International Journal of Scientific Engineering and Science
Volume 2, Issue 6, pp. 16-19, 2018. ISSN (Online): 2456-7361

Application and Implementation of Fuzzy Logic Controller (FLC) for Feed Chemical Concentration Process

Donatus O. Njoku[1], Alphonsus Onyekachi Agbakwuru[2], Amaefule I. A.[2], Igwe Stephen Onyema[3]
[1]Department of Computer Science, Federal University Technology, Owerri, Imo, Nigeria
[2]Department of Computer Science, Imo State University, Owerri, Imo, Nigeria
[3]Department of Computer Science, Federal Polytechnic, Nekede, Imo, Nigeria

Abstract—*This paper has presented application and implementation of fuzzy logic controller (FLC) for feed chemical concentration process. It is desired to improve the chemical composition of a feed chemical concentration control system whose initial response was undesirable. In order to achieve the objective of the paper, the dynamic model of a typical chemical concentration with a feed-flow valve is obtained and presented in the form of a transfer function. A fuzzy logic controller is designed using fuzzy block of the Simulink. Simulations are performed in MATLAB/Simulink environment considering two cases. The first simulation was performed considering the case where the designed controller has not been added to the closed-loop. The second simulation was performed considering the case where the FLC has been included in the close-loop. The Simulation results obtained showed that the output composition performance of the process was largely improved and maintain steady state within the acceptable percentage of the output composition.*

Keywords— *Chemical concentration, Closed-loop, Feed-flow, FLC, Simulation.*

I. INTRODUCTION

There are many industrial applications that require solution of a given chemical concentration. This can be achieved by ensuring that the chemical concentration is continuously being monitored. For instance, in application such as feed chemical composition where a certain level of concentration is required, the process would be effective if properly monitored and controlled. Also in industrial cleaning process, to keep process consistency, it is required to frequently take the measurement of the chemical concentration in a cleaning solution. pH and specific gravity are two common parameters that can be employed in determining the concentration of cleaning solution [1].

According to [2], such a given concentrations are obtainable by mixing a full strength solution with water in the desired proportions. A level of flow control is maintained. This mixing takes place two stages. The firstly, "A flow ratio controller on a mixing tank is set for a given flow rate of the full strength solution and a proportional flow rate of the water. The flow-ratio controller is set to produce a concentration slightly weaker than that which is desired. The flow-ratio controller should also be capable of warning operators when no liquid is actually flowing in the full strength solution and the water lines. Secondly, a control valve receiving input from a conductivity analyser functions as a "trim control". It adds a small amount of full strength solution to the mixing tank to produce the exact concentration desired [2]."

Also, in recent years, fuzzy logic has been implemented as part of industrial process to enhance the performance of the control loop. As an intelligent system it application in industrial process is gaining wide acceptance and is almost replacing traditional control system. The application of fuzzy logic control (FLC) has proven effective for complex nonlinear and imprecisely defined process [4]. Again conventional design methods require the development of a mathematical equation of the system to be monitored and then use of this equation to develop the control algorithm that is represented by the differential equations [6]. As opposed to traditional way of control design, FLC focuses on gaining an intuitive understanding of how best control the process or plant [7], [6].

Fuzzy logic base control system consists of an input stage, a processing stage, and an output stage [5]. It has membership functions which can be related with many possible shapes. The most common being the triangular, though other shapes like trapezoidal and bell curves are also used. The shape is generally less important than the number of curves and their placement [5]. It is also consists of logic rules that define the processing stage and are in the form of "IF-THEN" statement that maps the input to the output. The IF part is called the "antecedent" and the THEN is called the "consequent" [5]. Fuzzy logic control consists of [8]:

i. Data Base: It normalizes the input crisp values and contains the fuzzy partitions of the input and output space.
ii. Fuzzy Rule Base: It contains the type of fuzzy rules and the source and derivation of the fuzzy control rules.
iii. Fuzzy Inference Machine: The basic function is to compute the overall output of the control output variable based on individual contribution of each rule in the fuzzy rule base.
iv. Defuzzification: this converts the conclusions reached by interference mechanism into crisp ones [6].

International Journal of Scientific Engineering and Science
Volume 2, Issue 6, pp. 16-19, 2018. ISSN (Online): 2456-7361

II. PROBLEM FORMULATION

This paper intends to design a FLC system. A chemical concentration control system is considered as a case study. It is required that process maintains a level of concentration of 80 to 100%.

