

TUNABLE METHOD OF PID CONTROLLER FOR UNSTABLE SYSTEM

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ABSTRACT

In this paper the double feedback structure is used. It consists of two controllers. The inner loop controller is designed using Ziegler and Nichols method. The outer loop controller is designed using the analytical expressions from Mikhalevich method. This method provides desired phase margin. This method has been tested for unstable systems. The performances are compared in terms of integral performance index (ISE, IAE, and ITAE) to show the effectiveness.

Keywords: *PID Controller, Tuning, Integral-Square-Error (ISE), Phase Margin.*

1. INTRODUCTION

Cascade control is better in the case of system having internal disturbance. But it needs two measurements for effective control. But, in the case of double feedback system, it needs only one measurement. In double feedback system, the inner loop is used to stabilize the unstable system. The outer loop improves the overall response of the system. More number of people discussed about cascade system and double feedback system. Vijayan & Panda [1-2] designed PID controller with set point filters which reduces peak overshoot. Mikhalevich et al [3] proposed new method tuning PID controller based on phase margin specifications. Ziegler and Nichlos [4] first introduced tuning method. Jung et al [5] proposed synthesis method of tuning. Shamsuzzoha & Lee [6] designed a second order set point filters with PID tuning. Hu et al. [7] derived an analytical method for PID controller tuning with specified gain and phase margin. Nivetha [8-9] explained tunable method of PID controller. Panda [10] explained synthesis method of PID tuning. Chein [11] proposed IMC method of PID tuning. Nie [12] design lead/lag compensator for unstable system. Lee et al[13] proposed double first order method of PID tuning. Atchaya et al[14] proposed a new tuning method for unstable system. Recently, supraja and vijayan [15] designed optimal H2 IMC-PID controller for integrating process.

2. CONTROLLER DESIGN

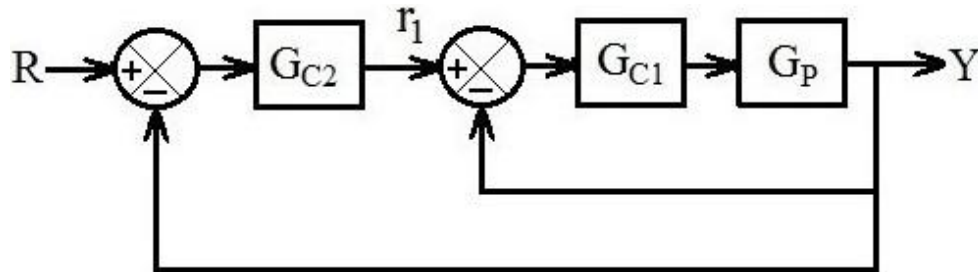


Figure 1 Double Loop Feedback Structure

2.1 Design of Secondary (Inner loop) Controller

The Figure 1 shows the double feedback controller structure. In the inner loop, Proportional controller is used. To tune the inner loop Proportional controller Ziegler and Nichols method is used. The Proportional controller $G_{c1} = K_{c1}$ is given by $K_{c1} = \frac{Ku}{2}$. With this K_{c1} , outer loop controller is tuned using Mikhalevich method.

2.2 Design of Primary (Outer loop) Controller

The block diagram (inner loop) is reduced as follows:

$$G_{p2} = \frac{G_{c1}G_p}{1 + G_{c1}G_p} \quad (1)$$

The outer loop PID controller is designed using Mikhalevich method which is described below. The dead time in G_p is approximated using Pade -approximation method.

