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Policy Proposals for Safety and Security Interface(SSI)

Jung Soo Kim [a*], Gee Man Lee[a], Woo Sik Jung[a*]
[a]*Nuclear Engineering, Sejong University, 209 Neungdong-ro, Gwanggin-gu, Seoul, Korea*
[*]*Corresponding author: woosjung@sejong.ac.kr*

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1. Introduction

In general, nuclear safety and security have a common of protecting the public and the environment from radiation hazards, and their defense-in-depth (DiD) strategy such as prevention, protection, mitigation and accident response are the same. However, differences exist in prevention and response methods due to different causes of problems. Also, in 2021, the IAEA published "The Nuclear Safety and Nuclear Security Interface," [1] technical report Series No. 1000, sharing the status of safety-security interface in each country and recommending that best practices be reflected in each country's systems. Meanwhile, the N-STAR report "Establishment of 3S interface Infrastructure" [2] published by KINAC in 2016 presented three high-priority issues related to safety and security interface. According to the report, the first was vital areas, the second was cybersecurity, and the third was spent nuclear fuel storage and transportation facilities. However, both reports approached the issue from an institutional perspective and did not mention the technical connection between safety and security interface. Therefore, this paper will focus on physical protection and examine the technical connections between key technologies, identify current position, and propose the policy proposal to these issues for each key technology.

2. Vital Area Identification

2.1 Current Position

The vital area of a nuclear power plant contains various devices, cables, pipes, and other equipment that can affect the safety of the plant. Applying enhanced physical protection requirements to the vital area could inadvertently affect safety. In 2015, the Nuclear Safety Commission redefined the vital area in accordance with the IAEA's physical protection recommendations through an administrative order. In case of U.S., the procedure for establishing the Vital Area is as follows: the fault trees generated from the probabilistic safety assessment are converted into sabotage fault trees, calculated using attack sets and defense sets, and the vital area is selected. And nuclear facilities follow the physical protection design procedures shown in Figure 1, and the physical protection design of nuclear power plants includes the selection of vital areas and the design of physical protection systems to protect those vital areas. But unlike in the United States, failure trees based on probabilistic safety assessments were not applied to ROK. And, the attack sets that must be calculated when redefining the vital area were not calculated, and therefore, the impact of the currently defined vital area on safety has not been analyzed in ROK. In order to minimize the vital area and optimize the efficiency of protective resources, it is necessary to calculate the attack set and defense set by changing the failure trees generated in the probabilistic safety assessment to sabotage failure trees, and then set the vital area. Furthermore, as shown in Figure 1, when setting the vital area, it is necessary to consider physical protection design from the construction stage (Security-By-Design) to ensure the smooth maintenance of major equipment located within the vital area during vital area operation.

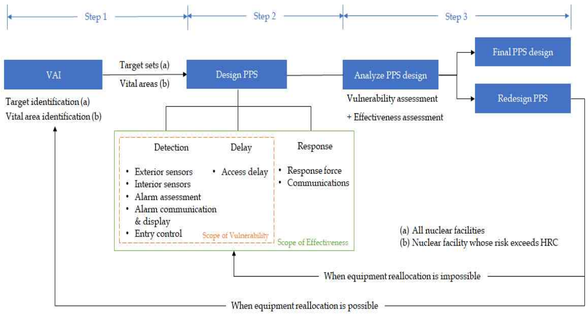

Fig 1. physical protection design procedures [3]

