Comparative Study of Performance in Three Mode Controller Tuning

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Abstract - A three mode Proportional–Integral–Derivative (PID) controller has a record in the automatic control field starting from the beginning of 1900. In recent times, it has been noticed that industrialists tune the PID controllers poorly, and some efforts have been made methodically resolve this matter[4]. Several algorithms are being in discussion in industry. Five tuning methods are evaluated based upon their ability to control the plant. The comparison criteria will be peak time, Rise time; Peak overshoots and settling time for an applied step input. The tuning methods chosen were the Ziegler- Nichols and Coohen& Coon open loop methods, the Ziegler- Nichols, Tyerus – Luyhen and Damped oscillation closed loop methods. The order of the system depends upon the order of the actuator, process and the transmitter and in our study, we reflect on a first-order transfer function for each and the third order for the entire system. The performance of different tuning techniques is analyzed and compared with Time.

Introduction

Presently, the PID algorithm is the most popular feedback controller used in industry[1]. Its wide usage can be seen in the chemical and food-processing industries as well as the automotive, electronic, and aerospace manufacturing industries. Since a three mode function that deals with transient and steady-state responses, the Proportional-Integral-Derivative controller offers a trouble-free, low-cost, yet strong algorithm that can provide excellent performance, despite the varied dynamic characteristics of the process or plant being controlled [1], [2], [3].

The capacity of proportional+integral (PI) and proportional+integral+derivative (PID) controllers to balance most practical developed processes have led to their wide acceptance in industrial applications. The PID controller use has been optional for the control of processes with low and medium order transfer functions with small-time delays. The PID control scheme is also well suited when parameter value must be made using tuning rules and when controller synthesis is performed either once or more often due to its facility to permit for easy parameter changes. The success of PID control on the process and manufacturing industry is based upon the ability to become stable and manage around 90% of existing processes. This success is affected, however, by a lack of performance in many applications. It has been reported that a substantial percentage of the installed PID controllers are operated in a manual mode, and that about 65% of the loops in the automatic mode generate a greater variance in closed-loop than in open-loop operation. This deficiency in controller performance is usually the result of a poorly chosen set of operating parameters due to

- Lack of awareness among commissioning personnel and operators,
- Common tuning methods based on criteria that do not match the specific desires, and
- The selection of PID structures, which leads to errors during the application of usual tuning rules.

These and other surveys show that the choice of PID controller tuning parameters is a general problem in many applications. The most basic way to set up controller parameters is through the use of tuning rules. At present, there are numerous literatures on the subject of PID tuning techniques and standards. The problem is that this information is scattered among a large variety of sources and therefore, is not easily communicated to the engineering and industrial community.

A. O'Dwyer has recorded around 408 tuning rules in his book, The Handbook of PI and PID Controller Tuning Rules. There are no single PID algorithm and distinct fields of engineering using closed-loop control have individual algorithms ever since controls systems began to be mathematically analyzed. The engineer responsible for tuning a control loop must be aware of the form of the algorithm used in the PID controller because different manufacturers implement the several algorithms. Controller tuning rules that work properly on one PID architecture may not work correctly on another. Another issue is that many engineers prefer one method of tuning over another due to knowledge or ease of use. The question is which method gives the lowest percent overshoot and settling time consistently for a variety of plants. This is a stimulus behind the work on this thesis on the assessment of tuning techniques used in industry. **Problem formulation**

Consider the following Transfer function of

Actuator $G_V(s) = \frac{2}{S+1}$,

Process $G_P(s) = \frac{3}{S+2}$

Measuring device $G_M(s) = \frac{5}{S+3}$

And hence the Transfer function of the system is$G(s) = \frac{30}{S^3+6S^2+11S+6}$

It is desired too improve time response (i.e.)

- To decrease the maximum Overshoot (Mp)
- To Decrease the settling time (ts)

The Simulink model is constructed as shown in figure 1.

