Comparison of Pid Controller Tuning Method For Flow Process

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Abstract— Instrumentation predominantly involves measurement of various variables both in process and manufacturing industries. Flow measurement plays an important role in every sector of our day to day life starting from a water dispenser in our home to a large scale solution mixture flow measurement in a tank in chemical industries. For the flow process described below we have employed Tuning methods like Cohen Coon- CC, Ziegler Nicholas-ZN, Internal Model Control- IMC for the PID controller used, and the Premier Controller is found using Time Integral Performance Criteria like-ISE- (Integral of the Square error), IAE- (Integral of the absolute value of the error), ITAE- (Integral of the time-weighted absolute error), MSE- (Mean square error), and based on the conclusions made, it is seen that IMC is the best for controlling flow in the (FOPDT)-First Order with Dead Time process since it provides good set point tracking.

Key words: PID Controller, CC, ZN, IMC, Time Integral Performance Criteria, Flow Process

I. INTRODUCTION

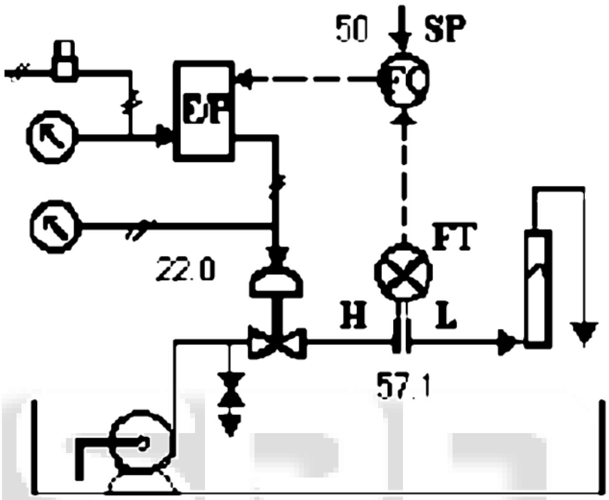
Flow is elementarily the volume of a fluid flowing per unit time. In many sophisticated applications in Industries like Food processing, Packing Sectors that employ assessment of both solid and fluid flow accurately, proper manipulation of flow and its related variables are of utmost importance. This paper aims at the robust analysis of a flow process control system

Generally, Process Control strategy consists of the following entities-Process to be controlled, the Controller. The variables are measured using suitable sensors and signals are given to the respective Final Control Elements from the Transmitters. Closed loop process is considered far better than open loop since it provides better controllability and robustness.

PID is a high level controller combination that has all the advantages of Proportional, Integral, Derivative controllers, as it anticipates future errors and uses history of errors for better control of the process The process of designing a controller is of vital importance in process control automation. When a controller design is based on an assumed model and implemented on the actual point, its close loop performance may be arbitrarily poor depending on the extent of mismatch between the model and the process. So we studied model uncertainty (model plant mismatch) more carefully and evaluated its impact on the expected performance of the control system. Apart from the objectives, stability and performance in designing a control system to maintain it’s above mentioned properties in the presence of model uncertainty.

Since PID Controller is used frequently in many industries, the robustness in PID controller should be eliminated because the desired output cannot be obtained. So we are going for conventional methods in PID controller like ZN-PID, CC-PID and IMC-PID.In this paper we describe that IMC-PID controller gives better performance in terms of performance indices and time domain specification.

II. EXPERIMENTAL SETUP OF THE PROCESS



The experimental setup of the flow process consists of an orifice meter, venturimeter, Pitot tube, flow and nozzle arrangement. Water is pumped by means of a pump to measure the flow. Control valve controls flow that is in turn measured by the orifice and venturimeter. This device is interfaced with a computer or an microprocessor to control the flow. The setpoint specified will be transmitted to the final control element- valves and so error is made zero, as the controller must track the setpoint.

III. MATHEMATICAL MODELING

The Controller design is the most important technique in any process. The transfer function of the process is determined by process reaction curve method. The first order plus dead time (FOPDT) is determined by the process reaction curve method.

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

IV. CONTROLLER TUNING TECHNIQUES

Tuning methods are classified intoopen loop tuning-tuned for a process in open loop state, closed loop tuning-process tuned in closed loop condition. The open loop method refers to tuning of controller using manual operation,so it will not suit for controlling the process in real time. Closed loop controller refers to different tuning techniques that are used in real time application.

