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Design and Comparison of PID & FUZZY Controller for Water Level Control of Coupled Tank System

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Abstract: **This paper presents the approach to design and comparison of the Tuning PID & FUZZY controller for interactive Water Level Process and to model a dynamic process which can be done easily, conveniently and very efficiently. In this paper MATLAB software of Simulink modelling is used for modelling and testing of the control system. The experimental results of the interacting water level process can be satisfyingly illustrated the transient response and the steady state response. Simulation results confirm the effectiveness of the proposed control methodology.**

Keywords: **Coupled-Tank, Interacting water level process, PID Controller & Fuzzy Controller.**

1. INTRODUCTION

Chemical, Food, Milk brewage Plants are tightly integrated processes, which exhibit non-linear behaviour and complex dynamic properties. Chemical manufacturing processes present many challenging control problems due to their non-linear dynamic behaviour, uncertain and time-varying parameters, constraints on manipulated and state variables, multivariable interactions between manipulated and controlled variables. In particular, it is well recognised that one of the most important characteristics of chemical processes that present formidable control problem is the inherent nonlinearity of the process.

Intelligent Process Control methods such as fuzzy logic control have shown some success, there is a significant need to evaluate their real time performance relative to conventional control approaches, particularly in an experimental setting. Such evaluations help to determine the performance of the new intelligent process control methods, and provide the engineer with general guidelines on how to apply them to more complex real-world applications[4]. Despite a lot of research and the large number of different solutions proposed, most industrial control systems are still based on conventional PID regulators.

Fuzzy control and Conventional control strategies have been applied to implement level control in the process control unit as shown in Fig.1. These strategies have been successfully implemented in cascade control configurations. In the cascade control configuration, it has been observed that the fuzzy controller gives out perform than the conventional controller.

In practice, it is often being integrated into complex control structures in order to achieve a better control performance. The advantages of easy implementation and potentially large control performance improvement have led to wide spread applications of cascade control for several decades. It has become a standard application provided by industrial process controllers [3, 5].

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However, conventional PID controllers cannot provide a general solution to all control problems. The processes involved are in general complex and time-variant, with delays and non-linearity, and often with poorly defined dynamics. When the process becomes too complex to be described by analytical models, it is unlikely to be efficiently controlled by conventional approaches. To overcome these difficulties, various types of modified conventional PID controllers such as autotuning and adaptive PID controllers were developed lately [6,7]. Also, a class of non-conventional type of PID controller employing Fuzzy logic has been designed and simulated for this purpose [5,7,8].

Fuzzy Logic Controller (FLC) has emerged as one of the most active and useful research areas in the fuzzy control theory. That is why fuzzy logic controllers have been successfully applied for control of various physical processes. Basically there are two approaches to a fuzzy controller design: an expert approach and a control engineering approach. In the first, the fuzzy controller structure and parameters choice are assumed to be the responsibility of the experts. Consequently, design and performance of a fuzzy controller depend mainly on the knowledge and experience of the experts, or intuition and professional feeling of a designer. This dependence, which is considered far from systematic and reliable, is the flaw of this approach.

However, this approach could assist in constructing a fuzzy model or an initial version of a fuzzy controller. The second approach supposes an application of the knowledge of control engineering and a design of a fuzzy controller in some aspects similar to the conventional design with the parameter's choice, depending on the information of their influence on the controller performance [3-4].

On the other hand best known industrial process controller is Proportional- Integral-Derivative (PID) controller because of its simple structure and robust performance in a wide range of operating conditions. The similarity of FLC and PID Controllers and there improvement is still being investigated [1].

