Sādhanā (2022)47:188
https://doi.org/10.1007/s12046-022-01962-8

Design of an improved robust fractional order PID controller for magnetic levitation system based on atom search optimization

SOHAM DEY[1,*], SUBRATA BANERJEE[2] and JAYATI DEY[2]

[1] Department of Electrical Engineering, DR. B.C. Roy Engineering College Durgapur, Durgapur, West Bengal 713206, India
[2] Department of Electrical Engineering, National Institute of Technology Durgapur, Durgapur, West Bengal 713209, India
e-mail: soham.dey@bcrec.ac.in; bansub2004@yahoo.com; deybiswasjayati@gmail.com

MS received 1 May 2022; revised 1 May 2022; accepted 23 July 2022

Abstract. A lucid methodology for the design and implementation of integer order PID (IOPID), integer order PID with derivative filter (IOPID-F), fractional order PID (FOPID) and fractional order PID with fractional order filter (FOPID-F) controllers for precisely controlling the position of an unstable Magnetic Ball Levitation System (Maglev) is reported in this work. Controller parameter values are obtained by numerically solving a constrained optimization problem incorporating desired performance criteria formulated by judiciously choosing selective transient performance metrics. The recently introduced Atom Search Optimization algorithm, used in this work, is fast, efficient and provides intelligent solutions for such complicated engineering design problems. Physical constraints are imposed on the optimization process when defining the feasible search space for the optimum controller parameter values. Both simulation and experimentation are carried out to establish the efficacy of the proposed technique. It has been observed from both simulation and experimental results that the FOPID-F controller showcases comparatively better performance in terms of transient specifications, stability margins and input reference tracking capability. Robustness to parameter variations for the proposed controllers is established with extensive experimentation on the Maglev set up.

Keywords. Atom search optimization; fractional order (FO) PID; FO derivative filter; optimized PID controllers; Maglev system; real time application.

1. Introduction

With the progress of advanced mathematics, fractional order calculus (FOC) has opened a new dimension for researchers in recent years. The internal physics of natural systems is now being captured accurately and precisely with this advanced mathematical tool [1]. The engineers are utilizing its magnificent potential to solve complex engineering problems, to develop the mathematical framework for physical processes including non-linear characteristics and to design models in diverse fields like signal processing [2], circuits and systems [3], robotics [4], control theory [5] and many more. This paper aims to utilize the powerful computational capability of the FOC in the domain of classical control theory and to develop a design methodology for fractional order (FO) control system for a magnetic levitation system (Maglev) which is a highly nonlinear and strictly unstable system. The proposed Maglev system has been linearized around an operating point and initially stabilized by a classical integer-order PID (IOPID) controller. Though the system had been stabilized in closed-loop, the Maglev system had a restricted zone of operation. Satisfactory performance is achieved by the classical controllers provided that the controllers operate in the vicinity of the equilibrium points and performance deteriorates with the change in the operating point. Maintaining system stability is quite difficult for the controllers if there is a large change of operating condition and other conditional parameters like frequency and amplitude of the input signal, etc. In this work, the performance of the proposed Maglev system is greatly enhanced by the FOPID controller as compared to the integer-order order PID controller in terms of transient and steady-state specifications, stability margins, trajectory tracking and robustness to a wide range of parameters variations.

The magnetic levitation system is an excellent application of modern technology spreading its influence in miscellaneous engineering fields such as active magnetic bearings, magnetic wind turbines and high-speed trains. Since magnetic levitation systems are inherently unstable and highly non-linear in nature, controlling of such complex systems is a challenging task. Linear feedback

*For correspondence
Published online: 10 September 2022