# APPLICATION THE CONTROL IN TANKS USING FUZZY THEORY

ADELSON MENEZES LIMA*, SAMEQUE FARIAS CUNHA DE OLIVEIRA*, MISSILENE DA SILVA FARIAS*, TARCISIO DA SILVA BARRETO*, ELMER ROLANDO LLANOS VILLARREAL†

* *Simulation and Computacional Insfrastructure Laboratory Post-graduation Program in Communication Systems and Automation Federal University of the Semi-Arid Region(UFERSA) CEP-59.625-900, Mossoro, RN, BRASIL*

† *Department of Exact and Natural Sciences (DCEN), Federal University of the Semi-Arid region (UFERSA) CEP- 59.625-900, Mossoró, RN, BRASIL*
*Simulation and Computacional Insfrastructure Laboratory Post-graduation Program in Communication Systems and Automation Federal University of the Semi-Arid Region(UFERSA)*

Emails: adelsonmlima@gmail.com, samequefarias@hotmail.com, missilenefarias@hotmail.com, tarcisiofip2@gmail.com, elmerllanos@ufersa.edu.br

**Abstract**— The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, store in tanks, then pumped to another tank. Through the use of Fuzzy Logic can control any process, in order to overcome the limitation imposed by the difficulty in obtaining accurate parameters of a conventional PI controller. In this paper, control is performed liquid level present in two water tanks QUANSER attached, and used the theory of fuzzy sets applied to the environment of high-level programming in MATLAB a for the design of Fuzzy Controller . In order to prove the effectiveness of the proposed control model, a comparison is made between the response of the controlled system exclusively by proportional integral (PI) to that obtained with the application of Fuzzy Controller, where you can observe the superiority of the latter in relation to conventional control.

**Keywords**— Fuzzy, Proportional Integral; Matlab, Level Control.

## 1 Introduction

The control of liquid level in tanks and flow between tanks is a basic problem in the process industries. The process industries require liquids to be pumped, store in tanks, then pumped to another tank. Many times the liquids will be processed by chemical or mixing treatment in the tanks, but always the level of fluid in the tanks must be controlled, and the flow between tanks must be regulated. Often the tanks are so coupled together that the levels interact and this must also be controlled. Level and flow control in tanks are at the heart of all chemical engineering systems. The Proportional-Integral (PI) has relatively simple structure and efficiency in control of a variety of industrial processes, as shown in Figure 1.

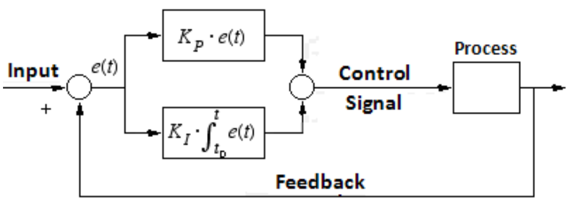


Figure 1: PI Controller

The integral action corresponds to a rate of change of the output signal relative to the input signal. So with a full action, improves the performance of the system response in steady state, tending to eliminate the steady state error due to the fact of increasing the order of the system, however, detract from the transitional regime, as it adds poles to the system tends to destabilize it, and thereby increase the settling time of the signal. The performance of a PI controller is the sum of the proportional action and integral action. This way you can improve both the transient, response with input from the proportional action, as the steady-state error corrected by the integral action. Despite the wide use in a range of processes, it is not hard to find PIs presenting unsatisfactory behavior, ie not passing correct the error or stationary presenting high values of overshoot due to the increased complexity, non-linearity, coupling between the variables, etc., making it difficult to define the parameters of control system. Thus, with the development of Modern Control Theory, made possible the development of more advanced control strategies such as the Fuzzy Controller, aiming to stabilize the plant effectively, thus increasing the accuracy of the system. In the case of having a narrow operating limit by fuzzy control can be achieved great effect in terms of control. The Fuzzy term have meanings that vary according to the context in which the basic concept revolves around the always vague, nebulous or uncertain. As its name suggests, has as main objective the computational modeling of human reasoning, sometimes inaccurate, ambiguous and vague, using fuzzy conditional statements, by quantifying the linguistic variables as (Amendola et al., 2005) and (Marro et al., 2006) . The paper is organized as follows: The fuzzy controller is explained in section II. The principle of operation of the level control tank is coupled discussed in section III. The simulation system applied to a fuzzy controller, for controlling the level of liquid in tanks is provided in section IV. The results and findings are reported in Sections V and VI, respectively.

