Consideration on the Applicability of Mobile Equipment in Nuclear Power Plants

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ABSTRACT

The experience of the Fukushima accident in Japan, where the stationary safety equipment at the power plant was not available, highlighted the usefulness of mobile equipment. In Korea, the implementation of an Accident Management Program (AMP) was mandated by law in 2015, and one of the requirements is to meet nuclear safety goals. Currently, the Korean utility recognizes that the use of mobile equipment is essential to meet the safety goals, which means that it has become important to introduce new mobile equipment at domestic nuclear power plants to reduce nuclear risk. However, in the initial application process to achieve the original purpose, there have been many trial-and-errors in terms of the type of equipment, the variety of specifications and accident management strategies used, and the adequacy of functional tests.

This paper discusses the basic safety strategy concepts for the introduction of mobile equipment in terms of a time-based approach and a safety function-based approach, and examines whether it is possible to establish specific acceptance criteria for risk reduction based on safety objectives when these concepts are considered. In addition, it will be examined whether it is possible to specify the currently proposed role of mobile equipment through this process.

Keywords: Mobile Equipment, Accident Management Program, PSA, Safety Goals, CDF, LERF, Nuclear Risk

I. Introduction

The Fukushima accident in Japan showed that stationary safety equipment at the nuclear power plants (NPPs), such as emergency diesel generators, could not be used under the adverse conditions of a combined natural disaster such as earthquake and tsunami, highlighting the utility of mobile equipment.

In Korea, the implementation of an Accident Management Program (AMP) became a legal requirement in 2015 [1]. The Korean utility was required to implement AMP for all their plants, which included operating guidelines for relevant equipment, including severe accident management, so the establishment of an accident management strategy for the effective operation of this equipment became an issue.

AMP-related requirements need compliance with nuclear safety goals and safety assessments for natural hazards. Nuclear safety goals, which respond to various internal and external events, include the core damage frequency (CDF), the frequency of large and early release (LERF) and, in particular, the CS-137 release requirement. At present, the domestic utility recognizes that safety systems with enhanced safety capabilities are needed to meet nuclear safety goals, and for this purpose it is essential to strengthen the in-depth defense of NPPs not only by strengthening existing stationary facilities but also by adding mobile equipment, i.e. MACST (Multiple-barrier Accident Coping Strategy) facilities. In other words, it has become important to reduce NPP's risks by introducing new mobile equipment at domestic NPPs.

However, there has been much trial-and-errors in the initial application to achieve the original purpose, including the variety of equipment types, specifications and accident management strategies used, as well as the adequacy of functional demonstration tests. There are two main approaches to assessing the safety of mobile installations. The first is to improve response capabilities through the design and strengthening of facilities, and the second is to establish accident mitigation strategies for the use of mobile equipment, taking into account the failure of stationary facilities. At this stage, deterministic or probabilistic methods are used to determine the level of accidents to be assessed. For example, the deterministic method is a method that increases the magnitude determined by the design criteria by a certain ratio (e.g. 1.5 times), and the probabilistic method is a magnitude determined based on a conventional cycle of 10,000 years as an example. Once the magnitude of the disaster has been determined, the impact of the NPP's facilities is assessed.

In a general concept, mobile equipment should be stored in a location that minimizes the possibility of damage from an extreme disaster, and the optimal transport route should be secured so that the equipment can be transported to the connection site of the reactor facility with minimal impact from the extreme disaster. There are two ways to verify the safety of mobile equipment: cyclic test and demonstration test. A cycle test is a test in which the mobile equipment is manually started at the storage site and connected to a simulated load to verify the possibility of continuous operation for a specified period of time. A demonstration test, as an example of power generator, is a way to verify the ability to supply power by moving and connecting the mobile equipment from the storage site to the electric bus connection point, manually starting it and applying loads to the bus in a specified sequence. These tests shall meet the evaluation criteria of the relevant test procedure. In addition, new operating guidelines and procedures must be prepared for the actual use of the mobile equipment in a NPP after safety verification.

Strategies for MACST facilities are currently being developed and there has been little research on the utilization or effectiveness of these facilities. Yoon [2] conducted a Probabilistic Safety Assessment (PSA) model-based sensitivity analysis to develop an optimization strategy for the effective use of limited MACST facilities in a multi-units site.

