Journal of Process Control 21 (2011) 620–626

Contents lists available at ScienceDirect

Journal of Process Control

journal homepage: www.elsevier.com/locate/jprocont

Classification of dynamic processes and PID controller tuning in a parameter plane

Tomislav B. Šekara, Miroslav R. Mataušek*

Faculty of Electrical Engineering, University of Belgrade, Bulevar Kralja Aleksandra 73, Belgrade 11000, Serbia

ARTICLE INFO

Article history:
Received 21 June 2010
Received in revised form 6 December 2010
Accepted 12 December 2010
Available online 20 January 2011

Keywords:
PID control
Process classification
Knowledge tuning
Performance prediction

ABSTRACT

A quadruplet, defined by the ultimate frequency ω_u, the ultimate gain k_u, the angle φ of the tangent to the Nyquist curve at the ultimate frequency and the gain $G_p(0)$, is sufficient for classification of a large class of stable processes, processes with oscillatory dynamics, integrating and unstable processes $G_p(s)$. From the model defined by the above quadruplet, a two parameter model $G_n(s_n)$ is obtained by the time and amplitude normalizations. Two parameters of $G_n(s_n)$, the normalized gain ρ and the angle φ, are coordinates of the classification ρ–φ parameter plane. Model $G_n(s_n)$ is used to obtain the desired closed-loop system performance/robustness tradeoff in the desired region of the classification plane. Tuning procedures and tuning formulae are derived guaranteeing almost the same performance/robustness tradeoff as obtained by the optimal PID controller, applied to $G_p(s)$ classified to the same region of the classification plane. Validity of the proposed method is demonstrated on a test batch consisting of stable processes, processes with oscillatory dynamics, integrating and unstable processes, including dead-time.

1. Introduction

PID controllers, in single and cascade loops, with or without derivative action, are still mostly used control systems in the majority of industrial applications. “Many strategies proposed can be easily eliminated if they are compared with well tuned PID” [1]. This is one of the reasons why a large number of tuning procedures is proposed for adjusting proportional gain k, integral gain k_i, derivative gain k_d and time constant T_f of the noise filter, in the PID controller:

$$C_{PID}(s)=\frac{k_d s^2+ks+k_i}{s(T_f s+1)}, \quad (1)$$

presented with transfer function $C(s)$ in Fig. 1. When k, k_i, k_d and T_f are determined, $G_{ff}(s)$ can be designed and tuned as in [2], while $C(s)$ can be implemented as in (1) or in the traditional form where noise filtering affects the derivative term only [3]. Finally, for $k_d=0$ one obtains PI controller, with $T_f=0$ or $T_f\neq 0$.

In practice, we are faced with the following situation: “In fact, a visit to a process plant will usually show that a large number of the PID controllers are poorly tuned” [4]. Moreover, as stated in [5]: “... 25% of all PID controller loops use default factory settings, implying that they have not been tuned at all”. The reasons for the so disappointing reality are the following facts. All processes (thermo and hydro dynamic, chemical, mechanical, nuclear) in a great number of different plants, with a much greater number of operating regimes in these process plants, constitute practically an infinite batch of possible linear stable, integrating and unstable models $G_p(s)$. The complete test batch, to be used for deriving and analyzing tuning procedures for the PID controller, is practically infinite. A large test batch from [6], defining different stable and integrating processes $G_p(s)$, covers a small domain in the parameter plane proposed here for classification of processes. Accordingly, to have an adequate insight into the problem of deriving and analyzing tuning procedures for the PID controllers it is necessary to have a reliable classification of different processes $G_p(s)$.

In the present paper, firstly a simple and effective way for classification of a large class of stable, oscillatory, integrating and unstable processes, including dead-time, is developed. This is done in the proposed classification ρ–φ parameter plane, defined by the normalized gain $\rho=1/(1+\kappa)$, $\kappa=1/(k_u G_p(0))$ and the angle φ of the tangent to the Nyquist curve at the ultimate frequency ω_u, of a process $G_p(s)$. Recently, it has been shown in [7,8] that this additional parameter φ defines in the frequency domain an extension of the Ziegler–Nichols approach [9] to the process dynamics characterization, which makes possible to capture the essential dynamic characteristics of a large class of stable, oscillatory, integrating and unstable processes, including dead-time. It is demonstrated in [7,8] that practically the same performance/robustness tradeoff is obtained by applying the PI/PID controller constrained optimiza-

* Corresponding author. Tel.: +381 11 324 84 64; fax: +381 11 324 86 81.
E-mail addresses: tomi@etf.rs (T.B. Šekara), matausek@etf.rs (M.R. Mataušek).

0959-1524/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.jprocont.2010.12.004