## 2 The Fuzzy Controller

### *2.1 Structure*

According with (Shaw and Simoes, 2007) , intelligent systems are part of a new paradigm as logic ”Fuzzy”, Neural Networks, Expert Systems and genetic algorithms. These systems seek to provide answers that solve problems, as appropriate to the specific situations of these problems, even if new or unexpected. The fuzzy logic can be applied to a control system for solving problems in systems from simple, small, embedded microcontrollers, even in data acquisition systems based workstation and control. Can be implemented in hardware, software or a combination of both, thus providing a simple way to arrive at a definite conclusion based on information input vague or ambiguous, or even incomplete as (Qi et al., 2010). The algorithms fuzzy contain the functions necessary to solve problems in a process controlled by a fuzzy controller, in which it can emphasize its basic components: the knowledge base, the inference procedure, the interface fuzzyfication, and interface defuzzification as follows figure 2.

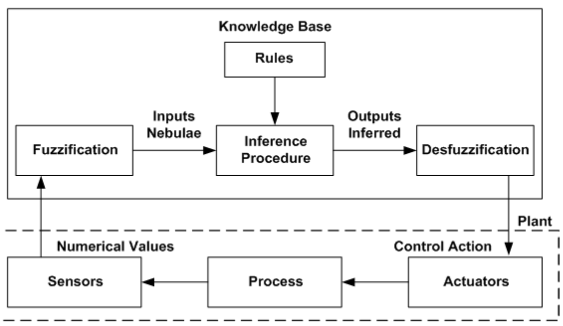


Figure 2: Fuzzy Controller

1. Knowledge Base: Contains settings that characterize the control strategy and goals.

2. Procedure of inference: Responsible for making decisions based on the information obtained in the system and act according to the rule base of the fuzzy logic decision making.

3. Fuzzification interface: Transforms the variables of the problem in real values for fuzzy sets.

4. Defuzzification interface: Convert the output fuzzy sets for real output value, ie, clear results.

### *2.2 Design of Fuzzy Controller*

The design of a fuzzy controller mainly involves the following four steps:

1. Fuzzification

   In the fuzzy control, the actual values must be processed in fuzzy sets to be calculated on the fuzzy rules. It is called fuzzification using these sets that express real signals. The first step in the representation of fuzzy sets is the choice of the membership function. The choice of this function depends on the problem to be modeled and also computational capacity available to process what you want. For example, if the relevant interval is $[0, 1]$, where 0 means an element not belonging to a particular group and 1 means complete relevance to the set, it is requested to say that values between 0 and 1 representing degrees of partial pertinence. In other words, the fuzzy logic element belongs to a group with a certain degree of membership, causing a given sentence can be partially true and, at the same time, partially be considered false. Furthermore, the same element may have different degrees of pertinence from 0 to more than one fuzzy set as (Qi et al., 2010). There are different ways to define the fuzzy sets, but the method proposed by Singleton is the most commonly used, where the calculations can be simplified if we consider fuzzy subsets of the entries consist of true values and fuzzy transforms real input $\epsilon$ for one or two values of a single fuzzy set a, in which:

$$\mu(A) = \begin{cases} 1 & \epsilon = \epsilon^2 \\ 0 & other \end{cases} \quad (1)$$

   If the entry receives a disturbance, fuzzy sets reflect this uncertainty in the measurement process.

2. Establishment of Fuzzy Inference Rules

   Would be associated with a linguistic variable x, each of these terms associated with a fuzzy set in order to establish its meaning. Are the keys of the fuzzy controller as a device for correcting or compensating the traditional control systems. Usually expressed through conditional statements like ”if ... else ...”

3. Selecting the synthesis algorithm for reasoning

   The optimal algorithm is one that can better adapt to frequent variations in load change and regime changes in operating conditions of a given process. From an operational standpoint, simplicity is also desirable. The algorithm for implementation of fuzzy rules must be directly related to the vague reasoning, present in these rules, using functions of relevance established. Gaussian membership functions, membership trapezoidal membership functions of triangular function and are most commonly used.

4. Defuzzification Is to transform the fuzzy sets result in a sharp, or to return results in actual numeric values for the machine within the range stipulated by the fuzzy logic. There are several known methods, however, the two most commonly used methods are the method based on center of mass and the method based on the average of the maximum of the membership functions, also known as Mamdani, created by Professor Ebrahim Mamdani of the University of London (UK) in 1975. Through these methods is the most appropriate numerical value in "$x$" axis and turning the membership functions elaborated by the rules, you discover how numerically this value means in terms of linguistic variables.

