Auto Tuning PID Controller for Multi-tank Process

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ABSTRACT
In process industries, control of liquid level in the process tank is important and complicated issues. In this work, authors have represented a case study involving mathematical modeling, system identification, and controller design of a three tank conical interacting level system (TTCILS). A nonlinear tank is identified mathematically and an auto tuning method of PID controller is implemented in simulation environment. The effectiveness of the control scheme has been studied on a TTCILS process in MATLAB environment.

General Terms
Process Control, Control System, Nonlinear Process.

Keywords
Nonlinear Tank, Auto Tuning Controller Scheme, MATLAB, Interacting Process.

1. INTRODUCTION
Since many of our chemical engineering processes are nonlinear, it would seem advantageous to use nonlinear controllers in some systems. The idea is to modify the controller action and settings, in some way to compensate for the nonlinearity of the process. PID controller and other linear controllers were the most popular control schemes that have been widely implemented throughout the chemical process industries for the past decades. However, control of nonlinear system using above linear control schemes don't give satisfactory performance at all operating points, the reason being that the process parameters of the nonlinear process will vary with the operating conditions.

In industrial environment PID controllers are widely used as combination of proportional, integral and derivative action. Combination of this action regulates its output. The PID control was first proposed in the market in the year 1939 and has remained the most widely used controller in process control until today.PID (Proportional Integral Derivative) controllers are important elements in various engineering applications. A Proportional Integral Derivative controller (PID) is a generic control loop feedback mechanism widely used in industrial control systems. The PID parameters used in the calculation must be tuned according to the nature of the system. In general, these three parameters i.e. the proportional (Kp), integral (Ki) and derivative (Kd) are determined according to several Open-Loop and Closed Loop step Response Methods, such as Ziegler-Nichols method [1],

Cohen-Coon method [2] and IMC [4]. J. Prakash, K. Srinivasan, have proposed a simple and straightforward procedure for designing a Nonlinear PID control (N-PID) scheme and Nonlinear Model Predictive Control scheme (F-NMPC) using local linear models for the CSTR process[3].[6]Discusses in detail about the simulated annealing (SA) algorithm, a CI technique, and its implementation in PID tuning. Simple robust estimation techniques provide new methods for automatic tuning of PID regulators which easily can be incorporated in single loop controllers [8]k. J. Astrom and t. Hagglund. The auto tuning technique of PID controller is adopted for more reliable and precise controlaction which incorporate the uncertain factors also Farhad Aslam, Mohd. Zeeshan Haider[9] the comparison of the conventional PID and auto tuning is clarified. In most of the chemical plants, level control is extremely important because desired production rates and inventories are achieved through proper control of flow and level. The performance of some processes such as chemical reactors depends critically on the residence time in the vessel which in turn depends on the level. At this point it is clear that level control is an important control objective.

Here, an inverted conical shaped process is taken, conical tanks are highly preferred for industrial storage process because of its shape it is more difficult to maintain the liquid level. It has nonlinear structure so effective control essential for the process to maintain the liquid level at particular point[10].

Pressure acting in the conical tank is different at each point, the liquid filled in the tank varies with respect to the inclination angle through which the tank is designed and in this article, three inverted conical tanks are arranged in series connection of interaction. It should be noted that, to achieve improved closed loop performance a different set of controller settings for each operating condition have been proposed. The process setup is considered as single input and single output i.e. tank1 has inlet upstream valve and tank3 has outlet downstream valve.

This paper addresses the implementing of PID parameters in two design modes called Basic design mode and extended design mode. PID Tuner provides a fast and widely applicable single-loop PID tuning method for the Simulink PID Controller blocks. With these methods, tuning of PID parameters is performed to achieve a robust design with the desired response time. PID controller is tuned by manually adjusting design criteria in two design modes. The tuner computes PID parameters that robustly stabilize the system.

In this work, the basic design mode is the original Ziegler Nichols scheme, described in Ziegler and Nichols (1943), the critical gain and the critical period are determined in the following way: a proportional regulator is connected to the system; the gain is gradually increased until an oscillation is obtained; the gain when this occurs is the critical gain and the period of the oscillation is the critical period. It is difficult to automatize this experiment, and perform it in such a way that the amplitude of the oscillation is kept under control. The method is based on the observation that a system with a critical gain K_u at high frequencies may oscillate with period P_u under relay control. To determine the critical gain and the critical period, the system is connected in a feedback loop with a proportional gain constant. It is also desirable to adjust the gain automatically. A reasonable approach is to require that the oscillation is a given percentage of the admissible swing in the output signal. The PID controller is tuned form oscillatory response parameters.

