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Performance Analysis of PID Tuning Techniques based on Time Response specification

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Abstract: Proportional- Integral- Derivative (PID) controllers are widely used in industrial control system because of the reduced number of parameters to be tuned. Tuning the parameters of a PID controller is very important in PID control. The determination of proportional (K_P), derivative (K_d) and integral (K_I) constants are known as tuning of PID controller. This paper presents PID tuning rules for higher order system. The performance of PID tuning techniques is analysed and compared on basis of time response specifications.

Keywords: PID controller, Tuning Methods, MATLAB Simulation.

I. INTRODUCTION

The PID controller can be said to be the “bread and butter of control engineering. It is an important component in every control engineer’s tool box. The PID controller is the most common form of feedback. The PID control method is most flexible and simple method. This method is more popular among all control methods. In the process control, more than 95% are of control loop are of PID type, most loops are actually PI control. PID controllers are today found in all areas where control is used. The controllers come in many different forms. 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 general form of PID controller is given in equation (1).

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

A basic control system configuration of PID controller is shown in Figure 1.

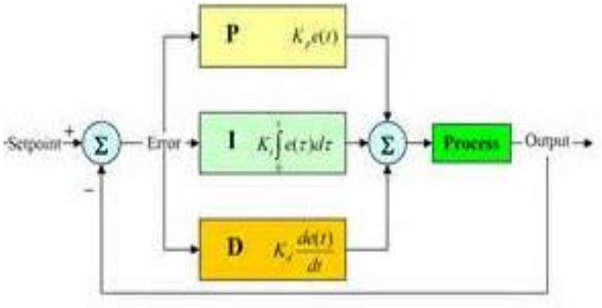

Fig.1. Basic control system configuration

II. DESIGN CONSIDERATION OF PID CONTROLLER

$$G(s) = 6/[(2s+1)(4s+1)(6s+1) \qquad \text{... (2)}$$

A third order system is choosen whose time response is unsatisfactory [1].

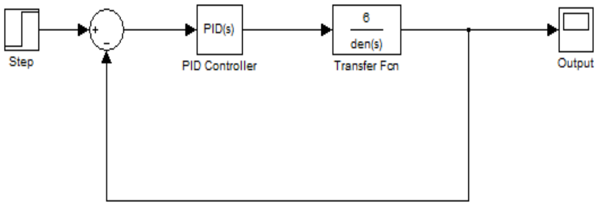

Fig.2. MATLAB/Simulink Model

It is desired to improve the time response of the system using PID controller. Fig.2 shows the simulink model of the PID controller and the plant with unity feedback.
Consider a close loop system having K_p =1,T_i =0 and T_d =0,

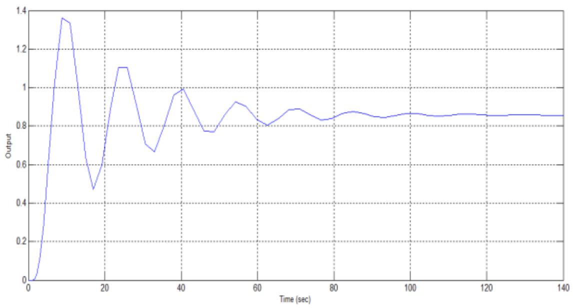

Fig.3. Response of close loop system

with the above values of K_p, T_i and T_d ,step response is shown in Fig.3.M_p =63.3%,t_s =85 sec, e_{ss} =0

III.TUNING OF PID CONTROLLER

Before a detailed analysis is done, a quick look at the tuning methods is considered first and thereafter, specific tuning parameters are computed for PID controller. Some of the generally used tuning methods are the Ziegler-Nichols method , Modified Ziegler-Nichols method, Damped oscillation method and Tyreus - Luyben method [11] and so on.

A. ZIEGLER –NICHOLS TUNING METHOD

This Method proposed by John G. Ziegler and Nathaniel B. Nichols, in 1942, this popular method is based on frequency response analysis of the process [11]. it is also known as ultimate gain method or ultimate cycle method. it employs the following steps.

1. Place the controller in close loop with low gain; no reset and no derivative contribution.
2. Adjusting the gain to make control system in continuous oscillation. The corresponding gain is referred to as the ultimate gain (K_u) and the oscillation period is termed as the ultimate period (P_u).
3. Note the gain (ultimate gain ,K_u) and period (ultimate period ,P_u)
4. Using the values of K_u and P_u ,Ziegler and Nichols recommended the following tuning parameters for various modes of controllers.

After applying above procedure, the step response for the k_p = 1.666 is shown in Fig. 4.

