International Journal of Dynamics and Control
https://doi.org/10.1007/s40435-020-00608-z

A new fractional order controller tuning method based on Bode's ideal transfer function

Bouziane Keziz[1] · Abdelbaki Djouambi[1] · Samir Ladaci[2,3]

Received: 17 December 2018 / Revised: 2 December 2019 / Accepted: 7 January 2020

Abstract
A new tuning method for Fractional Order Controllers (FOC) based on Bode's ideal transfer function as a reference model is proposed in this paper. The proposed fractional order controller parameters are obtained by a simple tuning technique in two steps. In the first step, the open loop reference fractional integrator is designed according to the desired performances, and then approximated by a rational transfer function using Charef's or Oustaloup's approximation method. In the second step, a standard pole placement technique is used to align each pole of the plant transfer function with the nearest one of the Rational Function Approximation (RFA). The FOC transfer function is then obtained by gathering the remained poles and zeros of the RFA. The most innovative character of the proposed method is its simplicity and its remarkable performances in terms of robustness towards the variation of the static gain. Simulation of some illustrative examples confirms and validates the proposed method.

Keywords Fractional order reference model · Fractional order tuning · Pole placement · Bode's ideal transfer function · Rational function approximation

1 Introduction

In recent years, fractional calculus (FC) has become an important tool in many areas of science and engineering such as mathematical modeling, identification and control theory [1–5]. In control theory, the fractional calculus and its applications leads to fractional order controllers, e.g., CRONE control (French abbreviation for Commande Robuste d'Ordre Non Entier) [6,7], Fractional PI$^{\lambda}$D$^{\mu}$ control [8–10] and Robust Fractional Adaptive Control [11–13].

✉ Samir Ladaci
samir_ladaci@yahoo.fr

Bouziane Keziz
bouziane.auto@gmail.com

Abdelbaki Djouambi
djouambi_abdelbaki@yahoo.fr

[1] LGEA Laboratory, Department of Science and Technology, University Larbi Ben M'Hidi, 04000 Oum El-Bouaghi, Algeria

[2] E.E.A. Department, National Polytechnic School of Constantine, Nouvelle ville Ali Mendjli, 25100 Constantine, Algeria

[3] SP-Lab Laboratory, University of Mentouri Brothers, 25000 Constantine, Algeria

Nowadays, tuning of fractional controllers becomes one of the most interesting topics for many researchers in the literature. Along these topics many tuning techniques were developed. Among them, optimization based tuning and reference model-based tuning where the open-loop is given by the so-called Bode's ideal transfer function or fractional order integrator [14,15], thanks to its best characteristic in terms of robustness ensured by its iso-damping property [16,17]. In several of these methods authors have reported many acceptable results in numerous works and review articles.

Djouambi et al. [15] have proposed a simple technique to design fractional order controllers using the Bode's ideal transfer function as a reference model of the open-loop transfer function. However, the author assumes that the process must be stable and not oscillatory. Therefore, in this paper, a generalization of the above method is proposed to the case where no assumption on the stability conditions is needed for any minimum phase systems.

The remainder of this paper is organized as follows. Section 2 presents a summary review of fractional order systems, fractional order integrator with their rational approximation. Section 3 presents the proposed tuning method to design a robust fractional order controllers. Simulation results are

Published online: 23 January 2020