heater

Figure 4.0 shows the connection line of the heater in the plant. The heater used in this plant was custom made dual band heater type with power rating of 1.5kW each.

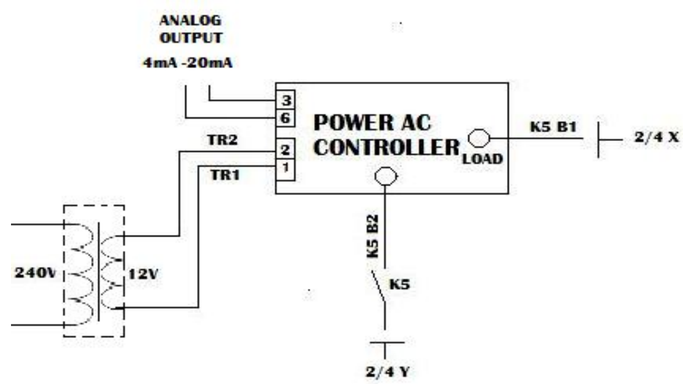


Figure 5.0: The schematic diagram of AC Power Controller

Figure 5.0 shows the schematic diagram of AC Power Controller used in this plant. The current 4-20mA was supplied from DAQ to the AC Power Controller in order to activate the heater.

IV. INTERFACING SYSTEM

In this study, the interfacing system consists of personal computer (PC), NI cDAQ and LabVIEW software package. The block diagram for the interfacing system implemented in this project is as shown in Figure 6.0.

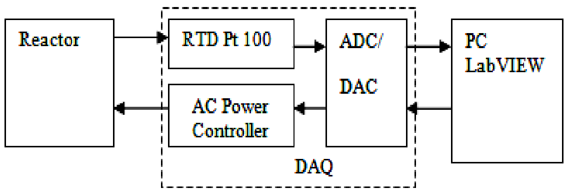
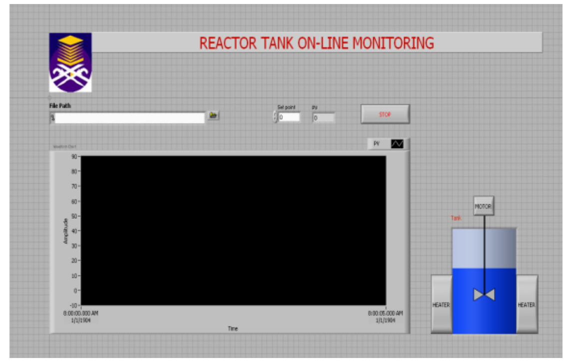


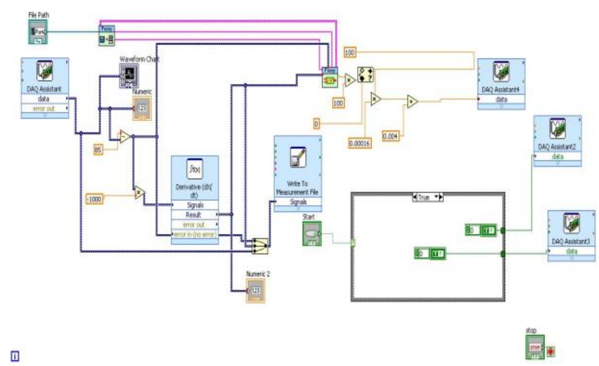
Figure 6.0: Temperature control interfacing system block diagram

A sensor, in this case, RTD senses the temperature and converted into analog electrical signal through NI9217 24bits 100s/s/ch DAQ module before send the output to the PC. The signals are then processed and the output signals are sent to the actuator, in this case, AC power controller through NI current AO DAQ module 4-20mA 16bits 100ks/s/ch to control the process. The measured temperature was monitored using developed user interface as shown in Figure 7.0. The program developed by using LabVIEW software package.

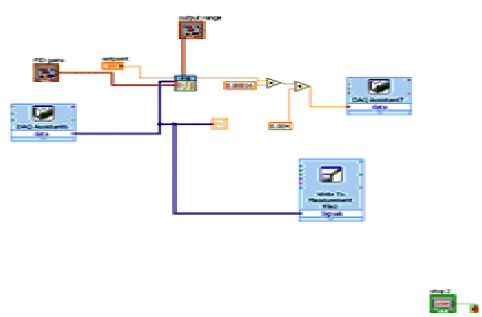
As shown in Figure 7.0(a), the controls and data displays for the system are designed by choosing objects from the control palette such as numeric displays, meter, thermometer, tank, charts and etcetera. The front panel user interface is created for the interactive control of software system. On the other hand, the block diagram as shown in Figure 7.0(b) is intuitively assembled to specify the functionality.