2. PROCESS DESCRIPTION

A dynamic model of this process contains ordinary differential equations , which arise from the mass balance on each of the tanks, the process sketched is shown in figure 1 consists of three inverted conical shaped process tank is taken for consideration as interacting system; tanks are connected in series. The process setup is considered as single input and single output. The structure of conical tank is nonlinear, so it is sliced into two regions to provide control action for each section separately. The feed of water to the tank comes from an upstream unit of tank1at the rate of 198 LPH. The liquid level in the tank3 is rises to 14.09 cm, and then inflow rate again increased to 132 LPH, liquid level attains steady state at 39.14 cm, liquid level is measured by using Differential Pressure Transmitter (DPT) and is controlled by manipulating the flow rate of liquid pumped from the tank1. The liquid level i.e. height h3 is maintained at desired level. Total radius of the cone 'R' is 19.25 cm, Maximum total height of the tank 'H' is 73 cm, Maximum inflow rate of the tank 'Fin' is 400 LPH and the Value co-efficient 'β12', 'β23' and 'β3' has 50.57cm ^{2}/s, 75.25cm^2/s and 14.65cm^2/s respectively.

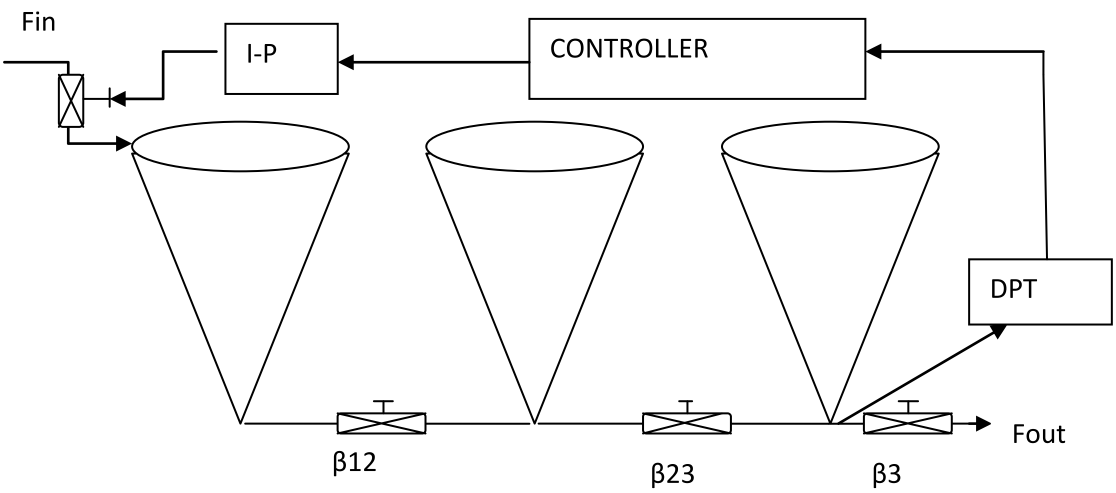

Fig 1: Three tank conical interacting system

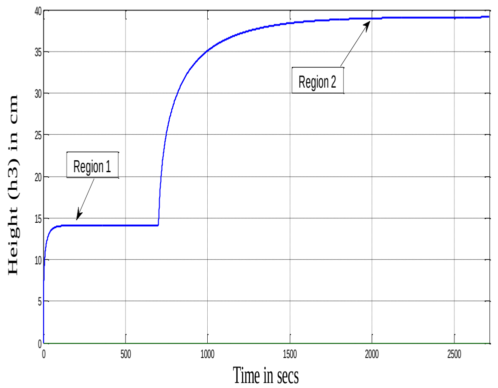

Fig 2:Simulated Response of Height in Tank 3

3. MATHEMATICALMODELING

The physical law governing the behavior of the liquid level system as described here is the principle of conservation of mass, which states that the time rate of change of the fluid mass inside the tank is equal to the mass flow rate in minus the mass flow rate out of the tank at time instant 't'.

Input – Output = Rate of Accumulation

Using the mass balance principle, we now derive the nonlinear differential equations for each tank[7].

Tank1,

$$\frac{dh1}{dt} = \left(\text{Fin1} - \beta12\sqrt{h1 - h2}\right) * \frac{1}{A(h1)}$$

Tank2,

$$\frac{dh2}{dt} = \left(\beta12\sqrt{h1 - h2} - \beta23\sqrt{h2 - h3}\right) * \frac{1}{A(h2)}$$

Tank 3,

$$\frac{dh3}{dt} = \left(\beta23\sqrt{h2 - h3} - \beta3\sqrt{h3}\right) * \frac{1}{A(h3)}$$