Chapter 2 of this paper describes the current accident management strategies for the use of mobile equipment, and Chapter 3 presents the evaluation results for each case based on the PSA analysis. Chapter 4 presents the available acceptance criteria and measures, and describes the application cases of the analyzed application results.

II. Accident Management Strategy for the Use of Mobile Equipment

An accident management strategy using mobile equipment in a NPP is to have equipment that can respond to simultaneous or sequential loss of essential safety functions. This is based on lessons learned from the Fukushima accident in Japan and focuses on the use of mobile equipment to restore essential safety functions in response to external events that exceed design criteria. For example, individual US NPPs have implemented FLEX (Diverse and Flexible coping strategy) strategies in accordance with NEI 12-06 guidance [3] to reduce the risk of core damage and release of radioactive material in the event of an extended loss of all AC power (ELAP) event and a loss of ultimate heat sink (LUHS) event.

The Korean AMP PSA model focuses on risk reduction by reflecting improvements to existing facilities and the addition of mobile equipment, taking into account their practical use. The types of accidents that require PSA to meet nuclear safety goals include not only internal events but also external events such as earthquakes, internal fires and internal floods. Therefore, it is not enough to get insights in the consequences of external events when assessing risks only based on internal event model.

A practical challenge is to ensure that the guidance required for the use of mobile equipment is properly aligned with existing plant procedures and/or guidelines. The accident management guidelines describe the specific actions to be taken by the personnel of the plant emergency organization to implement the accident management strategy in the event of an accident and are prepared taking into account the necessary information, wording and structure, terminology and units of measurement to enable efficient implementation of accident management. Examples of annexes to AMP and its guidance documents are given in Table 1.

In the event of a design basis accident or multiple failure incident, an applicable abnormal procedure is clearly defined and will be implemented through alarms and key parameter checks. Alternatively, if a reactor is shutdown, the applicable emergency operating procedures (EOPs) will be applied based on clear symptoms determined through diagnosis of the accident. A natural disaster that exceeds the design basis will always result in an initial response that is similar. If we need to respond to an accident using mobile equipment, such as in the event of an extreme disaster during the execution of the EOP, follow the multi-defense operation guidelines (MOGs). When the accident worsens during recovery and mobile equipment are required, this guideline is used. If the condition for entering any severe accident becomes during mitigation, the accident is mitigated by switching to the severe accident management guideline (SAMG). The extensive damage mitigation guideline implements a wide area damage mitigation strategy in case of man-made disasters that exceed the design criteria. The necessary measures can be linked to the EOP. It is essential that the impact assessment of these various accidents can be evaluated both deterministically and probabilistically.

Table 1. AMP Supplemental Reports/Guidelines

No.	Title of Guideline/Procedure	Remarks
1	Multi-Failure Incident Management Capability Assessment Report	Not related to PSA
2	Composite PSA Reports	
3	Emergency Operating Guidelines (EOGs)	
4	Multi-Defense Operation Guidelines (MOGs)	Related to MACST
5	Severe Accident Management Guidelines (SAMG)	Related to Level 2 PSA
6	Extensive Damage Mitigation Guidance (EDMG)	Not related to PSA

In this paper, we set out the fundamental safety strategy concepts for introducing mobile equipment. We can categorize the concepts as a mitigating time-oriented approach and a safety function-oriented approach, etc.

II.A. Mitigating Time-oriented Approach

The basic strategy for securing necessary functions to respond to accidents such as natural disasters that exceed design criteria is done by the MACST facilities, which consists of three phases depending on the time of utilization. Figure 1 shows the overall response strategy by phase.

* Phase 1: Response strategy using stationary equipment in a plant
* Phase 2: Response strategy using mobile equipment within a site boundary
* Phase 3: Response strategy using stationary-but-failed equipment restoration, mobile equipment within the site, and off-site resources.

The Phase 1 is to maintain the plant in a hot standby state with natural circulation using fixed stationary equipment until mobile equipment is available. The priority action in the Phase 1 is to quickly cool the reactor coolant system (RCS) within the maximum cooling rate using the atmosphere dump valves (ADVs) in accordance with the RCS early cooling/decompression strategy. In the ELAP event, non-essential loads are switched off to extend the life of the storage batteries as much as possible. In addition, plant walkdown is conducted to determine the damage to the plant caused by the accident, and mobile equipment is required to be appropriately deployed from the consolidated storage to a pre-planned area to prepare for the implementation of the second phase of the strategy.

