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INTEGRATED PID BASED INTELLIGENT CONTROL FOR THREE TANK SYSTEM

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ABSTRACT

In industrial control systems the liquid level is carrying its significance as the control action for level control in tanks containing different chemicals or mixtures is essential for further control linking set levels. The three tank level control techniques are well thought-out in our work. In conventional model for three tank liquid level, the control was done with predictable PID control model. The auto fine-tuning performance of PID regulator is adopted for more dependable and accurate control action which incorporate the uncertain factors also. A new evolution function including the system adjusting tiem, rise time, onreshoot, and system error is defined. By optimizing the PID controller and comparing the results obtained by conventional methods like Ziegler-Nichols using this techniques method the systems time delay and performance improved.

Keywords: PID controllers, controller tuning, multi- objective, Ziegler-Nichols, fuzzy logic, three tank liquid level system.

1. INTRODUCTION

Three tank liquid level system control is central to several divided areas ranging from petrochemical industry, waste water neutralization unit, industrialized chemical processing, boilers, food processing industry etc [1]. To nuclear power generation. Liquid level control for water tank is large lag, time varying and non- linear complex system and the main objective of the control system is to fill the tank as quickly and efficiently as possible. The plan and analysis of standard control system are based on their precise mathematical models, which are usually very difficult to achieve owing to the complexity, nonlinearity, time- varying and incomplete characteristics of the existing practical systems [2]. One of the most effective ways to solve the problem is to use the technique of intelligent control system, or fusion methodology of the usual and intellectual control techniques.

In this paper, the block diagram of classical feedback control system (FBC) is shown in Figure-1. The feedback controller cannot anticipate and prevent errors; it can only initiate corrective action after an error has already developed [3]. It cannot give close control when there is a large delay in the process. So, one of the tonic for the problem is intelligent fuzzy control system. Unlike a feedback control system, an intellectual fuzzy control system was urbanized using expert knowledge and experience gained about the process [4].

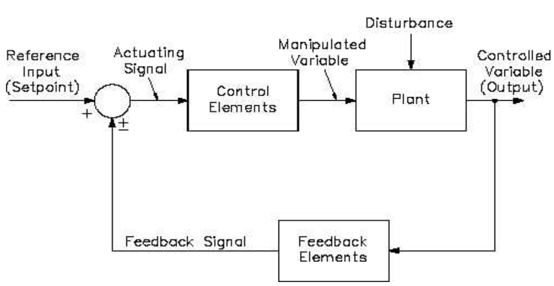

Figure-1. Functional blocks of feedback control system.

The block diagram of integrated intelligent fuzzy logic controller is shown in Figure-2.The conventional feedback controller is not replaced by the intelligent fuzzy controller [5]. The intelligent fuzzy controller design consists of three stages: Fuzzification stage, Decision making logic and Defuzzification stage. In this paper an attempt has been made to analyze the efficiency of an integrated intelligent fuzzy control using three tank level control system and the effects are studied through computer simulation using Matlab/Simulink toolbox [6].

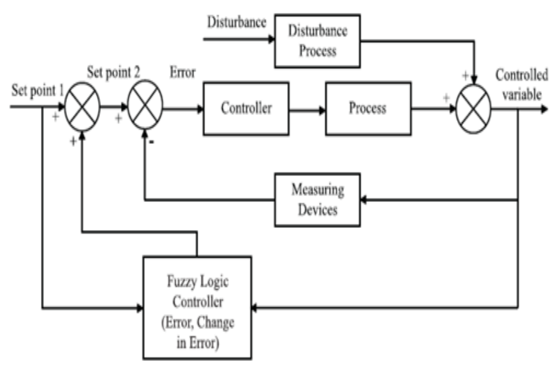

Figure-2. Block diagram of intelligent fuzzy control system.

According to the results obtained in this paper, considerably better results have been obtained in the case of the intelligent fuzzy control when compared to those by Ziegler-Nichols method in their respective step response on the system [7].

