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FKBC based Intelligent Liquid Level Regulator

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Abstract: *Fuzzy Logic is a paradigm for an alternative design methodology, which can be applied in developing both linear and non-linear systems for embedded control. By using fuzzy logic, designers can realize lower development costs, superior features, and better end product performance. Furthermore, products can be brought to market faster and more cost effectively. In this paper, the comparison of two design methodologies for a controller is illustrated using MATLAB/SIMULINK. One of them is conventional PID design methodology and another is Fuzzy Knowledge Based designing of controller. SIMULINK provides the user tools to build the process model according to the required specifications.*

Keywords: Simulink, Fuzzy, PID, FLC, FIS, FKBC.

1. INTRODUCTION

Fuzzy logic is all about the relative importance of precision: How important is it to be exactly right when a rough answer will do? Fuzzy logic is a convenient way to map an input space to an output space. This is the starting point for everything else, and the great emphasis here is on the word "convenient." Fuzzy Control provides a convenient method for constructing non-linear controllers via the use of heuristic information [1]. Such heuristic information may come from an operator who has acted as a "human in the loop" controller for a process.

Fuzzy logic sometimes appears exotic or intimidating to those unfamiliar with it, but once you become acquainted with it, it seems almost surprising that no one attempted it sooner [2]-[3]. In this sense fuzzy logic is both old and new because, although the modern and methodical science of fuzzy logic is still young, the concepts of fuzzy logic reach right down to our bones.

While modern control theory has made modest inroad into practice, fuzzy Logic control has been rapidly gaining popularity among practicing engineers [6]-[7]. This increased popularity can be attributed to the fact that fuzzy logic provides a powerful vehicle that allows engineers to incorporate human reasoning in the control algorithm. As opposed to the modern control theory, fuzzy logic design is not based on the mathematical model of the process. The controller designed using fuzzy logic implements human reasoning that has been programmed into fuzzy logic language (membership functions, rules and the rules interpretation)**.**

2. THE PROPOSED SCHEME

Here we concentrate on fuzzy logic control (one of the Intelligent Control Technique) as an alternative control strategy to the current proportional – integral – derivative (PID) method widely used in industry. Consider a generic liquid level control application shown in figure 1:

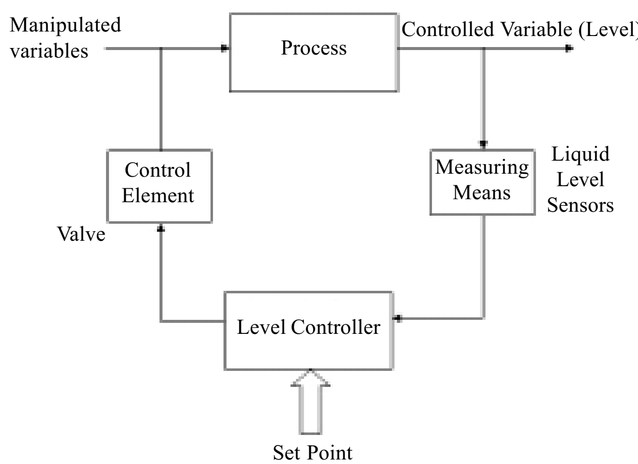

Figure 1: A Typical Industrial Liquid Level Control Problem

Water enters a tank from the top and leaves through an orifice in its base. The rate that water enters is proportional to the voltage, *V*, applied to the pump. The rate that water leaves is proportional to the square root of the height of water in the tank.

A differential equation for the height of liquid in the tank, *H*, is given by

$$\frac{d}{dt}Vol = A\frac{dH}{dt} = bV - \alpha\sqrt{H} \qquad [1]$$

where *Vol* is the volume of liquid in the tank, *A* is the cross-sectional area of the tank, *b* is a constant related to the flow rate into the tank, and *a* is a constant related to the flow rate out of the tank. The equation describes the height of liquid, *H*, as a function of time, due to the difference between flow rates into and out of the tank.

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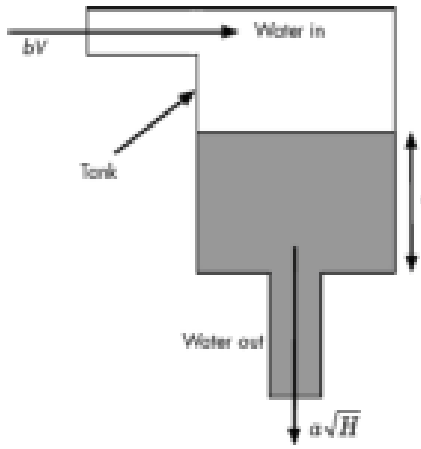

Figure 2: Schematic Diagram for the Liquid-Tank System

The equation contains one state, *H*, one input, *V*, and one output, *H*. It is nonlinear due to its dependence on the square-root of *H*. Linearizing the model, using Simulink Control Design, simplifies the analysis of this model. For information on the linearization process. The level is sensed by a suitable sensor and converted to a signal acceptable to the controller [6].