(a)



(b)



(c)

Figure 7.0: (a) User interface front panel
(b) Programming module for Fuzzy Logic Controller
(c) Programming module for PID Controller

V. CONTROLLER DESIGN

Fuzzy PD is combination of two controllers which are proportional and derivative controller. In this fuzzy PD controller two inputs are used which is error and change of error.

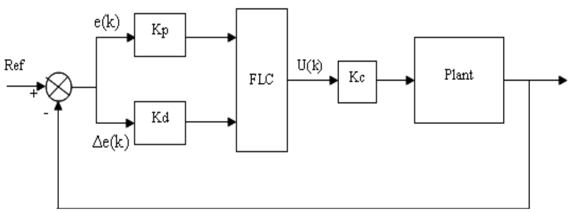


Figure 8.0: Fuzzy PD Control Structure

$$U(t) = Kp\ e(t) + Kd\ \frac{de(t)}{dt} \qquad (1)$$

In discrete, equation (1) can be written as:

$$U(k) = Kp\ e(k) + Kd\ (e(k) - e(k-1)) \qquad (2)$$

Where

$$e(k) = ysp - y(k) \qquad (3)$$

$$\Delta e(k) = e(k) - e(k-1) \qquad (4)$$

Kp is the proportional gains of the controller while Kd is derivative gain. The $e(k)$ and $\Delta e(k)$ is the error and chance or error respectively.

The experimental works were conducted by implementing Fuzzy Logic Controller to the process. First fuzzy input represents the error between measured temperature and set point. Figure9.0 shows the membership function of input error. While the crisp input for second input is change in error is shown as in Figure 10.0.The error input is scaled to the interval of [-100,100] while the second input which is change of error is scaled to the interval of [-50,50]. The rule base of the fuzzy controller gives the decision that in which of the three membership functions which have to fire. Rule evaluation part has 9 fuzzy rules which are shown in Table 1.0.

The fuzzy logic controller's output is the voltage level which is applied to voltage controlled current circuit. Figure 11.0 shows the membership function of the fuzzy output. The output variable is scaled to the interval of [-1, 1].

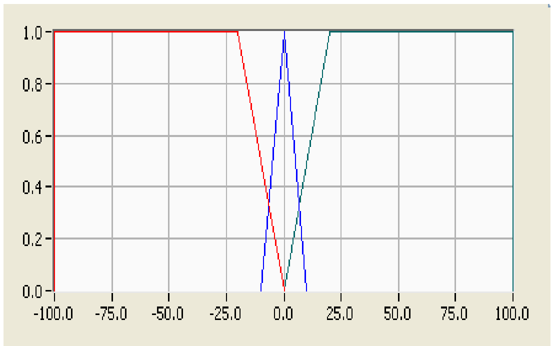


Figure 9.0: Input membership function for error

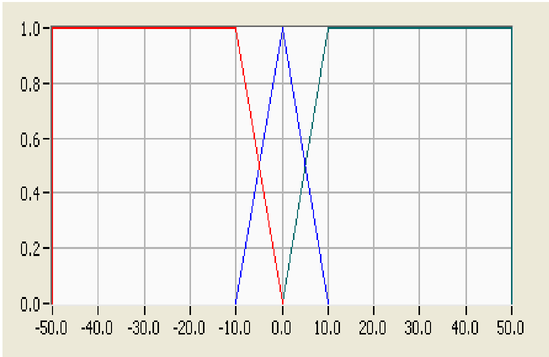


Figure10.0: Input membership function for change of error

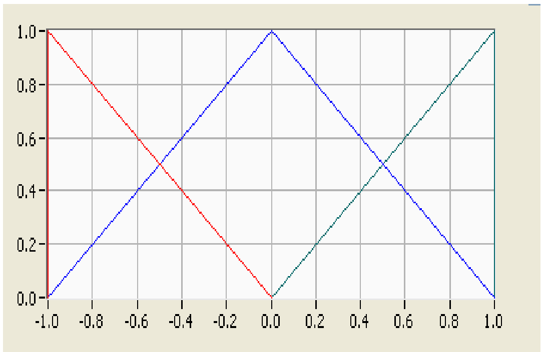


Figure 11.0: Output membership function

Center of gravity (COG) is one of the best defuzzyfication methods [8]. In this development COG type of defuzzyfication is used at the output membership function. Equation (5) represents the COG method of defuzzyfication where *Ui* the center of output membership is function and μ (y) is the degree of fulfillment.