## 3 Princíple of Control System of Liquid Level in Pond Coupled

The structure of the tank coupled system to control liquid level consists of two tanks in series of the same capacity, an outlet valve whose inflow is adjusted by an adjustable-speed pump, and a water level sensor to real-time changes in the reservoirs according to figure 3 as (Qi et al., 2010). According to the configuration of valves, the problem is to maintain the liquid level desired for the tanks, which decided on this system in controlling

Where as the system of Figure 3, the expression of its transfer function can be represented by equation 2 as (Qi et al., 2010):

$$G(s) \quad = \quad \frac{1}{[(A^2/K)s^2 + 2As + K]} \tag{2}$$

where:

A = area of the tank $0.15dm^2$;

K = constant flow of water $3.3cm^3/s/V$

Therefore, from the values of "A" and "K" can have equation (3):

$$G(s) \quad = \quad \frac{1}{[0.04s^2 + 0.3s + 3.3]} \tag{3}$$

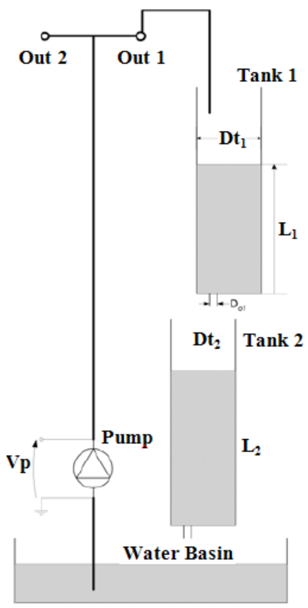


Figure 3: Scheme Plant Tank Coupled

## 4 Simulation System Apllied Fuzzy Control of Liquid Level

Generally to control the liquid level in tanks, traditionally used to control structure Proportional-Integral-Derivative (PID) to act on the valve installed in the liquid outlet. However, the main problem in this type of system is the transfer of oscillations that can occur to the load output flow. Only systems with small load fluctuations using the PID is satisfactory. For systems with large swings in load this driver, tuned to keep the level constant, the oscillations in the flow tank inlet propagate to the output, causing instability in the equipment installed downstream of the tanks. And in this case, a PI controller present in poor performance as (Amendola et al., 2005) and (Filho et al., 2002). So it is necessary to use a control algorithm that enables the damping of oscillations in the tanks, in other words, the ideal level controller must allow the level varied within an operating range (bandwidth) for the flow at the exit are less oscillatory and allow the oscillation of this controlled variable (level) within the limits (band), it is advisable to apply a control based on fuzzy logic as (Giovani, 2004). The PI control system, the input variable is the error measured by the liquid level e(t) in the tank, while the fuzzy control object has two inputs, one is the error e(t), the other is rate of change of error $\Delta e(t)$. The output voltage is proportional to the pump. Thus, the control system with fuzzy logic has dual input and single output.

### *4.1 Step Fuzzification*

The range of error e(t) was defined in [-1,0,1]. Fuzzy corresponding values are (High, Ideal and

Low). The range rate error $\Delta e(t)$ is $[-0.1, 0, 0.1]$ the corresponding fuzzy sets are considered (negative, zero, positive). The model of the membership functions are Gaussian in figures 4 and 5.

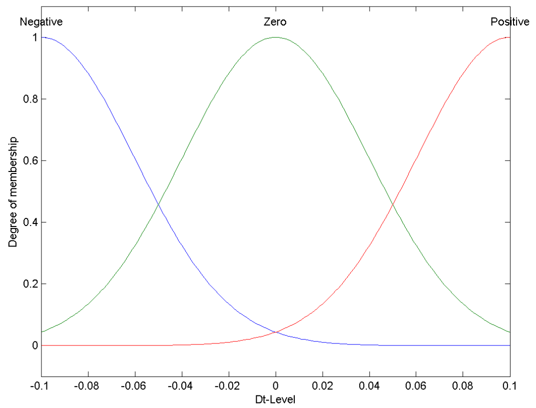


Figure 4: Input Membership Function for Error

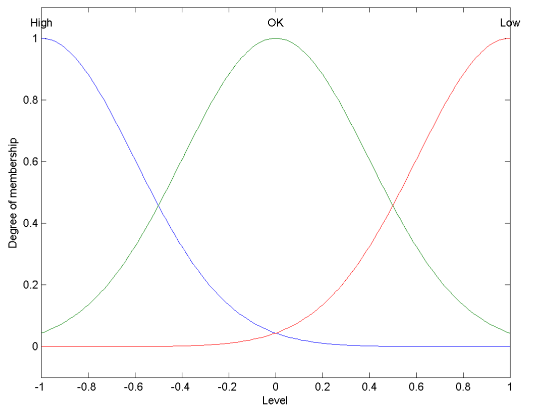


Figure 5: Membership function for the variation of the error

### *4.2 Establishment of Fuzzy Rules*

We used the algorithm Mandani type Fuzzy Inference System, as shown in figure 6. To establish the process of fuzzy reasoning, fuzzy rules were chosen as follows and shown in Figure 7:

1. If the level is optimal, then the output voltage remains constant;
2. If the level is low, then the output voltage rises rapidly
3. If the level is high, then the voltage decreases rapidly;
4. If the level is ideal and its variation is positive, then the output voltage decreases slowly;
5. If the level is ideal and its variation is negative, then the output voltage increases slowly.

### *4.3 Defuzzification*

In the problem shown here, the output variable was chosen as the voltage applied to the pump, whose domain is defined as [-1,0,1], and fuzzy sets were chosen (very low, low, stable, and high very high). The membership function has a triangular shape as shown in Figure 8.

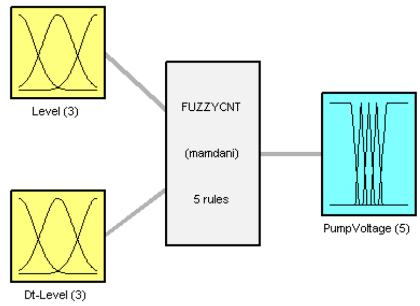


Figure 6: Mandani type Fuzzy Inference System

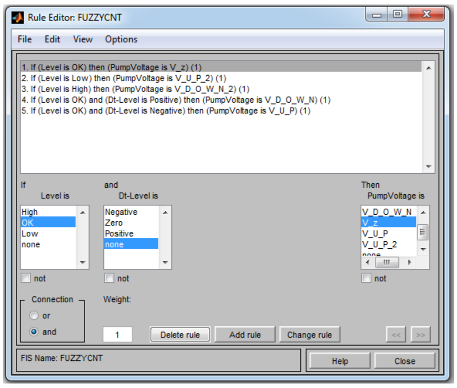


Figure 7: Rule bases

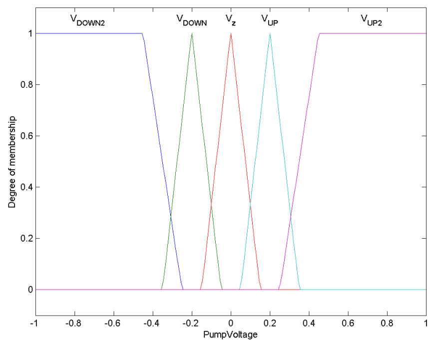


Figure 8: Member Function of the Output Variables

## 5 The Main Results

The simulated controllers are implemented in MATLAB® version 7.7 R2011 model for the PI controller and the fuzzy logic and the results obtained in Figure 9.

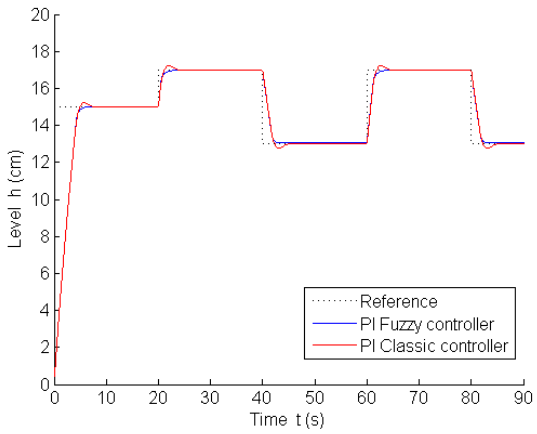


Figure 9: Comparison of Fuzzy and PI control

The responses to the controllers initially represent the average level in the tank 15cm. The test signal selected was applied with a setpoint change 2cm during a time interval varying the level up to 17cm and 13cm low level. The results obtained from the graphs in the system validates the modeling technique employed. The comparison between controllers shows the improvement in system performance using a fuzzy controller. The PI controller features an overshoot generating oscillations that occurs in the output flow of the pump.

## 6 Conclusion

This paper presents the result of simulations allowed the preliminary assessment of the behavior of the system when operated with the fuzzy controller. The Matlab/Simulink was very useful for the evaluation which showed that the fuzzy control system, the dynamic performance is better, no oscillation eliminated the maximum overshoot. The technique also appears to be quite useful for problems with non- linear systems. The system presented can be applied to more complex plants making up their adaptations.

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