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ADDRESSING THE SUSCEPTIBILITY OF DIGITAL SYSTEMS TO ELECTROMAGNETIC INTERFERENCE[1]

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ABSTRACT

This paper discusses the development of the technical basis for acceptance criteria applicable to the immunization of digital systems against electromagnetic interference (EMI). The work is sponsored by the U.S. Nuclear Regulatory Commission and stems from the safety-related issues that need to be addressed as a result of the application of digital instrumentation and control systems in nuclear power plants. Designers of digital circuits are incorporating increasingly higher clock frequencies and lower logic level voltages, thereby leading to potentially greater susceptibility of spurious interference being misinterpreted as legitimate logic. Development of the technical basis for acceptance criteria to apply to these digital systems centers around establishing good engineering practices to ensure that sufficient levels of electromagnetic compatibility (EMC) are maintained between the nuclear power plant's electronic and electromechanical systems. First, good EMC design and installation practices are needed to control the emissions from interference sources and thereby their impact on other nearby circuits and systems. Second, a verification and validation (V&V) program is needed to outline the EMI tests to be performed, the associated test methods to be followed, and adequate acceptance criteria to ensure that the circuit or system under test meets the recommended guidelines. V&V should be followed by periodic maintenance to assess whether the recommended EMI control practices continue to be adhered to as part of the routine operation of the nuclear power plant. By following these steps, the probability of encountering safety-related instrumentation susceptibility attributable to EMI will be greatly reduced.

1. INTRODUCTION

Instrumentation and control (I&C) systems in advanced nuclear reactors are expected to make extensive use of digital equipment and will be significantly different from the current analog-based designs. Digital signals can carry an increased amount of information as opposed to analog signals, and digital equipment generally has a much faster information processing capability than its analog counterpart. Thus, the widespread use of digital I&C systems in the design of monitoring, control, and protection systems is inevitable and, when properly used, can be expected to improve both safety and performance in nuclear power plants.

Several U.S. nuclear power plants have replaced selected analog systems with digital systems; however, the complete replacement of all analog systems in a plant has not been performed. With the limited operational experience of the nuclear industry with digital technology, the full extent of the susceptibility of digital I&C systems to electromagnetic interference (EMI) is unknown and hence of concern to the U.S. Nuclear Regulatory Commission (NRC). This concern is safety-related and, therefore, is consistent with the issues cited in Subpart B of Part 52 of Title 10 of the Code of Federal Regulations (10 CFR Part 52). This issue has led the NRC Office of Nuclear Regulatory Research to sponsor a research program for developing the technical basis for acceptance criteria specific to the electromagnetic compatibility (EMC) of digital I&C systems.

2. OVERVIEW OF TECHNICAL BASIS

Digital technology is constantly evolving, and manufacturers of digital systems are incorporating increasingly higher clock frequencies, faster operating speeds, and lower logic-level voltages into their designs. Recent experiences (Hyne 1984; Oranchak et al. 1980; Hanson 1989) have shown that industrial systems using the faster digital logic families generally have a greater susceptibility to the effects of EMI and, therefore, must be protected so that extraneous noise is not misinterpreted by the hardware as legitimate logic signals. This issue has led NRC to the conclusion that acceptance criteria are needed to ensure that EMI problems are minimized in nuclear power plants. The need for research was cited in Section 9.d of Enclosure 1 (List of Research Needs that Require Early Attention) to the NRC Policy Issue SECY-91-273, "Review of Vendors' Test Programs to Support the Design Certification of Passive Light Water Reactors."

Oak Ridge National Laboratory's (ORNL's) assistance in establishing the technical basis for acceptance criteria to address the susceptibility of digital systems against EMI has thus far focused on two primary areas: EMC practices and EMI verification and validation (V&V) techniques. The development effort first concentrated on EMC design and installation practices to ensure operational safety in equipment and then on EMI verification techniques to verify that the EMC practices do indeed achieve their intended purpose. A third area, surge-withstand capability (SWC), is also being investigated to ensure that digital I&C systems can withstand the transients typically encountered in the nuclear power plant environment. However, the SWC investigation is still in the preliminary stage and so will not be discussed in this paper. The end result will be recommendations for acceptance criteria intended to help the NRC staff establish the practices and techniques acceptable for complying with NRC regulations.

