A Preliminary Analysis of Fire-Related Events in Korean Nuclear Power Plants

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1. Introduction

In general, several important data used in a fire probabilistic safety assessment (PSA) can be derived from the systematic analysis of historical fire event records. For example, data for estimating fire ignition frequencies and fire suppression times used to determine non-suppression probabilities (NSPs) can be discovered from fire event data.

According to [1, 2], the generic data for use in fire PSAs are available through the Fire Event DataBase (FEDB), which evaluates historical records of fire incidents from U.S. nuclear power plants. The FEDB generally contains general event information, ignition sources, fire characteristics, and consequences.

In Korea, the Operational Performance Information System (OPIS) [3] provides data on operational incidents at Korean nuclear power plants (NPPs); however, it lacks a specialized focus on fire event analysis compared to dedicated fire databases. Consequently, it is challenging to comprehensively identify how many fire events occurred, or which categories of ignition sources are most prevalent in Korean NPPs.

Therefore, this study aims to conduct a preliminary screening of fire-related events from the OPIS records. Furthermore, an example of analyzing fire events is presented to explore the possibility of converting them into actionable information for fire PSAs.

2. Collection of Potential Fire Events from OPIS

Currently, the OPIS stores 811 event records covering all units and operational modes in Korea. Given the practical difficulties of reviewing all recorded events, an initial screening was carried out to collect *potential (fire-related) fire events* using the following 11 fire-related keywords:

'*fire', 'fire suppression', 'thermal damage', 'combustion', 'smoke', 'flame', 'overheating', 'carbonization', 'spark', 'flashover',* and *'arc'*.

To ensure a comprehensive collection of potential fire events, the keyword-based search was performed using both English and Korean terms, depending on the context.

As a result, a total of 221 potential fire events were retrieved, as presented in Table I.

Table I: Potential fire events from OPIS (1978~2025)

Keyword	No. events	Keyword	No. events
Fire	30	*Overheating*	19
Suppression	36	*Carbonization*	5
Thermal damage	57	*Spark*	16
Combustion	4	*Flashover*	16
Smoke	16	*Arc*	15
Flame	7	**Total**	221

It should be noted that these results may include duplicate search entries. For example, a single event could be retrieved by multiple keywords, such as '*fire*' as well as '*smoke'*. After excluding duplicate cases, a total of 131 cases were screened as potential fire incidents at Korean NPPs.

It is also important to note that some cases among the potential fire incidents might be completely irrelevant to a fire event, even though they were captured using the fire-related keywords. For example, if an incident record contains the sentence "*an event occurred during fire prevention maintenance…*," it would be retrieved by the keyword '*fire*', although it is not actually relevant to a fire event. Therefore, it is expected that the number of events ultimately identified as *actual fire events* will be significantly lower than the initial 131 cases.

3. Preliminary Analysis of Potential Fire Events

3.1 Deriving Information Useful for Fire PSAs from Potential Fire Events

The systematic review of potential fire events is essential for deriving actionable information for fire PSAs. The key information that can be extracted from fire event analysis includes fire severity level, the type of ignition source, and fire suppression times. According to [2], the following list outlines the results that can be derived from fire event analysis in the FEDB.

- Event date,
- Power mode,
- Fire severity,
- Ignition source (Bin designation),
- NSP category,
- Suppression time…

While the assigning ignition sources and the evaluation of fire suppression times can be relatively straightforward, classifying fire severity level requires a comprehensive judgment based on the narrative descriptions provided in the event reports. Fortunately, [2] provides a framework for how fire severity levels are established.

3.1.1 Fire Severity Classification Guidance [2]

Fire event data in the FEDB are classified into three fire severity levels to derive information useful for fire PSAs: challenging (CH), potentially challenging (PC), and non-challenging (NC). Additionally, cases with insufficient information are assigned to intermediate categories (Undetermined, U), such as PC-CH or NC-PC.

Table II shows the summary of fire severity classification guidance (See Sec. 4.2 of [2] for more details).

Once the fire severity levels are determined based on the criteria in Table II, this can be utilized for fire frequency analysis [4]. For instance, a CH fire event can be counted as 1.0 if specific plant information and the operating mode are verified; otherwise, various multipliers are assigned to incorporate the event into the frequency estimation [1].

3.2 Examples of Preliminary Analysis of Fire Events in Korean NPPs

Based on the guidance in Sec. 3.1.1, a brief overview of the potential fire events described in Sec. 2 was carried out. Examples of the fire events (retrieved by "*fire*" keyword) analyzed in this study are summarized in Table III. Despite being retrieved through fire-related keywords, incidents with no actual relevance to fire will be filtered out of the final dataset. Due to the preliminary scope of this study, the analysis remained at an exploratory level. Readers should be advised that the subsequent findings are highly preliminary and subject to revision.