III. METHODOLOGY

The method used in this paper is to obtain the dynamic model of a typical chemical concentration control system. Fig. 1 shows a system for monitoring a feed chemical concentration. The system takes a granular feed of different composition, and it is required to maintain a specific composition of the output mixture by regulating the feed-flow valve. The transfer function of the tank and output valve is [3]:

$$G_p(s) = \frac{5}{5s+1}e^{-1.5s} \tag{1}$$

The transport of the feed along the conveyor requires a delay time, $T = 1.5s$ [3].

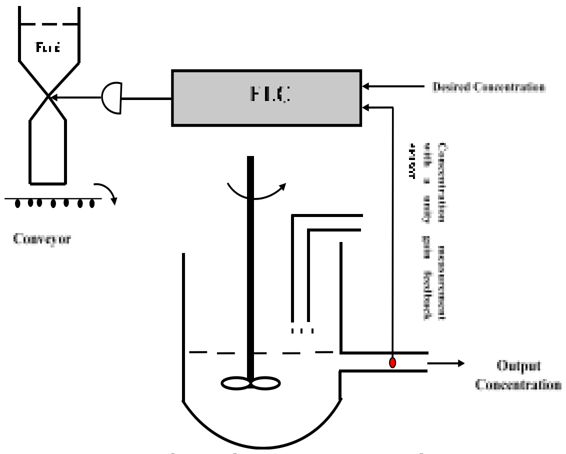

Fig. 1. A chemical concentration control system.

A. System Configuration and Design Algorithm

System Configuration:

Fig. 2 is the Simulink block model that will be used to control a cleaning chemical concentration. The inputs to the FLC are the error in the chemical composition and the rate of change of the chemical composition. The two inputs will be considered as the FLC determine the appropriate input valve setting.

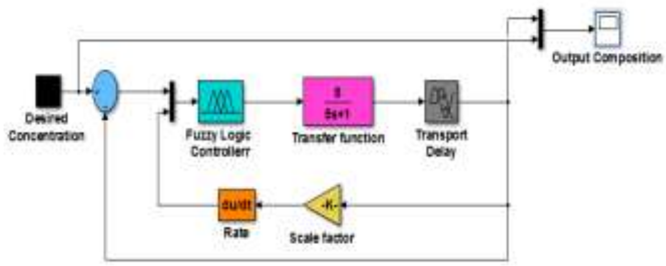

Fig. 2. Chemical concentration control configuration.

The closed-loop transfer function without the FLC is given by:

$$G(s) = \frac{5e^{-1.5s}}{5(s+e^{-1.5s})+1} \tag{2}$$

FLC Design:

The desired concentration is set using a step input. With the system modelled in Simulink, and FLC needs to be designed. The expression “fuzzy” is entered in the MATLAB command window and the default FIS editor is opened. The default FIS editor has only one input. The system under consideration uses two input so an input variable is added as shown in Fig. 3.

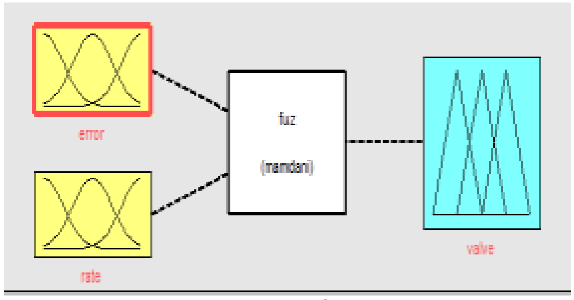

Fig. 3. FIS editor.

The membership functions used for the system are then defined for each input and output. Firstly, the linguistic variable of FLC are generated.

For the input error: NE = Negative, OK = Okay, PE = Positive. For input rate: NE = Negative, NO = None, PE = Positive. Five membership functions are augmented for the output (valve). These are: CF = Close Fast, CS = Close Slow, NC = No Change, OS = Open Slow, OF = Open Fast. Fig. 4, 5, and 6 are the membership function plots of error input, rate input, and output (valve).