For maximum benefit, acceptance criteria should first concentrate on the establishment of good engineering practices that will ensure that sufficient levels of EMC are maintained between the nuclear power plant's electronic and electromechanical systems. The goal here is to reduce the impact of interference sources on nearby circuits and systems. Second, acceptance criteria should emphasize the importance of implementing well-founded V&V techniques to demonstrate that the engineering practices used are adequate to meet the desired design criteria. These techniques should center around an EMI V&V program consisting of test criteria, their associated test methods, and adequate acceptance criteria. With nuclear power plants' incorporation of good EMC practices, followed up by EMI V&V, the probability of encountering safety-related problems associated with EMI should be greatly reduced.

The research effort began with reviewing the EMI-related guides and standards currently in widespread use for their applicability to digital systems. Also, a literature search was conducted to ensure that all relevant information was included in the process. The ORNL investigators found that the Institute of Electrical and Electronics Engineers, Inc. (IEEE) Standard 1050-1989, *Guide for Instrumentation and Control Equipment Grounding in Generating Stations*—for the most part—does an adequate job of specifying EMC design and installation practices that are applicable to the nuclear power plant environment. However, after uncovering some anomalies, exceptions were taken to portions of IEEE Std. 1050-1989. Because the U.S. military branches regularly incorporate digital systems into their hardware, Military Standard (MIL-STD)-461C, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*, and MIL-STD-462, *Measurement of Electromagnetic Interference Characteristics*, were found to be reasonable points from which to begin an evaluation of relevant test criteria and methods.

3. EMC DESIGN AND INSTALLATION PRACTICES

It is the opinion of the authors that the technical basis for EMC design and installation practices should be founded on those practices outlined in IEEE Std. 1050-1989. This standard was developed to provide guidance specific to a power generating plant for the design of grounding systems for I&C equipment. This standard was sponsored by the Energy Development and Power Generation Committee of the IEEE Power Engineering Society and approved by the IEEE Standards Board on February 2, 1989. It should be noted that the terms *standard* and *guide* are used interchangeably in IEEE Std. 1050-1989 and *standard* does not imply that the practices are to be required, as in its usual connotation.

3.1 Review of IEEE Std. 1050-1989

IEEE Std. 1050-1989 comprises eight sections, and the applicable technical content is contained primarily in Section 4 (**Design Considerations for Electrical Noise Minimization**), Section 5 (**Grounding**), and Section 6 (**Typical Grounding Requirements for Generating Station Applications**). Ancillary information is contained in Sections 1 and 2 (**Scope and Introduction**), Section 3 (**Definitions**), Section 7 (**Testing**), and Section 8 (**Bibliography**). IEEE Std. 1050-1989 is comprehensive in that it covers both the theoretical and practical aspects of grounding and EMC. Consequently, it can provide useful guidance to design engineers who lack an extensive background in grounding and noise-minimization techniques. The authors of the guide do a thorough job of describing EMI in the power generating plant environment.

IEEE Std. 1050-1989 is directed specifically toward grounding and noise-minimization techniques for I&C systems in a generating station environment. Section 4 covers the gamut of possible interference sources and the mechanisms by which noise can couple into equipment and systems. Section 5 gives the reader background information on the fundamentals of a grounding system, and Section 6 outlines the problems associated with designing typical grounding systems for the power plant environment. Also included are references to practices specific to the treatment of digital systems, which is of special concern to NRC. In particular, Section 6.6 addresses the grounding of control circuits on the basis of their susceptibility to EMI. The grounding and shielding practices for digital systems are described, along with the rationale used in their selection.

3.2 Complementary Documents

IEEE Std. 1050-1989 is intended to be complementary to and complemented by IEEE Std. 518-1982, *IEEE Guide for the Installation of Electrical Equipment to Minimize Noise Inputs to Controllers from External Sources*, and IEEE Std. 665-1987, *IEEE Guide for Generating Station Grounding*. These guides are referenced throughout IEEE Std. 1050-1989. Like IEEE Std. 1050-1989, IEEE Std. 665-1987 was also sponsored by the Power Generation Committee of the IEEE Power Engineering Society and identifies the grounding practices that have been generally accepted by the electric utility industry and provides guidance in designing a safe and effective grounding system. It is particularly thorough in its treatment of electrical bonding. Sponsored by the Industrial Control Committee of the IEEE Industrial Applications Society, IEEE Std. 518-1982 provides guidance for installing controllers and control systems to ensure proper operation in their intended environment. In addition, the guide thoroughly covers shielding, grounding, and bonding techniques used to minimize noise on signal cables.

