



NUREG-0800

U.S. NUCLEAR REGULATORY COMMISSION STANDARD REVIEW PLAN

BRANCH TECHNICAL POSITION 7-11

GUIDANCE ON APPLICATION AND QUALIFICATION OF ISOLATION DEVICES

REVIEW RESPONSIBILITIES

Primary - Organization responsible for the review of instrumentation and controls

Secondary - None

Review Note: The revision numbers of Regulatory Guides (RG) and the years of endorsed industry standards referenced in this branch technical position (BTP) are centrally maintained in Standard Review Plan (SRP) Section 7.1-T, "Regulatory Requirements, Acceptance Criteria, and Guidelines for Instrumentation and Control Systems Important to Safety," (Table 7-1). Therefore, the individual revision numbers of RGs (except RG 1.97) and years of endorsed industry standards are not shown in this BTP. References to industry standards incorporated by reference into regulation (IEEE Std 279-1971 and IEEE Std 603-1991) and industry standards that are not endorsed by the agency do include the associated year in this BTP. See Table 7-1 to ensure that the appropriate RGs and endorsed industry standards are used for the review.

Revision 6 – August 2016

USNRC STANDARD REVIEW PLAN

This Standard Review Plan (SRP), NUREG 0800, has been prepared to establish criteria that the U.S. Nuclear Regulatory Commission (NRC) staff responsible for the review of applications to construct and operate nuclear power plants intends to use in evaluating whether an applicant/licensee meets the NRC regulations. The SRP is not a substitute for the NRC regulations, and compliance with it is not required. However, an applicant is required to identify differences between the design features, analytical techniques, and procedural measures proposed for its facility and the SRP acceptance criteria and evaluate how the proposed alternatives to the SRP acceptance criteria provide an acceptable method of complying with the NRC regulations.

The SRP sections are numbered in accordance with corresponding sections in Regulatory Guide (RG) 1.70, "Standard Format and Content of Safety Analysis Reports for Nuclear Power Plants (LWR Edition)." Not all sections of RG 1.70 have a corresponding review plan section. The SRP sections applicable to a combined license application for a new light-water reactor (LWR) are based on RG 1.206, "Combined License Applications for Nuclear Power Plants (LWR Edition)."

These documents are made available to the public as part of the NRC policy to inform the nuclear industry and the general public of regulatory procedures and policies. Individual sections of NUREG-0800 will be revised periodically, as appropriate, to accommodate comments and to reflect new information and experience. Comments may be submitted electronically by email to NRO_SRP@nrc.gov.

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A. BACKGROUND

This branch technical position (BTP) provides guidelines for reviewing the use of electrical isolation devices to allow connections between redundant portions of safety systems or between safety and nonsafety systems. This BTP deals with the criteria and methods used to confirm that the design of isolation devices ensures that credible failures in the connected nonsafety or redundant channels will not prevent the safety systems from meeting their required functions. Guidance for other aspects of isolation-device qualification (e.g., electromagnetic compatibility, environmental and seismic qualification) may be found in SRP, Appendix 7.1-B, "Guidance for Evaluation of Conformance to IEEE Std 279," Subsections 4.5, 4.6, and 4.7, SRP Appendix 7.1-C, "Guidance for Evaluation of Conformance to IEEE Std 603," Subsection 5.6, and SRP Appendix 7.1-D, "Guidance for Evaluation of the Application of IEEE Std 7-4.3.2," Subsection 5.6. The devices that provide isolation between safety and nonsafety portions of power distribution systems are addressed in SRP Chapter 8, "Electrical Power." Communication independence between safety systems and nonsafety systems is not discussed in this BTP. Refer to SRP Appendix 7.1-C, Subsection 5.6 and SRP Appendix 7.1-D, Subsection 5.6.

1. Regulatory Basis

Title 10 of the *Code of Federal Regulations* (10 CFR) 50.55a(h), "Protection and Safety Systems," requires compliance with the Institute of Electrical and Electronics Engineers (IEEE) Standard (Std) 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," and the correction sheet dated January 30, 1995. For nuclear power plants with construction permits issued before January 1, 1971, the applicant or licensee may elect to comply instead with the plant-specific licensing basis. For nuclear power plants with construction permits issued between January 1, 1971, and May 13, 1999, the applicant or licensee may elect to comply instead with the requirements stated in IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations." IEEE Std 603-1991, Clause 5.6, "Independence," states in part, "No credible failure on the nonsafety side of an isolation device shall prevent any portion of a safety system from meeting its minimum performance requirements during and following any design basis event requiring that safety function." IEEE Std 279-1971, Clause 4.7.2, "Isolation Devices," states in part, "No credible failure at the output of an isolation device shall prevent the associated protection system channel from meeting the minimum performance requirements specified in the design basis."

