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Modified PID Controller Design Formulae for FOPDT System

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Abstract
Finding the best set of PID parameters has become the center of attraction for several researchers and the hunt is still on to find the next key methodology for PID tuning. PID controllers provide a common and competent solution to real world control problems. Its three-term functionality offers the analysis of both transient and steady-state responses. Increasing controller gain alone can decrease rise time, increase overshoot, slightly increase settling time, decrease the steady-state error, and decrease stability margins. So all the three parameters should be optimally tuned. In this paper, a method is proposed to find the set of PID parameters which is comparatively suitable for the system than that of Ziegler-Nichols method.

Keywords-RGA, DRGA, PID Controller, MIMO

I. Introduction

Many industrial processes are nonlinear and thus are complex mathematically. However, it is known that a good many nonlinear processes can satisfactory be controlled using PID controllers providing that controller parameters are tuned well. Practical experience shows that this type of control has a lot of sense since it is simple and based on 3 basic behavior types: proportional (P), integrative (I) and derivative (D). Instead of using a small number of complex controllers, a larger number of simple PID controllers is used to control simpler processes in an industrial assembly in order to automate the more complex process.

Delay system represents a class which is widely used for analysis and modeling of transportation or propagation phenomena of matter, energy or information. Naturally appearance of these systems can be seen in modeling processes found in biology, physics, mechanics, physiology, chemistry, economics and aeronautics. When a process does not contain a delay, the electronic devices used in development of its control law can generate required delays. These delay system can create a number of oscillations and may lead a process to instability. Delay is also known as dead time, transportation lag or time lag.

PID controllers in various combinations have been widely used for industrial processes due to their simplicity and effectiveness for linear systems, especially for first and second order systems.

Effects of independent P, I, and D tuning on closed-loop response is shown in the table 1.

For the purpose of controller designing, integral plants with time delay are frequently encountered in industrial process control.

II. Modified controller design

The open loop transfer function $G_O(s)$ is given as

$$G_O(s) = G(s)K_c\left[1 + 1/T_I\int_0^t e\,dt + T_D\frac{de}{dt}\right]$$

Or

$$G_O(jw) = G(jw)K_c\left[1 + j(\omega T_D - 1/\omega T_I)\right]$$

Where G(s) or G (jw) is the transfer function of the process model.

The value of T_D is so selected such that the net effect is an increased controller gain. Chidambaram has considered this ratio arbitrarily as 6.66 by selecting the value of T_D as 0.8 T_D/ω_{co}.. Usually, it is recommended to have T_I as $5/\omega_{co}$. In Ziegler Nichol settings the value recommended for T_D closes to $0.7854/\omega_{co}$ whereas T_I is approximately $5.236/\omega_{co.}$

Selecting the value of T_D as $0.8/\omega_{co.}$ And T_I as $5/\omega_{co}$.

These values give

$$G_O(jw_{co}) = G(jw_{co})K_c(1 + j0.6)$$

the value of ω is equal to ω_{CO} such that

$$\left|G_O(j\omega_{co})\right| = 1$$

Also,

$$Angle\ of\ G_O(j\omega_{co}) = -\pi = -\theta_D\omega_{co} - \tan^{-1}(\tau\omega_{co}) + \tan^{-1}0.6$$

$$\pi + \tan^{-1}0.6 = \tan^{-1}10\,\omega_{co} + 5\,\omega_{co}$$

Which simplifies to ω_{co}=0.47
Also at gain crossover frequency

$$|G_o(j\omega_{co})| = 1 = \frac{K}{\sqrt{1+(\tau\omega_{co})^2}} \cdot K_C \ . \sqrt{1+0.36}$$

$K\,K_C = K_{max} = 0.8574 \{ 1 + (\tau\,\omega_{co})^2 \}^{0.5}$
As, $G_p(s)=0.03\, e^{-5s}/(1+10s)$
Therefore, $K_C=0.8574 \{ 1 + (10 * 0.47)^2 \}^{0.5}=137.33$
Also, we have,
$T_I=5/\ \omega_{co}=10.63$ sec
$T_D=0.8/\ \omega_{co}=1.7$ sec
The transfer function of PID controller for this type of algorithm is given as:
$G_C=K_c [\ 1+ 1/\ T_I\, s + T_D\, s]$
The controller transfer function is mathematically derived as:
$(2493\, s^2 + 1452\, s + 137)\ /10.6\, s$
Thus, the closed loop transfer function is given as:
$(-74.8\, s^3-13.65\, s^2 + 13.32\, s + 1.644)\ /\ (31.2\, s^3 + 39.35\, s^2 + 17.56\, s + 1.644)$
The peak amplitude, peak time and settling time are shown in figure 1, for closed loop response of consistency process with controller designed based on Ziegler Nichol’s tuning method. The closed loop system is stable as shown in fig. 3.
The peak amplitude, peak time and settling time are shown in figure 2, for closed loop response of consistency process with controller designed based on modified design method. The closed loop system is stable as shown in fig. 4.
Fig. 5 shows the comparison of step responses for ZN and modified design formula.

