Designing an Improved Fuzzy Multi Controller

Saeed Barzideh [1], Arash Dana [2], Ahmad Ali Ashrafian[2] Gh.Sajedy Abkenar[3]

**[1] Scientific Association of Electrical & Electronic Eng. Islamic Azad University Central Tehran Branch
Tehran, Iran**

**[2] Dept. of Elect. Eng., Central Tehran Branch, Islamic Azad University
Tehran, Iran**

**[3] Scientific Association of Electrical & Electronic Eng. Islamic Azad University Central Tehran Branch
Tehran, Iran**

Abstract

Fluid level, pressure, temperature and flow control is a very common problem in the industry. Considering the advantages of fuzzy control systems instead of other conventional methods of control, in this paper a new approach using fuzzy logic to control the fluid level of biphasic (liquid and steam) fluid system, based on both temperature and pressure parameters presents. Simulations show that joining "pressure changes" parameter as third input of fuzzy controller, improves the efficiency of our control system and lead to more smooth changes in its output.

Keywords: *Fuzzy controller, Level, Pressure, Temperature.*

1. Introduction

Benefits of Artificial Intelligence (AI) based control systems compared to other classical control methods, has encouraged many interested researchers to study and design such systems. Reviewing and comparing between conventional and intelligent control systems, especially discussion about classical and fuzzy logic methods, in many articles shows the importance of AI in new controllers. Combination of conventional control methods and fuzzy is also an attractive research area for many researchers [1-4].

Artificial Intelligence based Control methods, especially in the case of non-linear systems or when system has many complications, are very efficient, because in these cases the system cannot be addressed simply by equations and mathematical descriptions.

In fuzzy control systems, human knowledge in the form of fuzzy if-then rules is the foundation for decision making in fuzzy inference system (FIS). In a fuzzy control system, which system parameters are crisp numbers, they must change into fuzzy sets by Fuzzifier to be able to react as the fuzzy inference engine inputs. Fuzzy inference engine interprets fuzzy input sets and assesses them with fuzzy if-then rules, finally the results will expressed by fuzzy output sets. Since, the equipments react by crisp inputs, fuzzy output sets have to change into crisp numbers by Defuzzifier. The various part of a fuzzy control system are shown in Fig. 1.

In the following paragraphs, in section two, controller design methods and section three simulation methods are described. Results are discussed in Section four and finally in section five conclusions and future works are expressed.

2. Design Method

In this paper pressure, temperature and pressure-derivation considered as proposed FIS inputs. In practice, information of temperature and pressure comes by sensors as crisp numbers and pressure derivation is obtained by calculating at any time. As shown in Fig. 1, these three inputs, after fuzzification will be given to FIS. Fuzzy inference engine is responsible for decision making according to if-then rules database. Final results will be explains as fuzzy sets. We used Mamdani's[1] method for this decision making. More details are available in [5].

In order to control the fluid level in the boiler, based on two parameters temperature and pressure, usually two separate control mechanisms and two separate outlet valves are considered. In this paper, using fuzzy logic, a control surface will be defined by the percent outlet valve openness, based on both these parameters. This surface is represented in (Fig. 2). To improve the efficiency of this mechanism, first derivation of the pressure -as third FIS input- is jointed in the final decision making. In reference

1. Ebrahim Mamdani [Mam75]

[6] by S. Panich, the similar method is presented for controlling the output level of a tank with pressure variable from 0 to 12 bars and temperature from 0 to 120 ° C. The pressure and temperature are the controller input and percent of output valve openness is the controller output. Fuzzy surface that obtained by Panich method is something similar to Fig. 2 that obtained in our simulations. But, because we have used three inputs, two other fuzzy surfaces are available for analyses: one surface represent controller output depending upon the "pressure" and "pressure derivation" and another surface, related to the "temperature' and "pressure derivation". For instance Fig. 3 shows the percent of outlet valve openness versus "pressure" and "pressure derivation".