The controller is given as

$$G_{c2} = K_{c2} + \frac{K_{I2}}{s} + K_{d2}s \quad (2)$$

By inserting $s=j\omega$, in the forward path transfer function is given as

$$G(j\omega) = G_{c2}(j\omega)G_{p2}(j\omega) \quad (3)$$

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

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

$$\text{Im } G(j\omega_c) = -\sin(\varphi_m)$$

Following condition must be fulfilled to minimize the overshoot

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

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

$$K_{c2} = \frac{\Delta_1}{\Delta}, K_{I2} = \frac{\Delta_2}{\Delta}, K_{D2} = \frac{\Delta_3}{\Delta} \quad (6)$$

Where, Δs are coefficients of equation (4) and (5)

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

3. SIMULATION RESULTS

3.1 Example 1

The First Order Delayed Unstable Process (FODUP) is considered from [1]

$$G_p(s) = \frac{1}{s-1} e^{-0.5s} \quad (7)$$

In this study the system with PID/P control mode is considered. The outer loop controller is tuned using Mikhalevich method. Then the response is compared with Vijayan et al method. The inner loop controller is using Ziegler and Nichols method is $K_{c1}=1.268$ The PID parameters of Mikhalevich method are $K_{c1}=0.3441$, $\tau_{i1}=1.6607$, $\tau_{d1}=0.4723$, $PM=70^\circ$ and $\omega=1.045$ rad/sec and the outer loop PID setting of Vijayan methods are $K_c=0.3533$, $\tau_i=1.5046$ and $\tau_d=0.5166$ and the inner loop controller value is $K_{c1}=1.268$ with set point filter $\lambda=0.4$.

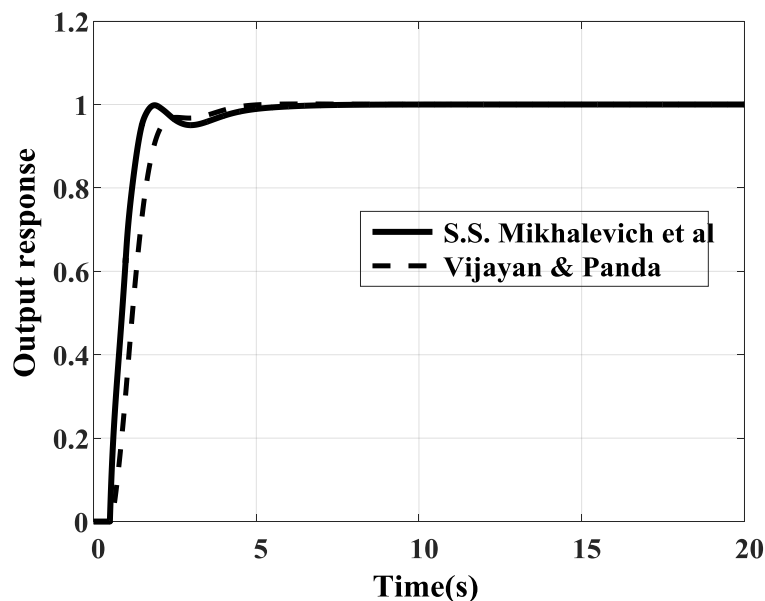


Figure 2 The Servo Response of Example1

Table 1 Performance Comparison for Example 1

METHODS	ISE	IAE	ITAE
Mikhalevich et al	0.7475	1.02	0.8453
Vijayan and Panda	0.926	1.202	0.8572

The response is shown in Figure 2. From the Table 1 Mikhalevich method produces less ISE, IAE, ITAE. So Mikhalevich is produces better response.

3.2 Example 2

The process with one unstable pole (SODUP) is considered from [6]

$$G_p(s) = \frac{1}{(5s-1)(2.07s+1)} e^{-0.939s} \quad (8)$$

The obtained value of inner loop controller using Ziegler and Nichols method is $K_{c1}=1.3965$ The PID parameters of outer loop controller values using Mikhalevich method are $K_{c2}=0.4544$, $\tau_{i2}=3.8528$, $\tau_{d2}=6.9848$, $PM=70^\circ$ and $\omega=0.398$ rad/sec. The PID setting of Shamsuzzoha and Lee method are $K_c=6.7051$, $\tau_i=5.4738$ and $\tau_d=1.333$ with second order filter.