The Phase 2 is to utilize mobile equipment as much as possible. This means that the mobile equipment that were moved and deployed from the consolidated storage in Phase 1 are operated according to the appropriate operating procedures for the plant conditions to continue maintaining the plant in a stable state. For power restoration, the 1 MW Mobile Power Generator (MPG) is connected to a 4.16 kV safety bus to provide alternating current power. After connecting the 1 MW MPG, the RCS inventory is maintained using charge pumps. If a charge pump is inoperable or the depressurization of RCS is delayed, a high-pressure mobile pump can be used to replenish the RCS inventory. If turbine-driven auxiliary feedwater (AFW) pump is inoperable, a low-pressure mobile pump is used to supply cooling water to the steam generator through the external injection line.

Finally, the third phase is basically to stabilize the plant by continuing to use stationary equipment and mobile equipment used before. This long-term recovery strategy also includes the use of resources within the site or at other nuclear sites in Korea. In particular, in the case of mobile equipment used in domestic NPPs, the MACST facilities can be effectively implemented because the equipment specifications and operation methods are the same for each mobile equipment at each NPP. The three-step strategy is to first connect a 3.2 MW MPG for the operation of component cooling water (CCW) system and essential service water (ESW) system. If the ESW pump is not operational, a high-flow mobile pump will be used to supply seawater to the CCW heat exchanger. Once the 4.16kV safety-rated power supply and the final heat removal source for the operation of the unit CCW system are secured, the shutdown cooling system is operated to maintain the plant in a safe shutdown state. Therefore, even in the event of a natural disaster that exceeds the design condition, such as ELAP or LUHS event, the RCS inventory is sufficiently maintained to ensure core cooling by responding to the accident according to these 3-phase strategies.

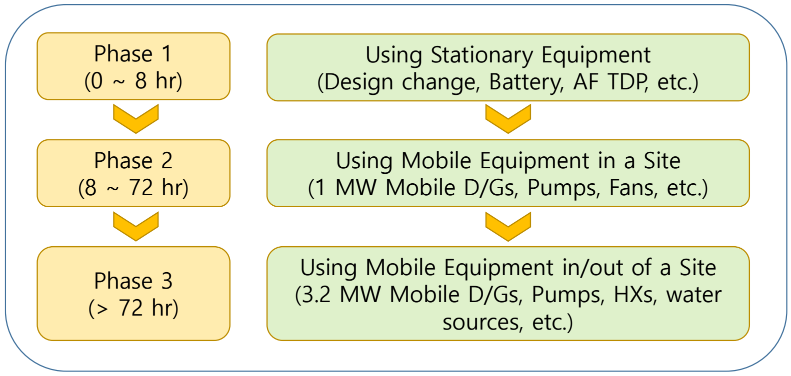

Figure 1. Strategy for utilizing Equipment (stationary and mobile) by 3 Phases

II.B. Safety Function-oriented Approach

MACST, like FLEX, is one of the critical accident prevention and mitigation strategies and facilities to maintain and restore essential safety functions under extreme natural disaster conditions, primarily through the provision of power and cooling water. Specific safety functions considered in the function-oriented approach are typically power supply, RCS inventory control, final heat removal source, containment overpressure protection, and spent fuel pool cooling, etc.

Depending on its safety function, mobile equipment is relevant to each of the initiating events covered by the PSA. For instance, MPGs supply power to essential loads by connecting to the local power grid within an acceptable timeframe if the alternate AC generator (AAC) installed to cope with a station blackout (SBO) is unavailable. Therefore, this equipment is closely related to the SBO mitigation function. At developing SBO event tree scenario in PSA, this equipment is modeled and evaluated in case of AAC failure, which is assigned as an additional mitigation function. This evaluation process is applied similarly to external events, though the evaluation modeling may change depending on the characteristics of an external event.

An ELAP event is a situation where both the emergency diesel generator and the alternate AC power source are unavailable due to a natural or man-made disaster that exceeds the external conditions considered in the multiple failure design criteria in the accident management scope. In such a case, a stationary AC power or mobile source shall be available to provide reliable power to the essential loads connected to the main electric safety bus. The utility has proposed a 3.2 MW MPG, a 1 MW MPG and a 10 kW MPG as means to fulfill the power supply function (Category A as shown in Table 2). A 1 MW MPG provides power to a series of safety-related AC bus, and a 10 kW MPG performs the function of supplying electricity to the control panel of AFW pump.