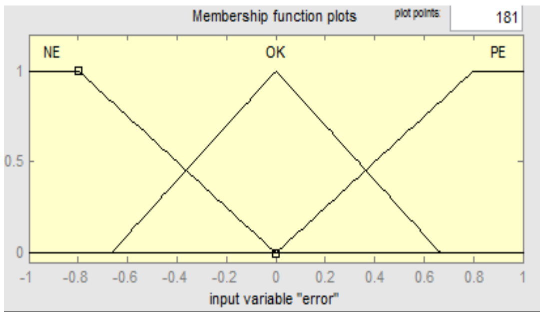

Fig. 4. Membership function of input error.

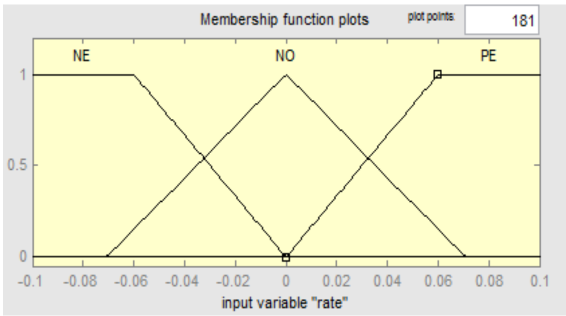

Fig. 5. Membership function of input rate.

Volume 2, Issue 6, pp. 16-19, 2018.
International Journal of Scientific Engineering and Science
ISSN (Online): 2456-7361

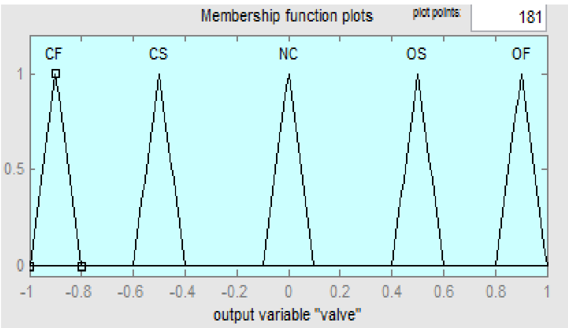

Fig. 6. Membership function of output valve.

Now that the input and output membership functions have been established then the rule base are to be established. In this paper the idea is that the system operation be such that chemical concentration increases when the error is PE. But the chemical concentration is not expected to over increase if the error is approaching towards zero (0) so fast otherwise the chemical concentration level will peak indiscriminately. So if the error is OK, the valve is expected to OPEN or CLOSE slowly. On the hand, if the error is NE or PE, it is expected to OPEN or CLOSE fast. The rule base implemented for this purpose is presented below:

a. If error is OK then valve is NC
b. If error is PE then valve is OF
c. If error is NE then valve is CF
d. If error is OK and rate is PE then valve is CS
e. If error is OK and rate is NE then valve is OS

As it can be seen from the rule base above, the AND operator is used to combine the error and rate membership functions. This AND operator gives the product of the two membership functions at the input values. When the error is large, rules 2 and 3 provide the action for the condition that error is large irrespective of rate. Rule defines the steady state of the response position such that when error is OK the valve stays constant. It should be noted that the overlapping makes sure that a mix of all the membership functions is maintained until the error and rate are at zero.

The rule surface is shown in Fig. 7. It shows how the value of the output (valve) relates to any combination of the input values.

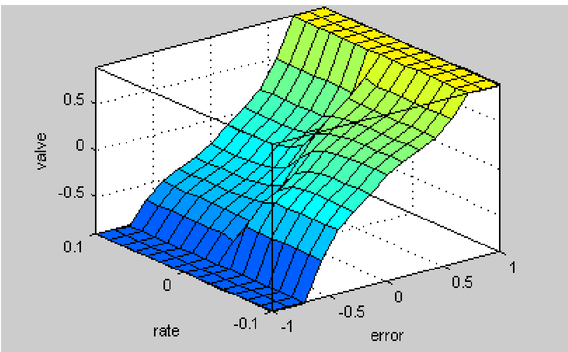

Fig. 7. Rule surface plot.

IV. Simulation Results and Discussion

A. Simulation Results

The simulations were performed considering two cases of the process. The output composition of the tank is assumed to be proportional to the valve. The first simulation as shown in Fig. 8 is the closed-loop output composition without FLC. Secondly the result presented in Fig. 9, is the response of the output composition with the FLC added to closed-loop of a cleaning chemical concentration control system.