IEEE Std. 518-1982 and IEEE Std. 665-1987 offer even greater detail and more effective explanations than does IEEE Std. 1050-1989 on some topics. For example, Sections 4.3.3 and 5.4 of IEEE Std. 1050-1989 describe the grounding requirements for signal cable shields in a somewhat incomplete style, whereas Section 4.4 on page 64 of IEEE Std. 518-1982 explains this subject matter more effectively. Also, the treatment of bonding (i.e., the interconnection of conductive parts so as to maintain a common electrical potential) is not concise in IEEE Std. 1050-1989; references to bonding in the discussions on grounding systems are vague and lack sufficient detail. Fortunately, Section 5.2 of IEEE Std. 665-1987 covers the subject in considerably greater detail.

3.3 Findings on IEEE Std. 1050-1989

The ORNL investigators found that IEEE Std. 1050-1989—for the most part—is accurate in its treatment of EMC design and installation practices and applicable to the nuclear power plant environment. Some exceptions have been taken, and these will be reviewed thoroughly before final recommendations are made. Several enhancements have also been suggested to improve the understanding and usefulness of IEEE Std. 1050-1989. The enhancements are meant to be helpful but are by no means necessary. The particulars of the exceptions and enhancements will be discussed in NUREG/CR-5941 (Ewing and Korsah), which will cover the activities of the entire development effort and is scheduled to be published in June 1993. Associated guides, like IEEE Std. 518-1982 and IEEE Std. 665-1987, may also be helpful but should be used only in a manner consistent with acceptance criteria based on IEEE Std.1050-1989.

4. EMI VERIFICATION AND VALIDATION

It is the opinion of the authors that MIL-STD-461C, *Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference*, and MIL-STD-462, *Measurement of Electromagnetic Interference Characteristics*, are applicable to the needs of the nuclear industry. MIL-STD-461C and -462 were developed for use by U.S. Department of Defense agencies to evaluate electromagnetic compatibility. Applying to both equipment designs and procurement specifications, the purpose of the standards is to ensure that equipment and subsystems are compatible with their intended electromagnetic operating environment and that EMI effects are considered early in the design process.

4.1 Review of MIL-STDS

MIL-STD-461 and -462, first issued in 1967, were intended to consolidate the requirements and test methods for the Army, the Navy, and the Air Force. The tri-services have since revised MIL-STD-461 such that it has become three separate documents under a single cover. The first two revisions, MIL-STD-461A and MIL-STD-461B, were issued on August 1, 1968, and April 1, 1980, respectively. They focus on establishing separate test requirements for each military service branch. The third and most recent revision was released on August 4, 1986, as MIL-STD-461C. This revision updated the standard to include electromagnetic pulse (EMP) requirements and changed the test limits for some existing requirements.

MIL-STD-462 has also been updated. Because each of the service branches adopted separate test requirements, modifications of the MIL-STD-462 test methods soon followed. To date, the original version has been superseded by six "Notices" designed to modify MIL-STD-462 to the unique requirements of the Army, the Navy, and the Air Force. Notices 1 and 2 were released by the Air Force on August 1, 1968, and May 1, 1970, respectively. Notice 1 corrected grammatical errors and modified the structure of the document. Notice 2 made changes to some of the test procedures and redefined the applicability of others. Notice 3 was released on February 9, 1971, by the Army as a complete, stand-alone document to meet their requirements. Notice 4 was released by the Navy on April 1, 1980, to add a test method for evaluating the susceptibility of equipment to common-mode currents. The most recent releases were issued as Notice 5 on August 4, 1986, for the Navy and Notice 6 on October 15, 1987, for the Air Force. Notices 5 and 6 include the new EMP test methods, along with changes to existing test methods.

MIL-STD-461C establishes the emission and susceptibility requirements for electronic, electrical, and electromechanical equipment and subsystems. The standard ensures that control of both conducted and radiated interference are addressed over the frequency range 30 Hz to 40 GHz. It also provides a basis for evaluating the electromagnetic characteristics of equipment and subsystems by setting operational test limits. The requirements of MIL-STD-461C are typically applicable only as specified in the contracting agreement between a private enterprise and the government. MIL-STD-462 establishes the procedures to be followed in making test measurements to determine the electromagnetic characteristics of the equipment or subsystem under test. MIL-STD-462 also specifies the test equipment, setup, and grounding configuration requirements to ensure meaningful and repeatable test data.

