A Risk-Informed Approach for Managing EMC Equipment in NPPs Using EMCAM

Jongseong Bang , Hak kyu Lim*
KEPCO International Nuclear Graduate School, 658-91 Haemaji-ro, Seosaeng-myeon, Ulju-gun, Ulsan 45014, Korea
*Corresponding author: hklim@kings.ac.kr

***Keywords :** ElectroMagnetic Interference, ElectroMagnetic Compatibility, Risk-Informed, EMCAM

1. Introduction

With the increasing use of digital instrumentation and control (I&C) systems in nuclear power plants, the influence of electromagnetic interference (EMI) has become a critical consideration. To ensure electromagnetic compatibility (EMC), equipment qualification is conducted for newly introduced digital devices. In Korea, the regulatory guidance on EMC (KINS/RG-N03.09), issued in 2011, is largely aligned with the U.S. NRC Regulatory Guide 1.180 (Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems), first published in 2000.

In the United States, extensive utility feedback was incorporated prior to the implementation of the regulation, which resulted in the inclusion of the "No Backfitting" principle. In contrast, in Korea, several nuclear power plants received design approval prior to 2000, and therefore the EMC of digital I&C equipment in these facilities cannot be fully assured. Moreover, Korean nuclear power plants are subject to Periodic Safety Review (PSR). In accordance with KINS guidance, an electromagnetic environment assessment should be performed to identify potential EMI or power surge sources that may pose risks within the plant environment.

This paper introduces practical approaches for managing electromagnetic environments and equipment qualification of digital components in operating nuclear power plants. The proposed methodology builds on the risk-informed concepts presented in Electric Power Research Institute (EPRI) technical reports on digital engineering, with the aim of enhancing the effectiveness of EMI control and ensuring continued safety in legacy nuclear facilities.

2. Methods and Results

In this section, the Digital Engineering Framework (DEF) proposed by the Electric Power Research Institute (EPRI) is introduced and applied to operating nuclear power plants. The framework progresses sequentially through DEG–HAZCADS–DownProcesses (including EMCAM, HFAM, DRAM, and TAM).

The Digital Engineering Guide (DEG) is applied during the conceptual and detailed design phases of digital I&C systems, providing comprehensive design guidance. Within this framework, Hazards and Consequences Analysis for Digital Systems (HAZCADS) employs System-Theoretic Process Analysis (STPA) to perform a comprehensive risk assessment and derive Risk Reduction Targets (RRTs). The derived RRTs then serve as the basis for implementing risk-informed measures within each DownProcess.

This paper specifically introduces the Electromagnetic Compatibility Assessment Methodology (EMCAM), one of the DownProcesses, and proposes a practical approach for its application to operating nuclear power plants.

The Electromagnetic Compatibility Assessment Methodology (EMCAM) consists of four principal steps:

Step 1: Review EMC documents.

Step 2: Profile electromagnetic emission zones within the plant.

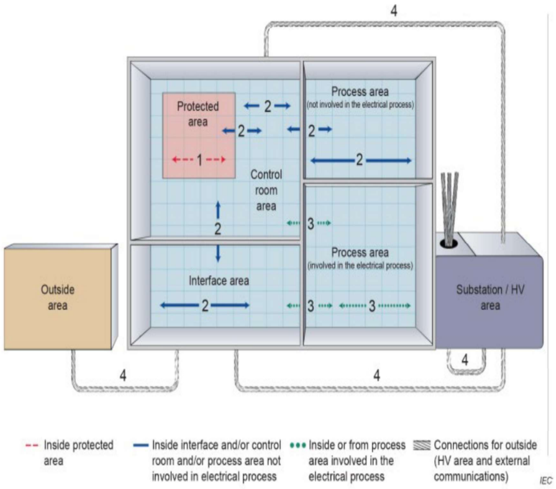
Step 3: Specify EMC acceptance criteria and scope based on the profiled zones and the Risk Reduction Targets (RRTs) derived from HAZCADS.

Step 4: Compare the existing EMC documentation against the EMCAM-recommended test scope and levels.

Through this process, the test scope and test levels can be selectively strengthened or relaxed depending on the electromagnetic emission zones of the plant and the safety significance of the digital I&C equipment. For Step 1, no additional measures are required for operating plants, since vendors are already obliged to submit the relevant documentation (e.g., CoC, EQ documents) during the procurement process. For Step 4, it should be noted that the test conditions introduced in EMCAM are relatively relaxed, as they are tailored to the zone classification and equipment importance, and are therefore less conservative compared to the qualification requirements already in practice.