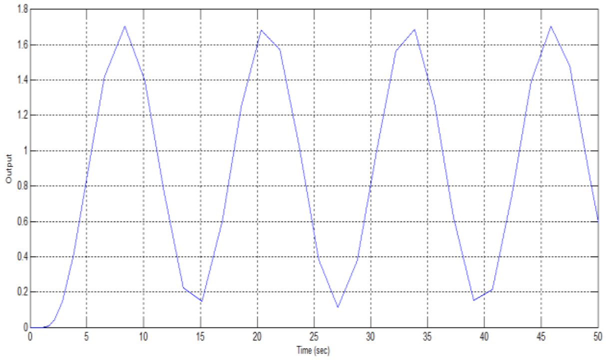

Fig.4. Step response for K_p=1.666

The above response clearly shows that sustained oscillation occurs for k_p = k_u = 1.66.The ultimate period T_u obtained from the time response is 12.56 sec.

Type of controller	Parameter		
	K_p	T_i	T_d
PID Controller	$0.6K_u$	$P_u/1.2$	$P_u/8$

Table 1: Controller parameters for Ziegler-Nichols method.

As per Table 1, K_P = 1, K_i =1/T_i = 0.095 and K_d = 1.57, with the above values of K_P, K_i and K_d, step response is shown in Fig. 5. M_p = 31.7%, t_s = 24.3 sec, e_{ss} = 0.

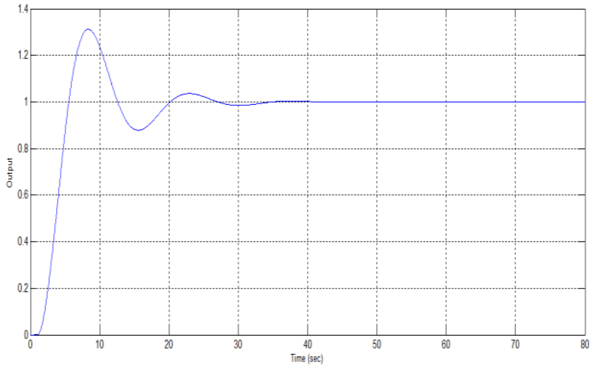

Fig.5. Time response of Ziegler-Nichols method

B. MODIFIED ZIEGLER –NICHOLS TUNING 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 :- Modified Ziegler –Nichols Tuning setting

Type of controller	Parameter		
	K_p	T_i	T_d
Some Overshoot	$0.33\ K_u$	$P_u/2$	$P_u/3$
No Overshoot	$0.2\ K_u$	$P_u/2$	$P_u/3$

As per Table 2, for some overshoot K_P = 0.555, K_i =1/T_i = 0.1592 and K_d = 4.1866, with the above values of K_P, K_i and K_d, step response is shown in Fig. 6. M_p = 6.84%, t_s = 25.7 sec, e_{ss} = 0.

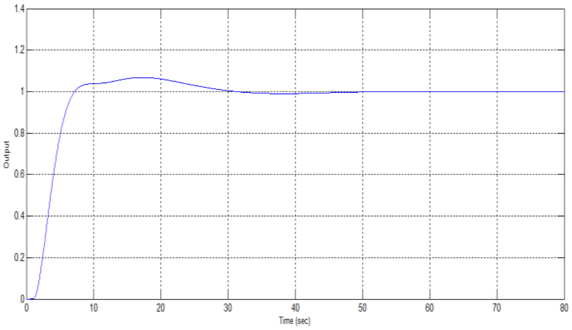

Fig.6. Time response of Modified Z-N method for some overshoot

C. Damped Oscillation Method

In many cases, plants are not allowed to undergo through sustained oscillations, as is the case for tuning using continuous cycling method. Damped oscillation method is preferred for these cases. Damped oscillation method is invented by Harriott [10]. The optimum settings for a P-I-D controller are shown in Table .3.

Table 3 : Harriott Tuning Parameters

Type of controller	**Parameter**		
	K_p	**T_i**	**T_d**
PID Controller	Adjusted	P_u /1.5	P_{u} /6

As per Table 3, K_P = 1, K_i =1/T_i = 0.119 and K_d = 2.0933, with the above values of K_P, K_i and K_d, step response is shown in Fig. 7. M_p = 26.9%, t_s = 17 sec, e_{ss} = 0.

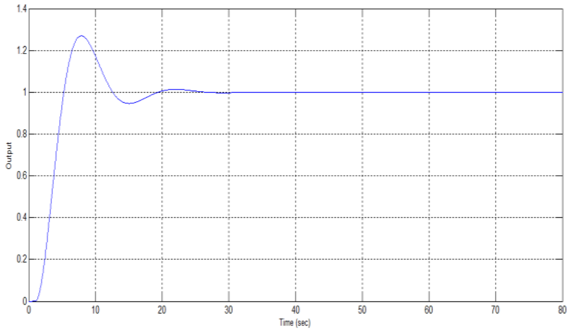

Fig.7. Time response of Damped Oscillation Method

D. TYREUS – LUYBEN METHOD

The Tyreus-Luyben procedure is quite similar to the Ziegler–Nichols method but the final controller settings are different [11]. This method is applicable for PI and PID Controller .This method are based on ultimate gain period and period given in table .4.