However, not many observations have been reported so far in the literature on the effect of use of fuzzy logic controller in the cascade control strategy *in real time.*

2. COUPLED TANK SYSTEM

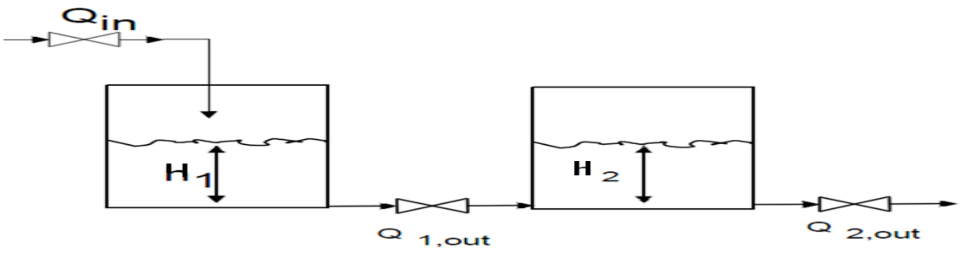

Figure 1: Coupled Tank System

From system can be obtained the non-linear system equations:

$$\frac{A_1 dH_1}{dt} = Q_{in} - Q_{1,out} \quad , \quad \frac{A_2 dH_2}{dt} = Q_{1,out} - Q_{2,out}$$

The flow out of the second tank is determined by the liquid head in that tank, i.e.

$$Q_{2,out} = k_2 \sqrt{H_2}$$

However, because of the coupling between the two tanks, the flow out of the first tank is determined by the difference in levels of the two tanks, i.e.

$$Q_{1,out} = k_1 \sqrt{H_1 - H_2}$$

Thus the final set of ODE's that describe system behaviour is given by:

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$$A_1 \frac{dH_1}{dt} = \left(Q_{in} - \alpha_1 \sqrt{H_1 - H_2}\right), \quad A_2 \frac{dH_2}{dt} = \left(\alpha_1 \sqrt{H_1 - H_2} - \alpha_2 \sqrt{H_2}\right)$$

After Linearized the above non-linear equations and taking Laplace Transform, we get

$$\frac{h_2(s)}{q_1(s)} = \frac{k_{21}\; k_1}{(T_1 s + 1)(T_2 s + 1) - k_{21}}$$

$$T_1 = 6.1459, \quad T_2 = 6.0109, \quad K_1 = 0.06557, \quad K_{21} = 0.549$$

After taking values, the Transfer Function obtained is:

$$TF = \frac{0.036}{36.942 s^2 + 12.1568 s + 0.451}$$

3. FUZZY CONTROLLER FOR COUPLED TANK SYSTEM

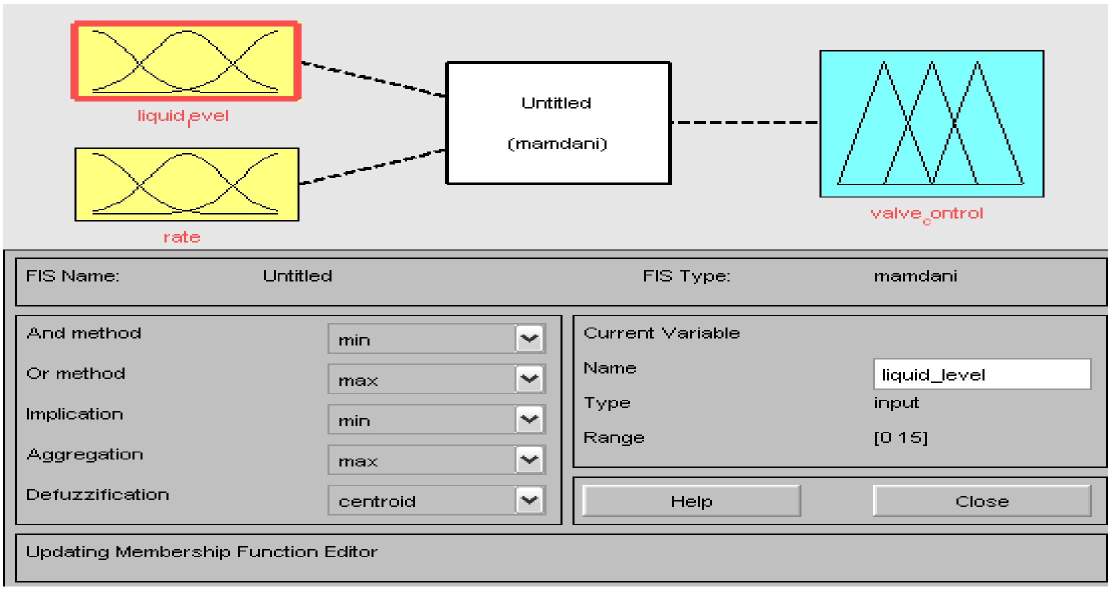

Figure 2: FIS window showing level, rate & valve control membership

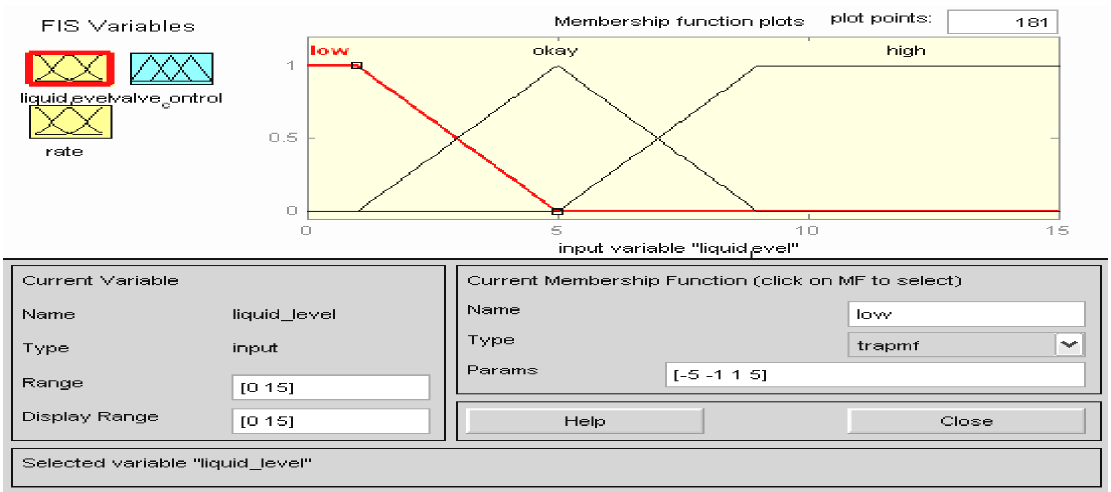

Figure 3: Membership degree editor files window

