Prioritization of Operation Range for Automation to Reduce Human Error by using an Descriptive Statistical Approach

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1. Introduction

Nuclear power plants are built based on reliable technical hardware developed to prevent radioactive material release due to accidents and operated by a well-trained operating organization. However, all engineering products might be forced to experience failures or accidents. Since experienced failures or accidents provide positive feedback on future operations or designs, it can be said that the history management of failures or accidents ultimately contributes greatly to enhance performance of engineering system.

It has already been more than 40 years since Kori Nuclear Power began commercial operation in 1978. Until now, many large and small failures or accidents have occurred, and record management has been carried out by KINS (Korea Institute of Nuclear Safety).

The most effective way to improve the safety of nuclear power plants was to improve or supplement existing facilities to elevate functional performance. However, through accidents at domestic and foreign nuclear facilities, human factors have been recognized as a key factor in weakening nuclear safety, and efforts are continuously being made to reduce the occurrence of human errors caused by operating organizations.

One of the active efforts to reduce human error is the introduction of an automated system. Automation allows the physical system to perform manual operations carried out by operators for nuclear power plant operation, and in recent years, it tends to be implemented through advanced information and communication technologies.

Automation is a technology that can be expected to benefit significantly, but determining which manual operation to automate is an important priority to ensure its effectiveness.

In this study, in order to lay the foundation for determining the operating range to be automated, cases of failures and incidents that occurred in Korea in the past were investigated.

2. Methods and Results

KINS is the organization that officially discloses nuclear events (incidents and accidents) to public and manages their cases in Korea. Through the OPIS (Operational Performance Information System), KINS has provided all nuclear event records from the start of commercial operation of domestic nuclear power plants to the present. The OPIS has a classification system for nuclear events. Depending on the classification system, it tells you what system is involved in all nuclear events and what the cause of them are. Also, OPIS provides an INES (International Nuclear Event Scale) level evaluated by the committee for each nuclear event case.

The OPIS provides the following items for each case.

- Site and unit
- Date
- Plant status (pre-operating/operating)
- Event title
- Reactor power
- Generator Power
- Related system (primary/secondary/other systems)
- Cause of event (Electric/Instrument/Human Error/External/Mechanical/Others)
- Type of trip/shutdown (by automatic system/by manual control)
- INES level (level 0~7)

The OPIS provides a total of 761 nuclear event cases occurred from 1987 to 2021.

2.1 Frequency Analysis of nuclear events and their causes

Table I: Causes of nuclear events

Cause	# of cases	Percentage
Instrumentational	217	29 %
Mechanical	199	26 %
Human	137	18 %
Electrical	137	18 %
External	64	8 %
Other	7	1 %
Total	761	100 %

It is found that more than 60% of nuclear events are related to the secondary system and the most frequent cause of nuclear events is an instrumentational failure (refer to Table I).

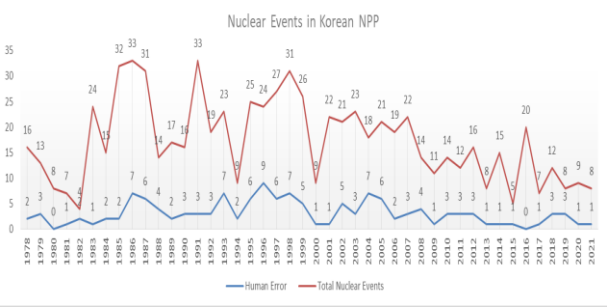

Fig. 1. Number of nuclear events (red) and human error (blue) for each year (from 1978 to 2021).

As Fig. 1 shows, the number of nuclear events is decreasing significantly in recent year and the number of human errors is not fluctuating greatly.

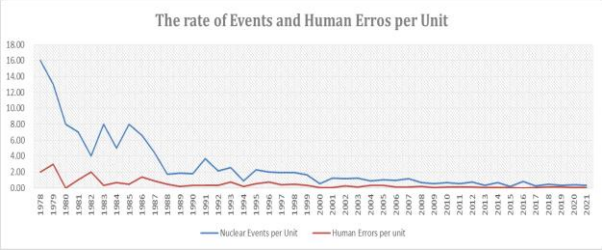

Fig. 2. The rate of the number of nuclear events (red) and human errors (blue) per operating unit.

A strong decrease in the number of nuclear events and human errors per unit is shown in the Fig. 2.

2.2 Location of human errors

The place in which a human error has occurred was investigated to know how many human errors occurred in the main control room (MCR) or local stations.

The 60 cases out of 137 total human error cases are occurred in the main control room.

2.3 Reactor power level and human errors

The nuclear event cases were investigated to confirm the relationship between reactor power and human error occurrence.

