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(Revision of
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577™

IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities

IEEE Power Engineering Society

Sponsored by the
Nuclear Power Engineering Committee

IEEE

3 Park Avenue, New York, NY 10016-5997, USA

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IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities

Sponsor

Nuclear Power Engineering Committee
of the
IEEE Power Engineering Society

Approved 9 August 2004

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Abstract: This standard sets forth minimum acceptable requisites for the performance of reliability analyses for safety-related systems of nuclear facilities when used to address the reliability requirements identified in regulations and other standards. The requirement that a reliability analysis be performed does not originate with this standard. However, when reliability analysis is used to demonstrate compliance with reliability requirements, this standard describes an acceptable response to the requirements.
Keywords: nuclear facilities, reliability analysis, safety systems

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Introduction

(This introduction is not part of IEEE Std 577-2004, IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities.)

This standard was first published in 1976 to standardize the application of reliability techniques in the design and operation of nuclear facilities. This revision, IEEE Std 577-2004, has been prepared to delete obsolete information and to update the standard to current references and practices within the nuclear industry. The standard is directed towards those systems in the nuclear facility that perform protective functions and fall within the scope of IEEE Std 603™-1998[a] and IEEE Std 308™-2001. However, the requirements of this standard may be applied to other systems within a nuclear facility if appropriate. This standard may also be used as a guide to establish periodic testing programs.

IEEE Std 352™-1987 supplements this standard by providing guidance in the application of reliability techniques.

IEEE Std 338™-1987 requires that programs be established for periodic testing that are based, in part, upon the minimum acceptable analyses described in this standard.

Reliability analysis is a method that can be used to demonstrate compliance with reliability requirements stated in regulations and other standards. When reliability analysis is used for this purpose, this standard describes an acceptable response to the requirements. The requirement that a reliability analysis be performed does not originate with this standard.

IEEE Std 379™-2000 describes the application of the single-failure criterion and also states in 6.3.2: "A probabilistic assessment shall not be used in lieu of the single-failure analysis."

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IEEE Standard Requirements for Reliability Analysis in the Design and Operation of Safety Systems for Nuclear Facilities

1. Overview

1.1 Scope

This standard sets forth the minimum acceptable requirements for the performance of reliability analyses for safety-related systems when used to address the reliability considerations discussed in the standards listed in Clause 2.

The methods of this standard may also be applied to other systems, including the interactions, if any, between safety-related and non-safety-related systems. The requirements should be applied during the phases of design, fabrication, testing, maintenance, and repair of systems and components in nuclear facilities. The timing of the analysis depends upon the purpose for which the analysis is performed. This standard applies to the facility owner and other organizations responsible for the activities previously stated.

1.2 Purpose

The purpose of this standard is to provide uniform, minimum acceptable requirements for the performance of reliability analyses for safety-related systems found in nuclear facilities, but not to define the need for an analysis. The need for reliability analysis has been identified in other standards that expand the requirements (e.g., IEEE Std 379™-2000,[1] which describes the application of the single-failure criterion).

IEEE Std 352™-1987 provides guidance in the application and use of reliability techniques referred to in this standard.

[1]Information on references can be found in Clause 2.

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2. References

This standard applies to all safety-related systems, or portions of said systems, for which reliability considerations are discussed, as in the following IEEE standards. When the standards are superseded by an approved revision, the revision shall apply.

IEEE Std 308™-2001, IEEE Standard Criteria for Class 1E Power Systems for Nuclear Power Generating Stations.[2,3]

IEEE Std 338™-1987 (Reaff 2000) IEEE Standard Criteria for the Periodic Surveillance Testing of Nuclear Power Generating Station Safety Systems.

IEEE Std 352-1987 (Reaff 1999) IEEE Guide for General Principles of Reliability Analysis of Nuclear Power Generating Station Safety Systems.

IEEE Std 379-2000, IEEE Standard Application of the Single-Failure Criterion to Nuclear Power Generating Station Safety Systems.

IEEE Std 603™-1998, IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations.

3. Definitions

The following definitions establish the meaning of words in the context of their use in this standard. Other definitions can be found in IEEE Std 352-1987.

3.1 availability: The characteristic of an item expressed by the probability that it will be operational at a randomly selected future instant in time.

3.2 reliability: The characteristic of an item expressed by the probability that it will perform a required function under stated conditions for a stated time.

4. Requirements

4.1 General

The purpose of reliability analysis is to assist in assuring that the nuclear-plant, safety-related systems within the scope of this standard will perform their required functions with an acceptable probability of success. The actions required to perform a reliability analysis and evaluate results of the analysis include one or more of the following elements:

a) Establish availability/reliability goals
b) Evaluate system designs
c) Evaluate equipment qualification records
d) Establish testing intervals that meet system goals
e) Evaluate the operational performance of installed equipment
f) Identify any necessary corrective action

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4.1.1 Qualitative use

When required, qualitative analysis shall be performed in accordance with 4.2 to assess conformance of safety-related systems to applicable design criteria.

4.1.2 Quantitative use

When required, quantitative analysis shall be performed in accordance with 4.3 and 4.4 to establish initial periodic testing intervals for safety-related system equipment and to provide a means for evaluating operational performance against requirements.

4.1.3 Standardized design

Wherever standardized designs are used for any portion of more than one nuclear facility, the analyses performed for the standardized portion of the first design will fulfill the requirements for that portion of later facilities provided that the initial analyses are verified to be applicable.

4.2 Qualitative analysis

4.2.1 Document for review

A qualitative analysis, when performed, shall be documented in a manner suitable for review.

