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## A Survey on Optimal Tuning PI Controllers for Integrator Delay-time Processes

B.S.Patil<sup>1</sup>, Dr. L. M. Waghmare<sup>2</sup>, Dr. M. D. Uplane<sup>3</sup>

Ph.D. Student, Department of Instrumentation, AISSMS'S Polytechnic, Pune, Maharashtra, India<sup>1</sup>

Guide, Department of Instrumentation, Shri Guru Gobind Singhji, Institute of Engineering & Technology, Vishnupuri, Nanded, Maharashtra, India<sup>2</sup>

Co-guide, Department of Instrumentation Science, Savitribai Phule Pune University, Pune, Maharashtra, India<sup>3</sup>

**ABSTRACT:** Here in this paper we are proposing the design of Proportional Integral and Derivative (PID) controllers based on internal model control (IMC) principles, direct synthesis method (DS), stability analysis (SA) strategy for pure integrating as well as double integrating process with time deferral and we match it with SIMC rules. The performances of the projected controllers are matched with the controllers planned by newly stated systems. In controller, there is usually a trade-off among performance and robustness, so there does not exist a single ideal controller. The strength of the planned controllers for the anxiety in model parameters is calculated seeing one factor at a time using different theorems. The proposed controllers are applied to numerous transfer task models and to non linear model of isothermal uninterrupted copolymerization of styrene-acrylonitrile in CSTR. An investigational set up of tank with the outlet connected to a pump is measured for implementation of the PID controllers designed by the three planned methods to show the usefulness of the methods.

**KEYWORDS:** PID controller; integrating systems; internal model controller; stability analysis; direct synthesis method; level control in cylindrical tank.

### I. INTRODUCTION

The ubiquitous PID controller has continued to be the most usually used process control technique for many decades. Although advanced control techniques such as model predictive control can provide significant improvements, a PID controller that is properly designed and tuned has proved to be satisfactory for the vast majority of industrial control loops. The enormous literature on PID controllers includes a wide variety of design and tuning methods based on different performance criteria. Incorporating systems with time suspension are create in the modeling of liquid level systems, liquid storage tanks, boilers, batch chemical reactors and the bottom level control of a distillation column [1]. Here we investigate optimal PID control of a double integrating plus delay process. What makes the double integrating process special, is that derivative action is actually necessary for stabilization.

DS design methods are usually based on specification of the desired closed-loop transfer function for set-point changes. Consequently, the resulting DS controllers tend to perform well for set-point changes, but the disturbance response might not be satisfactory. The IMC-PID controller provides good setpoint tracking but very sluggish disturbance responses for processes with a small time-delay/time-constant ratio. Fuentes and Luyben [2] have reported that the composition control loop of a high purity distillation column has a large time constant and hence, the response resembles that of a pure integrator plus dead time model. An isothermal continuous copolymerization reactor can be modeled as an integrating system with dead time [3]. The model contains only two parameters ( $k$  and  $Lp$ ) and the model is very simple for identification. The model is able to adequately represent the dynamics of many systems over the frequency range of interest for the PID controller design.



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## II. RELATED WORK

In [1] The classical example of an integrating process with inverse response is level control of a boiler steam drum. The “boiler swell” problem can lead to a transfer function between the drum level and boiler feed water flow rate that contains a pure integrator and a positive zero, in addition to some dead time and lags. This paper presents a procedure for identifying the transfer-function parameters for this type of system from step response data. In [2] A design method for PID controllers based on the direct synthesis approach and specification of the desired closed-loop transfer function for disturbances is proposed. Analytical expressions for PID controllers are derived for several common types of process models, including first order and second-order plus time delay models and an integrator plus time delay model. Although the controllers are designed for disturbance rejection, the set-point responses are usually satisfactory and can be tuned independently via a set-point weighting factor. In [3] a simple controller design rule and tuning procedure for unstable processes with delay time is discussed. The method is developed based on a -3 dB, gain crossover and phase crossover frequencies with pade approximation for the time delay. Simulation examples are included to show the effectiveness of the proposed method. In [4] a new tuning procedure is described for the ideal PID controller in series with the firstorder low pass filter. It is based on the direct synthesis approach. Analytical expressions for the PID controller are derived for a common type of process model. Although the controller is designed for disturbance rejection, the set point response is satisfactory and can be improved by adjusting a single set point weighting factor  $b$ . Three simulation examples demonstrate that the proposed design method results in very good control for process models. In [5] a frequency response based design method of PID controller is proposed for higher order (HO)/-plus delay time (HOPDT) systems. The HO/-PDT models are converted into real and imaginary part at a frequency where a criteria similar to amplitude and phase margin is utilized to get the constraints on the parameters of the controllers. In [6] Control system design involves input/output (IO) selection, that is, decisions on the number, the place, and the type of actuators and sensors. The choice of inputs and outputs affects the performance, complexity, and cost of the control system. In most of the multivariable systems controllers are designed by decomposing multi-loop systems into a number of equivalent single loops and design of a controller for each loop is performed. In [7] The proposed method has only one parameter to tune and therefore provides simple and effective solution for large class of systems. Two simulation examples and real time experimentation are incorporated to show the effectiveness of proposed algorithm.