External water injection facilities for inventory control are used to inject alternative emergency cooling water into the reactor, steam generators, and spent fuel pool to prevent a severe accident when stationary means of cooling water in the plant, such as emergency core cooling system or AFW system, are not available. Low-pressure mobile pump are proposed as a means of accomplishing this function (Category B). In addition, a high-pressure mobile pump is proposed for the reactor coolant pump (RCP) leakage replenishment and RCS inventory control.

To secure the ultimate heat sink function (Category C), a high-flow mobile pump is deployed and operated to supply alternative CSW to the residual heat exchanger during low-pressure cold leg recirculation operation. Containment pressure control function (Category D) is used to protect the containment building from high temperature and/or overpressure conditions that could be caused by a severe accident. For certain NPPs, this control function is considered to be either an emergency containment spray backup system (ECSBS) or a containment filtered-vent system (CFVS). The ECSBS also uses mobile pumps.

In case of large area damage caused by man-made disasters such as aircraft crashes (Category E), a high-pressure mobile sprinkler truck or a 30 kW MPG is provided. High-pressure mobile sprinkler truck can spray directly from outside of the plant building for cooling water supply. 30kW MPG performs the function of supplying electricity to the reactor cavity filling valve for cooling core melting materials in case of loss of core cooling function. In addition, a low-pressure mobile pump and a high-pressure mobile sprinkler truck are proposed as means for performing the cooling function in the spent fuel pool.

Table 2 lists the mobile equipment used for each of the above functions, classified by 5 categories. Auxiliary supporting equipment for each functions include fuel oil tankers, tow trucks, emergency lighting, communication equipment, mobile air compressors, and temporary fans and ducts, etc. The mobile equipment is primarily stored in the consolidated depot of plant headquarters. The mobile equipment stored in the consolidated depot is transported to the plant along the main or alternate transportation routes. In a natural disaster that exceeds the design criteria, for example, debris from the tornado causes road traffic obstructions, the consolidated depot is equipped with road restoration facilities. The road repair equipment removes debris from the traveled way to ensure the passage of towed or vehicle-mounted mobile equipment.

Table 2. List of Mobile equipment utilizations by Safety Function Categories

Category	Safety Function	Essential Equipment	Optional Equipment
A	Securing emergency power	Mobile Power Generators	
B	Obtaining/Refilling Coolant	Low Pressure Mobile Pump, High Pressure Mobile Pump	Mobile Water Purification
C	Secure ultimate heat sink	High-flow mobile pump	
D	Containment building overpressure protection	(ECSBS) Pumps	
E	Human-caused disaster response	High-pressure mobile sprinkler truck	

II.C. Operating mode-oriented Approach (Optional)

For some NPPs, a 3.2 MW MPG or a 1 MW MPG is being considered to be pre-positioned through the power cable installed at all times to solve the issue of power supplying time in the ELAP situation due to extreme disasters. Also, for some NPPs, pre-deploying mobile equipment nearby a NPP, such as low pressure mobile pump, during the shutdown operation is considered.

As such, selectively adopting different application situations such as the operation mode of mobile equipment may result in risk differences through the applicability assessment.

III. Results of Sensitivity Analysis

In order to understand the practical applicability of each proposed mobile equipment to currently operating NPPs, accident scenario analysis and system analysis, for example, are additionally performed. Also, ultimately, the following insights should be provided:

- The level of increased risk that would be affected by the exclusion of the mobile equipment
- The level of risk increase or decrease due to changes in the way the equipment is operated
- Determine the impact on key safety functions based on the level of risk change.

For the case of risk impact assessment, which includes accident scenario analysis, system analysis, and/or human reliability analysis, the level 1 PSA method is primarily used. However, if the mobile equipment affects the containment building integrity, Level 2 PSA method is used. The result is usually expressed as a delta CDF or LERF, which provides risk insight into the increase or decrease in risk with and without mobile equipment.

