Investigating natural disaster cases due to climate change and potential risks to nuclear power plants

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1. Introduction

Climate change is causing environmental changes on a global scale. Climate change is causing natural disasters all over the world [1]. In October 2023, floods caused by heavy rains in Nigeria resulted in casualties [2,3]. In April 2023, Chicago experienced heavy snowfall, with temperatures dropping below zero just four days after the highest recorded temperature [2,3].

Climate change changes air temperature, rainfall, wind speed, sea surface temperature, etc., and thus the intensity and frequency of natural disasters such as typhoons, floods, droughts, and forest fires change [1,4,5]. Natural disasters related to climate change also directly affect the safety and operation of nuclear power plants [1]. For example, in France, due to climate change, there was an incident where a heat wave caused a rise in seawater temperature, which caused a nuclear power plant to shut down or reduce its output [1]. In Korea, there was an incident where a rise in seawater temperature caused a rapid increase in marine life, which blocked the intake of a nuclear power plant and reduced its output [1].

Nuclear power plants worldwide are increasingly affected by climate change. Regulatory institutes, including the International Atomic Energy Agency (IAEA) and the Western European Nuclear Regulators' Association (WENRA), emphasize the necessity of incorporating climate change considerations into the safety assessment and design of nuclear power plants [6,7]. Ensuring the safe operation of nuclear power plants requires the implementation of protective measures and safeguards against climate change-related risks. Accordingly, this study examines the impact of climate change on nuclear power plants and analyzes historical climate-related external events through a comprehensive literature review. The findings contribute to assessing nuclear power plant safety and operational resilience in the context of climate change.

2. Cases and impacts of climate change-related events at nuclear power plants

Climate change-related events affecting nuclear power plants in Korea were analyzed using the Operational Safety Information System (OPIS) managed by the Korea Institute of Nuclear Safety (KINS) [1,8]. Between May 1978 and September 2024, a total of 75 events attributed to external events were identified, representing approximately 9.5% of the 797 recorded incidents. All external event-related incidents were classified as minor and did not compromise reactor safety.

The causes of external events are classified into seven types (Typhoons, Rainfall, Earthquakes, Lightning, Marine Organisms, Wildfire, and Others). Fig. 1 shows the occurrence ratio of external events by cause at domestic nuclear power plants from 1978 to 2024. Among the causes of external events, Typhoons, Rainfall, Marine Organisms, and Wildfire, which are related to climate change, may affect the operation and safety of nuclear power plants as their intensity and frequency change due to climate change. Sections 2.1 to 2.4 show the impact that major external events related to climate change may have on the operation and safety of nuclear power plants.

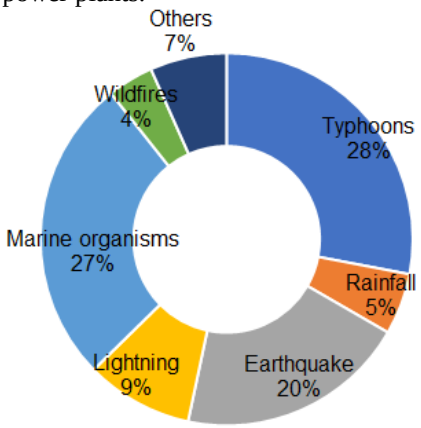

Fig. 1. Number of Incidents by Category of External Events by Site from 1978 to 2024[8]

2.1. Typhoons [1,8]

Typhoons can impact nuclear power plants' power grid and cooling systems(intake). The primary causes of incidents related to typhoons include damage to power facilities due to strong winds and lightning, degradation of insulation performance caused by seawater salt

deposition, airborne debris impact generated by typhoons, flashovers leading to ground faults, and damage to off-site power system components resulting in power supply disruption. The potential effects of typhoons on nuclear power plants can be summarized as follows:

• Structural and system damage due to strong winds (e.g., building collapse, debris impact)
•Damage to external power networks and transmission lines, including transmission line jumper cable vibrations and short circuits caused by strong winds
•Degradation of insulation performance and electrical failures due to salt deposition
•Malfunction and false signals triggered by strong winds and lightning
•Increased risk of corrosion and electrical malfunctions due to residual salt deposition after a typhoon

2.2. Rainfall [1,8]

Rainfall can cause flooding (external inundation), potentially infiltrating critical facilities within a nuclear power plant and leading to functional damage. Water ingress into the plant site due to heavy rainfall may degrade the performance of essential equipment and electrical systems. The potential impacts of heavy rainfall are as follows:

•High water pressure exerting physical stress on the reactor building and other critical structures
•Mechanical damage caused by strong water currents and the influx of debris

2.3. Marine organisms [1,8]

Due to climate change, nuclear power plants located along coastal areas may experience increased marine organism influx, which can impact their operations and potentially lead to plant shutdowns. The major effects of marine organisms on nuclear power plants are as follows:

•Blockage of intake structures, leading to disruptions in cooling water inflow
•Reduced functionality of the ultimate heat sink and cooling systems

2.4. Wildfires [1,8]

Climate change has led to an increase in both the frequency and severity of wildfires. Some nuclear power plants in Korea are located near forested areas, making them more susceptible to wildfire-related impacts. When a wildfire occurs, visibility around the nuclear power plant can be significantly reduced, making it difficult for operators to maintain a clear line of sight and restricting access to the facility.

Additionally, large amounts of smoke and delicate particulate matter generated by wildfires can necessitate respiratory protective equipment, thereby reducing operational efficiency. There is also a risk of wildfires spreading to the plant site, and the potential loss of external power supply due to wildfire damage to transmission lines may disrupt power generation.

3. Conclusion and Discussion

Climate change has been continuously progressing, influencing the frequency and intensity of various natural disasters. This study confirms that, to date, external events induced by climate change have primarily impacted the operational aspects of nuclear power plants rather than their direct safety. Most reported incidents have been minor, such as temporary reactor shutdowns. However, as climate change persists, its potential impact on the operation and safety of nuclear power plants is expected to gradually increase. In particular, failures in non-safety grade Structures, Systems, and Components (SSCs) may propagate to safety-grade SSCs, posing a significant risk. Therefore, it is crucial to ensure the continued safe operation of nuclear power plants by preparing for evolving climate conditions.

Changes in temperature, sea surface temperature, precipitation, and wind speed due to climate change are contributing to the increased intensity and frequency of natural disasters. This highlights the need for a new approach to evaluating the safety and operation of nuclear power plants. However, to date, no standardized methodology fully incorporates climate change's effects into nuclear power plant safety assessments. Existing hazard assessment methods rely primarily on historical observational data, which do not adequately account for the variability introduced by climate change. To accurately assess the impact of climate change on the frequency and characteristics of natural hazards, To accurately assess the impact of climate change on the frequency and characteristics of natural disasters, high-resolution analysis (spatial and temporal downscaling) of climate change data is necessary. Future research should focus on quantifying the impacts of climate change on nuclear power plants and developing appropriate safety measures to mitigate associated risks. By integrating climate change considerations into nuclear safety evaluations, a more resilient framework for the continued operation of nuclear power plants can be established.

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