

## Comparison of EMI/RFI requirements to qualify the equipments for nuclear power plant. (RG 1.180, EPRI TR 102323, IEC 62003 and GB/T 11684)

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### 1. Introduction

One issue that has been problematic for new plant equipment and especially for digital instrumentation and control (I&C) systems in recent years is electromagnetic compatibility (EMC). In some reports for nuclear power plant (NPP), 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.

There are mainly two reference guides for applying to qualify EMI/RFI requirements of the equipment used in a NPP: US NRC RG 1.180 and EPRI TR 102323. Recently, IEC published the standard for the equipment in the NPP, IEC 62003. This paper has compared the requirements of these, including comparing of the requirement of the Chinese national standard, GB/T 11684.

### 2. Comparison of EMI/RFI Requirements for NPP

#### 2.1 U.S. NRC RG 1.180 (2003)

This regulatory guide (RG 1.180) is to provide guidance on 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. Selected EMI/RFI test methods from MIL-STD-461E and the IEC 61000 Series are endorsed to evaluate conducted and radiated EMI/RFI phenomena. The SWC practices described in IEEE Std C62.41 and IEEE Std C62.45 are endorsed for evaluating the effect of power surges.

#### 2.2 EPRI TR 102323 (2004)

In this guide (EPRI TR 102323), recommended tests are referenced in standards defined by the military and commercial sectors, and the levels are conservative based on the analyzed data collected at several U.S. nuclear power plants. This document endorses both military and commercial standards where they can be supported by a technical basis. This referenced the IEC 61000 series; FCC 47CFR Parts 15 and 18; IEC CISPR 11, 14, 15, 16, and 22; ANSI 63.4 and 63.12, and IEEE 187 and 1140 commercial standards.

#### 2.3 IEC 62003 (2009)

This International Standard was prepared and based on the current application of the IEC 61000 series for

commercial equipment qualification for electromagnetic interference (EMI) and radio-frequency interference (RFI). It clarifies the criteria to be applied for qualification to EMI/RFI from the commercial standards.

#### 2.4 GB/T 11684 (2003)

This standard defines the classification of electromagnetic environment conditions, requirements and test procedures for electromagnetic immunity of nuclear power plant instrumentation. It seems to be based Chinese national standards which are similar with IEC 61000 series standards.

#### 2.5 Summary of comparison results

Reference [5] is detailed comparison results of the standards of 2.1, 2.2, 2.3 and 2.4. Table 1 and Table 2 show the summary of comparison results based on emission limit or test level, and test methods, respectively.

For LF CE and LF RE, there is no IEC 61000 test comparable to the CE101/RE 101 tests for the frequency range being covered. For HF CE, CE 102 covers 10 kHz to 2 MHz with peak detector, while IEC 61000-4 covers 150 kHz to 30 MHz with quasi-peak and average detectors. For HF RE, RE102 is based on near field measurement in a shielded enclosure up to 18 GHz, while IEC 61000-6-4 based on far field measurement below 1 GHz in Open Area Test Site. For LF CS, RG 1.180 requires a test of IEC 61000-4-16 for power/signal leads. But EPRI TR only required for power leads. For HF CS, RG1.180 specifies a different, customized CS114 limit and different limits for power & signal cables for both the CS114 and IEC EN 61000-4-6 tests.

For LF RS, the RS101 test covers the frequency range of 30 Hz to 100 kHz. The IEC 61000-4-8 test covers only the power distribution frequencies at 50 Hz or 60 Hz. The IEC 61000-4-9 test provides pulses that cover the frequency range of 60 Hz to 50 kHz. For HF RS, The RS103 test employs for square wave modulation with a 50 % duty cycle, while the IEC 61000-4-3 test employs for sinusoidal wave modulation with an 80 % duty cycle. The MIL-STD-461E RS103 test covers the frequency range of 10 kHz to 10 GHz. The IEC 61000-4-3 test covers the frequency range of 80 MHz to 1 GHz. There are differences in the test methods. The test area for the RS103 test can be either a shielded room or a partially anechoic room.

Table 1. Summary of comparison on Limit or Test Level

Test Items		EPRI	IEC	GB
Low Frequency CE (CE101, 30 Hz ~ 10 kHz)	NRC	C	C	C
	EPRI		C	C
	IEC			C
High Frequency CE (CE102, 10 kHz ~2 MHz)	NRC	B	B	C
	EPRI		B	C
	IEC			C
Low Frequency RE (RE101, 30 Hz ~ 100 kHz)	NRC	B	C	C
	EPRI		C	C
	IEC			N/A
High Frequency RE (RE102, 2 MHz~18 GHz)	NRC	B	C	C
	EPRI		C	C
	IEC			N/A
Low Frequency CS (CS101, 30 Hz~150 kHz)	NRC	B	B	C
	EPRI		B	C
	IEC			C
High Frequency CS (CS102, 10 kHz~30 MHz)	NRC	B	B	B
	EPRI		B	B
	IEC			B
Low Frequency RS (RS101, 30 Hz~100 kHz)	NRC	B	B	B
	EPRI		B	B
	IEC			B
High Frequency RS (RS103, 2 MHz~10 GHz)	NRC	B	B	B
	EPRI		B	B
	IEC			B
Surge withstand capability Ring / Damped oscillatory	NRC	B	B	B
	EPRI		B	B
	IEC			B
EFT/Burst	NRC	B	B	B
	EPRI		B	B
	IEC			B
Combination wave Surge	NRC	B	B	B
	EPRI		B	B
	IEC			B
Electrostatic Discharge (ESD)	NRC	C	C	C
	EPRI		B	C
	IEC			C
Power Quality Related (V dip & interruption)	NRC	N/A	C	C
	EPRI		C	C
	IEC			B

