

Preface

Proportional-Integral-Derivative (PID) controllers are by far the most adopted controllers in industry owing to the advantageous cost/benefit ratio that they are able to provide. In the last century, a large number of researchers have considered them, and industrial products have improved their functionality significantly.

Proposals for the design and tuning of PID based control systems have generated a really vast literature during the last decades. This sparked the special attention of the *IFAC Workshop PID'00 Present and Future of PID* control held in Terrassa, Spain, in April 2000. This event provided a state-of-the-art on many aspects of PID control, ranging from specialized theoretical research topics and tuning methods to interesting reviews of technological products, patents and software, confirming that the PID controller continues to generate deep interest and is a good augury for future research in the field of PID controllers.

Starting from this special event, in the last ten years there has been a renewed interest in the research on PID controllers, as witnessed by a large number of papers published on this subject. This book gives an overview of the advances made for PID controllers during this last decade.

The book is divided into four parts in which well-known experts and specialists address different topics (one for each chapter) in the following fields: (i) new approaches for tuning PID controllers; (ii) control structures and configurations for PID control; (iii) issues in PID control; (iv) non-standard approaches to PID control.

The first part concentrates on tuning methods. It starts with a review provided by A. O'Dwyer of the extensive literature of proposals for PI and PID controller tuning rules based on First-order plus Dead-time models. The next chapters follow by concentrating on specific topics related to PID tuning. A. Leva and M. Maggio discuss the availability of a process model and its use for assessing the behavior and characteristics of the control loop with respect to its robustness and performance, therefore addressing the problem of determining which tuning method is best suited to the particular problem at hand. An exposition of tuning rules for integral and unstable systems follows. In this chapter, A.S. Rao and M. Chidambaram introduce different design methods for PI/PID controllers for these systems. Different approaches are considered. In particular, analytical, IMC, pole placement and optimization methods. The advantage of using a two degree-of-freedom controller will

also be addressed as well as the robustness of the controllers. Robustness is specifically addressed in Chap. 4 by R. Vilanova, V. Alfaro and O. Arrieta by revisiting the new trends in robust PI/PID tuning. This chapter reviews the main concepts and measures for robustness in feedback systems and reviews the classical and modern approaches to robust PID design. The chapter also presents a series of new tuning rules that appeared in the literature during recent years that are based on the use of the maximum of the sensitivity transfer function as a robustness measure. The attainment of such robustness specification turns out to be a challenge that suggests alternative frameworks for robust PID controller tuning. As a matter of fact, one of the interests that has appeared in recent years is that of formulating tuning approaches in the form of simple tuning rules. In that respect, S. Skogestad and C. Grimholt present the Simple Internal Model Control approach by addressing the choice of the tuning parameters for fast and smooth control. In addition, their novel set-point overshoot method will be presented as an alternative approach. This first part of the book concludes with a chapter devoted to the control of MIMO systems. Q.G. Wang and Z.Y. Nie discuss the specific problems that appear when a MIMO system is to be controlled by using PID controllers. With a special emphasis on robustness, PID controller design for MIMO processes to achieve the desired gain and phase margins are presented. Tuning of decentralized MIMO PID controllers based on such margins is presented. In this way, the robust stability of the multivariable system can be readily achieved and guaranteed.

In the second part of the book, attention is turned to special control structures frequently used in conjunction with PID controllers for the achievement of specific purposes. Three chapters are devoted to such approaches. In the first chapter of this section, J.L. Guzmán, T. Hagglund and A. Visioli expose the use of feedforward compensation in conjunction with a feedback PID controller. Both set-point following and load disturbance rejection tasks are considered. While for the set-point following the generation of causal and non-causal feedforward actions are considered, for the load disturbance it is shown that both controllers (feedback and feedforward should cooperate). The use of alternative feedback compensation schemes such as the cascade control system for improving disturbance rejection is well known. In Chap. 8, S. Majhi presents different approaches for such series-feedback compensation schemes as well as dead-time compensation systems for use when there is a large time delay in the system. This part ends by a chapter that presents considerations for multi-input multi-output processes by addressing the control problem as a multivariable control problem per se. In this respect, R. Katebi presents and compares existing multi-loop tuning methods for their stability and performance robustness and formulates new design guidelines to improve their closed-loop robustness.