$$U = \frac{\sum_{i=1}^{l} Ui \ \mu(y)}{\sum_{i=1}^{l} \mu\ (y)} \qquad (5)$$

TABLE 1.0: THE FUZZY RULES

	INPUT		OUTPUT
	ERROR	CHANGE OF ERROR	
1.	N	N	N
2.	N	ZE	N
3.	N	P	N
4.	ZE	N	ZE
5.	ZE	ZE	ZE
6.	ZE	P	ZE
7.	P	N	P
8.	P	ZE	P
9.	P	P	P

VI. RESULTS AND DISCUSSION

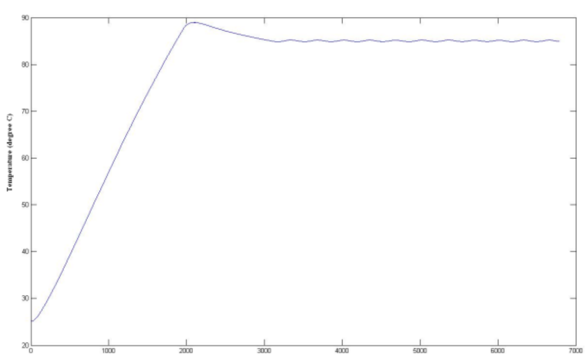


Figure 12.0: Output response for PID using Ziegler-Nichols

As shown in Figure 12.0, the output response for the PID Controller has produced stable response under the following conditions: P=1.433, I=0.0002 and D=149.2526. However, the response's rise time, settling time, overshoot, peak and peak time are high.

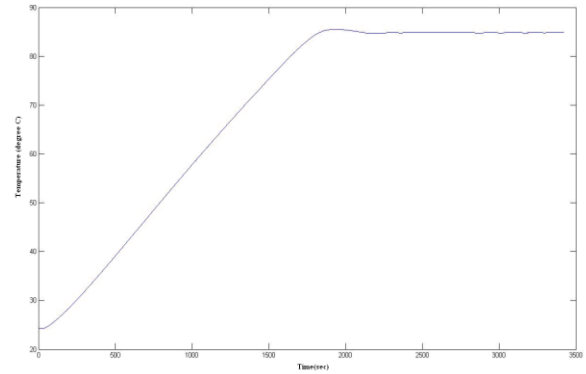


Figure 13.0: Output response for Fuzzy Logic Controller

TABLE 2.0: COMPARISON OF THE RESULT PARAMETERS FOR PID CONTROLLER VERSUS FUZZY LOGIC CONTROLLER

Parameter	**PID Ziegler-Nichols**	**Fuzzy Logic Controller**
Rise Time	1500.1 sec	1346.4 sec
Settling Time	2940.7 sec	1767.7 sec
Overshoot	4.3598	0.8248
Peak	88.7055	85.5082
Peak Time	2242 sec	1935 sec

The figure 13.0 shows the output response for the Fuzzy Logic Controller that was developed by NI cDAQ and LabVIEW software package. Table 2.0 shows the characteristics of output response when using PID-Ziegler Nichols and Fuzzy Logic Controller. It is observed that the Fuzzy Logic Controller gives the better performance compared to PID Controller. From the results, in term of rising time Fuzzy Logic Controller give the fasters rise time with 1346.4s compared to PID-Ziegler Nichols. For overshoot criteria, Fuzzy Logic Controller gives the lower overshoot with 0.8248 compared to PID Ziegler-Nichols which gives 4.3598. Fuzzy Logic Controller also gives the fasters settling time (1767.7s) compared to PID Ziegler-Nichols (2940.7) The Peak and Peak Time are also decrease by 3.1973 and 307 by implementing Fuzzy Logic Controller compared to PID Controller.

VII. CONCLUSION

In this work, the temperature of the glycerin bleaching process was successfully monitored and controlled using Fuzzy Logic Controller via NI cDAQ and LabVIEW software package. The developed user interface gives the flexibility to observe the variation of input and output of the process in real-time mode. It was observed that Fuzzy Logic Controller gives better performance compare to conventional PID controller.

VIII. FUTURE DEVELOPMENT

This work can be improved by increasing the number of membership function and rules to give better control performance.

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