A Study on the Technical Standards for EMP Effect Analysis of NPPs

Minyi Kim[a]*, Songhae Ye[a], Hyunki Kim[a]
[a]Central Research Institute, KHNP, 1312 Beon-gil, Yuseong-daero, Yuseong-gu, Daejeon, 34101, South Korea
*Corresponding author: kimmy611@khnp.co.kr

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 unintended external EMP attacks can cause the malfunction and disorder of electronic equipment and serious damages to electric power systems and communication networks. Yet, there is no standard that can be used to analyze the EMP effect for national infrastructure facilities such as nuclear power plants (NPPs). Hence, it is necessary to review and summarize international EMP technical standards for effect analysis of NPPs.

This paper provides review results of EMP environment technical standards that can be applied to analyze the EMP effect in operating nuclear power plants.

2. Status of Technical standards for EMP

2.1 EMP radiated environment standards

In the 1960s, the first openly published Bell Lab's EMP E1 waveform used the slowest and the widest pulse calculated [1]. However, that waveform cannot happen. The overall trend appears to indicate that the newer HEMP E1 environments tend to have a faster rise time and a shorter fall time like IEC standards [2].

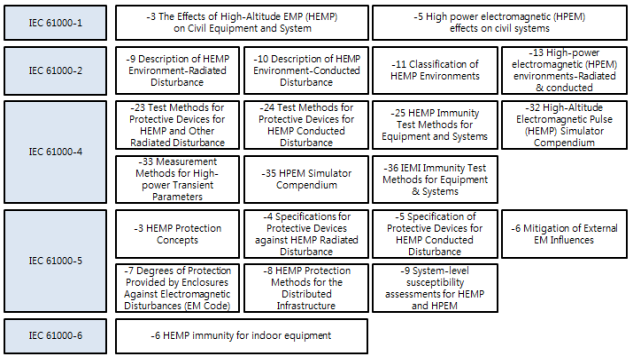

Fig 1. IEC 61000 standards and publications for HEMP

Since 1989, the IEC (International Electrotechnical Commission) has been developing and publishing standards dealing with HEMP environments and methods to protect commercial system from EMP attacks. There are several papers that provide IEC standards about HEMP shown in Figure 1.

IEC 61000-2-9 standard deals with radiated HEMP environment. HEMP is caused by a nuclear explosion at an altitude of 30 km or more. HEMP E1 pulse was defined as shown in Figure 2, 3 [3]. RS105 test method of MIL-STD-461F also specifies HEMP pulse parameters with the same parameters as IEC 61000-2-9 [4]. Each technical standard parameter was compared in Table 1 [5]-[6].

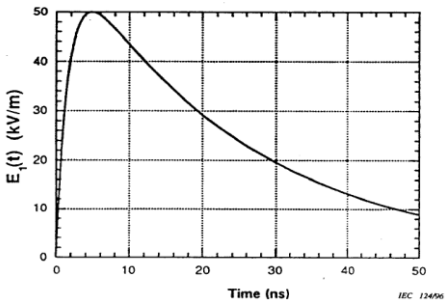

Fig 2. HEMP E1 Pulse of IEC 61000-2-9

$$E_1(t) = \begin{cases} 0 & t \le 0 \\ E_{01} \cdot k_1 (e^{-a_1 t} - e^{-b_1 t}) & t > 0 \end{cases}$$
$$E_{01} = 50\,kV/m$$
$$a_1 = 4 \times 10^7 s^{-1}$$
$$b_1 = 6 \times 10^8 s^{-1}$$
$$k_1 = 1.3$$
Fig 3. HEMP E1 pulse time domain expression of IEC 61000-2-9

Table 1. Comparison of HEMP E1 Standards

Parameter	Bell labs (1960s)	IEC 61000-2-9 (1996)	MIL-STD-461F (2007)
t_r(10~90%)	4.6 ns	2.5 ns	2.5 ns
Peak E-field(E_{01})	50 kV/m	50 kV/m	50 kV/m
FWHM	184 ns	23 ns	23 ns
k_1	1.05	1.3	1.3
$a_1(s^{-1})$	4×10^8	4×10^7	4×10^7
$b_1(s^{-1})$	4.76×10^8	6×10^8	6×10^8
Energy density(J/m^2)	0.891	0.114	0.114