4. Conclusions

In this study, potential fire events were screened from the OPIS records using fire-related keywords, and preliminary fire event analysis was conducted for several selected cases based on the fire severity classification guidance.

While this study focused on a limited number of cases, further research is required to systematically conduct fire severity classification, suppression time analysis, and ignition source evaluation for the remaining 131 identified potential fire incidents.

If all potential fire events are analyzed, even at a preliminary level, it is expected that statistical evaluations and trend analyses of fire events at Korean NPPs will become feasible. For example, Bayesian updates on fire ignition frequencies can also be performed by utilizing the results of Korean fire event analysis.

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[4] EPRI, An Improved Methodological Approach for Estimating Fire Ignition Frequencies, EPRI1022994, 2011

Table II: Summary of the classification scheme for fire severity levels [2]

Category	Descriptions	Key Indicators	Suppression
CH	"Fires that had an observable and substantive effect on the environment outside the initiating source."	High energy arcing fault (HEAF), explosions, …or secondary ignition.	Significant suppression actions: Use of manual hose streams, fixed suppression systems
PC	"Events that were not CH but could have reached a CH state under foreseeable alternate circumstances."	Small open flaming internal or external to the component…	Minor suppression actions: Use of a single portable extinguisher or simple, prompt manual intervention
NC	"Fires that did not and would not have caused damage to adjacent objects regardless of the duration."	Overheating conditions without flaming or smoldering…	Self-extinguishment without any active intervention

Table III: Examples of preliminary analysis of fire events in Korean NPPs (Events retrieved by "*fire*" keywords)

Date	**Plant** (Power %)	**Fire Severity** (Preliminary)	**Basis for judgement**	**Ignition source**	**Suppression time (min)**
24.11.16	Saeul (100%)	U(NC-PC)	- Flame and smoke detected in the water drum heater control panel. - The external fire department confirmed that it was a fire event. - Immediate suppression by a local operator using a single fire extinguisher.	Control panel	0
24.03.19	Wolsong (87%)	CH	- HEAF occurred. - Impact on adjacent structures (e.g., cable trays) was identified. - Manual hose streams were used.	13.8kV BUB	230
22.12.15	Kori (100%)	U(NC-PC)	- Fire detection triggered by smoke from the CORS FEED pump in the water treatment room (overheating). - Initial response by a local operator using a single fire extinguisher.	Pump	0
22.02.05	Hanbit (100%)	PC	- An automatic smoke detection was actuated, and a single portable extinguisher was used.	HV	6
21.06.22	Saeul (100%)	N/A	- Non-fire event - A CO_2 extinguisher was used, but the external fire department concluded it was minor thermal damage, not a fire event.	N/A	N/A
21.05.29	Saeul (100%)	CH	- Multiple portable fire extinguishers (18) and manual hose streams (2) were used.	Collector Housing	64
19.01.21	Wolsong (91%)	U(PC-CH)	- Fire incident following a reactor trip triggered by a ground fault. - Sparks and smoke observed in the braking systems of PHT (Primary Heat Transport) pumps #1, 3. - Deployment of five fire extinguishers for suppression. - Minor fire with delayed full suppression due to restricted accessibility.	Pump	72
18.01.14	Wolsong (89%)	U(NC-PC)	- Sparks occurred at the oxygen bottle pressure regulator upon opening the isolation valve, triggering the smoke detector. - The fire was suppressed by a fire extinguisher (for one second).	N/A	1

15.08.08	Hanbit (96%)	CH	- HEAF occurred. - Impact on adjacent structures was identified. - The fire was suppressed using three CO_2 fire extinguishers.	HEAF	16
09.08.19	Hanul (100%)	NC	- Fire detection triggered by smoke in the CCM area of the radioactive waste vitrification facility. - Smoke originated from the exterior wall of the CCM; however, only carbonization of the external fire-retardant paint was observed. - Confirmed no progression to ignition; consequently, no active fire suppression measures were required.	N/A	N/A
04.06.30	Wolsong (100%)	N/A	- Non-fire event - The entry was identified through the keyword "Fire Prevention Construction."	N/A	N/A
04.02.28	Kori (75%)	N/A	- Non-fire event - The entry was identified through the keyword "No Fire Hazard."	N/A	N/A
03.02.06	Hanbit (100%)	U(PC-CH)	- Initial suppression attempts using a fire extinguisher and a fire hydrant lasted for several minutes.	N/A	N/A
02.04.22	Kori (100%)	CH	- Main transformer explosion - A fire detector was and fixed water spray system was actuated.	Main Transformer	N/A
00.04.11	Hanul (86%)	N/A	- Non-fire event (Not applicable to fire PSA) - Wildfire	N/A	N/A
00.04.07	Hanul (100%)	N/A	- Non-fire event (Not applicable to fire PSA) - Wildfire	N/A	N/A
87.08.13	Hanbit (100%)	N/A	- Non-fire event - The deluge valve was inadvertently opened due to human error.	N/A	N/A