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DRAFT REGULATORY GUIDE DG-1119

(Proposed Revision 1 of Regulatory Guide 1.180)

GUIDELINES FOR EVALUATING ELECTROMAGNETIC AND RADIO-FREQUENCY INTERFERENCE IN SAFETY-RELATED INSTRUMENTATION AND CONTROL SYSTEMS

A. INTRODUCTION

This regulatory guide is being revised to provide up-to-date guidance to licensees and applicants on methods acceptable to the NRC staff for complying with the NRC's regulations on design, installation, and testing practices for addressing the effects of electromagnetic and radio-frequency interference (EMI/RFI) and power surges on safety-related instrumentation and control (I&C) systems. The changes in this revision include endorsing Military Standard (MIL-STD) -461E and the International Electrotechnical Commission (IEC) 61000 series of EMI/RFI test methods, extending the guidance to cover signal line testing, incorporating frequency ranges where portable communications devices are experiencing increasing use, and relaxing the operating envelopes (test levels) when experience and confirmatory research warrants. Exemptions from regulatory requirements are also offered in the performance of the tests depending on plant conditions and the intended location of the safety-related I&C equipment.

The NRC's regulations in Part 50, "Domestic Licensing of Production and Utilization Facilities," of Title 10 of the Code of Federal Regulations (10 CFR Part 50) state that structures, systems, and components important to safety in a nuclear power plant be designed to accommodate the effects of environmental conditions (i.e., remain functional under all postulated service conditions) and that design control measures such as testing be used to check the adequacy of design. Section 50.55a(h) of 10 CFR Part 50 states that protection systems must

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This regulatory guide is being issued in draft form to involve the public in the early stages of the development of a regulatory position in this area. It has not received complete staff review or approval and does not represent an official NRC staff position.

Public comments are being solicited on this draft guide (including any implementation schedule) and its associated regulatory analysis or value/impact statement. Comments should be accompanied by appropriate supporting data. Written comments may be submitted to the Rules and Directives Branch, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555-0001. Comments may be submitted electronically or downloaded through the NRC's interactive web site at <WWW.NRC.GOV> through Rulemaking. Copies of comments received may be examined at the NRC Public Document Room, 11555 Rockville Pike, Rockville, MD. Comments will be most helpful if received by **November 8, 2002.**

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[1]IEEE publications may be purchased from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855-1331.

certification. Methods for addressing electromagnetic compatibility (EMC) constitute Tier 2 information under the 10 CFR Part 52 requirements.[2]

Electromagnetic interference (EMI), radio-frequency interference (RFI), and power surges have been identified as environmental conditions that can affect the performance of safety-related electrical equipment. Confirmatory research findings to support this observation can be found in NUREG/CR-5700, "Aging Assessment of Reactor Instrumentation and Protection System Components"[3] (July 1992); NUREG/CR-5904, "Functional Issues and Environmental Qualification of Digital Protection Systems of Advanced Light-Water Nuclear Reactors"[3] (April 1994); NUREG/CR-6406, "Environmental Testing of an Experimental Digital Safety Channel"[3] (September 1996); and NUREG/CR-6579, "Digital I&C Systems in Nuclear Power Plants: Risk-Screening of Environmental Stressors and a Comparison of Hardware Unavailability With an Existing Analog System"[3] (January 1998). Therefore, controlling electrical noise and the susceptibility of I&C systems to EMI/RFI and power surges is an important step in meeting the aforementioned requirements.

This regulatory guide endorses design, installation, and testing practices acceptable to the NRC staff for addressing the effects of EMI/RFI and power surges on safety-related I&C systems in a nuclear power plant environment. The design and installation practices described in IEEE Std 1050-1996, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations,"[1] are endorsed for limiting EMI/RFI subject to the conditions stated in the Regulatory Position. EMC testing practices from military and commercial standards are endorsed to address electromagnetic emissions, EMI/RFI susceptibility, and power surge withstand capability (SWC). Selected EMI/RFI test methods from MIL-STD-461E, "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment,"[4] and the IEC 61000 Series are endorsed to evaluate conducted and radiated EMI/RFI phenomena for safety-related I&C systems. The IEC standards include IEC 61000-3, "Electromagnetic Compatibility (EMC) - Part 3: Limits," IEC 61000-4, "Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques," and IEC 61000-6, "Electromagnetic Compatibility (EMC) - Part 6: Generic Standards." This regulatory guide provides acceptable suites of EMI/RFI emissions and susceptibility methods from the most recent versions of the military standard and international commercial standards. These suites of test methods can be applied as alternative sets (guidance is provided in the Regulatory Position). This regulatory guide also endorses electromagnetic operating envelopes corresponding to the MIL-STD-461E test methods. These operating envelopes were tailored from the MIL-STD-461E test limits to represent the characteristic electromagnetic environment in key locations at nuclear power plants. Comparable

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[2]An applicant who references an advanced reactor certification is not allowed to depart from the Tier 2 commitments without NRC approval. Thus, changes cannot be made under a process such as that in 10 CFR 50.59.

[3] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; <http://www.ntis.gov/ordernow> (telephone (703)487-4650;. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

[4]Military Standards are available from the Department of Defense, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

operating envelopes for the IEC 61000 test methods are also endorsed. The operating envelopes are presented within the Regulatory Position, along with descriptions of the endorsed MIL-STD-461E and IEC 61000 test methods.

The SWC practices described in IEEE Std C62.41-1991 (Reaffirmed in 1995), "IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits,"[1] and IEEE Std C62.45-1992, "IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits,"[1] are acceptable to the NRC staff regarding the effect of power surges on safety-related I&C systems in nuclear power plants. A specific set of surge test waveforms are endorsed from IEEE Std C62.41-1991[1] as acceptable SWC test criteria. The associated test methods in IEEE Std C62.45-1992[1] are endorsed to describe the approach to be employed when assessing SWC. General withstand levels are endorsed for use with the SWC test criteria and are presented within the Regulatory Position, along with the description of the endorsed surge waveforms. Alternative SWC practices from IEC 61000-4[5] are acceptable to the NRC staff and are also presented within the Regulatory Position.

The practices endorsed in this regulatory guide apply to both safety-related I&C systems and non-safety-related I&C systems whose failures can affect safety functions. The rationale for the selection of the practices depicted in this guide is that they provide a well established, systematic approach for ensuring EMC and the capability to withstand power surges in I&C equipment within the environment in which it operates. The technical basis for selecting these particular practices is given in NUREG/CR-5941, "Technical Basis for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related I&C Systems"[3] (April 1994), NUREG/CR-6431, "Recommended Electromagnetic Operating Envelopes for Safety-Related I&C Systems in Nuclear Power Plants"[3] (April 1999), NUREG/CR-5609, "Electromagnetic Compatibility Testing for Conducted Susceptibility Along Interconnecting Signal Lines"[3] (draft, July 2002), and NUREG/CR-6782, "Comparison of U.S. Military and International Electromagnetic Compatibility Guidance"[3] (draft, July 2002).

In general, information provided by regulatory guides is reflected in the Standard Review Plan (NUREG-0800, "Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants").[3] NRC's Office of Nuclear Reactor Regulation uses the Standard Review Plan to review applications to construct and operate nuclear power plants. This regulatory guide will apply to the revised Chapter 7, "Instrumentation and Controls," of the Standard Review Plan.

Regulatory guides are issued to describe to the public methods acceptable to the NRC staff for implementing specific parts of the NRC's regulations, to explain techniques used by the staff in evaluating specific problems or postulated accidents, and to provide guidance to applicants. Regulatory guides are not substitutes for regulations, and compliance with regulatory guides is not required. Regulatory guides are issued in draft form for public comment to involve the public in developing the regulatory positions. Draft regulatory guides have not received complete staff review; they therefore do not represent official NRC staff positions.

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[5] IEC publications may be purchased from the International Electrotechnical Commission, 3 rue de Varembé, Geneva, Switzerland. Telefax: +41 22 919 0300.

The information collections contained in this draft regulatory guide are covered by the requirements of 10 CFR Part 50, which were approved by the Office of Management and Budget (OMB), approval number 3150-3011. 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.

B. DISCUSSION

Existing I&C equipment in nuclear power plants is currently being replaced with computer-based digital I&C systems or advanced analog systems. However, these technologies may exhibit greater vulnerability to the nuclear power plant EMI/RFI environment than existing I&C systems. This regulatory guide provides an acceptable method for qualifying digital and advanced analog systems for the projected electromagnetic environment in nuclear power plants.

The typical environment in a nuclear power plant includes many sources of electrical noise, for example, hand-held two-way radios, arc welders, switching of large inductive loads, high fault currents, and high-energy fast transients associated with switching at the generator or transmission voltage levels. The increasing use of advanced analog- and microprocessor-based I&C systems in reactor protection and other safety-related plant systems has introduced concerns with respect to the creation of additional noise sources and the susceptibility of this equipment to the electrical noise already present in the nuclear power plant environment.

Digital technology is constantly evolving, and manufacturers of digital systems are incorporating increasingly higher clock frequencies and lower logic level voltages into their designs. However, these performance advancements may have an adverse impact on the operation of digital systems with respect to EMI/RFI and power surges because of the increased likelihood of extraneous noise being misinterpreted as legitimate logic signals. With recent advances in analog electronics, many of the functions presently being performed by several analog circuit boards could be combined into a single analog circuit board operating at reduced voltage levels, thereby making analog circuitry more susceptible to EMI/RFI and power surges as well. Hence, operational and functional issues related to safety in the nuclear power plant environment must address the possibility of upsets and malfunctions in I&C systems caused by EMI/RFI and power surges.

The NRC staff accepted the Electric Power Research Institute (EPRI) topical report TR-102323, "Guidelines for Electromagnetic Interference Testing in Power Plants,"[6] in a Safety Evaluation Report (SER) by letter dated April 17, 1996,[7] as one method of addressing issues of EMC for safety-related digital I&C systems in nuclear power plants. The original Regulatory Guide 1.180 (January 2000) complemented the position set forth in the SER and this revision complements the SER as well. Both methods provide acceptable guidance for qualifying safety-related I&C systems for the projected

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[6]EPRI publications may be purchased from the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523, telephone (510) 934-4212.

[7]Copies are available for inspection or copying for a fee from the NRC Public Document Room at 2120 L Street NW., Washington, DC; the PDR's mailing address is Mail Stop LL-6, Washington, DC 20555; telephone (202) 634-3273; fax (202) 634-3343.

electromagnetic environment in nuclear power plants. The licensee or applicant has the freedom to choose the method best suited to the situation.

The EMI/RFI practices, SWC practices, and operating envelopes endorsed in this guide are only elements of the total package that is needed to ensure EMC within nuclear power plants. In addition to assessing the electromagnetic environment, plants should apply sound engineering practices for non-safety-related upgrades and I&C maintenance as part of an overall EMC program. While non-safety-related systems are not part of the regulatory guidance being developed, control of EMI/RFI from these systems is necessary to ensure that safety-related I&C systems can continue to perform properly in the nuclear power plant environment. When feasible, the emissions from non-safety-related systems should be held to the same levels as safety-related systems.

As with the original Regulatory Guide 1.180, this revision endorses IEEE Std 1050-1996 with one exception as stated in Regulatory Position 2. The exception was cited in NUREG/CR-5941. IEEE Std 1050-1996 provides guidance on the engineering practices needed to control upsets and malfunctions in safety-related I&C systems when exposed to EMI/RFI and power surges. IEEE Std 1050-1996 was developed to provide guidance on the design and installation of grounding systems for I&C equipment specific to power generating stations. Further purposes of the standard are to achieve both a suitable level of protection for personnel and equipment and suitable electrical noise immunity for signal ground references in power generating stations.

IEEE Std 1050-1996 addresses grounding and noise-minimization techniques for I&C systems in a generating station environment. This standard recommends practices for the treatment of both analog and digital systems that address the grounding and shielding of electronic circuits on the basis of minimizing emissions and their susceptibility to EMI/RFI and power surges. The standard is comprehensive in that it covers both the theoretical and practical aspects of grounding and electromagnetic compatibility.

Design verification measures for EMI/RFI testing (emissions and susceptibility) are beyond the scope of IEEE Std 1050-1996. To determine the adequacy of safety-related I&C system designs, the NRC staff has endorsed the applicable EMI/RFI test methods in MIL-STD-461E and the IEC 61000 Series (i.e., the most recently issued military and international commercial guidance), along with custom operating envelopes developed to represent the characteristic electromagnetic environment for nuclear power plants. The test methods and operating envelopes are cited in Regulatory Positions 3, 4, and 6 of this guide.   MIL-STD-461E is included in this revision because it replaced MIL-STD-461D and MIL-STD-462D.   The associated changes are discussed in NUREG/CR-6782. The original Regulatory Guide 1.180 cited EMI/RFI test guidance from MIL-STD-461C, -461D, -462, and -462D. MIL-STD-461E was developed as a measure to ensure the electromagnetic compatibility of equipment. The application of the MIL-STD-461E test methods is tailored for the intended function of the equipment and the characteristic environment (i.e., which tests are applied and what levels are used depend on the function to be performed and the location of operation). Previous versions of the standard have been used successfully by the U.S. Department of Defense for many years and are commonly referenced in commercial applications. The IEC 61000 series of tests include IEC 61000-3, IEC 61000-4, and IEC 61000-6.

Regulatory Position 3 describes the conducted EMI/RFI emissions tests and operating envelopes acceptable to the NRC staff. In turn, Regulatory Position 4 describes the acceptable EMI/RFI susceptibility tests and operating envelopes. The rationale for the selection of the particular EMI/RFI tests and operating envelopes is discussed in NUREG/CR-6782. These discussions include how the EMI/RFI tests were selected, how the IEC 61000 tests should be applied, the exemptions that can be applied with the use of some tests, and the adjustments made to the operating envelopes recommended in MIL-STD-461E.