However in this method, we increased applied FIS rules up to 75 but it is not so complicated for new control systems to analyze 75 rules instead of 25. New added rules will increase the system flexibility and this will make a smooth and more careful outlet valve operation. We will discuss more about outlet valve operation in various situations and through the system input changes in the fourth section.

Most of the time and depends on system contents and features, changes in temperature could be sense with some delay for obvious reasons. But in the case of pressure changes, instruments usually could sense variations almost as soon as theirs happens. This is the reason that prods us to elect this parameter as third input of fuzzy inference system.

On the other hand considering water thermodynamic properties [7], in our certain range (160 to 230 ° C and pressure 17 to 21 bars) temperature and pressure of biphasic system (water and steam) are also in thermodynamically equilibrium. So regardless of changes in other parameters, reducing or increasing the temperature and pressure should be commensurate.

3. Simulation Method

Mass may not be transferred in or out of a close system boundaries that always contain the same amount of matter whereas heat and work could be exchanged across the boundary of the system. In open systems, matter may flow in and out of the system boundaries. The first law of thermodynamics for open systems states: the increase in the internal energy of a system is equal to the amount of energy added to the system by matter flowing in and by heating, minus the amount lost by matter flowing out and in the form of work done by the system [7].

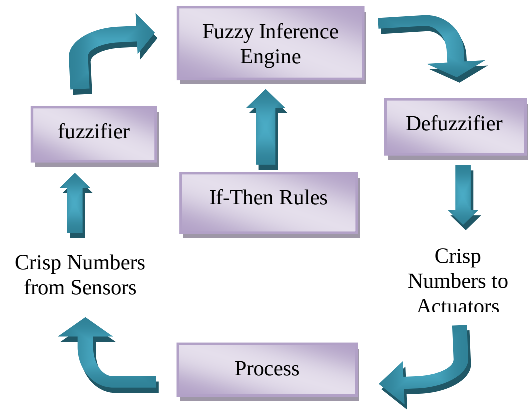

Fig. 1. Various part of fuzzy control system.

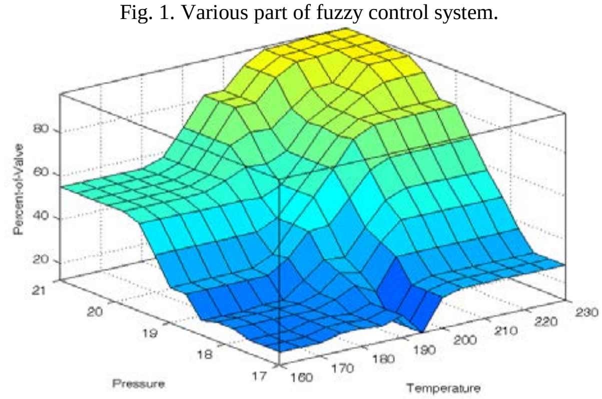

Fig. 2. Output control surface.

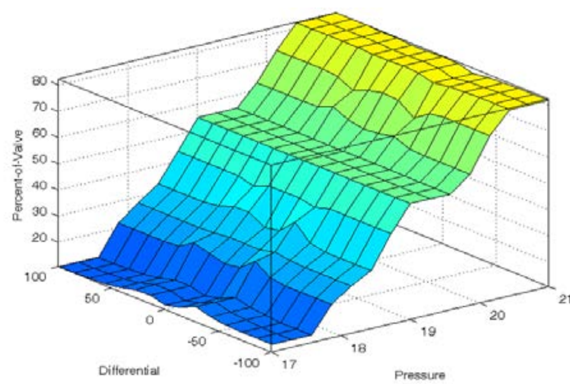

Fig. 3. Percent of outlet valve openness versus pressure and pressure derivation.

In simulation, for better investigations, sometimes we have considered that pressure and temperature changes amongst each other. That is because basically we don't experience a closed system. And for example the boiler input water may affect our system properties.