Unless explicitly stated otherwise, the applicability of the MIL-STD-461C test requirements depends on the class designation assigned to the equipment or subsystem under review. MIL-STD-461C consists of 10 parts that describe the requirements for different classes of equipment and subsystems according to their mission, platform, and intended environment. Part 1 of MIL-STD-461C establishes the general documentation and design requirements, and Parts 2 through 6 cover the requirements for equipment and subsystems installed in critical areas. Parts 7 through 10 cover support and miscellaneous general-purpose equipment. The equipment and subsystem class designations and their applicable parts in MIL-STD-461C are shown in Table I.

The MIL-STD-461C test requirements are specified by alpha-numeric codes, as shown in Table II. The first designation declares the requirement as either radiated (R) or conducted (C) and the second designation specifies whether it covers emissions (E) or susceptibility (S). A unique method (UM) assignment is given to requirements that do not fall into these predefined designations. The alphabetic notation is followed by a numbering system that is specific to the particular test requirement. The test methods corresponding to the MIL-STD-461C requirements are described in MIL-STD-462 and are designated by the same alpha-numeric codes.

4.2 Findings on Test Requirements and Test Methods

MIL-STD-461C and -462 were developed as measures to rate the required electromagnetic compatibility of equipment and subsystems according to their intended electromagnetic environments. The standards have been used successfully by the military for many years and are commonly referenced in commercial applications as well. As related to the needs of NRC, the scope of the ORNL development effort has focused on only the *susceptibility* test requirements in MIL-STD-461C and their associated MIL-STD-462 test methods, shown in Table III.

Table I. MIL-STD-461C equipment and subsystem classes vs applicable parts

Class	Description		Applicable parts
A	Equipment and subsystems which must operate compatibly when installed in critical areas, such as the following platforms and installations:		
	A1	Aircraft (including associated ground support equipment)	2
	A2	Spacecraft and launch vehicles (including associated ground equipment)	3
	A3	Ground facilities (fixed and mobile including tracked and wheeled vehicles)	4
	A4	Surface ships	5
	A5	Submarines	6
B	Equipment and subsystems which support the Class A equipment and subsystems but will not be physically located in critical ground areas. Examples are electronic shop maintenance and test equipment used in noncritical areas, theodolites, navaids, and similar equipment used in isolated areas.		7
C	Miscellaneous general purpose equipment and subsystems not usually associated with a specific platform or installation, such as the following specific items:		
	C1	Tactical and special purpose vehicles and engine-driven equipment	8
	C2	Engine generators and associated components, uninterruptible power sets and mobile electric power equipment supplying power to or used in critical areas	9
	C3	Commercial electrical and electromechanical equipment	10

Some of the MIL-STD-461C susceptibility test requirements were found to be directly applicable to digital equipment. Tabular information characterizing the applicability of the MIL-STD-461C test requirements versus equipment and subsystems is available in two formats, according to the different classes of equipment and subsystems. Data entries are sometimes presented in tables that compare the applicability of the test requirements to an entire class of equipment or subsystems. Conversely, the data are sometimes tabulated in a manner that compares the applicability of the test requirements to specific types of equipment within a class. For the sake of this research effort, the second format proved to be the more useful because "digital equipment" was one of the types of equipment being compared to the requirements.

The information in MIL-STD-461C specifically pertinent to the susceptibility test requirements for digital equipment can be extracted and compiled for four classes of equipment and subsystems: platforms for aircraft (A1), ground facilities (A3), surface ships (A4), and submarines (A5). Although the resemblance of these platforms to a nuclear power plant is not immediately apparent, a comparison of their test requirements gives some insight into the commonality of specific test requirements for digital equipment.

Table IV summarizes the susceptibility requirements in MIL-STD-461C that apply to particular classes of digital equipment. The entries in the table denote the relationship between the classes and the requirements. Depending on the type of entry, the extent to which any given