III.A. Assumptions

When performing the evaluation with the relevant mobile equipment, the followings are assumed in the accident scenario analysis or human reliability analysis, and the others.

a) If initial secondary heat removal operation by turbine-driven AFW pump is successful after an alternate diesel generator fails to start, and both the restoration of offsite power and the mobile MPG are unsuccessful, the external feedwater supply is provided to at least one of the two steam generators using a mobile pump, and steam release is performed using at least one of the two ADVs installed on the steam generator to which the feedwater is supplied or one or more main steam safety valves.

b) In the accident of steam generator tube rupture, if the operator is unable to perform IRWST filling from the boric acid water storage tank and the supplementary water tank, the IRWST filling is performed using a low-pressure mobile pump.

c) In the event of a complete loss of CCW and a RCP seal failure, a high-pressure mobile pump shall be used to fill the RCS inventory.

d) If RCP seal is intact, the secondary side heat removal is maintained using the turbine drive AFW pump by supplying power to the battery charger using a MPG within the battery availability time extended by non-essential load shedding.

e) Maintaining containment heat removal by supplying external cooling water to the containment spray nozzles using the mobile pump of the ECSBS.

f) Assuming the establishment of a response organization to operate the mobile equipment, the operator arrives at the consolidated depot and operates and applies it in available time. The related human tasks are divided into cognition, execution, and recovery measures. So, available times are assumed for accident diagnosis, arrival at the depot, moving the equipment and taking the load, and additional allowances.
- 3.5 hours to remove a mobile equipment from depot, connect it to the grid, and start it up.
- 2 hours for pre-deployed mobile equipment during planned maintenance to be connected to the grid and operation.
- 1.5 hours to connect to the grid and start operation of a pre-positioned MPG (with pre-laid power lines)

III.B. Evaluation Case #1 - Impact on the whole Exclusion of Mobile Equipment

The sensitivity analysis of Level 1 full power (FP), including low power and shutdown (LPSD) states, PSA for all initiating events (internal, earthquake, fire, and flooding) for recently operating NPPs (specific #1) is shown in Table 3, reflecting the exclusion situation of mobile equipment. The internal event has the largest increase in CDF when mobile equipment is excluded, while the flooding event has the smallest impact on CDF.

Table 3. Results of Level 1 PSA sensitivity analysis for Specific NPP #1

Initiating Events	Operating Mode	Increasing Rate of CDF w/o Mobile Equipment	Remark
Internal Events	Full Power (FP)	307.4 %	
Seismic	FP	56.4 %	
Fire	FP	96.1 %	
Flooding	FP	53.7 %	On-going Update
Internal Events	Low Power and Shutdown (LPSD)	264.6 %	
Seismic	LPSD	3.6 %	
Fire	LPSD	84.7 %	
Flooding	LPSD	2.8 %	
Total Value		200.4 %	

Table 4 also shows that the sensitivity analysis results of Level 1 PSA for all initiating events on the relatively-old NPP (specific #2). The initiating event with the largest increase in CDF, when mobile equipment is excluded, is internal events during LPSD operation, while the initiating event with the smallest impact in CDF is the FP flooding event.

As shown in the results of evaluation case above, we can identify that mobile equipment are more useful for internal events and relatively less useful for external events. The reason for these results is probably due to differences in analysis methodology or assumptions for using mobile equipment and different event response conditions. Also, in the LPSD internal event model, mobile equipment provide mitigation measures for scenarios where it is difficult to mitigate the accident with conventional stationary facilities, reducing the CDF of the corresponding accident scenarios in the base model. The details of sensitivity analysis show that some of changed accident scenarios without mobile equipment are located in the upper minimal cutset of CDF.

Table 4. Results of Level 1 PSA sensitivity analysis for Specific NPP #2

Initiating Events	Operating Mode	Increasing Rate of CDF w/o Mobile Equipment	Remark
Internal Events	FP	84.8 %	On-going Update
Seismic	FP	18.8 %	
Fire	FP	20.7 %	
Flooding	FP	0.0 %	
Internal Events	LPSD	1,257.0 %	
Seismic	LPSD	28.1 %	
Fire	LPSD	30.6 %	
Flooding	LPSD	362.6 %	
Total Value		336.8 %	

There is a difference between the results in Table 3 and Table 4 for each initiating event in terms of the percentage increase in CDF when whole mobile equipment are excluded. This may be due to the presence or absence of safety design enhancements between the new and old plants, differences in analytical modeling, and differences in the baseline CDF values themselves, and a detailed understanding of the causes would require a lot of effort from an expert perspective that encompasses the knowledge of both plants. However, there is an interesting point that the CDF change rate in terms of total CDF (for both full power and LPSD modes in all initiating event cases) has no significant difference between the specific NPPs, but it's hard to say for sure without more information. A comparison of the two reveals that specific NPP #2 is more likely to contribute to plant safety than specific NPP #1 with regard to the utilization of mobile equipment.

