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Comparison of PID Controller Tuning Techniques for a FOPDT (First Order Plus Delay) System

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Abstract: *Flow is a non-linear rapid process when compared to other process in process industry and controlling the same is quiet challenging for which Set point tracking algorithm is employed by the method of soft computing. It is done by PID (proportional-integral-derivative), IMC and IMC-PID.A PID controller is otherwise called as three term control which has three constant parameters and it takes the present error, accumulation of past errors and prediction of future errors into account based upon the current rate of change of error respectively. The objective of this paper is to compare IMC (Internal Model Control) with conventional tuning methods for single input single output (SISO) systems such as Z-N, modified Z-N, C-H-R and to predict the most efficient controller. The factors for comparison include time domain specifications and performance of the controller. These parameters are implemented in Mat lab platform, in which IMC-PID outperformed well when compared to all other controllers in terms of time domain specification and performance indexes.*

Keywords: *IMC, IMC-PID, Flow, MATLAB, PID, SISO.*

1. Introduction

In Many industrial Units, controlling the flow of liquid is the essential criteria for obtaining Optimum result in the plant. In recent years, flow control has turn into an extremely multi disciplinary research activity encompassing theoretical, computational and experimental fluid dynamics. Many controllers have developed for controlling the flow parameter in many industrial plants. Most commonly used and the conventional controlled is proportional - integral - derivative (PID) controller which came into existence. It is being used even today since it provides generic and efficient solution for real world control problems. Hence it is widely accepted in major process industries. It is designed to eliminate the continuous operator attention. In this study we have compared various tuning techniques for PID controllers. To achieve optimum performance following are essential, Dynamic model of the system, Desired closed loop performance on the basis of known physical parameters, Adopting controller strategies for desired performance, Implementation of the controller using suitable platform, Validation of controller performance. The controllers such as ZN-PID, Modified ZN-PID, and CHR with 0% overshoot and IMC-PID are designed for the flow process. In which IMC-PID gives better performance when compared to other controller in terms time domain specification and performance indices. IMC-PID is the most common controller used in the flow process. Disturbance rejection is the important criteria in IMC-PID, than set point tracking, but it results in long settling time. The tuning factors produced long outstanding performance and give better performance. By varying the tuning parameter the controller output get better performance.

Even though Conventional Controller (PID) controller has three tuning parameter and are used in many industrial plant, finding an opposite setting is not an easy task in PID controller so that we are going for many other controller in real time implementation of industrial plants. The problem in PID controller is overcome by many sophisticated controller such as IMC-PID, CHR etc.

2. EXPERIMENTAL SETUP

The main aim of flow process is to control the outlet flow in the process. The Flow Process is the fast and nonlinear process. The schematic diagram of flow process contains flow sensors like orifice, venturimeter, Pitot tube, flow nozzle etc.

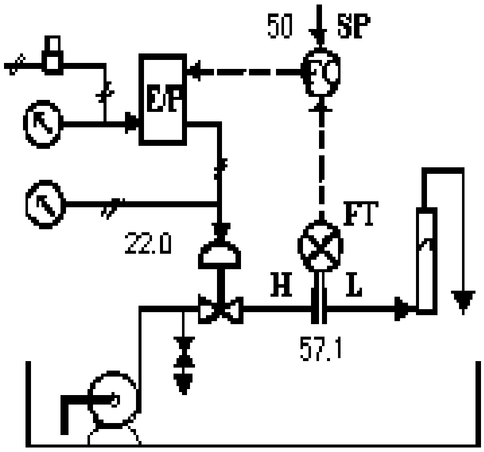

Fig 1: *Experimental Setup*

Mathematical Modeling:

The development of a process model plays a vital role in process model. The Transfer function of the process in determined by process reaction curve method (PRC), First Order plus Dead Time (FOPDT) model is obtained by the process reaction curve method.

$$G(s) = \frac{Ke^{-\tau ds}}{\tau s + 1}$$

3. CONTROLLER TUNING

The open loop method refers to the tuning of controller when it is in manual state and the system is said to be in open loop configuration. The closed loop method refers to tuning of controller when it is in automatic state and the system is said to be in closed loop configuration. The closed loop methods considered for simulation are

1. Ziegler-Nichols method
2. Modified Ziegler-Nichols method
3. C-H-R method
4. IMC method

3.1. Ziegler –Nichols Method

This method is a trial and error tuning method based on sustained oscillations that was first proposed by Ziegler and Nichols (1942) this method that is probably the most known and the most widely used method for tuning of PID controllers is also known as or online or continuous cycling or ultimate gain tuning method. Having the ultimate gain and frequency (Ku and Pu) and using Table 1, the controller parameters can be obtained. A ¼ decay ratio has considered as design criterion for this method. The main advantage of this method is that it does not require a process model.

