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Markov Modeling of Complex Engineering Systems

F. Ferrante, B. Dasgupta, and G. Adams
Center for Nuclear Waste Regulatory Analyses
Southwest Research Institute®
San Antonio, Texas 78238

Abstract

Redundant components, subsystems and control mechanisms are part of the design of highly reliable engineering systems used in several industrial applications, including power generation facilities. Such complex engineering systems do not lend themselves well to commonly used reliability modeling techniques (such as fault tree and event tree analysis) because of the inherent dependencies and interactions among redundant components and operating states [1]. These component failures not only may be strongly dependent, but they may even occur when the system is already operating at reduced capacity (e.g., partially shutdown for maintenance). Using such methods may lead to inaccurate estimates of the performance of a complex system design, which may be overcome by the implementation of Markov Methods.

Markov techniques could be applied to model these systems by decomposing them into a set of operating (or failed) states with an associated set of transitions among these states. For example, system states can be characterized by (1) all components operating normally, (2) one or more components in a failed state or operating at reduced capacity although the system is still functional, or (3) one or more components in a failed state or at reduced capacity and the system is no longer functional [2]. Once transition probabilities, p_{ij}, from state i to state j are defined, a Markov Model can be used to estimate system reliability.

This paper will discuss the Markov Modeling approach for the development of reliability estimates and its implementation to complex engineering systems used in the power generation industry (e.g., heating and ventilation, electrical supply, control systems). The analyses will identify failure modes and modeling of the system states and compare the results to those from other modeling techniques. The comparison will illustrate the efficiency of the proposed Markov approach to reliability modeling of complex engineering systems.

This paper is an independent product of the Center for Nuclear Waste Regulatory Analyses and does not necessarily reflect the view of regulatory position of the U.S. Nuclear Regulatory Commission.

References

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