In addition, Regulatory Position 4 describes the conducted EMI/RFI susceptibility tests and operating envelopes that are acceptable to the NRC staff for addressing the susceptibility of signal lines to interference. The rationale for the selection of the test methods and operating envelopes is discussed in detail in NUREG/CR-5609. Regulatory Position 6 describes test methods and operating envelopes that are acceptable to the NRC staff for validating the performance of safety-related I&C systems above 1 GHz. The underlying rationale is described in NUREG/CR-6782.

Design verification measures for power surge withstand testing are also beyond the scope of IEEE Std 1050-1996. Accordingly, the NRC in the original regulatory guide endorsed the test criteria recommended in IEEE Std C62.41-1991 and the associated test methods recommended in IEEE Std C62.45-1992. This revision would update that guidance to also include the IEC 61000-4 tests relevant to power surge withstand testing. The entire complement of SWC test criteria, test methods, and operating envelopes endorsed by the NRC are described in Regulatory Position 5. Comparisons of the IEEE and IEC power surge withstand tests, along with rationale for adjusting test levels, are discussed in NUREG/CR-6782.

General operating envelopes that form the basis for establishing EMI/RFI and power surge testing levels are cited in this regulatory guide. The technical basis for the electromagnetic operating envelopes is presented in NUREG/CR-6431, NUREG/CR-5609, and NUREG/CR-6782. The operating envelopes are applicable for locations within a nuclear power plant where safety-related I&C systems either are or are likely to be installed. These locations include control rooms, remote shutdown panels, cable spreading rooms, equipment rooms, relay rooms, auxiliary instrument rooms, and other areas (e.g., the turbine deck) where safety-related I&C system installations are planned. The operating envelopes are also applicable for both analog and digital system installations.

Any modifications to the electromagnetic operating envelopes (e.g., lower site-specific envelopes) should be based on technical evidence comparable to that presented in NUREG/CR-6431, NUREG/CR-5609, and NUREG/CR-6782. Relaxation in the operating envelopes should be based on actual measurement data collected in accordance with IEEE Std 473-1985 (reaffirmed in 1991), “IEEE Recommended Practice for an Electromagnetic Site Survey (10 kHz to 10 GHz).”

C. REGULATORY POSITION

1. GENERAL

Establishing and continuing an EMC program for safety-related I&C systems in nuclear power plants contributes to the assurance that safety-related structures, systems, and components are designed to accommodate the effects of and to be compatible with the environmental conditions associated with nuclear power plant service conditions. Application of consensus standard practices regarding the design, testing, and installation of safety-related I&C system modifications or new installations constitutes an important element of such a program. This guidance recommends design and installation practices to limit the impact of electromagnetic effects, testing practices to assess the emissions and susceptibility of equipment, and testing practices to evaluate the power SWC of the equipment. Operating envelopes characteristic of the electromagnetic environment in nuclear power plants are cited in this guidance as the basis for establishing acceptable testing levels. Table 1 lists the specific regulatory positions on EMC that are set forth below. This guidance is applicable to all new safety-related systems or modifications to existing safety-related systems that include analog, digital, or hybrid (i.e., combined analog and digital) electronics equipment. The endorsed test methods for evaluating the electromagnetic emissions, EMI/RFI susceptibility, and power surge withstand capability of safety-related equipment are intended for application in test facilities or laboratories before installation.

The electromagnetic conditions at the point of installation for safety-related I&C systems should be assessed to identify any unique EMI/RFI sources that may generate local interference. The EMI/RFI sources could include both portable and fixed equipment (e.g., portable transceivers, arc welders, power supplies, and generators). Steps should be taken during installation to ensure that systems are not exposed to EMI/RFI levels from the identified sources that are greater than 8 dB below the specified operating envelopes.

To ensure that the operating envelopes are being used properly, equipment should be tested in the same physical configuration as that specified for its actual installation in the nuclear power plant. In addition, the equipment should be in its normal mode of operation (i.e., performing its intended function) during the testing. Following the tests, the physical configuration of the safety-related I&C system should be maintained and all changes in the configuration controlled. The design specifications that should be maintained and controlled include wire and cable separations, shielding techniques, shielded enclosure integrity, apertures, gasketing, grounding techniques, EMI/RFI filters, and circuit board layouts.

Exclusion zones should be established through administrative controls to prohibit the activation of portable EMI/RFI emitters (e.g., welders, transceivers, cameras, flash attachments) in areas where safety-related I&C systems have been installed. An exclusion zone is defined as the minimum distance permitted between the point of installation and where portable EMI/RFI emitters are allowed to be activated. The size of the exclusion zones should be site-specific and depend on the effective radiated power and antenna gain of the portable EMI/RFI emitters used within a particular nuclear power plant. The size of exclusion zones should also depend on the allowable electric field emission levels designated for the area in the vicinity of the installed safety-related I&C

system. To establish the size of an exclusion zone, an 8 dB difference between the susceptibility operating envelope and the allowed emissions level should be maintained. For the radiated electric field operating envelope of 10 V/m (140 dBµV/m), the size of the exclusion zones should be set such that the radiated electric fields emanating from the portable EMI/RFI emitters are limited to 4 V/m (132 dBµV/m) in the vicinity of safety-related I&C systems. The minimum distance of an exclusion zone (d) in meters should be calculated by:

$$d = \frac{\sqrt{30 P_t G_t}}{E} (meters)$$

Where:

P_t = the effective radiated power of the EMI/RFI emitter (in Watts);
G_t = the gain of the EMI/RFI emitter (dimensionless); and,
E = the allowable radiated electric field strength of the EMI/RFI emitter (in Volts/meter) at the point of installation.

Table 1 Specific Regulatory Positions for EMC Guidance

Regulatory Position	EMC Issue Addressed	Standards Endorsed	Comments/Conditions
2	EMI/RFI limiting practices	IEEE Std 1050-1996	Full standard endorsed with one exception taken.
3, 4, 6	EMI/RFI emissions and susceptibility (radiated, conducted power line and conducted signal line) testing	MIL-STD-461E IEC 61000-3 IEC 61000-4 IEC 61000-6	Selected MIL-STD-461E test methods and tailored operating envelopes endorsed. Selected IEC 61000 test methods and operating envelopes endorsed. Option of alternative test suites from most recent versions of MIL-STD and IEC guidelines. General electromagnetic operating envelopes for key nuclear power plant locations are included in Regulatory Positions 3, 4, and 6.

5	SWC testing	IEEE Std C62.41-1991 IEEE Std C62.45-1992	Selected IEEE Std C62.41-1991 surge test waveforms endorsed with associated IEEE Std C62.45-1992 test methods.
		IEC 61000-4	Selected IEC 61000-4 surge test waveforms and test methods endorsed.
			General withstand levels for nuclear power plants are included in Regulatory Position 5.

Note that unintentional transmitters (welders, cameras, etc.) will typically have a gain that is less than or equal to 1 (the gain of an isotropic emitter), and the gain for intentional transmitters (two-way radios, cell phones, etc.) will typically be greater than 1. Typical values for the gain of intentional transmitters might vary from 1.5 for a short dipole antenna to 3 for a monopole antenna to 6 for a horn antenna.

2. IEEE Std 1050-1996

IEEE Std 1050-1996, "IEEE Guide for Instrumentation and Control Equipment Grounding in Generating Stations,"[1] describes design and installation practices that are acceptable to the NRC staff regarding EMI/RFI- and power surge-related effects on safety-related I&C systems employed in nuclear power plants with the following exception.

Section 4.3.7.4, "Radiative Coupling," of the standard maintains that the "field strength" of propagating electromagnetic waves is inversely proportional to the square of the distance from the source of radiation. This statement needs to be re-evaluated because radiative coupling is a far-field effect. A distance, r, greater than the wavelength divided by 2π ($r > \lambda/2\pi$) from the source of radiation is considered to be far field, which is the region where the wave impedance is equal to the characteristic impedance of the medium. Both the electric and magnetic "field strengths" fall off as 1/r in the far field, i.e., in inverse proportion to distance (not as its square). This concept is not to be confused with the propagation of electromagnetic waves in the near field ($r < \lambda/2\pi$) where the wave impedance is determined by the characteristics of the source and the distance from the source. In the near field, if the source impedance is high (>377Ω), the electric and magnetic "field strengths" attenuate at rates of $1/r^3$ and $1/r^2$, respectively. If the source impedance is low (<377Ω), the rates of attenuation are reversed: the electric "field strength" will fall off at a rate of l/r^2 and the magnetic "field strength" at a rate of $1/r^3$. The user should understand that radiative coupling is a far-field effect and the "field strength" falls off as 1/r, not as $1/r^2$.

IEEE Std 1050-1996 references other standards that contain complementary and supplementary information. In particular, IEEE Std 518-1982 (reaffirmed in 1990), "IEEE Guide for the Installation of Electrical Equipment To Minimize Noise Inputs to Controllers from External Sources," and IEEE Std 665-1995, "IEEE Guide for Generating Station Grounding," are referenced frequently. The portions of IEEE Std 518-1982 and IEEE Std 665-1995 referenced in

IEEE Std 1050-1996 are endorsed by this guide and are to be used in a manner consistent with the practices in IEEE Std 1050-1996.

3. EMI/RFI EMISSIONS TESTING

MIL-STD-461E, "Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment," contains test practices that can be applied to characterize EMI/RFI emissions. IEC 61000-6, "Electromagnetic Compatibility (EMC) – Part 6: Generic Standards," also specifies test practices that can be applied to characterize EMI/RFI emissions for industrial environments. The specific test methods acceptable to the NRC staff in regard to emissions testing for safety-related I&C systems in nuclear power plants are presented in Tables 2 and 3. Table 2 lists the EMI/RFI emissions test methods in MIL-STD-461E while Table 3 lists the corresponding criteria in IEC 61000-6-4, "Electromagnetic Compatibility (EMC) – Part 6: Generic Standards – Section 4: Emission standard for industrial environments." These test methods cover conducted (along power leads) and radiated interference emitted from equipment under test.

Table 2 MIL-STD-461E Test Methods for EMI/RFI Emissions

Method	Description
CE101	Conducted emissions, low-frequency, 30 Hz to 10 kHz
CE102	Conducted emissions, high-frequency, 10 kHz to 2 MHz
RE101	Radiated emissions, magnetic field, 30 Hz to 100 kHz
RE102	Radiated emissions, electric field, 2 MHz to 1 GHz

C = conducted, R = radiated, and E = emissions.

Table 3 IEC 61000-6-4 Test Methods for EMI/RFI Emissions

Method	Description
None	Conducted emissions, low-frequency, 30 Hz to 10 kHz
CISPR 11	Conducted emissions, high-frequency, 150 kHz to 30 MHz
None	Radiated emissions, magnetic field, 30 Hz to 100 kHz
CISPR 11	Radiated emissions, electric field, 30 MHz to 1 GHz

MIL-STD-461E provides the latest revision of domestic guidance for emissions test methods (including improvements based on experience and the most recent technical information), thus it represents current practice. IEC 61000-6-4 provides the most recent international guidance for emissions test practices and incorporates by reference the test methods of CISPR 11, "Limits and Methods of Measurement of Electromagnetic Disturbance Characteristics of Industrial, Scientific and Medical (ISM) Radio-Frequency Equipment." It is intended that either set of test methods be applied in its entirety, without selective application of individual methods (i.e., no mixing and matching of test methods) for emissions testing. Because of the absence of IEC 61000 test methods to address low-frequency conducted emissions testing, low-frequency (magnetic field) radiated emissions testing, and high-frequency conducted emissions testing in the frequency range from 10 kHz to 150 kHz, the IEC emissions testing option is only acceptable under conditions that correspond to the special exemption conditions for the MIL-STD emissions testing option (see below).

The MIL-STD-461E test methods listed in Table 2 have associated operating envelopes that serve to establish test levels. General operating envelopes that are acceptable to the NRC staff are given below in the discussion of the listed MIL-STD-461E test methods. Likewise, operating envelopes for the IEC 61000-6-4[5] test methods have been identified that are comparable to the corresponding MIL-STD counterparts and are given below in the IEC discussion. These operating envelopes are acceptable for locations where safety-related I&C systems either are or are likely to be installed and include control rooms, remote shutdown panels, cable spreading rooms, equipment rooms, auxiliary instrument rooms, relay rooms, and other areas (e.g., the turbine deck) where safety-related I&C system installations are planned. The operating envelopes are acceptable for analog, digital, and hybrid system installations.

The detailed technical basis for the electromagnetic operating envelopes is presented in NUREG/CR-6431, NUREG/CR-5609, and NUREG/CR-6782. The technical basis for the operating envelopes begins with the MIL-STD envelopes corresponding to the electromagnetic environment for military ground facilities, which were judged to be comparable to that of nuclear power plants based on general layout and equipment type considerations. Plant emissions data were used to confirm the adequacy of the operating envelopes. From the MIL-STD starting point, adjustments to the equipment emissions envelopes were based on consideration of the primary intent of the MIL-STD envelopes (e.g., whether the envelopes were based on protecting sensitive receivers on military platforms) and maintaining some margin with the susceptibility envelopes. When changes to the operating envelopes from the MIL-STD origin were motivated by technical considerations, consistency among the envelopes for comparable test methods was promoted and commercial emissions envelopes for industrial environments were factored into adjustments of the operating envelopes. As a result of these considerations, the operating envelopes presented in this regulatory guide are equivalent or less restrictive than the MIL-STD envelopes that served as their initial basis.

Generic envelopes for industrial environments were identified in IEC 61000-6-4 for both conducted and radiated emissions. These envelopes were compared with the tailored operating envelopes associated with the equivalent MIL-STD tests and selected based on their compatibility with the nuclear power plant environment. As a result, the IEC 61000-6-4 envelopes are equivalent or as restrictive as the general operating envelopes that were confirmed against nuclear power plant electromagnetic data.