Therefore, for operating nuclear power plants, it is proposed to apply EMCAM primarily through Step 2 (zoning of plant areas) and Step 3 (determination of test levels).

Area	Plant Room or Area
4	Switchyard, SAT, UAT, etc.
3	MCC, Large pump rooms, Generator, etc.
2	RSP, MCR PNLs, UPS, Cable spreading Room, etc.
1	Computer rooms, Network Rooms, EER rooms, etc.



Once the target equipment has been categorized according to the zones defined in EMCAM, its safety significance can be further classified using the Risk Reduction Targets (RRTs) derived from HAZCADS. In this framework, EMCAM assumes that equipment associated with higher RRT values identified through HAZCADS risk analysis should be considered of higher importance.

For operating nuclear power plants, however, conducting a full DEG–HAZCADS risk analysis may not be practical. As an alternative, the importance of EMC-relevant equipment can be determined using Probabilistic Risk Assessment (PRA) significance measures. By integrating PRA insights into the EMCAM process, risk-informed prioritization of equipment can be achieved.

It is therefore proposed that operating plants adopt an EMC monitoring and management scheme by combining electromagnetic emission zoning (as recommended by EMCAM) with importance classification of equipment (based on PRA analysis). This approach enables the establishment of a systematic electromagnetic field monitoring framework tailored to actual plant conditions.

The zones can be broadly categorized into four types:

1) High-importance equipment located in high-field environments.

2) Low-importance equipment located in high-field environments.

3) High-importance equipment located in low-field environments.

4) Low-importance equipment located in low-field environments.

Such a classification provides a practical basis for strengthening or relaxing EMC test levels and surveillance measures depending on both the environmental exposure and the safety significance of the equipment.

For Zone 1 (high-importance equipment in high-field environments), establishing a long-term electromagnetic field monitoring system—such as those recommended by AMS—would allow effective surveillance. This approach facilitates the early detection of malfunctions or performance degradation in high-importance equipment caused by excessive electromagnetic interference.

For Zones 2 and 3, periodic evaluations of the plant's electromagnetic environment should be conducted in accordance with the Periodic Safety Review (PSR) cycle. This ensures that any long-term changes or anomalies in the electromagnetic environment during plant operation can be systematically identified and addressed.

For Zone 4 (low-importance equipment in low-field environments), the impact of electromagnetic emissions and susceptibility is expected to be negligible. Consequently, digital I&C equipment in this zone may reasonably be excluded from the list of EMC management targets.

Moreover, it should be recognized that the electromagnetic emissions of digital I&C devices may increase over extended operational periods due to filter degradation, shielding damage, or grounding deterioration. The proposed classification and monitoring approach therefore also supports an aging management strategy for digital devices, ensuring both their continued EMC performance and their reliability over the long term.

3. Conclusions

Korean nuclear power plants that were not subject to EMC regulatory requirements at the time of initial construction are now required to perform Periodic Safety Reviews (PSR). If operating plants classify the zones where electromagnetic emissions are actually significant, and manage the emission environment by also considering the safety importance of each device, this would result in a more practical and risk-informed management framework for electromagnetic compatibility.

Acknowledgement

This research was supported by the 2025 Research Fund of KEPCO International Nuclear Graduate School, the Republic of Korea

REFERENCES

[1] Electric Power Research Institute (EPRI), Electromagnetic Compatibility Assessment Methodology (EMCAM): Revision 0, Palo Alto, CA: EPRI, Oct. 2023. Report No. 3002023743

[2] U.S. Nuclear Regulatory Commission (NRC), Regulatory Guide 1.180: Guidelines for Evaluating Electromagnetic and Radio-Frequency Interference in Safety-Related Instrumentation and Control Systems, Rev. 2, Washington, DC: NRC, Oct. 2023.

[3] Korea Institute of Nuclear Safety (KINS), 안전관련 계측 및 전기기기의 전자파 장해에 대한 검증 (Verification of Electromagnetic Interference for Safety-Related

Instrumentation and Electrical Equipment), KINS/RG-N03.09, Rev. 3, Daejeon, South Korea: KINS, Dec. 2019.
[4] M.F. Berg, C.J. Kiger, and T.S. Gavin, “Automated System to Characterize Electromagnetic Environments in Nuclear Power Plants,” in Proc. 2021 ANS Winter Meeting, Washington, DC, USA, Nov. 2021, pp. 278–280, doi: 10.13182/T125-37044.