# Derivation of main drivers affecting the possibility of human errors during low power and shutdown operation

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## 1. Introduction

It is widely known that the performance of the human operator is one of the crucial factors that determine the safe operation of nuclear power plants (NPPs). Operators may make human errors when they perform tasks in an inappropriate manner or in stressful environments. In this situation, human error may lead to unwanted problems in NPPs.

In order to estimate the possibility of human error and identify its nature, human reliability analysis (HRA) methods have been implemented. For this, various HRA methods have been developed so far: techniques for human error rate prediction (THERP), cause based decision tree (CBDT), the cognitive reliability and error analysis method (CREAM) and so on. Most HRA methods have been developed with a focus on full power operation of NPPs even though human performance may more largely affect the safety of the system during low power and shutdown (LPSD) operation than it would when the system is in full power operation [1].

In this regard, it is necessary to conduct a research for developing HRA method to be used in LPSD operation. For the first step of the study, main drivers which affect the possibility of human error have been developed. Drivers which are commonly called as performance shaping factors (PSFs) are aspects of the human's individual characteristics, environment, organization, or task that specifically decrements or improves human performance, thus respectively increasing or decreasing the likelihood of human errors [2]. Here, in order to derive main drivers, two approaches have been used: 1) literature review and 2) event report analysis. In the case of literature review, eight literatures related to human performance during LPSD operations were reviewed. In the case of event report analysis, the OPIS (operation performance information system) database that provides domestic NPP event reports which contain several information such as event data, failed system, causes, reactor power was analyzed by using root cause analysis (RCA) method.

## 2. Review of literatures related to human performance during LPSD operation

For the literature review, eight literatures related to human performance during LPSD operation were reviewed. The eight literatures are as follows.

- NUREG/CR-6093 [3]
- NUREG/CR-6883 [4]
- NUREG/CR-7114 [1]
- SAND 99-1815 [5]
- NEA/CSNI/R17 [6]
- NEA/CSNI/R11/VOL2 [7]
- IAEA-TECDOC-1144 [8]
- KAERI/AR-458/97 [9]

As a result of literature review, seven characteristics of human performance were investigated. 1) Mistakes and EOC are the predominant types and modes of human error. 2) Operators face continuously changing plant conditions and configurations. 3) Greater amounts of work activities being performed, such as tests, maintenance and repairs. 4) Many pieces of equipment are more frequently manually operated. 5) Even in the case in which procedural guidance is present for the actions required of operator following initiating events during LPSD operation, it is usually less detailed and insufficient. 6) Operators usually have less training in response to accidents during LPSD operation. 7) Since there is more time available to respond, operators may fell less stress.

This seven characteristics of human performance were compared to the common drivers including teamwork, experience level, workload/stress, procedures/guidelines, training, human system interface (HSI), and so on. As a result of comparison, among common drivers, four drivers should be considered in performing HRA during LPSD operation: experience level, workload/stress, procedure/guidelines, and training as shown in Fig. 1.

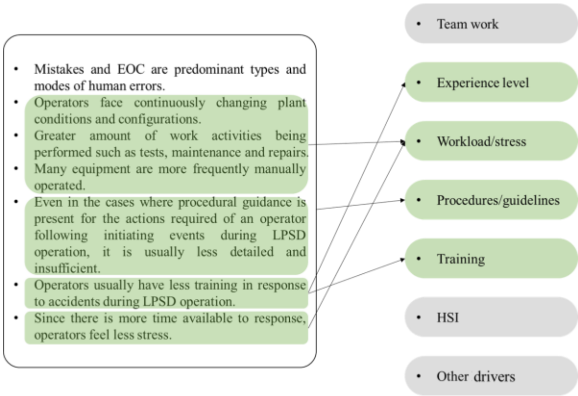


Fig. 1. The result of literature review: drivers that should be considered in HRA during LPSD operation.

