Available online www.jsaer.com

***Journal of Scientific and Engineering Research*, 2021, 8(12):118-122**

Research Article

ISSN: 2394-2630
CODEN(USA): JSERBR

The Effects Of PID Controller on System Response and an Example Application

Dr. Mehmet ÇINAR

Bitlis Eren University, Tatvan Vocational School, Bitlis, Turkey
Corresponding author e-mail: mcinar@beu.edu.tr

Abstract The analysis and design of the controller circuits that enable the systems to operate in the desired properties are among the main areas of control theory. In this area, controllers with different structures and characteristics have been developed. One of them is the most widely used basic PID (proportional-integral-derivative) controller structure for industrial purposes. In particular, if the mathematical model of the system is unknown and therefore analytical design methods cannot be used, PID control is the most useful method. The parameters of PID controllers can be obtained both experimentally and analytically. In addition, the design stages do not include many processes. Therefore, they are widely used in industrial applications. The PID controller consists of K_p (proportional term), K_I (integral term) and K_D (derivative term). K_p provides the net proportional control behaviour for the error signal. K_I reduces steady-state errors with low-frequency compensation provided by an integrator. The K_D provides high-frequency compensation with a derivative receiver, improving transient response and generally improving the dynamic performance of the system; but it increases the gain at higher frequencies.

In this study, the PID controller structure, the effects of the PID controller parameters K_p, K_I and K_D on the system response are mentioned, and the effect of the parameters on the step response of the system on a sample system is mentioned. The percentage overshoot rate, settling time and rise time change according to the parameters were determined and interpreted. In order to achieve this, the program was written in the Matlab environment and the results were shown graphically.

Keywords PID controller, K_p (Proportional term), K_I (Integral term), K_D (Derivative term), Step response

Introduction

Until now, the proportional-integral-derivative controller (PID) is the most widely used controller in the industry due to its simplicity, robustness and ease of implementation [1]. Many practical control applications are based on PID control [2-4]. In process control, a PID controller tries to correct it by calculating the error between the measured process variable and the desired setpoint, and then giving a corrective action that can adjust the process accordingly. The performance of the control system is based on the selection of three parameters: proportional, integral and derivative gains. Many process plans controlled by PID controllers have similar dynamics. It is possible to set satisfactory controller parameters from less plan information than a complete mathematical model [2]. In practice, systems often have some complex features such as non-linearity and time delay that make tuning a PID controller difficult. Traditionally, the problem has been handled with a trial and error approach. In the last decade, more systematic methods have been introduced. Ziegler Nichol's (ZN) PID parameters tuning formula is a widely used experimental Formula [2]. One of the disadvantages of this method is that it requires prior knowledge of the planned model. After tuning the controller with the ZN method, a good but non-optimal system response will be achieved. Other methods for tuning the PID controller have been proposed by many researchers in the field of control engineering [5-7].

There are many methods for setting the parameters of the PID controller. With the help of these methods, criteria such as settling time, overshoot, rise time of the closed loop control system can be adjusted in the unit step response. In the literature, Ziegler Nichols and CHR (Chien-Hrones-Reswick) methods are frequently used to adjust PID parameters [8]. However, these methods can give wrong results in nonlinear systems. Optimization algorithms are often used to set the optimum PID parameters [9-12].

PID Controller Structure

The proportional integral derivative (PID) controller is one of the most widely used and universally accepted control algorithm used in the control industry. The PID controller is popular for its qualities, partly with its extensive powerful performance work and partly with its simplified operation. The term PID defines its three main components, a proportional control term (K_P), an integral control term (K_I), and a differential control term (K_D). Table 1 describes the effect of a PID controller for its three components. In Equation (1), the mathematical equation of the PID controller is given.

$$u(t) = K_p \left[e(t) + \frac{1}{T_i} \int_0^t e(\tau) d(\tau) + T_d \frac{de(t)}{dt} \right] \tag{1}$$

The effects of PID controller parameters on the system response are given in Table 1.

Table 1: Effects of PID control parameters on system response

	Proportional (K_p)	**Integrative (K_I)**	**Derivative (K_D)**
Rise time	Decrease	Decrease(Little)	Little effect
Overshoot	Increase	Increase	Decrease
Settling time	Decrease(less)	Increase	Decrease
Steady-state error	Decrease	Decrease (more)	Little effect

In order to obtain the desired response in PID controller design, the following steps are followed:

a) Open loop response is found and needs are identified.
b) A proportional controller is added to correct the rise time.
c) Derivative controller is added to correct the overshoot.
d) An integral controller is added to eliminate the steady-state error.
e) Adjust K_p, K_I and K_D until the desired response is achieved.