The results in Table 4 show that mobile equipment contributed significantly to the growth rate of internal events in SBO accidents. However, cases such as flooding events had little change in the CDF growth rate when mobile equipment were excluded because these events do not cause a loss of offsite power or SBO due to their event characteristic.

III.C. Evaluation Case #2 - Impact on the Fire Risk of Specific Plant Exclusion

The sensitivity analysis result of FP fire PSA for specific NPP #2 shows that the impact of mobile equipment (20.7%) is not significant. Also, the sensitivity analysis results for the LPSD fire PSA without mobile equipment show an increase by 29.0% compared to the original result. We can find that, in case of fire event, the increase is smaller than internal events, when excluding mobile equipment, because some mitigating features are not often available due to lack of supplying electric power or water from mobile equipment due to cable fire and/or equipment fire damage.

Table 5. Results of Sensitivity Analysis for Selected Fire Zones of Specific NPP #2

Fire Zones	Initiating Event	Mobile Equipment used in the Analysis	Increasing Rate of CDF (in a fire zone) w/o Mobile Equipment
Room A (given with safety-grade switchgear)	Loss of Offsite Power	3.2 MW MPG and 1 MW MPG	162 %
Room B (Ditto)			213 %
Room C (given with CCW pumps)	Loss of CCW	High-pressure Mobile Pump	256 %
Room D (given with ESW pumps)			256 %

In addition, the following results of Specific NPP #2 show in Table 5 that a significant increase of CDF without mobile equipment for each fire zone. Table 5 also provides the list of mobile equipment used in the analysis with representative initiating event of the fire zone. For example, because it typically results in the loss of equipment and cables due to room C or room D fires, while the impact of high-pressure mobile pump, which can provide cooling water at loss of CCW event to replace stationary equipment failure due to fire, is identified as more significant. We believe that the currently proposed role of mobile equipment and its risk impact, depending on equipment-specific initiating event, could be identified.

III.D. Evaluation Case #3 – Impacts by Pre-positioning and/or Pre-deployment Strategy

Pre-positioning means that some of mobile equipment normally stored in the consolidated site depot is regarded as permanently-placed on a NPP. On the other hand, pre-deployment refers to the temporary deployment of some of mobile equipment stored in the consolidated site depot to a plant during preventive maintenance period.

The 1 MW MPG, which is considered as a representative pre-positioning equipment, has one for each unit in the NPP and spare one in the consolidated site depot. Therefore, human error probability estimation for 1 MW MPG excludes the task associated with moving to the site, unlike other mobile equipment. For other mobile equipment, the human action associated with moving to the site is added because they are stored in a consolidated site depot. This is the same for both FP and LPSD periods. The sensitivity analysis without pre-positioning of mobile equipment, reflected in the Level 1 LPSD PSA, shows that the CDF increases by approximately 3.9%.

III.E. Evaluation Case #4 - Impact on the Medium MPG Uninstallation

In the case of Specific NPP #2, a 500 kW medium-sized MPG was initially proposed to reduce the risk by using it as a direct power supply to the containment fan cooler (RCFC) to maintain the integrity of the containment building during severe accident. However, as a result of Level 2 PSA, it was found that there was little risk reduction from the operation of the RCFC with this mobile equipment, therefore, the installation of the equipment was ultimately canceled.

IV. Risk Metrics and Acceptance Criteria for the Application

One of consideration in the application of mobile equipment is checking the applicability by the choice of risk metrics. Depending on the selected metric, sound decisions can be made, such as prioritizing the adoption of the equipment. The most common metric can be selected is the delta CDF. Other metrics other than delta CDF may be considered, e.g., targets such as LERF. As you know, LERF and other endpoints can be determined by performing a Level 2 PSA or Level 3 PSA. Therefore, for mobile equipment (e.g., one for external containment spraying) that contribute to the results of the PSA, and also the relevant evaluation metrics, including calculated Cs-137 releases, should be applied.

We checked whether it is possible to establish acceptance criteria or specific selection categories for risk reduction based on the delta CDF when reflecting the basic safety strategy concept presented in Chapter 2. We also checked whether it is possible to prioritize the adoption of the currently proposed mobile equipment through this process.

