Chapter 8

Design and Implementation of the FOIMC Using the PSO Algorithm for the Coupled Tank System

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ABSTRACT

In this work, a fractional order internal model controller (FOIMC) is developed for the level control of a coupled tank system. The parameters of the FOIMC are optimized by the particle swarm optimization (PSO) algorithm. The controller parameters obtained by the PSO algorithm, are compared with the gray wolf optimizer (GWO) and the whale optimization algorithms (WOA), and the PSO algorithm gave better results. The performance of the proposed FOIMC is compared with the state of the art. The experimental results obtained from the laboratory setup of the cylindrical tank system using the proposed FOIMC are also presented. The step responses from the simulation and the experimental results, indicated that the proposed FOIMC has good time domain performance than the state of the art. The proposed controller showed better robustness to a change in the operating point. The novelty of the present work is, for the first time, a comparative study of latest swarm algorithms is done for the tuning of FOIMC parameters.

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INTRODUCTION

The coupled tank system has two modes of operation: interacting and noninteracting. In the interacting mode, the tanks are connected in cascade physically, and in the noninteracting mode the tanks are not connected physically. In this work interacting coupled tank system is considered as the case study. The level control problem of the coupled tank system usually involves, changing the level of the tank from the one value to another value, or keeping the level constant at one value. Many works in the control literature discussed the level control problem. Patel and Shah (2018) discussed a fault tolerant controller for the level control of the coupled tank system using the artificial intelligence (AI) techniques. The controller parameters are tuned using the neural networks. Sathish et al. (2017) developed a linear quadratic regulator (LQR) for the multi-input multi-output (MIMO) model of the cylindrical three tank system level control (Kumar et. al, 2017). Singla et al. (2018) proposed a modified proportional integrator differentiator (PID) controller for the coupled tank system. Mahapatro et al. (2019) discussed the design and implementation of a decentralized proportional integrator (PI) controller for the level control of the coupled tank system. A reduced order model of the coupled tank system is obtained based on the frequency response fitting. Gouta et al. (2019) discussed the design of an adaptive high gain observer-based controller design, for the coupled tank system. A generalized predictive controller is used to minimize the multi stage objective function. Dumlu and Ayten (2018) proposed an adaptive sliding mode controller for the coupled tank system level control. The design combines the feedforward action with the adaptive feedback. Other popular controllers for the level control of the coupled tank system are conventional PID controller, internal model control (IMC), Model predictive controller (MPC), and adaptive controller etc.

Among the controllers available for the coupled tank system level control, the IMC has the advantages like stability, and minimum number of the parameters to be tuned. Some of the recent literature works on the IMC design are presented here. Li and Zhu (2019) developed an IMC- PID based controller for the speed control of the servo motor using an extended state observer. Pati and Negi (2019) designed a two degrees of freedom IMC for the magnetic levitation system. The controller parameters are tuned using the PSO algorithm. Vadamalu and Beidl (2019) designed an adaptive IMC for the internal combustion engine's torsional oscillations control. The controller reduces the disturbances at various operating speeds. Tasoujian et al. (2019) discussed the design of a robust IMC for the blood pressure regulation. An IMC-PID controller is developed including the uncertainty, with a time varying model. Li and Bing (2019) proposed a Smith predictor-based IMC for a second order time delay system.

The fractional order control became popular in the past three decades for the engineering, economic, biological problems. The fractional order proportional integrator differentiator (FOPID) is proposed by Podlubny (1994). Later many authors extended the fractional order concept to the popular controllers like IMC, MPC, and adaptive control etc. Vinopraba et al. (2012) discussed the design of a two degrees of freedom (2-DOF) FOIMC based on the closed loop system bandwidth. The FOIMC is the fractional order version of the IMC. Rodrigues et al. (2019) proposes an analytical design of the FOIMC for a FOPDT system. The controller parameters are obtained from optimizing an objective function. Erhan et al. (2019) proposed a FOPID controller for the higher order process. The controller parameters are tuned using the frequency domain specifications. Rayalla et al. (2019) discussed the design of the FOPID for a FOS using the higher order fractional filter based FOIMC. The controller parameters are tuned using the maximum sensitivity by minimizing the integral absolute Error (IAE). Wen et al. (2020) developed a FOIMC for the force/ position control of a parallel robot. Chekari et al. (2019), proposed a 2-DOF FOIMC satisfying the disturbance rejection and servo tracking. The peak overshoot of the servo response

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