2. PID CONTROLLERS

PID- Proportional, Integral, and Derivative controllers because of their simplicity and wide acceptability are playing an imperative role in process

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control and are still the best solutions for the industrial control processes [8]. Recent industrial controls are often required to regulate the closed- loop response of a system and PID controller's credit for the 90% of the total controllers used in the industrial automation. A PID controller based system is represented in simple block level diagram as in Figure-3.

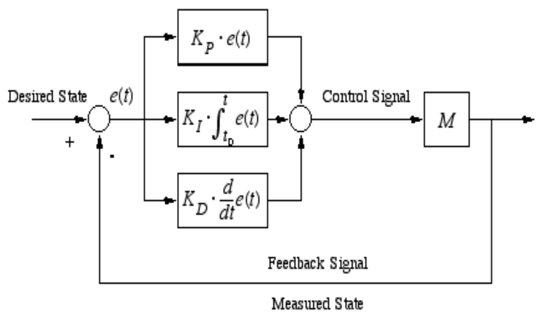

Figure-3. Schematic representation of unity feedback.

PID controller system architecture

The common equation for a PID controller for the above figure can be given as:

$C(s) = K_p.R(s) + K_i \int R(s)\, dt + K_d\, dR(s)/dt$

Where K_p, K_i and K_d are the controller gains, C(s) is output signal, R(s) is the different between desired output are output obtained [9].

Various types of tuning techniques are followed and to expand a stability of this model. they techniques are: mathematically criteria, process reaction curve Method, Trail and Error Method, Ziegler-Nichols Method and now a days the Soft-Computing techniques, being lesser prone to error when compared to conventional methods; like Fuzzy Logic, Genetic Algorithms, Particle Swarm Optimization, Neuro-Fuzzy, Steel Annealing and Artificial Neural Networks, are also becoming dominant in research methodologies [10].

3. MATHEMATICAL MODEL OF A THREE TANK LIQUID LEVEL SCHEME

In this paper, the three tank liquid level control system consists of non interacting connection with first order system as shown in Figure-4.

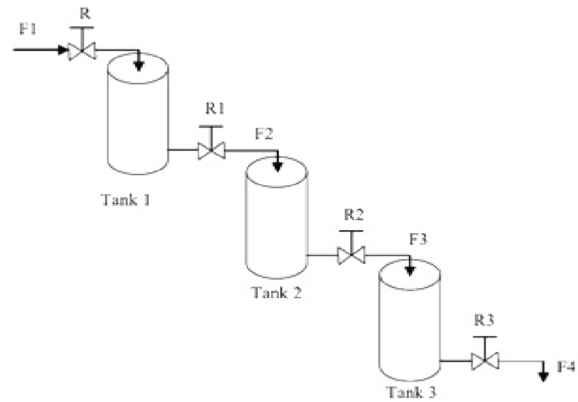

Figure-4. Three tank non interacting system.

The basic model equation of Non interacting three tank system is given by

Tank1

$$F_1(t) - F_2(t) = A_1 dh_1 / dt \quad (1)$$

Where,
F (t) = tank1 inflowing liquid (m^3/s),
A = area of the tank1 (m2) and
H= Elevation of the liquid level in tank1

Tank 2

$$F_2(t) - F_3(t) = A_2 dh_2 / dt \quad (2)$$

Where,
F (t) = tank2 inflowing liquid (m^3/s),
F (t) = tank2 out flowing liquid (m^3/s),
A = area of the tank2 (m^2) and
h = Elevation of the liquid level in tank2 (m).

