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Design of Tunable Method for PID Controller for Higher Order System

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ABSTRACT

In this paper tuning of PID Controller for higher order system is given. Conventionally higher order system is reduced to lower order model, and then controller is designed. But in this method higher order system is considered as it is and controller designed based on desired Phase Margin (PM) method. Analytical expression for controller design is given which is based Mikhalevich method. The Mikhalevich method gives a way to select the desired phase margin.

Keywords: *PID Controller, Tuning, phase margin, higher order process, Integral-Square-Error (ISE), Integral Absolute Error (IAE)*

1. INTRODUCTION

Designing PID controller for higher order is very difficult. But most of the industrial processes are higher order. Conventionally higher order process is converted into lower order with dead time process, and then controller is designed. But in the model reduction technique the system dynamics will be lost. For effective process out, a new controller design without model reduction is needed. Mikhalevich et al [1] method gives analytical way to design PID controller for higher order system based on design Phase Margin. Many more methods are reported for tuning of PID in the literature. Isaksson et al [2] reported PID controller for higher order system. Malwatkar et al [3] proposed a tuning method for higher order oscillator system. Shamsuzzoha & Lee [4] and Vijayan & Panda [5-6] reported a set point filters to improve the loop performance and to decrease peak overshoot.

Lee et al. [7] considered set point weight to reduce peak overshoot. Zhang [8] proposed a simple set point filter to reduce the peak overshoot. Nie et al [9] considered compensator based on gain and phase margin specifications to reduce the peak overshoot. Nusret Tan et al [10] proposed a method to calculate all stabilizing PI controllers. Anwar and Somnath [11] considered a tuning method based on Frequency response of the system. Jeng et al [12] reported a PID controller based on plant step response data. Hamamci and Tan [13] proposed a tuning method based frequency domain specifications. Panda [14] proposed analytical method of PID tuning for various processes. Panda [15] proposed a synthesis method of PID controller for integrating process. Many tuning formulas tuning of PID are found in literature (Dwyer [16]). Rajinikanth [17] reported set point weight based PID design for unstable system. Vijayan et al [18] discussed about stability analysis of PID controller. Many researchers (Rivera et al. [19], Chien and Fruehauf [20], Chen and Seborg [21], Skogestad [22]) proposed IMC type PID controllers design. These equivalent PID controllers can used be for higher order systems. Sarayana [23], Ramadevi [24], Devikumari [25], Selvakumar et al [26] and Sivakumar [27] designed PID controller for multivariable system. Rajinikanth [28-29] proposed a tuning algorithm based on Bacterial foraging optimization method. **S**akthiyaram repoted [30] PID controller design for nonlinear process. Sundaravadivu [31] reported fractional order controller design for various processes. Dey et al [32] and Ajmeri [33] designed PID controller for integrating process. Hu et al. [34] derived an analytical method for PID controller tuning with specified gain and phase margin. Jung et al [35] explained about tuning of PID controller using direct synthesis method. Nivetha et.al [36] discussed about tunable method of PID controller for integrating processes. Recently, Suresh Manic et al [37] designed centralized PI controller for interacting conical tank system. Dinesh kumar et al [38] designed a gain scheduled PI controller for nonlinear system. Anusha Rani et al [39] designed sliding mode controller for chemical process. Recently, Atchaya et al [40] proposed PID controller design based synthesis method. In this paper tuning of PID controller for higher order based on Mikhalevich is given. This method is compared with Anwar et al [41] method.

2. THE DESIGN METHOD

Mikhalevich et al [1] design method for higher order process described below.

The generalized transfer function is given as

$$G_1(s) = \frac{N_1(s)}{D_1(s)} e^{-Ls} = \frac{N(s)}{D(s)} \qquad (1)$$

The delay time 'L' is expanded using Pade approximation method.