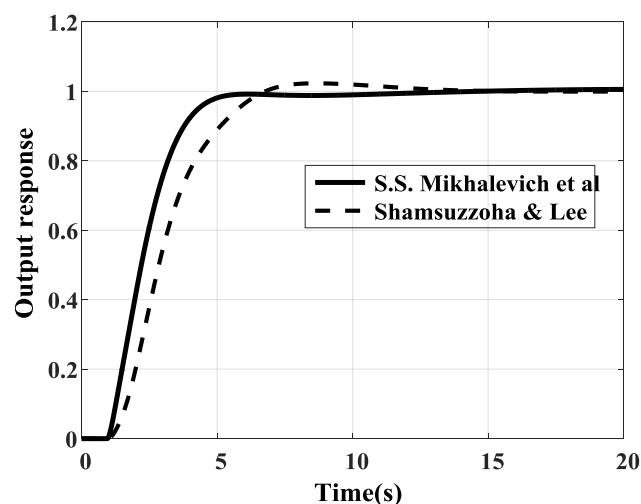


Figure 3 The Servo response of Example2

Table 2 Performance comparison for Example 2

METHODS	ISE	IAE	ITAE
Mikhalevich et al	1.845	2.478	4.312
Shamsuzzoha and Lee	2.389	3.244	6.846

The response is shown in Figure 3. From the Table2 Mikhalevich method produces less ISE, IAE, ITAE value. Thus Mikhalevich method produces better response.

3.3 Example 3

The process with one unstable pole (SODUP) is considered from [12]

$$G_p(s) = \frac{1}{(0.5s+1)(2s-1)} e^{-0.5s} \quad (9)$$

The PID parameters of outer loop controller values using Mikhalevich method are $K_{c2}=0.4824$, $\tau_{i2}=1.8596$, $\tau_{d2}=1.6063$, $PM=70^\circ$ and $\omega=0.85$ rad/sec and the secondary controller using Ziegler and Nichols method is $K_{c1}=1.3977$ and the outer loop PI setting of Nie et al method are $K_c=0.155$, $\tau_i=0.314$ and the inner loop has proportional controller with gain value 2 along with compensator.

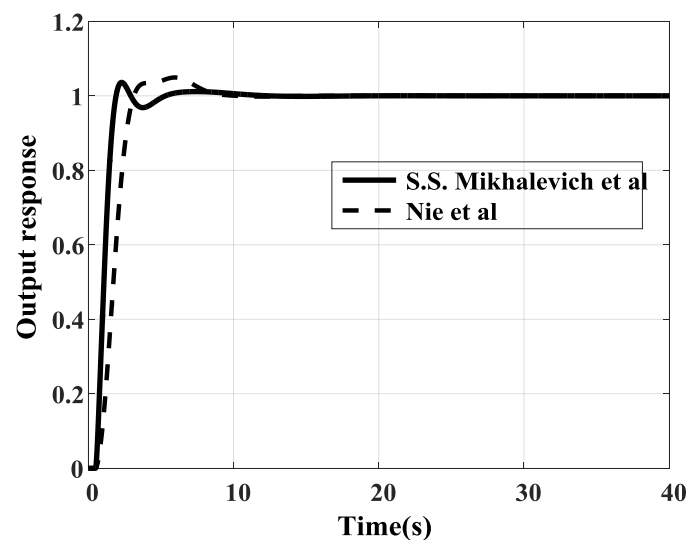


Figure 4 The Servo response of Example3

Table 3 Performance comparison for Example 3

METHODS	ISE	IAE	ITAE
Mikhalevich et al	0.9208	1.241	1.419
Nie et al	1.418	1.955	2.893

The response is shown in Figure 4. From the Table3 Mikhalevich method produces less ISE, IAE, ITAE value.

4. CONCLUSION

In this work the secondary controller designed using Zigler-Nichols method and the primary controller designed using Mikhalevich method which provides the desired phase margin in the system. PID settings are obtained by adjusting the crossover frequency with desired phase margin. The performances criteria like IAE, ISE, ITAE and Peak overshoot were obtained by Mikhalevich method is better when compared to Vijayan, Shamsuzzoha and Nie et al. methods.

“The author(s) declare(s) that there is no conflict of interest regarding the publication of this paper.”

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