Table 4 : Tyreus – Luyben Parameter

Type of controller	**Parameter**		
	K_p	**T_i**	**T_d**
PID Controller	K_u/3.2	P_u/0.45	P_u/6.3

As per Table 4, K_P = 0.518, K_i =1/T_i = 0.0361 and K_d = 1.9936, with the above values of K_P, K_i and K_d, step response is shown in Fig. 8. M_p = 0 %, t_s = 76 sec, e_{ss} = 0.

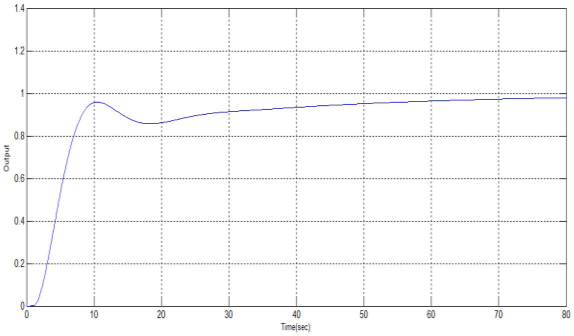

Fig.8. Time response of Tyreus and Luyben method

IV. SIMULATION RESULT

Simulation results using MATLAB for different PID tuning techniques are summarized in Table .5.

Table 5: Time response parameters

Algorithm	**Maximum Overshoot (M_p)**	**Settling time (T_s)**	**Steady state error (e_{ss})**
Untuned PID	63.3	85	0.4
Z-N Method	31.7	24.3	0
Modified Z-N Method	6.84	25.7	0
Damped Oscillation Method	26.9	17	0
Tyreus – Luyben	0	76	0

V. CONCLUSION

In this paper, design of PID controller by using Z-N Method, Modified Z-N Method, Damped oscillation method and Tyreus –Luyben Techniques and its effect on time response of a higher order (third) is presented. Ziegler-Nichols techniques give high overshoot and settling time. Modified Z-N tuning techniques give small overshoot but settling time is large. Damped oscillation method gives large overshoot but settling time is small. Tyreus -Luyben tuning techniques gives zero overshoot with very high settling time. From the simulation results, it is desired that modified Z-N Method may be preferred if smaller overshoot is desired and Damped oscillation method is preferred if smaller settling time is desired.

REFERENCES

[1] " Process Control (Principles and Applications)" By Surekha Bhanot

[2] J. Nagrath, M. Gopal, "Control System Engineering", New Age International Publications, 3rd Edition, 2002

[3] K. Ogata: "Modern Control Engineering", Prentice-Hall India, Fourth Edition

[4] S.R.Vaishnav and Z.J.Khan ," Design and Performance of PID and Fuzzy Logic Controller with Smaller Rule Set for Higher Order System" WCECS , October 24-26, 2007, San Francisco, USA.

[5] S. S. Gade, S. B. Shendage & M. D. Uplane," Performance Comparison of on Line Auto Tune PID Controller with Conventional PID Controller" International Journal of Computer Science & Communication, Vol. 1, No. 1, January-June 2010, pp. 273-277.

[6] K. J. Astrom and T. Haglund, "PID Controller Theory Design and Tuning," 2nd ed. Research Triangle Park, NC: Instrum. Soc. Amer, 1995.

[7] G. K. I. Mann, B. G. Hu, and R. G. Gosine, "Time-domain based design and analysis of new PID tuning rules," Proc. Inst. Elect. Eng.—Control Theory and Applications, vol. 148, no. 3, pp. 251–261, 2001.

[8] Pradeep Kumar Juneja, A K Ray & R Mitra," Various Controller Design and Tuning Methods for a First Order Plus Dead Time Process", International Journal of Computer Science & Communication, Vol. 1, No. 2, July-December 2010, pp. 161-165

[9] E.Kalaiselvan, J. Dominic Tagore," A Comparative Novel Method of Tuning of Controller for Temperature Process", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering ,
Vol. 2, Issue 11, November 2013

[10] P.W.Murrill,P.D.Schnelle,B.G.Liptak,J.Gerry,M.Ruel,F.G.Shinsky," Tuning PID Controller".

[11] Finn Haugen," Comparing PI Tuning Methods in a Real Benchmark Temperature Control System", Modeling, Identification and Control, Vol. 31, No. 3, 2010, pp. 79-91,

BIOGRAPHIES

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