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2DOF PID Controller Design for a Class of FOPTD Models – An Analysis with Heuristic Algorithms

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Abstract

In recent years, a number of controller design procedures are developed and implemented in process industries to enhance the performance of closed loop processes. In this paper, heuristic algorithm based Two Degrees Of Freedom (2DOF) PID controller design is proposed for a class of First Order Plus Time Delay (FOPTD) systems existing in the literature. Minimization of the weighted sum of multiple objective functions is considered to monitor the heuristic search towards the optimal controller parameters. A detailed comparative analysis between well known heuristic methods, such as Particle Swarm Optimization (PSO), Bacterial Foraging Optimization (BFO), Cuckoo Search (CS) and Firefly Algorithm (FA) are presented. The popular 2DOF PID structures, such as Feed Back Structure (FBS) and Feed Forward Structure (FFS) are considered in this work to enhance the performance of FOPTD systems. From the results, it is noted that, proposed controller provides enhanced results for the reference tracking and disturbance rejection operations.

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Keywords: FOPTD; 2DOF PID controller; heuristic algorithm; reference tracking; disturbance rejection.

1. Introduction

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In process industries, despite the major progress in superior process control methodologies, PID controllers are widely used because of its structural simplicity, reputation, easy in performance, acceptance simplicity and adaptability [1, 6]. In the literature, several articles are available to study the tuning procedures and implementation of a single Degree Of Freedom (1DOF) PID controller for stable, unstable and nonlinear systems [1,7,9]. The recent studies on fine tuning the 1DOF PID have provided insight for better understanding of the controller performance for a class of process models. For most of the systems, 1DOF PID offers a feasible outcome either for reference tracking operation or disturbance rejection operation.

Nomenclatures

K_p	Proportional gain
K_i	Integral gain
K_d	Derivative gain
α, β	Tuning parameters
M_p	Overshoot
t_s	Settling time
D	Dimension of search
J_{min}	Objective function to be minimized

Abbreviations

PID	Proportional + Integral + Derivative
DOF	Degree Of Freedom
ITAE	Integral Time Absolute Error
ITSE	Integral Time Square Error

In recent years, various forms of Two Degrees Of Freedom (2DOF) PID controllers are widely discussed by the researchers [6,9,]. A detailed study on various 2DOF structures existing in the literature can be found in the article by Araki and Taguchi [2].

Most of the conventional controller tuning methods existing in the literature is purely model dependent. The tuning methodology employed for one particular reduced process model may not offer a suitable response for other process models. Hence, in recent years, heuristic algorithm based model free controller design procedure is widely adopted by the researchers [6,8-10].

In the proposed work, popular 2DOF PID structures, such as Feed Back Structure (FBS) and Feed Forward Structure (FFS) are considered to stabilize First Order Plus Time Delay (FOPTD) models existing in the literature using heuristic algorithms, such as PSO, BFO, CS and FA. The performances of the considered algorithms are analyzed based on the time domain parameters (M_p, t_s), error values (*ITSE*, *ITAE*) and the search time taken by the algorithms.

2. 2DOF PID

In general, 2DOF PID structure improves the overall closed loop performance of the process. A detailed study on various 2DOF structures are clearly presented by Araki and Taguchi [2]. In this work, the 2DOF PID structures considered by Latha and Rajinikanth [6] is adopted to stabilize the FOPTD process models.

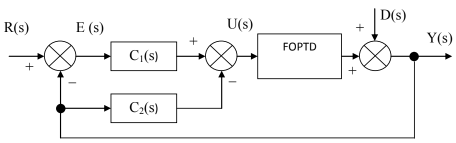

Fig 1. Feedback structure

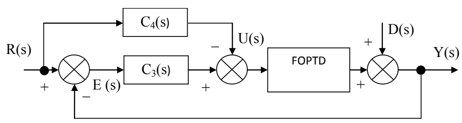

Fig 2. Feed forward structure

$$C_1(s) = K_p(1-\alpha) + K_i + (1-\beta)K_d D_f(s) \quad (1)$$