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# Performance assessment of PID control loops subject to setpoint changes☆

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ABSTRACT

This paper aims at assessing the setpoint tracking performance of PID control loops, under certain constraints such as the processes under control are linear-time invariant and the instrumentations of control loops work properly. The lower bounds of integrated absolute errors (IAEs) are established, based on the widely used internal model control (IMC) principle, from closed-loop responses subject to setpoint changes in the form of step, ramp or other general types. Taking the lower bound as a benchmark, an IMC-IAE-based index is proposed to assess the setpoint tracking performance of PID control loops. Numerical and experimental examples, as well as an industrial case study, are provided to verify the lower bound as the performance benchmark and to illustrate the effectiveness of the proposed performance index.



## 1. Introduction

Many industrial feedback control loops suffer from performance problems, possibly due to incorrect tuning, large unmeasured disturbances, inappropriate control structures [1,2]. These problems may cause inferior products, large waste and even safety issues. The objectives of control loop performance assessment are to develop tools that deliver information to users such as how well control loop performance meets with their control targets. To reach this objective, one of the most important tasks is to find a benchmark against which the current control-loop performance can be assessed. The celebrated minimum variance control (MVC) benchmark introduced by Harris [3] is such a benchmark to assess the control-loop performance.

Proportional-integral-derivative (PID) controllers are extensively used in industrial feedback control loops. Improper PID settings may result in sluggish, aggressive or oscillatory loop responses, poor disturbance rejection ability, low robustness and even safety problems. Hence, finding a benchmark to assess the performance of PID control loops is very important for industrial practice. The traditional performance indices include the overshooting, rising time, and settling time. Ko and Edgar [4,5], Jain and Lakshminarayanan [6], and Sendjaja and Kariwala [7] took the same idea of the MVC benchmark, with a specific consideration of the restricted PID controller structure, to calculate the best achievable minimum variance bound for PID/PI controllers. Grimble [8], Huang [9] and Horton et al. [10] studied the benchmark based on the LQG cost function with consideration on the restricted structure imposed by PID/PI controllers. Huagglund [11], Kuehl and Horch [12] and Visioli [13] used the area index and the idle index to tell whether a PID control loop is sluggish or oscillatory when the load disturbance presents. Recently, researchers have been focusing on the integrated absolute error (IAE) based indices. Swanda and Seborg [14] and Huang and Jeng [15] estimated the lower IAE bound for PI/PID control loops from step response by simulations. Veronesi and Visioli [16,17] proposed two indices for PID controllers based on IAE from closed-loop step responses by following the Skogestad internal model control tuning rule; they [18] later generalized the results based on both setpoint and load disturbance step responses for integral processes.

This paper studies the performance assessment of PID control loops subject to setpoint changes, under certain constraints, e.g., the processes under control are linear-time invariant (LTI) and the instrumentations of control loops work properly (to be clarified later in Section 4). While the existing studies in this category are limited to closed-loop step responses, we would also like to consider other types of setpoint changes that appear even more often than step changes in industrial practice, in order to avoid adverse effects caused by abrupt step changes. In addition, the current control loop performance is evaluated against the expected one using a PID controller following the internal model control (IMC) tuning rule. This tuning rule is preferred, because it usually leads to a

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