C:conducted, R:radiated, E:emissions, S:susceptibility and 'A' means that two standards to be compared are 'same' and 'B' means 'similar' which is required some modifications for application and 'C' means 'big difference' which cannot be applied as an alternative.

The IEC 61000-4-3 test calls for an anechoic room for the test area. For Ring wave surge test, IEC 61000-4-12 test is comparable to the IEEE C62.41-1991 test. RG 1.180 specifies different levels for signal cables for CS116, IEC EN 61000-4-5 and IEC EN 61000-4-12. For EFT/Burst test, RG 1.180 specifies CS115 only for signal cables and to a lower level than in MIL-STD-461E. RG 1.180 specifies levels of 2-4 kV for power and 1-2 kV for signal leads. For combination surge test, RG 1.180 specifies different levels for signal cables for IEC 61000-4-5. ESD is not addressed in RG 1.180.

### 3. Conclusions

Comparisons of test items, requirements, test method for RG 1.180 (2003), EPRI TR 102323(2004), IEC 62003(2009) and GB/T 11684(2003) were implemented. There are many significant differences in the emission limits/test level and test methods. RG1.180 does not allow mixing of tests from different standards for sets of tests.

Table 2. Summary of comparison on Test Methods

Test Items		EPRI	IEC	GB
Low Frequency CE (CE101, 30 Hz ~ 10 kHz)	NRC	A	C	C
	EPRI		C	C
	IEC			C
High Frequency CE (CE102, 10 kHz ~2 MHz)	NRC	B	C	C
	EPRI		C	C
	IEC			C
Low Frequency RE (RE101, 30 Hz ~ 100 kHz)	NRC	B	C	C
	EPRI		C	C
	IEC			N/A
High Frequency RE (RE102, 2 MHz~18 GHz)	NRC	B	B	C
	EPRI		B	C
	IEC			N/A
Low Frequency CS (CS101, 30 Hz~150 kHz)	NRC	B	B	C
	EPRI		B	C
	IEC			C
High Frequency CS (CS102, 10 kHz~30 MHz)	NRC	B	B	C
	EPRI		B	C
	IEC			C
Low Frequency RS (RS101, 30 Hz~100 kHz)	NRC	B	B	B
	EPRI		B	B
	IEC			B
High Frequency RS (RS103, 2 MHz~10 GHz)	NRC	A	B	B
	EPRI		B	B
	IEC			B
Surge withstand capability Ring / Damped oscillatory	NRC	B	B	B
	EPRI		B	B
	IEC			B
EFT/Burst	NRC	B	B	B
	EPRI		B	B
	IEC			B
Combination wave Surge	NRC	B	B	B
	EPRI		B	B
	IEC			B
Electrostatic Discharge (ESD)	NRC	B	B	B
	EPRI		B	B
	IEC			B
Power Quality Related (V dip & interruption)	NRC	N/A	C	C
	EPRI		C	C
	IEC			B

For emissions testing, the MIL-STD-461E, IEC or FCC testing scope should be completed in its entirety. For susceptibility testing the 461E or IEC testing scope should be completed in its entirety. There are many significant differences between RG 1.180(2003), EPRI TR 102323(2004) and IEC 62003(2009) as the contents.

### REFERENCES

- [1] EPRI TR-102323 Revision 3: 2004, Guidelines for Electromagnetic Interference Testing in Power Plants, Electric Power Research Institute, Palo Alto, CA, 1996
- [2] Regulatory Guide 1.180: 2003, Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems, U.S. Nuclear Regulatory Commission, January 2000.
- [3] IEC 62003 Ed. 1.0: 2009-03, Nuclear power plants–Instrumentation and control important to safety–Requirements for electromagnetic compatibility testing
- [4] GBT 11684:2003, Electromagnetic environment conditions and testing procedures for nuclear instrumentation
- [5] Harmonization result of REG 1.180, EPRI TR 102323, IEC 62003 and IEEE 323, IEC60780 and GB/T 11684 standard for EMI/RFI requirements for Nuclear Power Generating Stations, Kepco Research Institute & Korea Electric Power Industry Code, Jong-Seog Kim, 2011