Study on Equipment Separation Distance in NPPs Considerating Radiated Electromagnetic Field Radiation Emission (RE102)

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1. Introduction

Electromagnetic waves consist of wave components made up of electric and magnetic fields, which can be classified as conductive or radiative depending on the transmission path. The purpose of electromagnetic compatibility(EMC) verification is to confirm that the target equipment does not adversely affect other equipment through electromagnetic wave emissions (EMI), is not affected by other equipments (EMS), and can perform its intended in electromagnetic environment.

With the addition of non-safety equipments emission testing requirements near safety equipments in NRC Reg. Guide 1.180 Rev.2, control areas are managed so that only portable and fixed devices are exposed below the allowable levels of electromagnetic field radiation resilience, considering the level of electric field resilience(RS103). In this study, we study on the separation distance settings for non-safety equipment subject to electromagnetic field radiation emission tests (RE102).

2. Evaluation of Equipment Separation Distance

2.1 Methods for Calculating Exclusion Zone

The calculation method for exclusion zone in RG 1.180 calculates the exclusion zone(separation distance) based on the free space propagation model.

$$D = \frac{\sqrt{30 P_t G_t}}{E} = \frac{\sqrt{30 EIRP}}{E} [m]$$

- P_t: Effective radiated power of the EMI/RFI source[W]
- G_t: Gain of the EMI/RFI radiator[dimensionless]
- EIRP: Effective Isotropic Radiated Power [W]
- E: Allowable electric field radiation tolerance level

2.2 Review of Antenna Gain(G_t)

Antenna gain refers to a unit expressing the relative size of a specific antenna's radiation pattern compared to that of an isotropic antenna. According to RG 1.180 Rev. 1, unintentional emitters (such as motors and welding machines) have an antenna gain less than 1, whereas intentional emitters(like radios and mobile phones) exhibit an antenna gain greater than 1.

Table I: List of Antenna Gain (Based on RG 1.180 Rev.1)

Classification	Antenna Gain(Gt)	
	[dBi]	[Dimensionless]
Motors and Welding Machines (unintentional)	less than 0	less than 1
radios and mobile phones (intentional)	Greater than 0	Greater than 1
Short Dipole Antenna	1.75	1.5
Monopole Antenna	4.77	3
Horn Antenna	7.78	6

In domestic NPPs, I&C instruments do not utilize antennas for wireless communication; hence, they fall under the category of unintended emitters according to RG 1.180. Consequently, the antenna gain should be considered as 1 or less conservatively. Therefore, we apply a value of 1.

2.3 Review of EIRP

EIRP (Effective Isotropic Radiated Power) is defined as the standard representing the power radiated in the maximum intensity direction from a transmission system, calculated either as the product or sum of Effective Radiated Power (P_t) and Antenna Gain (G_t), depending on the units used.

$$EIRP[W] = P_t[W] \times G_t \,/\, EIRP[dBm] = P_t[dBm] + G_t[dBi]$$

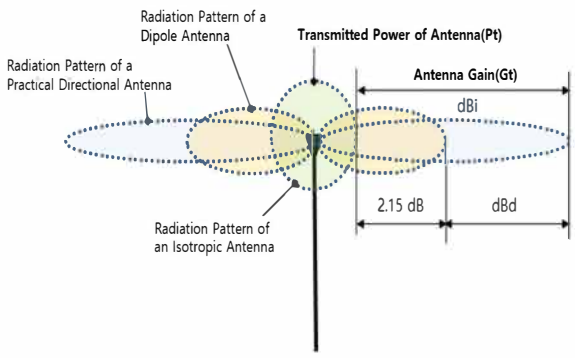

Fig. 1. Conceptual Diagram of EIRP

The maximum allowable EIRP for I&C equipment in NPPs must be smaller than that of wireless repeaters. Accordingly, we review:

① The maximum allowed EIRP for domestic wireless repeaters
② The maximum allowed EIRP in the EPRI ISM band
③ Overseas electromagnetic field radiation emission
④ Domestic electromagnetic field radiation emission

2.3.1 Maximum Allowable EIRP Limit for Domestic Wireless Repeaters

The maximum allowable EIRP for domestic wireless repeaters is set at 0.5 W (= 0.125 W x 4.0) according to domestic wireless technical standards (Wireless Equipment Regulations). This is computed from the maximum permissible effective radiated power (P_t) of 0.125 W and the maximum permissible antenna gain (G_t) of 4.0.