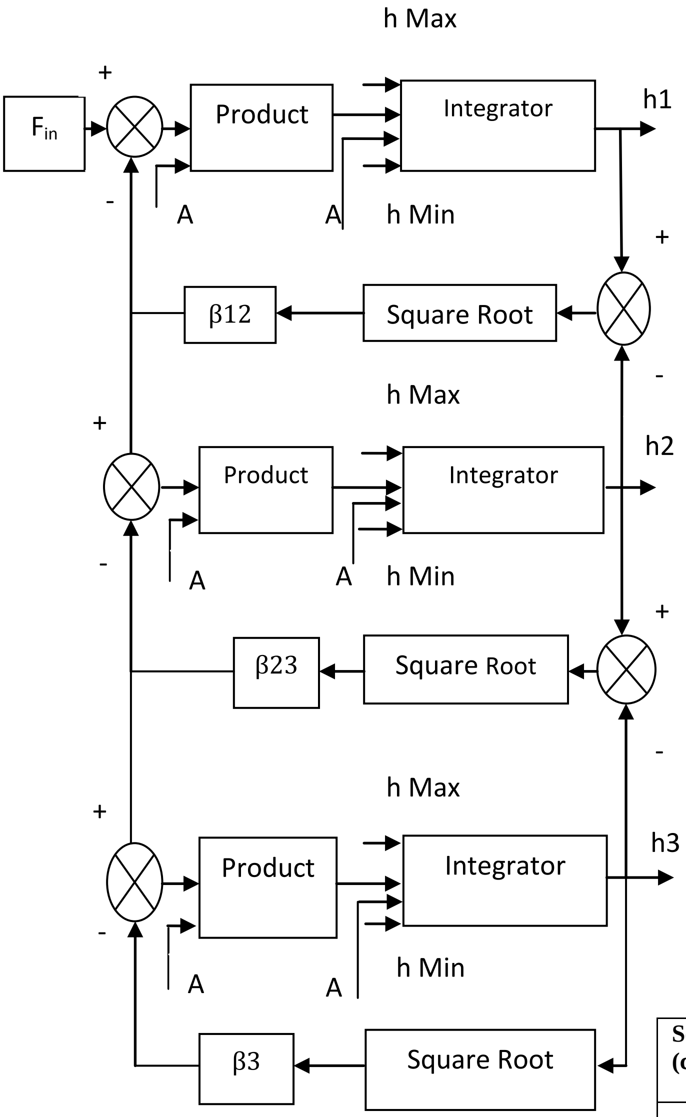

Fig 3: Simulink Model of Three Tank Conical Interacting System

The above shows the SIMULINK schematic diagram open loop model is implanted in MATLAB model window.

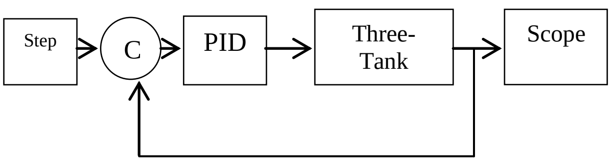

Fig 4:Closed Loop Structure of TTCILS

Here, by keeping integral and derivative gain in zero, by changing proportional gain, critical gain Ku and ultimate period Pu is obtained from sustained oscillation. Using the values of critical gain and ultimate period, the controller parameters were calculated and implemented in PID controller block.

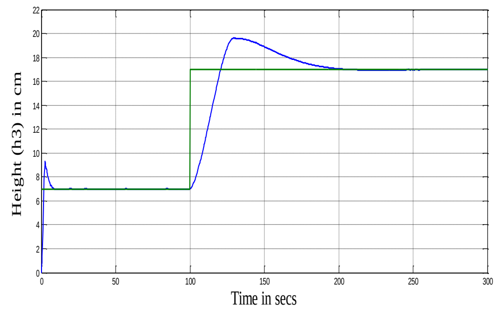

Fig 5: Response of height in tank 3 for conventional PID controller

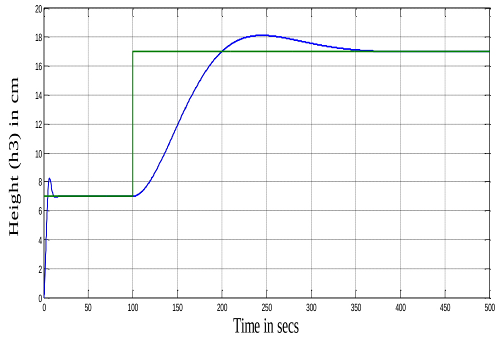

Fig 6: Response of height in tank 3 for extended design of PID controller

The above result shows the response of liquid level in tank 3 with respect to change in reference values7 cm and 17 cm in two different methods of control action.

Table1. Comparison of Control Action

Set Point (cm)	Controller	Tr (sec)	Ts (sec)	Over shoot (%)	IAE	ISE
7	ZN-PID	1.8	15	20	13	44
	Auto-tuning	4.5	11.5	18	22	94
17	ZN-PID	21	120	28	218	1032
	Auto-tuning	100	190	11	618	3821

4. CONCLUSION

Simulation based auto tuning of PID controller in extended mode design and conventional type were designed and implemented in MATLAB environment. The performances of controllers were studied on the basis of rise time (Tr), settling time (Ts) and overshoot are tabulated in table 1. From Figure 5 and Figure 6, auto tuning of PID controller based on extended mode which gives better performance than conventional PID controller.

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