The MIL-STD- 461E and IEC test methods that demonstrate EMI/RFI emissions compliance are discussed below. These methods are acceptable to the NRC staff for accomplishing EMI/RFI emissions testing for safety-related I&C systems intended for installation in nuclear power plants. Where applicable, conditions permitting exemption of specific tests are described.

3.1 CE101—Conducted Emissions, Low Frequency

The CE101 test measures the low-frequency conducted emissions on power leads of equipment and subsystems in the frequency range 30 Hz to 10 kHz. Equipment could be exempt from this test if the following two conditions exist. First, the power quality requirements of the equipment are consistent with the existing power supply; and second, the equipment will not impose additional harmonic distortions on the existing power distribution system that exceed 5% total harmonic distortion (THD) or other power quality criteria established with a valid technical basis. When the test is employed, it is applicable to ac and dc power leads, including grounds and neutrals, that obtain power from other sources not part of the equipment under test. Conducted emissions on power leads should not exceed the applicable root mean square (rms) values shown in Figure 3.1. Alternative envelopes are given for ac-operated equipment based on power consumption (less than or equal to 1 kVA and greater than 1 kVA). For ac-operated equipment with a fundamental current (i.e., load current at the power line frequency) greater than 1 ampere, the envelopes in Figure 3.1 may be relaxed as follows:

$$\text{dB relaxation} = 20 \log(\text{fundamental current}).$$

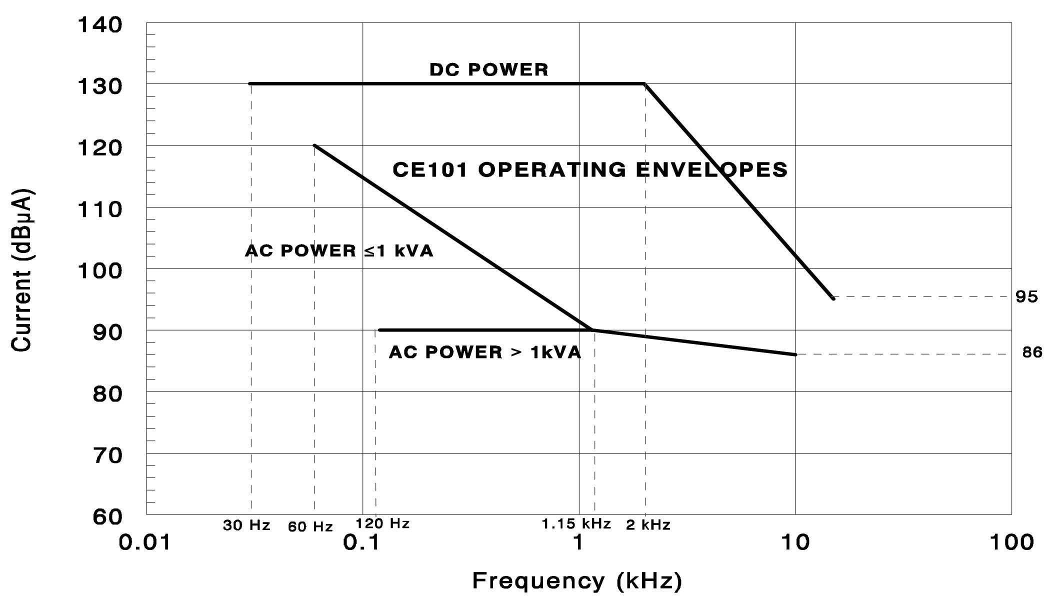

Figure 3.1 Low-Frequency Emissions Envelopes

3.2 CE102—Conducted Emissions, High Frequency

The CE102 test measures the high-frequency conducted emissions on power leads of equipment and subsystems in the frequency range 10 kHz to 2 MHz. The test is applicable to ac and dc power leads, including grounds and neutrals, that obtain power from other sources that are not part of the equipment under test. Conducted emissions on power leads should not exceed the applicable rms values shown in Figure 3.2. The values are specified according to the voltage of the power source feeding the equipment under test. Equipment could be exempted from application of this test in the frequency band from 10 kHz to 450 kHz if the nuclear power plant employs power quality control (see the conditions for exemption of the CE101 test). Otherwise, the CE102 test should be performed over the full frequency range from 10 kHz to 2 MHz.

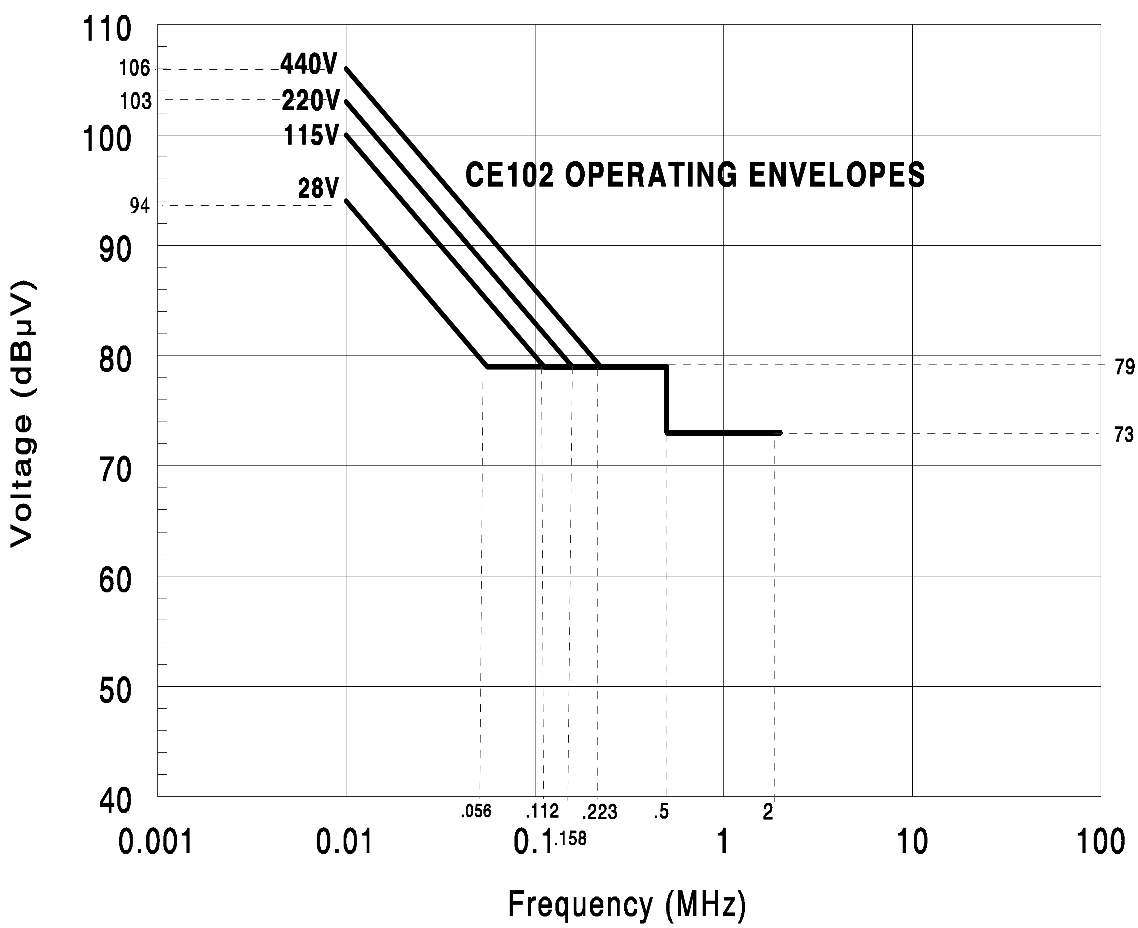

Figure 3.2 High-Frequency Conducted Emissions Envelopes

3.3 RE101—Radiated Emissions, Magnetic Field

The RE101 test measures radiated magnetic field emissions in the frequency range 30 Hz to 100 kHz. Equipment not intended to be installed in areas with other equipment sensitive to magnetic fields could be exempt from this test. The test is applicable for emissions from equipment and subsystem enclosures, as well as all interconnecting leads. The test does not apply at transmitter fundamental frequencies or to radiation from antennas. Magnetic field emissions should not be radiated in excess of the levels shown in Figure 3.3. Magnetic field emissions are measured at the specified distances of 7 cm and compared against the corresponding envelope.

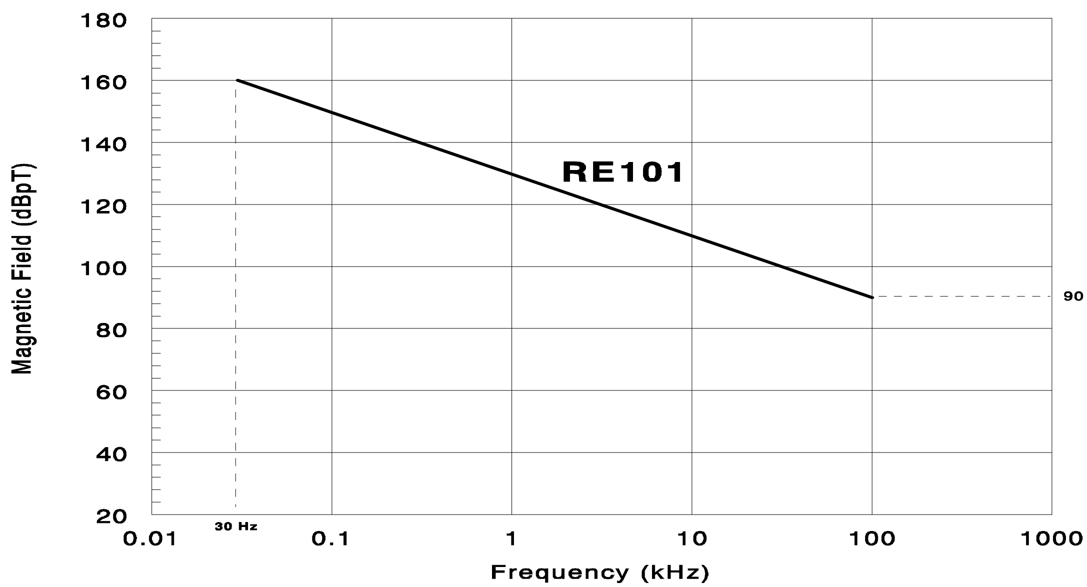

Figure 3.3 Magnetic-Field Radiated Emissions Envelope

3.4 RE102—Radiated Emissions, Electric Field

The RE102 test addresses measurement of radiated electric field emissions in the frequency range of interest, 2 MHz to 1 GHz. It is applicable for emissions from equipment and subsystem enclosures, as well as all interconnecting leads. The test does not apply at transmitter fundamental frequencies or to radiation from antennas.

Electric field emissions should not be radiated in excess of the rms values shown in Figure 3.4. At frequencies above 30 MHz, the test method should be performed for both horizontally and vertically polarized fields.

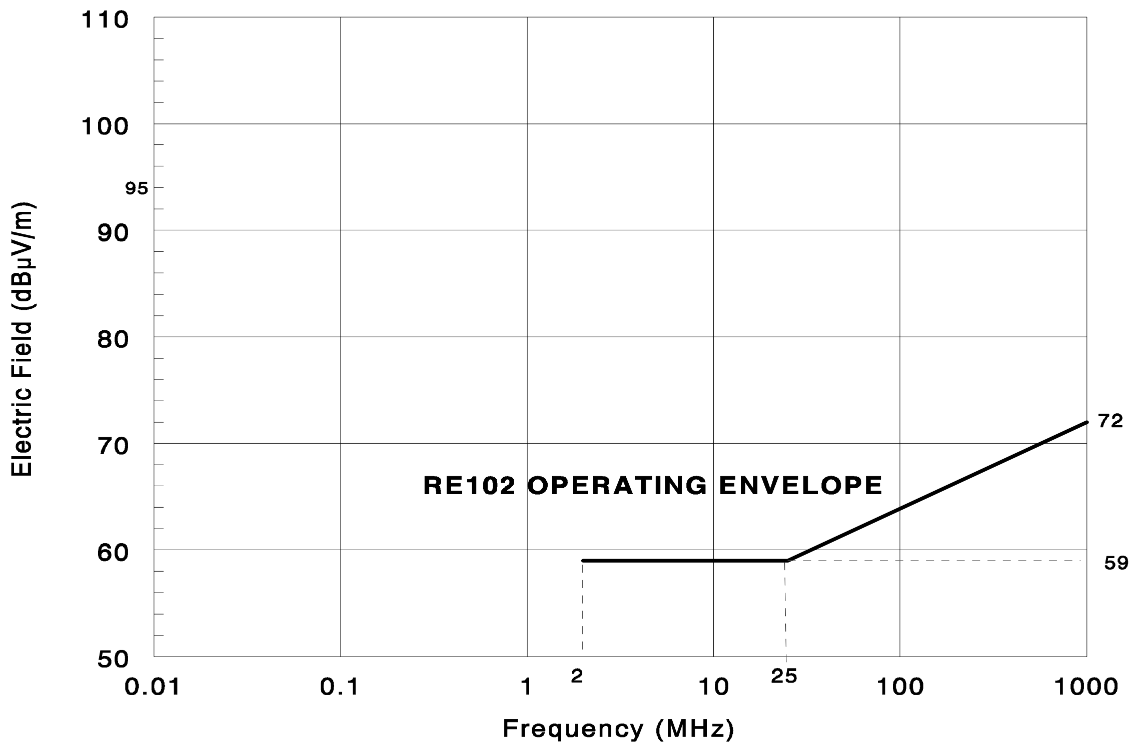

Figure 3.4 Electric-Field Radiated Emissions Envelopes

3.5 IEC Emissions Tests

The IEC 61000-6-4 test practices that demonstrate EMI/RFI emissions compliance incorporate the test methods of CISPR 11 by reference. Under the following conditions, these methods are acceptable to the NRC staff for accomplishing EMI/RFI emissions testing for safety-related I&C systems intended for installation in nuclear power plants. For the IEC emissions testing option to be acceptable, two conditions must be met. First, power quality controls must be in place, which eliminates the need to perform the CE101 test. Second, separation from equipment that is sensitive to magnetic fields must be maintained, hence it is unnecessary to perform the RE101 test.