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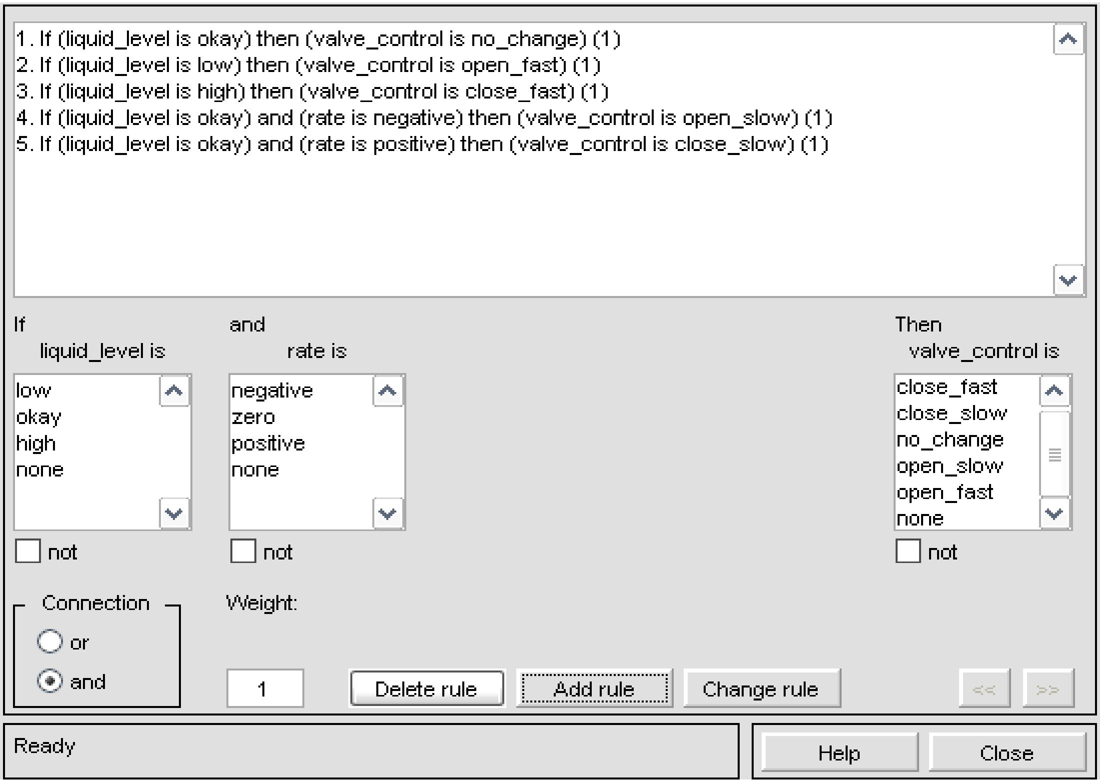

Figure 4: 5 Rule creator editor window file

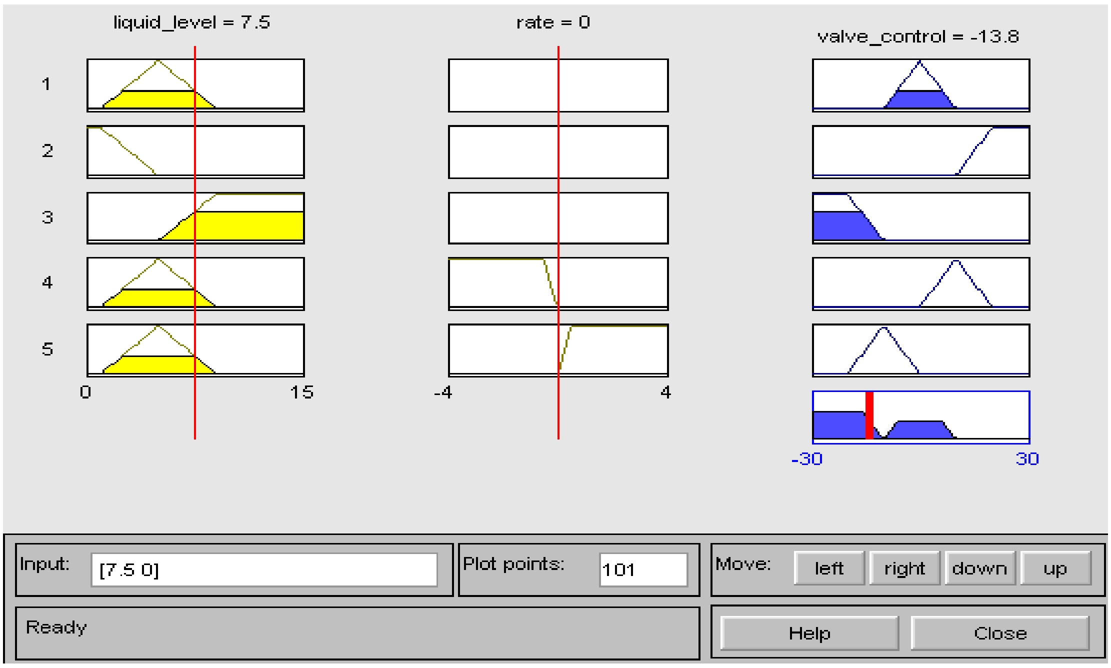

Figure 5: Five Rule Viewer window file

Three rule tuning System:

(a) If Level is low then valve is open slowly.

