Development of Design Information Template for Nuclear Power Plants for Electromagnetic Pulse (EMP) Effect Analysis

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1. Introduction

An electromagnetic pulse (EMP) is a transient electromagnetic shock wave that has powerful electric and magnetic fields that can destroy electronic equipment. It is generally well-known that EMPs can cause the malfunction and disorder of electronic equipment and serious damages to electric power systems and communication networks. Yet, little analysis and research have been devoted to the EMP effect. Hence, it is necessary to plan safety measures for domestic nuclear power plants. Research is being carried out to protect nuclear power plants (NPPs) from EMP threats. Penetration routes of EMPs can be roughly categorized into two groups, radioactivity and conductivity. The penetration route is shown in Figure 1 [1]. The radioactive effect refers to an impact transmitted to the ground from high-altitude electromagnetic pulses (HEMP). Such an impact may affect target equipment through the point of entry (POE) of the concrete structure of an NPP. The conductive effect refers to induced voltage or current coupled to the NPPs cable structure. The induced voltage and current affect the target equipment via connected cables. All these factors must be considered when taking into account EMP effect analysis for NPPs. To examine all factors, it is necessary to fully understand the schemes of NPPs.

This paper presents a four type design information template that can be used to analyze the EMP effect in operating nuclear power plants.

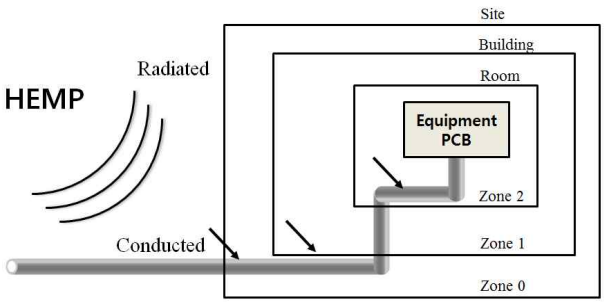

Fig 1. EMP penetration route

2. Purpose of Template Development

2.1 Creation of Interface Block diagram

Prior investigation of NPP complex systems must be used as precedent for any analysis of the EMP effect. One example of such study comes from the US Nuclear Regulatory Commission, which proceeded with the creation of block diagrams of NPP system interfaces as can be seen in Figure 2 [2]. Likewise, the creation of interface block diagrams should come prior to any effect analysis of EMPs in domestic nuclear power plants.

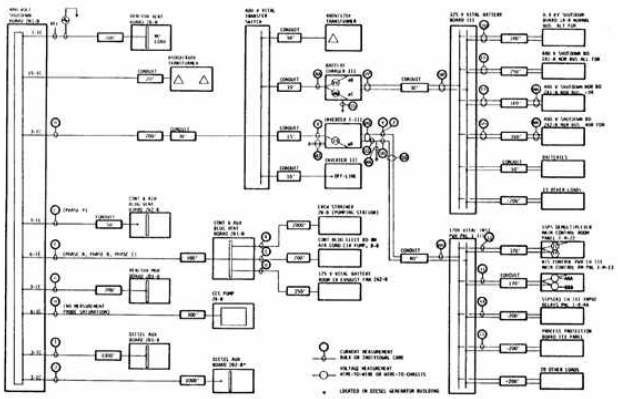

Fig 2. Block diagram of NUREG/CR-3069

2.2 Simulation of radioactivity and conductivity of EMP

An EMP is able to penetrate through the POE and the building of an NPP concrete structure. It can adversely affect target equipment that is coupled to internal circuits. Therefore, simulation to confirm the shielding effectiveness (SE) of the structure is required. The simulation software for radioactive EMPs calculates the shielding effect using 3D FIM (Finite Integration Method) modeling of the concrete structure and plant information. For the shielding effectiveness simulation, it is required to obtain design information such as installation positions, the inside and outer wall sizes, the material properties, and the POE shape.