10 CFR Part 50, "Domestic Licensing of Production and Utilization Facilities," Appendix A, "General Design Criteria for Nuclear Power Plants," General Design Criterion (GDC) 1, "Quality Standards and Records," requires in part that "structures, systems, and components important to safety shall be designed, fabricated, erected, and tested to quality standards commensurate with the importance of the safety functions to be performed." GDC 1 also requires that "where generally recognized codes and standards are used, they shall be identified and evaluated to determine their applicability, adequacy, and sufficiency and shall be supplemented or modified as necessary to assure a quality product in keeping with the required safety function."

GDC 21, "Protection System Reliability and Testability," requires in part that "redundancy and independence designed into the protection system shall be sufficient to assure that no single failure results in a loss of the protection function."

GDC 22, "Protection System Independence," requires that "the effects of natural phenomena, and of normal operating, maintenance, testing, and postulated accident conditions on redundant channels do not result in loss of the protection function."

10 CFR Part 50, Appendix B, "Quality Assurance Criteria for Nuclear Power Plants and Fuel Reprocessing Plants," Criterion III, "Design Control," requires in part that "where a test program is used to verify the adequacy of a specific feature in lieu of other verifying or checking processes, it shall include suitable qualifications testing of a prototype unit under the most adverse design conditions."

2. Relevant Guidance

If a referenced industry code or standard has been separately incorporated into the U.S. Nuclear Regulatory Commission's (NRC's) regulations, licensees and applicants must comply with that code or standard as set forth in the regulations. If the referenced code or standard has been endorsed by the NRC staff in a RG, that code or standard constitutes an acceptable method of meeting the related regulatory requirement as described in the RG. If a referenced code or standard has neither been incorporated into the NRC's regulations nor endorsed by a RG, licensees and applicants may consider and use the information in the referenced code or standard, if appropriately justified, consistent with current regulatory practice.

RG 1.75, "Criteria for Independence of Electrical Safety Systems," endorses IEEE Std 384, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," which identifies specific electrical isolation criteria for isolation devices used in instrumentation and control circuits. These isolation criteria form part of the basis for this BTP.

Additional guidance on applying the safety system criteria of IEEE Std 603-1991 to computer-based safety systems is provided in IEEE Std 7-4.3.2, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations," as endorsed by RG 1.152, "Criteria for Use of Computers in Safety Systems of Nuclear Power." SRP Appendix 7.1-D provides additional guidance.

IEEE Std C37.90.1-2002, "IEEE Standard for Surge Withstand Capability (SWC) Tests for Protective Relays and Relay Systems Associated with Electric Power Apparatus," specifies design tests for relays and relay systems that relate to their immunity to electrical transients induced by fault conditions.

IEEE Std C62.41.1-2002, "IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits," describes the temporary overvoltages induced by fault conditions in low-voltage alternating current (ac) power circuits.

IEEE Std C62.41.2-2002, "IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits," characterizes the overvoltage environment at locations on ac power circuits described in IEEE Std C62.41.1-2002 by means of standardized waveforms and other stress parameters.

IEEE Std C62.45-2002, "IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits," provides acceptable guidance for overvoltage testing of equipment connected to low-voltage ac power circuits.

IEEE Std C62.23-1995 (R2001), "IEEE Application Guide for Surge Protection of Electric Generating Plants," describes electric utility industry practices, accepted theories, existing standards and guides, definitions, and technical references as they pertain specifically to surge protection of electric power generating plants.

IEEE Std C62.36-2000, "IEEE Standard Test Methods for Surge Protectors Used in Low Voltage Data, Communications, and Signaling Circuits," provides guidance for test methods for surge protectors used in low voltage data, communications, and signaling circuits. This guidance is acceptable when credit is taken for surge protection in these types of circuits.

American National Standards Institute (ANSI) Std C84.1-1989, "American National Standard for Electric Power Systems and Equipment Voltage-Ratings (60 hertz)," discusses nominal voltages and guidelines for steady-state tolerances.

