

Evaluation of electromagnetic interference environment of the instrumentation and control systems in nuclear power units



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HIGHLIGHTS

- We surveyed the electromagnetic emissions at the location of I&C systems.
- We assessed the electromagnetic levels on reactor types from thirteen nuclear plants.
- We evaluated the margin between plant emission limits and the highest composite levels.
- We presented the formula of radiated susceptibility test levels to non-safety-related I&C systems.

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ABSTRACT

The electromagnetic interference (EMI) generated from sources in power units can interfere with digital Instrument and Control (I&C) systems. When EMI is emitted with conducted and radiated noise, it interferes with the signals of the I&C systems. Since the digital I&C systems are efficient and competitively priced, the analogue I&C systems have been upgraded and replaced with digital I&C systems, but these systems have less EMI immunity. When safety-related I&C systems are installed in the units, the verification of equipment EMI should not be done in site-specific tests but in test facilities. There are needs to do the overall site-specific EMI assessment of I&C systems depending on the reactor types from thirteen operating units. This study evaluated the margin between plant emission limits and the highest composite plant emissions of the EMI. When the non-safety-related I&C equipment or systems are placed in the units, there are no individual test levels of the radiated electrical field. If need be, the level should comply with the test levels of the radiated electrical field on the safety-related I&C systems. This paper presents the test levels of radiated electrical fields to non-safety-related I&C equipment or systems.

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1. Introduction

Electromagnetic interference (EMI) can interfere with the functionality of digital Instrument and Control (I&C) systems in an electrical equipment room (EER), main control room (MCR), local control room (LCR), and computer room (CR). When EMI is emitted with conducted and radiated noise, it interferes with the signals of I&C systems. A major reason for the replacement from analogue systems with digital systems is that digital systems can provide reduced operation and maintenance costs and improved plant availability during maintenance. Since it is inevitable that digital I&C systems will be applied, analogue I&C systems are being retrofitted or upgraded with digital I&C systems, which have less

EMI immunity. The transients in the power units have a higher impact on digital circuits over analogue circuits because the digital circuits have a higher possibility of EMI influence due to their low voltages.

There has been a thorough evaluation conducted by US NRC (Nuclear Regulatory Commission) for safety-related I&C systems and non-safety I&C systems whose failures can affect safety functions, but no overall evaluation of both safety-related I&C systems and all non-safety-related I&C systems in an EER, MCR, LCR and CR. When safety-related I&C equipment is placed in the units, the verification of equipment EMI should not be done in site-specific tests but in test facilities. The test methods in Nuclear Regulatory Guide 1.180 Revision 1 are intended for application in test facilities before installation (USNRC, 2003). Although the verification in test facilities is a practical and cost-effective approach that ensures quality control over the way equipment is tested, the verification of equipment EMI in test facilities is not identical as the verification of

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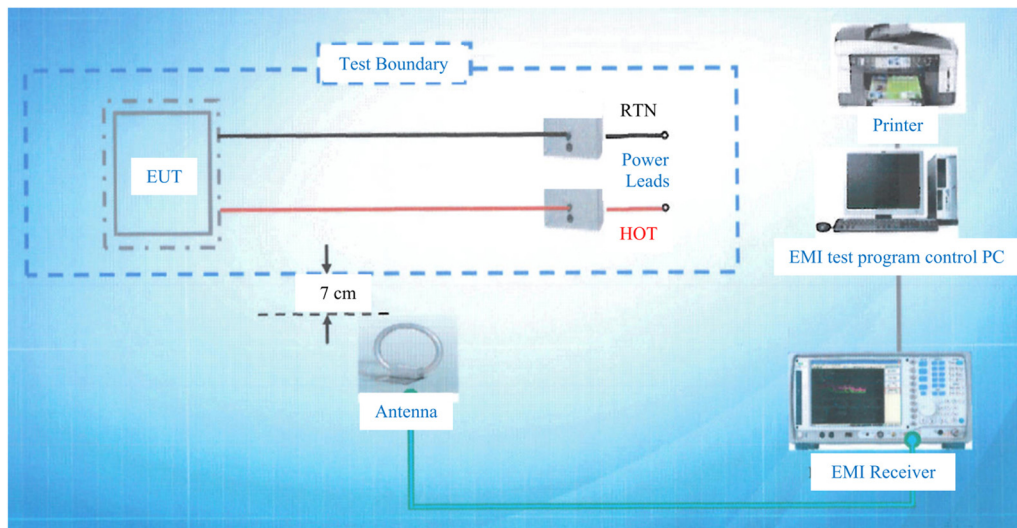


