

Improving scheduled maintenance by missing data reconstruction: a double-Loop Monte Carlo approach

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ABSTRACT: *This paper describes a Monte Carlo (MC) based approach for reconstructing missing information in a dataset used by General Electric (GE) for reliability analysis, which contains data coming from field observations at inspection of Gas Turbine components. The approach is based on a combination of Maximum Likelihood Estimation technique to estimate the failure model parameters, Fisher Information Matrix to estimate the confidence intervals on the estimated parameters, and a double-loop MC approach to estimate the missing equivalent starts (i.e., data of turbine state without the relative equivalent starts). The proposed methodology reduces the uncertainty in the estimation of the parameters of the turbine. Results of the application of the novel approach to a real industrial dataset are discussed along with a sensitivity analysis for the quantification of the robustness of the methodology to deal with different sizes of datasets.*

1 INTRODUCTION

Gas Turbines (GTs) are complex and expensive industrial systems, which generate revenue when they are in working state, only. From this, it emerges the relevance for GT operation of optimizing maintenance according to a number of possibly conflicting criteria, the minimization of the system unavailability being surely among them.

The economic importance of maintenance is one of the main justifications of the dramatic increase in the outsourcing of equipment maintenance experienced in recent years, especially in case of complex and expensive products such as the GTs [1]. Other reasons are the fast technological advancements and the more stringent safety and environmental legislation in production processes, which call for increasing needs of well-trained maintenance workforce, and a more specific maintenance management capability. This also increases the cost of maintenance, and makes small maintenance departments within the owner's organization not economically competitive with maintenance outsourcing (i.e. the scale of operation is too small, [2]). Moreover, the relative affordability of on-line monitoring technology has led to a growing interest in new maintenance paradigms such as the CBM and PrM [3]: the possibility of monitoring the system and, by so doing, collecting information on its conditions is used to both identify problems at an early stage and predict their evolution in the future. This gives the possibility of building an agile logistic network, which allows for a significant reduction in the system unavailability by providing the right part in the right place at the right time, with the necessary resources to perform the maintenance [4]. This has boosted the interest in new maintenance service contracting models (i.e., vendor logistics support, integrated operational support, service by the hour or power by the hour contracts, depending on the industrial field) in which the owner (i.e., who buys GTs from GE to generate revenue) directly buys the availability of the system, rather than the system itself [5]. In business terms, this yields to the owner the advantages of *i*) transferring the risk of unavailability (e.g., business interruption [6]) to the manufacturer who pays penalties when the performance under contract is not guaranteed, *ii*) streamlining its own maintenance department, and *iii*) simplifying the business model, in where there will be a single cost item for the asset management [4].

This situation, i.e., need for maintenance outsourcing and power by the hour contracting, has led to an increasing interest by the owner in the maintenance service contracts offered by the GT manufacturers (i.e., GE), first because it may be the mandatory condition to sell the GTs, and then because it may be an important source of income, with new opportunities arising if GE is able to sell added values by taking over parts of clients' business

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Table of Contents Scheduled Maintenance Guide 200monte Carlo

1. Understanding the eBook Scheduled Maintenance Guide 200monte Carlo
 - The Rise of Digital Reading Scheduled Maintenance Guide 200monte Carlo
 - Advantages of eBooks Over Traditional Books
2. Identifying Scheduled Maintenance Guide 200monte Carlo
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Scheduled Maintenance Guide 200monte Carlo
 - User-Friendly Interface
4. Exploring eBook Recommendations from Scheduled Maintenance Guide 200monte Carlo
 - Personalized Recommendations
 - Scheduled Maintenance Guide 200monte Carlo User Reviews and Ratings
 - Scheduled Maintenance Guide 200monte Carlo and Bestseller Lists
5. Accessing Scheduled Maintenance Guide 200monte Carlo Free and Paid eBooks
 - Scheduled Maintenance Guide 200monte Carlo Public Domain eBooks
 - Scheduled Maintenance Guide 200monte Carlo eBook Subscription Services
 - Scheduled Maintenance Guide 200monte Carlo Budget-Friendly Options
6. Navigating Scheduled Maintenance Guide 200monte Carlo eBook Formats

- ePub, PDF, MOBI, and More
- Scheduled Maintenance Guide 200monte Carlo Compatibility with Devices
- Scheduled Maintenance Guide 200monte Carlo Enhanced eBook Features
- 7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Scheduled Maintenance Guide 200monte Carlo
 - Highlighting and Note-Taking Scheduled Maintenance Guide 200monte Carlo
 - Interactive Elements Scheduled Maintenance Guide 200monte Carlo
- 8. Staying Engaged with Scheduled Maintenance Guide 200monte Carlo
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Scheduled Maintenance Guide 200monte Carlo
- 9. Balancing eBooks and Physical Books Scheduled Maintenance Guide 200monte Carlo
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Scheduled Maintenance Guide 200monte Carlo
- 10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
- 11. Cultivating a Reading Routine Scheduled Maintenance Guide 200monte Carlo
 - Setting Reading Goals Scheduled Maintenance Guide 200monte Carlo
 - Carving Out Dedicated Reading Time
- 12. Sourcing Reliable Information of Scheduled Maintenance Guide 200monte Carlo
 - Fact-Checking eBook Content of Scheduled Maintenance Guide 200monte Carlo
 - Distinguishing Credible Sources
- 13. Promoting Lifelong Learning
 - Utilizing eBooks for Skill Development
 - Exploring Educational eBooks
- 14. Embracing eBook Trends
 - Integration of Multimedia Elements
 - Interactive and Gamified eBooks

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