(b) If Level is high then valve is close slowly.

(c) If Level is okay then no change in valve.

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4. SIMULATION AND RESULTS

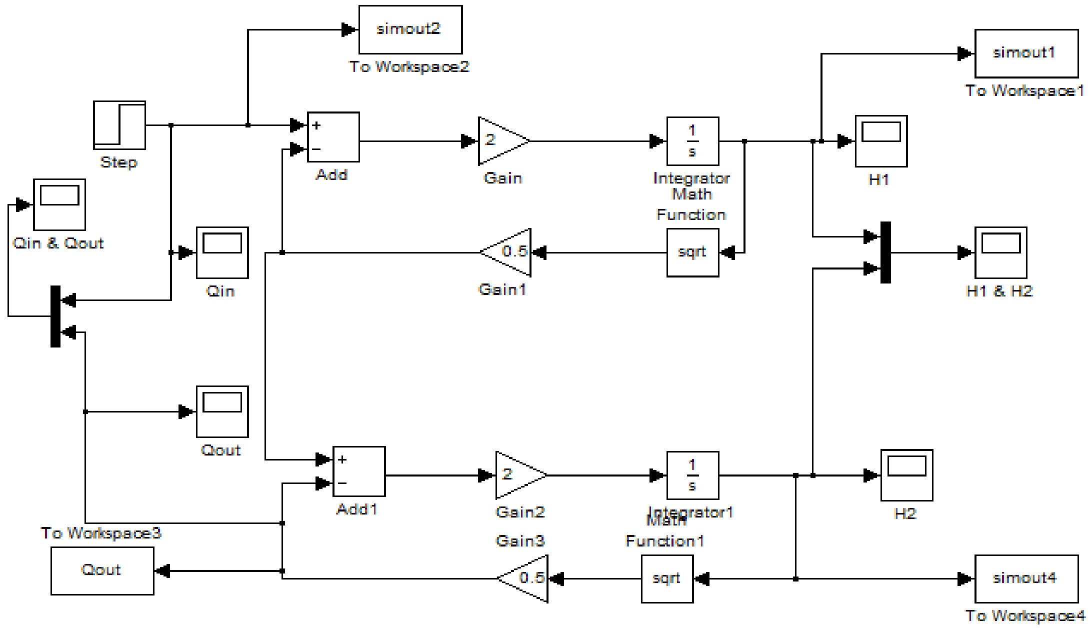

Figure 6: Coupled Tank System

4.1 For PID Controller:

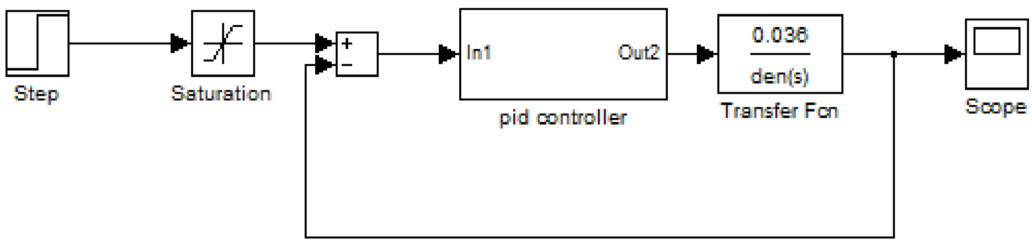