The specifications for the IEC 61000-6-4 test call for employing the CISPR 11 measurement techniques. These techniques are similar to those used in the MIL-STD-461E CE102 and RE102 tests, with some differences. For example, CISPR 11 requires a quasi-peak or average test signal detector, while CE102 requires a peak detector. Also, CISPR 11 requires that radiated electric field measurements be made at 30 meters and 10 meters in an open area site, while RE102 requires that the testing be performed in a shielded enclosure and that measurements be made at a distance of 1 meter. Despite the differences, the tests are expected to yield similar results. Values for the IEC 61000-6-4 operating envelope for conducted emissions are given in

Table 4. Values for the IEC 61000-6-4 operating envelope for radiated emissions are given in Table 5.

Table 4 IEC 61000-6-4 Conducted Emissions Envelopes

Frequency Range	Test Level (dBµV)
150 kHz to 500 kHz	79 quasi-peak, 66 average
500 kHz to 5 MHz	73 quasi-peak, 60 average
5 MHz to 30 MHz	73 quasi-peak, 60 average

Table 5 IEC 61000-6-4 Radiated Emissions Envelopes

Frequency Range	Test Level (dBµV)
30 MHz to 230 MHz	30 quasi-peak, measured at 30 m
230 MHz to 1 GHz	37 quasi-peak, measured at 30 m

4. EMI/RFI SUSCEPTIBILITY TESTING

MIL-STD-461E contains test methods that can be applied to address EMI/RFI susceptibility for a selection of environments. IEC 61000-4, "Electromagnetic Compatibility (EMC) – Part 4: Testing and Measurement Techniques," also specifies test methods that can be applied to characterize equipment susceptibility to conducted and radiated EMI/RFI. The specific test methods acceptable to the NRC staff in regard to susceptibility testing for safety-related I&C systems in nuclear power plants are presented in Tables 6 and 7. Table 6 lists the EMI/RFI test methods in MIL-STD-461E while Table 7 lists the corresponding methods in IEC 61000-4. It is intended that either set of test methods be applied in its entirety, without selective application of individual methods (i.e., no mixing and matching of test methods) for susceptibility testing. These methods cover susceptibility to conducted and radiated interference resulting from exposure to electric and magnetic fields and noise coupling through power and signal leads.

Table 6 MIL-STD-461E EMI/RFI Susceptibility Test Methods

Method	Description
CS101	Conducted susceptibility, low frequency, 30 Hz to 150 kHz
CS114	Conducted susceptibility, high frequency, 10 kHz to 30 MHz
CS115	Conducted susceptibility, bulk cable injection, impulse excitation

CS116	Conducted susceptibility, damped sinusoidal transients, 10 kHz to 100 MHz
RS101	Radiated susceptibility, magnetic field, 30 Hz to 100 kHz
RS103	Radiated susceptibility, electric field, 30 MHz to 1 GHz

C = conducted, R = radiated, and S = susceptibility.

Table 7 IEC 61000-4 EMI/RFI Susceptibility Test Methods

Method	Description
61000-4-4	Conducted susceptibility, electrically fast transients/bursts
61000-4-5	Conducted susceptibility, surges
61000-4-6	Conducted susceptibility, disturbances induced by radio-frequency fields
61000-4-13	Conducted susceptibility, low frequency, 16 Hz to 2.4 kHz
61000-4-16	Conducted susceptibility, low frequency, 15 Hz to 150 kHz
61000-4-8	Radiated susceptibility, magnetic field, 50 Hz and 60 Hz
61000-4-9	Radiated susceptibility, magnetic field, 50/60 Hz to 50 kHz
61000-4-10	Radiated susceptibility, magnetic field, 100 kHz and 1 MHz
61000-4-3	Radiated susceptibility, electric field, 26 MHz to 1 GHz

The MIL-STD-461E test methods listed in Table 6 have associated operating envelopes that serve to establish test levels. General operating envelopes that are acceptable to the NRC staff are given below in the discussion of the MIL-STD 461E test methods. Likewise, operating envelopes for the IEC 61000 test methods have been identified that are comparable to the corresponding MIL-STD counterparts and are given below in the IEC discussion. These operating envelopes are acceptable for locations where safety-related I&C systems either are or are likely to be installed and include control rooms, remote shutdown panels, cable spreading rooms, equipment rooms, auxiliary instrument rooms, relay rooms, and other areas (e.g., the turbine deck) where safety-related I&C system installations are planned. The operating envelopes are acceptable for analog, digital, and hybrid system installations.

The detailed technical basis for the electromagnetic operating envelopes is presented in NUREG/CR-6431, NUREG/CR-5609, and NUREG/CR-6782. The technical basis for the operating envelopes begins with the MIL-STD envelopes corresponding to the electromagnetic environment for military ground facilities, which were judged to be comparable to that of nuclear power plants based on general layout and equipment type considerations. Plant emissions data were used to confirm the adequacy of the operating envelopes. From the MIL-STD starting point, susceptibility envelopes were adjusted to account for the plant emissions data reported in NUREG/CR-6436, “Survey of Ambient Electromagnetic and Radio-Frequency Interference Levels in Nuclear Power Plants” (November 1996) and EPRI TR-102323. When changes to the operating envelopes from the MIL-STD origin were motivated by technical considerations, consistency among the envelopes for comparable test criteria was promoted. As a result of these considerations, the operating envelopes presented in this regulatory guide are equivalent or less restrictive than the MIL-STD envelopes that served as their initial basis.

The MIL-STD-461E and IEC test methods that demonstrate EMI/RFI susceptibility compliance are discussed below. These methods are acceptable to the NRC staff for accomplishing EMI/RFI susceptibility testing for safety-related I&C systems intended for installation in nuclear power plants. Where applicable, conditions permitting exemption of specific test methods are described.

4.1 EMI/RFI Conducted Susceptibility Testing—Power Leads

The MIL-STD-461E test methods that are acceptable to the NRC staff to address conducted EMI/RFI susceptibility along power leads are listed in Table 8. The comparable IEC 61000-4 test methods that are acceptable to characterize equipment susceptibility to conducted EMI/RFI along power leads are listed in Table 9. These test methods cover susceptibility to conducted interference resulting from noise coupling through the power leads of safety-related I&C systems in nuclear power plants. Discussions of the test methods and operating envelopes follows below.

Table 8 MIL-STD-461E EMI/RFI Conducted Susceptibility Test Methods—Power Leads

Method	Description
CS101	Conducted susceptibility, low-frequency, 30 Hz to 150 kHz
CS114	Conducted susceptibility, high-frequency, 10 kHz to 30 MHz

C = conducted and S = susceptibility.

Table 9 IEC 61000-4 EMI/RFI Conducted Susceptibility Test Methods—Power Leads

Method	Description
61000-4-6	Conducted susceptibility, disturbances induced by radio-frequency fields
61000-4-13	Conducted susceptibility, low-frequency, 16 Hz to 2.4 kHz
61000-4-16	Conducted susceptibility, low-frequency, 15 Hz to 150 kHz

4.1.1 CS101—Conducted Susceptibility, Low Frequency

The CS101 test ensures that equipment and subsystems are not susceptible to EMI/RFI present on power leads in the frequency range 30 Hz to 150 kHz. The test is applicable to ac and dc input power leads, not including grounds and neutrals. If the equipment under test is dc operated, this test is applicable over the frequency range 30 Hz to 150 kHz. If the equipment under test is ac operated, this test is applicable starting from the second harmonic of the power line frequency and extending to 150 kHz.

The equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to a test signal with the rms voltage levels specified in Figure 4.1. Alternative envelopes are given for equipment with nominal source voltages at or below 28 V and those operating above 28 V. Acceptable performance should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

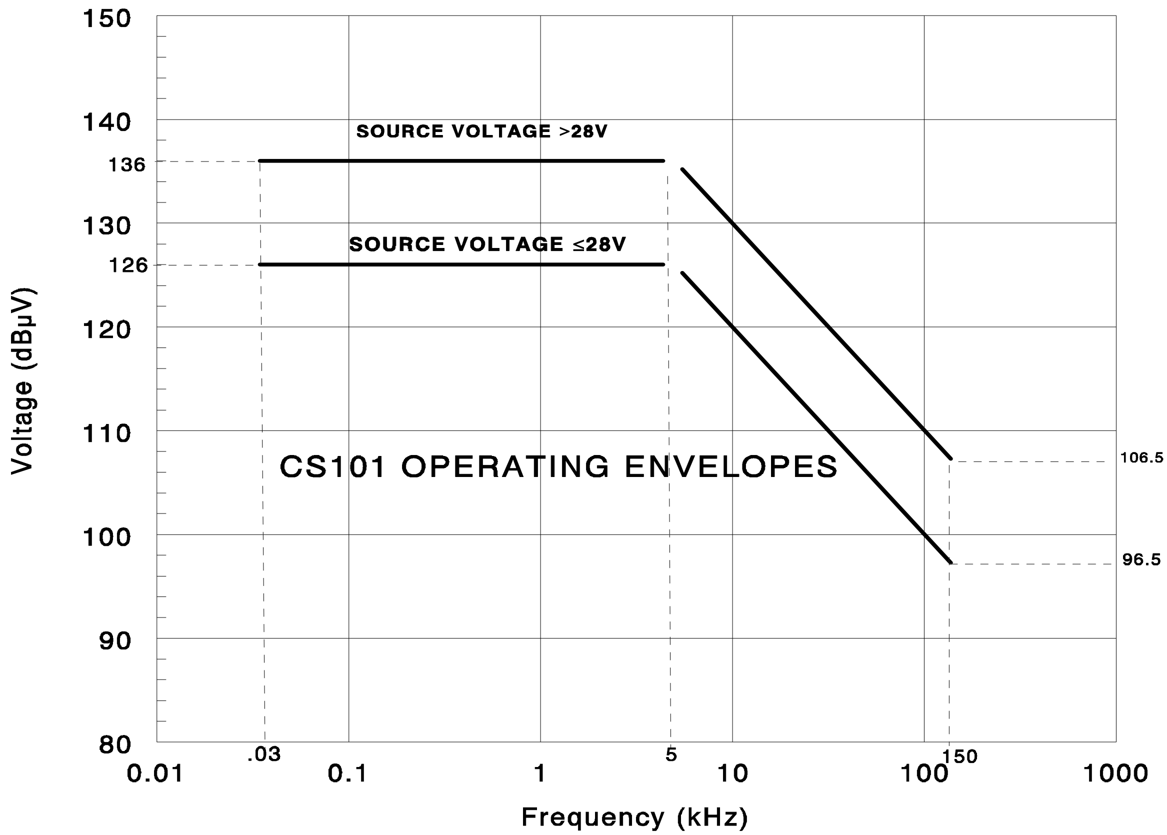

Figure 4.1 Low-Frequency Conducted Susceptibility Operating Envelopes

4.1.2 CS114—Conducted Susceptibility, High Frequency

The CS114 test simulates currents that will be developed on leads as a result of EMI/RFI generated by antenna transmissions. The test covers the frequency range 10 kHz to 30 MHz and is applicable to all interconnecting leads, including the power leads of the equipment under test. Although the CS114 test can be applied to assess signal line susceptibility, the test levels given in this section apply only to power and control lines.

The equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to a test signal with the rms levels shown in Figure 4.2. Acceptable performance should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

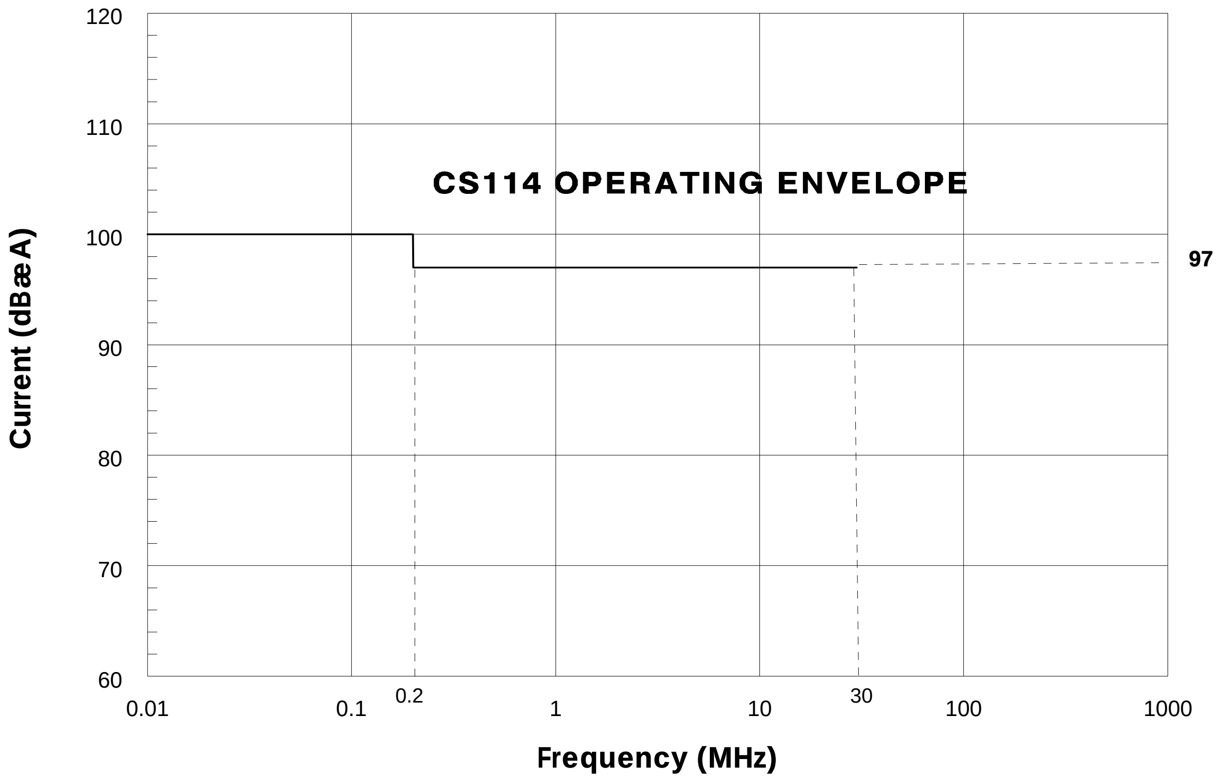

Figure 4.2 High-Frequency Conducted Susceptibility Operating Envelopes for Power Leads

4.1.3 IEC Conducted Susceptibility Tests—Power Leads

The IEC counterparts to the CS101 test are IEC 61000-4-13 and IEC 61000-4-16. The IEC counterparts to the CS114 test are IEC 61000-4-16 and IEC 61000-4-6. The test classes for IEC 61000-4-13 are shown in Table 10 and the test levels for IEC 61000-4-16 are shown in Table 11. The test classes for IEC 61000-4-6 are shown in Table 12. The Class 2 devices in IEC 61000-4-13 are similar to the industrial-grade devices utilized in nuclear power plants and the Class 2 operating envelope is shown in Table 13. For the IEC 61000-4-16 test, the Level 3 (typical industrial) environment is representative of the nuclear power plant environment. The Level 3 operating envelopes for the IEC 61000-4-16 test are shown in Table 14. The Class 3 test level for IEC 61000-4-6 is 140 dBμV and is most similar to the CS114 operating envelope recommended for a typical industrial environment. These are the levels acceptable to NRC staff.

