A Study on Performance of Different PID Tuning Techniques

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Abstract— The ability of Proportional Integral Derivative (PID) controllers to compensate many practical industrial processes has led to their wide acceptance in industrial applications. There are several methods for tuning a PID controller. This paper takes a qualitative look at six PID tuning methods, with comparison of accuracy and effectiveness. In this Paper a Second order system is selected for study. The performance of PID tuning techniques is analyzed and compared on basis of Time response specifications.

Keywords :- PID controller, Tuning Methods, Simulation, MATLAB, Comparision.

I. INTRODUCTION

PID controllers have been at the heart of control engineering practice for seven decades. In the process control, more than 95% of the control loops are of the Proportional-Integral-Derivative (PID)type. A Proportional–Integral–Derivative (PID) controller is a three-term controller that has a long history in the automatic control field, starting from the beginning of the last century (Bennett, 2000). The PID control method is most flexible and simple method. This method is more popular among all control methods. The determination of proportional (K_P), derivative (K_d) and integral (K_i) constants are known as tuning of PID controller. A PID controller is shown in Figure 1 and is given by

$$G_c(s) = K_c\left(1 + \frac{1}{T_i s} + T_d s\right) \qquad \text{……….(1)}$$

With Kc = proportional gain, T_i = integral time constant and T_d = derivative time constant. The introduction of integral action facilitates the achievement of equality between the measured value and the desired value, as a constant error produces an increasing controller output. The introduction of derivative action means that changes in the desired value may be anticipated, and thus an appropriate correction may be added prior to the actual change. Thus, in simplified terms, the PID controller allows contributions from present, past and future controller inputs.

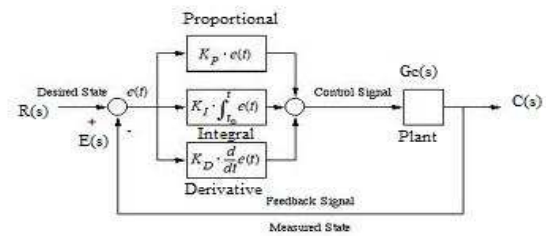

Fig.1. Basic control system configuration

II. CONTROLLER TUNING

Controller tuning methods provide the controller parameters in the form of formulae or algorithms. They ensure that the obtained control system would be stable and would meet given objectives. In fact, since Ziegler–Nichols proposed their first tuning rules [5], an intensive research has been done from modifications of the original tuning rules to a variety of new techniques; analytical tuning; optimization methods; gain and phase margin optimization, just to mention a few. Recently, tuning methods based on optimization approaches with the aim of ensuring good stability and robustness has received attention in the literature [6]. In this paper Performances of some PID tuning algorithms is analysed and compared for second order system without time delay. Simulation results are shown using MATLAB.

III. CONVENTIONAL PID TUNINGS TECHNIQUE

A. Ziegler-Nichols Method

The Ziegler-Nichols design methods [2] are the most popular methods used in process control to determine the parameters of a PID controller. Although these methods were presented in the 1940s, they are still widely used. The step response method is based on an open-loop step response test of the process [3]. 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 drawing a tangent line at the inflexion point, where the slope of the step response has its maximum value.

The intersections of the tangent and the coordinate axes 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 are shown in Table1.

Table.1. PID controller parameters in the Ziegler-Nichols step Response method

Controller Parameter	K_p	T_i	T_d
PID Controller	1.2T/L	2L	0.5L

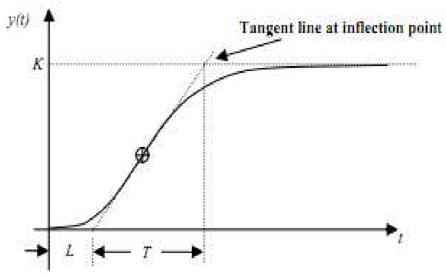

Fig.2. Response curve for Z-N method

From the step response in Fig. 2, T & L are obtained as T= 2.4, L = 1.8. As per Table 1, K_P = 1.6, K_i =1/T_i = 3.6101 and K_d = 0.9, with the above values of K_P, K_i and K_d, step response is shown in Fig. 3. M_p = 10.1%, t_s = 10.5 sec, e_{ss} = 0.