### Methods in proposed system

The present work is intended to design PID controllers for pure integrating systems with time delay using three methods (i) IMC method (ii) direct synthesis method and (iii) stability analysis method.

#### 1. IMC Method

A well-known control system design strategy, internal model control (IMC) was developed by Morari and coworkers [20] and is closely related to the direct synthesis approach. Like the DS method, the IMC method is based on an assumed process model and relates the controller settings to the model parameters in a straightforward manner. The IMC approach has the advantages that it makes the consideration of model uncertainty and the making of tradeoffs between control system performance and robustness easier.

The process transfer function is given by

$$G_p = \frac{k_p e^{-Ls}}{s} \quad (1)$$

Using Pade's approximation for time delay, Eq (1) is rewritten as

$$G_p = \frac{k_p (1 - 0.5Ls)}{s(1 + 0.5Ls)} \quad (2)$$

IMC controller for the above system consists of two parts. First part is the inverse of the stable portion of the process and second part is IMC filter. The numerator order of the IMC filter is equal to the number of unstable poles.



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## Direct Synthesis method

In general, both the direct synthesis and IMC methods do not necessarily result in PI/PID controllers. However, by choosing the appropriate desired closed-loop response and using either a Pade' approximation or a power-series approximation for the time delay, PI/PID controllers can be derived for process models that are commonly used in industrial applications.

The process transfer function is given by Eq (1). The controller transfer function istaken as

$$G_c = k_c \left(1 + \frac{1}{\tau_I s} + \tau_D s\right) \frac{1}{(1 + \tau_f s)}$$

Where  $\tau_f = \beta \tau_D$

## Stability analysis method

Generally we will deal with a semi discrete model: discrete in space and continuous in time. In the time domain the model is given by ordinary differential equations (ODE) in time.

Amplification Methods. Also called von Neumann stability analysis. Based on decomposition of motion into normal modes, often using Fourier analysis, and superposition. The analysis looks at the growth or decay of perturbations from one step to the next, and can be implemented using standard linear algebra procedures. It is local in nature, but so is the concept of stability. Amore severe restriction is that it strictly applies only to linear systems. Despite this limitation it is frequently applied to nonlinear systems through linearization. Energy Methods. Also known, notably in control theory, as Lyapunov methods. These look at the variation of certain function (or functional) measures of the motion amplitude. Often these are related to energy measures of various kinds, hence the name. Energy methods are not restricted to linear systems, but require the construction of suitable measures, and this has to be done case by case.

The process transfer function for pure integrator with time delay is given by equation Eq (1). The phase angle criterion for pure integrator with time delay is given by

$$\phi(\omega) = -\frac{\pi}{2} - L\omega \tag{3}$$

## Kharitonov's theorem:

The stability regions of the model parameters for the PID controller designed are calculated by Kharitonov's theorem considering uncertainty in one parameter at a time. Kharitonov's theorem is a result used in control theory to assess the stability of a dynamical system when the physical parameters of the system are not known precisely. When the coefficients of the characteristic polynomial are known, the Routh-Hurwitz stability criterion can be used to check if the system is stable (i.e. if all roots have negative real parts). Kharitonov's theorem can be used in the case where the coefficients are only known to be within specified ranges. It provides a test of stability for a so-called interval polynomial, while Routh-Hurwitz is concerned with an ordinary polynomial.

An interval polynomial is the family of all polynomials  $p(s) = a_0 + a_1 s^1 + a_2 s^2 + \dots + a_n s^n$  where each coefficient  $a_i \in R$  can take any value in the specified intervals  $l_i \leq a_i \leq u_i$ . It is also assumed that the leading coefficient cannot be zero:  $0 \notin [u^m, l^m]$ .