4.2.2 Documentation criteria

The minimum documentation for a qualitative analysis to satisfy applicable criteria (e.g., single failure, independence, channel integrity) shall include the following:

Boundary of analysis. The area of design included within the scope of the work and germane to the analysis.

Level of analysis. The basic level of the system at which the faults of interest are investigated, including a list of components, modules, or devices included in the analysis.

System diagram. A logical arrangement of components basic to the system's primary function or operational mode for which the analysis is performed (e.g., schematics, process diagrams).

Failure mode. All applicable, significant failure modes for each class of component, module, or device.

Results. The output of the analysis that is normally part of a standard worksheet (e.g., cause of failure, method of detection, effects of the failure).

4.2.3 Complex failures

The analysis must consider multiple failures attributable to a single cause and cascading-type failures. Analyses performed using the methods described in 4.5 of IEEE Std 352-1987 are acceptable to fulfill this requirement.

4.2.4 Expected and initial conditions

Expected normal and abnormal environmental conditions and initial conditions assumed in the analysis shall be stated.

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4.2.5 Design changes

Qualitative analyses shall adequately account for design changes. As a minimum, an analysis shall exist which reflects the final design. Partial analyses may be performed to account for changes to critical portions of a design. A partial analysis shall consider system interactions caused by the design change. (Programming changes are more sensitive to unknown interactions than hardware modifications.)

4.3 Quantitative analysis

4.3.1 Document for review

Quantitative analyses may consist of any of the methods described in Clause 5 or Appendix A of IEEE Std 352-1987. The analysis shall be documented in a manner suitable for review. The analytical model should be capable of being expanded into a higher level system model as suggested in Appendix A of IEEE Std 352-1987.

4.3.2 Required calculations

A quantitative analysis is performed to calculate the predicted availability or reliability (or both) of the various safety-related systems in the plant. The use of a reliability or availability model (or both) shall be selected in terms of the functions of the system in the operational mode being analyzed. This analysis shall include pertinent system interactions and shall include sufficient detail to establish testing intervals consistent with the goals for the system. Appendix A of IEEE Std 352-1987 illustrates an acceptable method of analysis.

4.3.3 Analysis goals

Quantitative analyses shall be used to determine if a design can meet a specified goal. Goals for the safety-related systems shall be determined by the organizations responsible for the designs. Determination of the goals shall consider the following, as appropriate:

a) Overall plant goals
b) System performance requirements
c) Rate of demand on the system
d) Complexity of system design
e) Consequences of system failure
f) Testing limitations
g) Risk requirements
h) Owner’s requirements
i) Regulatory requirements

Examples of acceptable model formats include the following:

1) Fault tree
2) Reliability block diagram
3) Truth tables (or other appropriate tabular model)

Appropriate calculational techniques for quantification of the reliability or availability or both, of systems modeled in items 1) through 3), include the concepts and methods of the following:

— Boolean algebra
— Probability theory

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— Conditional probability
— Minimum cut sets (appropriate bounds must be specified)
— Monte Carlo simulation (calculational uncertainties should be evaluated)
— Markov matrices

Combinations of any of the preceding model formats and calculational methods may be supplemented or replaced by a simple comparison with similar systems that have been analyzed in detail. Any difference between the similar systems shall be defined; analyses of each difference shall be performed, including system interactions to demonstrate that the existing detailed analysis is applicable.

4.3.4 Design changes

Quantitative analyses shall adequately account for design changes. As a minimum, an analysis shall exist that reflects the final design. Partial analyses may be performed to account for changes to critical portions of a design. A partial analysis shall consider system interactions caused by the design change. (Programming changes are more sensitive to unknown interactions than hardware modifications.)

4.3.5 Documented failure data

All component failure data sources and assumptions used in the analysis shall be documented. When practical, actual plant specific failure data should be used.

4.3.6 Credible sources

Failure data shall be obtained from credible sources. Standard failure data shall be modified by the application of appropriate adjustment factors when such application reflects experience in a significantly different operating environment from that to which the standard failure data are being applied.

4.3.7 Treatment of uncertainties

Failure rates based on judgment may be used, provided the basis for the judgment is described and documented in the analysis. Uncertainties shall be propagated through the analyses or approximated by sensitivity analyses.

4.3.8 Uses of analysis

Quantitative analysis is intended to be one of the bases for the plant technical specifications minimum surveillance requirements and limiting conditions for operation. The testing intervals shall be determined in this manner to meet the requirement of 4.7, 4.8, and 6.5 of IEEE Std 338-1987.

4.4 Evaluation

IEEE Std 338-1987 requires that periodic testing programs be established to assure that Class lE power and protection systems function with high availability. The requirements stated in 4.4.1 and 4.4.2 amplify or complement those of IEEE Std 338-1987.

4.4.1 Overly conservative goals

If operational data reveal that the goals are being achieved with wide margins, the testing interval may be lengthened, redundancy requirements may be reduced, or limiting conditions for operation may be relaxed.

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4.4.2 Nonconservative goals

If actual performance falls significantly short of the goal, actions must be taken to assure that the goals can be attained. These actions include investigation for systematic causes, such as design deficiencies or maintainability problems, shortening the test interval, requiring more stringent limiting conditions for operation, or reassessment of the goal.

4.4.3 Changes to tests or limits

The requirements of IEEE Std 338-1987 complemented by the methods of 7.3, IEEE Std 352-1987, shall be adhered to for changes in test intervals or operating limitations.

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