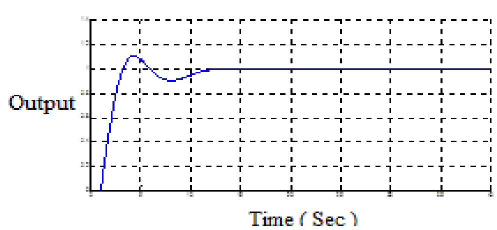

Fig.3. Ziegler-Nichols method (PID Simulation)

B. Fine tuned PID controller

The individual effect of K_P, K_i and K_d summarized in Table 2 can be very useful in fine tuning of PID controller [10]. Beginning with the values of K_P, K_i and K_d obtained from Z-N step response method, unit step response for different combination of K_P, K_i and K_d were observed. After fine tuning, PID controller parameters obtained are K_P = 1.3, K_i = 0.55 and K_d = 2.The unit step response for K_P = 1.3, K_i = 0.55 and K_d = 2 is shown in Fig. 4, which gives M_p =5.58%, t_s = 6.1 sec and e_{ss} = 0

Table.2. Effect of K_p ,K_i and K_d

Close loop Response	Overshoot	Settling Time	Steady – state Error
Increasing Kp	Increase	Small Increase	Decrease
Increasing Ki	Increase	Increase	Large Decrease
Increasing Kd	Increase	Decrease	Minor change

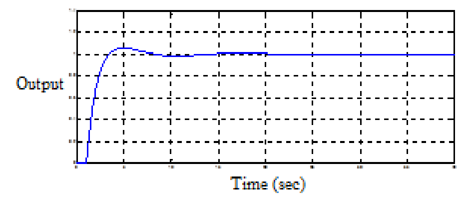

Fig.4 Step Response of Fine Tuned PID controller

C. Cohen Coon Method

The Cohen-Coon method is a more complex version of the Ziegler-Nichols method [9] .This method is more sensitive than the Ziegler-Nichols method. The controller parameters with this method are given by equation (2),(3) and (4).

$$K_p = \frac{1}{K}\frac{\tau}{L}\left(\frac{16\tau+3L}{12\tau}\right) \quad \text{------ (2)}$$

$$K_i = \frac{L\left(32+\frac{6L}{\tau}\right)}{13+8\frac{L}{\tau}} \quad \text{--------- (3)}$$

$$K_d = 4\frac{L}{11+2\frac{L}{\tau}} \quad \text{---------- (4)}$$

τ & L are obtained from the open loop responses as τ = 2.4, L = 1.8, K_P = 3.3796, T_i = 3.4590 therefore K_i = 1/T_i = 0.2891 and K_d = 0.576.With the above values of K_P , K_i and K_d, step response is shown in Fig. 5. M_p = 23.9%, t_s = 7.07sec, e_{ss} = 0.

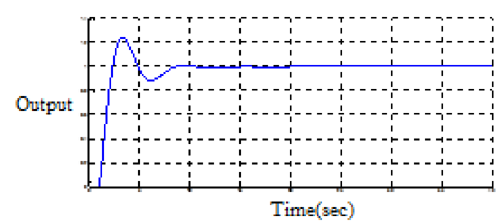

Fig.5. Response for Cohen-Coon method

D. Chien, Hrones and Reswick method (CHR)

Chien-Hrones-Reswick (CHR) method is the modified version of the Ziegler-Nichols method [9]. This method was developed in 1952 by Chien-Hrones-Reswick which provides a better way to select a compensator for process control applications. In process industry, controller parameters are often tuned according to CHR Recommendation. The controller parameters from Chien, Hrones and Reswick set point response method are summarized in Table 3.

Table 3.Controller parameter

Overshoot	0%			20%		
Controller	K_p	T_i	T_d	K_p	T_i	T_d
P	0.3/a	--	--	0.7/a	--	--
PI	0.35/a	1.2T	--	0.6/a	T	--
PID	0.6/a	T	0.5L	0.95/a	1.4T	0.47L

From the open loop response T and a are obtained as T = 2.4, a=0.5937.With this value of T and a, the controller parameter are K_P = 1.0106, K_i =0.2876 and K_d = 0.962 .With controller parameters K_P = 1.0106, K_i = 0.2876 and K_d = 0.962, Step response is shown in Fig. 6. M_p = 5.35%, t_s = 12 sec, e_{ss} = 0.

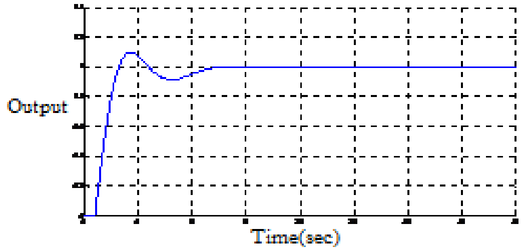

Fig.6. Response for Chien, Hrones and Reswick

E. ITAE Tuning Method

ITAE method is described in [4].Integral of Time multiplied by Absolute Errors (ITAE) Criterion is given by

$$I_{ITAE} = \int_0^T t|e(t)|dt \qquad \text{--------- (5)}$$

Where t is the time and e (t) is the error which is calculated as the difference between the set point and the output.

