A New Approach to Tune the Two-Degree-of-Freedom (2DOF)

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Abstract - This paper proposes a new tuning method for PI controllers in two-degree-of-freedom (2DOF) structure. In design approach, first order plus dead time (FOPDT) model is used. The aim is to have good set-point response and disturbance rejection and also maximum robustness to model uncertainties. The tuning strategy is based on using Butterworth rules and genetic algorithm optimization. Simulation results demonstrate the effectiveness and validity of proposed method in coping with conflicting design objectives for a wide variety of processes including minimum phase and non-minimum phase and also integrating processes.

I. INTRODUCTION

Since the most commonly and widely used controllers in process control industry is, PID/PI controllers [1]. This is due to its noticeable effectiveness and simple structure. Tuning of PID/PI controllers has been attracting interest for many years. Structure of using controller is one of the most challenging problems in control theory. Consider the typical one-degree-of-freedom (1DOF) structure shown in Fig. 1. Note that in a control system, the degree of freedom is defined as the number of closed-loop transfer functions that can be adjusted independently [2].

![Fig. 1. Block diagram of one-degree-of-freedom control system.](image)

It is so clear that, in this structure if the disturbance response is optimized, the set-point response is often found to be poor, and vice versa. For this reason, some of the researches [3, 4] on the optimal tuning of PID controllers gave two tables: one for the “optimal disturbance rejection” parameters, and the other for the “optimal set-point response” parameters. The two-degree-of-Freedom (2DOF) PI controller handles such a problem. Some of advantages of using 2DOF structure are described in [5]. In [5-8], various 2DOF PID controllers are presented.

A great number of tuning methods are presented in new researches in the structure of 2DOF. Astrom suggested a tuning approach based on Non-Convex optimization in [9].

This work is one of the most powerful tuning algorithms in 2DOF structure. This algorithm is based on numerical methods. We will compare proposed method with this one in simulation results section. A tuning of 2DOF PID controllers within a cascade control configuration is presented in [10]. A robust tuning of 2DOF PID controllers within a cascade control configuration is presented in [11]. These two new works are a little different from proposed structure. A multi-Objective optimization approach is presented in [12]. This work will be compared with proposed method, also.

In this paper a new tuning formula for a 2DOF PI controller is presented. Generally, good set-point response and disturbance rejection is the primary objective. And the robustness of closed-loop system to modeling uncertainties is second goal. The main idea is using Butterworth rules and genetic algorithm optimization.

This paper is organized as follows. In section II, some preliminaries such as controller formulation, plant model and requirements of control is presented. In section III the details of design procedure is described and tuning formulation is developed. In section IV Simulation results presented and we tried to compare proposed method with some well-known methods in some details. Finally, section V concludes this paper.

II. PRELIMINARIES

A. Controller and Plant Models

Block diagram of a Two-Degrees-of-Freedom (2DOF or TDOF) PI control system [13] can be expressed as in Fig. 2.

![Fig. 2. Block diagram of two degree of freedom control system.](image)

The process is described by transfer function $G_p(s)$. $G_f(s)$ and $G_{ff}(s)$ are respectively the feedback controller and feed-forward controllers and as shown in (1) and (2) are typical PI controllers

$$G_c(s) = k_c \left(1 + \frac{1}{T_g} \right)$$

(1)