Tank 3

$$F_3(t) - F_4(t) = A_3 dh_3 / dt \quad (3)$$

Where,
F (t) tank3 inflowing liquid (m^3/s),
F (t) tank3 out flowing liquid (m^3/s),
A area of the tank3 (m^2) and h_3 liquid level in tank3 (m)

$$F_2 = h_1/R_1 \quad (4)$$

$$F_2 = h_2/R_2 \quad (5)$$

$$F_4 = h_3/R_3 \quad (6)$$

Where,
R_1, R_2 and R_3 linear resistance value of tank1, tank 2 and tank3 ($m/(m^3/s)$) .The general transfer function of non interacting three tank system is given by,

$$H_3(S)/F_1(S) = R_3/(\tau_1 S + 1)(\tau_2 S + 1)(\tau_3 S + 1) \quad (7)$$

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By considering $A_1=A_2=1.0\ m^2$; $A_3=0.52m^2$ and $R_1=2.2(m/m^3/s))$; $R_1=2.2\ (m/m^3/s))$; $R_3=4.1(m/m^3/s))$

$$H_3(s) / F_1(s)= 4.1 / (2s+1) (2s+1) (2s+1) \quad (8)$$

4. DESIGNING OF THE PID CONTROLLERS

a) Designing By Ziegler-Nichols method

Mathematical model is unavailable, the parameters must be determined experimentally. Controller tuning is the process of determining the controller parameters which produce the desired output [11]. Controller tuning allows for optimization of a process and minimizes the error between the variable of the process and its set point .Types of controller tuning methods include the trial and error method, and process reaction curve methods . The most common classical controller tuning methods are the Ziegler-Nichols and process reaction curve methods. These methods are often used when the mathematical model of the system is not available. The Ziegler-Nichols method can be used for both closed and open loop systems, while process reaction method is typically used for open loop systems [12]. A closed-loop control system is a system which uses feedback control.

b) Design of PID controller for three tank system

The output of the process is measured and its value is compared with the current set point to generate the error signal. The controller acts upon this error to generate a corrective action. The controller output and the error can be related by the following ways:[13]

(i) The controller output is proportional to the error;
(ii) The controller output proportional to the integral of the error;
(iii) The controller output proportional the derivative of the error.

In this paper Zeigler-Nichols (Z-N) tuning method is used to find the controller parameters [14]. The controller parameter for different arrangements of three tank system is provided in the Table-1.

Table-1. Ziegler-Nichols ultimate sensitivity test.

Types of Controller	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$0.833T_{cr}$	0
PID	$0.6K_{cr}$	$0.5T_{cr}$	$0.125T_{cr}$

The servo and regulatory responses of the non interacting and interacting three tank system is obtained and analyzed under P, PI, and PID controllers. Frequency-domain stability analysis tells that the above way of applying the Ziegler–Nichols step response method to processes with self-regulation tends to set the parameters on the safe side, in the sense that the actual gain and phase margins become larger than the values expected in the case of integrating processes [15]. These methods to determine PID parameter using empirical formula, as well as several other tuning methods developed on the same principle, are often referred to as "classical" tuning methods.

5. RESULTS AND DISCUSSIONS

In this paper, a dynamic model of a three tank liquid level system has been designed and implemented in MATLAB. The parameters obtained by using Ziegler-Nichols rules are used in the formation of the initial boundary limits for the intervals for the design parameters are to control the controller by minimizing the error, and hence the determination of the optimum parameters for the plant. The results have been presented in Table-2.

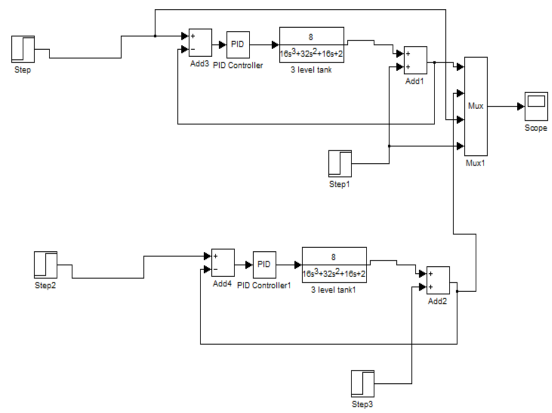

Figure-5. Simulink diagram for PID controller.