$$K_p = \frac{0.965}{K\ (\frac{T}{L})^{0.855}} \qquad \text{--------- (6)}$$

$$T_i = \frac{T}{(0.796 - 0.147\ \frac{L}{T})} \qquad \text{-------- (7)}$$

$$T_d = 0.308\ T(\frac{L}{T})^{0.929} \qquad \text{----------- (8)}$$

From the open loop response T & L are obtained as T= 2.4, L = 1.8.With K = 0.6, K_P =1.31981, K_i =1/T_i = 3.49993, K_d = 0.5684 in the above values of K_P, K_i and K_d, step response is shown in Fig 7. M_p = 16.3%, t_s = 7.8 sec, e_{ss} = 0.

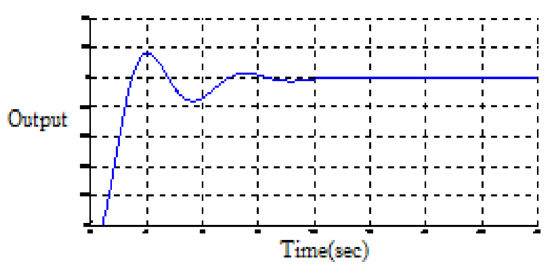

Fig.7. Response for ITAE Tuning Method

F. AMIGO Tuning Method

In Astrom and Hagglund [11] an approximate method is proposed that accomplishes this goal in a simple way. The Method which is known as AMIGO (Approximate M-constrained integral gain Optimisation), which consist in applying a set of equation to calculate the parameter of the Controller in a similar way to the procedure used in Ziegler-Nichols method. The suggested AMIGO Tuning Rule for PID Controller is

$$K_p = \frac{1}{K}(0.2 + 0.45\frac{T}{L}) \qquad \text{------ (9)}$$

$$T_i = \frac{0.4L + 0.8T}{L + 0.1T}L \qquad \text{----- (10)}$$

$$T_d = \frac{0.5LT}{0.3L + T} \qquad \text{------- (11)}$$

From the step response in Fig. 2, T & L are obtained as T= 2.4, L = 1.8. K is 0.6, K_P =1.3333, K_i =1/T_i = 0.4229, K_d = 0.7346.With the above values of K_P, K_i and K_d, step response is shown in Fig. 8. M_p = 24.3%, t_s = 17.4 sec, e_{ss} = 0.

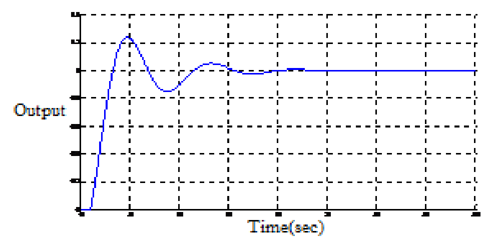

Fig.8. Response for AMIGO Tuning Method

IV. PROBLEM FORMULATION

Consider the following Second Order system without Time Delay system

$$G(s) = \frac{2}{5s^2 + 2s + 1} \qquad \text{-------- (12)}$$

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

- To decrease the maximum Overshoot (M_p)
- To Decrease the settling time (t_s)
- To Reduce Steady state error (e_{ss})

The Simulink model is constructed as shown in figure 9.

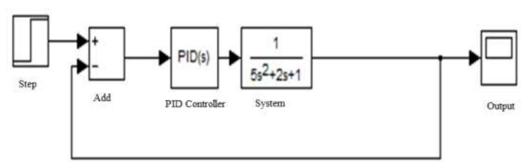

Fig 9:- MATLAB/Simulink Model

V. MATLAB SIMULATION RESULT

Simulation results using MATLAB for different PID tuning techniques are summarized in Table 4.

Table 4: Time response parameters

Algorithm	Maximum Overshoot (M_p)	Settling time (T_s)	Steady state error (e_{ss})
Untuned PID	43.2	18.1	0.333
Z-N Method	10.1	10.5	0
Fine Tune	5.58	6.1	0
Cohen coon method	23.9	7.07	0
Chien, Hrones and Reswick method	5.35	12	0
ITAE Tuning Method	16.3	7.8	0
Amigo Method	24.3	17.4	0

VII. CONCLUSION

The paper describes design of PID controller for a second order system without time delay. Total Six PID tuning techniques were implemented and their performances analyzed. The system exhibits a largest peak overshoot and settling time with Amigo tuning technique. Fine tuned exhibits smallest maximum overshoot and settling time. Among the Six PID tuning techniques, the fine tuned PID controller gives the best results for a second order system.

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