Controller design should be as simple as possible. If the desired response is achieved with the PI controller, a derivative controller should not be added to the system and the system should not be complicated**.**

Effects Of PID Controller Parameters on System Response

Let's consider the system given in Equation 2 to see the effect of K_p, K_I and K_D parameters on the system response:

Effect of K_P value on system response

$$G(s) = \frac{1}{(s+1)^3} \tag{2}$$

If we assume that K_I and K_D from PID controller parameters are constant but K_P varies between 0,1 and 1; The effect of this on the system response can be seen in Figure 1. The Matlab codes used to achieve this are as follows**:**

```
Gs= tf(1,[1,3,3,1]);
for Kp=[0.1:0.1:1];
G=feedback(Kp*Gs,1);
step(Gs),
```

```
hold on;
end
```

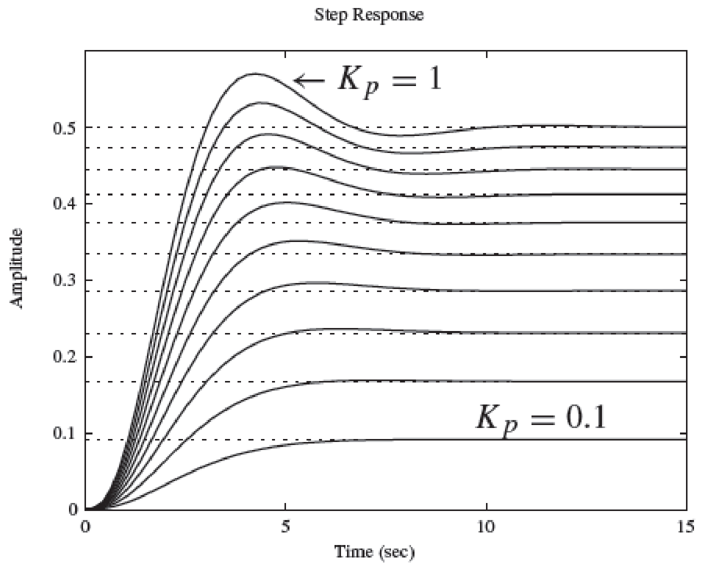

Figure 1: Step response of the closed loop system according to the change of K_P

As can be seen from Figure 1, when K_p increases, the response speed of the system increases, the percent overshoot of the closed-loop system increases and the steady-state error decreases.

Effect of K_I value on system response

If K_p=1 is taken, the system response according to the change in the K_I value is shown in Figure 2. The Matlab codes used to obtain Figure 2 are given below.

```
Kp=1; s=tf('s');
for Ti=[0.7:0.1:1.5]
Gc=Kp*(1+1/Ti/s);
Gs=feedback(G*Gc,1);
step(Gs)
hold on
end
```

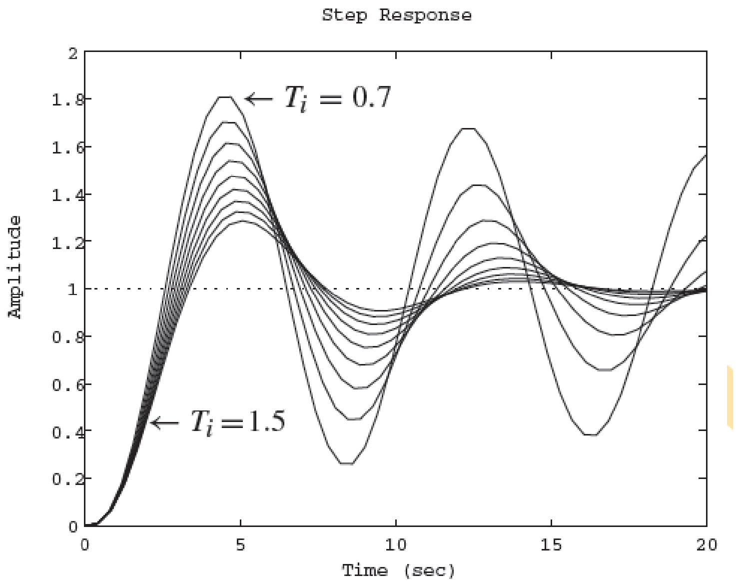

Figure 2: Step response of the closed loop system according to the change of K_I

When Figure 2 is examined; It can be seen that when T_i is increased, the overshoot tends to be smaller, but the response speed is slower.