2.2 Policy proposal for vital area

To address the issues mentioned in Section 2.1, the following methods are proposed. 1) Regarding the use of probabilistic safety analysis results when establishing vital area, the fault tree analysis technique based on probabilistic safety assessment should be applied when establishing vital area for new nuclear power plants and SMRs. To this end, the following should be added to the Enforcement Decree of the Act on Physical Protection and Radiological Emergency (APPRE)[4], "Requirements for the Protection of Nuclear Facilities, etc. (Related to Article 16) 3. Nuclear Material...Sabotage Protection Requirements, "the following should be added: "The establishment of vital areas shall follow 'KINAC RS-107' (Vital Area Establishment)." Additionally, the following items should be added to KINAC RS-107: Specifically, add to the vital area setting method: "When establishing vital areas for new nuclear power plants and SMRs, the failure tree analysis technique based on the latest probabilistic safety assessment shall be applied within the scope that does not compromise safety. 2) When establishing vital area, physical protection regulations must be submitted and reviewed from the construction phase regarding the relocation of key equipment. Specifically, the main text of Article 9, Paragraph 1 of the Act on Physical Protection and Radiological Emergency (APPRE), excluding the items listed therein, states: "Nuclear... Article 10, Article 30, Article 35(1), and Article 63, or who has applied for standard design approval under Article 12 of the same Act)", and renumber the existing paragraph 2 as paragraph 3, and add a new paragraph 2 to the same Article as follows: 2) The effect of matters approved pursuant to Paragraph 1 for an applicant who has applied for standard design approval under Article 12 of the Nuclear Safety Act shall continue until the expiration date of the relevant standard design approval. However, the Nuclear Safety Security Commission(NSSC) may order correction or supplementation of the approved matters even during the validity period if it determines that there is a significant impact on physical protection. Furthermore, Article 17, Paragraph 1 of the Enforcement Decree of the same Act shall be amended to read: "...the nuclear business operator shall submit an application for approval regarding this to the Nuclear Safety Security Commission(NSSC) at the construction permit stage as stipulated by the Nuclear Safety Act." This amendment references the legislative bill proposed by Representative Choi Min-Hee [5]. 3) When operating a vital area, the fault tree analysis technique based on probabilistic safety assessment must be applied for the maintenance of major equipment located within the vital area establishing vital area for new nuclear power plants and SMRs. To this end, the Enforcement Decree of the Act on Physical Protection and Radiological Emergency (APPRE) should add the following to "Protection Requirements for Nuclear Facilities, etc. (Related to Article 16) 3. Nuclear Materials...Sabotage Protection Requirements," and add the following to KINAC RS-107. Specifically, the method for establishing vital areas should be amended to state: "When establishing vital areas for new nuclear power plants and SMRs, the fault tree analysis technique based on the latest probabilistic safety assessment shall be applied within the scope that does not compromise safety." Furthermore, the method for operating vital areas should be amended to state: "The protection requirements stipulated in the Act on Physical Protection and Radiological Emergency (APPRE) shall be complied with," and this should be added to KINAC RS-107.

3. Vulnerability/Effectiveness Assessment

3.1 Current Position

Table 1 is a comparison table of domestic and international physical protection vulnerability assessment tools. As shown in Table 1, most vulnerability assessment tools were analyzed to be capable of path analysis and also capable of calculating P_I (Probability of Interruption). Sensitivity serves as a metric for evaluating the relative importance of each protective facility's contribution to the overall protection system. Internationally, only SAVI and ASSESS software support these functions. Domestically, only SAPE and TESS implement this feature. Furthermore, P_N (Probability of Neutralization) and P_E (Probability of Effectiveness Assessment), required for effectiveness evaluation, are only implemented in ASSESS software. Table 1 presents the pro. and con. of vulnerability analysis tools. However, as shown in Table 1, vulnerability/effectiveness assessment tools for physical protection design intended for industrial use have not yet been developed. In the past, KINAC utilized vulnerability/effectiveness assessment tools developed in the United States for limited purposes through international cooperation. However, it is deemed impossible for the domestic physical protection industry to obtain licenses for these tools. Furthermore, KINAC developed vulnerability/ effectiveness assessment tools for R&D purposes, limiting their commercial use by the domestic physical protection industry. Furthermore, the production of physical protection data for domestic physical protection design is necessary. Physical protection data, such as the probability of interruption of attack sets against protected facilities, which is core to vulnerability/effectiveness assessment tools, is classified information that cannot be accessed.

Table 1. the comparison of domestic and international physical protection vulnerability assessment tools

vulnerability analysis tools						
Software	International			Domestic		
	EASI	SAVI	ASSESS	KAVI	SAPE	TESS
ASD	1D	1D	2D	1D	2D	2D
Vulnerability Analysis Method	Single	Multi path (ASD)	Multi path (ASD)	Multi path	Multi path (based on algorithm)	
Path (Single, Multiple)	Single path only	Multi path	Multi path	Multi path	Multi path	Multi path
Detection, Delay, Response	Single path only	Multiple detection and delay factor settings available	Multiple detection and delay factor settings available	Multiple detection and delay factor settings available	Multiple detection and delay factor settings available	Multiple detection and delay factor settings available
Facility Location Coordinates	No	No	No	No	Yes	Yes
Protection Equipment Coordinates	No	No	No	No	Yes	Yes
Intrusion Pathway Coordinates	No	No	No	No	Yes	Yes
DB	Cannot be transferred outside the United States			Public records unavailable		

