IJIREEICE

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

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

"Study of PID Controller for Closed Loop System"

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Abstract: This paper is concerned with the study of PID i.e. Proportional, Integral and Derivative Controller. PID controller is used in the various process industries because of their simplicity, robustness as well as successful practical application. In this study, the PID controller is applied for a second order process to obtain the fast rise time, no overshoot and no steady-state error.

Key Words: P, PD, PI and PID Controller, Closed loop system.

I. INTRODUCTION

A PID controller is a controller commonly used in industrial control systems which is continuously calculates an error values which is the difference between the measured variable and set point. The controller attempts to minimize the error over time by adjustment of a control variable, like the position of a control valve, a damper etc [1]. Consider the unity feedback system as shown in fig 1: the PID controller can implement to meet various design specifications for the system i.e. rise time, settling time and the overshoot for the step response.

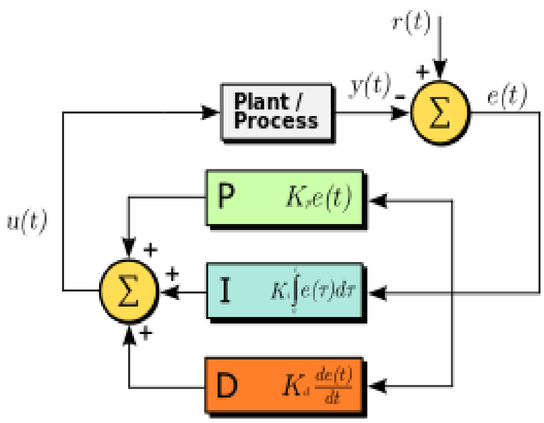

Fig: 1 Block diagram of PID controller in a feedback loop

Following are the terms used in PID controller:

1. Proportional Control (I): Proportional control mode is a pure gain adjustment mode which acting on the error signal to adjust the speed of the system.

2. Integral Control (I): Integral control is the introduction of an integrator to provide the required accuracy for the control system.

3. Derivative Control (D): Derivative action is normally introduced to increase the damping in the system and also amplifies the existing noise which can cause instability. Equation 1.1 shows the transfer function PID controller.

$$Gc(s) = K_p[1 + \frac{1}{T_i s} + T_d s] \ldots\ldots\ldots\ldots\ldots(1.1)$$

A more conventional transfer function form from equation 1.1:

$$Gc(s) = \frac{K_p(T_i.T_d.s^2 + T_i s + 1)}{T_i s} \ldots\ldots\ldots\ldots(1.2)$$

Where,
K_p = Proportional Gain
T_i = Integral Time
T_d = Derivative Time

Characteristics of P, I, and D controllers:
A proportional control (Kp) have the effect of reducing the rise time, but it this cannot eliminate the steady-state error. An integral control (Ki) has the effect of eliminating the steady-state error, but it may make worse transient response [2]. A derivative control (Kd) have the effect of increasing the stability, reducing the overshoot and improving the transient response [3, 4]. Table 1 shows the effects of Kp, Kd, and Ki on a closed-loop system.

Table 1 Effects of each of controllers Kp, Kd, and Ki on a closed-loop system.

C l response	Rise time	Steady state error	Settling time	Over shoot
K_p	Decrease	Decrease	Small change	Increase
K_i	Decrease	Eliminate	Increase	Increase
K_d	Small change	Small change	Decrease	Decrease

II. IMPLEMENTATION OF PID WITH SECOND ORDER SYSTEM USING MAT LAB

For the study of PID controller, consider simple plant a second order transfer function to determine how each of Kp, Ki and Kd contributes to obtain the no steady-state error, fast rise time and minimum overshoot.

$$G_p(s) = \frac{1}{s^2 + 10s + 20}$$

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1. Open-loop step response:

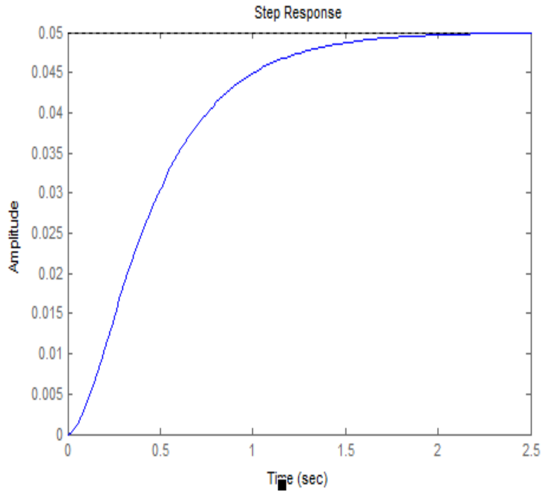

Fig: 2 Open-loop step responses

The gain of the system transfer function is 1/20, so it is the final value of the output for a unit step input. This corresponds to the steady-state error quite large of 0.95. Furthermore, the rise time is about 1 second, and settling time is about 1.5 seconds.
Thus by using a controller that will reduce the rise time, settling time also eliminates the steady-state error which is a P controller.

2. P Control:
The closed-loop transfer function of the system for a proportional controller is:

$$G_{cl}(s) = \frac{K_p}{s^2 + 10s + (20 + K_p)}$$

By referring the table 1, the proportional controller (Kp) reduces the rise time, steady-state error, increases the overshoot as shown in fig: 3.