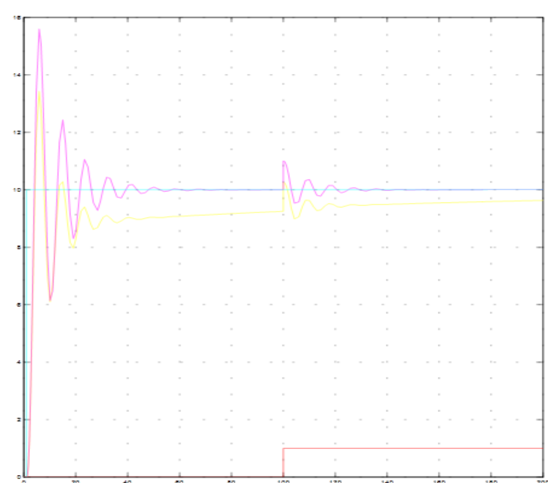

Figure-6. Responses of three tank non interacting system (MATLAB screen).

Curve-I: PI controller
Curve-II: PID controller

Table-2. PID tuning result.

controller		Non Interacting System
P	K_c	1
PI	K_c	0.9
	T_i	5.8
PID	K_c	1.2
	T_i	3.5
	T_d	0.875

Implementation of Fuzzy logic controller

The simulink model of three tank system with fuzzy controller shown in Figure Mamdani type fuzzy logic controller is developed for three tank system shown in Figure the inputs (error and feedback) and output with triangular membership functions are shown in Figure.

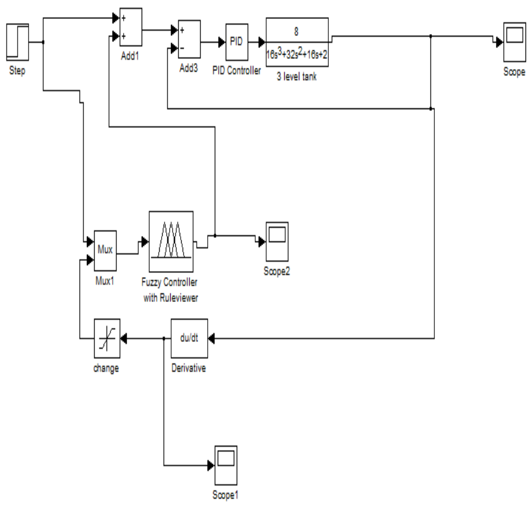

Figure-7. Simulink diagram for Fuzzy controller.

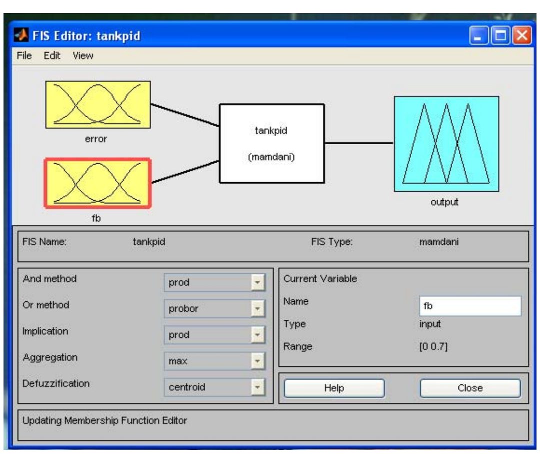

Figure-8. Mamdani type fuzzy logic.

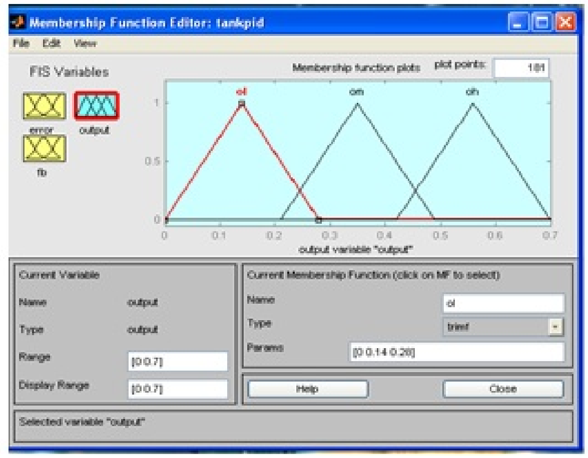

Figure-9. Membership functions for output.