An interval polynomial is stable (i.e. all members of the family are stable) if and only if the four so-called Kharitonov polynomials are stable.

$$\begin{aligned} k_1(s) &= l_0 + l_1 s^1 + u_2 s^2 + u_3 s^3 + l_4 s^4 + l_5 s^5 + \dots \\ k_2(s) &= u_0 + u_1 s^1 + l_2 s^2 + l_3 s^3 + u_4 s^4 + u_5 s^5 + \dots \\ k_3(s) &= l_0 + u_1 s^1 + u_2 s^2 + l_3 s^3 + l_4 s^4 + u_5 s^5 + \dots \\ k_4(s) &= u_0 + l_1 s^1 + l_2 s^2 + u_3 s^3 + u_4 s^4 + l_5 s^5 + \dots \end{aligned}$$



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What is somewhat surprising about Kharitonov's result is that although in principle we are testing an infinite number of polynomials for stability, in fact we need to test only four. This we can do using Routh-Hurwitz or any other method. So it only takes four times more work to be informed about the stability of an interval polynomial than it takes to test one ordinary polynomial for stability.

Kharitonov's theorem is useful in the field of robust control, which seeks to design systems that will work well despite uncertainties in component behavior due to measurement errors, changes in operating conditions, equipment wear and so on.

### III. CONCLUSION AND FUTURE WORK

Three methods of designing PID controllers for pure integrating system with time delay are proposed based on IMC method, stability analysis method and direct synthesis method. The performance of the proposed controllers is better than the recently reported methods. Stability region for various model parameters considering uncertainty in one parameter at a time is obtained using theorem and compared with that of the literature reported methods. The stability region for all the model parameters is comparable with that of the literature reported methods. The advantage of these methods is that the controller is PID and simple conventional feed back control structure is used.

### REFERENCES

- [1] Chien, L. and Fruehauf, P. S. 1990. Consider IMC tuning to improve performance. *Chem Eng Progr*, 10: 33-41.
- [2] Fuentes, C. and Luyben, W. L. 1983. Control of high purity distillation columns. *Ind Eng Chem Process Des Dev*, 22: 362.
- [3] Srividya, R. and Chidambaram, M. 1997. On line controller tuning for integrator plus delay processes. *Process Contr Qual*, 9: 59-66.
- [4] Astrom, K. J., and Hagglund, T. 1995. "PID controllers: Theory, Design and Tuning", Instr Soc. America, North Carolina.
- [5] Yu, C. C. 1999. "Auto Tuning of PID controllers", Springer-Verlag, Berlin
- [6] Ziegler, J. G. and Nichols, N. B. 1942. Optimum settings for automatic controllers. *Trans ASME*, 64: 759-765.
- [7] Tyreus, B.D. and Luyben, W.L. 1992. Tuning PI controllers for integrator/dead-time processes. *Ind Eng Chem Res*, 31: 2625.
- [8] Chidambaram, M. 1994. Design of PI controller for integrator/dead-time processes. *Hungar J Ind Chem*, 22: 37.
- [9] Poulin, E. and Pomerleau, A. 1999. PI settings for integrating processes based on ultimate cycle information. *IEEE Trans Contr Syst Tech*, 7: 509.
- [10] Luyben, W. L. 1996. Design of Proportional Integral and Derivative controllers for integrating dead-time processes. *Ind Eng Chem Res*, 35: 3480.
- [11] Wang, L. and Cluette, W.R. 1997. Tuning PID controllers for integrating processes. *IEE Proc Contr Theor Appl*, 144: 385.
- [12] Kookos, I. K., Lygros, A. I., and Arvanitis, K. G. 1999. On-line PI controller tuning for integrator / dead time processes. *Eur J Contr*, 5: 19.
- [13] Wang, Y.G. and Cai, W.J. 2002. Advanced proportional integral derivative tuning for integrating and unstable processes with gain and phase margin specifications. *Ind Eng Chem Res*, 41: 2910-2914.
- [14] Visioli, A. 2001. Optimal tuning of PID controllers for integral and unstable processes. *IEE Proc Contr Theor Appl*, 148: 180.
- [15] Zhang, W., Xu, X., and Sun, Y. 1999. Quantitative performance design for integrating processes with time delay. *Automatica*, 35: 719-723.
- [16] Ali, A. and Majhi, S. 2010. PID controller tuning for integrating processes. *ISA Trans*, 49: 70-78.
- [17] Rivera, D.E., Morari, M., and Skogestad, S. 1986. Internal Model Control - 4, PID controller design. *Ind Eng Chem Process Des Dev*, 25: 1684.
- [18] Skogestad, S. 2003. Simple analytical rules for model reduction and PID controller tuning. *J Process Contr*, 13: 291-309.
- [19] Shamsuzzoha, Md. and Lee, M. 2008. PID controller design for integrating processes with time delay. *Kor J Chem Eng*, 25, 4: 637-645.
- [20] Sung, S.W. and Lee, I.B. 1996. Limitations and counter measures of PID controllers. *Ind Eng Chem Res*, 35: 2596-2610.