Effect of K_D value on system response

If K_p=T_i=1, the change of the step response of the system according to the K_D value is shown in Figure 3. The Matlab codes used to obtain Figure 3 are given below:

```
Kp=1; s=tf(’s’);
for Ti=[0.7:0.1:1.5];
Gc=Kp*(1+1/Ti/s);
Gs=feedback(G*Gc,1);
step(Gs)
hold on
end
```

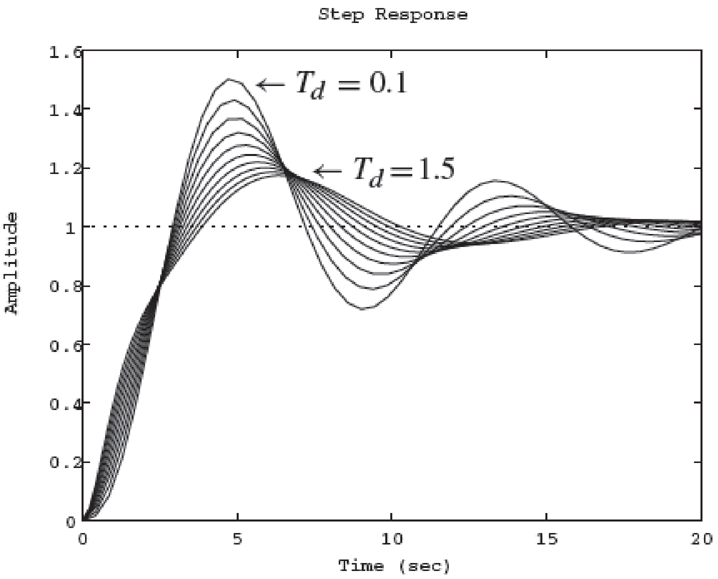

Figure 3: Step response of the closed loop system according to the change of K_D

As can be seen from Figure 3, when T_d increases, the response has a smaller percentage overshoot with a slightly slower rise time but a similar settling time.

Conclusion

There are various methods for setting PID parameters in the literature. However, the calculated controller parameters found by these methods may not be the most appropriate values for the systems. In this case, the controller performance can be increased by experimentally changing the obtained PID parameters to improve the steady state error or settling time. However, this is both a time-consuming process and it cannot be guaranteed that the parameter values of the controller used will be the best values.

References

[1]. Chatterjee, A., Mukherjee, V., Ghoshal, S. (2009). Velocity relaxed and craziness-based swarm optimized intelligent PID and PSS controlled AVR system. International Journal of Electrical Power& Energy Systems, 31, 323-333.

[2]. Xue, D., Chen, Y., Atherton, D. P. (2007). Linear feedback control: Analysis and Design with MATLAB, Siam.

[3]. Farkh, K. L. R., Ksouri, M. (2014). Stabilizing Sets of PI/PID Controllers for Unstable Second Order Delay System. International Journal of Automation and Computing, 11, 210-222.

[4]. Ou, L. L., Chen, J. J., Zhang, D. M., Zhang, L., Zhang, W. D. (2014). Distributed H∞ PID feedback for improving consensus performance of arbitrary-delayed multi-agent system. International Journal of Automation and Computing, 11, 189-196.

[5]. Chidambaram, M., Sree, R. P. (2003). A simple method of tuning PID controllers for integrator/dead-time processes. Computers & chemical engineering, 27, 211-215.

[6]. Shen, J. C. (2005). New tuning method for PID controller. ISA Transactions, 41, 473-484.

[7]. Liang, L. H., Liu, F. C., Gao, J. J. (2014). Fuzzy PID Control of SpaceManipulator for Both Ground Alignment and Space Applications. International Journal of Automation and Computing, 11, 353-360.

[8]. Aström, K. J., Hagglund, T. (1995). PID Controllers: Theory, Design and Tuning. Instrument Society of America, New York.

[9]. Ayaz, B. (2011). PID kontrolörlerinin optimal parametrelerinin belirlenmesi amacıyla bir bulanık mantık karar mekanizması tasarımı. İTÜ Fen Bilimleri Enstitüsü.

[10]. Gaing, Z. (2004). A Particle Swarm Optimization Approach For Optimum Design of PID Controller in AVR system. IEEE Trans. on Energy Conversion, 19 (2), 384-391.

[11]. Rani, M., Selamat, H., Zamzuni, H., Ibrahim, Z. (2012). Multi-Objective Optimization For PID Controller Tunning Using The Global Ranking Genetic Algorithm. International Journal of Innovative Computing, Information and Control, 8, 269-284.

[12]. Tokuda, M., Yamamoto, T. (2010). Self-Tuning PID Controller Based on Control Performance Evalutions. International Journal of Innovative Computing, Information and Control, 6, 3751-3762.