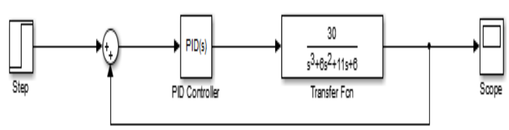

Figure 1. MATLAB Simulation Model

CONTROLLER TUNING

A. Ziegler-Nichols Method

The Ziegler-Nichols open loop methods are the most accepted methods used in process control to determine the parameters of a PID controller [5], [7]. Even though these methods were presented in the 1940s, they are still commonly used. The step response method is based on an open-loop step response test of the process hence requiring the process to be stable; the unit step response of the process is characterized by two parameters L and T. These are determined by a tangent line at the inflexion point, where the slope of the response has its highest value. The intersections of the tangent and the coordinate axes in the sigmoidal response give the process parameters as shown in Figure 2, and these are used in calculating the controller parameters. The parameters for PID controllers obtained from the Ziegler- Nichols step response method is shown in Table1

Table 1. PID parameter for ZN open loop Tuning

Controller Parameter	K_P	T_I	T_D
PID	$\frac{1.2T}{KL}$	2L	0.5L

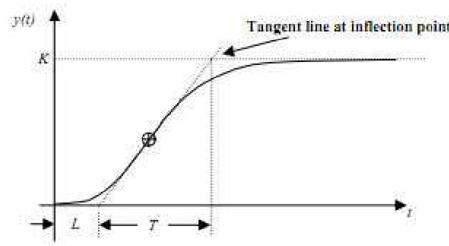

Figure 2. Response curve for ZN method

From MATLAB simulation T and L, values are obtained as T = 6.4 Sec and L = .1.1 Sec The controller parameters for PID controller are calculated as per the Table 1 and with K_P = 1.3964, T_I = 2.2 Sec and T_D = 0.55 Sec, the step response is shown in Figure 3.

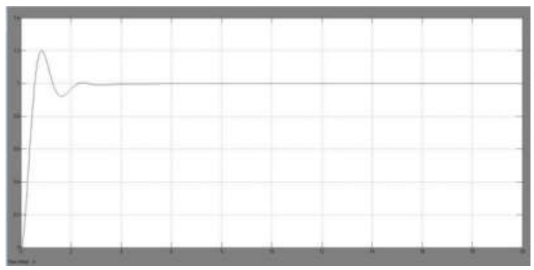

Figure 3 Response for Z-N open loop tuning

B. Cohen Coon Method

The Cohen-Coon method is a modified and more complex version of the Ziegler-Nichols method. This method is more sensitive than the Ziegler-Nichols method. The controller parameters in this method are given in Table 2.

Table 2. PID parameter for Cohen – Coon Tuning

Controller Parameter	K_P	T_I	T_D
PID	$\frac{\tau}{KL}[\frac{4}{3}+\frac{L}{4\tau}]$	$L[\frac{32+\frac{6L}{\tau}}{13+\frac{8L}{\tau}}]$	$L[\frac{4}{11+\frac{2L}{\tau}}]$

K, τ & L is obtained from the open-loop responses as K = 5, τ = 6.4 sec, L = 1.1 sec, K_P = 1.5976, Ti = 2.527 sec therefore, K_i = 1/Ti = 0.3957 and Kd = 0.3879. With the above values of K_P, K_i and K_d, step response is shown in Figure. 4. Mp = 28.14%, ts = 5.846 sec, ess = 0.

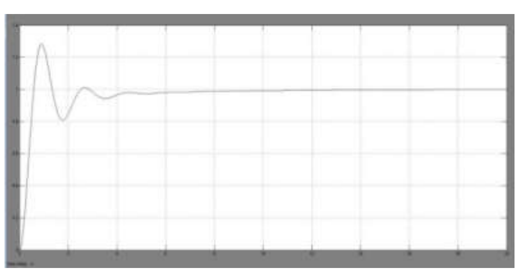

Figure 4 Response for Cohen - Coon tuning

C. Ziegler-Nichols Continuous Cycling Method

This Tuning technique is a closed-loop procedure. In this tuning method, after bringing the integral and derivative effect to a minimum and using proportional control only, introduce a step point change in a given closed loop and vary the proportional gain until the system oscillates continuously. The frequency of the oscillation is the crossover frequency ωco. Let M be the amplitude ratio of the system's response at the crossover frequency. Ultimate gain $K_U = \frac{1}{M}$, and Ultimate period $P_U = \frac{2\pi}{\omega co}$. From the knowledge of KU and PU, Ziegler – Nichols recommended the settings as in Table 3 and the step response is shown in Figure 5.

Table 3. PID controller parameter for ZN closed loop Tuning

Controller Parameter	K_P	T_I	T_D
PID	$\frac{KU}{1.7}$	$\frac{PU}{2}$	$\frac{PU}{8}$

The ultimate gain and the ultimate period are noted from the response as K_U = 2. 00and P_U = 2.9925 sec. The closed-loop response for the calculated parameter for the step input is shown and Mp = 21.6%, ts = 2. 5145sec.

