Springer Series in Reliability Engineering

Ajit Kumar Verma
Srividya Ajit
Durga Rao Karanki

Reliability and Safety Engineering

Second Edition

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To our gurus:
Bhagwan Sri. Sathya Sai Baba
Paramhamsa Swami Sathyananda
Pujya Mata Amritanandaji
Smt. Vijaya and Sri. B. Jayaraman
Smt. Kasturi and Sri. C.S. Rao

To our parents:
Late Sri. K.P. Verma and Late Smt. S. Verma
Late Sri. B.C. Khanapuri
and Smt. V.B. Khanapuri
Sri. K. Manikya Rao and Smt. K. Anjali

Foreword

I take immense pleasure in writing the foreword for this very well-written book on "Reliability and Safety Engineering" that connects the bridge between the quintessential first principles of reliability with subsequent theoretical development of conceptual frameworks, and their relevance to practical realization of complex engineering systems. Interspersed with ample demonstrative examples and practical case studies, this is a self-contained exposition, written in a commendably lucid style.

Successful realization of sustainable and dependable products, systems, and services involves an extensive adoption of Reliability, Quality, Safety, and Risk-related procedures for achieving high assurance levels of performance; also pivotal are the management issues related to risk and uncertainty that govern the practical constraints encountered in their deployment. A need for a book that addresses these issues in comprehensive rigor without compromising on the underlying goal of succinct precision and simplicity has been long felt. And, I am sure this book has succeeded in achieving this fine balance.

This book is aimed at giving a conceptually sound introduction to reliability engineering and its allied interdisciplinary applications, especially for students at the graduate level. Building upon the first principles, this gradually evolves into a knowledge bank that can be relied on for gaining insights into the performance analysis of complex systems. With its equally precise explanations both in breadth and scope, researchers and practicing engineers alike will find this a valuable authority as a ready reference and a handbook. After a detailed introduction and models of reliability, risk, and uncertainty analysis, this elaborates on the applications through sufficient exposure to the varied fields of nuclear engineering, electronics engineering, mechanical engineering, software engineering, and power systems engineering.

I strongly recommend this book for its elegant discourse on the fundamentals of reliability and the much needed practical outlook it succeeds in constructing.

Hoang Pham
Distinguished Professor
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and Systems Engineering
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Preface

Nothing lasts forever and so is the life of engineering systems. The consequence of failures of engineering system ranges from minor inconvenience to significant economic loss and deaths. Designers, manufacturers, and end users strive to minimize the occurrence and recurrence of failures. In order to minimize failures in engineering systems, it is essential to understand 'why' and 'how' failures occur. It is also important to know how often such failures may occur. If failures occur, inherent safety systems/measures must ensure the consequences of failures are minimal. Reliability deals with the failure concept, whereas safety deals with the consequences of failure. Reliability and Safety Engineering explores failures and consequences of failures to improve the performance of engineering systems. It plays a vital role in sectors such as chemical and process plants, nuclear facilities, and aerospace which can impose potential hazards. The main benefit of its application is to provide insights into design, performance, and environmental impacts, including the identification of dominant risk contributors and the comparison of options for reducing risk. In addition, it provides inputs to decisions on design and back fitting, system operation and maintenance, safety analysis and on regulatory issues.

Reliability and safety are the core issues to be addressed during the design, operation, and maintenance of engineering systems. LCC and sustainability are key to the understanding of risk and environmental impact of operation and maintenance of systems over the designed life leading to what one may call the 'Green Reliability'. This book aims to present basic concepts and applications along with latest state of art methods in Reliability and Safety engineering. The book is organized as follows:

Chapter 1 introduces reliability and safety concepts and discusses basic terminology, resources, past, present challenges, and future needs. Chapter 2 provides a detailed review of probability and statistics essential for understanding the reliability and safety analysis methods discussed in the remaining chapters.

Chapter 3 discusses various system reliability modeling techniques such as Reliability Block Diagram, Fault Tree Analysis, and Markov modeling. Component (or basic event) reliability values are assumed to be available in analyzing system level reliability. Repairable systems are also addressed and several practical examples are given. In Chap. 4, methods that focus on reliability analysis of complex systems, Monte Carlo simulation, and dynamic fault tree analysis are explained.

Conventional engineering fields, viz., Electronics Engineering, Software Engineering, Mechanical Engineering, and Structural Engineering, have their own terminology and methodologies in applying the reliability concepts. Though the basic objective is to improve the system effectiveness, approach in adopting reliability concepts is slightly case specific to each area. Chapters 5–8 present reliability terminology in the various above-mentioned conventional engineering fields. The current practices, resources, and areas of research are highlighted with respect to each field.

Chapter 9 focuses on maintenance of large engineering systems. Essentially this chapter covers two areas of maintenance, i.e., prioritizing of equipment and optimization in maintenance decision making.

Methodology for Probabilistic Safety Assessment (PSA) in general is addressed in Chap. 10. Various elements of PSA including common cause failure analysis, human reliability analysis, and importance measures are presented. Chapter 11 introduces dynamic methods in safety analysis with special emphasis on dynamic event tree analysis; the elements involved in the method and comparison among its implementation are also discussed. Practical applications of PSA in operation and maintenance activities of complex systems like nuclear power plants are discussed in Chap. 12.

Uncertainty is present in any reliability and safety calculation due to limitations in exactly assessing the parameters of the model. Creditability and practical usability of reliability and risk analysis results is enhanced by appropriate treatment of uncertainties. Various uncertainty propagation and analyzing methods including Monte Carlo simulation, Fuzzy arithmetic, Probability Bounds, and Dempster-Shafer theory are explained in Chaps. 13 and 14.

This book is useful for advanced undergraduate and postgraduate students in Nuclear Engineering, Aerospace Engineering, Industrial Engineering, Reliability and Safety Engineering, Systems Engineering, Applied Probability and Statistics, and Operations Research. The book is also suitable for one semester graduate course on Reliability and Safety Engineering in all conventional engineering branches like Civil, Mechanical, Chemical, Electrical, Electronics, and Computer Science. It will also be a valuable reference for practicing engineers, managers, and researchers involved in reliability and safety activities of complex engineering systems.

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