Table1:

CONTROLLER	Kc	τ_i	τ_d
P	$0.5k_u$	-	-
PI	$0.45k_u$	$P_u/1.2$	-
PID	$0.6k_u$	$P_u/2$	$P_u/8$

3.2. Modified Ziegler-Nichols Method

For some control loops the measure of oscillation, provide by ¼ decay ratio and the corresponding large overshoots for set point changes are undesirable therefore more conservative methods are often preferable such as modified Z-N settings These modified settings that are shown in Table 2 are some overshoot and no overshoot.

Table 2:

CONTROLLER	K_c	τ_i	τ_d
Some overshoot	$0.33k_u$	$P_u/2$	$P_u/3$
No overshoot	$0.2k_u$	$P_u/2$	$P_u/3$

3.3. C-H-R Method

This method that has proposed by Chien, Hrones and Reswich is a modification of open loop Ziegler and Nichols method. They proposed to use “quickest response without overshoot” or “quickest response with 20% overshoot” as design criterion. They also made the important observation that tuning for set point responses and load disturbance responses are different.

Table 3:

CONTROLLER	K_c	τ_i	τ_d
PID	$(0.6/k_m)(\tau_m/d)$	τ_m	0.5d

3.4. Internal Model Controller

The internal model control philosophy relies on the internal model principle, which states that control can be achieved only if the control system encapsulates either implicitly or explicitly, some representation of the process to be controlled. Morari and his co-workers have developed an important new control system strategy that is called internal model control or IMC. The IMC approach has two important advantages: a) It explicitly takes into account model uncertainty and (b) it allows the designer to trade-off control system performance against control system robustness to process changes and modeling errors.

Table 4:

CONTROLLER	K_c	τ_i	τ_d
PID	$2+d/2(\lambda+d)$	$\tau+(d/2)$	$\lambda d/(2\tau+d)$

4. RESULT AND COMPARISON

The IMC controller is designed for flow process. IMC controller is compared with different conventional controller it is examined that IMC outperformed in terms of time domain specification and performance indices.

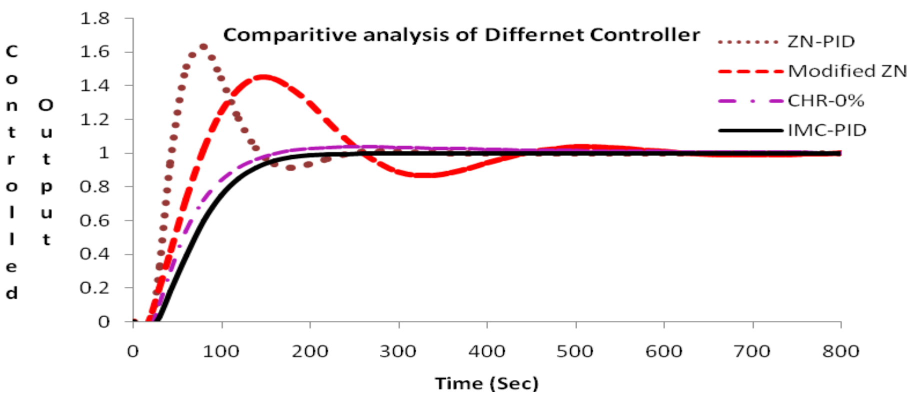

Fig: 2 *Simulated Results for the Controllers*

Table 5. *Comparisons of Time Domain Specifications*

Tuning method	PEAK OVERSHOOT	RISE TIME	SETTLING TIME	PEAK TIME
Z-N	65%	16.74	353	74.1
MODIFIED Z-N	46.8%	47.71	988	151.565
CHR- 0% OVERSHOOT	3.56%	86.26	800	250
IMC	-	98.86	260	-

Table 6. *Comparison of Performance Index*

Tuning method	IAE	ITAE	ISE	MSE
Z-N	288.8405	4.6029e+003	350.0312	1.4910
MODIFIED Z-N	255.3775	4.6405e+003	334.2930	1.6106
CHR- 0% OVERSHOOT	295.0900	7.9014e+003	304.1553	1.2048
IMC	309.8544	1.0864e+004	319.138	1.0618

From the above time domain specifications IMC have very negligible peak overshoot than other methods .Z-N have sitting time slight higher than IMC .Modified Z-N method when compared with other methods have higher value in specifications so the proposed controller for this method should be IMC

5. CONCLUSION

The obtained transfer function is processed by PID controller tuning method using three parameters such as proportional band, integral time and delay time and from that proportional gain, integral gain and derivative gain are obtained. The values obtained from different tuning methods are simulated using MATLAB and the corresponding time domain specification and performance index are tabulated. From the tabulation it is clear that IMC have better efficiency when compared to other tuning methods for instance it is clear that it has the least settling time than any other tuning methods possess. So from that it is concluded that IMC is the suitable and efficient controlling method for flow processing systems further its scope is vast for other applications too.

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