Temperature Control of Water Tank Level System by using Fuzzy –PID Controllers

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Abstract- **In many industrial processes, control of liquid level is required. Water level control is highly important in industrial applications such as boilers in nuclear power plants. A number of controlling techniques has been proposed to control the processes to get the better efficiency. In that PID controllers are the most commonly used approach which is effectively control the temperature control process. In Proportional Integral Derivative (PID) controllers, the PID constants are incorrect at all times due to the lack of understanding of the temperature control process such as higher order systems and its parametric changes making the system complex. An Fuzzy Logic Control(FLC) system is an alternative method for controlling the process which reduces the complexity of the system. FLC system also helpful for defining the known and unknown parameters such as dead zone saturation and hysteresis. The implementation of FLC system uses less number of rules is proposed to be developed.**

In this paper we try to define the performance of water tank level control system for the PID controller and Fuzzy Logic Controllers (FLC).FLC is implemented using a smaller rule set and PID Controller is tuned. For the tuning of PID controller and the calculation of PID parameters we prefer Ziegler Nichols second method (process reaction curve method). The study is conducted using the help of MATLAB Simulink Software.

Keywords- Temperature Control, PID Controller, Fuzzy Logic Control, Time Delay

I INTRODUCTION

Water level control is highly important in industrial applications such as boilers in nuclear power plants . In many industrial processes, control of liquid level is required. It was reported that about 25% of emergency shutdowns in the nuclear power plant are caused by poor control of the steam generator . Such shutdowns greatly decrease the plant availability and must be minimized .The Fig.1. shows the schematic diagram of water tank level control systems

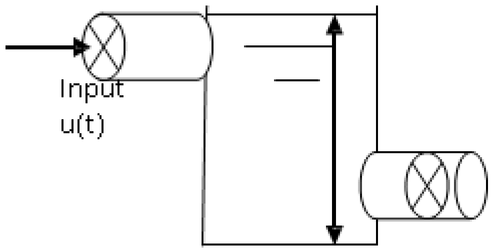

Fig.1 schematic diagram of surge tank system

The flowing of water is supplied via a pump from a storage tank and water flow rate is adjusted with an actuator The level of liquid is measured through a pressure transmitter. The transmitted pressure data is transferred to control circuit. Here, u(t) is the input flow (control input), which can be positive or negative that is it can both pullout the liquid from tank or put it in, h(t) is the liquid level (the output of the plant),

Water level control system is a very complex system, because of the nonlinearities and uncertainties of a system. There are various approaches to the design of the level controllers. Most commonly used controllers are PID controllers. Some Advanced control methods such as linear quadratic Gaussian (LQG) based controller designs were also used Most commonly used controllers are PID controllers, nuclear organizations for boiler water level control at high power operations. However, at low power operations, PI controllers can not maintain water level properly. A need for performance improvement in existing water level regulators is therefore needed .And also provides robust and reliable performance. The main drawback of PID controller is that the controller constants are incorrect at all times, if the order of the systems increases the controller constants values are inaccurate due to this the response of the system will be very poor. i.e. ,PID controllers are applicable only for linear systems. It doesn't helps to define the values of nonlinearities such as dead zone, saturation, and hysteresis. If the order of the system increases then it becomes nonlinear. Such that the PID controllers doesn't applicable for higher order systems. But most of the industrial applications are higher order systems and nonlinear. i.e., For getting the better performance we proposed Fuzzy controllers.

In recent years most of the processes are controlled by using Fuzzy. Fuzzy logic control mainly designed for nonlinear, high order & time delay system, In this thesis a simple water level indicator and a water level controller based on fuzzy logic is proposed. The fabricated electronic level indicator defines 2 levels minimum and maximum through LEDs. The fuzzy logic controller is based on Mamdani type Fuzzy Inference System. The fuzzy controller has two inputs, error in level and rate of change of error and one output, valve position.

The paper has been organized as follows II controller designations which explains generalized models of PID controller and fuzzy logic controller. III Designing of water tank level control system IV presents the simulation results of fuzzy and PID controllers which studied by using the MATLAB Simulink software.