The controller compares the level signal to the desired set-point temperature and actuates the control element. The control element alters the manipulated variable to change position of the valve so that the quantity of liquid being added can be controlled in the process [4]-[5]. The objective of the controller is to regulate the level as close to the set Point As Possible.

3. IMPLEMENTATION

We have defined two Inputs for the Fuzzy Controller. One is Level of the liquid in the Tank denoted as "**level**" and the other one is rate of change of liquid in the Tank denoted as "**rate**". The Fuzzy Inference System Characterizing the Inputs and the output is shown below:

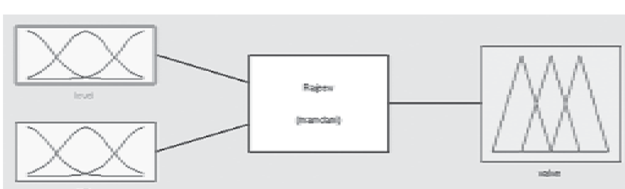

Figure 3: Fuzzy Inference System

Both these Inputs are applied to the Rule Editor. In Rule Editor the rules are written which are shown as under:

1. if (level is ok) and (rate is none) then (valve is no_change) (1)
2. if (level is low) and (rate is none) then (valve is open_fast) (1)
3. if (level is high) and (rate is none) then (valve is close_fast) (1)
4. if (level is ok) and (rate is positive) then (valve is close_slow) (1)
5. if (level is ok) and (rate is negative) then (valve is open_slow) (1)
6. if (level is low) and (rate is positive) then (valve is open_fast) (1)
7. if (level is low) and (rate is negative) then (valve is open_fast) (1)
8. if (level is high) and (rate is negative) then (valve is close_fast) (1)
9. if (level is high) and (rate is positive) then (valve is close_fast) (1)

Figure 4: Rules written in Rule Editor

According to the Rules written in the Rule Editor the controller takes the action and governs the opening of the Valve which is the Output of the controller and is denoted by "**valve**". Rule Matrix is shown below:

Rate \ Level	low	okay	high
-ve	OF	OS	CF
zero	OF	NC	CF
+ve	OF	CS	CF

Figure 5: The Rule Matrix:
where OF: open_fast
OS: open_slow
CF: close_fast
CS: close_slow
NC: no_change

Now this designed controller can be used in the SIMULINK by giving the desired path. Simulink Block Diagrams for the PID and the FLC (Fuzzy Logic Controller) may be shown as

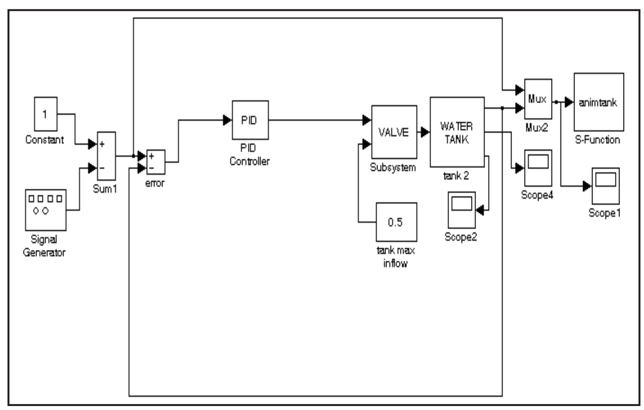

Figure 6: For Conventional (PID) Controller

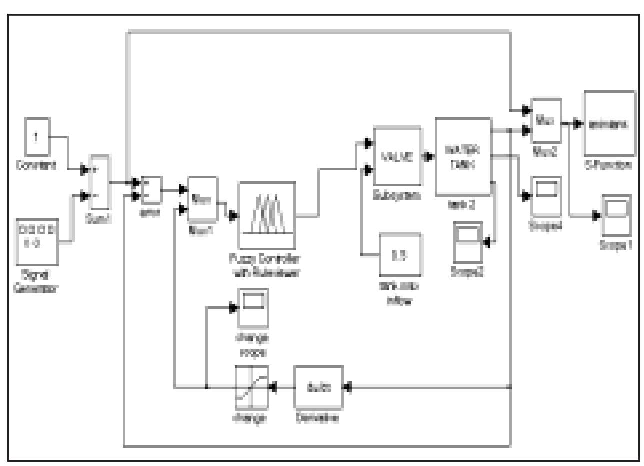

Figure 7: For (FLC) Fuzzy Logic Controller

A continuous square wave is applied at the I/P to the controller for creating continuous disturbance. Another I/P to the controller comes from feedback. The controller takes the action according to the error generated. This error and its derivative is applied to the controller which then takes the necessary action and decides the position of the valve which gives the desired flow of the liquid into the tank.

