IJIREEICE

ISSN (Online) 2321 – 2004
ISSN (Print) 2321 – 5526

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH IN ELECTRICAL, ELECTRONICS, INSTRUMENTATION AND CONTROL ENGINEERING
Vol. 4, Issue 2, February 2016

Comparison of Tuning Methods of PID Controllers for Level Process for Single Tank System

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Abstract: In process industries, the automatic controllers has been introduced as an efficient controllers. PID controllers are the most widely used controllers because of their robustness and simplicity and economical. One of the major controlling parameter in industries are considered to be the level process. In today's industrial environments ,level measurements have the wide variety needs and applications.In this paper, the main objective is the comparison of tuning of PID to maintain the level of water in the liquid tank. The analysis has been done using Ziegler-Nicholas(ZN), Internal Model Control(IMC) and Chien, Hrones and Reswich(CHR) methods. The comparison is done between the performance criteria and time domain specifications. These parameters are implemented in MATLAB platform and found that the IMC has outperformed well when compared to other controllers.

Keywords: PID controllers, IAE, ISE, ITAE, MATLAB.

I. INTRODUCTION

The Proportional Integral and Derivative Controllers are widely used in industrial and process control applications. PID controller is designed by obtaining the basic transfer function of a process. The transfer function and controlled parameters such as proportional gain, integral time, derivative time has been determined for particular temperature process. Comparisons of Time Domain specifications of those controllers has been carried out and also the performance error criterians like Integral Absolute Error (IAE), Integral Square Error (ISE), Integral Time Absolute Error (ITAE), Mean Square Error (MSE) has also been compared. PID controller enhances the transient response of a system by denigrating the overshoot and by holding the settling time of a system.

$$Gc(S) = Kp\left[1 + \frac{1}{TIS} + TDS\right] = Kp + \frac{KI}{S} + KDS \ldots\ldots (1)$$

Where

$Gc(S)$ is the Transfer function of the PID Controller

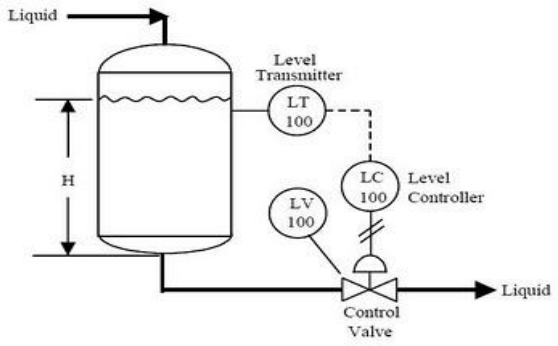
Kp is the Proportional Gain

KI is the Integral Gain

KD is the Derivative Gain

II. PROCESS SETUP

The Level process setup consists of a cylindrical tank, a water reservoir, pump, Rota meter, and a differential pressure transmitter, a current to pressure converter (I /P converter), a pneumatic control valve, and a personal computer(PC).The pressure difference is calculated using Differential Pressure Transmitter .It also senses the current signal and sends it to the display box.The current to pressure converter converts the current signal (4-20mA) to pressure signal (3-15psi).The control valve is used to adjust the flow. The purpose of Level Transmitter is to sense the level and produce an output current.



III.CONTROLLER TUNING METHOD

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. C-H-R method
3. IMC method

A. Zeigler Nichols Method

This method is a trial and error tuning method based on sustained oscillations that was first proposed by Ziegler and Nichols. This method is probably the most known and widely used method for tuning of PID controllers. It 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 Table1, 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.

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Table 1:

CONTROLLER	Kc	τi	τd
P	0.5Ka	-	-
PI	0.45Ka	Pu/1.2	-
PID	0.6Ka	Pu/2	Pu/8

B. C-H-R Method

This method that has proposed by Chien, Hrones and Reswich. It 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 2:

CONROLLER	Kc	τi	τd
PID	(0.6/Km)(τm/d)	τm	0.5d

C. Internal Model Controller Method

The internal model control philosophy depend upon on the internal model principle. It states that the 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.

b) it allows the designer to trade-off control system performance against control system robustness to process changes and modeling errors.

Table 3:

CONROLLER	Kc	τi	τd
PID	2+d/2(λ+d)	τ+(d/2)	λd/(2τ+d)

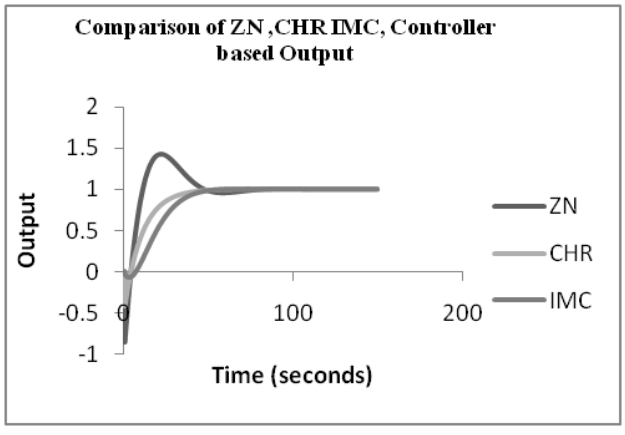

Table 4: Comparison Of Time domain specifications

Tuning Method	Peak Overshoot	Rise Time (seconds)	Settling Time (seconds)	Peak Time (seconds)
Z-N	0.45	12.5	105	22
CHR	-	30	75	75
IMC	-	35	70	70

Table 5: Comparison Of Performance Index

Tuning Method	*IAE*	*ITAE*	*ISE*	*MSE*
Z-N	124.1195	1.616E+004	0.1084	1.599E-008
CHR	129.0506	1.2998E+004	0.0075	6.1401E-004
IMC	166.4060	6.634E+003	0.0255	0.0015

IV. COMPARISON AND RESULT

A tabulation of the time domain specifications comparison and the performance index comparison for the above tuning methods are tabulated and compared. The time domain specifications are peak time, rise time, settling time and peak overshoot and performance indices are ISE, ITAE, ISE and ITAE.

From the above time domain specifications IMC have very negligible peak overshoot than other methods .Z-N have setting time slightly higher than IMC.

V. CONCLUSION

Tuning parameters of PID controller are estimated by seven tuning methods (Z-N method, C-H-R method, IMC method, ISE, ITE, ISAE and ITAE) for level process for using Matlab/Simulink. 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. it is also clear that it has the least settling time than other tuning methods. So from that it is concluded that IMC is the suitable and efficient controlling method for level processing systems. This method can be also used in a variety of non-linear process control systems with large transportation lag processes. This paper will be extended in future to the evolutionary algorithms to determine optimum PID tuning parameters.

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