Novel Tuning Strategy for Two-Degree-of-Freedom PI Controllers

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Abstract: In this paper, a new tuning procedure for PI controllers in Two-Degree-of-Freedom (2DOF) structure is proposed. In design procedure, First Order plus Dead Time (FOPDT) model is used. The aim is to have good set point tracking and disturbance rejection and also maximum robustness to model uncertainties. The tuning strategy is based on using analytical rules and some conceptual rules about closed loop poles and also an exhaustive search. 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.

Keywords: 2DOF PI controller, FOPDT model, Optimization, Robustness.

1. INTRODUCTION

Proportional plus Integral plus Derivative (PID) controllers are widely used in the industry (Astrom and Hagglund, 1984; Ho et al., 1996). The main reason is its relatively simple structure, which can be easily understood and implemented in practice (Wang et al., 1999). The widespread use of PID type controllers in industry has increased efforts in the design and tuning of conventional PID controllers so as to achieve desired performance for the control system (Cheng and Hwang, 2006).

Structure of using controller is a challenging problem 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 (Horowitz, 1963).

![Fig. 1. Block diagram of 1DOF control structure.](image)

In 1DOF structure, if the disturbance rejection is desired, the set-point response is often found to be poor, and vice versa. So, in some researches (Chien et al., 1952 and Kuwatam, 1973) on the optimal tuning of PID controllers two tables to tune controller is given, one for the “optimal disturbance rejection”, and the other one for the “optimal set point response”. The 2DOF PI controller handles such a problem, that is, in this structure both set point tracking and disturbance rejection optimization is possible. Some of advantages of using 2DOF structure are described in (Araki, 1984a), (Araki et al., 2003 and Yuikitomo et al., 2004), 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 (Astrom et al., 1998). This work is one of the most powerful tuning algorithms in 2DOF structure. 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 (Alfaro et al., 2008). A robust tuning of 2DOF PID controllers within a cascade control configuration is presented in (Alfaro et al., 2009). These two new works are a little different from proposed structure. A multi objective optimization approach is presented in (Tavakoli et al., 2007). This work will be compared with proposed method, also. Newly done work in this field is (Nemati and Bagheri, 2010). In this work a new method for tuning proposed. There are some deficiencies in this work. In this study, we try to solve these problems and present a new method. Also a comparison with this work will be done in simulation section. 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 modelling uncertainties is second goal.

This paper is organized as follows. In section 2, some preliminaries such as controller formulation, plant model and requirements of control is presented. In section 3 the details of design procedure is described and tuning formulations are developed. In section 4 simulation test results involved to make comparison the proposed method with other methods in some details. Finally, section 5 concludes this paper.

2. PRELIMINARIES

Now, some initial steps of design procedure are presented.