CHAPTER 55

MANUFACTURING PROCESSES & AUTOMATION ENGINEERING

Doctoral Theses

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Modeling and Analysis of Resilience-Driven Engineered Systems.
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Abstract

Engineered systems are employed across a wide range of industrial applications, where achieving high performance is a critical requirement. This research work develops models and methodologies for assessing the availability and resilience of such systems. Analytical approaches for availability assessment provide closed-form solutions that are both accurate and computationally efficient, requiring only a single iteration as opposed to repeated simulations. Since the time to failure and repair of engineered systems or components often follows non-exponential distributions, a Semi-Markov approach is employed for availability assessment. A suitable model is developed to quantify system availability under different maintenance strategies, such as opportunistic maintenance and condition-based maintenance, thereby supporting informed decision-making for the efficient allocation of maintenance resources. Furthermore, a structured framework is proposed for the resilience assessment of engineered systems. It is defined as a system's inherent capacity to maintain or recover a dynamically stable state, enabling continued operation after a severe disruption or under ongoing stress. This property is critical because, regardless of how well a system is engineered, unexpected disturbances are inevitable. In such cases, availability and reliability alone are insufficient; the system must also be resilient enough to withstand disruptions and sustain service, even if only in a degraded operating mode. The first step in the proposed approach is the identification of relevant resilience dimensions or enablers through an extensive literature review or group-based problem-solving techniques. A Resilience Index (RI) is then formulated by combining these enablers using a structural framework based on graph theory and matrix methods. The interdependencies among the enablers are represented through a digraph, which is analysed using the Grey-DEMATEL approach. From this, an analogous matrix is constructed to derive a resilience assessment function, ultimately leading to the evaluation of the RI. A higher index value indicates greater system resilience. The proposed methodology facilitates benchmarking by comparing system performance against industry best practices. This work supports maintenance and practicing engineers in decision-making and contributes to the design and development of resilient systems.

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