Table 10. IEC 61000-4-13 Test Classes

Class	Description
1	Devices expected to operate with protected supplies, such as uninterruptible power supplies, filters, or surge capacitors
2	Devices connected to public networks or operating in a light industrial environment
3	Devices operating in a heavy industrial environment, i.e., an environment where a major part of the load is fed through converters, where welding machines are present, where large motors may be turned on and off frequently, or where loads vary rapidly

Table 11. IEC 61000-4-16 Test Levels

Level	Description
1	**Well-protected environment.** The installation is characterized by the following attributes: (a) separation of the internal power supply network from the mains network, e.g., by dedicated isolation transformers; and (b) electronic equipment earthed to a dedicated earthing collector, connected to the earthing system (ground network) of the installation. A computer room may be representative of this environment.
2	**Protected environment.** The installation is characterized by the following attributes: (a) direct connection to the low-voltage mains network; and (b) electronic equipment earthed to the earthing system of the installation. Control rooms or terminal rooms located in dedicated buildings of industrial plants and power plants may be representative of this environment.
3	**Typical industrial environment.** The installation is characterized by the following attributes: (a) direct connection to the low-voltage or medium-voltage mains network; (b) electronic equipment earthed to the earthing system of the installation (ground network); and (c) use of power converters injecting stray currents into the ground network. Industrial installations and power plants may be representative of this environment.
4	**Severe industrial environment.** The installation is characterized by the following attributes: (a) direct connection to the low-voltage or medium-voltage mains network; (b) electronic equipment connected to the earthing system of the installation (ground network) common to high-voltage equipment and systems; and (c) use of power converters injecting stray currents into the ground network. Open-air high-voltage substations, and the related power plant, may be representative of this environment.
x	Special situations to be analyzed.

Table 12. IEC 61000-4-6 Test Classes

Class	Description
1	**Low-level electromagnetic radiation environment.** Levels typical of radio/television stations located at a distance of more than 1 km, and of low-power transceivers.
2	**Moderate electromagnetic radiation environment.** Low-power portable transceivers (typically less than 1-W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
3	**Severe electromagnetic radiation environment.** Portable transceivers (2-W and more) are in use relatively close to the equipment but at a distance of not less than 1 m. High-powered broadcast transmitters are in close proximity to the equipment, and industrial, scientific, medical equipment may be located close by. A typical industrial environment.
X	X is an open level that may be negotiated and specified in the dedicated equipment specifications or equipment standards.

Table 13. IEC 61000-4-13 Operating Envelope for 115-V System

Harmonic no. (n)	Class 2 (% of supply voltage)	Class 2 (voltage level)
2	3	3.5
3	8	9.2
4	1.5	1.7
5	8	9.2
6	n.a.	—
7	6.5	7.5
8	n.a.	—
9	2.5	2.9
10	n.a.	—
11	5	5.8
12	n.a.	—
13	4.5	5.2
15	n.a.	—
17	3	3.5
19	2	2.3
21	n.a.	—
23	2	2.3
25	2	2.3
27	n.a.	—
29	1.5	1.7
31	1.5	1.7
33	n.a.	—
35	1.5	1.7
37	1.5	1.7
39	n.a.	—

Table 14. Operating Envelopes for IEC 61000-4-16 Conducted Susceptibility Tests

Disturbance	Selected level	Test level
dc and power line frequency, continuous disturbance	Level 3—typical industrial environment	10 Vrms
dc and power line frequency, short-duration disturbance	Level 3—typical industrial environment	100 Vrms
Conducted disturbance, 15 Hz to 150 kHz	Level 3—typical industrial environment	3–0.3 Vrms (15–150 Hz) 1 Vrms (150–1.5 kHz) 1–10 Vrms (1.5–15 kHz) 10 Vrms (15–150 kHz)

4.2 EMI/RFI Conducted Susceptibility Testing—Signal Leads

MIL-STD-461E contains test methods that can be applied to address conducted EMI/RFI susceptibility for interconnecting signal leads. In addition, IEC 61000-4 specifies test methods that can be applied to characterize equipment susceptibility to conducted EMI/RFI along interconnecting signal leads. The specific test methods acceptable to the NRC staff in regard to conducted susceptibility testing for signal leads of safety-related I&C systems in nuclear power plants are presented in Tables 15 and 16. Table 15 lists the EMI/RFI test methods for signal leads in MIL-STD-461E, while Table 16 lists the corresponding methods in specific sections of IEC 61000-4. These test methods cover susceptibility to conducted interference resulting from noise coupling through interconnecting signal leads.

Table 15 MIL-STD-461E Conducted Susceptibility Test Methods—Signal Leads

Method	Description
CS114	Conducted susceptibility, high-frequency, 10 kHz to 30 MHz
CS115	Conducted susceptibility, bulk cable injection, impulse excitation
CS116	Conducted susceptibility, damped sinusoidal transients, 10 kHz to 100 MHz

C = conducted and S = susceptibility.

Table 16 IEC 61000-4 Conducted Susceptibility Test Methods—Signal Leads

Method	Description
61000-4-4	Electrical fast transient/burst immunity test
61000-4-5	Surge immunity test
61000-4-6	Immunity to conducted disturbances, induced by radio-frequency fields
61000-4-12	Oscillatory waves immunity test
61000-4-16	Test for immunity to conducted, common mode disturbances in the frequency range 0 Hz to 150 kHz

The MIL-STD-461E test methods listed in Table 15 have associated operating envelopes that serve to establish test levels for signal leads. General operating envelopes that are acceptable to the NRC staff are shown in Table 17. Likewise, signal lead operating envelopes for the IEC 61000-4 test criteria listed in Table 16 have been identified in Table 18 and are comparable to their corresponding MIL-STD counterparts.

Table 17 MIL-STD-461E Conducted Susceptibility Operating Envelopes—Signal Leads

Method	Description
CS114	91 dBmA – 6 dB less than power leads at Army ground installations
CS115	2 A – Reduction of 5A level recommended for Army ground installations
CS116	5 A – Reduction of 10A level recommended for Army ground installations

Table 18 IEC 61000-4 Conducted Susceptibility Operating Envelopes—Signal Leads

Method	Description
61000-4-4	Level 3: 1 kV test voltage
61000-4-5	Class 2: 1 kV open-circuit test voltage
61000-4-6	Class 3: 134 dBµV test voltage
61000-4-12	Ring wave: Level 3 - 1kV test voltage Damped oscillatory wave: Level 2 - 0.5 kV test voltage
61000-4-16	Level 3: ½ of the values in Table 14

4.3 EMI/RFI Radiated Susceptibility Testing

The MIL-STD-461E test methods that are acceptable to the NRC staff for addressing the radiated EMI/RFI susceptibility of safety-related I&C systems in nuclear power plants are listed in Table 19. The comparable IEC 61000-4 test methods deemed acceptable to characterize equipment susceptibility to radiated EMI/RFI are listed in Table 20. These test methods cover susceptibility to radiated interference resulting from electromagnetic emissions in nuclear power plants. Discussions of the test methods and operating envelopes follows below.

Table 19 MIL-STD-461E EMI/RFI Radiated Susceptibility Test Methods

Method	Description
RS101	Radiated susceptibility, magnetic field, 30 Hz to 100 kHz
RS103	Radiated susceptibility, electric field, 30 MHz to 1 GHz

Table 20 IEC 61000-4 EMI/RFI Radiated Susceptibility Test Methods

Method	Description
61000-4-8	Radiated susceptibility, magnetic field, 50 Hz and 60 Hz
61000-4-9	Radiated susceptibility, magnetic field, 50/60 Hz to 50 kHz
61000-4-10	Radiated susceptibility, magnetic field, 100 kHz and 1 MHz
61000-4-3	Radiated susceptibility, electric field, 26 MHz to 1 GHz

4.3.1 RS101—Radiated Susceptibility, Magnetic Fields

The RS101 test ensures that equipment and subsystems are not susceptible to radiated magnetic fields in the frequency range 30 Hz to 100 kHz. Equipment that is not intended to be installed in areas with strong sources of magnetic fields (e.g., CRTs, motors, cable bundles carrying high currents) and that follows the limiting practices endorsed in this regulatory guide could be exempt from this test. The test is applicable to equipment and subsystem enclosures and all interconnecting leads. The test is not applicable for electromagnetic coupling via antennas.

The equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to the rms magnetic field levels shown in Figure 4.3. Acceptable performance should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

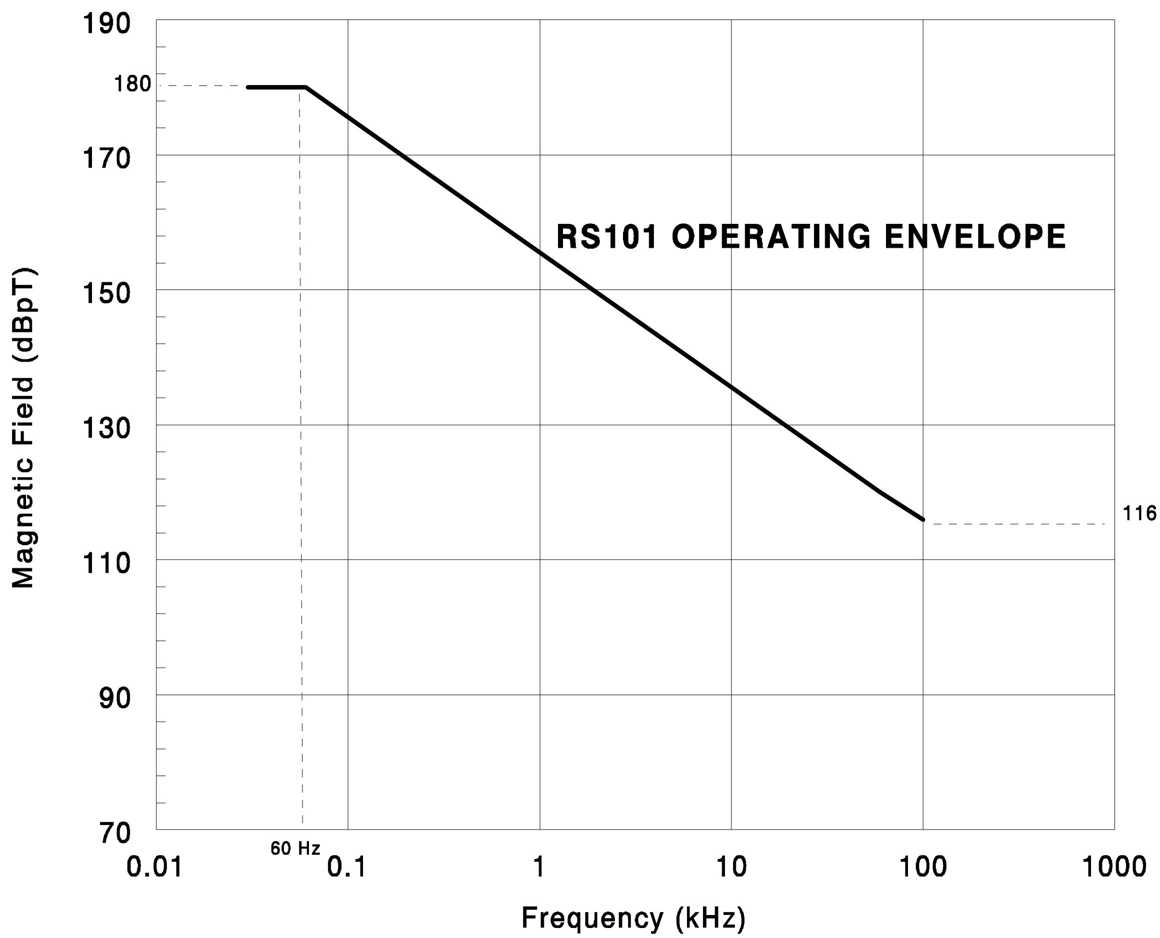

Figure 4.3 Low-Frequency Radiated Susceptibility Envelopes

4.3.2 RS103—Radiated Susceptibility, Electric Fields

The RS103 test ensures that equipment and subsystems are not susceptible to radiated electric fields in the frequency range 30 MHz to 1 GHz. The test is applicable to equipment and subsystem enclosures and all interconnecting leads. The test is not applicable at the tuned frequency of antenna-connected receivers unless otherwise specified.

The equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to the radiated electric fields. The impressed electric field level should be 10 V/m (rms), measured in accordance with the techniques specified in the RS103 test method. The test method should be performed for both horizontally and vertically polarized fields. According to MIL-STD-461E, circularly polarized fields are not acceptable because radiated electric fields are typically linearly polarized. Acceptable performance should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

4.3.3 IEC Radiated Susceptibility Tests

The IEC counterparts for the RS101 test are IEC 61000-4-8, IEC 61000-4-9, and IEC 61000-4-10. Tables 21 and 22 describe the IEC test classes and Class 4 (typical industrial environment) for all of the tests is representative of the nuclear power plant environment. Operating envelopes for each of the tests in the Class 4 environment are shown in Table 23. The IEC counterpart for the RS103 test is IEC 61000-4-3 and its test classes are shown in Table 24. The Level 3 in IEC 61000-4-3 is most similar to the nuclear power plant environment and requires a test level of 10 V/m. This level is equal to the RS103 operating envelope of 10 V/m. These levels are acceptable to NRC staff for the IEC radiated susceptibility tests.

Table 21 IEC 61000-4-8 Test Classes

Class	Description
1	Environmental level where sensitive devices using electron beams can be used. Monitors, electron microscopes, etc., are representative of these devices.
2	**Well-protected environment.** The environment is characterized by the following attributes: (1) absence of electrical equipment such as power transformers that may give rise to leakage fluxes and (2) areas not subjected to the influence of high-voltage bus bars. Household, office, hospital protected areas far away from earth protection conductors, areas of industrial installations, and high-voltage substations may be representative of this environment.
3	**Protected environment.** The environment is characterized by the following attributes: (1) electrical equipment and cables that may give rise to leakage fluxes or magnetic fields; (2) proximity of earth conductors of protection systems; and (3) medium-voltage circuits and high-voltage bus bars far away (a few hundred meters) from the equipment concerned. Commercial areas, control buildings, fields of not heavy industrial plants, or computer rooms of high-voltage substations may be representative of this environment.
4	**Typical industrial environment.** The environment is characterized by the following attributes: (1) short branch power leads as bus bars; (2) high-power electrical equipment that may give rise to leakage fluxes; (3) ground conductors of protection systems; and (4) medium-voltage circuits and high-voltage bus bars at relative distances (a few tens of meters) from the equipment concerned. Fields of heavy industrial and power plants and the control rooms of high-voltage substations may be representative of this environment.
5	**Severe industrial environment.** The environment is characterized by the following attributes: (1) conductors, bus bars, or power leads carrying tens of kA; (2) ground conductors of the protection system; (3) proximity of medium-voltage and high-voltage bus bars; and (4) proximity of high-power electrical equipment. Switchyard areas of heavy industrial plants and power plants may be representative of this environment.
X	Special environment.

Table 22 IEC 61000-4-9 and -4-10 Test Classes

Class	Description
1	Test not applicable to this environment where sensitive devices using electron beams can be used (monitors, electron microscopes, etc. are representative of these devices).
2	**Well-protected environment.** Test not applicable to this environmental class because the areas concerned are not subjected to the influence of switching of high-voltage bus bars by isolators. Shielded areas of industrial installations and high-voltage substations may be representative of this environment.
3	**Protected environment.** The environment is characterized by medium-voltage circuits and high-voltage bus bars switched by isolators far away (a few hundred meters) from the equipment concerned. Computer rooms of high-voltage substations may be representative of this environment.
4	**Typical industrial environment.** The environment is characterized by medium-voltage circuits and high-voltage bus bars switched by isolators at relative distance (a few tens of meters) from the equipment concerned. Fields of heavy industrial and power plants and the control rooms of high-voltage substations may be representative of this environment.
5	**Severe industrial environment.** The environment is characterized by the following attributes: (1) proximity of medium-voltage and high-voltage bus bars switched by isolators and (2) proximity of high-power electrical equipment. Switchyard areas of heavy industrial plants and power plants may be representative of this environment.
X	Special environment.

Table 23 IEC 61000-4-8, -4-9, and -4-10 Operating Envelopes

Method	Selected Class	Test Level
IEC 61000-4-8	Continuous pulses: Class 4 – typical industrial environment	30 A/m (152 dBpT)
	Short duration pulses: Class 4 – typical industrial environment	300 A/m (172 dBpT)
IEC 61000-4-9	Class 4 – typical industrial environment	300 A/m (172 dBpT)
IEC 61000-4-10	Class 4 – typical industrial environment	30 A/m (152 dBpT)

Table 24 IEC 61000-4-3 test classes

Class	Description
1	**Low-level electromagnetic radiation environment.** Levels typical of local radio/television stations located at more than 1 km, and transmitters/receivers of low power.
2	**Moderate electromagnetic radiation environment.** Low-power portable transceivers (typically less than 1-W rating) are in use, but with restrictions on use in close proximity to the equipment. A typical commercial environment.
3	**Severe electromagnetic radiation environment.** Portable transceivers (2-W rating or more) are in use relatively close to the equipment but not within less than 1

m. High-power broadcast transmitters are in close proximity to the equipment, and industrial-scientific-medical equipment may be located close by. A typical industrial environment.

X Special environment.

5. SURGE WITHSTAND CAPABILITY

The SWC practices described in IEEE Std C62.41-1991 (reaffirmed in 1995), “IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits,” and IEEE Std C62.45-1992, “IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits,” are acceptable to the NRC staff regarding the effect of power surges on safety-related I&C systems in nuclear power plants. IEEE Std C62.41-1991 defines a set of surge test waveforms that has manageable dimensions and represents a baseline surge environment. IEEE Std C62.45-1992 describes the associated test methods and equipment to be employed when performing the surge tests. Typical environmental conditions for power surges in a nuclear power plant can be represented by the waveforms given in Table 25.

Table 25 IEEE C62.41-1991 Power Surge Waveforms

Parameter	Ring Wave	Combination Wave		EFT
Waveform	Open-circuit voltage	Open-circuit voltage	Short-circuit current	Pulses in 15-ms bursts
Rise time	0.5 µs	1.2 µs	8 µs	5 ns
Duration	100 kHz ringing	50 µs	20 µs	50 ns

The IEC 61000-4 tests comparable to the IEEE C62.41-1991 tests are listed in Table 26. The test waveforms are the same and the test procedures are very similar. Hence, a direct interchange of the test methods is acceptable to the NRC staff. Test levels for the IEC 61000-4 tests are specified according to the intended environment.

Table 26 Comparable SWC Test Methods

IEEE C62.41-1991	IEC Method
Ring Wave	61000-4-12
Combination Wave	61000-4-5
EFT	61000-4-4

General withstand levels that are acceptable to the NRC staff are given with each surge waveform. IEEE Std C62.41-1991 describes location categories and exposure levels that define applicable amplitudes for the surge waveforms that should provide an appropriate degree of SWC. Location categories depend on the proximity of equipment to the service entrance and the associated line impedance. Exposure levels relate to the rate of surge occurrence versus the voltage level (e.g., surge crest) to which equipment is exposed. The withstand levels presented in this regulatory position are based on *Category B* locations and *Low Exposure* levels. *Category B* covers feeders and short branch circuits less than 10 meters from the service entrance. *Low Exposure* levels encompass systems in areas known for little load or capacitor switching and low-power surge activity. The basis for the IEEE C62.41-1991 withstand levels provides reasonable assurance that the general power surge environment in nuclear power plants is adequately characterized. The IEC 61000-4 withstand levels for Class 3 environments (typical industrial) are the same as the accepted IEEE C62.41-1991 levels. The withstand levels are acceptable for locations where safety-related I&C systems either are or are likely to be installed and include control rooms, remote shutdown panels, cable spreading rooms, equipment rooms, auxiliary instrument rooms, relay rooms, and other areas (e.g., the turbine deck) where safety-related I&C system installations are planned.

5.1 Ring Wave (IEC 61000-4-12)

The Ring Wave simulates oscillatory surges of relatively high frequency on the ac power leads of equipment and subsystems and is represented by an open-circuit voltage waveform. The waveform, 100-kHz sinusoid, has an initial rise time of 0.5 µs and continually decaying amplitude. A plot of the waveform is shown in Figure 5.1. The rise time is defined as the time difference between the 10% and 90% amplitude points on the leading edge of the waveform. The amplitude of the waveform decays with each peak being 60% of the amplitude of the preceding peak of the opposite polarity.

V_p, the peak voltage value of the Ring Wave, should be 2 kV. During the performance of the test, the equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to the Ring Wave. Acceptable performance of the equipment under test should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

5.2 Combination Wave (IEC 61000-4-5)

The Combination Wave involves two exponential waveforms, an open-circuit voltage and a short-circuit current. It is intended to represent direct lightning discharges, fuse operation, or capacitor switching on the ac power leads of equipment and subsystems. The open-circuit voltage waveform has a 1.2-µs rise time and an exponential decay with a duration (to 50% of initial peak level) of 50 µs. The short-circuit current waveform has an 8-µs rise time and a duration of 20 µs. Plots of the waveforms are shown in Figures 5.2 and 5.3.

The rise time is defined as the time difference between the 10% and 90% amplitude points on the leading edge of the waveform. The duration is defined as the time between virtual origin and the time at the 50% amplitude point on the tail of the waveform. Virtual origin is the point where a straight line between the 30% and 90% points on the leading edge of the waveform intersects the V=0 line for the open-circuit voltage and the i=0 line for the short-circuit current.

V_p, the peak value of the open-circuit voltage of the Combination Wave, should be 2 kV. I_p, the peak value of the short-circuit current, should be 1.0 kA. During the performance of the test, the equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to the Combination Wave. Acceptable performance of the equipment under test should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

