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PID controller tuning rules for integrating processes with varying time-delays

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Abstract

This paper discusses PID controller tuning for integrating processes with varying time-delays. Most of the existing tuning rules for the first-order lag plus integrator plus delay (FOLIPD) processes that we mainly focus on have the same general structure, and the properties of these rules are discussed in conjunction with varying time-delays. The analysis leads to novel tuning rules, where the maximum amplitude of an arbitrarily varying time-delay can be given as a parameter, which makes the use of the rules attractive in several applications. We will also extend the analysis to integrating processes with second-order lag and apply the design guidelines for a networked control application. In addition, we propose a novel tuning method that optimizes the closed-loop performance with respect to certain robustness constraints while also providing robustness to delay variance via jitter margin maximization. Further, we develop new PID controller tuning rules for a wide range of processes based on the proposed method. The new tuning rules are discussed in detail and compared with some of the recently published results. The work was originally motivated by the need for robust but simultaneously well-performing PID parameters in an agricultural machine case process. We also demonstrate the superiority of the proposed tuning rules in the case process.

Keywords: PID control; Tuning; Integrating processes; Varying time-delay systems; Networked control systems

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1. Introduction

The tuning of the PID controller has been discussed in numerous articles and books, and there exists a variety of tuning methods. Maybe the best-known tuning rules are those proposed by Ziegler and Nichols (Z–N) already in 1942 [1]. Still today the Z–N methods and their variants are popular in process control. It is obvious that the Z–N tuning methods do not meet the requirements of all the processes in today's industry. An example of this is a networked control system where varying time-delays might endanger the stability.

PID tuning is not a completely solved problem despite of the decades of research. On the contrary its research seems to grow [2]. Some recent industrial PID control methods are discussed in [3]. Nevertheless, the PID tuning problem has not been addressed very often in conjunction with varying time-delay systems even though careful tuning is a prerequisite for applying the control algorithm in such systems. Various more complicated algorithms have recently been proposed for varying time-delay systems, e.g. LQG controllers [4,5], due to rapidly increasing interest towards networked and wireless control systems, where varying time-delays and packet loss need to be compensated with appropriate control laws. The drawbacks of the advanced controllers include complicated implementation, which impedes applying the controllers in practice. The previous work regarding PID tuning in varying time-delay systems has focused on developing tuning procedures and rules for stable systems [6] and also integrating processes have been considered [7].

The research described in this paper was originally motivated by the need for PID tuning rules for integrating processes where variable transport delays and gain parameters affect the system stability and performance. The present tuning rules are investigated in this framework and a new tuning method and also tuning rules are proposed. This paper extends the results in [7] with new analysis and a case example related to networked control.

2. Control system and preliminaries

The general layout of the considered control system and its components are discussed in this section. The PID controller tuning rules currently found in the literature are also reviewed for this process type. The performance measures used in this paper such as the distance from the "robustness circle" and the jitter margin are presented.

2.1. Process model

The general layout of the control system is shown in Fig. 1. We consider an integrating process in conjunction with a low-pass measurement filter. Alternatively, the low-pass filter can be a part of the process (integrator + first-order lag). In both cases the process model is

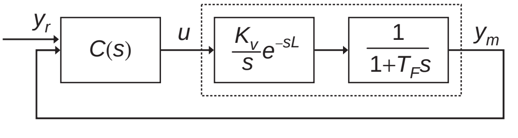

Fig. 1. The general layout of the control system.