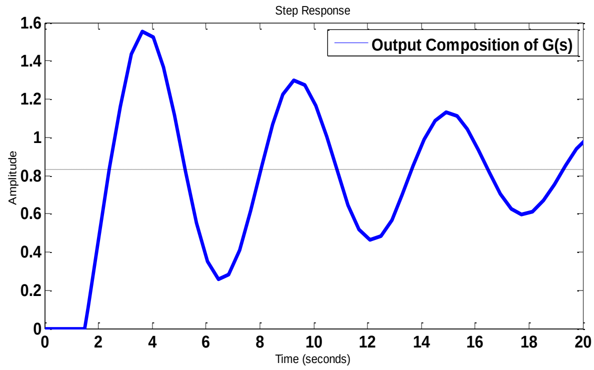

Fig. 8. Output composition response of uncompensated process with feedback.

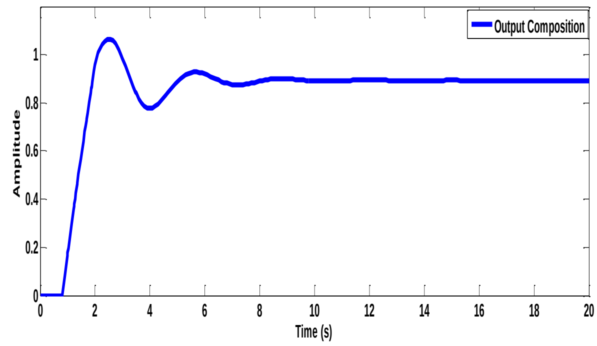

Fig. 9. Output composition response of process plus FLC.

B. Discussion

In Fig. 8, the response of the system indicates that the chemical composition increases well above 100% which is undesirable with high peaking effect. It also shows that the system is unstable and requires improvement. In Fig. 9, it can be seen that the response performance of the system has been largely improved.

In Fig. 9, as the system takes a granular feed of the different composition, the fuzzy logic controller (FLC) responds immediately and opens the feed-flow valve so that 100% level of the desired composition is reached. It then slows down to 80%, open up the valve again, and gradually closes the valve for the feed chemical concentration to remain at a level in the range of desired concentration (90%) which is the steady state.

V. Conclusion

This paper has presented application and implementation of fuzzy logic controller (FLC) for cleaning chemical concentration process. The paper considered a cleaning chemical concentration control system whose performance is

Volume 2, Issue 6, pp. 16-19, 2018. ISSN (Online): 2456-7361

required to be improved and maintain composition within acceptable level of concentration. Initially when the simulation was performed with the FLC, the response performance of the output composition was undesirable. The FLC is added and the output composition was largely enhanced and maintained within desired range of acceptable concentration. The simulations are conducted in MATLAB/Simulink.

REFERENCES

[1] J. Fuchs, “Chemistry –Measuring Cleaning Chemical Concentration,” techblog.ctgclean.com, posted on July 23, 2013. Accessed on 18th June, 2018.

[2] Rosemount Analytical, “Chemical Concentration Control,” www.RosemountAnalytical.com

[3] C. D. Richard and R. H. Bishop, “Stability in the frequency domain,” *Modern Control System*, Upper Saddle River, NJ: Prentice Hall, 10 ed., pp. 497-580, 2005.

[4] T. Upalanchiwar and A. V. Sakhare, “Design and implementation of the fuzzy PID controller using MATLAB/SIMULINK model,” *International Journal of Research in Computer and Communication Technolog*y, vol. 3, issue 3, pp. 369-372, 2014.

[5] R. Malhorta and R. Sodhi, “Boiler flow control using PID and fuzzy logic controller,” *International Journal of Computer Science Engineering and Technology* (*IJCSET)*, vol. 1, issue 6, pp. 315-319, 2011.

[6] K. Arshdeep and K. Amrit, “Comparison of fuzzy logic and neuro fuzzy algorithm for air conditioning system,” *International Journal of Soft Computing and Engineering*, vol. 2, issue 1, 2012.

[7] K. M. Passino and S. Yurkovich, *Fuzzy Control*, Addison Wesley, 1998.

[8] K. B. Uplenchwar and V.R. Ingle, “Design of fuzzy inference system for autonomous air conditioner,” *International Journal of Computer Application*, pp. 25-28, 2015.