Preface

Automation via feedback is not new. Early application of automatic control principles appeared in antiquity, and widespread use of automation began in the nineteenth century when machinery was becoming the dominant method for manufacturing goods. Great advances have been made in theory and practice so that automation is now used in systems as commonplace as room heating and as exciting as the navigation of interplanetary exploration and telecommunications. The great change over the recent years is the integral—at times essential—role of automation in our daily lives and industrial systems.

Process control is a sub-discipline of automatic control that involves tailoring methods for the efficient operation of chemical processes. Proper application of process control can improve the safety and profitability of a process, while maintaining consistently high product quality. The automation of selected functions has relieved plant personal of tedious, routine tasks, providing them with time and data to monitor and supervise operations. Essentially every chemical engineer designing or operating plants is involved with and requires a background in process control. This book provides an introduction to process control with emphasis on topics that are of use to the general chemical engineer as well as the specialist.

GOALS OF THE BOOK

The intent of this book is to present fundamental principles with clear ties to applications and with guidelines on their reduction to practice. The presentation is based on four basic tenets.

Fundamentals

First, engineers should master control technology fundamentals, since there is no set of heuristics or guidelines that can serve them through their careers. Since these fundamentals must be presented with rigor, needed mathematical tools are presented to assist the student. It may be worth recalling that these principles were selected because they provide the *simplest* approaches for solving meaningful problems.

Practice

Second, we are not efficient if we "start from scratch" every time we encounter a problem; similar situations can be analyzed to develop guidelines for a defined set of applications. Also, the fundamental concepts can be best reinforced and enriched through the presentation of good engineering practice. With this perspective, important design guidelines and enhancements are presented as logical conclusions and extensions to the basic principles. Coverage of implementation issues includes pitfalls with the straightforward "textbook" approaches along with modifications for practical application.

Complexity

Third, the presentation in this book follows the guideline "Everything should be made as simple as possible, and no simpler." Naturally, many issues are easily resolved using straightforward analysis methods. However, the engineer must understand the complexity of automating a system, even when a closed-form solution does not exist at the present time.

Design

Fourth, design is a capstone topic that enables engineers to specify, build and operate equipment that satisfies predetermined goals. Currently, closed-form solutions do not exist for this activity; thus, a comprehensive design method for managing the numerous interlocking design tasks is presented along with a step-by-step approach to guide the engineer through problem definition, preliminary analysis of degrees of freedom and controllability, and selecting process and control structures. Many guidelines, checklists, and examples aid the student in making well-directed initial decisions and refining them through iterations to achieve the design goals.

THE READERS

Hopefully, readers with different backgrounds will find value in this treatment of process control. A few comments are now addressed to the three categories of likely readers of this book: university students, instructors, and practitioners.

Students

Many students find process control to be one of the most interesting and enjoyable courses in the curriculum, because they apply the skills built in fluid mechanics, heat transfer, thermodynamics, mass transfer, and reactor design. This presentation

emphasizes the central role of the process in the performance of control systems. Therefore, dynamic process modelling is introduced early and applied throughout the book. To help students, realistic process systems are studied in solved examples.

The student may notice two important differences from other courses. First, process control is often concerned with *operating* plants in which process equipment has been built. Thus, the proper answer to the question "how can the exchanger outlet temperature be raised to 56°C?" is not "increase the heat transfer area"; perhaps, the modification to operation would be "increase the heating medium flow rate." Second, process control must operate over a wide range of conditions in which the process behavior will change; thus, the engineer must design controls for good performance with an imperfect knowledge of the plant. Deciding operating policies for imperfectly known, non-linear processes is challenging but provides an excellent opportunity to apply skills from previous courses, while building expertise in process control.

Instructors

The book is flexible enough to enable each instructor to structure a course covering basic concepts and containing the instructor's special insights, perhaps placing more emphasis on instrumentation, mathematical analysis, or a special process type, such as pulp and paper or polymer processing. The fundamental topics have been selected to enable subsequent study of many processes, and the organization of the last three parts of the book allows the selection of material most suited for a particular course.

The material in this course certainly exceeds that necessary for a single-semester course. In a typical first course, instructors will cover most of Parts I–III along with selected topics from the remainder of the book. A second semester course can be built on the multivariable and design material, along with some non-linear simulations of chemical process like binary distillation. Finally, some of the topics in this book should be helpful in other courses. In particular, topics in Parts IV–VI (e.g., selection of sensors, manipulated variables and inferential variables) could be integrated into the process design course. In addition, the analyses of operating windows, degrees of freedom, and controllability are facilitated by the use of flowsheeting programs used in a design course.

Practitioner

This book should be useful to practitioners who are building their skills in process control, because fundamental concepts are reduced to practice throughout. The development of practical correlations, design rules, and guidelines are explained so that the engineer understands the basis, correct application and limitations of each. These topics should provide a foundation for developing advanced expertise in empirical model building, loop pairing, centralized Model Predictive Control, statistical process monitoring and optimization.

COMPUTER TOOLS AND LEARNING AIDS

Computers find extensive application in process control education, because many calculations in process control education are too time-consuming to be performed

by hand. To enable students to concentrate on principles and investigate multiple cases, the *Software Laboratory* has been developed to complement the topics in this book. The software is based on the popular MATLAB™ system. A User's Manual provides documentation on the programs and provides extra problems that students can solve using the software.

Computers can also provide the opportunity for interactive learning tools, which pose questions, give students hints, and provide solutions. The *Process Control Interactive Learning Modules* have been developed to help students enhance their knowledge through self-study. This is available via the WEB.

To learn about these and other complementary learning materials, visit the Internet site established at McMaster University for process control education, http://www.pc-education.mcmaster.ca.

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Finally, I would like to acknowledge the great assistance provided me by two mentors. Professor Tom McAvoy has always set high standards of rigor in investigating meaningful engineering problems. Dr. Nino Fanlo, one of the best practitioners of process control, reminded me that good control theory must work in the plant. I can only hope that this book passes on some of the benefit from collaboration with these skilled engineers and fine individuals.

FEEDBACK

Feedback, using a system output to determine the value of an input, is the basic concept in process control, but it also applies to a good textbook! I would appreciate comments from readers and can assure you that every suggestion will be considered seriously.

T. Marlin
Hamilton, Ontario
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