The simulation of a conductive EMP signal can be performed to identify the coupled conductive effect. To verify the conductive effect of an EMP, the signal level can be simulated using coupled power line or cables. The simulation of a conductive EMP signal can be performed by dividing the analysis region and configuring the network using 2D commercial software. There are various needs for basic design information, such as the length and thickness of the cables, and the power of the signal.

2.3 Radioactive and Conductive Tests of EMP

The corresponding test will proceed on the basis of the simulation results shown in Table 1 [3-4]. For the measurement of the shielding effectiveness of the installed position, the nuclear power plant design information is required for radioactive testing. This information is also required for the conductive test to measure the signal transmitted through the cables.

Table 1. Radioactive and Conductive Test Methods

NUREG/CR-3069	The corresponding test methods
CW direct injection Test	BCI test(MIL-STD-461F)
Inadvertent Penetration Test	CWI test(MIL-STD-188-125-1)
Facility Insertion Loss Measurements	SE test(MIL-STD-188-125-1)

3. Design Information Template of NPP

The design information template for NPP EMP effect analysis was developed into the four types shown in Figure 3.

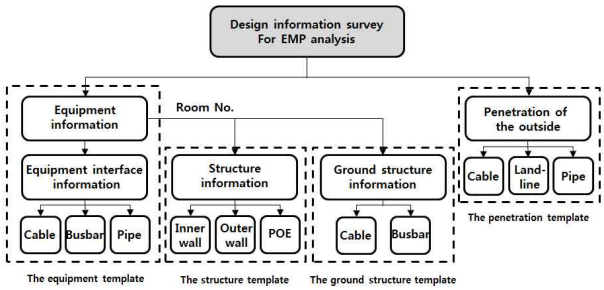

Fig 3. Composition of Design Information Template of NPP

The contents of the template are shown in Table 2. The equipment template includes the room number, the tolerance information and information on the system interface. Also, it will be able to verify the conductive EMP threat level through the interface survey.

Table 2. Contents of the Template

Sort	Contents
Equipment	o Radioactive and conductive tolerance information o Interface information for conductive threat level
Structure	o Structural design information for shielding effectiveness
Ground structure	o Ground structure information o Signal ground and power ground
Penetration of the outside	o Signal level can be simulated by power line or coupled cables

To analyze the shielding effectiveness, the target structure template is composed of the structural design information and the POE information. The information that can be investigated using this template, such as information about the lining, outer walls, POE, and ground, will be used to perform the shielding effectiveness simulation and test.

The ground structure template includes the ground information of the room holding the selected equipment. The ground information such as information on cables, busbars, and the main ground method will be utilized in the conductive EMP simulation and test.

The penetration model of the outside template includes the conductive path information. Through this template, the conductive EMP threat level can be identified using coupled cables and pipes.

Table 3 shows the ground structure template design information.

Table 3. Ground Structure Template

Template Item		Template Item	
Room number		Outside exposure	
Composition		Main ground connection method	
Insulation		Busbar	Floor plan
Cable	Floor plan		Thickness/Width
	Specifications		Length
	Thickness/Width		Material
	Length		Inlet/Outlet
	Inlet/Outlet		

4. Conclusion

In order to analyze of the effects of EMPs on operating NPPs, we must consider both the conductive and radioactive effects on the target (system, equipment, structure). For these reasons, not only the equipment information, but also the information about the structure and the external penetration will be required. We are developing a design information template for robust nuclear design information acquisition. We expect to develop a block diagram on the basis of the template. Also, conductive and radioactive simulation and tests will be conducted for the cables and for the ground information. Through the developed design information template, it will be possible to perform analysis of EMP effects on NPPs; from there, it will be possible to establish the measures.

REFERENCES

[1] IEC 61000-5-9
[2] NUREG/CR-3069, Interaction of Electromagnetic Pulse with Commercial Nuclear Power Plants, Feb 1983.
[3] MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, Dec 2007.
[4] MIL-STD-188-125-1, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Based C4I Facilities Performing