We have used MATLAB7.5 to design and simulate controller. Temperature has considered in the range from 160 to 230 ° C and pressure could vary between 17 to 21 bars. It is an under pressure tank operation range, that could be applied as a part of super hot steam production chain, in power plants and refineries.

3.1. Fuzzification and Defuzzification Parts

In FIS the Fuzzifier classifies crisp input parameters, temperature and pressure into five fuzzy sets, from lowest value to the highest. All input and output linguistic variables have been normalizing in the range from 0 to 1. Very Low (VL), Low (L), Medium (M), High (H), and Very High (VH) are the linguistic variable terms that could be considered to describe the severity of two input variables temperature and pressure. We have used trapezoidal membership function for the sake of its simplicity and applicability for those parameters. Fuzzy membership functions for temperature and pressure are shown in Fig. 4 and Fig. 5. Using sigmoid curve membership function, pressure derivation could be expressed by three linguistic variables: negative, zero and positive. Fig. 6 depicts membership function for input variable pressure derivation. After calculation, pressure derivation crisp data, has been normalized in the range of -100 to +100. Percent of valve openness is the single system output. Because we are trying to have more softly changes in outlet valve operation, we have used Gaussian membership function in defuzzification part. Being very smooth, Gaussian membership function will provide our favourite results. Strong Close (SC), Close (C), Medium (M), Open (O) and Strong Open (SO) are our five linguistic variables in FIS defuzzification part (Fig. 7).

3.2. Inference Engine and If-Then Rules

The main part of decision making in our algorithm is depended on pressure and temperature parameters changes, and only some percent (in this paper about 15%) of outlet valve operation is considered to affect by the

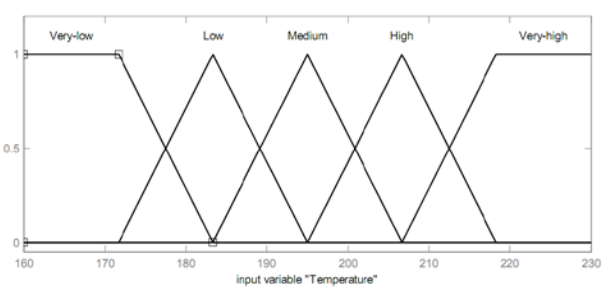

Fig. 4. Membership function for input variable: temperature.

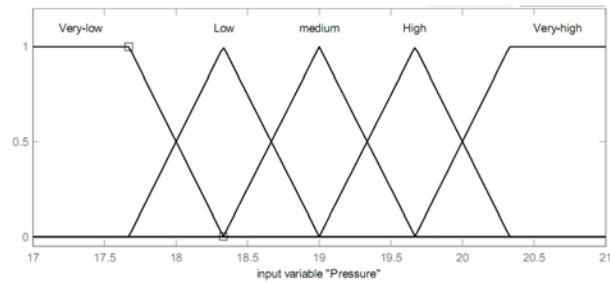

Fig. 5. Membership function for input variable: pressure.

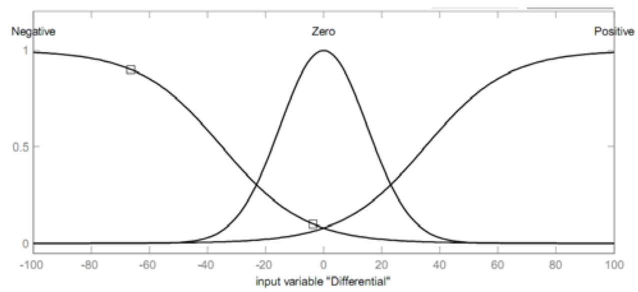

Fig. 6. Membership function for input variable: differential.

