# DESIGN AND OVERVIEW OF CASCADE WATER TANK SYSTEM USING FUZZY-PID CONTROLLER

Tulsi Bothikar[1], Hafiz Shaikh[2], Dr.Prof.Mrs.N.R.Kulkarni[3]
[1]M.E.Student, Department of Electrical Engineering, Modern College of Engineering, Pune University, Pune-05, India
[2]Ph.D. Student, Department of Electrical Engineering, Modern College of Engineering, Pune University,Pune-05,India
[3]H.O.D. Dept. of Electrical Engg., Modern College of Engineering, Pune University, Pune -05, India.

**Abstract**

**The main issue in the process industry is to control and measure the liquid level in the tanks. There are many control strategies are available through which we can control the liquid level in the tank. The liquid level in the tank can be control by using the Conventional PID controller.PID controller response can be tuned for obtaining better oscillations, steady state response and reduced error by changing the PID parameters. By using PID parameter, the fuzzy rules we can get the promising results through fuzzy logic controller. The continuous updating of its output scaling factor a self-tuning fuzzy PID controller is designed. One and two dimensional rules bases are used in parallel. Then this output is given to the water tank within the maximum level limit. It improves the overall performance of the proposed system.**

**Keyword:-Fuzzy PID controller,PID controller, Self-tuning**.

## INTRODUCTION:

Control of liquid is the main control parameter in every process industries. Due to the poor control of the steam generator water level many nuclear power plant has been shutdown. Because of this emergency shutdown the availability of the power plant has been decreased rapidly. The presence of Nonlinearities and uncertainties of a system, design of the water level control system is very complex. Many industries go for the constant gain PI controllers which are used in the nuclear organizations for boiler water level control at high power operations.at low power operations, the PI controller cannot maintain water level properly. So the maintaining the water level in the tank is needed. This paper proposes PID control and fuzzy control together and showed the performance of the fuzzy-PID control which uses the signals of feedback as input and deals with them via fuzzy rules and the results of fuzzy inference are the parameters of $\Delta Kp$,$\Delta Ki$ and $\Delta Kd$. This parameter can be modified in order to control the output of the control signal. The advantages of the both PID controller and fuzzy controller are present in the fuzzy-PID controller. The fuzzy-PID controller contains fast responding, small steadily error, independent of system model and suitable for non-linearity systems etc.

## I] LIQUID STORAGE TANK SYSTEM

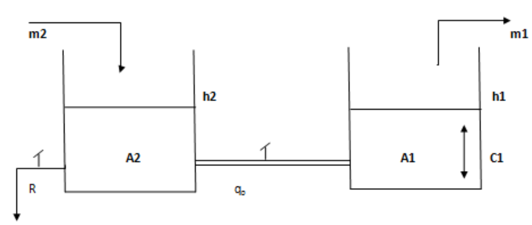



**Fig.1 Liquid Storage tank**

Storage tank Figure 1. Storage tank Fig.1 shows a storage tank of constant cross – sectional area a. The density of the liquid is assumed to be constant. The exit pipe resistance is R. The exit flow qo can be laminar or turbulent (nonlinear). For a laminar flow, qo =h/R, and for a turbulent flow, qo =Kh1/2, where K is the discharge coefficient [1].

## II] MODEL EQUATION

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 [1, 2].

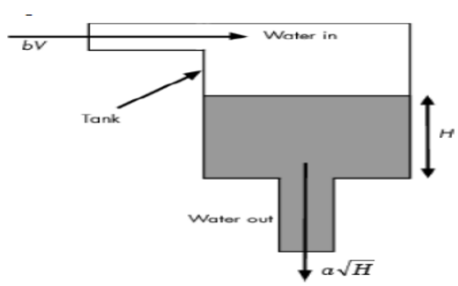



**Fig.2 Schematic Diagram for the Liquid-Tank System**

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

$$\frac{dVol}{dt} = A\frac{dH}{dt} = bV - a\sqrt{H}$$

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. 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. the analysis of the model is done by linearizing the model, using Simulink Control Design. The sensor is used to sense the level and convert it into the signal acceptable for the controller. Then the controller compares the level of the signal with the desired set point. Then the set point is actuate 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. The main role of the controller is to set the set point close to the desired set point.