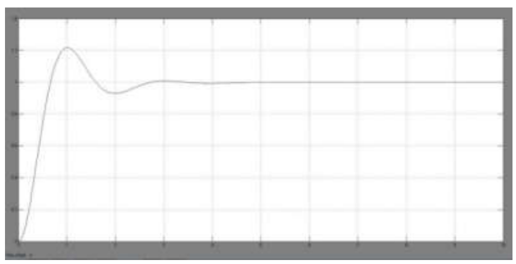

Figure 5 Response for Z-N continuous cycling Tuning

D. Tyreus-Luyben Method (Closed-loop P-Control test)

The Tyreus- Luyben procedure is quite similar to the Ziegler - Nichol's method, but the controller settings are unusual. In addition, this method only proposes settings for PI and PID controllers. These settings that are based on ultimate gain, and period are given in below Table 4 and the step input response is given in Figure 6.

Table 4. PID parameter for Tyreus-Luyben Method

Controller Parameter	K_P	T_I	T_D
PID	$\frac{KU}{2.2}$	$\frac{PU}{2.2}$	$\frac{PU}{6.7}$

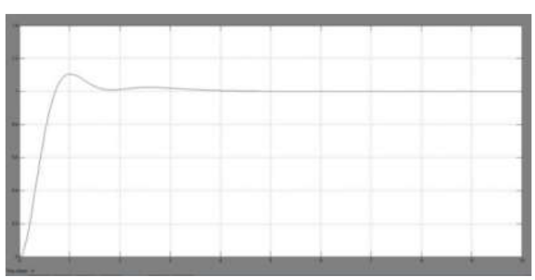

Figure 6 Response for Tyreus - Luyben tuning

E. Damped Oscillation Method

In many plants, sustained oscillations for testing purposes are not allowable. The modification is easy to follow and perhaps more accurate. Conducting a closed-loop test with P only control adjustments, the transient response shows a decay ratio of one fourth. The control parameter settings are derived from the period of oscillation, and the expression is in Table 5, and response is shown in Figure 7.

Table 5. PID parameter for Damped Oscillation Method

Controller Parameter	K_P	T_I	T_D
PID	K	$\frac{P}{6}$	$\frac{P}{1.5}$

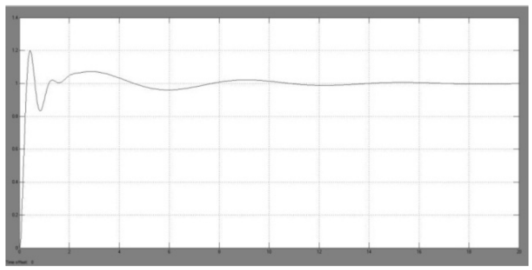

Figure 7 Response for Damped oscillation Tuning

Simulation Result

Simulation results using MATLAB for different PID tuning techniques are summarized in Table 6 and the MATLAB simulation responses of all the tuning methods considered are shown in Figure 8.

Table 6.Simulation results for different PID Tuning

Parameters	Zn open loop	Cohen-coon	Zn closed loop	Tyerus-lyuben	Damped oscillation
Rise time	0.5519	0.585	0.6625	0.7137	0.3
Peak time	0.8385	0.9076	1.0	1.0	0.4372
Settling time	2.087	5.846	2.5145	3.0	9.45
Peak overshoot	19.9%	28.14%	21.6%	10.63%	19.9%
Steady state error	0	0	0	0	0

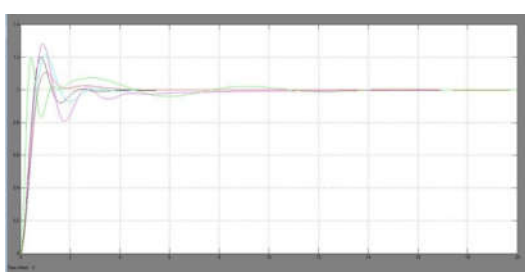

Figure 8 MATLAB simulation responses of all the tuning methods

Conclusion

The paper describes the design of PID controller for a Third-order system without time delay. Total Five PID tuning techniques were implemented, and their performances analyzed. The system exhibits a largest peak overshoot with Cohen – Coon technique and major settling time with Damped oscillation tuning technique. Tyerus – Lyuben method exhibits smallest maximum overshoot and moderate settling time. Among the Five PID techniques, the Tyerus – Lyuben tuned PID controller gives the best results.

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