Probabilistic Safety Assessment of Wildfire Risks to the Off-site Power System Connected to the Kori Nuclear Power Plant

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1. Introduction

The off-site power system, which supplies AC power to nuclear power plants, is typically routed through forested areas in Korea. Consequently, wildfires near power system components can significantly impact power delivery, potentially resulting in a Loss of Off-site Power (LOOP) event. Globally, instances of power system disruptions due to wildfires have been reported, and climate change is expected to increase the wildfire potential due to rising temperatures and decreasing humidity [1]. In Korea, wildfire occurrence is projected to rise, particularly during spring, when the effects of climate change are more pronounced [2]. Domestic cases have been reported where wildfires have disrupted off-site power systems, leading to reactor shutdowns and activation of emergency diesel generators.

This study highlights the necessity of a quantitative safety assessment of the off-site power system due to the growing wildfire threat. We estimated the probability of wildfire-induced LOOP events by applying a probabilistic safety assessment (PSA) methodology to the off-site power system connected to the Kori Nuclear Power Plant (NPP).

2. Estimation of Off-site Power System Failure Probability Due to Wildfire

During normal operation, off-site power is used to support auxiliary systems in a nuclear power plant. Under abnormal or accident conditions, it powers the reactor protection and engineered safety systems. Wildfires can disrupt off-site power, thereby affecting plant safety. Kim [3] proposed a PSA methodology that uses spatial data of off-site power systems and wildfire hazard maps to estimate the probability of LOOP events. This study applied this methodology to the off-site power system connected to the Kori NPP.

2.1 Wildfire Hazard Near the Kori NPP Site

A wildfire hazard map was created by determining the burn probability within the area of interest. Based on data from the 2023 Forest Fire Statics Annual Report, the number of wildfire occurrences over 10 years for each region was divided by the forested area, and then uniformly distributed to the cells located within forested areas in the Area of interest [4]. The resulting wildfire hazard map was prepared as raster data consisting of square grid cells with a resolution of 90 m×90 m. Cells located within Busan were assigned a Burn probability of 2.73E-04/yr, whereas cells located within Ulsan were assigned a probability of 1.53E-04/yr.

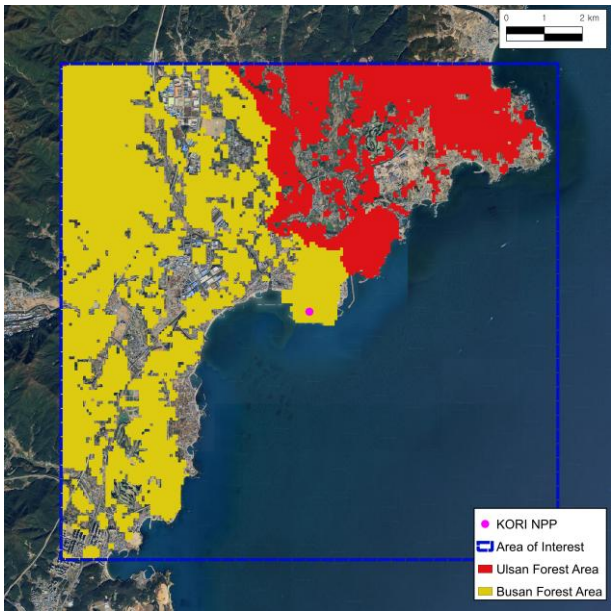

Fig. 1. Wildfire hazard map centered on the Kori Nuclear Power Plant

2.2 Extracting Spatial Information of the Off-site Power System

Spatial information on the off-site power system connected to the Kori Nuclear Power Plant was obtained using OpenStreetMap and Google satellite imagery. Five transmission lines and three substations were identified as power sources; other sources were assumed nonexistent. Interconnections between units were excluded due to a lack of available data. The

spatial information of the components is rasterized to match the cell resolution of the wildfire hazard map. Figure 2 shows the rasterized spatial information for substations and transmission lines.