2.3.2 Maximum Allowable EIRP Limit in the EPRI ISM Band

EPRI restricts the maximum allowable EIRP for fixed wireless devices in the ISM band to 0.533 W at a separation distance of 1 meter. [Reference: EPRI TR-102323 Rev.5 Wireless Emission Management Guidelines (Appendix I)]

2.3.3 Measurement of Electromagnetic Field Radiation Emission Abroad (EPRI)

According to EPRI, the measured maximum electromagnetic field radiation emission(E) from four U.S. nuclear reactors was 0.25 V/m, occurring in the 7.2 GHz frequency band generated by the communications room microwave guide system[Reference: EPRI TR-102323 Rev.5].

Calculating the EIRP at a 1-meter separation distance using the control distance calculation method in RG 1.180 results in 0.002 W, which represents only 0.4% of the maximum allowable EIRP for wireless repeaters.

2.3.4 Measurement of Electric Field Radiation Emission in HANUL Unit 5

In HANUL Unit 5, the maximum electric field radiation(E) measured in the Main Control Room (MCR) and Electrical Equipment Room (EER) amounts to 0.16 V/m. This emission originates from the wireless keyboard in the main control room operating within the 2.4 GHz frequency band. [Measured by a domestic testing agency].

Calculating the EIRP at a 1 m separation distance based on the control distance calculation method in RG 1.180 for the maximum electric field radiation emission (0.16 V/m) yields 0.001 W, equivalent to just 0.2% of the maximum allowable EIRP for wireless repeaters.

Considering the possibility of incorporating wireless communication functions (IoT, AP) into I&C equipment, we conservatively apply the EPRI-approved EIRP value (533 mW) for wireless devices to the maximum EIRP for I&C.

2.4 Electromagnetic Field Radiation Immunity Level

To determine the controlled distance (separation distance) according to the calculations in Regulatory Guide (RG) 1.180, it is necessary to verify the allowable electromagnetic field radiation immunity level (E) of the I&C equipment.

For safety-related I&C equipment, prior to 1997, the electromagnetic field radiation immunity level for the RS103 test was verified at an immunity level of 5-10 V/m according to MIL-STD-461D (1993).

After 1997, according to EPRI TR-102323 Rev.0 (1997) and RG 1.180, RS103 was verified at an immunity level of 10 V/m.

For general I&C equipment, the National Radio Research Agency verifies the electromagnetic field radiation immunity level for the RS103 test at a minimum level of 3 V/m.

Consequently, for safety-related I&C equipment, RS103 is applied at 10V/m, and when the RS103 test is absent, the lowest immunity level of 3V/m is conservatively applied. In the existing RG 1.180 exclusion zone calculation method, an 8-dB margin is applied to the RS103 immunity level; thus, safety-related equipments apply a level 8 dB lower than the RS103 level(10V/m), resulting in 4V/m, while general devices conservatively apply a level 8 dB lower than the minimum immunity level(3V/m), resulting in 1.2 V/m.

2.5 Review of Separation Distance

For the Electromagnetic Field Radiation Emission Test (RE102), applying the maximum allowable EIRP of wireless repeaters (0.533 W) and the minimum allowable electromagnetic field radiation immunity level (1.2 V/m) in the calculation method of RG 1.180 shows that if separated by 3.3 meters or more, there will be no effect of electromagnetic waves.

By adding a conservative margin of 50% to the calculated minimum separation distance of 3.3m, setting the separation distance to 5m, and confirming that non-safety equipments can be exempted from the electromagnetic field radiation emission test (RE102) if they are separated by more than 5m from safety equipments because they leave the vicinity of the safety equipments according to RG 1.180.

3. Conclusion

The safety equipment in NPPs requires high reliability, hence the EMC validation methods, procedures, and results require high reliability. With the recent advancement of digital devices, various I&C installations inside the power plant have been improved with new equipment, significantly increasing the workload for EMC validation. Through this paper, it is expected to contribute to efficiently performing validations while maintaining high EMC reliability during the improvement of nuclear power plant equipment.

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REFERENCES

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