For example, there is a regulatory document [4] that provides general requirements and procedures that are considered appropriate for checking relevant issues and assessing their impacts during the review process when risk information is utilized in an application for a license to modify a reactor facility submitted by the licensee. Since this regulatory guidance is intended to provide a general basis for decision-making in the safety review of risk-informed applications, we believe that it can be adopted as an acceptance criterion for the applicability of the problem in this paper.

The acceptance criteria in the relevant regulatory guidance, i.e., Reference [4], are applied to ensure that the increase in risk from the proposed modification is minimized and consistent with safety objectives. They also represent a judgment on the cumulative and synergistic effects of the proposed modification on the overall risk profile of the reactor facility, as well as the risk variation. Reference [4] establishes acceptable, unacceptable and detailed evaluation zones for risk changes representing specific adoption categories. An example of the results of applying the above Evaluation Case #1 for Specific NPP #2 is shown in Figure 2.

Referring to Figure 2, it can be seen that the sensitivity analysis of the total delta CDF of this NPP without mobile equipment is in the unacceptable zone, indicating that the proposed mobile equipment is essentially required for this NPP.

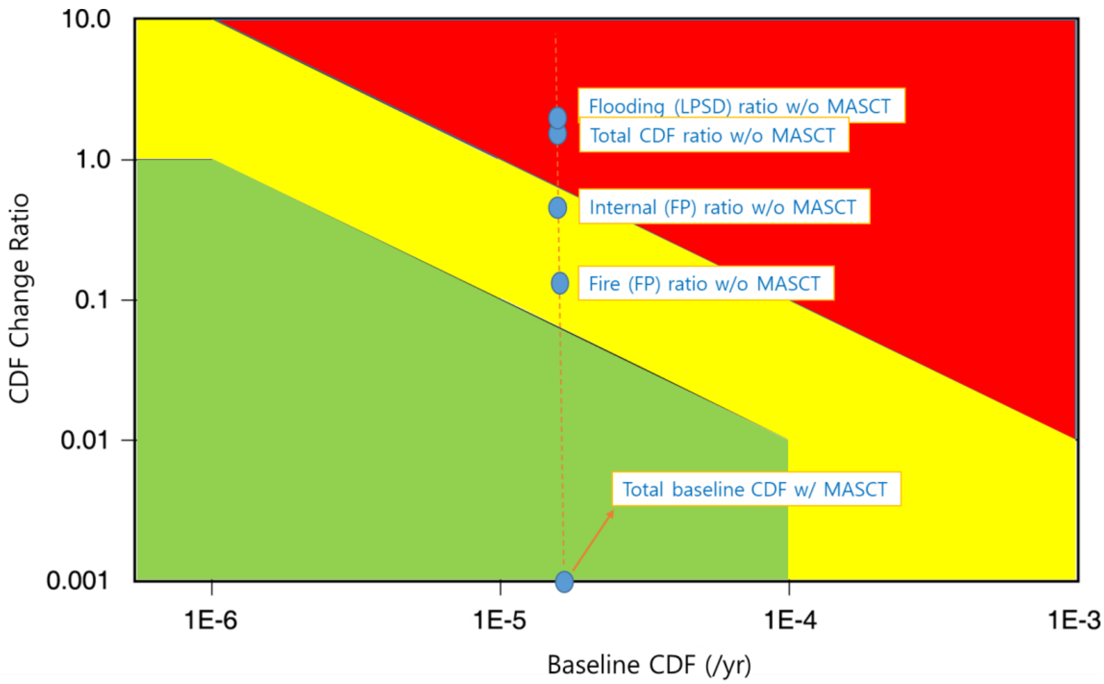

Figure 2. Results of Applying Acceptance Criteria from Reference [4] to Evaluation Case #1 (Specific NPP #2)

V. Conclusions

In this paper, we first discussed various concepts for implementing AMP strategies for extreme disasters in NPPs and the current application status of related mobile equipment. In addition, to determine the applicability of each proposed mobile equipment to currently operating NPPs, we evaluated the level of increased risk affected by excluding these equipment and the level of increased risk due to specific changes in the way the equipment is not utilized.

The risk matrices for the application of mobile equipment were considered and the results of the sensitivity analysis of the change of these risk measures to the exclusion of mobile equipment from certain NPP were presented, as well as the acceptance criteria. Finally, we can identify that this approach can support to confirm the applicability of each of the proposed mobile equipment.

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