Foreword

As technological systems become more and more complex, the dependence on their control systems has also increased significantly. This is particularly true in safety-critical applications where either the success of a mission or ultimate protection of human lives, property, and environment becomes a paramount goal. For any practical control systems, no matter how ingenious the design is, and how immaculate the manufacture process is carried out, things will break. It is a matter of time, sooner or later. One way to ensure reliable operation of a system for intended purposes, despite those undesirable circumstances, such as failures, is to rely on fault-tolerant control strategies.

A fault-tolerant control system is a control system specifically designed with potential system component failures in mind. Clearly, a fault-tolerant control may not offer optimal performance in a strict sense for normal system operation, but generally it can mitigate effects of system component failures without completely jeopardizing the mission or putting the users/public at risk. Clearly, the philosophy of fault-tolerant control systems design is different from other design methodologies. Consequently, their behavior under system component failures will also be different.

Design of control systems to achieve fault-tolerance for closed-loop control of safety-critical systems has been an active area of investigation for many years. It becomes more and more clear that there are certain trade-offs between achievable normal performance and fault-tolerance capability. A fault-tolerant control system design has essentially become a decision on manipulation of such trade-offs.

Despite the efforts in control system community, the field of fault-tolerant control systems is still wide open. Most of the contributions so far are theoretical in nature. It is important to emphasize that when a failure occurs in a system, either in sensors or actuators, the characteristics of the entire system can undergo significant change, i.e., degradation. The actuators may not be able to provide the same level of driving power, while the sensors may not supply dependable measurements. Without full understanding of those prac-

tical constraints and respecting the failure induced limitations, fault-tolerant control system design based purely on theory will be bound to fail in practice.

In the past decade, most of the work in this area has been theoretical in nature. It is refreshing to read this book which has put the emphasis on the practical applications. This book will certainly be an important addition to the library on fault-tolerant control systems. It is one of very few books in this area that considers practical aspects of fault-tolerant control. It is certainly a welcome addition and valuable reference for anyone working in this area.

The basic concepts of fault-tolerant control systems are introduced in Chap. 1. Classification of fault-tolerant control strategies is presented in terms of fault severity levels. Fault-tolerant control system design and analysis against actuator and sensor failures have been treated in detail in Chap. 2 for linear and nonlinear systems. All the important concepts have been presented using physical system examples by comparing normal system performance against those under component failures. Both partial and complete failures of sensors and actuators have been considered. In this chapter, techniques for fault diagnosis and fault estimations have also been presented. Finally, a general architecture of a fault-tolerant control system is developed.

Chapter 3 is devoted to the application of fault-tolerant control strategies on a physical lab-scale winding machine. The authors have provided basic control objectives for this system with sufficient detail. The performance of the system under normal conditions is analyzed first to provide a baseline benchmark for fault-tolerant control system design and analysis. Subsequently, various actuator and sensor failure scenarios have been dealt with. In this chapter, both linearized and nonlinear system models are considered. The book has clearly shown that the effects of faults can be compensated with properly designed fault-tolerant control systems.

A well known three-tank system is used in Chap. 4 to illustrate design and analysis techniques for fault-tolerant control systems. An advantage of choosing this system is that the physical relationships among key system variables can be easily obtained. Using the dynamic models obtained, the detailed procedure for fault-tolerant control system design and analysis can be clearly demonstrated. The authors have also included some MATLAB® scripts to guide the readers through the process and to encourage readers to try by themselves. Both linear and nonlinear system models have been utilized in the design and analysis process.

Finally, fault-tolerant control system design and analysis against sensor failures in an active suspension of a full vehicle system have been considered. Detailed mathematical description of the suspension is derived first. Based on this model, fault-tolerant control systems performance against several commonly encountered sensor failures have been investigated. The originality of the work in this chapter is the breakdown of the entire suspension system into several interconnected subsystems. Each subsystem has its own local controller and its own fault diagnostic module. A higher level control system coordinates the information issued from these local modules.

In summary, the authors have successfully presented some most important concepts and procedures in fault-tolerant control system design and analysis. The authors have done this with elegance of mathematics, as well as in-depth physical understanding of the limitations of handicapped actuators and sensors. This is a must read book on the subject of fault-tolerant control systems.

The logical introduction and the easy to understand styles of presentation have made this book particularly suitable for graduate students and practising engineers who are looking for some guidance in applying active fault-tolerant control methods in their own fields of interests.

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