## 3. Event report analysis by using RCA method

In order to analyze accident/incident reports, the root cause analysis (RCA) method for human-related events was used to identify root causes of inappropriate human activities in a systematic as well as consistent manner. RCA is a technique to figure out the causes of problems (here, inappropriate human activities) in order to clearly identify the root causes of problems and predict future problems from occurring [10]. Among various RCA methods, the human related event root cause analysis method plus (HuRAM+) was applied. HuRAM+ was developed by the Korea Institute of Nuclear Safety (KINS) to scrutinize error causes of human-related events in domestic NPPs that are reported to the regulatory agent [11]. The process of HuRAM+ consists of four steps: (1) gathering the information, (2) entering input into HuRAM+ worksheet, (3) analyzing error modes, and (4) analyzing root causes of error. In HuRAM+, root causes are regarded as factors that may drive improper human activities. There are eight root cause categories provided in HuRAM+: procedure/guideline/drawing, workload, training/education, HSI, communication, personnel (team), supervision, and task preparedness. In this study, in order to derive drivers that affect the probability of human error in implementation of LPSD HRA, root causes for domestic NPP events were mainly analyzed.

There are a total of 388 event reports between 1995 to 2015; 110 events were caused by humans or were human-related. Among them, 36 events happened during LPSD operation and there are 53 inappropriate human activities. For 53 inappropriate human activities, we performed root cause analysis using HuRAM+ in order to find the main drivers that affect the potential for human error during LPSD operation. However, in this study, 'carelessness of worker' in the cause category of 'personnel (team)' was excluded because even this root cause is one of the major contributors cause human error, but it is not the kind of drivers that consider aspects of the human's individual characteristics, environment, organization, or task.

The results of analyzing root causes are presented in Table I. As shown in Table I, the cause categories of 'procedure/guideline/drawing' and 'personnel (team)' are major contributors that lead to unwanted human activities. The cause category of 'workload' is difficult to observe in the analysis of root causes, even though this is one of big differences between full power and LPSD operations, as addressed in the literature review.

Table I: The result of HuRAM+ analysis

| Root cause category | # of observed by HuRAM+ analysis |
|---|---|
| 1. Procedure/guideline/drawing | 24 |
| 2. Workload | 5 |
| 3. Training/education | 10 |
| 4. HSI | 6 |
| 5. Communication | 9 |
| 6. Personnel (Team) | 29 |
| 7. Supervision | 4 |
| 8. Task preparedness | 11 |

## 4. Result of deriving main drivers

As a result of deriving main drivers for LPSD HRA method, four drivers were derived: experience level, procedure, workload/stress, and training. From the literature review and event report analysis, why abovementioned four drivers were derived can be expected as below. In the case of experience level, there are two reasons. Firstly, workers are less familiar with system responses and equipment during non-routine tasks and configurations. Secondly, subcontract workers who have less understanding of NPPs perform the tasks. In the case of procedure, as addressed in many reports, procedure is not properly developed and barely tested because the plant states are dynamically changed and there are too many unexpected contingencies. In the case of workload/stress, there are plenty of work activities including tests, maintenance and repairs. In the case of training, as addressed in many reports, personnel usually have less training to mitigate the accident.

## 5. Conclusions

Human error has been considered one of the main contributors to serious problems of nuclear power plants. Accordingly, it is necessary to identify human error and estimate the potential of human error. There has been a huge amount of research to develop more accurate human reliability analysis methods; so far, however, these methods have focused on only full power operation of nuclear power plants. Low power and shutdown probabilistic safety assessment has shown that risks in low power and shutdown situations can be comparable to those during full power operation, even though the duration is much shorter. In this regard, a comprehensive human reliability analysis method considering low power and shutdown operation is needed. In performing human reliability analysis, the probability of human error is increased or decreased by drivers such as procedures, training, workload, experience level and so on. It is critical to know what kinds of drivers should be considered and how much these drivers affect the probability of human error. In this study, as a first step toward developing a human reliability analysis method, main drivers which affect the potential of human errors, were analyzed.

As a result of reviewing eight literatures and performing event report analysis, four main drivers were derived, including procedure, experience level, workload/stress, and training. Since there was less attention paid to the risks during LPSD operations, there have been insufficient human performance data. In this aspect, even though there is a limitation due to insufficient data from operating experience, it is believed that this research may be a reasonable starting point in the study of main drivers in the development of comprehensive HRA methods for LPSD operation.

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