Table II. MIL-STD-461C emission and susceptibility requirements

Requirement*	Description
CE01	Conducted emissions, power and interconnecting leads, <15 kHz
CE03	Conducted emissions, power and interconnecting leads, 0.015 to 50 MHz
CE06	Conducted emissions, antenna terminals, 10 kHz to 26 GHz
CE07	Conducted emissions, power leads, spikes, time domain
CS01	Conducted susceptibility, power leads, 30 Hz to 50 kHz
CS02	Conducted susceptibility, power and control leads, 0.05 to 400 MHz
CS03	Intermodulation, 15 kHz to 10 GHz
CS04	Rejection of undesired signals, 30 Hz to 20 GHz
CS05	Cross-modulation, 30 Hz to 20 GHz
CS06	Conducted susceptibility, spikes, power leads
CS07	Conducted susceptibility, squelch circuits
CS09	Conducted susceptibility, structure (common mode) current, 60 Hz to 100 kHz
CS10	Conducted susceptibility, damped sinusoidal transients, pins and terminals, 10 kHz to 100 MHz
CS11	Conducted susceptibility, damped sinusoidal transients, cables, 10 kHz to 100 MHz
RE01	Radiated emissions, magnetic field, 0.03 to 50 kHz
RE02	Radiated emissions, electric field, 14 kHz to 10 GHz
RE03	Radiated emissions, spurious and harmonics, radiated technique
RS01	Radiated susceptibility, magnetic field, 0.03 to 50 kHz
RS02	Radiated susceptibility, magnetic and electric fields, spikes and power frequencies
RS03	Radiated susceptibility, electric field, 14 kHz to 10 GHz
RS05	Radiated susceptibility, electromagnetic pulse field transient
UM03	Radiated emissions and susceptibility, tactical and special purpose vehicles and engine-driven equipment
UM04	Conducted emissions and radiated emissions and susceptibility, engine generators and associated components, uninterruptible power sets and mobile electric power equipment
UM05	Conducted and radiated emissions, commercial electrical and electromechanical equipment

*C = conducted, E = emission, R = radiated, S = susceptibility, and UM = unique method.

Table III. MIL-STD-461C susceptibility requirements

Requirement*	Description
CS01	Conducted susceptibility, power leads, 30 Hz to 50 kHz
CS02	Conducted susceptibility, power and interconnecting control leads, 0.05 to 400 MHz
CS03	Intermodulation, 15 kHz to 10 GHz
CS04	Rejection of undesired signals, 30 Hz to 20 GHz
CS05	Cross-modulation, 30 Hz to 20 GHz
CS06	Conducted susceptibility, spikes, power leads
CS07	Conducted susceptibility, squelch circuits
CS09	Conducted susceptibility, structure (common mode) current, 60 Hz to 100 kHz
CS10	Conducted susceptibility, damped sinusoidal transients, pins and terminals, 10 kHz to 100 MHz
CS11	Conducted susceptibility, damped sinusoidal transients, cables, 10 kHz to 100 MHz
RS01	Radiated susceptibility, magnetic field, 0.03 to 50 kHz
RS02	Radiated susceptibility, magnetic and electric fields, spikes and power frequencies
RS03	Radiated susceptibility, electric field, 14 kHz to 10 GHz
RS05	Radiated susceptibility, electromagnetic pulse field transient
UM03	Radiated emissions and susceptibility, tactical and special purpose vehicles and engine-driven equipment
UM04	Conducted emissions and radiated emissions and susceptibility, engine generators and associated components, uninterruptible power sets and mobile electric power equipment

*C = conducted, R = radiated, S = susceptibility, and UM = unique method.

Table IV. MIL-STD-461C requirements vs classes for digital equipment*

Susceptibility requirement**	Aircraft	Ground facilities	Surface ships	Submarines
CS01	Y_L	Y_L	Y	Y
CS02	Y	Y	Y	T
CS03				
CS04				
CS05				
CS06	Y	Y	Y	Y
CS07				
CS09		Y_L	Y_L	Y_L
CS10		T	T	T
CS11		Y_L	Y_L	
RS01		Y_L	Y	Y
RS02		Y_L	Y	Y
RS03	Y	Y	Y	Y
RS05		Y_L	Y_L	

*Y = applicable, Y_L = applicable with limitations, and T = tailored on a case-by-case basis.

