Transactions of the Korean Nuclear Society Autumn Meeting
Goyang, Korea, October 24-25, 2019

Review for Analysis of Electromagnetic pulse(EMP) Effect in Nuclear Power Plants

Bum-suk Jang[1*], Chang-ho Sohn[1], Kyung-min Lee[2]
[1]R&D center, HanvitPower Inc., Yuseong-gu, Daejeon, Korea
[2]Chungnam National University, Yuseong-gu, Daejeon, Korea
[*]*Corresponding author : lohgbow@hanvitpower.com, lohgbow@hanmail.net*

1. Introduction

This study is intended to determine whether the external electromagnetic waves, such as electromagnetic pulse could affect nuclear power plants.

Electromagnetic pulse(EMP) effects can be divided into radiative and conductive, and radiative paths are transmitted through the space and affect through the openings of the structure and through the concrete structure. The conductive path affects the logic operating device by electromagnetic pulses induced by voltage or current through power cable, control cable, etc.[1].

2. Method

This study refers to NUREG / CR-3069, ITU-T K.81, and IEC 61000-5-9, an international study on electromagnetic pulses [2, 3, 4]. The evaluation criteria were established in order of definition of threat level of external electromagnetic pulse, analysis of coupling to logic operating device through evaluation of electromagnetic pulse transmission path of nuclear power plant, and damage level of electromagnetic pulse. We approached the process of assessing the impact by analyzing the data obtained in each process. Electromagnetic pulse threat level standards are separated by copied and conducting threat and radiated threat IEC 61000-2-9, Mil-Std-461F standards related to conducting threat IEC 61000-2-10, Mil-Std-188-125 -1 The standard was set based on the threat level [5, 6, 7].

2-1 Radiated Threat Level Criteria

The Radiated threat level criteria are defined in IEC 61000-2-9 international standard for radionuclides at higher altitudes than 30 km, and the same parameters for radiated electromagnetic pulses are specified in the RS105 test for Mil-Std-461F [5,6,7]. The radiated threat level criterion for electromagnetic pulse effects is the pulse field of a double exponential waveform, as shown in Fig. 2-1. with the parameters of Table 2-1.

Table 2-1. Radiated threat level criteria

Classify	Rise time	Pulse width	E/H	Peak value electric field intensity
Early-time	2.5ns	23ns	377Ω	50kV/m

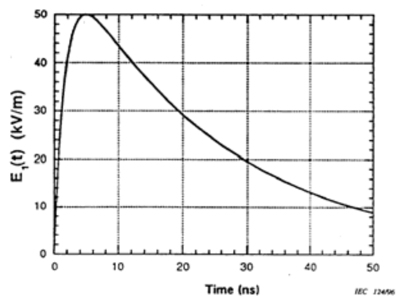

Fig. 2-1. Radiated threat level reference waveform

2-2 Conductivity Threat Level Criteria

Conductive threat level criteria are caused at high altitude by a nuclear explosion is defined in the international standard IEC 61000-2-10 conductively induced in the power cables and communication cables [8]. Conductive threat level standard was used for the parameters specified in the strictest Mil-Std-188-125-1. Fig. 2-2. shows the waveform of the double exponential function, which is divided into the initial electromagnetic pulse waveform and the mid-term electromagnetic pulse waveform. Each parameter is shown in Table 2-2. This criterion is applicable to cables exposed outside of nuclear power plant structures.

Table 2-2. Conductive threat level criteria

Classify	Rise time	Pulse width	source impedance	peak value current
Early-time	20ns Less	500ns ±10%	60Ω	5kA±10%
Intermediate - time	1.5us± 30%	4ms±2 5%	10Ω	250A±10 %

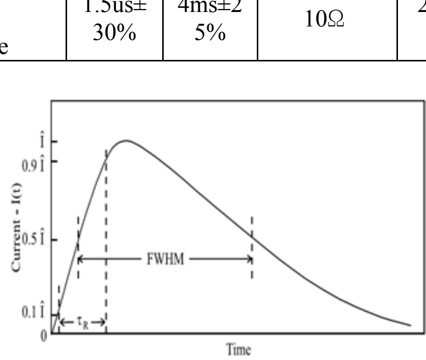

Fig. 2-2. Conductive threat level reference waveform

$$I_{(t)} = K_{DE}\hat{I}(e^{-\beta t} - e^{-\alpha t}) \qquad (2\text{-}2)$$

Here, the maximum instantaneous current, (t) is the time (s), K_{DE}, α, β are a function of the FWHM, the time it takes to rise from 10% of the maximum current up to 90%, FWHM is 50% of the maximum current It indicates the time (pulse width) between the branches [13]

3. Results and Discussions

3-1 Radiated effect analysis

The minimum number of formations passing logical operation device through simulation is calculated by multiplying the back shielding performance was analyzed using the design data. Source used for the simulation is analyzed by a waveform showing an electric field intensity in a time domain representation to Fig. 3-1. by applying the waveform E1 of IEC 61000-2-9.

