# Multi External Event Probabilistic Safety Assessment Framework

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## 1. Introduction

It is expected that there will be changes in the safety assessment for natural disasters in nuclear power due to the impact of climate change. In particular, the Korea Climate Change Assessment Report predicts that temperature, precipitation, typhoons, seawater temperature, and sea level will increase. The average temperature is increasing by about 1.8℃ from 1912 to 2017, and the average precipitation is increasing by 11.6mm per decade from 1912 to 2017. Sea temperature is rising by 0.024℃ per year from 1984 to 2013, and sea level rose by 2.9mm per year from 1989 to 2017.

As the frequency of natural disasters and accidents are expected to increase due to climate change, studies on the safety analysis of nuclear power plants have recently been conducted abroad. Safety evaluation of extreme natural disasters in nuclear power plants and development of safety improvement technology using the results are required, and a systematic and quantitative evaluation method for analysis of natural disasters is required. Accordingly, we present a methodology to analyse possible extreme natural disaster scenarios, evaluate the safety of nuclear power plants, and derive safety improvement measures.

## 2. External Event Probabilistic Safety Assessment

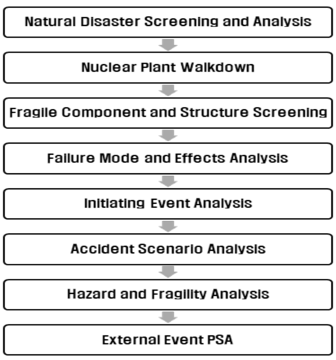


**Fig. 1. External Event Probabilistic Safety Assessment**

Fig.1 is a framework for evaluating the probabilistic safety of power plants against natural disasters. This framework is developed with reference to NEA and EPRI reports. An evaluation was conducted on the site for Shin-Kori Units 1 and 2 in Korea, and an analysis was conducted on natural disasters related to high wind and external flooding.

### *2.1. Natural Disaster Screening and Analysis*

In the case of extreme natural disasters, the frequency of occurrence is low, but analysis is necessary because the impact on power plants will be very large, and the frequency of occurrence of natural disasters is predicted to increase according to climate change. In this study, an analysis of high winds and external flooding were conducted.

### *2.2. Nuclear Plant Walkdown*

In this step, Structures, Systems and Components (SSC) affected by high winds and external flooding are derived using site visits and drawings. The survey includes up to 1km from the power plant area, and most of the buildings outside the nuclear power plant are targeted.

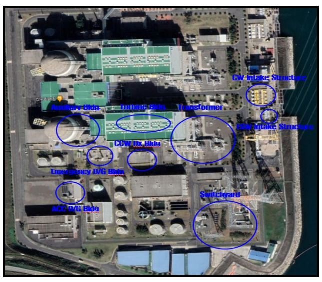

**Fig. 2. Shin-Kori Site information (Google Map)**

### *2.3. Fragile SSC Screening*

In this study, SSC selection is carried out through walkdown and case analysis of external events. A total of 25 external events caused by high wind and external flooding in Korea were analyzed, and the systems likely to be damaged by high wind and external flooding include the component cooling water system, circulation water system, and off-site power system.

### *2.4. Failure Mode and Effects Analysis*

The failure mode of the SSC, which is vulnerable to high winds, must be evaluated, and the failure mode and effect analysis of the derived devices is performed by referring to the internal event data.

*2.5. Initiating Event Analysis*

The initial event analysis is performed by referring to the external event case analysis and the internal event data. Accidents affected by high wind and external flooding include Loss of Offsite Power (LOOP), Station Black Out (SBO), and Loss of Component Cooling Water (LOCCW).

*2.6. Accident Scenario Analysis*

Accident scenarios were derived by considering SSC vulnerable to high wind and external flooding. It was analyzed by assuming that the component would be damaged if the structure was damaged. Fig. 3 is the high wind accident scenario used in this study. Fig. 4 is the external flooding accident scenario used in this study.

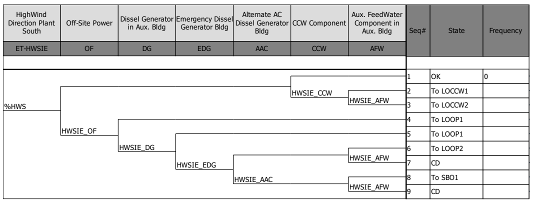

**Fig. 3. High Wind Accident Scenario**

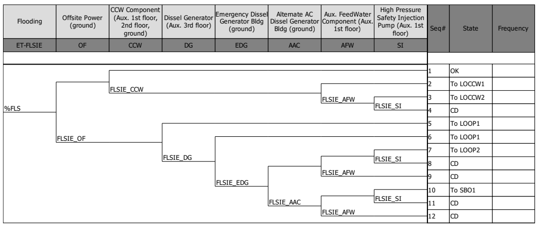

**Fig. 4. External Flooding Accident Scenario**

*2.7. Hazard and Fragility Analysis*

The hazard of high wind and external flooding was derived using the data of the Korea Meteorological Administration, and the fragility of high wind was assumed by referring to the fragility of earthquake.

*2.8. External Event PSA*

The Core Damage Frequency (CDF) was derived using the accident scenario of high wind and external flooding, the hazard, and the fragility. For existing equipment failure rates, internal event PSA was referenced. Results such as the table below were derived. In the case of external flooding fragility, it was assumed that it would fail as it was flooded according to the elevation.