Fig. 1. Test configuration for RE101 EMI measurement.

equipment EMI on site because the I&C equipment or systems will be surrounded with various EMI sources such as non-safety-related I&C cabinets, lighting, switching, relay operating, and communication equipment (FPRI, 2008) (IEEE, 2012) (Journal of Exposure, 2010<). There are needs to access the site-specific EMI evaluation of both safety-related I&C systems and non-safety-related I&C systems affected by EMI sources and the interacting coupling of them on site (ERPI, 2010). The site-specific electromagnetic emissions were surveyed in different reactor types in thirteen nuclear power units. This study evaluates the margin between plant emission limits (allowable plant levels) and the highest composite plant emissions of the EMI.

When non-safety-related I&C equipment or systems whose failures can affect safety functions are placed in the units, there are no individual test levels of the radiated electrical field. If it is necessary, the level should comply with the test level of the radiated electrical field on the safety-related I&C equipment. Therefore, this paper presents the alternative test levels of radiated electrical fields to non-safety-related I&C systems when plants need to apply the test level from the measured EMI emissions.

2. Test guidance for conducted and radiated EMI

2.1. Test method and equipment

The conducted and radiated emissions were tested according to the Nuclear Regulatory Guide 1.180, the MIL-STD-461E (MIL-STD-461E, 1999), and IEC 61000-6-4 (IEC-61000-6-4, 2006). Low-frequency conducted emissions (CE 101, 30 Hz–10 kHz) are tested to measure the harmonics emissions on the power cables, and high-frequency emissions (CE102, 10 kHz–2 MHz) are tested to measure the emissions on the power cables, including

returns and neutrals. Radiated magnetic field emissions (RE101, 30 Hz–100 kHz) are tested to measure the magnetic field equipment emissions, and radiated electric field emissions (RE102, 10 kHz–10 GHz) are tested to measure the high-frequency radiated electric field equipment emissions to ensure that measuring emissions do not adversely affect existing plant equipment and systems. The test equipment is configured to measure the conducted and radiated emissions, as shown in Table 1 and Fig. 1.

2.2. Measuring point

The conducted emissions are measured in the plant protection system, plant process system, monitoring system, remote shutdown panels, cable spreading rooms, equipment rooms, auxiliary instrument rooms, relay rooms, and other areas where the I&C systems installations are planned. The radiated emissions are measured in the EER, MCR, LCR, and CR with different reactor types such as the Westinghouse (WH) type, Optimized Power Reactor (OPR)-1000 type, Canadian Deuterium Uranium Reactor (CANDU) type, and Advanced Power Reactor (APR)-1400 type (Table 2).

2.3. Test standard

Electromagnetic emissions must meet operating envelopes (Limits) presented in the U.S Nuclear Regulatory Guide 1.180. Operating envelopes that serve to establish acceptable test levels are acceptable for locations where the I&C systems are installed or are likely to be installed. The plant emissions limits are chosen as 8 dB below the recommended equipment susceptibility limits to provide additional conservatism (ERPI, 1997), which means that the plant emissions limits have a 2.5-times greater margin for equipment susceptibility limits, as shown in Fig. 2.

Table 1
List of EMI measuring equipment.

Equipments	Frequency	Specification	Note
EMI test receiver	20 Hz–26.5 GHz	LSA-265	Used commonly
Current probe	20 Hz–1 MHz	BCP-510	CE101
Current probe	20 kHz–100 MHz	BCP-511	CE102
Loop antenna	20 Hz–2 MHz	SAS-560	RE101
Monopole antenna	9 kHz–60 MHz	SAS-550-1B	RE102
Bi-conical antenna	20 MHz–330 MHz	SAS-542	RE102
Log-periodic antenna	290 MHz–2 GHz	SAS-510-2	RE102
Horn antenna	700 MHz–18 GHz	SAS-571	RE102

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