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

requirement is applicable and the level to which the associated test limit will be imposed can vary. A Y entry denotes that the requirement is applicable and the limit shall be met by using the test method described in MIL-STD-462. A Y_L entry denotes that there are limitations in the applicability of the test requirement, and a T entry denotes that the applicability of the requirement will be determined on a case-by-case basis. *Absence of an entry means that the test requirement is not applicable.*

With the evaluation criterion that a requirement must be applicable to multiple classes of equipment before it can be termed generally applicable, the susceptibility requirements in Table IV can be narrowed. The test requirements listed in Table V meet this evaluation criterion and are suggested for consideration as test criteria to evaluate the susceptibility of digital equipment in nuclear power plants. The rationale for the selection of the susceptibility criteria in Table V is that NRC can take advantage of the tri-services' experience in evaluating digital equipment. A critique of the test criteria indicates that they are applicable to a nuclear power plant environment and also address the specific concerns of NRC. These susceptibility criteria cover conducted and radiated interference, transients, exposure to both electric and magnetic fields, and noise entry through the power and control leads. By specifying these susceptibility criteria and their associated test methods, a conclusion can be reached as to whether equipment and subsystems can be expected to function properly in their intended electromagnetic operating environments.

The test methods specified in MIL-STD-462 are applicable to the evaluation of the susceptibility of digital systems in nuclear power plants only to the extent that they follow the test requirements; they are just the means by which compliance can be demonstrated. The MIL-STD-462 test methods have become well developed through the years and are generally accepted in industry. This acceptance would make their adaptability to a V&V program relatively easy and inexpensive because many laboratories already have the necessary test equipment and are familiar with the test procedures.

4.3 Findings on Acceptance Criteria

The acceptance criteria in MIL-STD-461C are specified according to the particular application and the expected electromagnetic environment in which equipment and subsystems must operate. This environment may vary from low-interference levels at ground-based locations to extremely

Table V. Applicable C susceptibility criteria for digital equipment

Requirement*	Description
CS01	Conducted susceptibility, power leads, 30 Hz to 50 kHz
CS02	Conducted susceptibility, power and interconnecting control leads, 0.05 to 400 MHz
CS06	Conducted susceptibility, spikes, power leads
RS01	Radiated susceptibility, magnetic field, 0.03 to 50 kHz
RS02	Radiated susceptibility, magnetic and electric fields, spikes and power frequencies
RS03	Radiated susceptibility, electric field, 14 kHz to 10 GHz

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

harsh levels on the decks of aircraft carriers. In past surveys of nuclear power plant environments (Cirillo and Prussel 1986), the levels of radiated emissions from most equipment were found to be moderate or below. Nevertheless, equipment was identified that could not operate reliably in its intended environment. From the results of these surveys, it is reasonable to assume that a nuclear power plant can be categorized as an industrial environment, with its electromagnetic ambient being considerably less harsh than a typical military environment.

In areas where digital systems will be installed, the radiated and conducted emission levels should be measured and the susceptibility criteria established accordingly. Acceptance criteria that are less stringent than those specified in MIL-STD-461C will allow the avoidance of unnecessary test costs and modifications in equipment designs. The acceptance criteria for the nuclear power plant environment should be based on susceptibility levels developed from radiated and conducted emission profiles anticipated at various sites. The profiles will provide an assessment of the ambient electromagnetic environment; a safety margin can then be added to ensure the operability of the equipment and subsystems. This type of approach will help in establishing acceptance criteria that are both appropriate and realistic.

Of the environments described for the classes of military equipment and subsystems, the noncombat ground facilities environment most closely resembles that of a nuclear power plant. Thus, the MIL-STD-461C acceptance criteria specified for noncombat ground facilities (or some variation thereof) could be used in the interim for nuclear power plant environments until acceptance criteria based on actual nuclear power plant profiles can be established. These acceptance criteria were found to be representative of the criteria already informally accepted in the nuclear industry, and are at least equal to or slightly more stringent than the proposed American National Standards Institute (ANSI) C63.12 (ANSI 1987) immunity criteria in the areas common between the ANSI standard and the MIL-STDs.

5. SUMMARY

This paper has detailed the effort to date to develop the technical basis for evaluating the susceptibility of digital I&C systems to EMI. To summarize, IEEE Std. 1050-1989, with minor exceptions, was found to provide good EMC design and installation practices. As an added precaution, periodic maintenance checks would ensure that the EMC design and installation practices continue to perform their intended function. Specific MIL-STD-461C test criteria and their associated MIL-STD-462 test methods were found to form the basis for an EMI V&V program. Also, interim acceptance criteria based on the MIL-STD-461C criteria for noncombat ground facilities could be established for the test criteria until adequate measurement data can be compiled to profile the electromagnetic ambient environment in nuclear power plants. By following this approach, we believe that a greatly reduced probability of encountering EMI-associated problems with upgrades to digital I&C systems could be realized.

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