Analysis of EMP Shielding Performance for Nuclear Power Plant Structures using Simulation

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1. Introduction

The nuclear power plant structures performance can be analyzed through actual testing to determine the EMP(Electromagnetic pulse) shielding performance for nuclear power plant structures [1,2] In the case of nuclear power plants in operation, the simulation of EMP could lead to the risk of control device failure, which led to the study of shielding performance analysis of the nuclear power plant structures to ensure the safety of control devices operating at low voltages within the plant structure.
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2. Methods and Results

3D modeling of nuclear power plant structures is required to obtain the energy delivered to the control equipment. The wall is 3 m × 3 m size, which is the size of the test area set-up condition in MIL-STD-188-125-1, modeled as a network structure in which two thick bars are longitudinal and four thin bars are arranged laterally based on detailed design information such as [3], rebar structure, etc.

Material information used in shielding performance is shown in Table 2-1, and material information extracted from 40-year-old concrete in the case of nuclear power plant structures is applied to assume Steel-1010, which uses data provided by CST Corporation's Microwave Studio Tool. CST Company's Microwave Studio Tool is a program that can perform 3D electromagnetic field analysis of various high-frequency components used in the range of several MHz to several THz, and it is also utilized in electromagnetic wave research for shielding performance analysis.

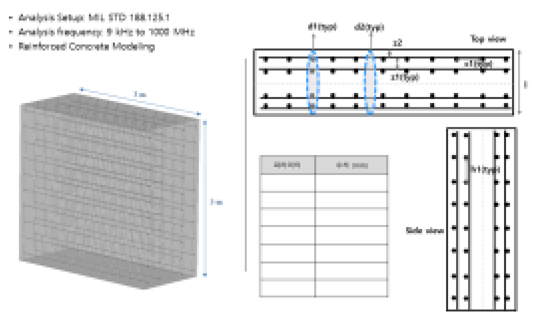


Fig. 2-1. Modeling Nuclear Power plant

Table 2-1 Material Information of Concrete and Reinforcement Used in Simulation

	Material Concrete (forty years old)	Material Steel-1010
Type	Normal	Lossy metal
Mue.	1	1
El. cond.	-	6.993e+06 [S/m]
Rho	2400 [kg/m^3]	7870 [kg/m^3]
Therm. cond.	1.7 [W/K/m]	65.2 [W/K/m]
Heat cap.	0.8 [kJ/K/kg]	0.45 [kJ/K/kg]
Diffusivity	8.85417e-07 [m^2/s]	1.84103e-05 [m^2/s]
Young's Mod.	30 [kN/mm^2]	205 [kN/mm^2]
Poiss. Ratio	0.2	0.29
Thermal Exp.	13 [1e-6/K]	13.5 [1e-6/K]

Were composed of the same distance and the shielding effect test standard in typical C4I conditions of MIL-STD-188-125-1 for the evaluation of the major military to calculate the energy to reach through the nuclear structure to control devices[4,5], The plane wave was applied in place of the antenna, and a 1.5 m height probe was placed on the opposite side of the structure to check the transmitted field strength. First, obtain a Reference value in the absence of nuclear superstructure, ask the transfer function of the state where the nuclear structure is inserted at the same distance, the value for the shielding performance of the nuclear power plant structure emerges as shown in Fig. 2-2. This value is the difference between the values pass the reference level and nuclear structure in accordance with formula (3-1) may know that the shielding performance of the nuclear structure.

$$SE(dB) = 20\log V_{ref} - 20\log V_{trans} \quad (3\text{-}1)$$

- V_{ref} : Reference Levels (Reference), V_{trans} : value passed through the nuclear structure

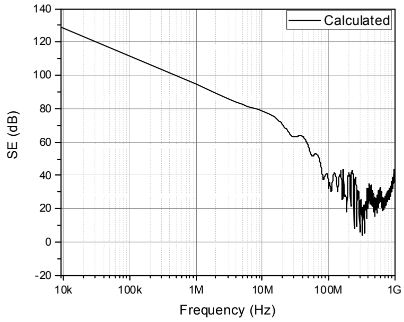
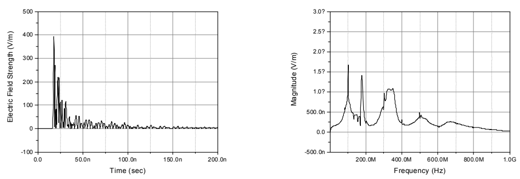


Fig. 2-2. Shielding performance of reinforced concrete structures

The intensity of the electric field when the modeled EMP source is passed through one wall is shown in Fig. 3-2. EMP waveform was assumed to be a plane wave incident on the transmission type from a distance, the size was set to 50 kV / m [7]. The distance was set to 3 m of the probe to the monitor through the nuclear structure in the original source. Most control units are located more than 3 m away from the outermost nuclear power plant.

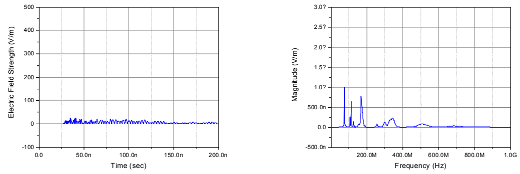
Also, The nuclear power plant in which the control units are located is protected by at least one to four nuclear power plants. The distance from the outermost nuclear power plant structure to the control device is not taken into account. Since the electromagnetic field decreases in proportion to the distance, the actual transmitted field strength is expected to be smaller than the simulation results.

The source used for the simulation was the 50 kV / m E1 waveform of IEC 61000-2-9 as a waveform representing the intensity of the field strength in the time domain. The electric field strength passed through the nuclear power plant structure is shown in Fig. 2-3. Fig. 2-4. shows 26.5 V / m through two nuclear power plant structures. Fig. 2-5. confirms the decrease of 0.467 V / m through four nuclear power plant structures.



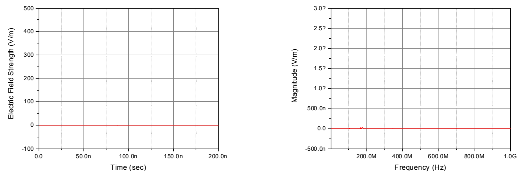
(a) Time domain (b) Frequency domain

Fig. 2-3. Field strength through nuclear power plant structure (one wall)



(a) Time domain (b) Frequency domain

Fig. 2-4. Field strength through nuclear power plant structure (Two wall)



(a) Time domain (b) Frequency domain

Fig. 2-5. Field strength through nuclear power plant structure (Four walls)

As can be seen from the time-domain and frequency-domain waveforms, the peak value of the electric field strength according to the number of passages of the nuclear power plant structure was found to decrease rapidly as the number of passes of the nuclear power plant structure increased.

3. Conclusions

Analysis result of shielding performance through simulation Input of 50kV / m E1 the waveform is 394.1 V / m when passing one nuclear power plant structure, 26.5 V / m when passing two, 0.467 V / m when passing four. It was confirmed to decrease. The more the number of passes of nuclear structure and the electric field intensity is drastically reduced, it can be seen that convergence to 0 V / m From after passing through the four or more nuclear structures. The shielding performance results through analysis of nuclear material structures could be used as an important material for future nuclear constructions.

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