RG 1.204, "Guidelines for Lightning Protection of Nuclear Power Plants," provides guidance for the design and installation of lightning protection systems to ensure that electrical transients resulting from lightning phenomena do not render safety-related systems inoperable or cause the spurious operation of such systems.

3. Purpose

The purpose of this BTP is to provide guidance to address the application and qualification of isolation devices through the application of maximum credible fault¹ (MCF) voltages and currents. This BTP has three objectives:

- Confirm that the design and implementation of isolation devices conforms to the guidance of RG 1.75.
- Confirm that the qualification basis for isolation devices is consistent with accepted industry standards and use in the plant.
- Confirm that qualification testing demonstrates that the isolation devices meet the acceptance criteria of IEEE Std 603-1991 or IEEE Std 279-1971.

B. BRANCH TECHNICAL POSITION

1. Introduction

This BTP addresses the electrical qualification and application of isolation devices. Other qualification requirements (such as those that pertain to environmental conditions, EMI/RFI, and seismic events) are addressed in SRP Section 7.1.

The following types of isolation devices are examples of devices that have been found to be acceptable, provided the guidelines of this BTP are satisfied:

¹IEEE Std 384 defines a maximum credible voltage or current transient as voltage or current transient that may exist in circuits, as determined by test or analysis, taking into consideration the circuit location, routing, and interconnections combined with failures that the circuit may credibly experience.

- Isolation amplifiers
- Isolation transformers
- Fiber-optic couplers
- Fiber-optic cable²
- Photo-optic couplers
- Relays (coil to contact isolation)

Qualification of isolation devices should be based on a combination of design analysis and qualification testing. The analysis should demonstrate the adequacy of the design, considering the range of possible fault conditions and variability between individual units. The qualification testing should validate the results of the analysis at the extremes of fault conditions.

2. Information to Be Reviewed

Information to be reviewed includes the applicant's or licensee's description of the: (1) device application, (2) device design, (3) test method, and (4) test results.

3. Acceptance Criteria

General acceptance guidelines for application and qualification are provided in IEEE Std 603-1991, or IEEE Std 279-1971, and RG 1.75. Acceptance criteria for the descriptions of the device application, device design, test methods, and test results are as follows:

Description of Device Application

Isolation devices should be classified as part of the safety system and powered in accordance with criteria of IEEE Std 603-1991 or IEEE Std 279-1971 and the guidelines of RG 1.75. If nonsafety power sources interface to the isolation device, the applicant or licensee should verify that the nonsafety power is not required for the device to perform its isolation function.

MCF requirements should be established by an analysis of proximate circuits that are credible sources of the fault, either through inadvertent application from human error or through a fault or failure postulated to occur that involves proximate circuits, cabling, or terminations (e.g., a "hot short" from an adjacent conductor). The determination of specific MCF characteristics is plant-specific.

Surge waveforms and characteristics should be defined for the worst-case conditions expected at the installation.

The acceptable leakage current into the safety system should be identified for specified MCFs.

Description of Device Design

² While fiber optic cables are not specifically isolation devices, they do provide an inherent electrical isolation capability. Since the fiber does not provide a conductive path and the separation distance associated with the cable run mitigates the potential for arcing, the isolation provided by fiber optic cable should be credited.

The design of isolation devices should conform to IEEE Std 603-1991, or IEEE Std 279-1971, and RG 1.75 guidelines for: (1) independence of redundant safety divisions, and (2) independence between protection (safety) and control (nonsafety) systems.

The isolation device should include design features for which credit is taken (e.g., surge protectors or barriers) and identification of the application limits of the device.

The device should be designed for postulated electrical faults or failures, including open circuits, short circuits, ground, and application of an MCF. The specified MCF should equal or exceed the application requirements. RG 1.75 suggests that the MCF include the levels and duration of the fault current on the non-safety side of the device. American National Standards Institute (ANSI) Std C84.1-1989, Table 1, "Standard Nominal System Voltages and Voltage Ranges," provides an acceptable basis for identifying nominal voltages and guidelines for steady-state tolerances.

The device design should accommodate the fault voltage and current waveforms and characteristics defined for the application. Appropriate industry standards should be used as a basis for establishing the fault-transient exposure level (e.g., IEEE Std C62.41.1-2002, IEEE Std C62.41.2-2002).