## III] FUNDAMENTALS OF CASCADE CONTROL SYSTEMS

The configuration of cascade control scheme is shown in Fig.3, where an inner loop is embedded within an outer loop and the outer loop output variable is to be controlled. The control system consists of two processes and two controllers with outer loop transfer function GP, inner loop transfer function G, outer loop controller G and inner loop controller G, respectively. The two controllers of cascade control systems are standard feedback controllers (i.e., P, PI,'orPID). Usually, a proportional controller is used for the inner loop, integral action is needed when the inner loop process contains essential time delays and the outer process is such that the loop gain in the inner loop must be limited. To serve the purpose of reducing or eliminating the inner loop disturbance before its effect can spill over to the outer loop, it is essential that the inner loop exhibit a faster dynamic response that that of outer loop (as industry rule of thumb, it should be at least five times).
Consequently, the phase lag of the closed inner loop will be less than that of the outer loop.
This feature leads to the rationale behind the use of cascade control. The crossover frequency for the inner loop is higher than that for the outer loop, which allows higher gains in the inner loop controller in order to regulate more effectively the effect of a disturbance occurring in the inner loop without endangering the stability of the system.

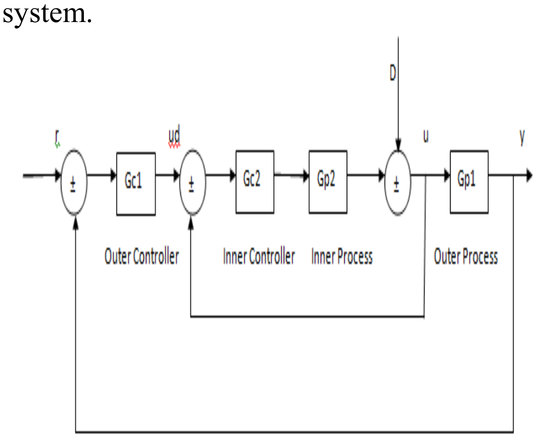



**Fig.3 Configuration of cascade control system**

Transfer Function of Cascade Control System

$$G_{ud}= \frac{G_{p2}(s)\ G_{c2}(s)}{1+G_{p2}(s)G_{c2}(s)}$$

$$G_y= \frac{G_{p1}(s)\ G_{c1}(s)\ G_{ud}(s)}{1+G_{p1}(s)\ Gc1(s)\ G_{ud}}$$

## IV] FUZZY-PID CONTROLLER

Self-Tuning Fuzzy PID Controller. There are two inputs and three outputs given to the Fuzzy controller. Inputs to the fuzzy logic controller are error between set level and actual level and the other is the rate of change in error. Three parameters of PID that is Proportional gain (Kp), Integral gain (Ki) and Derivative (Kd)when varied with the help of fuzzy logic controller it is termed as Auto tuning fuzzy based PID controller. Fig. 4 Auto tuning fuzzy based PID controller Error (set point Manipulated value) and rate of change in error is calculated and fed to the controller as shown in fig. 4. These are used as the input variables to the fuzzy controller, and the output (defuzzified) variables are the parameters of PID control, those are ΔKp, ΔKi and ΔKd. Here, denotes the error in liquid level; denotes rate of change in error in process.

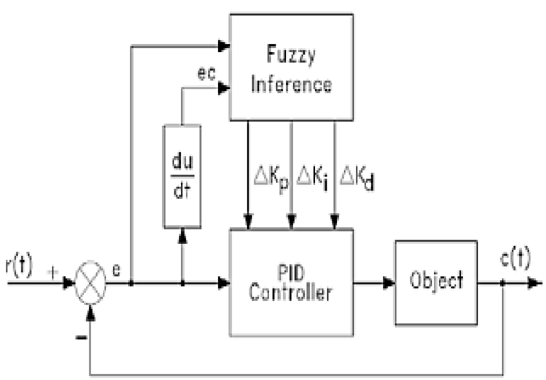



**Fig.4 Auto tuning fuzzy based PID controller**

## V] Formulation of auto tuning fuzzy logic based PID controller

The fuzzy controllers two Mamdani types should be used separately to control the manipulated which are the actual level coming out from the each tank so that the controlled signal is passed to each process tanks separately.

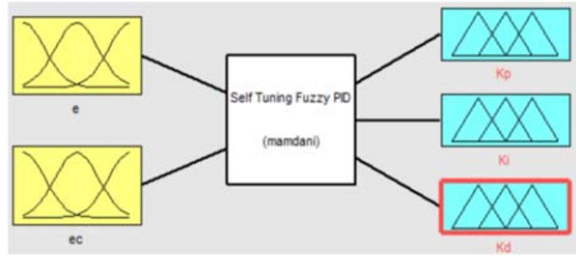
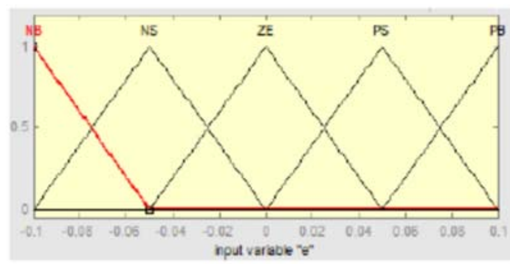
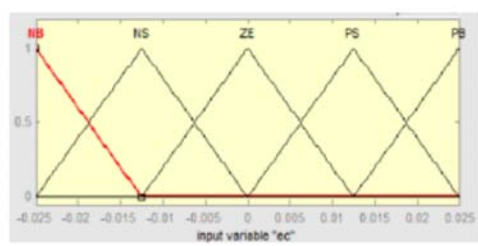



**Fig.5 Fuzzy inference block**

The PID controller parameters Kp, Ki and Kd are given in the range of *Kpmin* to *Kpmax*, *Kimin* to *Kimax*, *Kdmin* to *Kdmax*. Based on the rule base, probability of error in the system and simulation results of PID the ranges of PID parameters are decided.




