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The Field Test Methods for the Effect Analysis of Electromagnetic Pulse (EMP) in Operating Nuclear Power Plants

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1. Introduction

The EMP field test measures the transfer characteristics in which the external electromagnetic pulse (EMP) threat is coupled internally in the EMP impact assessment of operating NPPs. The EMP transfer characteristics are classified into radiation and conductivity depending on the propagation path. Radiative transmission characteristics measure the local shielding effectiveness, while the conductive transmission characteristics measure the cable path's loss. The EMP field test also includes a continuous wave inflow test to verify the current generated by the external radiated electromagnetic field is coupled to the internal cable. Since the physical size of a nuclear power plant is very large and the use of high-frequency signals in the nuclear power plant is strictly restricted, it is practically difficult to evaluate the EMP transfer characteristics by using a high-level EMP signal. In this paper, we propose field test methods to evaluate the EMP transfer characteristics that consider these limitations. These tests measure the local wall's shielding effectiveness and the attenuation characteristics of some cables at various test points by using low-level continuous-wave electromagnetic waves based on relevant technical requirements.

2. EMP Field Test Methods

Radiation transfer characteristics measure the local shielding effectiveness to measure the penetration (transfer) of external EMP threats into the interior. The EMP conductive transmission characteristics measure the path loss of the cable. In addition, a local continuous wave inflow test is performed to confirm the current generated by the external radiated electromagnetic field is coupled to the internal cable.

2.1 The local shielding effectiveness tests of structures

The shielding effect of a structure is defined as the ratio of signal strength received in the absence of a wall to that of the wall, expressed in dB.

$$SE = 20\log_{10}\left(\frac{V_c}{V_m}\right) \tag{1}$$

V_c : Signal strength received without wall
Vm : Signal strength received through the wall

The local shielding effectiveness measurement is shown in the following figure. A signal generator and a transmission antenna are installed outside the structure, and a reception antenna and a reception spectrum analyzer are installed in the structure to apply a low-level electromagnetic field from the outside. This test measures an internal electromagnetic field passing through the structure.

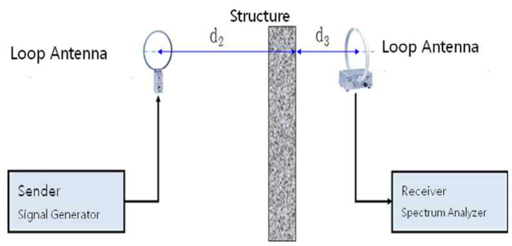

Fig. 1. The measurement diagram of shielding effectiveness at a low frequency band (10kHz~20MHz)

The shielding effect measurement shall be carried out for the frequency band from 10 kHz to 1 GHz. The 10 ㎑ ~ 20 ㎒ frequency band covers the magnetic shielding effect, the 20 ㎒ ~ 100 ㎒ frequency band covers the resonance frequency shielding effect, and the 20 ㎒ ~ 1 ㎓ frequency band covers the plane wave shielding effect. The minimum required sampling frequency of the measured frequency is shown in the following table.

Table I: The Measurement Frequency of Shielding Effect

Measurement frequency band	Frequency number
10 kHz ~ 100kHz	20
100 kHz ~ 1MHz	20
1 MHz ~ 10MHz	40
10 MHz ~ 100MHz	150
100MHz ~1 GHz	150

For the test setup, the input power of the antenna is set to 0dBm (1mW) for the biconical and logperiodic antennas. The input power of the loop antenna is also set to 20dBm (100mW) because the antenna factor value is low.

2.2 Cable path loss test

The cable path loss measurement is measured by connecting the signal generator to the test cable located on the load center side via the amplifier and attenuator, as shown in Figure 2. The receiver spectrum analyzer is connected to the load side of the cable for the test. If the signal is attenuated and resolution is not ensured, the signal level shall be increased. There is no effect on the target device during the test because the load cable is disconnected to the cable and the 48V load center.

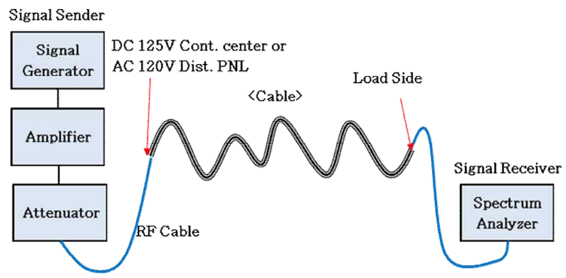

Fig. 2. The test diagram of cable path loss

At this time, the output of the applied signal is 0dBm (1mW), and the maximum current is 4.5mA when the termination resistance is assumed to be 50 Ω. The test is performed at the frequency band of 10 kHz to 1 GHz, as shown in Table Ⅱ.

Table Ⅱ: Conductivity path loss measurement frequency

Measurement frequency band	Increase width	Frequency number
10kHz-99kHz	1kHz	90
100kHz-990kHz	10kHz	90
1MHz-9.9MHz	100kHz	90
10MHz-199MHz	1MHz	191
200MHz-1GHz	10 MHz	90

2.3 Local continuous wave inflow test

In order to measure the penetration (transmission) of external EMP threats, a local continuous wave inflow test is carried out to confirm the current in which the external radiated electromagnetic field is coupled to the internal cable at a frequency range of 10 ㎑ kHz to 1 ㎓ GHz. The strength of the applied electromagnetic field is the same as the local shielding effectiveness test procedure, and the technical document refers to MIL-STD-188-125-1[4]. The local continuous wave inflow test measures the current in which an external radiated electromagnetic field passes through the structure and is directly coupled to the cable inside the structure.

3. Conclusions

The physical size of a nuclear power plant is very large and the use of high-frequency signals in the nuclear power plant is strictly restricted, making it is practically difficult to evaluate the EMP transfer characteristics using a high-level EMP signal. Therefore, EMP field tests should be carried out during the overhaul period of the nuclear power plants. The measured shielding effect will be compared with the simulation results to identify weak points in the walls and openings. The test results of the structure shielding effectiveness and cable path loss are used to predict the actual radiated and conducted EMP threat level in the room where the object device is located.

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