A. Z-N Method:

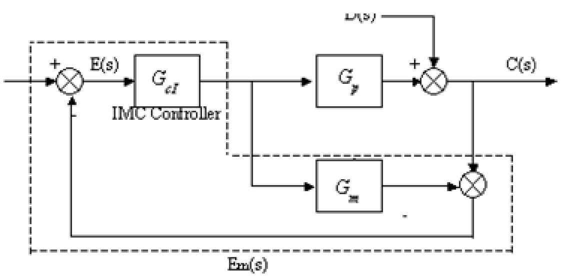
The Ziegler–Nichols tuning method (1942) ultimate-cycle tuning method, is a PID controller tuning method. It was developed by John G. Ziegler and Nathaniel B. Nichols. It is performed by setting the *I* (integral) and *D*(derivative) gains to zero. The "P" (proportional) gain, K_P is then increased (from zero) until it reaches the ultimate gain K_u, at which the output of the control loop oscillates with a constant amplitude. K_u and the oscillation period T_u are used to set the P, I, and D values.[5

Controller	K_C	T_I	T_D
P	$0.5K_u$	-	-
PI	$0.45K_u$	$P_u/1.2$	-
PID	$0.6K_u$	$P_u/2$	$P_u/8$

Table 1: Controller Parameter of ZN Tuning Technique:

B. Internal Model Control (Imc):

Morari developed a control system strategy called Internal Model Control or IMC. The IMC approach has important advantage of explicitly taking into account the model uncertainty. The block diagram of IMC is shown in which G_c is the controller design for the given process, the model and the plant transfer function are placed parallel to each other. It is used for the reason that the robustness of the process and inaccuracy in the process are get eliminated and the desired output is reached.



In IMC controller the filter parameter are chosen in such a way that desired output is reached. Hence the dead time in the process are approximated so that it performs better.

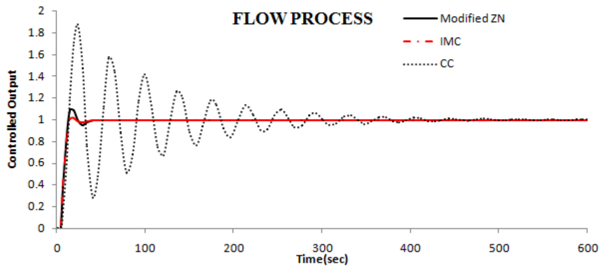
Controller	K_C	K_i	K_d	λ/d
PI	$\frac{T}{\lambda}$	T	-	>1.7
PID	$\frac{2T+d}{2(\lambda+d)}$	$T+\frac{d}{2}$	$\frac{\lambda d}{2T+d}$	>0.25

Table 2: Controller Parameter of IMC

C. Cohen Coon Method:

Cohen Coon (CC) method uses open loop transfer function PID parameters for tuning.This method is best suited for systems with large deadtime (td) when compared with time constant. This method aims for quarter amplitude damping response.

Controller	K_c	T_i	T_d
P	$\frac{T}{K_c * T_d}\left[1+\frac{T_d}{3T}\right]$	—	—
PI	$\frac{T}{K_c * T_d}\left[0.9+\frac{T_d}{12T}\right]$	$\frac{T_d\left[30+3\left(\frac{T_d}{T}\right)\right]}{9+20\left(\frac{T_d}{T}\right)}$	—
PID	$\frac{T}{K_c * T_d}\left[\frac{4}{3}+\frac{T_d}{4T}\right]$	$\frac{T_d\left[32+6\left(\frac{T_d}{T}\right)\right]}{13+8\left(\frac{T_d}{T}\right)}$	$\frac{4T_d}{11+2\left(\frac{T_d}{T}\right)}$



Comparison of Time Domain Specification:

Tuning Method	Rise Time	Settling Time	Peak Time
Modified ZN	20	50	0.2
CC	25	600	0.9
IMC	15	30	0.01

Time Integral Performance Criteria are also used to determine the best method of tuning for a process, since it sues entire system response into account . They are:

IAE: (Integral Absolute Error) Eliminates smaller numbers as it involves squaring of the values.

ISE: (Integral Square Error) Suppresses large errors through squaring.

ITAE: (Integral Time Absolute Error)To suppress errors that exist for a long time.

MSE: (Mean of the Squared Error) Focuses on large errors and eliminates the negative positive errors.

Comparison of Time Integral Performance Criteria:

Tuning Method	Iae	Ise	Itae	Mse
IMC	88.8893	70.6605 0.0142	6.8099e+003	263.3350
Modified ZN	3.8825e+003	9.1115e+004 1.097e-005	4.7693e+003	117.6814
CC	3.405e+003	3.5327e+004 2.8307e-	5.1341e+003	138.4722

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V. RESULTS

Due to their inability to cope with uncertainties and non-linearity, conventional tuning methods are not that as agile as IMC, as it provides transparent framework for control system design and tuning. It is widely used in various industries like chemical industries due to its robustness, and for being successful in practical applications. IMC is better for set point tracking for an unstable system.

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