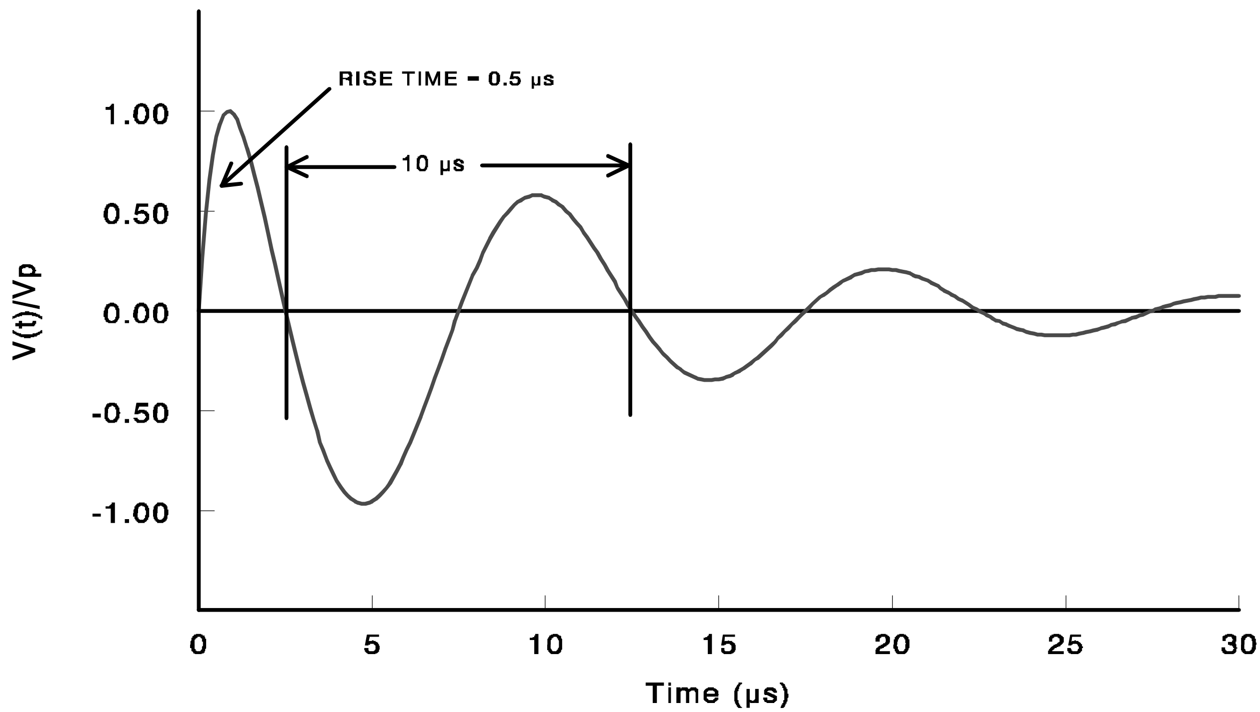

Figure 5.1 100-kHz Ring Wave

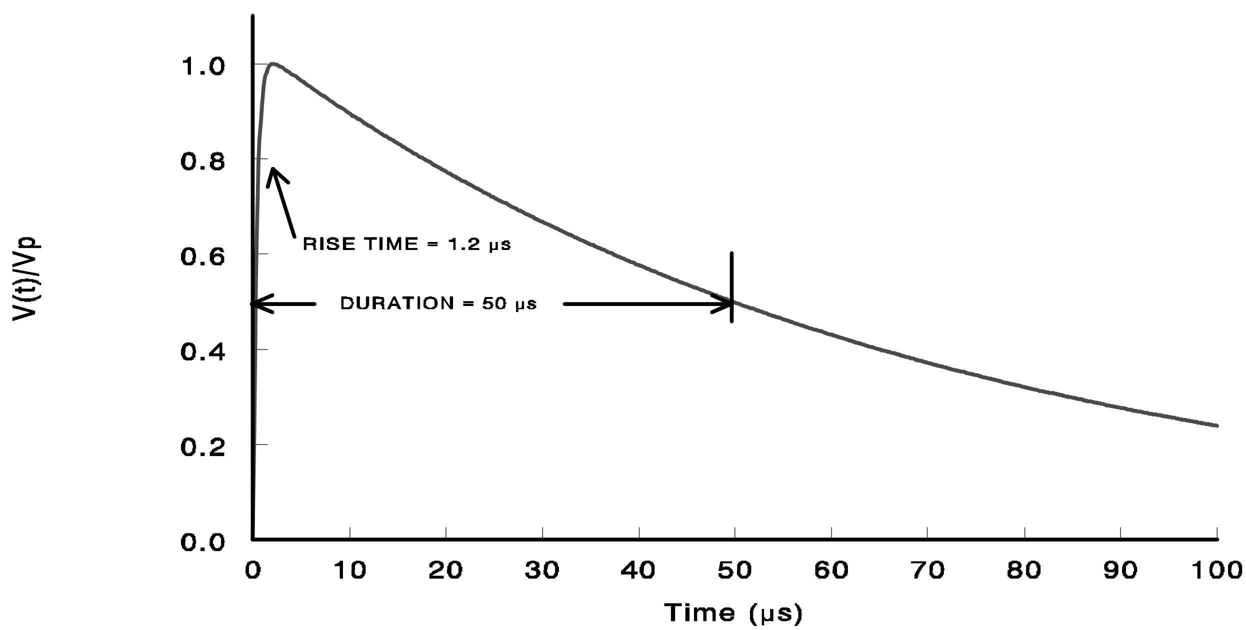

Figure 5.2 Combination Wave, Open-Circuit Voltage

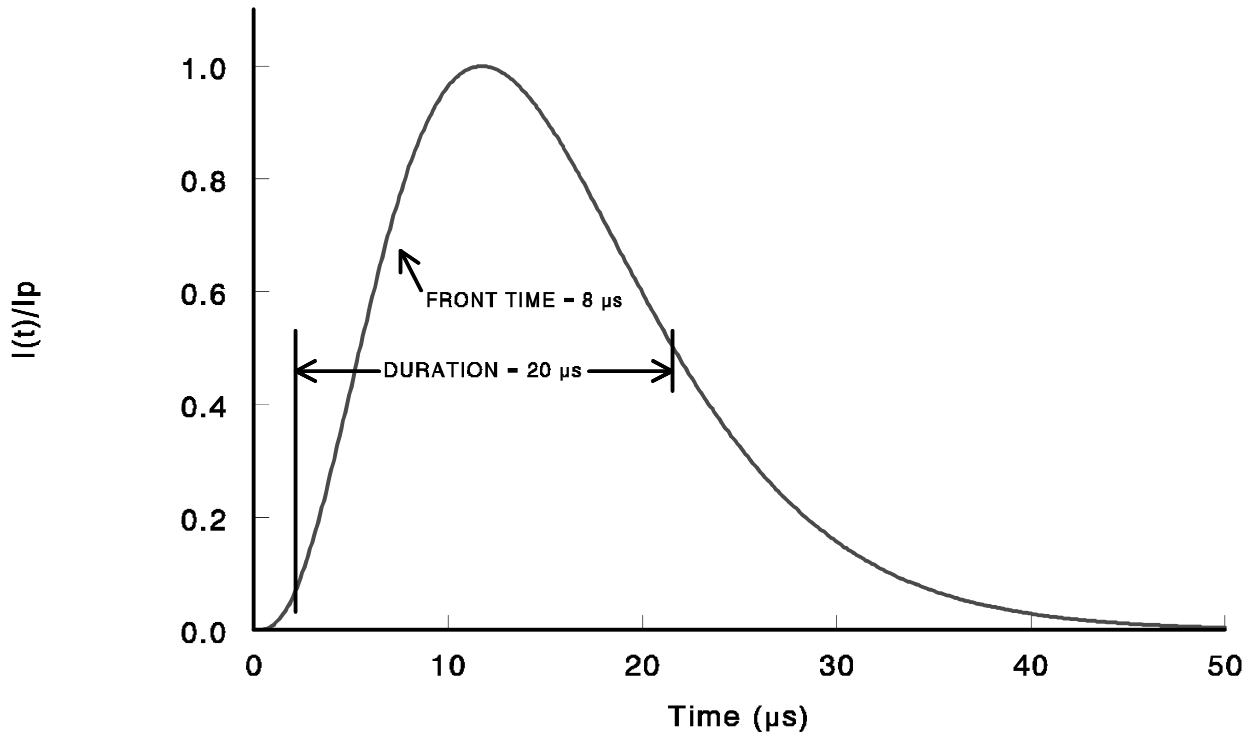

Figure 5.3 Combination Wave, Short-Circuit Current

5.3 Electrically Fast Transients (IEC 61000-4-4)

The EFT waveform consists of repetitive bursts, with each burst containing individual unidirectional pulses, and is intended to represent local load switching on the ac power leads of equipment and subsystems. The individual EFT pulses have a 5-ns rise time and a duration (width at half-maximum) of 50 ns. Plots of the EFT pulse waveform and the pattern of the EFT bursts are shown in Figures 5.4 and 5.5. The number of pulses in a burst is determined by the pulse frequency. For peaks less than or equal to 2 kV, the frequency will be 5 kHz±1 kHz.

The rise time is defined as the time difference between the 10% and 90% amplitude points on the leading edge of the waveform. The duration is defined as the time between the 50% amplitude points on the leading and trailing edges of each individual pulse. Individual pulses occur in bursts of 15 ms duration.

The peak value of the individual EFT pulses should be 2 kV. During the performance of the test, the equipment under test should not exhibit any malfunction or degradation of performance beyond specified operational tolerances when subjected to the EFT pulses.

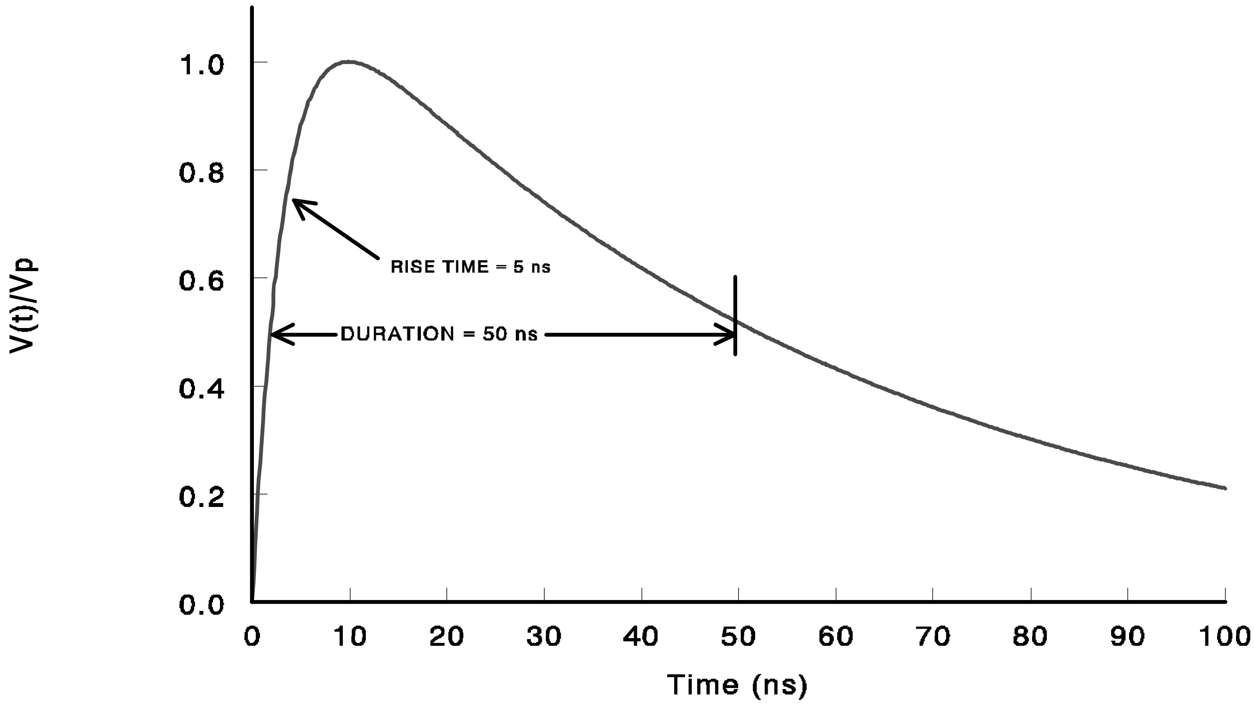

Figure 5.4 Waveform of the EFT Pulse

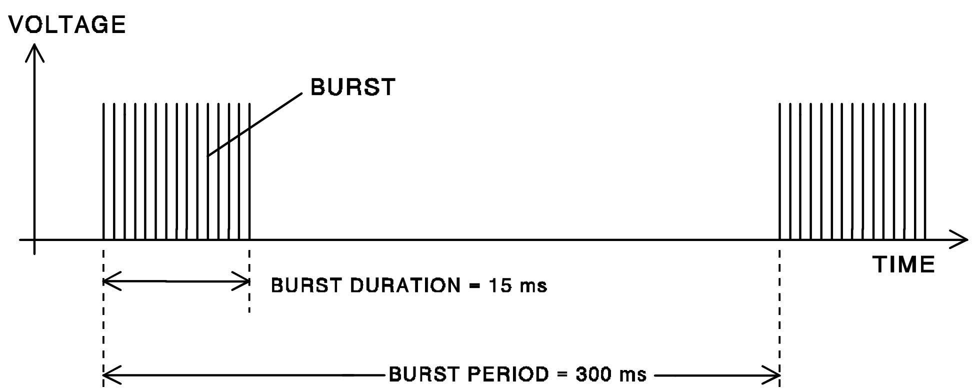

Figure 5.5 Pattern of EFT Bursts

Acceptable performance of the equipment under test should be defined in the test plan by the end user or testing organization according to the applicable equipment, subsystem, or system specifications.

6. RADIATED EMI/RFI SUSCEPTIBILITY TESTING ABOVE 1 GHz

MIL-STD-461E contains test methods and methods that can be applied to address radiated EMI/RFI susceptibility above 1 GHz for a selection of environments. IEC 61000-4 does not. The specific test method acceptable to the NRC staff in regard to radiated susceptibility testing above 1 GHz for safety-related I&C systems in nuclear power plants is contained in the

MIL-STD-461E presentation of RS103. This method covers susceptibility above 1 GHz to radiated interference resulting from exposure to electric fields.

Radiated susceptibility testing is needed in the frequency range 1 GHz to 10 GHz. This would cover the unlicensed frequency bands where much of the communications activity is taking place (2.45 GHz and 5.7 GHz). The new developments are not expected to be strong emitters because of FCC restrictions, so the test level will remain the same as at lower frequencies, 10 V/m.

7. DOCUMENTATION

Electromagnetic compatibility documentation should provide evidence that safety-related I&C equipment meets its specification requirements and is compatible with the projected electromagnetic environment, that the user adheres to acceptable installation practices, and that administrative controls have been established covering the allowable proximity of portable EMI/RFI sources. Data used to demonstrate the compatibility of the equipment with its projected environment should be pertinent to the application and be organized in a readily understandable and traceable manner that permits independent auditing of the conclusion presented.

The content of electromagnetic compatibility documentation should contain the information listed below, as well as any additional information specified in the standards cited by this regulatory guide. These items, as a minimum, could be included as part of a qualification or dedication file.

(1) Identification of the equipment
(2) Specifications on the equipment
(3) Identification of safety functions to be demonstrated by test data
(4) Test plan
(5) Test results, including
 5.1 Objective of the test
 5.2 Detailed description of test item
 5.3 Description of test setup, instrumentation, and calibration data
 5.4 Test procedure
 5.5 Summary of test data, accuracy, and anomalies
(6) The installation practices employed and administrative controls established to alleviate potential EMI/RFI and power surge exposure
(7) Summary and conclusions
(8) Approval signature and date.

D. IMPLEMENTATION

The purpose of this section is to provide information to applicants and licensees regarding the NRC staff's plans for using this draft regulatory guide. No backfitting is intended or approved in connection with the issuance of this guide.

This draft guide has been released to encourage public participation in its development. Except when an applicant or licensee proposes or has previously established an acceptable alternative method for complying with the specified portions of the NRC's regulations, the methods to be described in the active guide reflecting public comments will be used in the evaluation of licensee compliance. This guide will also be used to evaluate submittals from operating reactor licensees who propose system modifications that are voluntarily initiated by the licensee if there is a clear connection between the proposed modifications and this guidance.

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IEC 61000-4-5, “Electromagnetic Compatibility (EMC) - Part 4: Testing and Measurement Techniques, Section 5: Surge Immunity Test," International Electrotechnical Committee, 1995.[1]

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[1] International Electrotechnical Commission documents are available from the IEC at 3 rue de Varembe, PO Box 131, 1211 Geneva 20, Switzerland.

[2] EPRI publications may be purchased from the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523, telephone (510) 934-4212.

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[3] IEEE publications may be purchased from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855.

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[4] Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

[5] Military Standards are available from the Department of Defense, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

[6] Copies are available at current rates from the U.S. Government Printing Office, P.O. Box 37082, Washington, DC 20402-9328 (telephone (202)512-1800); or from the National Technical Information Service by writing NTIS at 5285 Port Royal Road, Springfield, VA 22161; (<http://www.ntis.gov/ordernow>; telephone (703)487-4650;. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike, Rockville, MD; the PDR’s mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or (800)397-4209; fax (301)415-3548; email is PDR@NRC.GOV.