2.2 EMP conducted environment standards

IEC 61000-2-10 standard presents the conducted HEMP environment. This standard presents the magnitude of the current when the electromagnetic waves generated by high-altitude nuclear explosion are induced in the cable. Intermediate-time HEMP conducted short-circuit currents as a function of cable length. It has a maximum pulsed current output of 4 kA at over 200 m. The longer the cable length, the lower the current is induced [7]. MIL-STD-188-125-1, a

stringent standard for US military installations, also specifies PCI test waveforms for EMP conducted environments as shown in Figure 4 [8].

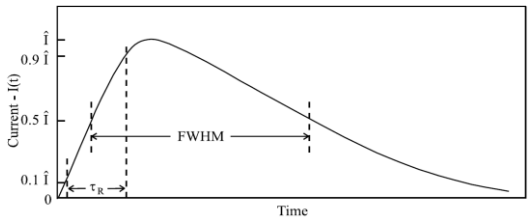

Fig 4. HEMP Pulse of MIL-STD-188-125-1

2.3 EMP susceptibility level

Regulatory Guide 1.180 test methods are used as a method for measuring the level of EMP susceptibility of NPPs equipment. The specific test methods for conducted susceptibility are presented by CS114, CS115 and CS116. The RS103 requirements are specified by the radiated susceptibility level test method. Table 2 lists the test methods in Regulatory Guide 1.180 [9].

ITU-T (International Telecommunications Union-Telecommunications Standardization Sector) has been working to protect telecommunications and datacenters from disruption from EMP threats. Study Group 5 (SG5) has published a recommendation for protecting telecommunications and datacenters against the HEMP E1. ITU-T K.81 presents the vulnerability of the telecommunication systems and the protection method for communication equipment. This recommendation classifies the EMP penetration route along the distance as shown in Figure 5. EMP susceptibility is shown as an example of a general device (router server) in Table 3 [10]. As mentioned above, the level of NPPs device susceptibility to EMP can be confirmed through electromagnetic field radiation, conductive voltage, electrostatic discharge and surge testing.

Table 2. EMI/RFI Susceptibility Test Methods (Reg. guide 1.180)

Method	Description
CS114	Conducted susceptibility, High frequency, 10 kHz to 30 MHz
CS115	Conducted susceptibility, bulk cable injection, impulse excitation
CS116	Conducted susceptibility, damped sinusoidal transients, 10 kHz to 100 MHz
RS103	Radiated susceptibility, electric field, 30 MHz to 1 GHz

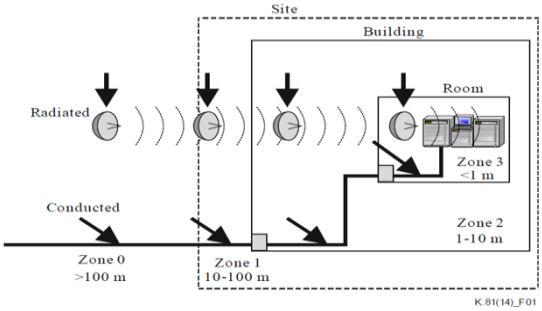

Fig 5. Classification of intrusion areas

Table 3. Immunity levels of Router Server

Type of EM emanation	Immunity level
Radiated electromagnetic field	3 V/m (actual field value)
Conducted voltage	3 V (actual voltage value)
Static discharge	8 kV (direct discharge)
Lightning surge	4 kV (power port - line to ground) 2 kV (communications port - line to ground)

3. Conclusion

In order to analyze the effects of EMPs on operating NPPs, international EMP technical standards were summarized and compared. EMP technical standards can be roughly divided into three categories; radiation, conduction, and susceptibility level. It will be possible to setup appropriate guideline for the EMP on NPPs by setting up related technical standards.

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