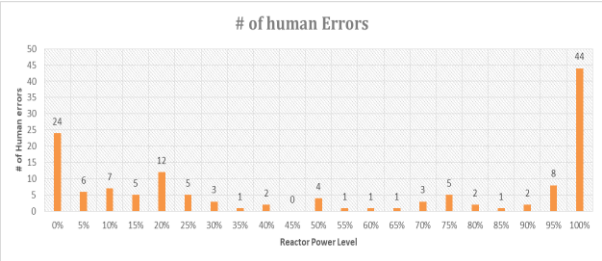

Fig. 3. The number of human errors along with reactor power level.

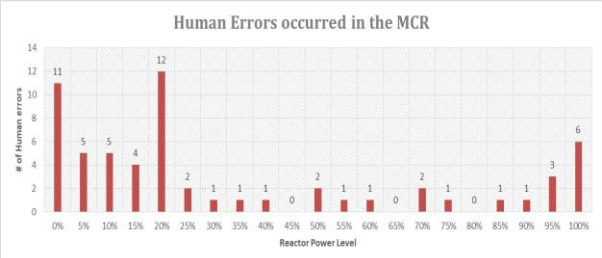

Fig. 4. The number of human errors occurred in the MCR along with reactor power level.

As shown in Fig. 3 and Fig. 4, most of human errors are occurred at the low level of reactor power and also much portion of human errors occurred in the MCR are also appeared at the low reactor power level.

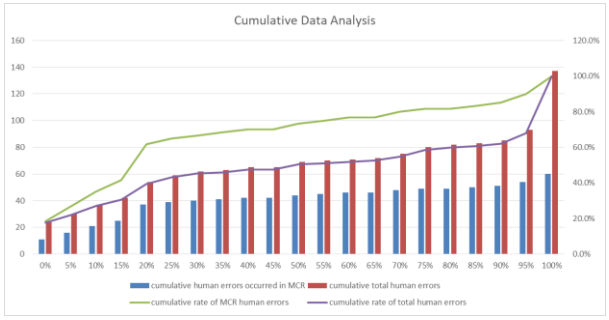

Fig. 5. Cumulative analysis of human errors along with reactor power level. The green curve shows the cumulative rate of human error occurred in the MCR, the violet curve shows the cumulative rate of total human errors. Bar graphs shows cumulative number of human errors (red bar) and human errors occurred in the MCR (blue bar) along with reactor power level.

Figure 5 shows the cumulative amount of human error occurrence compared to the reactor power. In the cumulative curves, the slope of a curve is related to the amount of occurrence, and it can be seen that the slope of the curve is very steep in low reactor power situations, so there are many human errors in low reactor power level.

One noteworthy fact is that the ratio of MCR human error to total human error is the highest (69%) at the reactor power level of 20%. This means that a considerable number of human errors occurred in the MCR for the low reactor power range from 0% to 20%.

2.4 Human errors and INES level

The highest grade of INES for nuclear events in Korea is grade 2, incident. Total four incidents has been occurred in Korean nuclear power plants. Of the four grade 2 incidents, three incidents were caused by human error and occurred in the MCR and in a situation where the reactor power level was low, around 0%.

In addition, it is necessary to be particularly careful that all grade 2 incidents occurred after 2012. This means that the possibility of incidents or more serious events is very high at present.

The proportion of grade 1 events (anomaly) caused by human error is the highest, about 37% of total grade 1 events (27 cases). Among grade 1 events, the rate caused by both human error and low power situation (less than 20%) is around 30% of total grade 1 events.

Table II: Causes and situation of graded nuclear events

INES grade(meaning)	2 (incidents)	1 (anomaly)
total cases	4	27

caused by human error	3 (75%)	10 (37%)
caused by human error occurred in the MCR	3 (75%)	4 (15%)
Caused by human error at the low reactor power level	3 (75%)	8 (30%)
caused by human error in the MCR and low power situation	3 (75%)	4 (15%)

3. Conclusions

From the descriptive statistical analysis of domestic nuclear events, the followings are found.

- While nuclear events caused by other factors are decreasing, nuclear events caused by human errors record a certain level of occurrence.
- Human errors were mainly occurring in low-power situations.
- About half of the human errors occurred in the main control room.
- Most of the human errors in the main control room occurred in low-power situations.
- Most of INES grade 2 incidents were caused by human error. All human errors have occurred in MCR and in low-power operating situations.
- Human error was the most common cause of INES grade 1 nuclear events, and most of them occurred in low-power operating situations.

As a result of descriptive analysis, it was confirmed that, in order to obtain the effect of reducing human error, it is necessary to prioritize the low-power operation situation performed by MCR operators as a target operation range to be automated.

REFERENCES

[1] OPIS (Operational Performance Information System for Nuclear Power Plant), http://opis.kins.re.kr/, visit in Feb. 2022.