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Fault-Tolerant Process Control

Methods and Applications

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Preface

The chemical industry is a vital sector of the global economy. Increasingly faced with the requirements of safety, environmental sustainability, energy efficiency, and profitability, chemical process operation is relying extensively on automated process control systems involving a large number of control actuators and measurement sensors. While process automation is critical in achieving the above requirements, the increasing reliance on actuators and sensors tends to increase the vulnerability of the process to faults (for example, defects/malfunctions in process equipment, sensors and actuators, failures in the controllers or in the control loops), leading to the failure of the control system and potentially causing a host of economic, environmental, and safety problems that can seriously degrade the operating efficiency of the process. Problems due to faults may include physical damage to the process equipment, raw material and energy waste, increase in process downtime, resulting in significant production losses, and jeopardizing personnel and environmental safety. Management of abnormal situations resulting from actuator and sensor malfunctions is a challenge in the chemical industry since abnormal situations account for tens of billions of dollars in annual lost revenue in the US alone.

The above considerations provide a strong motivation for the development of methods and strategies for the design of advanced fault-tolerant control systems that ensure an efficient and timely response to enhance fault recovery, prevent faults from propagating or developing into total failures, and reduce the risk of safety hazards. To this end, this book presents methods for the design of advanced fault-tolerant control systems for chemical processes which explicitly deal with actuator/controller failures and sensor data losses. Specifically, the book proposes: (i) a fault-detection, isolation, and diagnosis framework for handling actuator and sensor faults for nonlinear systems; (ii) reconfiguration and safe-parking based fault-handling methodologies; (iii) integrated data and model based fault-detection and isolation and fault-tolerant control methods; (iv) methods for handling sensor malfunctions; and (v) methods for monitoring the performance of low-level proportional-integral-derivative (PID) control loops. The proposed methods employ tools ranging from nonlinear systems analysis, Lyapunov techniques, optimization, statistical methods, and hybrid systems theory and are predicated upon the idea of integrating fault-detection, local feedback control, and supervisory control. The applicability and performance of the proposed methods are demonstrated through a number of chemical process examples.

Application of the proposed fault-tolerant control methods to processes subject to actuator and sensor malfunctions is expected to significantly improve their operation and performance, increase process safety and reliability, and minimize the negative economic impact of failures on overall process operation.

The book requires basic knowledge of differential equations, linear and nonlinear control theory, and optimization methods, and is intended for researchers, graduate students, and process control engineers. Throughout the book, practical implementation issues are discussed to help engineers and researchers understand the application of the methods in greater depth.

Finally, we would like to thank all the people who contributed in some way to this project. In particular, we would like to thank our colleagues at McMaster University, the University of Alberta, and UCLA for creating a pleasant working environment. Last, but not least, we would like to express our deepest gratitude to our families for their dedication, encouragement and support over the course of this project. We dedicate this book to them.

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