Chapter 38
SOSPD Controllers Tuning by Means of an Evolutionary Algorithm

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ABSTRACT

The Proportional Integral Derivative (PID) controller is the most widely used industrial device to monitoring and controlling processes. There are numerous methods for estimating the controller parameters, in general, resolving particular cases. Current trends in parameter estimation minimize an integral performance criterion. Therefore, the calculation of the controller parameters is proposed as an optimization problem. Although there are alternatives to the traditional rules of tuning, there is not yet a study showing that the use of heuristic algorithms it is indeed better than using the classic methods of optimal tuning. In this paper, the evolutionary algorithm MAGO is used as a tool to optimize the controller parameters. The procedure is applied to a range of standard plants modeled as a Second Order System plus Time Delay. Better results than traditional methods of optimal tuning, regardless of the operating mode of the controller, are yielded.

1. INTRODUCTION

There are two types of controller operation. One is a regulator (Alfaro, 2002) when the reference value *R(s)* remains constant (a system behavior insensitive to disturbances is preferred). The other one is a servomechanism (Alfaro, 2003) when the reference *R(s)* may change over time (therefore good tracking is expected). For a process matching some predetermined design specifications and robustness according with a performance criteria, the controller tuning based on PID structure consists on setting their parameters K_C, T_i, and T_d, representing the proportional, integral and derivative criteria, respectively.

Before the controller tuning it is necessary to identify the dynamics of the process to be controlled and representing that by some model $G_p(s)$.

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It is common that the model is a low order transfer function (first or second order, plus time delay). After having characterized the dynamics of the process and the type of operation, the choosing of the method for controller tuning proceeds. The process model has great influence on the selected tuning rule. The selection of the tuning rule is based on the required performance and the desired robustness. O'Dwyer (2009) reports that 90% of the tuning rules developed to date are based on a model of first and second order plus time delay. The controller tuning rules most frequently used are not based on an integral performance criterion. The optimal tuning rules based on second-order models are just 14 of the 84 reported until 2009.

A comparative study of performance of different tuning classical methods for PI and PID controllers is achieved in Desanti (2004). This study concludes that tuning methods that require a *Second Order System Plus Time Delay model* (SOSPD) perform better than those that require a *First Order Lag Plus time Delay model* (FOLPD). This is the reason why the second order models plus time delay are dealt in this paper. The second order system plus time delay model was selected as representing the plants in order to compare the performance of a heuristic algorithm with the "best" techniques developed for PID controllers optimal tuning. For SOSPD models represented by Equations (1) and (2), 147 tuning rules have been defined based on the ideal structure of a controller PI/PID (O'Dwyer, 2009). In general, those rules are based on several relationships and/or conditions of the parameters defining the process model.

$$G(s) = \frac{K_p e^{-\tau_m s}}{T_{m1}^2 s^2 + 2\xi_m T_{m1} s + 1} \qquad (1)$$

$$G(s) = \frac{K_p e^{-\tau_m s}}{(1 + T_{m1} s)(1 + T_{m2} s)} \qquad (2)$$

where, *Kp*: Plant Gain; τ_m : Time Delay; *Tm1*, *Tm2*: Time constants of the plant; ξ: Damping factor of the plant.

In Mora (2004) and Solera (2006) the performance and robustness of some tuning rules are evaluated, and a complete analysis of the methods of tuning controllers based on SOSPD is made.

Each of the developed tuning rules for PI and PID controllers has only been applied to a certain group of processes. Alternative methodologies, such as design based on the root locus, tuning by pole-zero cancellation, tuning by the location of the closed-loop poles, among others, require cumbersome procedures and specialized knowledge in control theory. Additionally, most methods for optimal tuning of SOSPD systems require additional system information from experiments carried out directly on the plant; activities that are not always possible to perform because the presence of extreme stresses and oscillations which may create instability and damage to the system.

The studies mentioned suggest the lack of a general rule for tuning PI and PID controllers. Due to the large number of existing tuning rules it is necessary to find a tuning method that best satisfies the requirements of each problem and also ensures optimal values for the controller parameters according to the selected performance criterion.

However, the tuning of controllers that minimize an integral performance criterion can be established as an optimization problem that consists of minimizing an objective function. The minimum is the result of obtaining a suitable combination of the three parameters required by the PID controller.

There is a trend to develop new methods for tuning controllers of type PI and PID (Unar, 1996; Liu, 2001; Solera, 2005; Tavakoli, 2007), posed as a nonlinear optimization problem. Evolutionary algorithms have excelled in solving this problem (Fleming, 2002). In reviewing the literature is