GENERALISED MODEL OF CONTROLLER SPECIFICATIONS

PID Controller

In many industrial applications most commonly used controllers are PID controllers. The PID controller consists three parameters Proportional, Integral, Derivative..Proportional controller The PID controller estimates the error before it occurs i.e. it forecasts the value in the immediate future and takes control action accordingly. Thus the PID control is also referred to as 'Anticipatory control the adjective of proportional action is to reduce the error signal value to zero, the main objectives of proportional action is, the controller gain can be adjusted to make the controller output changes as sensitive as desired to deviations between the set point and controlled variable and the controller gain K_p sign can be chosen to make the controller output increase or decrease as the error signal increases ,when ever the set point changes or disturbance occurs in the operation the offset will occurs in proportional action ,this can be eliminated by manually by resetting the set point after the offset occurs bat it is inconvenient because the operator intervention is required and the set point value can be determined by trail and error .i.e. the offset can be eliminated by integral action, for integral action the controller output depends on the integral of the error signal. The process being controlled to be steady state, The controller output must be constant o that the manipulated value also constant. The controller output changes automatically until it attains the value which makes the steady state error is zero. due to this integral action it tends to produce oscillations of the controlled variable ,i.e. the stability of the system will be reduces,i.e. to improve the stability of the system derivative action is included ,the derivative action estimates the future behavior of error signal by considering the rate of change of error, it also referred as pre-act or anticipatory control. In temperature water level tank when ever the temperature increases 10^oC in 30 minits,then it indicates the reduction of level of water in the tank. this situation not appear in proportional and integral action.

The transfer function of the PID controller in continuous domain is given

$$P'(s)=P+I+D$$
$$= K_P + K_i/S+K_dS$$
$$P'(s)=K_p(1+ 1/T_iS+ T_dS)$$

In the above equation,Kp is the proportional gain, Ki is coefficient of integration and Kd is the coefficient of derivation. Ti is referred as
integral action time in Sec and Td to referred as derivative action
time in Sec.

Therefore the PID controller has three adjustable parameters such as (Kp, Ti, & Td), which interact with each other. In order to get the desired response for higher order systems ,the PID controllers takes more operating time and time consuming to tune the three parameters(K_p,T_i,T_d).

To tune the controller parameters we have number of techniques. in this thesis we prefer Ziegler-Nicholas second method .In 1942 Ziegler and Nicholas proposed an online tuning method for tuning the parameters. This technique is done in a single step. After the process has reached the steady state then the controller is placed is placed in manual mode .then a small step change in the controller(3-5%)is introduced ,these controller settings are based by defining the process reaction curve also known as step test method.

Two types of curves are shown in fig2.for a step changes at t=0,after an initial transient .the output for case(1) increased act a constant level and the process acts as integrating element and is non-self regulating. In this case the slope of the tangent through the inflection point. In case(2) the hypothetical process considers ,is self regulating because the step response reaches a new steady state., the slope is equal to K/τ..

The temperature water level control plant is a second order system ,Which controls the level of the water in the tank based on the temperature. Fig.3.shows the schematic model diagram for PID controller

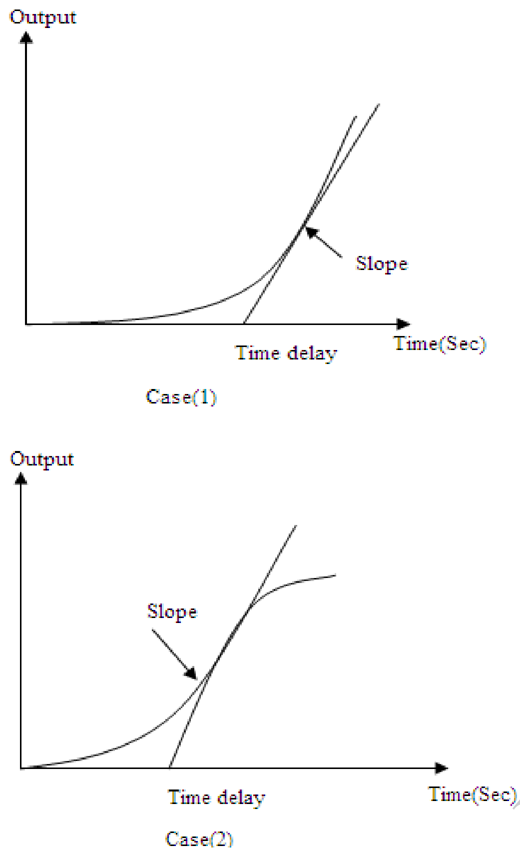

Fig.2..Process reaction curves for, case(1) non-self regulating ,case(2) self regulating

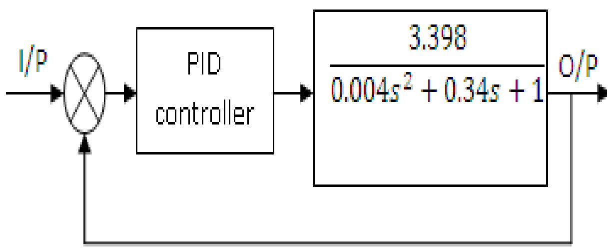

Fig.3.Model of the system based on Conventional PID controller

Fuzzy logic controller

Fuzzy logic concept was introduced by Lofti. A. Zadeh, a professor at the University of California at Berkley. The fuzzy logic system is mainly based on Reasoning and the fuzzy controller is very easier to design and also applicable for nonlinear and higher order system. and these gives desired responses. In this section, we represent the brief idea about the FLC. The Fuzzy Logic control comprises four principal components: fuzzyfication ,fuzzy interface, base, defuzzification .The fig.4.shows the block diagram representation for FLC system.