Figure 7: PID Control System

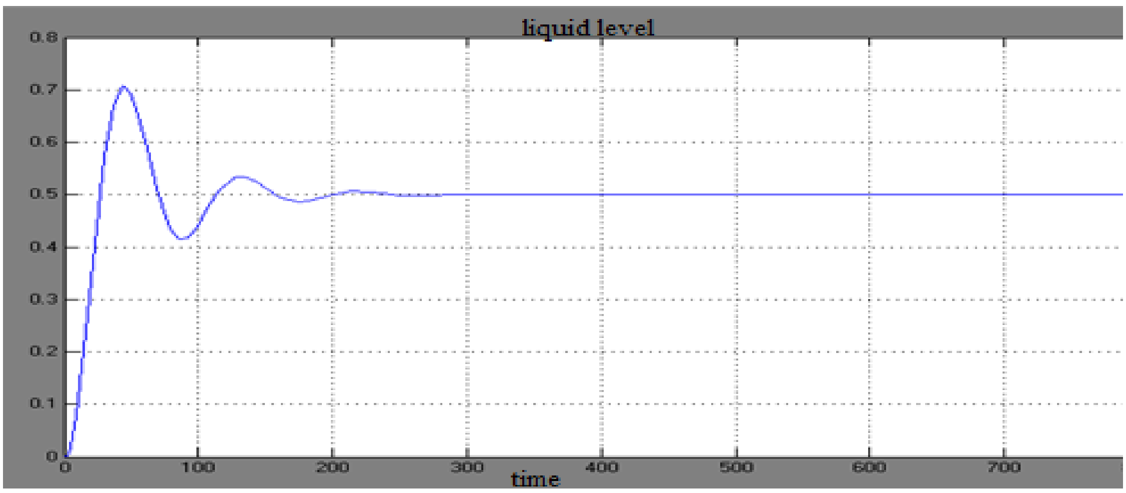

Figure 8: Response for PID Controller

4.2 Fuzzy controller for coupled Tank System:

4.2.1 Three Rule Based Method:

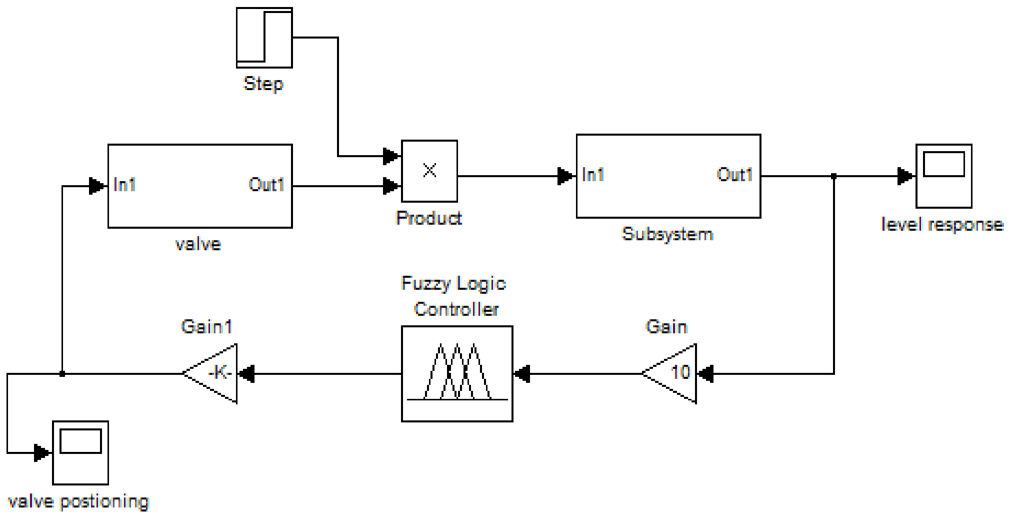

Figure 9: Three Rule Based Fuzzy Controller

