On-line PI control method for Stable Processes

Utkal Mehta and Somanath Majhi

Abstract

The aim of this paper is to present a method for on-line tuning of PI controller for stable processes. Without breaking closed-loop control, an explicit process model is developed from a single relay test and then controller gains are re-tuned non-iteratively to improve the performance. An explicit tuning rules based on ISTE performance criterion are derived with special emphasis on minimizing the control efforts. Examples are given to illustrate the simplicity and superiority of the proposed method compared with some existing ones.

Index Terms

On-line PI Control; Relay feedback; ISTE criterion

I. Introduction

Inspite of many well-known tuning formulas derived to tune the PI / PID controllers, manual tuning which is somewhat tedious and time consuming is in widespread use. The results of manual tuning mainly depends on the experience and the process knowledge of an operator. Automatic or on-line tuning methods thus draw more and more attention from researchers and practicing engineers. One of the simplest and most robust auto-tuning techniques for process controllers is a relay feedback method that has been adopted by several researchers. But the controller tuning techniques based on a basic relay method are essentially an off-line in which the controllers needs to be detached to extract some information about the process. Off-line tuning has associated implications in the tuning-control transfer, affecting operational process regulation which may not be acceptable for certain critical applications [1]. It has also been reported, off-line tuning may be too expensive or dangerous if the control loop to be broken for tuning purposes, and so tuning under tight continuous closed-loop control is necessary.

Schei [2] suggested an on-line iterative method for closed loop automatic tuning of PID controllers. Tan et al. [1] have proposed an on-line tuning method which is effective against many constraints of the basic relay auto-tuning method. The identification procedure by their direct method is not straightforward and one needs to have prior knowledge about the system to decide about the suitable frequency response prototypes. Further, their indirect controller tuning method uses the approximate describing function analysis to obtain a first order transfer function model of the system. Ho et al. [3] have presented relay autotuning of PID controllers by iterative feedback method with specified phase margin and bandwidth. The complexities of the method is apparent from the problems associated with choosing the number of parameters and computing the gradient of the quadratic criterion. Further, when a static load is present during the tuning experiment, their describing function based analysis may yield erroneous results. Majhi [4] has presented the on-line tuning method based on limit cycle measurements and minimization of ISTE criterion. Recently, Tsay [5] has proposed on-line computing rules by introducing a relay with a pure time lag in the loop to find parameters of PI and lead compensators based on specified gain and phase margin. His method requires to initiate repeatative process identification till an acceptable gain margin is found.

Many approaches exist for tuning PI/PID controllers based on process model parameters that has been discussed comprehensively in [6], [7]. Generally, the information are provided in terms of the parameters of the first order plus dead time (FOPDT) model and separate rules are designed for setpoint control and load disturbance. Tuning rules are derived based on integral criteria which give appreciable results after minimizing performance indices like IAE and ITAE criteria by [8] and the exponential time weighted ISE criteria by [9]. One of the performance index ITAE, based on which a new property called balanced tuning for PI controller is derived by Klan and Gorez [10], [11]. Their tuning rules are designed with respect to equal amount of P and I actions.

In this paper, a simple structure for on-line tuning of PI controller is suggested. Without breaking a closed-loop control, the process model are estimated based on limit cycle measurements and then controller parameters are calculated using a simple empirical rules. These rules are developed in line with the work [11] for automatic tuning of PI controller based on the relation between ISTE criterion and P-I control actions. The proposed on-line tuning scheme is non-iterative and shows robust performance to preserve the actuator from the large variation of the control signals. Results from the simulation studies are given to show the simplicity and effectiveness of the proposed identification and control methods.

REFERENCES

[1] K. K. Tan, T. H. Lee, X. Jiang, Robust on-line relay automatic tuning of PID control system, ISA Trans. 39 (2) (2000) 219–232.

[2] T. S. Schei, A method for closed loop automatic tuning of PID controllers, Automatica 28 (3) (1992) 587–591.

[3] W. K. Ho, Y. Honga, A. Hanssonb, H. Hjalmarssonc, J. W. Denga, Relay auto-tuning of PID controllers using iterative feedback tuning, Automatica 39 (2003) 149–157.

[4] S. Majhi, On-line PI control of stable processes, J. Proc. Contr. 15 (2005) 859–867.

[5] T.-S. Tsay, On-line computing of PI/lead compensators for industry processes with gain and phase specifications, Comp. Chem. Eng. 33 (2009) 14681474.

[6] K. J. Åström, T. Hägglund, PID Controllers: Theory, Design and Tuning. Instrument, Society of America, Research Triangle Park, 1995.

[7] A. O'Dwyer, Handbook of PI and PID Controller Tuning Rules, Imperial College Press, 2003.

[8] A. A. Rovira, P. W. Murrill, C. J. Smith, Tuning controllers for setpoint changes, Instr. Control Syst. 42 (1969) 6769.

[9] M. Zhuang, D. P. Atherton, Automatic tuning of optimum PID controllers, IEE Proc.-Contr. Theory Appl. 140 (1993) 216–224.

[10] P. Klan, R. Gorez, Balanced tuning of pi controllers, European J. Contr. 6 (2000) 541 – 550.

[11] P. Klan, R. Gorez, Simple analytic rules for balanced tuning of PI controllers, Proceedings 2nd IFAC Conference on Control System Design (2004) 47–52.

[12] S. Majhi, D. P. Atherton, Autotuning and controller design for processes with small time delay, IEE Proc.-Contr. Theory Appl. 146 (1999) 415–424.

[13] S. Skogestad, Simple analytic rules for model reduction and pid controller tuning, J. Proc. Contr. 13 (2003) 291309.

[14] T. Hägglund, Automatic detection of sluggish control loops, Control Eng. Pract. 7 (1999) 1505 – 1511.

[15] A. Savitzky, M. J. E. Golay, Smoothing and differentiation of data by simplified least squares procedures, Analytical Chemistry 36(2) (1964) 1627.