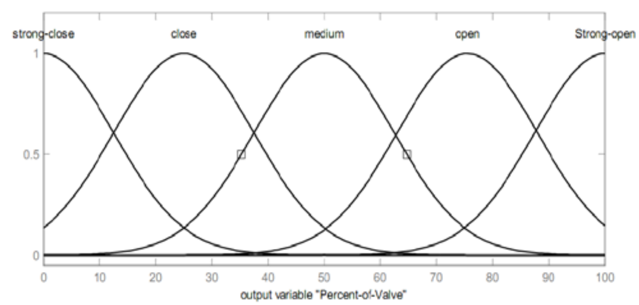

Fig. 7. Membership function for output variable: percent of valve openness.

parameter "temperature-derivation". This percent can prepare or change by if-then rules and depended on designer practical experience. It is expected that this method make outlet valve operation more smooth and improve its reaction by forecasting changes in system parameters. We will investigate this idea during our simulations. In the simulations that carried out in this paper, 75 fuzzy if-then rules have been used for decision making in FIS. 75 if-then rules constitute a three dimensional rule table. Each rule in our proposed method will participate in decision making with a weight number between 0 and 1, which represent severity of effect of that particular rule. In this way the control surface (Fig. 2) is extremely flexible and under the designer desire control. The fifteen first rules are as bellow:

1. If (Pressure is Very-low) and (Differential is Positive) and (Temperature is Very-low) then (Valve is strong-close)(1)
2. If (Pressure is Low) and (Differential is Positive) and (Temperature is Very-low) then (Valve is strong-close) (1)
3. If (Pressure is medium) and (Differential is Positive) and (Temperature is Very-low) then (Valve is close) (1)
4. If (Pressure is High) and (Differential is Positive) and (Temperature is Very-low) then (Valve is medium) (1)
5. If (Pressure is Very-high) and (Differential is Positive) and (Temperature is Very-low) then (Valve is medium) (1)
6. If (Pressure is Very-low) and (Differential is Zero) and (Temperature is Very-low) then (Valve is strong-close) (0.6)
7. If (Pressure is Low) and (Differential is Zero) and (Temperature is Very-low) then (Valve is strong-close) (0.6)
8. If (Pressure is medium) and (Differential is Zero) and (Temperature is Very-low) then (Valve is close) (0.6)
9. If (Pressure is High) and (Differential is Zero) and (Temperature is Very-low) then (Valve is medium) (0.6)
10. If (Pressure is Very-high) and (Differential is Zero) and (Temperature is Very-low) then (Valve is medium) (0.6)
11. If (Pressure is Very-low) and (Differential is Negative) and (Temperature is Very-low) then (Valve is strong-close) (0.2)
12. If (Pressure is Low) and (Differential is Negative) and (Temperature is Very-low) then (Valve is strong-close) (0.2)
13. If (Pressure is medium) and (Differential is Negative) and (Temperature is Very-low) then (Valve is close) (0.2)
14. If (Pressure is High) and (Differential is Negative) and (Temperature is Very-low) then (Valve is medium) (0.2)
15. If (Pressure is Very-high) and (Differential is Negative) and (Temperature is Very-low) then (Valve is medium) (0.2)

3.3. Defuzzifier Part

FIS classifies its outputs in five fuzzy sets: Strong Close (SC), Close (C), Medium (M), Open (O) and Strong Open (SO). These sets must change into crisp numbers for being applicable in actuators and tools. We used Center of Gravity method to defuzzify FIS outputs. Defuzzifier output, explains percent of valve openness by a crisp number that could be apply to actuators. In other similar cases for example, this number might use to express a buster pump power. Fig. 8 has graphically depicted some part of defuzzification by center of gravity method.

