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Fault-tolerant process control. Methods and applications. (English) Zbl 1270.93002

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The book is dedicated to the development of active Fault-Tolerant Control (FTC) methods for processes of the chemical industry.

Increasing automation makes chemical plants susceptible to defects in process equipment, sensors and actuators, failures in the controllers or in the control loops. The traditional ”passive” approach to handling faults assumes that sufficient control effort can be achieved in the presence of faults that are treated as disturbances. The book is focused on designing advanced active fault tolerant control methods where the specific action is triggered by the detection (and isolation and, where applicable, diagnosis) of the fault. These methods are founded on nonlinear system analysis, Lyapunov techniques, optimization, statistical methods, and hybrid systems theory.

Some basic results on the analysis and control of nonlinear systems are reviewed in Chapter 2.

Chapter 3 focuses on actuator faults for single-input nonlinear systems with input constraints subject to control actuator failures and presents a methodology to detect and handle the actuator fault through controller reconfiguration.

These results are generalized in Chapter 4 for multi-input multi-output nonlinear systems subject to multiple faults in the control actuators and constraints on the manipulated inputs. A framework is presented for integrated Fault Detection and Isolation (FDI) and fault-tolerant control.

Chapter 5 considers the case when faults cannot be handled via robust control approach or activation of redundant control configurations. A safe-parking framework is developed to drive the system to an appropriately chosen temporary operating point until the fault is rectified. The fault location and magnitude are assumed to be known here.

In Chapter 6 the last assumption is relaxed, and a model-based integrated fault diagnosis and self-parking design is proposed, which cannot only identify the failed actuator, but also estimate the fault magnitude.

Chapter 7 presents the use of FDI consideration in both control design and performance monitoring. The first part of the chapter develops a data-based method of fault detection and isolation that utilizes the design of the controller to enhance the isolability of the faults in the closed loops system. The second part of the chapter is focused on the problem of monitoring and retuning of low-level proportional-integral-derivative control loops used to regulate control actuators to the values computed by advanced model-based control systems.

Chapter 8 considers the problem of sensor FDI and FTC for nonlinear systems subject to input constraints. The idea of the presented method is to exploit model-based sensor redundancy through state observer design. An output feedback control design using high-gain observers is proposed, and then an FDI scheme is presented, which comprises of a bank of high-gain observers.

Finally, Chapter 9 addresses to the problem of control and fault-handling subject to asynchronous measurements and data losses. An approach is developed for handling sensor data losses via Lyapunov-based model predictive control. In this control scheme, when feedback is lost due to sensor data losses, the actuators implement the last optimal input trajectory evaluated by the controller.

All main results of the book are presented in the form of mathematical propositions and theorems.

To illustrate the effectiveness of the approaches developed, simulations are carried out for chemical process examples.

The book will be useful and interesting both for academic researchers and for industrial practitioners working in the given area.

Reviewer: Boris Ivanovich Konosevich (Donetsk)

MSC:

- 93-02 Research monographs (systems and control)
- 34H05 ODE in connection with control problems
- 37N35 Dynamical systems in control
- 93B35 Sensitivity (robustness) of control systems
- 93C30 Control systems governed by other functional relations

Keywords:
asynchronous measurements; control of chemical processes; fault detection and isolation; fault-tolerant control; Lyapunov function; safe-parking; switched and hybrid systems

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