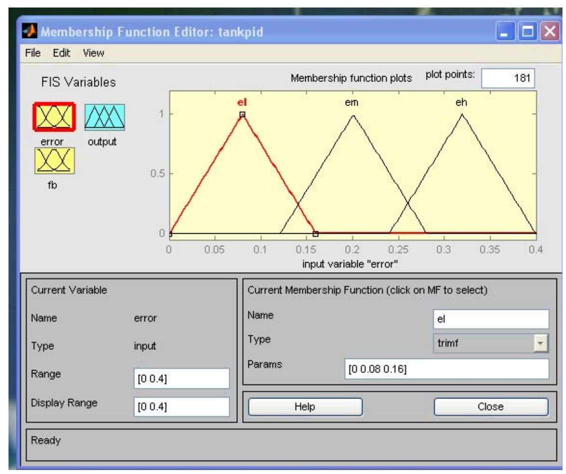

Figure-10. Membership function of error signal.

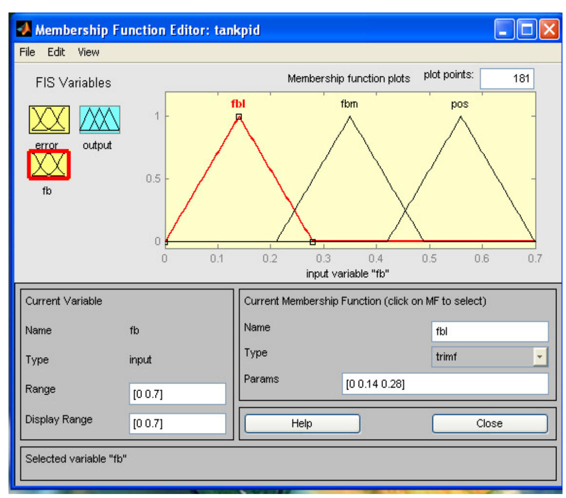

Figure-11. Membership functions for feedback.

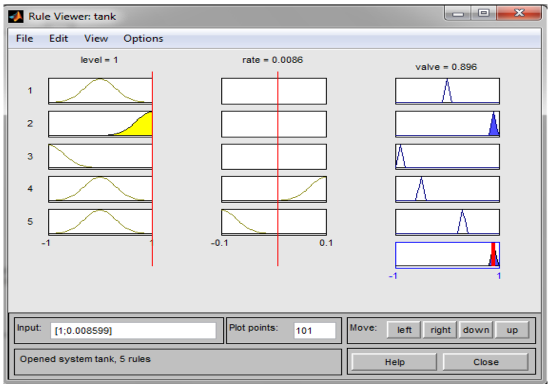

Figure-12. Fuzzy controller rule viewer.

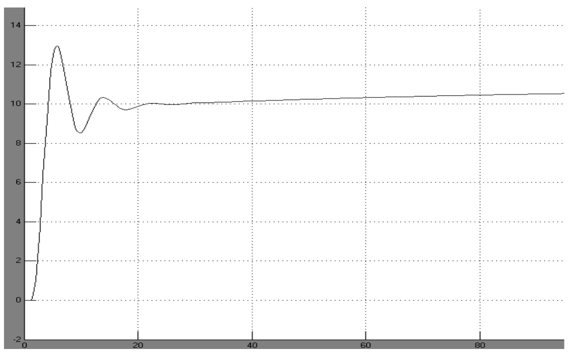

Figure-13. Response of three tank non interacting system under fuzzy logic controller.

6. CONCLUSIONS

The use of Integrated PID based intelligence control for three tank system as presented in this paper offers advantages of decreased peak overshoot percentage and settling time. This Ziegler-Nichols tuning method is better than the other tuning method. Because the rise time is better in this case of response. An added advantage of this response of controller obtained after optimization offers a lesser oscillatory response when compared to conventional method and so promises a better and smooth operation of the system. Results when compared with the conventional tuning parameters, it has proved superior in achieving the steady-state response and performance index.

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