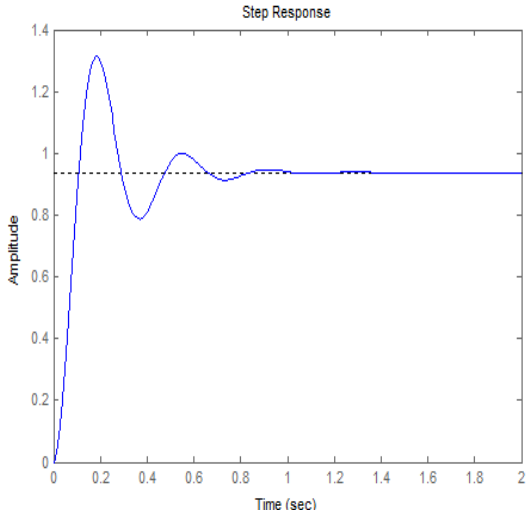

Fig: 3 P Control

3. PD Control:
The closed-loop transfer function of the system for a PD controller is:

$$G_{cl}(s) = \frac{K_d s + K_p}{s^2 + (10s + K_d)s + (20 + K_p)}$$

By referring the table 1, the derivative controller reduces both the overshoot and settling time as shown in fig: 4.

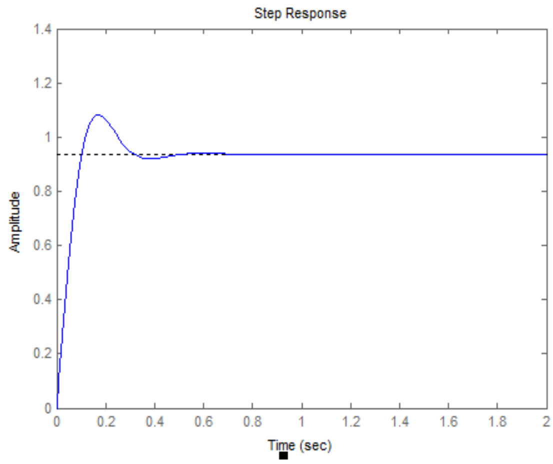

Fig: 4 PD control

4. PI Control:
The closed-loop transfer function with a PI control is:

$$G_{cl}(s) = \frac{K_p s + K_i}{s^3 + 10s^2 + (20 + K_p)s + K_i}$$

By using the table 1, K_I eliminates steady-state error, decreases rise time and increases both the overshoot and settling time as shown in fig: 5.

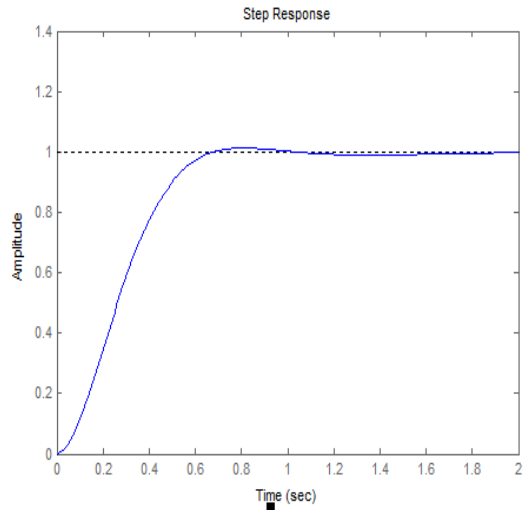

Fig: 5 PI control

5. PID Control:
The closed-loop transfer function of the system with a PID controller is:

$$G_{cl}(s) = \frac{K_d s^2 + K_p s + K_i}{s^3 + (10 + K_d)s^2 + (20 + K_p)s + K_i}$$

After trial and error, the gains are K_p=350, K_I=300, and K_d=50 to obtained the system with no overshoot, no steady-state error and fast rise time.

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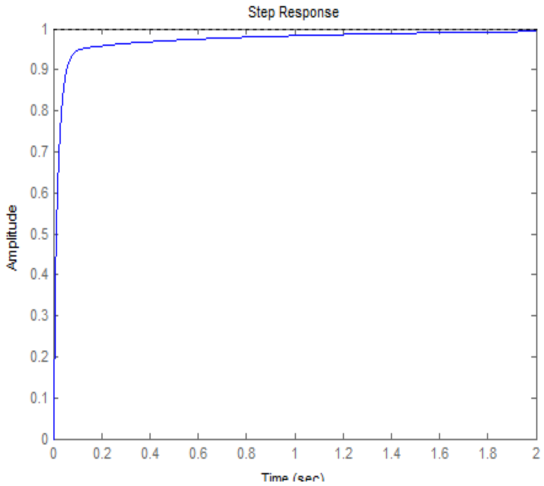

Fig: 6 PID Control

III. CONCLUSION

In the PID controller, P controller reduces the rise time, increases the overshoot but I controller eliminates the steady-state error and D controller reduces both overshoot and settling time, and having the small effect on the rise time and the steady-state error. Finally, in the combination of the three mode of PID controller we get the desired response of the system with no overshoot and steady-state error, fast rise time.

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