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REGULATORY ANALYSIS

1. PROBLEM

Part 50 of Title 10 of the Code of Federal Regulations (10 CFR 50), "Domestic Licensing of Production and Utilization Facilities," delineates the NRC's design and qualification regulations for commercial nuclear power plants. Appendix A, "General Design Criteria for Nuclear Power Plants," to 10 CFR Part 50 "establishes minimum requirements for the principal design criteria for water-cooled nuclear power plants," and 10 CFR 50.55a(h) requires that reactor protection systems also satisfy the criteria of the Institute of Electrical and Electronics Engineers (IEEE) standard (Std) 603-1991, "Criteria for Safety Systems for Nuclear Power Generating Stations,"[1] or IEEE Std 279-1971, "Criteria for Protection Systems for Nuclear Power Generating Stations,"[1] contingent on the date of construction permit issuance. In particular, General Design Criterion (GDC) 4 in Appendix A to 10 CFR Part 50 requires that structures, systems, and components be designed "to accommodate the effects of and to be compatible with the environmental conditions associated with normal operation, maintenance, testing, and postulated accidents, including loss-of-coolant accidents." Furthermore, 10 CFR 50.49 and 50.55a(a)(1) address verification measures such as testing that can be used to confirm the adequacy of design.

While these regulations address environmental compatibility for electrical equipment that is important to safety, they do not explicitly identify approaches to establishing electromagnetic compatibility (EMC). As a result, Regulatory Guide 1.180, "Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and

[1] IEEE publications may be purchased from the IEEE Service Center, 445 Hoes Lane, Piscataway, NJ 08855.

Control Systems,"[2] was developed to identify practices acceptable to the NRC staff that can be employed to establish EMC for safety-related instrumentation and control (I&C) systems in nuclear power plants. In addition, Electric Power Research Institute (EPRI) topical report TR-102323, "Guidelines for Electromagnetic Interference Testing in Power Plants,"[3] was accepted in a Safety Evaluation Report (SER) by letter dated April 17, 1996,[4] with some exceptions and clarifications. The guidance offered in the regulatory guide and the SER constitute consistent approaches to addressing issues of EMC for safety-related digital I&C systems in nuclear power plants, with each serving as equally valid, acceptable methods. However, experience in the nuclear industry has indicated some concern that the available guidance incorporates some conservatism that could be reduced through development of an enhanced technical basis. In addition, certain EMC considerations (i.e., radiated emissions and susceptibility in the frequency band from 1 to 10 gigahertz and conducted susceptibility along signal lines) have been identified by the NRC staff and the EPRI EMI Working Group as open issues that should be addressed. Finally, a revised complete series of EMC standards by the International Electrotechnical Commission (IEC), which has been issued recently, warrants consideration for use by the U.S. nuclear power industry. The need to develop and maintain specific practices for the nuclear power industry to address the effects of EMI/RFI and power surges on safety-related I&C systems is stated in SECY-91-273, "Review of Vendors' Test Programs To Support the Design Certification of Passive Light Water Reactors."[4]

2. ALTERNATIVE APPROACHES

The existing guidance is based on military and industrial methods for ensuring the compatibility of I&C equipment with the electromagnetic conditions to which they are subjected in nuclear power plants. This guidance relies on consensus standards in the EMC community to ensure widespread familiarity and reasonable levels of agreement. Recently, the U.S. Department of Defense (DoD) issued a revision of the EMC testing standards, replacing military standard (MIL-STD) 461D and 462D with MIL-STD 461E.[5] In addition, the IEC has revised the complete series of standards (IEC 61000)[6] that offer a potential alternative to the military EMC standards. The approach taken was to evaluate the recent standards to establish conditions under which they can be applied as equivalent suites of test methods that are relevant to the nuclear power plant electromagnetic environment. The revised standards contain test methods that are applicable for assessing conducted susceptibility along signal lines so that issue was addressed. The issue of high-frequency radiated EMC was also addressed with the identification of test methods that are applicable for assessing radiated emissions and susceptibility above 1

[2] Requests for single copies of draft or active regulatory guides (which may be reproduced) or for placement on an automatic distribution list for single copies of future draft guides in specific divisions should be made in writing to the U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Reproduction and Distribution Services Section, or by fax to (301)415-2289; email <DISTRIBUTION@NRC.GOV>. Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

[3] EPRI publications may be purchased from the EPRI Distribution Center, 207 Coggins Drive, P.O. Box 23205, Pleasant Hill, CA 94523, telephone (510) 934-4212.

[4] Copies are available for inspection or copying for a fee from the NRC Public Document Room at 11555 Rockville Pike (first floor), Rockville, MD; the PDR's mailing address is USNRC PDR, Washington, DC 20555; telephone (301)415-4737 or 1-(800)397-4209; fax (301)415-3548; e-mail <PDR@NRC.GOV>.

[5] Military Standards are available from the Department of Defense, Standardization Documents Order Desk, Building 4D, 700 Robbins Avenue, Philadelphia, PA 19111-5094.

[6] International Electrotechnical Commission documents are available from the IEC at 3 rue de Varembe, PO Box 131, 1211 Geneva 20, Switzerland.

GHz. The alternative approach considered was to take no action and retain the existing guidance for EMC at nuclear power plants. Thus, the two approaches considered are:

1. Take no action,
2. Update the existing guidance through development of an enhanced technical basis.

The first alternative, taking no action, requires no additional cost for the NRC staff or applicants over current conditions since no change to the process would occur. The existing guidance in the regulatory guide and SER provides clear, systematic approaches that are acceptable for ensuring electromagnetic compatibility. However, the guidance endorses dated versions of EMC standards that have been superseded by recent revisions. While there is currently substantial experience among testing laboratories with the test methods from the previous versions of the standards, it is anticipated that such capabilities will diminish in a few years as most industries adopt the methods of the current versions. Thus, taking no action places the responsibility for justifying the use of the most recent domestic and international standards on the applicants at some future time. Continuing with the existing guidance unchanged does not address the issues of high-frequency radiated EMC and conducted susceptibility along signal lines. As a result, the process of establishing EMC for safety-related I&C modifications of new installations may involve significant effort on the part of the applicant to anticipate the type and level of evidence that is acceptable to the NRC staff to demonstrate compatibility of equipment in response to these phenomena. In addition, the NRC staff review may involve considerable effort in evaluating submitted approaches for addressing the open issues and reviewing the use of the revised standards on a case-by-case basis.

The second alternative, updating the existing guidance by developing an enhanced technical basis, was considered. Consensus standards on methods for establishing EMC are available and represent current good practice as agreed upon by responsible professionals in the U.S. military and industrial (domestic and international) EMC community. These standards are maintained by their respective standards bodies and each revision permits refinement of the consensus positions and improvement of the standards through the resolution of open issues. Endorsing the current version of EMC standards allows the staff and applicants to obtain the benefit of the work of responsible EMC professional standards committee volunteers. In addition to the availability of a revised EMC standard from the U.S. DoD, the recent completion of a series of international EMC standards by IEC offers the opportunity to introduce greater flexibility in the choice of acceptable methods. Also, the issues related to high-frequency radiated EMC and conducted susceptibility along signal lines can be addressed through identification of acceptable test methods in the recent EMC standards. Adopting this approach requires NRC staff effort to review the revised or new standards to select for endorsement those criteria and methods that address EMC issues of concern for safety-related I&C systems in nuclear power plants. In addition, NRC staff effort for this approach includes a review of existing evidence characterizing the electromagnetic conditions at nuclear power plants and the rationale for electromagnetic operating envelopes to determine whether any conservatism can be identified and justifiably reduced (i.e., by relaxing the operating envelopes as warranted). The level of effort for each application is reduced for both NRC staff and applicant over that involved with Alternative 1 because systematic review and endorsement of current standards by NRC staff and up-front resolution of open EMC issues is a more effective use of resources than an *ad hoc*, case-by-case method of handling the transition to recent standards that more fully address the range of EMC issues. The result of this approach is an up-to-date, more complete guide on acceptable EMC practices with the flexibility to select among suites of test methods from domestic and international standards. Of course, the applicant retains the flexibility to establish an equivalent technical basis for different criteria and operating envelopes by performing its own detailed assessment of the electromagnetic conditions at the point of installation and evaluating any emerging practices.

3. VALUES AND IMPACTS

Values and impacts for each of the two identified approaches are analyzed below. In this analysis, the probability of an alternative approach having a positive effect on EMC and the probability of that effect on the achievement of overall safety goals are not known quantitatively. However, based on a qualitative assessment of experience in the military and commercial industries, as well as the nuclear industry, EMI/RFI and power surges clearly hold the potential for inducing an undesirable safety consequence. Therefore, a positive correlation between EMC and the achievement of safety goals is inferred from the negative effects of EMI/RFI and power surge susceptibility. Thus, EMC is a necessary but not wholly sufficient factor by itself in achieving safety goals.

In the summary below, an impact is a cost in schedule, budget, or staffing or an undesired property or attribute that would accrue from taking the proposed approach. Both values and impacts may be functions of time.

3.1 Alternative 1—Take No Action

This alternative has the attraction that its initial cost is low since there are no "start-up" activities. However, the burden of establishing the technical basis for the suitability of revised or new EMC standards would rest with the applicants. In addition, it would remain for the applicant to determine what practices, test criteria, and test methods are necessary to resolve the issues of high-frequency radiated EMC and conducted susceptibility along signal lines. NRC staff would have to act on a case-by-case basis for applications or requests to review safety questions involving the open issues or employing unreviewed versions of EMC standards. The absence of a clearly established technical basis regarding use of these revised standards or the resolution of these open issues could have adverse effects on the level of staff effort required to conduct reviews or to ensure consistency among reviews of the EMC for each I&C system modification. Thus, NRC staff review could take longer and require greater effort. From the applicant's perspective, the marketplace will ultimately drive the industry to use the revised or new standards as the testing resources that support the older standards diminish. As a result, the absence of guidance regarding the revised standards and the open issues could lead to higher costs for the applicants because of potential unknowns associated with demonstrating compliance with regulations using unreviewed methods. Thus, although the initial cost would apparently be low, taking no action could result in greater total costs, both to the NRC staff and the applicant, during the safety evaluation process.

Value – No value beyond the status quo
Impact – Schedule, budget, and staffing cost, to the staff and applicant, associated with remaining regulatory uncertainty regarding technical basis for use of revised or new standards and resolution of open issues on a case-by-case basis

3.2 Alternative 2—Update Existing Guidance

If the NRC staff endorses revised or new consensus EMC standards on the basis of a systematic review, the staff and applicants obtain the benefit of the effort of expert professional organizations to establish methods and practices to achieve and assess EMC. In addition, the update of the existing guidance provides the opportunity to address open issues and reduce conservatism as warranted. The cost of this approach involves NRC staff effort in reviewing the revised or new EMC standards, identifying practices to address the open issues, and reevaluating the technical basis for plant operating envelopes. Given the participation of NRC staff members on standards committees that are considered to address issues important to safety, this cost can be kept to a minimum. The value in this alternative is the common understanding between the NRC staff and applicants of approaches that have current acceptance as good practice in the expert technical community. The benefit of this approach would be a more comprehensive understanding of current EMC practices by the NRC staff and reduction of the burden on the applicants. From the applicant's perspective, a clear determination of acceptable resolutions to open EMC issues, the flexibility of using methods from current domestic and international EMC standards, and the potential reduction in conservatism would reduce the regulatory burden.

Value –
- Maintenance and evolution of the current definition of good practices by the EMC community in military and commercial industries
- Probable improvement in the likelihood of achieving safety goals as a consequence of resolution of open EMC issues
- Greater flexibility added in establishing EMC through the endorsement of equivalent suites of test methods from both domestic and international standards
- Reduction of conservatism in existing guidance as warranted by the enhanced technical basis

Impact –
- Staff cost of evaluating revised or new EMC practices for endorsement
- Reduction of burden for applicants

4. CONCLUSIONS

There is clear evidence that the electromagnetic conditions can adversely affect the performance of safety-related I&C equipment. The Code of Federal Regulations requires that systems, structures, and components important to safety be compatible with and accommodate the effects of environmental conditions associated with nuclear power plant service conditions. EMC is an element of addressing that requirement. Addressing open EMC issues and adopting improved or revised consensus practices, where the safety case is maintained, can enhance the assurance of safety while potentially reducing regulatory burden. Two approaches to maintaining existing EMC guidance were examined.

Taking no action may result in accumulating regulatory expense as applicants propose *ad hoc* solutions to open EMC issues or adopt unreviewed methods from revised or new standards as the basis for providing evidence to the staff that safety-related equipment is compatible with the electromagnetic conditions at the site and, thus, meet the requirements of NRC's regulations.

General endorsement of military and commercial EMC standards addresses the stated problem with good value and minimal impact. However, regulatory uncertainty regarding the applicability of each technical element embodied in the standards and the means to adequately determine the electromagnetic service conditions could still lead to accumulating regulatory expense as applicants submit proposed methods based on the general practices for staff review. Eventually, a *de facto* standard set of practices would emerge through an inefficient review process.

The second alternative, updating the existing guidance through development of an enhanced technical basis, provides good value with minimal impact. While this approach involves some additional NRC staff effort, it maintains the long-term relevance of the existing guidance through adoption of current versions of EMC standards, introduces greater flexibility in the generation of the safety case by offering the option of equivalent suites of test methods from domestic and international EMC standards, and reduces the potential burden on the applicants by addressing open EMC issues in a systematic manner and reducing conservatism as warranted by the enhanced technical basis. Therefore, the second alternative provides the highest value with reasonable impact on NRC staff and the greatest potential for reducing the regulatory burden for applicants. Note that neither of these approaches present new regulatory requirements; they define acceptable approaches for meeting existing requirements.

5. DECISION RATIONALE

Based on the highest value and reasonable impact for problem solution capability (especially regulatory burden), the second alternative, updating existing guidance by developing an enhanced technical basis, has been chosen. The highest value will be achieved by reviewing revised and new consensus EMC standards (both domestic and international), assessing the applicability and equivalence of each technical element embodied in the standards, reevaluating the electromagnetic environment characteristic of nuclear power plants and the technical basis for the current operating envelopes, determining testing methods that can address the open EMC issues, and identifying equivalent suites of test methods from the alternative standards and the conditions under which they may be applied. This approach will contribute to satisfying the safety goal for nuclear power plants.