



Experimental study of fractional order proportional derivative controller synthesis for fractional order systems

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ABSTRACT

In recent years, studies on real systems have revealed inherent fractional order dynamic behavior, and fractional order systems have attracted more and more attentions. It is intuitively true that these fractional order models require the corresponding fractional order controllers to achieve desired performance. In this paper, an experimental study of the fractional order proportional and derivative (FO-PD) controller systematic design is presented, to validate the control performance for the fractional order systems with generalized fractional capacitor membrane model. The performance of the designed FO-PD controller is compared with both the integer order and fractional order controllers which are designed based on the approximate integer order system. This comparison results are presented both in the simulation and the hardware-in-the-loop experiment.

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1. Introduction

Fractional calculus is a generated by generalizing the traditional integration and differentiation to the fractional order. This conception of extending classical integer order calculus to non-integer order case has been known since of the development of the classical calculus, and has a long-standing theoretical research history. The first reference may be associated with the correspondence between Leibniz and L'Hospital [21] in 1695. Some initial research literatures on the fractional calculus can be found in [17,3,4,18, 2,23,14]. Recently, studies on real systems have revealed inherent fractional order dynamic behavior, and fractional order systems have attracted more and more attentions. Mechanical systems are described by fractional order state equations [1,2,16]; in electricity, several applications have proposed a concept of fractance, which has intermediate properties between resistance and capacitance [18,22,19,28]; many real systems in bioengineering are modeled or fitted by fractional order systems [7,15]; some new fractional derivative based models have been demonstrated in [3,4,20,8], which provide powerful instruments for the description of memory and hereditary effects in various substances.

Fractional order systems can model various real systems more adequately than integer order ones, and thus provide reliable modeling tool in describing many real dynamical processes. It is intuitively true that these fractional order models require the corresponding fractional order controllers to achieve desired performance. In most cases, however, researchers consider the fractional order controllers applied to the integer order plants to enhance the system control performance [29,10,13].

The significance of fractional order control is that it is a generalization of classical integral order control theory, which can lead to more accurate and more robust control performance [26,10, 12]. In general, there is no systematic way of designing proper fractional order controller for the fractional order systems. However, we may be able to get practical and simple fractional order controller parameters tuning schemes for certain specific fractional order plants.

In this paper, a fractional order proportional and derivative (FO-PD) controller is designed systematically for the fractional order systems with generalized fractional capacitor membrane model. In the simulation and experiment sections, the performance of the FO-PD controller designed based on the fractional order system (FOS), is compared with the integer order and fractional order controllers which are designed based on the approximate integer order system (IOS).

The major contributions of this paper include: (1) Simulation illustration of the performance comparison between the designed

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