The positioning of the valve is decided by PID Controller or by the rules written in the Fuzzy Logic Controller Rule Editor. If the liquid level in the tank is low then the valve open completely and if the liquid level is high in the tank then the valve closes or opens upto an extent. When the level is full then the valve closes completely.

The designing of the PID controller can be changed by changing the values of Proportional Gain, Integral Gain & Derivative Gain and the effect of the changed values can be seen effectively using Rule Viewer. The designing of the Fuzzy Logic Controller is covered as a separate topic and is explained in the next section.

4. RESULTS

The computational analysis is implemented on a IBM Think Centre Pentium IV 2.80 GHz computer with 512 MB RAM. The support analysis software used is MATLAB.

The responses of the liquid level controller using PID controller and the Fuzzy Logic controller are shown as:

Figure 8: Response of Liquid Level Controller using PID Controller

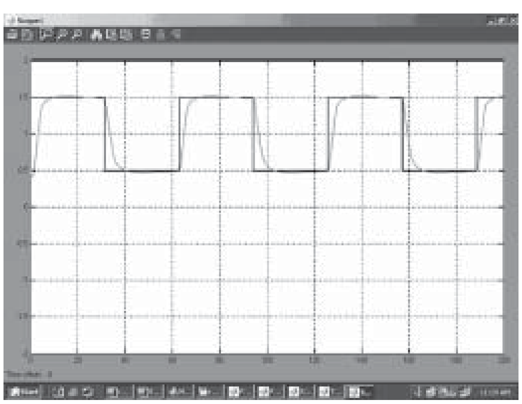

Figure 9: Response of Liquid Level Controller using Fuzzy Logic Controller

For comparison purposes, simulation plots include a conventional PID controller, and the fuzzy algorithm. As expected, FLC provide good performance in terms of oscillations and overshoot in the absence of a prediction mechanism. The FLC algorithm adapts quickly to longer time delays and provides a stable response while the PID controllers drives the system unstable due to mismatch error generated by the inaccurate time delay parameter used in the plant model. From the simulations, in the presence of unknown or possibly varying time delay, the proposed FLC shows a significant improvement in maintaining performance and preserving stability over standard PID method. Comparison results of PID and FLC are shown above.

The overall performance may be summarized as:

Parameter	PID	FLC
Overshoot	Present	Not Present
Settling Time	More (19m sec)	Less (10 m sec)
Transients	Present	Not Present
Rise Time	almost equal in both cases (8 m sec in PID & 9 m sec in FLC)	

Figure 10: Comparison of PID Controller & Fuzzy Logic Controller

5. CONCLUSION

Unlike some fuzzy controllers with hundreds, or even thousands, of rules running on dedicated computer systems, a unique FLC using a small number of rules and straightforward implementation is proposed to solve a class of level control problems with unknown dynamics or variable time delays commonly found in industry. Additionally, the FLC can be easily programmed into many currently available industrial process controllers. The FLC simulated on a level control problem with promising results can be applied to an entirely different industrial level controlling apparatus. The result shows significant improvement in maintaining performance over the widely used PID design method in terms of oscillations produced and overshoot. As seen from the graphs in figures 8 and 9, the rise time in case of PID controller is less but oscillations produced and overshoot and settling time is more. But in case of fuzzy logic controller, oscillations and overshoot and settling time are low, so FLC can be applied where oscillations can not be tolerated in the process. The FLC also exhibits robust performance for plants with significant variation in dynamics.

Here FLC and PID both are applied to the same exactly modeled level control system and simulation results are obtained. Had these techniques been applied to a system whose exact system dynamics were not known, PID wouldn't have taken care of the unknown dynamics or variable time delays in the system.

Fuzzy Logic provides a completely different, unorthodox way to approach a control problem. This method focuses on what the system should do rather than trying to understand how it works. One can concentrate on solving the problem rather trying to model the system mathematically, if that is even possible. This almost invariably leads to quicker, cheaper solutions.

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