Chapter 11

A Novel Moth–Flame Algorithm for PID–Controlled Processes With Time Delay

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ABSTRACT

This chapter proposes a classical controller to control the industrial processes with time delay. A new population-based metaheuristic technique, called moth flame optimization (MFO) algorithm, is employed to tune the parameters of the classical proportional-integral-derivative (PID) controller for achieving the desired set point and load disturbance response. MFO-based PID controller may deal with wide ranges of processes, which includes integrating and inverse response as well as it may control the processes of any order with time delay. The transient step response profile obtained from the proposed MFO-based PID controller is juxtaposed with those obtained from other methods for optimizing the gains of the PID controller to control the processes with time delay. The proposed controller is analyzed by implementing step disturbance in the process at a specific simulation time. For few time delay processes, reference models are employed for better transient response as well as to analyze the controller for controlling the overall system with reference model.

INTRODUCTION

In the process industries, proportional integral derivative (PID) controllers are still being broadly used even after significant development of control theory. Since the genesis of the automation systems, for the process industry, the PID controller has been the cardinal technique of feed forward and feedback control. Process industries have accepted the PID controller for its cost-to-benefit ratio.

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BACKGROUND

In the process industries, proportional-integral-derivative (PID) controllers are still being broadly used even after significant development of control theory. Since the genesis of the automation systems, for the process industries, the PID controller has been the cardinal technique of feed forward and feedback control. Process industries have accepted the PID controller for its cost-to-benefit ratio (McMillan, 2011).

The controller has proved to be simple in control, easily perceived, cheap in cost and can be maintained easily. In the last few decades, various methods have been proposed for its proper tuning. Numerous aspects of control performance requirements are considered in these tuning methods, such as, controller output, set-point response, load disturbance rejection and robust operation. The parameters of the PID controller sway the performance of the control system. The PID controller has been designed by many researchers using various methods (Astrom & Hagglund, 1995), such as, Ziegler-Nichols method (Ziegler & Nichols, 1942), cohen-coon method (Cohen and Coon, 1953) and so on.

The IMC structure is a well-accepted technique with ameliorate robustness. The desired closed loop time constant can be used by the user to specify the performance in terms of a single parameter. The IMC structure is used by Rivera et al. in (1986) to design the controller whose main objective is to show that IMC leads the PID controller in a natural way. Generally, the procedure of the IMC design is felicitous despite of the system considered. There is no requirement of any allocation to bestow with a system of very single type. The IMC configuration can be employed in the classical feedback configuration to enumerate a PID controller. The IMC design method is exploited mainly for low-order processes but, by employing model reduction technique, the high-order process can be reduced to low-order one to apply the technique for high-order processes. Lee et al. (1998) and Shamsuzzoha and Lee (2007) have employed the IMC configuration based Maclaunin series expansion of the equivalent classical feedback controller to obtain the gains of the PID controller. Panda in (Panda, 2008; Panda, 2009) has used the Laurent series expansion for obtaining the desired controller performance. In 2012, for stabilizing the unstable process, Vijayan and Panda (2012) used the double feedback loops with the inner loop to propose the PID controller based on the IMC scheme. Wang et al. proposed another IMC approach based on minimization of frequency response error (refer (Wang et al., 2001)).

For obtaining the parameters of the PID controller, model matching technique can be applied in the frequency domain, without model reduction in high-order processes. In the year 1995, Wang et al. (1995) proposed new frequency domain design method for the PID controller. Later on, optimization technique and multiple frequency points for matching purpose have been employed by Wang et al. (1997). For stable and unstable process, Rao et al. (2009), Vanavil et al. (2015) as well as Chen and Seborg (2002) have employed the direct synthesis (DS) approach for the design of the PID controller, where the design is based on a desired closed loop transfer function (Seborg et al., 1989). The DS approach also requires model reduction technique like IMC approach, as it is also based on low-order model. Skogested (2003) presented analytic rules for tuning the PID controller model reduction which is simple. For a first order or second order time delay model, Skogested (2003) has employed a single tuning rule and also used ‘half rule’ for achieving time delay. Jeng and Lin (2012) have designed a robust PID controller for inverse response and time delay based stable/integrating processes. Chen et al. (2006) have designed an analytical PID controller based on IMC structure to transform inverse processes with single adjustable control parameters. Ho et al. (1995) have derived a tuning formula for PI and PID controllers to obtain the user-specified gain and phase margins. The integral squared error criterion is minimized in (Ali & Majhi, 2010) to propose the tuning formulas for integrating processes. The researchers have proposed it with
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