The controller is given as

$$C(s) = K_1 + \frac{K_2}{s} + K_3 s \qquad (2)$$

By inserting s=jω, the forward path transfer function is given as

$$G(j\omega) = C(j\omega) G_1(j\omega) \qquad (3)$$

The desired Phase margin and real and imaginary part the equations (3) are equated which is given as

$$\begin{aligned} \operatorname{Re} G(j\omega_c) &= -\cos(\varphi_m) \\ \operatorname{Im} G(j\omega_c) &= -\sin(\varphi_m) \end{aligned} \qquad (4)$$

To minimize the peak over shoot, the following condition must be fulfilled

$$\frac{\operatorname{Re}\left[G(j\omega_c)\right]}{d\omega_c} = 0 \qquad (5)$$

Where , φ_m – Desired Phase Margin and ω_c –Cross over frequency

The above equations (4) and (5) are solved to get PID settings.

$$K_1 = \frac{\Delta_1}{\Delta}, K_2 = \frac{\Delta_2}{\Delta}, K_3 = \frac{\Delta_3}{\Delta} \qquad (6)$$

The equation (6) gives the unknown values of PID settings.

3. SIMULATION RESULT

3.1. Example 1

An example for Fifth order plus time delay Process [27] is given by

$$Gp = \frac{e^{-8s}}{(2s+1)^3 (s+1)^2} \qquad (7)$$

The PID setting of Mikhalevich are kc =0.6454, ki = 0.0621 and kd =2.3447. The PID setting of Anwar methods are kc=0.543, ki=0.055 and kd=2.3. The servo response this system is shown in Figure 1.

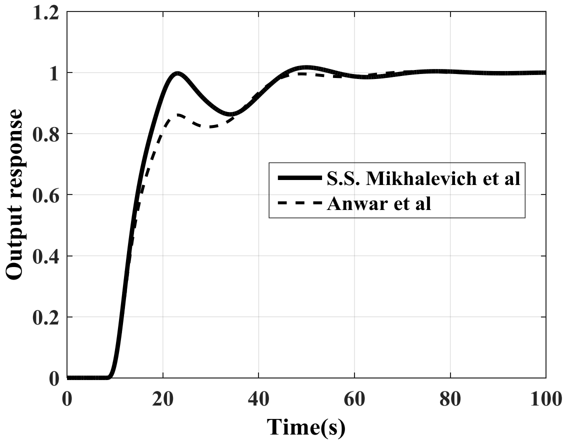

Figure 1 Servo Response of the Example 1

Table 1 Performance Index of Example 1

Method	ITAE	IAE	ISE	PV (%)
Mikhalevich method	**187.1**	**16.42**	**12.71**	1.7
Anwar method	224.9	18.25	13.3	**0.33**

The Figure 1 and Table 1 shows that the Mikhalevich method produces better result compared with Anwar method in terms of less ITAE, IAE, ISE.

3.2 Example 2

A twentieth order system [6] is given by

$$Gp = \frac{1}{(s+1)^{20}} \qquad (8)$$

The PID setting of Mikhalevich are kc =0.6206, ki = 0.04585 and kd =3.057. The PID setting of Anwar methods are kc=0.525, ki=0.055, kd=1.66.

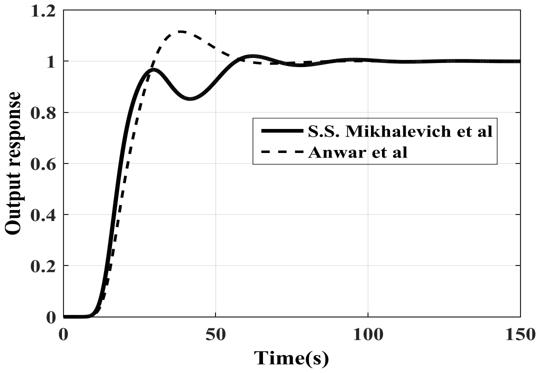

Figure 2 Servo Response of the Example 2

Table 2 Performance Index of Example 2

Method	ITAE	IAE	ISE	PV (%)
Mikhalevich method	315	**21.14**	**15.98**	**2**
Anwar method	**304**	22.1	17.38	11.56

The Figure 2 and Table 2 shows that the Mikhalevich method produces better result compared with Anwar method in terms of less IAE, ISE and peak overshoot.

4. CONCLUSION

In this paper, analytical tuning for higher order processes was developed. The Mikhalevich method provides the desired phase margin to the system. PID settings are obtained by varying the crossover frequency with desired phase margin. Better closed loop performances like IAE, ISE and Peak overshoot obtained. Mikhalevich method produces better result than Anwar method.

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