The physical arrangement of components in the isolation device should be configured to prevent, in the event of failure, the effects of shattered parts or material (e.g., solder spatter), fire, and smoke from breaching the isolation barrier.

Description of Test Method

A description of the specific testing performed for each type of isolation device should be provided. This should include elementary or schematic diagrams as necessary to describe the test configuration and how the MCF and surges will be applied to the devices during the test.

The basis for the set of postulated electrical faults and failures should be included in the test program.

A specific definition of pass/fail acceptance criteria for each type of device should be provided. This should include justification that the pass/fail acceptance criterion is sufficient to demonstrate that the tested device meets the requirements of IEEE Std 603-1991, Clause 5.6, or IEEE Std 279-1971, Clause 4.7.2.

RG 1.75 recommends that the following:

- The maximum credible voltage or current transient applied to the device output should not degrade below an acceptable level the operation of the circuit connected to the device input.
- Shorts, grounds, or open circuits occurring in the output will not degrade below an acceptable level the circuit connected to the device input.
- Transient voltages that may appear in the output circuit (e.g., surges) should also be considered.

- The qualification should consider the levels and duration of the fault current on the nonsafety side of the device.

For safety and nonsafety isolation, during and following the application of the MCF or surge test, there should be no degradation or distortion of the isolation device input that would have a detrimental effect on the performance of the safety system. For the isolation of redundant safety circuits, there should be no degradation or distortion of the redundant channel that would have a detrimental effect on the performance of the safety system.

Applicable industry standards should be used as the basis for performing the qualification testing (e.g., IEEE Std C62.45-2002).

Devices might be used either for isolation of safety circuits from nonsafety circuits or for isolation of redundant safety divisions. For qualification testing, the detailed device configuration depends on the objective of the isolation and the specific type and configuration of the isolation device (e.g., relay, isolation amplifier, optical-electronic device).

The MCF represents the application of the maximum credible ac and direct current (dc) voltages and currents that are applied to the device in common and differential modes (as defined by IEEE Std 100-2000, “The Authoritative Dictionary of IEEE Standards Terms Seventh Edition”) that exist based on the installation of the device. Common mode refers to faults between both signal terminals and a common reference plane (ground) and causes the potential of both sides of the transmission path to be changed simultaneously and by the same amount relative to the common reference plane (ground). Differential mode refers to faults between the signal terminals that cause the potential of one side of the signal transmission path to be changed relative to the other side. The mode of application should satisfy the following guidelines for test configurations.

For isolation of safety circuits from nonsafety circuits:

- MCFs and surges should be applied between the signal output terminals of the (nonsafety) circuits (differential mode) and between any output terminal and ground (common mode).
- Surges should be applied to power terminals. The guidance of IEEE Std C62.45-2002 is acceptable for surge testing at the power input.
- The signal input terminals should be monitored to ensure that no unacceptable interactions (degradations or distortions) between the safety and nonsafety circuits would occur.

For isolation between redundant safety circuits:

- MCFs should be applied between the signal input terminals (differential mode) and between any input terminal and ground (common mode); the output should be monitored to ensure that no unacceptable interactions (degradations or distortions) between redundant safety circuits will occur.

- Surges should be applied to power terminals. The guidance of IEEE Std C62.45-2002 is acceptable for surge testing at the power input.
- MCFs should also be applied to the output terminals in the differential mode and between any output terminal and ground (common mode); the input should be monitored to assure that no unacceptable interactions (degradations or distortions) between redundant safety circuits will occur.

MCFs should be applied to the isolation device for a sufficient duration to allow any measurable effects to occur on the isolation device and to allow monitored values or effects to reach steady-state.

Description of Test Results

Test data and results should verify that the design basis faults, including short circuits, open circuits, grounds, MCF, and surge were applied to the device in all of the applicable connection modes (i.e., applicable input, output, power, and ground connection modes).

Test data and results should verify that the test acceptance criteria are met.

4. Review Procedures

Confirm that the device design conforms to the guidance of RG 1.75.

Confirm that the applicant or licensee has established an acceptable test method and that the specified testing addresses the conditions of the intended applications.

Confirm that the applicant's or licensee's testing properly applied the MCF and surges to devices under test.

Confirm that the acceptance criteria of IEEE Std 603-1991, or IEEE Std 279-1991, and RG 1.75 were met during the tests.