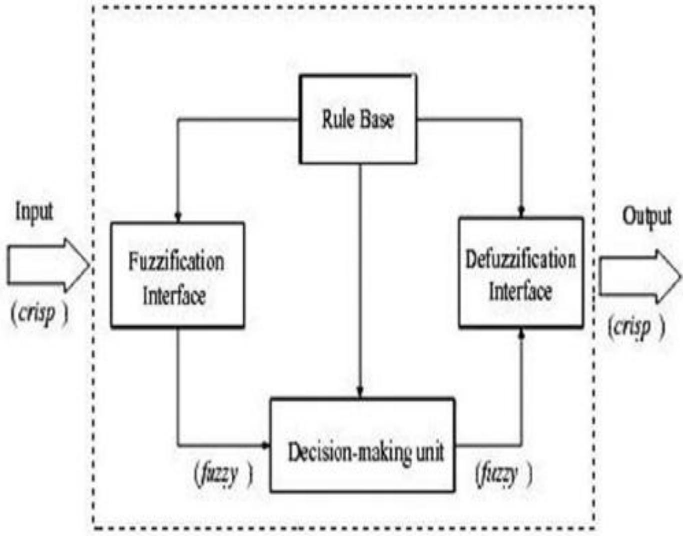

Fig.4.Blocks in Fuzzy logic System

Fuzzyfication : Fuzzy interface is vagueness and very nearer to human language. The fuzzification module converts the input into corresponding linguistic values.

Membership functions: To define the fuzzy set we have an approach of MF. Such functions are used in FLC, because they lead themselves to manipulation through the use of fuzzy arithmetic. The Fig.3 represents the Gaussian Membership function,helps to define the linguistic variables involved in the construction of the rule base of the FLC system.

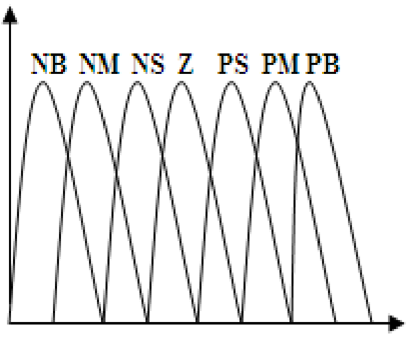

Fig.5.Gaussian Membership function

NB	Negative Big
NM	Negative medium
NS	Negative small
Z	Zero

PS Positive Small
PM Positive medium
PB Positive Big

Fuzzy Inference: There are two major types of control rules in fuzzy control

1) Mamdani System – This method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type FIS entails a substantial computational burden.

2) Takagi- Sugeno - This method is computationally efficient and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic non-linear systems. These adaptive techniques can be used to customize the membership functions so that fuzzy system best models the data. The most fundamental difference between Mamdani -type FIS and Sugeno-type FIS is the way the crisp output is generated from the fuzzy inputs. While Mamdani-type FIS uses the technique of defuzzification of a fuzzy output, Sugeno-type FIS uses weighted average to compute the crisp output. The expressive power and interpretability of Mamdani output is lost in the Sugeno FIS since the consequents of the rules are not fuzzy. But Sugeno has better processing time since the weighted average replace the time consuming defuzzification process. Due to the interpretable and intuitive nature of the rule base, Mamdani-type FIS is widely used in particular for decision support. intuitive nature of the rule base, Mamdani-type FIS is widely used in particular for decision support application. Other differences are that Mamdani FIS has output membership functions whereas Surgeon FIS has no output membership functions. Mamdani FIS is less flexible in system design in comparison to Sugeno FIS as latter can be integrated with ANFIS tool to optimize the outputs.

Defuzzification:

The defuzzification gives the numerical value regarding to the fuzzy controller output. We mainly have three methods for defuzzification.
1.Centroid method
2.Center of sums method
3.Mean of Maxima method.
In this paper we use the centroid method for the process of defuzzification.
1.Gives superior results.
2. Gives good steady-state performance.
3. Yields a lower mean square error.

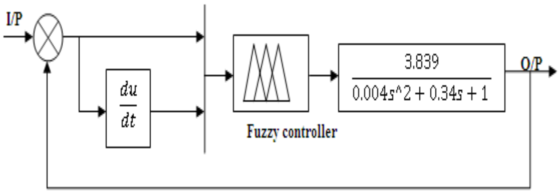

Fig.6.Palnt model based on Fuzzy controller

DESIGNING OF PLANT MODEL

For the design of FLC system, we prefer Mamdani-type fuzzy inference system is used. The rule base is implemented in the Fuzzy Inference The rule base for the FLC regarding to the plant is as follows.

