Studies in Infrastructure and Control

Arun Mozhi Devan Panneer Selvam ·
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Optimal Fractional-order Predictive PI Controllers

For Process Control Applications with Additional Filtering

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This work is dedicated to:

My favourite Tamil Mozhi, my parents Panneer Selvam and Gomathi, my brother Arul Sivanantham, my sister Anbarasi, my sister-in-law Kavitha and my friends for their endless love, support and encouragement

—P. Arun Mozhi Devan

The love of my life Fazleen, and my hero Faheem, you have been my inspirations, my love will always be with you.

—Fawnizu Azmadi Hussin

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—Kishore Bingi

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—M. Nagarajapandian

Preface

This book describes the design, development, and implementation of improved PI control techniques using dead-time compensation, structure enhancements, learning functions and fractional ordering parameters. These upgrades will obtain effective set-point tracking abilities with minimal load variations via improved disturbance rejection robust control action. Two fractional-order PI controllers are designed in line with this: fractional-order predictive PI and hybrid iterative learning based fractional-order predictive PI controller, described in the first part of this book. In addition, to minimize the initial load disturbances and stochastic noises, set-point and noise filters are designed by incorporating the essential dynamic parameters of the process models, which are described in Chap. 4. Furthermore, the fractional-order control strategies and filters presented in this book are simulated over first and second-order benchmark process models and further validated using the real-time experimentation of the pilot pressure process plant.

A novel arithmetic-trigonometric optimization algorithm developed is presented in Chap. 5 aims to obtain the effective controller parameters of the proposed techniques. The design uses the essential arithmetic and trigonometric operators to get the optimal parameters even during stochastic disturbances. Furthermore, the optimization technique is simulated with various fields of interest over thirty-three benchmark functions. Also, the proposed method is again validated using the real-time experimentation of the pilot pressure process plant for effective disturbance rejection with robust control actions. In all the performance studies, the proposed controllers, filters, and optimization techniques are compared with the conventional methods to validate the performance improvement.

In this book, these five chapters are structured with a logical sequence of details to provide a better understanding for the readers. A general introduction is presented in Chap. 1. In Chap. 2, a review of the PI controllers and their modifications are presented. Then, a detailed review of these modified PI control techniques such as PPI, FOPI, and ILC-PI controllers are presented. The following section presents the design and development of the proposed fractional-order predictive PI (FOPPI) controller with the help of a dead-time compensating Smith predictor and the robust fractional-order PI (FOPI). The subsequent section discusses the study on

PI controller application in the real-time process plant, followed by selecting benchmark process models. Lastly, the results and discussion of the proposed controller on benchmark process models and the real-time experimentation of the pilot pressure process plant are given.

In the first part of Chap. 3, a review of the PI-based iterative learning controllers, modified structures of the ILC and their modifications are presented. Then, the design of the proposed hybrid iterative learning controller based fractional-order predictive PI (FOPPI) controller based on the current cyclic feedback structure is presented. Lastly, the results and discussion of the proposed controller on benchmark process models and the real-time experimentation of the pilot pressure process plant are given.

Chapter 4 presents the development of the proposed filtering techniques. The first part discusses a review of the various types of filtering techniques in the process control loop. Then, the design of the proposed set-point and noise filters using the essential process dynamics are given. The last part presents the results and discussion of the proposed filters on benchmark process models and the real-time experimentation of the pilot pressure process plant.

Chapter 5 proposes the improvement of the existing sine cosine algorithm (SCA) and arithmetic optimization algorithm (AOA) to form a novel arithmetic-trigonometric optimization algorithm (ATOA) to accelerate the rate of convergence in lesser iterations with mitigation towards getting caught in the same local position. Then the simulation analysis over various benchmark test functions is carried out for validation. In addition, the proposed FOPPI controller will be tuned based on the integral time absolute error (ITAE) value as the desired objective function to find the controller parameters with minimal error while comparing the actual input in the closed-loop system.

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Acronyms

AI	Analogue Input
AO	Analogue Output
AOA	Arithmetic Optimization Algorithm
APAOA	Adaptive Parallel Arithmetic Optimization Algorithm
ARX	Auto Regressive eXogenous
ATOA	Arithmetic-Trigonometric Optimization Algorithm
CRONE	Commande Robuste d'Ordre Non Entier
DTC	Dead-Time Compensator
FOC	Fractional-Order Controller
FOMCON	Fractional-Order Modelling and Control
FOPDT	First-Order Plus Dead Time
FOPI	Fractional-Order PI
FOPPI	Fractional-Order Predictive PI
FOTF	Fractional-Order Transfer Function
FPI	Fuzzy PI
FPPI	Filtered Predictive PI
AGGPC	Generalized Predictive Controller
HV	Hand Valve
ILC	Iterative Learning Control
ILCFOPPI	Iterative Learning Control Fractional-order Predictive PI
ITAE	Integral Time Absolute Error
LabVIEW	Laboratory Virtual Instrument Engineering Workbench
LOF	Lower Order Filter
MATLAB	Matrix Laboratory
MIMO	Multi Input Multi Output
MOA	Math Optimizer Accelerated
MOP	Math Optimizer Probability
MPC	Model Predictive Control
MPCPI	Model Predictive Control PI
MRAC	Model Reference Adaptive Control
NPI	Non-linear PI