**Table 1. High Wind CDF**

| | LOCCW | LOOP | SBO | Total |
|---|---|---|---|---|
| **CCDP** | 8.49E-08 | 2.86E-07 | 1.13E-07 | 4.84E-07 |

**Table 2. External Flooding CDF**

| | LOCCW | LOOP | SBO | Total |
|---|---|---|---|---|
| **CCDP** | 7.32E-08 | 1.60E-07 | 1.26E-08 | 2.46E-07 |

## 3. Multi Probabilistic Safety Assessment Framework

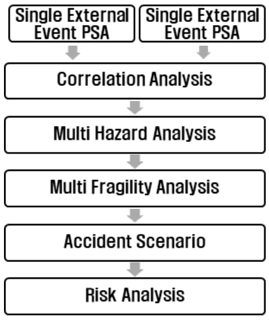


**Fig. 5. Multi External Event Probabilistic Safety Assessment**

Risk assessment of multi external events using the results derived from single external event risk assessment.

*3.1. Correlation Analysis*

Correlation analysis was performed using daily data from the Korea Meteorological Administration (1997-22). If the correlation coefficient C is close to the absolute value of 1, it is a very strong correlation, and if the absolute value is about 0.5, it can be said that there is a correlation, and if the absolute value is about 0.2, it can be said that there is no correlation The correlation coefficient C in this study was about 0.3, so it proceeded because there was no correlation between high wind and external flooding..

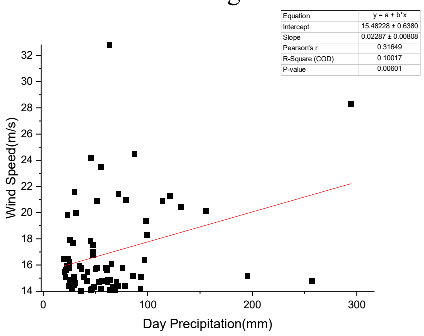


**Fig. 6. High wind and External Flooding Correlation Analysis**

*3.2. Multi-Hazard Analysis*

The Hazard derived from the Single External Event PSA and the correlation analysis result were used to derive the following multi hazard.

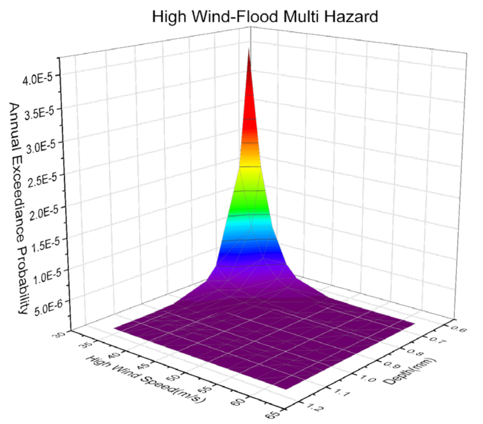


**Fig. 7. High wind – External Flooding Multi Hazard**

### *3.3. Multi-Fragility Analysis*

Multi-Fragility was similarly derived using Fragility Data obtained from Single External Event. All fragile SSCs derived from both strong wind and external flooding events were used.

**Table 2. High wind-External Flooding Fragile SSCs**

| Structure | Component | High Wind | Flooding |
|---|---|---|---|
| Aux Building | CCW Component | △ | O |
| | Dissel Generator | O | O |
| | Aux. Feedwater Pump | O | O |
| | Safety Injection | X | O |
| | ECW Pump | O | O |
| EDG Building | | O | O |
| AAC DG Buildfing | | O | O |
| ESW IS Building | | O | O |
| CCW Hx Building | | O | O |
| Swithch Yard Structure | | O | O |

### *3.4. Accident Scenario Analysis*

In the case of the accident scenario, it was derived using the multi-fragility SSCs and the accident scenarios used in the single event(high wind, external flooding).

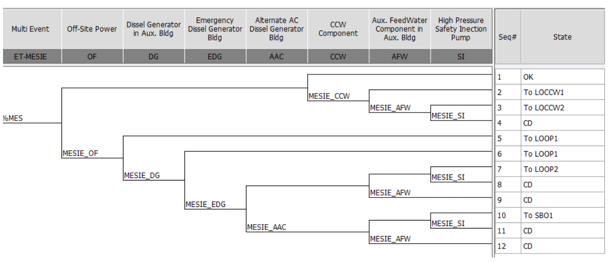


**Fig. 5. Multi Event Accident Scenario (High Wind – External Flooding)**

### *3.5. Risk Analysis*

Risk analysis was conducted using ARES, the earthquake PSA analysis tool. In order to perform 3D convolution, the risk of high winds was evaluated for each external flooding depth bin. The results are shown in the table3.

**Table 3. high wind-External flooding CCDP per depth bin**

| Depth (m) | 0.53-0.61 | 0.61-0.69 | 0.69-0.77 | 0.77-0.85 | Total |
|---|---|---|---|---|---|
| CCDP | 2.68E-09 | 1.76E-10 | 1.50E-11 | 4.74E-13 | 2.87E-09 |

## 4. Result

In this study, the high wind and external flooding risk evaluation for the Korean nuclear power plant site was conducted according to the external event framework as shown in Figure 1. As shown in Figure 2, in the case of SSC affected by high wind and external flooding, most of the buildings outside were affected. Such as Auxiliary building, Off-Site Power, Diesel Generator building, CCW Heatexcahnger structure, CW Intake structure. In the case of high wind CDF, it was derived as 4.84E-7/yr, and in the case of external flooding CDF, it was derived as 2.46E-7/yr. In addition, in the case of the multi event CDF, it was derived as 2.87E-9/yr. Depending on climate change, analysis of other external events is also needed.

## Acknowledgements

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