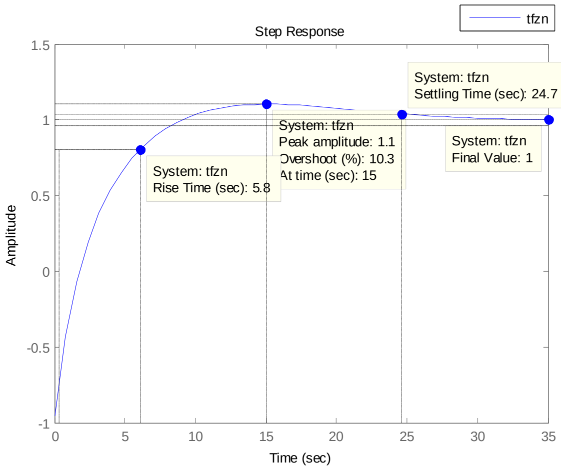

Figure 1: Step Response for ZN tuning method

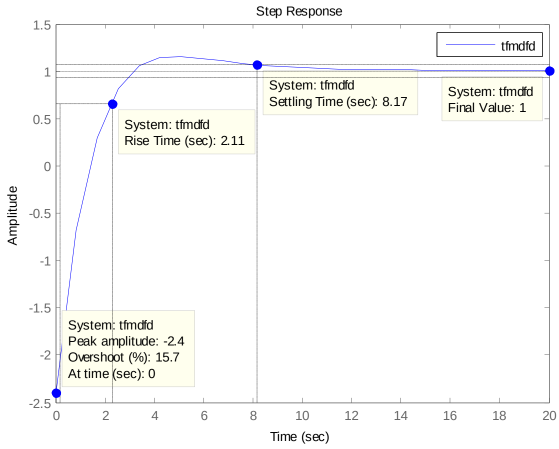

Figure 2: step response for modified design formula

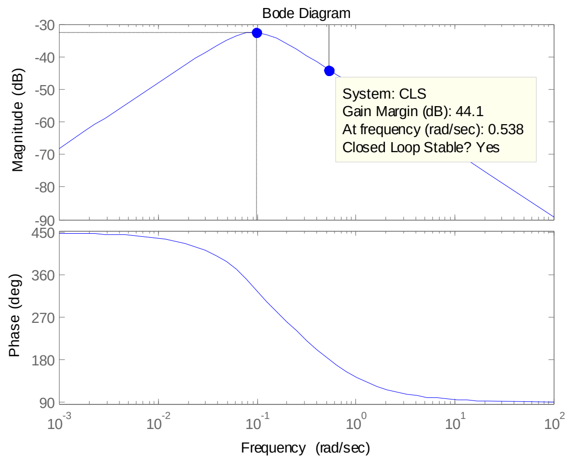

Figure 3: Bode Plot for ZN tuning

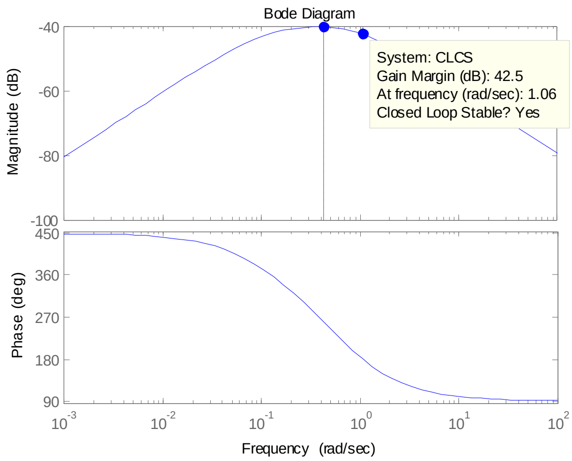

Figure 4: Bode diagram for modified design formulae

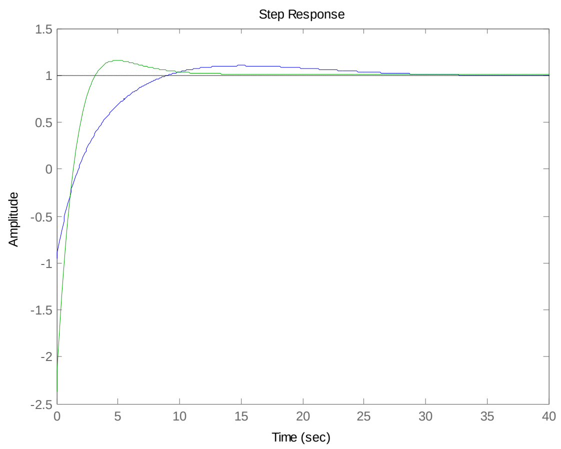

Figure 5: Comparison of step responses for ZN (blue) and modified design formula (green)

III. Conclusion

Present analysis reveals that the modified design formula is better. Ziegler Nichol method as the characteristics peak time, peak amplitude, settling time and rise time values are less in comparison to Ziegler Nichol method. Although the peak overshoot is less in case of ZN method and steady state error is same in both the cases.

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