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DESIGN OF TUNABLE METHOD OF PID CONTROLLER FOR INTEGRATING PROCESS

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ABSTRACT
A classical PID controller tuning method for the integrating processes is presented to provide the desired phase margin which acts as the major tuning parameter along with the crossover frequency. Analytical expressions are given for controller setting based on Mikhalevich method. This method provides a way to select the desired phase margin. This method has been tested successfully and compared with the various examples on the basis of integral performance index (ISE and IAE) to show the effectiveness.
Keywords: *PID Controller, Tuning, Peak Overshoot (PO), Integrating Process, Integral-Square-Error (ISE), Integral Absolute Error (IAE)*

1. INTRODUCTION

Still new methods for tuning of PID Controller are most welcome by the process industries due to the necessity to improve the process quality and to achieve desired safety and economics. A survey was taken to know the actual status for the further development. Lee et al. [1] considered two loop controls to reduce the undesirable overshoot by using an ideal PID controller and set point weight where their set point filter needs information on process parameters. Shamsuzzoha & Lee [2] and Vijayan & Panda [3-4] designed set point filters to improve the loop performance and to decrease peak overshoot. Zhang [5] also proposed a simple set point filter to reduce the peak overshoot. Recently, Nie et al [6] derived certain PID tuning rules and also implemented compensator based on gain and phase margin specifications to reduce the peak overshoot. Nusret Tan et al [7] designed a method to calculate all stabilizing PI controllers. Anwar and Somnath [8] designed a tuning method based on Frequency response of the system. Jeng et al [9] designed PID controller based on plant step response data. Hamamci and Tan [10] proposed a tuning method based frequency domain specifications. Panda [11] proposed analytical method of PID tuning for various processes. Panda [12] designed PID controller for integrating process by synthesis method. Many tuning formulas describing the three controller parameters of PID are found in literature (Dwyer [13]). Vijayan et al [14] discussed about stability analysis of PID controller. IMC type PID controller are designed by many researchers (Rivera et al.[15], Chien and Fruehauf [16], Chen and Seborg [17], Skogestad[18]). These equivalent PID controllers are robust in nature and even they are being used for higher order systems. Sarayana [19] and Ramadevi [20] designed PID controller for multivariable system. Rajinikanth [21] proposed a tuning algorithm based on Bacterial foraging optimization method. Dey et al [22] and Ajmeri [23] designed PID controller for integrating process. Hu et al. [24] derived an analytical method for PID controller tuning with specified gain and phase margin. Mikhalevich et al [25] proposed new method tuning PID controller based on phase margin specifications. This paper gives tuning method for only stable systems. But in this paper, the same tuning method is used for integrating process. Since, integrating process is a special class of unstable processes which has to be controlled effectively.

2. THE DESIGN METHOD

Mikhalevich et al [25] design method for integrating process is 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 dead 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

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

The real and imaginary part are equated to desired Phase Margin which is given as

$$\operatorname{Re} G(j\omega_c) = -\cos(\varphi_m)$$
$$\operatorname{Im} G(j\omega_c) = -\sin(\varphi_m) \quad (4)$$

The following condition must be fulfilled to minimize the overshoot

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

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

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

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

From the determinant of known coefficients, the unknown values PID settings are obtained.

3. SIMULATION EXAMPLES

3.1 Example 1

An integrating plus dead-time (IPDT) process is considered from the literature [26] as given by

$$G_p(s) = \frac{0.0506}{s} e^{-6s}$$

The PID controller is designed using Mikhalevich method and its performance is compared with Anwar method. Set point filer is used in Anwar method. The PID setting of Mikhalevich are kc = 2.3318, ki = 0.0015 and kd =7.4054. The PID setting of Anwar methods are kc=4.32, ki=0.24, kd=9.46 and the time constant of set point filer is 11.5.

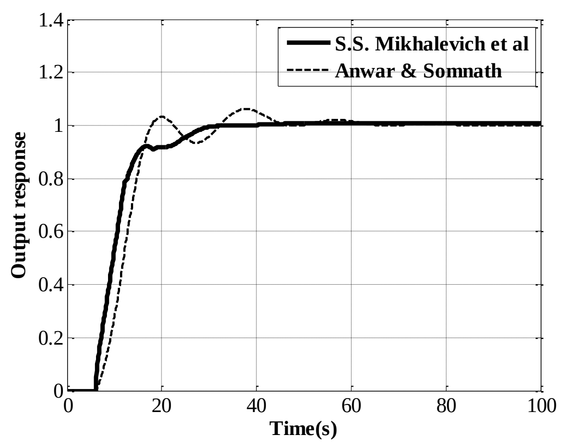

Figure 1. The servo response of Example 1

Table 1 Performance comparison for Example 1

Method	ISE	IAE	PO (%)
Mikhalevich et al	8.542	11.36	0.7003
Anwar & Somnath	10.37	13.25	6.1742

The servo response is shown in Figure 1. From the Table 1 Mikhalevich method produces less ISE, IAE and Peak Overshoot value. So, Mikhalevich is produces better response.

3.2 Example 2

An integrating second order plus dead-time (ISOPDT) process is taken from [3]. The transfer function of the process is

$$G_p(s) = \frac{e^{-4s}}{s(4s+1)}$$

The PID setting of Mikhalevich are kc = 0.0981, ki = 0 and kd =0.446 . The PID setting of Anwar methods are kc=0.2348, ki=0.0083, kd=0.54 and the time constant of set point filer is 17.

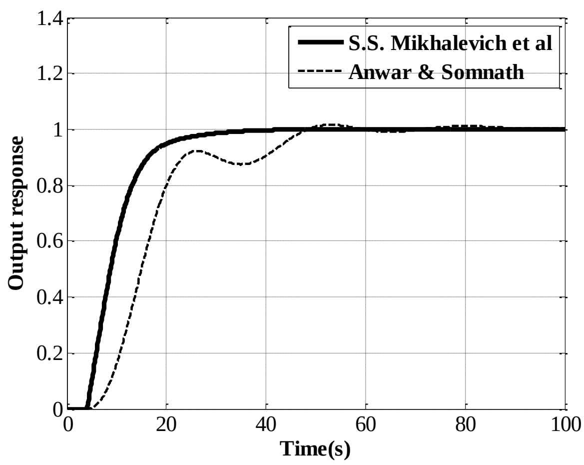

Figure 2. The servo response of Example 2

Table 2 Performance comparison for Example 2

Method	ISE	IAE	PO (%)
Mikhalevich et al	7.446	10.2	0.0757
Anwar & Somnath	12.69	17.74	1.591

The servo response of Example 2 is shown in Figure 2. From the Table 2 Mikhalevich method produces better response in terms of less ISE, IAE and Peak Overshoot value.

4. CONCLUSION

In this paper, analytical tuning for integrating processes were developed and provides the desired phase margin in the system. PID settings are obtained by adjusting the crossover frequency with desired phase margin. A very better closed loop performances like IAE, ISE and Peak overshoot obtained. The Anwar and Somnath method uses set point filer. Hence the computation complexity increases. But, The Mikhalevich method produces better result even without set point filter.

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