Transactions of the Korean Nuclear Society Autumn Meeting
Gyeongju, Korea, October 27-28, 2016

The Establishment of Object Selection Criteria for Effect Analysis of Electromagnetic Pulse (EMP) in Operating Nuclear Power Plants

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1. Introduction

The electromagnetic pulse (EMP) can be used as a strategic weapon by inducing damaging voltage and currents that the electrical circuits are not designed to withstand. EMPs are lethal to electronic systems. All EMP events have three common components: a source, coupling path, and receptor. The smaller and more sophisticated electronics are especially prone to damage. The electromagnetic pulse travels through wires, pipes, and antennas. It can also travel across power grids, destroying electronics as it passes in less than a second. There have been no research studies on the effect analysis for EMP in domestic nuclear power plants and power grids. To ensure the safety of operating nuclear power plants in this environment, the emission of EMP is needed for the effect analysis and safety measures against EMPs. Actually, it is difficult and inefficient to conduct the effect analysis of EMP with all the equipment and systems in nuclear power plants (NPPs). Therefore, this paper presents the results of establishing the object selection criteria for the effect analysis of EMP in operating nuclear power plants through reviewing previous research in the US and the safety related design concepts in domestic NPPs.

2. The Selection of Research Objects

In this section, some of the methods used to select the objects for the effect analysis of EMPs in operating power plants (NPPs) are described. The establishment of the selection criteria of objects, which are systems, equipment, and the structures in the plants, indicate the process of selection.

2.1 Literature Review

In 1983, the US Nuclear Regulatory Authority (NRC) presented the results of an evaluation through a technical report (NUREG/CR-3069). In that report, it shows that it is possible to keep a plant safe under a shutdown capability against nuclear EMP attacks [1]. The NRC's research objectives were limited to selected systems required for the safe shutdown of nuclear power plants. Therefore, the systems of interest must be defined. Three essential functions must be accomplished to safety shut down a nuclear plant. The fission process must be terminated, i.e., the reactor must be shutdown. The coolant inventory must be maintained so that the core remains covered. The heat generated from the radioactive decay of fission products must be removed. Given the systems required for a safe shutdown, the following functions should be included [2]:

- The reactor protection system
- The AC/DC emergency power system
- The auxiliary feed water system
- The residual heat removal system
- The chemical and volume control system
- The component cooling water system
- The essential raw cooling water system
- Portions of the heating, ventilating, and air conditioning systems
- The instrument air system

In considering EMP protection for nuclear power plants, it is important to ensure the safety of the public and the plant. It is not necessary to ensure the continued operation of the plant in intense multiple EMP environments.

2.2 The Maintenance of Critical Safety Functions

In the case of the domestic NPPs, they have design concepts of the critical safety function that prohibit the core damage and escape of radiation. The priority of the critical safety function is to maintain the safety status of NPPs, as shown in Table 1. If the EMP occurs, the reactor shutdown should be made for the plant safety. The cold shutdown related systems should operate properly after the EMP accident. In other words, it is not necessary to ensure the continued operation of the plant in intense multiple EMP environments.

Table 1: The Priority of Critical Safety Function in NPPs

1	Reactivity Control	5	Core Heat Removal
2	Secure the essential power	6	RCS Heat Removal
3	RCS Inventory Control	7	Containment Bldg Isolation
4	RCS Pressure Control	8	Containment Bldg Temperature, Pressure, Flammable Gas Control

Therefore, the engineered safety equipment actuation systems (ESFAS) for performing the emergency safety shutdown of NPPs and residential heat removal (RHR) system for the cold shutdown entry must be included in the main objects of EMP effect analysis.

The main systems of the EMP effect analysis are shown in Fig.1 as analysis objects.

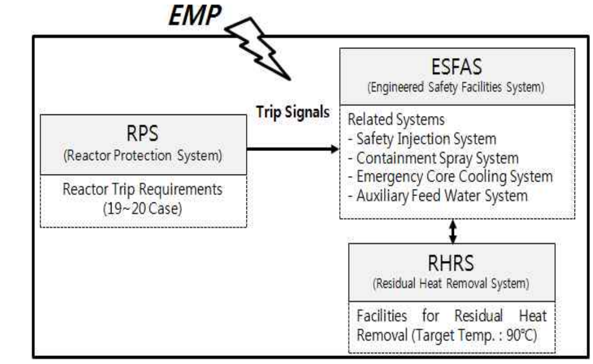

Fig. 1. The main systems for EMP effect analysis

These systems are included as the analysis objects because the most probable effect of EMP on a modern nuclear power plant is an unscheduled shutdown. EMP may also cause an extended shutdown by unnecessary activation of some safety-related systems [3].

2.3 Selection Process of Analysis Objects

The EMP effects analysis is paramount to secure the safety of nuclear power and must show that a safe shutdown is possible. Therefore, this study considered the reactor cooling and the safety shutdown to the relevant system / equipment / structures as EMP impact analysis. The reactor shutdown and cooling are defined as top priority essential safety functions in domestic nuclear power plants. The equipment is also classified in most of the safety devices. All safety related equipments in nuclear power plants are the Equipment Qualification (EQ) devices. They are classified according to their functions, as shown in Table 2.

Table 2: The categorization of safety related equipments

SR-1	Maintain the reactor coolant pressure boundary
SR-2	Perform the safety shutdown
SR-3	Prohibit and isolate the radiation
SR-4	Mitigate and prevent the accidents
PAM	Post accident monitoring

The selected objects results for EMP effects analysis through consideration of these design concepts are consistent with the results of previous studies (NUREG/CR-3069, ORNL-5029). Moreover, issues such as interference with high power electromagnetic waves at spent fuel storage, the earth magnetic field, and establishment of countermeasures for these issues are emphasized. If the spent fuel system lost cooling functions, it can lead to accidents such as the Fukushima nuclear accident. Therefore, performing the analysis should include the equipment of the spent nuclear fuel system and SR-2 equipment as objects of the EMP effect analysis.

As shown in Figure 2, the selection and filtering process helps in selecting the objects for the nuclear EMP effect analysis.

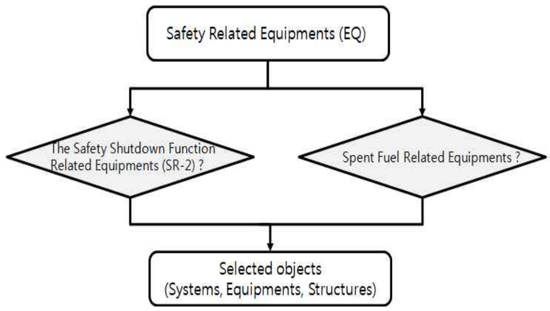

Fig. 2. The filtering process of objects for EMP effect analysis.

3. Conclusions

In considering EMP protection for nuclear power plants, it is important to ensure the safety of the public and the plant. It is not necessary to ensure the continued operation of the plant in intense multiple EMP environments. The most probable effect of EMP on a modern nuclear power plant is an unscheduled shutdown. EMP may also cause an extended shutdown by the unnecessary activation of some safety related systems. In general, EMP can be considered a nuisance to nuclear plants, but it is not considered a serious threat to plant safety. The results of EMP effect analysis show less possibility of failure in the tested individual equipment. It was also confirmed that there is no possibility of simultaneous failure for devices in charge of the safety shutdown in the NPP. The EMP effects analysis is paramount to secure the safety of nuclear power and must show that a safe shutdown is possible. Therefore, this study helped in considering the reactor cooling and the safety shutdown to the relevant system / equipment / structures as EMP impact analysis.

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