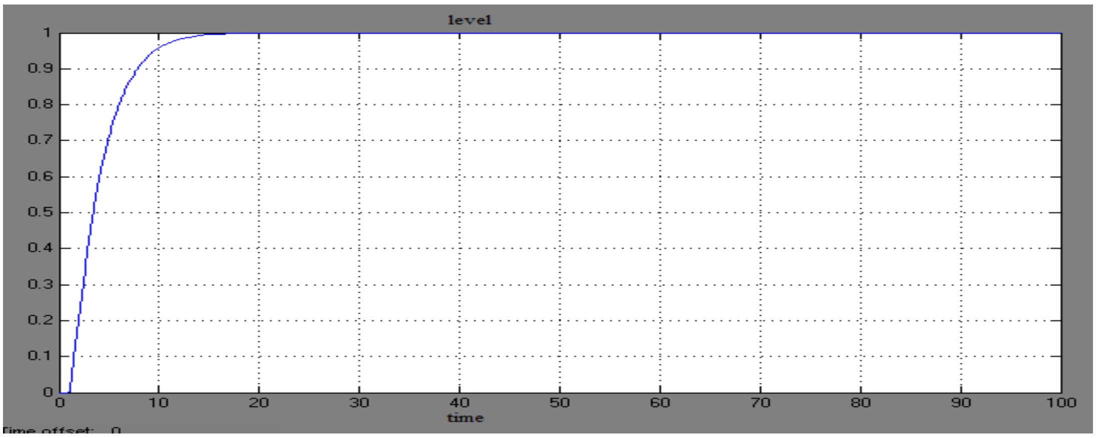

Figure 10: Response for Level Control using Three Rule Based Fuzzy Controller

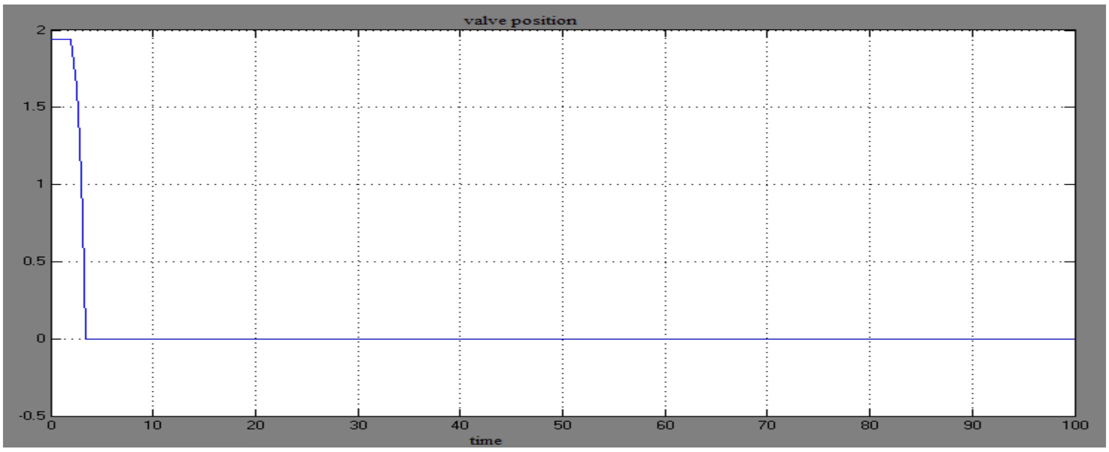

Figure 11: Response for Valve Position using Three Rule Based Fuzzy Controller

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4.2.2 Five Rule Based Method:

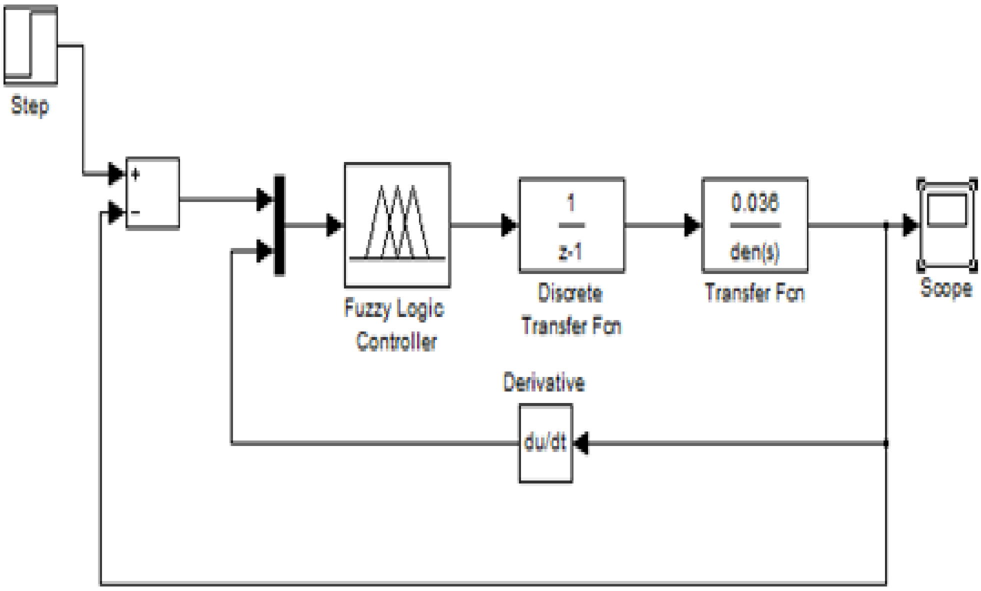

Figure 12: Five Rule Based Fuzzy Controller for Coupled Tank System

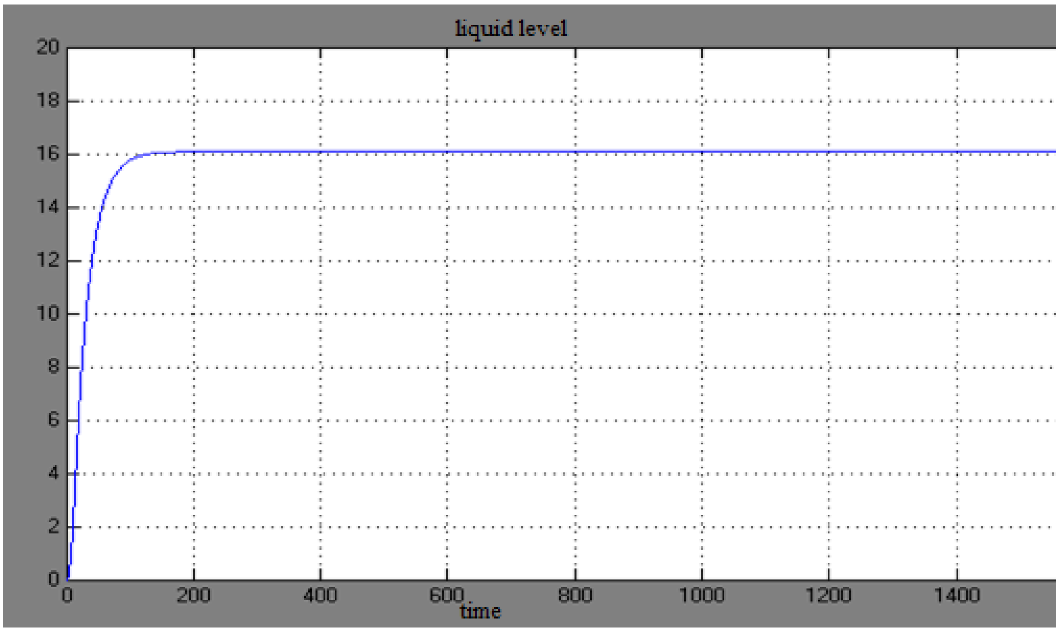

Figure 13: Response for the Coupled Tank System using Five Rule Based

5. CONCLUSION

Fuzzy Controller and conventional controllers were successfully implemented in real time, using in cascade control loops. The overall system performance was realized using the Fuzzy system is much smoother than the PID Controller but due the rules fuzzy system becomes the complex system, so speed of system is much lesser than PID Controller.

On the other hand, three rule based system is less complex, more smoother and high speed of response than the five rule based system.

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