E = {-6, -5, -4, -3, -2, -1, -0, +0,1,2,3,4,5,6}
EC = {-6, -5, -4, -3, -2, -1,0,1,2,3,4,5,6}
U = {-7, -6, -5, -4, -3, -2, -1,0,1,2,3,4,5,6,7}
E, linguistic variables EC and U values were:
E = {NB, NM, NS, NZ, PZ, PS, PM, PB}
EC = {NB, NM, NS, Z, PS, PM, PB}
U = {NB, NM, NS, Z, PS, PM, PB}

The fig.7. represents schematic arrangement of fuzzy inference system. By observing that ,where in error E and rate of change in error CE are the two inputs to the FLC, and U refers the controller output. By making use of the trial-and-error approach, for the design of FLC controller we picked up 21 rules out of 49 rules.

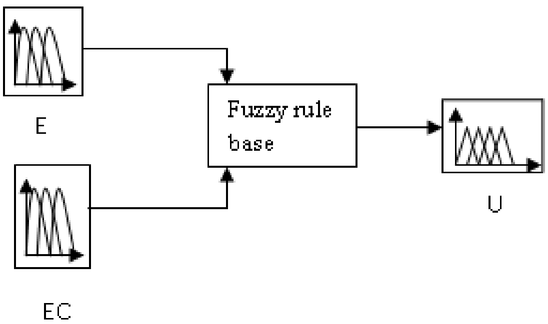

Fig.7. Fuzzy rule base structure

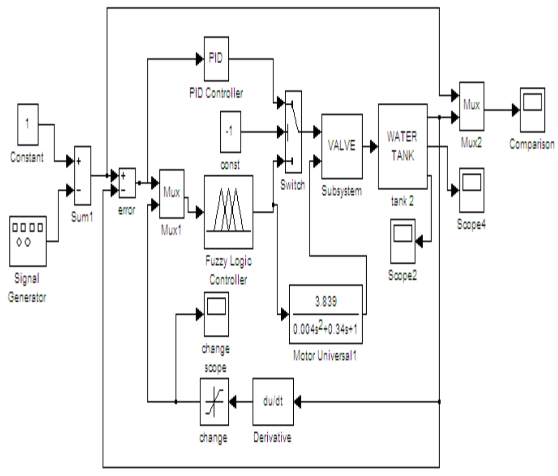

Fig.8.Simuink diagram for water tank level system

SIMULATION & RESULTS ANALYSIS

In order to obtain the desired control action of the system by PID controller is done by using the process reaction curve tuning method .In this it is essential to choose the appropriate values for proportional constant value Kc ,up to the continuous cycling occurs. with that the response should be plotted. While in the case of Fuzzy logic controller we have to take two inputs, error and rate of change of error. we have range for error (E), rate of change of error (DE) and the output (OP) range as well. By using fuzzy rule base the performance of the system should be defined. The zero error range is set relative to the values of the positive and negative error ranges of all the membership functions. The simulation time is set to 0.5 seconds and temperature is set at . The same can be implemented for various ranges of 1000 DC, 1500°C, and respectively. The below figure shows the output response for the system using the PID controller with a set point, and FLC for the same set point.

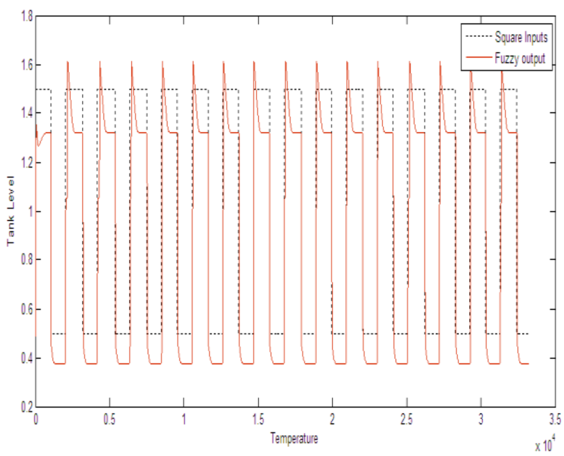

Fig.9.Responce of water tank system for fuzzy-PID controller

CONCLUSION

The temperature control of a boiler water level control system is controlled by the two controllers, conventional PID controller and Fuzzy logic controller .The simulation is done by using the software of MATLAB SIMULINK .If the system is designed by using the Z-N method ,the tuning of the PID controller is done by using the software. The Process reaction curve method gives high overshoots and the steady state error is high. therefore To get the desired response ,the obtained values of PID parameters are changed through out the process. While in the proposed system, the design of the controller is easier than PID, and get the desired output. By this instance can greatly reduce the workload of the designer to further deepen such as domain linguistic variables , membership functions , fuzzy control rules.

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