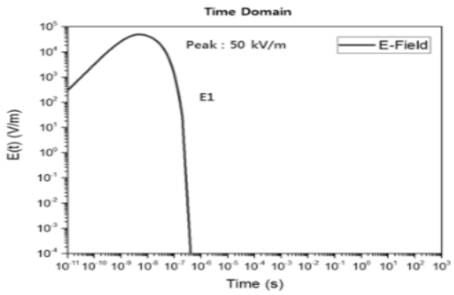

Fig. 3-1. Source wave form for radiated simulation

3-2 conductivity effect analysis

Using the Mil-Std-188-125-1, PCI waveforms for the logic operating equipment, the immunity levels for the components are analyzed. In order to apply the setting criteria, the transformer's noise calculation, cable cross-sectional allowable current and cable length were examined. As a result of the frequency response obtained through the conductive threat level based on the simulation and testing to establish a conductive path from the frequency response characteristics can be used to calculate the conductivity of the threat level to the control unit. Further, as compared with the resistance level of controlled device obtained through the test was an electromagnetic pulse effect analysis.

3-3 Part resistance level analysis

Resistance tests were analyzed using the same physical board or component used in nuclear power plants. The lower power input electromagnetic pulse signal (Mil-Std-461F CS115, it was the resistance test to the pulse from the A 5 1 A in accordance with the evaluation criteria of the CS116. Signal of the PCI test of Mil-Std-188-125-1) The low levels of the board or components were analyzed progressively from level to 1 kA.

3-4 Effect Analysis Comparison

Effects were analyzed by comparing the current conductive transfer parts broken current delivered to the logic operation unit through the simulation. Conducting the safety margin of the logical operation device can be determined by applying a transfer current and a current break in the formula (3-1),

$$\text{conductive safety margin} = 20_{\log}\frac{\text{damaged current}}{\text{transfer current}}[dB] \qquad (3\text{-}1)$$

4. Conclusions

A study was conducted to analyze whether electromagnetic pulses could affect nuclear power plants. For the analysis of logic operating devices, the evaluation control board, external electromagnetic pulse threat level definition, coupling analysis to control devices through electromagnetic pulse transmission path evaluation, damage level evaluation, and data obtained from each process are analyzed and compared to analyze the impact of electromagnetic pulse. It summarizes the conclusions on the impact of conducted and radiated electromagnetic pulses evaluated through a process of analysis.

We have experienced copy effects logical operation device depend on a structure which is protected by a reinforced concrete structure at least a number of shielding, radiated electromagnetic pulse level to penetrate into the interior structure has been determined to be lower.

Conductive threat voltage level look at the conductive effect is transmitted to the logic operation unit, the current threat level, the peak value was confirmed to be very low when compared with the resistance level of the control board a DC-DC converter of the conductive threat level that is passed to the control unit.

Results safety margin the breakage current and current delivered when compared to the resistance level and the threat level of the logical operation unit is applied to the calculation showed a sufficient resistance to electromagnetic pulse threat level that is passed through a conductive path to a positive value.

Therefore, considering the analysis of the effects of the radiated and conductive electromagnetic pulses, we analyzed the results of the simulation that there was no effect on the operation function of the logic operation device when electromagnetic pulses were generated. Even if exposed to, it could be confirmed that there is no problem in maintaining safety.

REFERENCES

[1] Jeahoon Cho, "Conducted and Radiated Coupling Analysis under High-Altitude Electromagnetic Pulse (HEMP) Environment" pp. 2-3, Feb. 2015.
[2] NUREG/CR-3069, SAN D&2-2738/2, "Interaction of Electromagnetic Pulse with Commercial Nuclear Power Plant Systems,"
[3] IEC 61000-5-9, "System-level susceptibility assessments for HEMP and HPEM,"
[4] ITU-T K.81, "High-power electromagnetic immunity guide for telecommunication systems,"
[5] IEC 61000-2-9, "Description of HEMP Environment – Radiated Disturbance," Feb. 1996.
[6] MIL-STD-461F, Requirements for the Control of Electromagnetic Interference Characteristics of Subsystems and Equipment, 10 Dec 2007.
[7] MIL-STD-188-125-1, High-Altitude Electromagnetic Pulse (HEMP) Protection for Ground-Base C4I Facilities Performing Critical, Time-Urgent Missions, 7 Apr 2005.
[8] IEC 61000-2-10, "Description of HEMP Environment – Conducted Disturbance," Nov. 1998.
[9] YoungJin Kim, "Assessment and analysis of the performance of EMP filters for protective facilities," pp. 14, Aug. 2005.
[10] ORNL-5029, The Effects of Nuclear Electromagnetic Pulse (EMP) on Nuclear Power Plants, September 1977.
[11] MIL-STD-461C, Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference, 4 August 1986.
[12] Meta-R320, "The Early-Time (E1) High-Altitude Electromagnetic Pulse (HEMP) and Its Impact on the U.S. Power Grid," Jan. 2010.
[13] EPRI, 2011. EMC/EMI/RFI Training material Knoxiville TN Facility