C. REFERENCES

1. American National Standards Institute, ANSI Std C84.1-1989, "American National Standard for Electric Power Systems and Equipment-Voltage Ratings (60 Hz)," New York, NY.
2. Institute of Electrical and Electronics Engineers, IEEE Std C37.90.1-2002, "IEEE Standard for Surge Withstand Capability (SWC) Tests for Relays and Relay Systems Associated with Electric Power Apparatus," Piscataway, NJ.
3. Institute of Electrical and Electronics Engineers, IEEE Std C62.23-1995 (R 2001), "IEEE Application Guide for Surge Protection of Electric Generating Plants," Piscataway, NJ.
4. Institute of Electrical and Electronics Engineers, IEEE Std C62.36-2000, "IEEE Standard Test Methods for Surge Protectors Used in Low-Voltage Data, Communications, and Signaling Circuits," Piscataway, NJ.

5. Institute of Electrical and Electronics Engineers, IEEE Std C62.41.1-2002, "IEEE Guide on the Surge Environment in Low-Voltage (1000 V and Less) AC Power Circuits," Piscataway, NJ.
6. Institute of Electrical and Electronics Engineers, IEEE Std C62.41.2-2002, "IEEE Recommended Practice on Characterization of Surges in Low-Voltage (1000 V and Less) AC Power Circuits," Piscataway, NJ.
7. Institute of Electrical and Electronics Engineers, IEEE Std C62.45-2002, "IEEE Recommended Practice on Surge Testing for Equipment Connected to Low-Voltage (1000 V and Less) AC Power Circuits," Piscataway, NJ.
8. Institute of Electrical and Electronics Engineers, IEEE Std 100-2000, "The Authoritative Dictionary of IEEE Standards Terms Seventh Edition," Piscataway, NJ.
9. Institute of Electrical and Electronics Engineers, IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations," Piscataway, NJ.
10. Institute of Electrical and Electronics Engineers, IEEE Std 384, "IEEE Standard Criteria for Independence of Class 1E Equipment and Circuits," Piscataway, NJ.
11. Institute of Electrical and Electronics Engineers, IEEE Std 603-1991, "IEEE Standard Criteria for Safety Systems for Nuclear Power Generating Stations," Piscataway, NJ.
12. Institute of Electrical and Electronics Engineers, IEEE Std 7-4.3.2, "IEEE Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Stations."
13. U.S. Regulatory Commission, "Criteria for Independence of Electrical Safety Systems," Regulatory Guide 1.75.
14. U.S. Regulatory Commission, "Criteria for Use of Computers in Safety Systems of Nuclear Power Plants," Regulatory Guide 1.152.
15. U.S. Regulatory Commission, "Guidelines for Lightning Protection of Nuclear Power Plants," Regulatory Guide 1.204.

PAPERWORK REDUCTION ACT STATEMENT

The information collections contained in the Standard Review Plan are covered by the requirements of 10 CFR Part 50, and were approved by the Office of Management and Budget, approval number 3150-0011.

PUBLIC PROTECTION NOTIFICATION

The NRC may not conduct or sponsor, and a person is not required to respond to, a request for information or an information collection requirement unless the requesting document displays a currently valid OMB control number.

BTP Section 7-11
Description of Changes

BTP 7-11, “Guidance on Application and Qualification of Isolation Devices”

This BTP Section affirms the technical accuracy and adequacy of the guidance previously provided in BTP 7-11, Revision 5, dated March 2007. See ADAMS Accession No. ML070550080.

The main purpose of this update is to incorporate the revised software Regulatory Guides and the associated endorsed standards. For organizational purposes, the revision number of each Regulatory Guide and year of each endorsed standard is now listed in one place, Table 7-1. As a result, revisions of Regulatory Guides and years of endorsed standards were removed from this section, if applicable. For standards that are incorporated by reference into regulation (IEEE Std 279-1971 and IEEE Std 603-1991) and standards that have not been endorsed by the agency, the associated revision number or year is still listed in the discussion. Additional changes were editorial.

Part of 10 CFR was reorganized due to a rulemaking in the fall of 2014. Quality requirement discussions in the former 10 CFR 50.55a(a)(1) were moved to 10 CFR 50.54(jj) and 10 CFR 50.55(i). The incorporation by reference language in the former 10 CFR 50.55a(h)(1) was moved to 10 CFR 50.55a(a)(2). There were no changes either to 10 CFR 50.55a(h)(2) or 10 CFR 50.55a(h)(3).