An Approach for Effect Analysis of Electromagnetic Pulsein Operating NPPs

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1. Introduction

Recently, there is a growing Electromagnetic Pulse (EMP) threat caused by North Korea's nuclear weapons and unmanned aerial vehicles (UAVs).

KHNP CRI is currently conducting a research project that will evaluate the safety of domestic nuclear power plants (NPPs) against EMP effects and prepare safety measures to counter vulnerable points.

However, it is not possible to directly evaluate EMP impact on operating NPPs. We will instead use simulation tools to evaluate the electromagnetic shielding ability and the conductivity of cables through vulnerable points in NPPs.

Through a study of electromagnetic simulation techniques and tools, this paper suggests a simulation method for analysis of EMP effects in operating NPPs.

2. Review of EMP Simulations

In general, 3D full wave simulation tools (3D tools) are mainly used for electromagnetic field analysis. Because 3D tools use a variety of numerical analysis methods to divide target models into small sizes, these tools can be used to provide relatively accurate analysis. However, 3D tools have a problem in that they require too much run time in cases of analyzing huge and complex models. Because of limited computer performance, it is practically impossible to use only 3D tools to perform EMP analysis of huge and complex structures.

Huge and complex structures can be analyzed by a simulation tool called the Electromagnetic Topology (EMT) tool. This EMT tool is capable of rapid analysis because it can simplify huge and complex structures into 2D models. However, this tool is less accurate than 3D tools because it uses simplified models.

Using the EMT tool, we will simplify the NPPs into 2D models, analyze the conduction path, and search for points that are vulnerable to EMP threat; then, using a 3D tool, we will proceed with a detailed analysis at the system level to find vulnerable points.

3. Method of EMP simulation

This chapter introduces numerical analysis techniques that can be used with simulation tools and suggests ways of using simulation tools to simulate the analysis of EMP effects using simulation tools.

3.1. EMT simulation

The EMT divides huge and complex systems into EMT networks and analyzes the electromagnetic effects[2].

EMT networks are made up of combinations of junctions and tubes, as shown in Figure 1. In Figure 1, the letter J represents a junction and the letter T represents a tube. A junction is located at the boundary of a segmented analysis region; a tube is a passage of electromagnetic power flow between junctions.

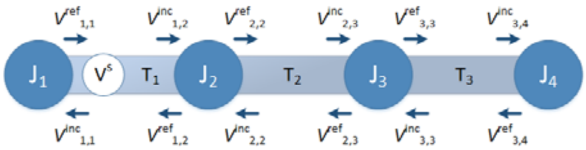

Fig. 1. Flow diagram of signal in EMT network

The EMT tool can quickly analyze the penetration path of EMP threats and the conduction to cables exposed outside the building of NPPs.

The conductive EMP threat signal may be different depending on the impedance between the source and the load the shielding performance of the cables, and the conductivity of the cables; through the simulation of this system, the effect of the conductivity to the target device can be deduced. In order to trace the EMP penetration path, Figure 2 shows an EMT model changed into an EMT network for a building.

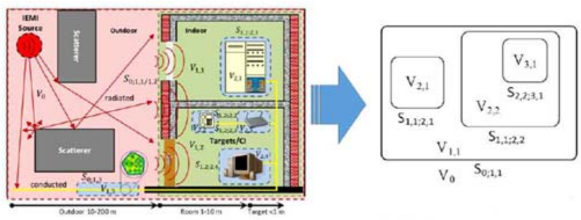

Fig. 2. EMT conversion of building

3.2.3D Full wave simulation

There are a variety of techniques for 3D full wave simulation. The standard techniques are MoM, FEM, FDTD, and FIM. The Method of Moment(MoM) has good performance for analyzing huge structures; however, it is less accurate for analyzing complex systems that include small objects. The Finite element method(FEM) can be used to obtain the most accurate solutions from electromagnetic numerical methods. However, the time of analysis for complex and huge structures is longer than it is for other techniques.The Finite-Difference Time Domain (FDTD) method has the advantage that it can be easily implemented with simplicity and possible parallel computation. However, FDTD has a disadvantage in that it requires a long time for analysis. The Finite Integration Method(FIM) can accurately implement complex shapes and researchers can easily know the results because the analysis takes place in the time domain. However, if a wrong mesh value is set, this method can be less accurate than other tools.

The 3D tool, which makes it possible to interpret the system level, is used to determine the shielding effect of a structure. The radiated threat of an EMP signal transmitted in the air is transmitted at a reduced level to the target devices in the room[3]. The shielding performance is called the attenuation of the radiated threat, and is defined as the damping ratio, as in Equation (1).

$$SE = 20\log_{10}\left(\frac{V_C}{V_M}\right) \quad (1)$$

The damping ratio is calculated as the ratio of V_C to V_M. V_C is the intensity of the signal received in the absence of shielding. V_M is the intensity of the signal received in the shielded area.

Figure 3 shows a 3D model of a reinforced structure. The shielding effect of the reinforced structure is different depending on the thickness, the distance of the reinforcement, and the properties of the concrete.

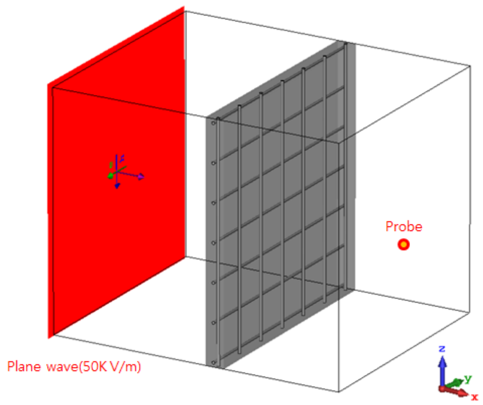

Fig.3. Simulation of reinforced structure

4. Conclusions

Although 3D tools are relatively accurate, is difficult to use only 3D tools to simulate EMP effects for huge and complex structures such as NPPs. It is more efficient in terms of cost and time to use a 3D tool and an EMT tool for the simulation of such structures. We have compared the advantages and disadvantages of various methods and have selected the most appropriate tools; we will proceed in our next paper with the simulation of EMP effects.

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