The third part of the book presents a range of issues related to the application of a PID controller. In this respect, this part starts with the contribution of K. Tsakalis and S. Dash that addresses issues arising in system identification-based plant modeling for the purpose of tuning PID controllers. Minimal and maximal process model information methods are considered. Especially attractive are recent methods that provide several nominal models as well as a description of the uncertainty, and aim

for a tuning that combines high performance, adequate robustness, and high reliability. Besides finding of a good model, the nominal stability of the feedback control system is always the central and first aspect to be considered. When dealing with a restricted structure controller such as a PI/PID, the problem becomes more difficult. In Chap. 11, L.H. Keel and S.P. Bhattacharyya provide a design approach based on the determination of the entire set of PID controllers that stabilizes a given plant. In addition, it is shown that the entire set of stabilizing PID controllers for a given plant can be found without an analytical model being available. This chapter also shows that the complete set of stabilizing PID controllers for a finite dimensional LTI plant, possibly cascaded with a delay, can be calculated directly from the frequency response (Nyquist/Bode) data. Once the controller is obtained, there are two different aspects that come into the scenario: those of the fragility of the resulting tuning and performance assessment. Then next two chapters deal, respectively, with these aspects. In Chap. 12, V.M. Alfaro and R. Vilanova provide an introduction to fragility measures for PID controllers. Subsequently, the fragility of PID controllers tuned with several of the available performance optimized and/or robust tuning rules will be evaluated using the delta 20 fragility index. The introduction of the fragility as part of the development process of a robust tuning rule for PID controllers is also considered. Considerations on performance assessment follow in Chap. 13, authored by A.W. Ordys and M.J. Grimble. Since many PID controllers are set up using intuition or very approximate tuning rules, it is even more important that PID designs can be benchmarked and the quality of control assessed. Furthermore, benchmarking methods can provide guidance for controller tuning. One of the advances made in the last decade has been the development of the so-called restricted structure benchmarking which provides a figure of merit which is much more representative of what might be achievable if the controller is tuned optimally. The use of these methods for controller tuning is also discussed. This third part ends with G.K. McMillan's contribution that introduces industrial considerations for PID based control loops. Different process control applications are addressed in this chapter, and it is shown how to deal with them when using a PID controller. In particular, challenging applications (namely, with the presence of high valve stiction, large wireless refresh times, high process nonlinearity and dead-time, multiple process constraints, abnormal operations and communication failures, to name a few) are discussed. Then, process control operations such as bioreaction, chemical reaction, crystallization, distillation, evaporation, neutralization and compression are considered.

The last part of the book comprises four chapters devoted to non-standard approaches to PID control. They constitute novel approaches of PID control that have recently appeared in the PID field. A (now) very popular theme is that of fractional-order PID control. B.M. Vinagre and C.A. Monje present the main characteristics of Fractional-order Control (FOC), an approach that has attracted a growing interest in the last decade. The application of the fractional order operators to the PID algorithm, thus giving the fractional-order PID (FOPID) controller, is first introduced. Then, the FOPID controller is studied in both the frequency and the time domains, and the structures, the tuning rules, and the ways for their implementation

proposed in the literature will be reviewed and discussed, as well as their practical applications. Another different perspective for addressing the controller design problem is that of event based control. J. Sánchez, A. Visioli and S. Dormido present the basic concepts of event-based control where feedback control actions are computed when the process output is outside a certain detection band located around the set-point value; and once the process is inside the detection band, new control actions are not produced until the process leaves the region as a consequence of disturbances or a change of the set-point value. The chapter starts with a description of the first event-based PI controller published in the literature and continues by describing the evolution of this type of controller, to finish with the most recent implementations, as, for instance, a 2-DOF pure event-based PI controller. As another non-standard approach to obtaining a PID controller we have the data-driven, or also called model-free, methods. T. Yamamoto introduces the concept of data-driven (DD) controllers where a suitable set of PID parameters is automatically generated based on input/output data pairs of the controlled object stored in the database. This scheme can adjust the PID parameters in an on-line manner even if the system has nonlinear properties and/or time-variant system parameters. The fourth part of the book ends by introducing some considerations on predictive control approaches for PID control design. In this case, the design of PID control systems based on advanced control, e.g., generalized minimum variance control and generalized predictive control is described. In this chapter, generalized predictive control is attained by PID control by considering the GPC control law approximation and introducing the considerations needed in order to deal with future information. Finally, to obtain further high performance, predictive control based PID systems are extended to multirate systems.

The methodologies considered in this book are presented in order to highlight the theoretical and the implementation issues, so that they are clearly characterized both from an academic and industrial perspective. The book can therefore serve as a reference and source book for academic researchers who will consider it also as a stimulus for new ideas as well as for industrial practitioners and manufacturers of control systems who will find appropriate advanced solutions to their application problems.

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