3.2 Policy proposal for Vulnerability Assessment

To address the issues mentioned in the previous section, the following policy directions are proposed. First, regulatory agencies responsible for vulnerability/validity assessments should, concurrently with the revision of the Act on Physical Protection and Radiological Emergency (APPRE) mentioned in Section 2.2, establish a new KINAC RS-118 (Technical Standard for Vulnerability Assessment) within KINAC's technical standards. The content of this technical standard should be based on the UK ONR Technical Assessment Guide (TAG) CNS-TAST-GD-6.4 "Vulnerability Assessments Guide."[6] That is, a Vulnerability Assessment Guide must be established. That is, it is judged that the relevant contents of UK ONR Technical Assessment Guide (TAG) can be modified to suit domestic circumstances. Second, a vulnerability/effectiveness assessment tool suitable for domestic conditions must be developed. As mentioned earlier, the vulnerability/effectiveness assessment tools previously developed by KINAC have limitations for commercial use within the domestic physical protection industry. Therefore, it is necessary to develop vulnerability/effectiveness assessment tools that can be used commercially not only by regulatory authorities but also by the industry. Third, securing the physical protection data required for the tools is crucial. To achieve this, KINAC INSA's SETT should be actively utilized, and some data should be obtained with support from the relevant industry to ensure the necessary data for the assessment tools is available.

4. NPP extreme event

4.1 Current Position

In 2015, EPRI published guideline for high wind hazards. This guideline provides instructions for high winds, including assessing missile hazards from high winds and wind-driven debris, evaluating the vulnerability of nuclear power plants to high winds, and risk modeling. Generally, nuclear power plants are designed to withstand earthquakes and wind loads. However, older plants can be damaged by external hazards. The intensity of recent typhoons (as measured by central pressure differences and wind speeds) has increased due to climate change. Strong winds can generate flying debris, which can damage plant structures. Meanwhile, the EPRI guidelines illustrate a procedure for selecting a list of plant equipment related to high winds, as shown in Figure 2.

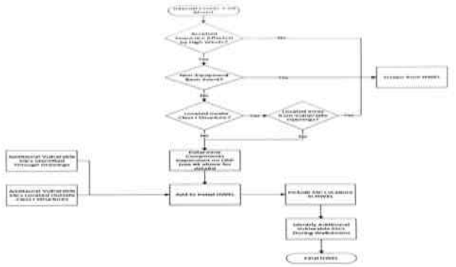

Fig. 2 The procedure for selecting a list of plant equipment related to high wind[7]

This procedure requires forming an expert team to select wind-related plant equipment. This team includes experts with extensive experience in wind hazards, vulnerability, plant systems, and PRA modeling (civil engineers), and plant structural experts who identify System, Structure & Component (SSC) elements. They then compile the relevant equipment list through site inspections. In this guideline, high wind-driven debris are defined as EPRI guideline. That is, potential high wind-driven debris include containers near switchyards, fence posts and streetlights and trees, hydrogen tanks outside turbine buildings, and non-failing electrical cabinets. Consequently, the list of structures/equipment susceptible to strong winds at the domestic Shin Kori Units 1 & 2 power plant is shown in Figure 3.

	SSC's	Failure mode	Note
Structures	Reactor bldg.	-	Except
	AUX bldg.	-	Except
	Turbine bldg.	Functional	Pull out
Components	Transmission tower	Structural Functional	Collapse Line break
	Transformers	Functional	Wind born missile
	CST	Structural	Wind born missile
	Crane	Structural	Overturn Collapse
	ESW pump room	Structural	Wind born missile
	CCW HX	Structural	Wind born missile
	EDG oil tank	Structural	Wind born missile

Fig. 3. the list of structures/equipment susceptible to strong winds at the domestic Shin Kori Units 1 & 2 power plan[8]

Although potential high wind-driven debris is included, it was excluded from the "List of Structures/Equipment Affected by Strong Winds" for Shin Kori Units 1 & 2, as shown in Figure 3. It was confirmed that the research project is being conducted excluding potential high wind-driven debris from fences, pillars, trees, etc. Therefore, potential high wind-driven debris such as fences, pillars, and trees should be included in the analysis to determine what impact they could have on safety structures.