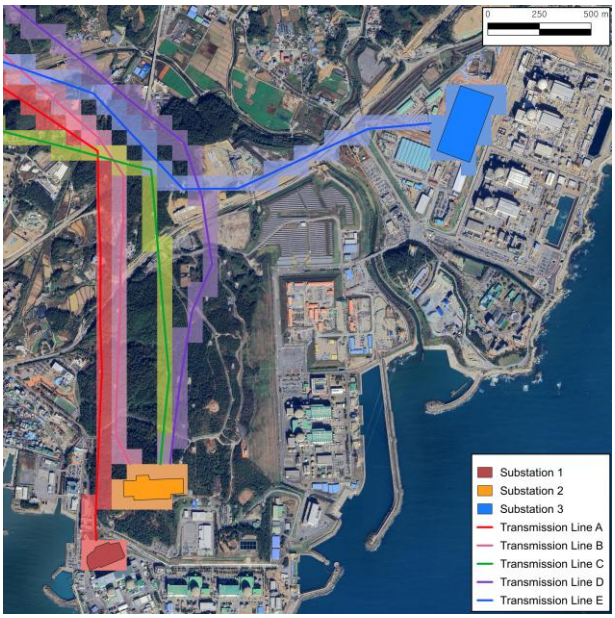

Fig. 2. Rasterized spatial information of substations and transmission lines

2.3 Deriving LOOP Probability Due to Wildfires

The probability of wildfire-induced LOOP was derived using Monte Carlo Simulation (MCS) and fault tree analysis. First, failure probabilities of individual components were calculated by applying the burn probability of the cell where each component is located. If a cell is burned, all components within it are assumed to fail. Substations and transmission lines were modeled by cells combined with OR gates, such that damage to any part resulted in component failure. The MCS iteration number was 2^{25} times, and the number of component failures was divided by the total simulations to derive the failure probabilities. To calculate the LOOP probability, all components were assumed to be independent, and a fault tree was constructed based on their connectivity. For Substation 2, which is connected to three transmission lines, all three lines (Transmission Lines A, B, and C) must fail to result in power loss—thus connected via an AND gate. The top event, LOOP, occurs only if power from all substations (Substations 1, 2, and 3) is lost; hence, these were also connected via an AND gate. The constructed fault tree is shown in Figure 3.

This PSA evaluates the off-site power system by its connectivity and does not consider its availability. The derived wildfire-induced LOOP probability at the Kori NPP Site is 4.34357E-06/yr.

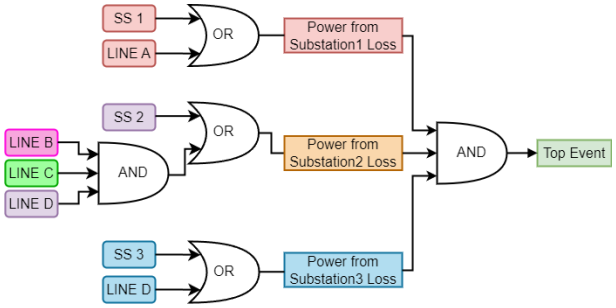

Fig. 3. Fault tree of wildfire-induced LOOP event at the Kori Nuclear Power Plant

3. Conclusion

This study applied the PSA methodology proposed by Kim [3] to evaluate the probability of wildfire-induced LOOP events for the off-site power system at the Kori Nuclear Power Plant. Spatial data of system components and wildfire hazard maps were used to derive cell-based failure probabilities. Monte Carlo Simulation was employed to calculate individual component failure probabilities, which were then integrated using a fault tree to calculate the overall LOOP probability. The result confirmed that the LOOP probability due to wildfires can be quantitatively assessed. As climate change is expected to increase wildfire occurrences, the necessity for quantitative safety assessment of off-site power systems also increases, especially those routed through forested areas. The PSA methodology implemented in this study can contribute to the analysis of wildfire threats and the development of mitigation strategies for nuclear power plant safety.

Acknowledgments

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