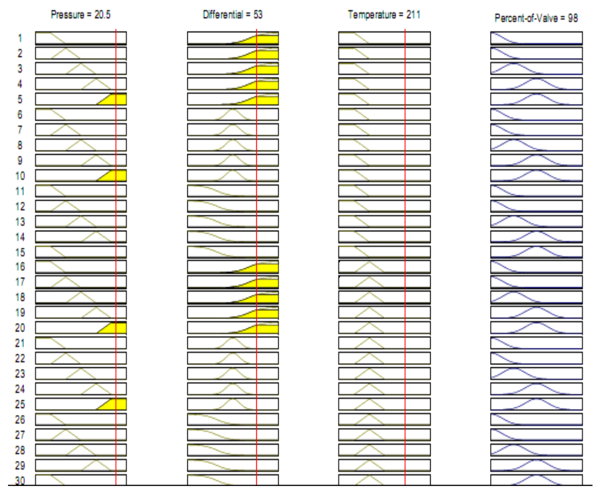

Fig. 8. Defuzzification by center of gravity method.

4. Simulation Analysis

Simulation output results are shown in Fig. 9. The output of fuzzy controller with only two fuzzy inputs designed by Panich is shown in blue. We called this method ***"fuzzy controller"***. And proposed controller output, with three fuzzy inputs is shown in red, and under the title of ***"improved fuzzy controller"***. We applied temperature and pressure to controllers as those inputs. The controller's output will be investigated in different cases and with changes in those parameters. Obviously the controller must response to increasing and decreasing of its inputs by opening and closing some proportionate percent of outlet valve.

According to simulation output results (Fig. 9), at time 15, reducing in the temperature is correctly diagnosed by improved fuzzy controller and its outlet valve is shown appropriate response by closing for about 15 percent. Fuzzy controller doesn't show any suitable response to this situation. At time 30 increasing in pressure on both controllers have been correctly diagnosed. But the slope has more gentle changes in the proposed controller.

At time 35 the pressure has been kept fixed, improved controller was started to opening the outlet valve more softly considering the increment in temperature. After that, increasing in temperature lead to increase the speed of valve opening in the improved controller that shows the prediction capability of improved fuzzy controller. But we can't see remarkable sensitivity in reaction of Panich's fuzzy controller.

Both controllers respond the same near the time 40. After that, improved fuzzy controller has been senses the reduction of the temperature and starts to closing the valve. Fuzzy controller reaction takes place with some delay. At time 45 we have a minimum in temperature. After that time with increasing in temperature fuzzy controller starts to opening the valve immediately but improved fuzzy controller starts the same action with some delay. Both of these two behaviours of improved fuzzy controller are reasonable, because of atypical minimum (fault) in temperature reporting. (We have a minimum in temperature while pressure has been kept constant near to its maximum). This is a fault in system considering the water and vapour thermo dynamic equivalence carves as mentioned by Gordon J.Van Wylen in [7]. In fact in this case improved fuzzy controller compensates this fault by increasing in temperature, keeping the valve in its close state some more.

Decreasing in pressure while the temperature is constant is also an unusual case in time 70, Because of above mentioned reasons. We discuss this case only for study.

There is a little point to mention too. As we could see in times 5 and 50, sometimes when it is needed to close the outlet valve, fuzzy controller opens it a little before start to closing! Improved fuzzy controller shows it's better reaction in that cases too and have a smooth operation at reminded times.

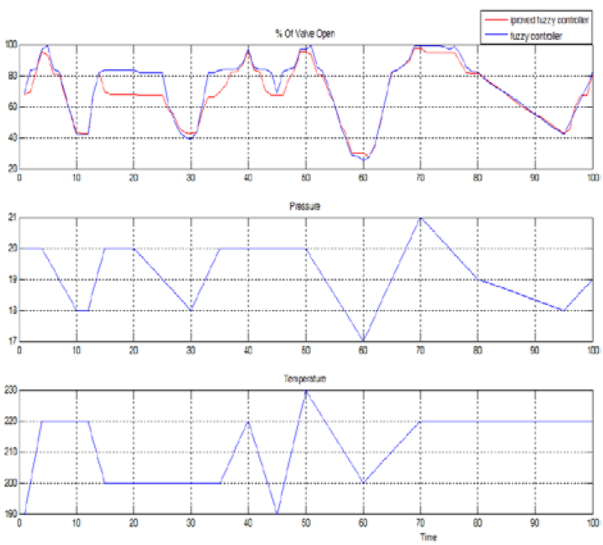

Fig. 9. Simulation output results.