4.2 Policy proposal for NPP extreme event

According to the previous section, an assessment of safety structures against high winds was conducted for all U.S. nuclear power plants in accordance with EPRI guidelines. However, as shown in Figure 3, these are excluded from the "List of Structures/Equipment Potentially Affected by Strong Winds" for Shin Kori Units 1 & 2. Therefore, the new research project should proceed to include the impact of physical protection structures such as fences, pillars, and CCTV on safety structures during strong winds or typhoons.

5. Radiological Emergency Plan & Contingency Plan

5.1 Current Position

The contingency plan controls personnel entering and exiting the vital area through a minimum number of access points. Conversely, the radiological emergency plan requires all personnel within vital areas to evacuate as quickly as possible according to the emergency plan, necessitating that all access points to the vital area remain open. To resolve this contradiction, IAEA Technical Report Series No. 1000, "Linking Nuclear Safety and Nuclear Security" [1], recommends the following: First, during the preparedness process, synergies between nuclear safety and nuclear security should be considered. It is crucial to allocate roles and responsibilities for decision-making at all levels. High-level decision-making must ultimately be performed by a single agency or designated official, who must consider the interaction between safety and security. To improve the decision-making process at all levels, special training on this interaction should be provided to responsible agencies at the national level. Second, a system should be established at the national level to coordinate revisions to contingency plans and radiological emergency plans prior to implementation. Third, the linkage between safety and security is recommended to be addressed "during the conduct of exercises, including emergency scenarios triggered by nuclear security incidents and other scenarios requiring responses from both security and safety."

5.2 Policy proposal for Radiological Emergency Plan & Contingency Plan

To address these issues and comply with the recommendations in IAEA Technical Report No. 1000, it is proposed to establish a provisional "Act on Physical Protection and Radiological Emergency's Consultative Body" (between KINAC and KINS) under Act on Physical Protection and Radiological Emergency. This body will implement the IAEA recommendations by dividing the process into preparatory, implementation, and post-implementation phases. The outcomes derived from this process will be incorporated into KINAC Technical Guideline KINAC RS-113, "Establishment of Contingency Plans." Table 2 summarized SSI issues and policy proposal at each item.

Table 2. SSI technical issues and policy proposal

item	issues	Policy proposal
Utilization of probabilistic safety analysis results when establishing vital area	fault trees based on probabilistic safety assessments were not applied. simplify fault trees qualitatively	Added to Enforcement Decree of APPRE & added to KINAC RS-107
Relocation of crucial equipment when setting up vital areas	Physical protection design was completed before security plan were submitted, making it impossible to change protection equipment or rearrange key equipment.	Revised the APPRE
Maintenance of key equipment located within the vital area during vital area operation	The vital areas that were reset after 2015 are not linked to safety and do not comply with the security requirements stipulated in the Act on Physical Protection and Radiological Emergency Preparedness.	Revised the APPRE & KINAC RS-107
Analysis of safety-related severe accidents when assessing vulnerabilities in the design of physical protection systems	In the U.S, the Modular Accident Analysis Program (MAAP) severe accident analysis code developed by the Electric Power Research Institute (EPRI) is used in the industry. (Safety Analysis Code) (Similar to MELCORE) code to evaluate the source term spreading inside and outside the containment vessel in the event of sabotage. In ROK, such analysis is not performed.	A new guideline make KINAC RS-118(Technical Standard for Vulnerability Assessment) based on UK ONR Technical Assessment Guide (TAG)
Correlation between extreme event and physical protection	Physical protection equipment (e.g., fences, CCTV structures, etc.) is not included for debris related to high winds or tornadoes.	new research project begin to include the impact of physical protection structures such as fences, pillars, and CCTV on safety structures during strong winds or typhoons
The relationship between contingency plan and radiological emergency plan	No link between contingency plan and radiation emergency plan	"Act on Physical Protection and Radiological Emergency's Consultative Body" and revised KINAC RS-113 "Establishment of Contingency Plans."

3. Conclusions

This report categorizes key security-safety linkage areas into the following six categories: (1) vital area utilization of probabilistic safety analysis results during configuration (sabotage fault trees, probabilistic safety analysis fault trees) (2) Relocation of major equipment during vital area configuration, (3) Correlation with maintenance of major equipment located within the vital area during vital area operation. (4) Analysis of safety-related major accidents during vulnerability assessment of physical protection system design (5) Correlation between extreme event and physical protection (6) Correlation between protection emergency plans and radiation emergency plans. Policy proposals for safety-security linkage in each sector were presented accordingly. Table 5-1 summarizes these.

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