**(A) Membership functions of e(t).**

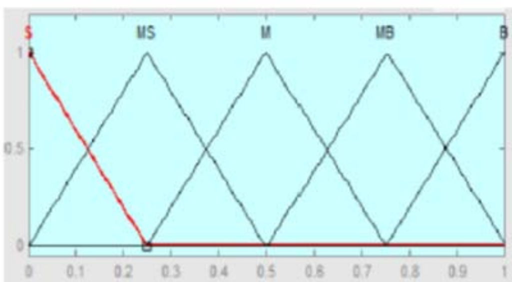



**(B) Triangular Membership functions for ec**

The ranges of these fuzzy inputs are between -0.1 to 0.1 for error and -0.025 to 0.025 for rate of change in error. As per the above triangular functions for output, when set value is equal to manipulated value the fuzzy output should be near 0.5.

**Table 1. Nomenclature of Linguistic membership functions**

| Input Membership | | Output Membership | |
|---|---|---|---|
| **NB** | **Negative Big** | **S** | **Small** |
| **NS** | **Negative Small** | **MS** | **Medium Small** |
| **ZE** | **Zero** | **M** | **Medium** |
| **PS** | **Positive Small** | **MB** | **Medium Big** |
| **PB** | **Positive Big** | **B** | **Big** |




**(A) Triangular Membership functions for Kp', Ki' and Kd'**

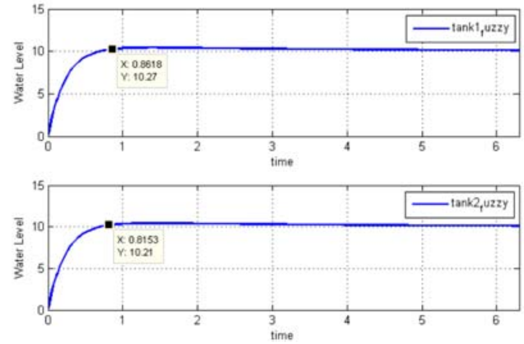
| De\e | NB | NS | ZE | PS | PB |
|---|---|---|---|---|---|
| NB | S | S | MS | MS | M |
| NS | S | MS | MS | M | MB |
| ZE | MS | MS | M | MB | MB |
| PS | MS | M | MB | MB | B |
| PB | M | MB | MB | B | B |

### (B) Formulation of Rules for Fuzzy Inference System

The practical experiments performed on the process can give a brief idea about the crisp values and rules can be according defined as, the outputs ranges from 0 to 1 that is positive signal is given to PID.

### VI] Simulation Responses and Discussion

These are desired simulation responses for the system. The output response for the coupled tank interacting system using Fuzzy-PID controller has no oscillations and there is almost no overshoot.



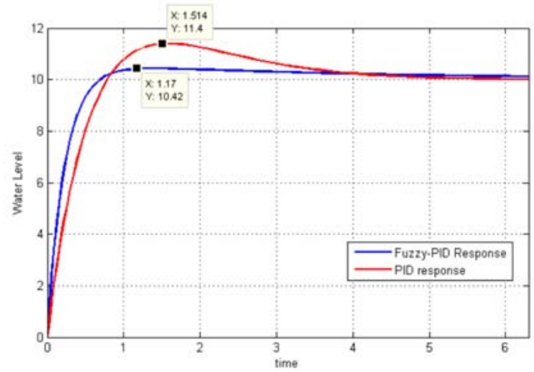




**Table 2. Controller's performance Comparison**

| Controller Type | Integral Square Error for set point of 10 cm |
|---|---|
| PID | 20.02 |
| Fuzzy-PID | 10.87 |

### VII] Conclusion

In this paper we have designed and implemented PID controller and Auto-tuning fuzzy-PID controller to control (Cascade) coupled tank interacting system The result shows significant improvement in maintaining performance over the widely used PID design method in terms of oscillations produced and overshoot. It has excellent dynamic and steady performance rather than PID and fuzzy controllers. The cascade interacting system responses indicate that the water level in both the tanks can be controlled perfectly by the courtesy of the new Auto-tuning fuzzy-PID controller.

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