5. Conclusions and Future Works

This is a very important problem in mechanical fluid systems to have smooth changes in fluid flow. Sever changes in flow may cues mechanical damages in system considering water hammer phenomenon. Water hammer (or, more generally, fluid hammer) is a pressure surge or wave resulting when a fluid (usually a liquid but sometimes also a gas) in motion is forced to stop or change direction suddenly (momentum change). Water hammer commonly occurs when a valve is closed suddenly at an end of a pipeline system, and a pressure wave propagates in the pipe. It may also be known as hydraulic shock.

This pressure wave can cause major problems, from noise and vibration to pipe collapse. It is possible to reduce the effects of the water hammer pulses with accumulators and other features, [8].

In this paper a new method based on fuzzy logic was present to controlling the biphasic fluid level according to both temperature and pressure parameters. Industry usually uses two separate mechanisms and two independent control valves to carry out this problem. Simulations show that joining pressure changes, as third input parameter to fuzzy controller improve its behavior in controlling the outlet valve operation. In this paper fuzzy surface for a particular situation was considered. It is possible to optimize if-then rules of this surface for other situation and problems too. In this paper we considered some percent of outlet valve operation relevant to defined third parameter. It caused our controller to have gently operations and also being more flexible and sensitive. Depended on designer experience and problem necessity in similar cases the penetration of the last parameter could be optimized.

References

[1] V. KUMAR, K.P.S. RANA and V. GUPTA "Real-Time Performance Evaluation of a Fuzzy PI + Fuzzy PD Controller for Liquid-Level Process" INTERNATIONAL JOURNAL OF INTELLIGENT CONTROL AND SYSTEMS VOL. 13, NO. 2, pp. 89-96, JUNE 2008.

[2] M. Suresh and G. J. Srinivasan and R. R. Hemamalini," Integrated Fuzzy Logic Based Intelligent Control of Three Tank System" SERBIAN JOURNAL OF ELECTRICAL ENGINEERING Vol. 6, No. 1, pp. 1-14, May 2009,.

[3] E. Natsheh, K. A. Buragga" Comparison between Conventional and Fuzzy Logic PID Controllers for Controlling DC Motors" IJCSI International Journal of Computer Science Issues, Vol. 7, Issue 5, September 2010.

[4] D. Kolokotsa," Comparison of the performance of fuzzy controllers for the management of the indoor environment" Available online at www.sciencedirect.com

[5] Timothy J. Ross,"FUZZY LOGIC WITH ENGINEERING APPLICATIONS" John Wiley & Sons, 2004.

[6] S. Panich," Development of Fuzzy Controller for Water Level in Stream Boiler Tank" Journal of Computer Science 6 (11) pp. 1233-1236, 2010.

[7] Gordon J.Van Wylen and Richard E. Sonntag,"Fundamentals of Classical Thermodynamics (6th Edition)" Jhon Wiley &Sons 2002.

[8] Thorley, ADR, "Fluid Transients in Pipelines", 2nd ed. Professional Engineering Publishing, 2004

Saeed Barzideh received his B.S degree in control & instrumentation in 2007 from the enghlab eslami college Tehran, Iran. Currently, he is developing his electronics M.Sc. degree at Islamic Azad University Central Tehran Branch. His research interests are in the area of analysis and design advanced control

systems based on Artificial Intelligence and also Industrial Data communications and applications like wireless sensor networks.

Arash Dana and **Ahmad Ali Ashrafian,** are academic members of Electrical Engineering Department, Islamic Azad University Central Tehran Branch, Tehran, Iran.

G.h Sajedy Abkenar is a member of Scientific Association of Electrical & Electronic Eng. Islamic Azad University Central Tehran Branch. Tehran, Iran. He is also a student member of IEEE.