

Wildfire Probabilistic Safety Assessment of Off-site Power System Considering Local Wildfire Duration

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1. Introduction

The off-site power system (OPS) of nuclear power plants (NPPs) is vulnerable to wildfire-induced damage, which may lead to the interruption of AC power supply [1]. In particular, the frequency and magnitude of wildfires are expected to increase under climate change, making the safety assessment of transmission networks around NPPs a crucial issue [2]. Wildfire duration is a key determinant of fire spread and is significantly affected by human activities such as firefighting capability [3]. If the variability of wildfire duration across different regions is not properly considered, the reliability of assessment results may be undermined. Therefore, it is essential to incorporate the regional statistical characteristics of wildfire duration into the evaluation process. This study focuses on the Kori NPP to quantitatively examine the influence of detailed input data on the wildfire safety assessment of the OPS. The findings of this research are expected to serve as a reliable reference in decision-making processes related to the design and operation of NPPs.

2. Safety Assessment of the Off-Site Power System Considering Wildfire Duration

The safety assessment of the OPS against wildfires was carried out by performing Monte Carlo Simulation (MCS) using wildfire propagation simulation programs. Through this process, wildfire hazard maps surrounding the nuclear power plant were generated, and the probability of OPS loss caused by wildfires was estimated [4]. In this framework, wildfire duration functions as a critical input variable that governs the distribution of wildfire hazard, thereby exerting a substantial influence on the safety assessment outcomes.

2.1 Localized Wildfire Duration Distribution Estimation

Using wildfire records provided by the Korea Forest Service [5], the wildfire duration distribution in the vicinity of the Kori nuclear power plant was derived. Data on wildfire durations over the past 10 years in

Gijang-gun and Ulju-gun were collected and fitted to a lognormal distribution, and the results were compared against nationwide wildfire statistics.

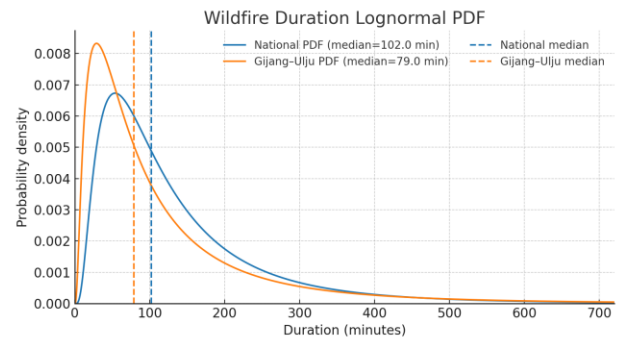
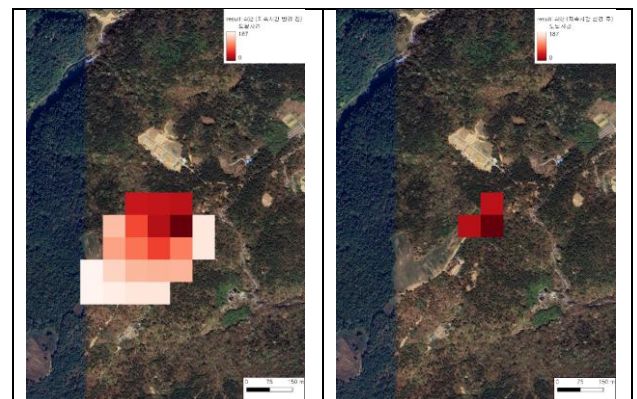


Fig. 1. Wildfire Duration PDF Graph Comparison

The analysis showed that the local wildfire duration distribution exhibited a lower median value and a higher proportion of short-duration wildfires compared to the national distribution. These comparisons are illustrated in Fig. 1.

2.2 Derivation of Wildfire Hazard Map

FlamMap was employed to derive wildfire hazard maps through MCS. Wildfire durations sampled from both the nationwide distribution and the Gijang-Ulju distribution were applied as inputs to the simulation.



(a) 187 minutes	(b) 30 minutes
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Fig. 2. Comparison of Wildfire Spread simulation in different Durations

All other input variables were held constant. As shown in Fig. 2, simulation results differed significantly depending on wildfire duration. By superimposing all simulation outcomes and normalizing them by wildfire occurrence frequency, the final wildfire hazard maps were obtained.

2.3 Safety Assessment Result Comparison

Safety assessments were conducted using the two wildfire hazard maps, and the resulting probabilities of off-site power system loss were compared to evaluate the effect of localized wildfire duration inputs. The off-site power system was modeled as a network that reflected both component locations and interconnections. By applying wildfire hazard maps and performing MCS, the annual loss probability of the system was derived. When the Gijang–Ulju wildfire duration distribution was applied, the probability of off-site power system loss was approximately 21% lower than that derived from the nationwide distribution. Detailed results are summarized in Table I.

Table I: Safety Assessment Result by Duration

	National Wildfire Duration	Gijang-Ulju Duration
Loss of OPS Probability	7.83E-06/yr	6.17E-06/yr
CDifference	21.18%	

3. Conclusions

Wildfires can damage the OPS, posing a significant threat to the safety of NPPs. Wildfire duration is closely associated with human suppression efforts and varies across regions. This study incorporated localized wildfire duration distributions into the safety assessment of the OPS and quantitatively analyzed their impact. Using FlamMap-based MCS, wildfire hazard maps were generated, and wildfire durations sampled from both national and regional distributions were compared. The results indicated that applying the localized distribution reduced the annual loss of OPS probability by approximately 21%. This reduction is attributable to the statistical characteristics of the Gijang–Ulju region, where the wildfire duration distribution exhibits a lower median and a higher proportion of short-duration fires compared to the nationwide average, thereby limiting the extent of wildfire spread.

In conclusion, wildfire safety assessment results are highly sensitive to wildfire duration. To enhance the reliability of such assessments, it is necessary to incorporate localized wildfire duration distributions. The findings of this study contribute to improving the credibility of safety assessment results and can support

decision-making processes for NPP operation and emergency response.

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REFERENCES

- [1] Assessment of Vulnerabilities of Operating Nuclear Power Plants to Extreme External Events IAEA TECDOC SERIES, <http://www-ns.iaea.org/standards/>.
- [2] M. Goss, D.L. Swain, J.T. Abatzoglou, A. Sarhadi, C.A. Kolden, A.P. Williams, N.S. Diffenbaugh, Climate change is increasing the likelihood of extreme autumn wildfire conditions across California, *Environmental Research Letters* 15 (2020). <https://doi.org/10.1088/1748-9326/ab83a7>.
- [3] E. Marshall, A. Dorph, B. Holyland, A. Filkov, T.D. Penman, Suppression resources and their influence on containment of forest fires in Victoria, *Int J Wildland Fire* 31 (2022) 1144–1154. <https://doi.org/10.1071/WF22029>.
- [4] Y. Choi, S. Eem, K. Kim, S. Kwag, Probabilistic Safety Assessment Methodology for Loss of Off-site Power System Due to Wildfires, submitted
- [5] Kim, J. O., Choi, B. S., & Kim, E. E. (2024). *2023 Forest Fire Statistics Annual Report*. www.forest.go.kr