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A Process for Analyzing Category-B Actions for Multi-Unit LOOP

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1. Introduction

Category-B actions are human errors that cause an initiating event to occur or they may be initiators in their own right. Therefore, such initiating events are also referred to as human-induced initiating events. Category-A and category-C human actions are pre- and post-initiators respectively. Most of the literature on human reliability analysis (HRA) consider only pre-initiators (latent errors) and post-initiators (during event response) [1]. Similarly, according to the committee on safety of nuclear installations (CSNI) [2], the category-B actions which are human interactions that initiate a scenario are rarely explicitly identified in probabilistic safety assessments (PSAs) and analyzed in terms of specific causes for nuclear power plant incidents.

It is often assumed in conventional PSAs that the experience-based frequencies of initiating events already reflect these type of human interactions. However, this assumption may not be satisfactory because experience has shown that human interactions may contribute to both a specific type of initiator (e.g. loss of coolant accidents) and the failure of a subsequently required safety function otherwise called latent error (e.g. safety injection) [2]. Hence, there is need to incorporate human-induced initiators explicitly in PSA models.

A loss of offsite power (LOOP) event is the simultaneous loss of electrical power to all unit safety buses (class 1E buses) and requiring all emergency power generators to start and supply power to these safety buses. The non-essential buses may also be de-energized as a result of this [3]. This is an initiating event that is often given high priority in the nuclear power plant (NPP) safety analysis. It can lead to a station blackout (SBO) when the safety-class power generators fail to start.

An attempt has been made previously to analyze category-B actions [4]. The work highlighted the fact that other HRA methods used for EOC identification are unsuitable for identifying category-B actions for reasons such as unsuitability of the kind of procedures and PSA importance measures suggested. However, the research only focused on analyzing the human-induced initiators during the low power and shutdown plant operating states. It also inferred that the method used may be inadequate for quantification. Hence, there is a need to develop other methods for analyzing category-B actions.

This paper attempts to suggest a process for analyzing category-B actions that lead to a multi-unit LOOP (MULOOP) scenario. For this work, MULOOP is defined as a scenario where two or more units experience LOOP simultaneously. Therefore, the NPP operation experience is described in the second section with particular attention to insights learned from the Korean experience. Subsequently in the third section, the proposed analysis process is described and lastly, a conclusion is provided.

2. LOOP Operation Experience

It is important to review the operating experiences to gain the following insights;

- To find out if human errors contribute to LOOP incidents.
- To find out if MULOOP has been recorded or are possible.
- To see if there is a possibility of human errors causing a MULOOP.
- To find out the prevalent operating status of NPPs when human errors occur for LOOP.
- To see if procedures are being used during human error occurrences.

A broad review of NPP LOOP in four databases including operating experiences in Europe and the United States of America was conducted in the year 2016 [5]. The results show that most of the LOOP events occurred during at power mode, the main contributors were switchyard centered, and plant centered events. Additionally, their root causes were mainly human failure during testing, inspection or maintenance activities. However, the review did not consider MULOOP.

A preliminary analysis of the LOOP events in Korea for the period of 1978-2017 was conducted based on the operational performance and information system (OPIS) database. The indices are decided based on the event report headings and the detailed description of the events. The result is shown in Table 1. The type of LOOP and the affected units are indicated. The types of LOOP are classified as either Single-unit LOOP (SULOOP), Multi-unit LOOP (MULOOP), or Potential Multi-unit LOOP (PMULOOP).

An event is categorized as PMULOOP when the event is reported as “loss of offsite power on 4.16kV safety bus” or a “loss of voltage on 4.16kV bus” and all emergency diesel generators (EDGs) are started.

The causes of LOOP could either be due to electrical equipment failures, instrumentation failures, human errors or external effects. The external effects refer to causes that are beyond the control of operators like high winds, typhoons, or transmission line failures, which are sometimes outside the NPP site.

Table I: LOOP incidents in Korean NPP operating experience

No.	Event Date	Incidence Unit	Affected units	Type	Cause
1	1985.04.19	WU1	WU1	SULOOP	Electrical
2	1986.08.28	KR4	KR3&4	MULOOP	External
3	1987.04.21	KR1&2	KR1&2	MULOOP	External
4	1987.07.16	KR1&2	KR1&2	MULOOP	External
5	1987.07.17	KR3&4	KR3&4	MULOOP	External
6	1993.01.17	KR4	KR4	SULOOP	Electrical
7	1997.01.01	HU2	HU2	SULOOP	External
8	1998.09.27	KR2	KR2	SULOOP	Electrical
9	2001.01.30	HU1	HU1	SULOOP	Electrical
10	2002.11.03	HB5&6	HB5&6	MULOOP	External
11	2004.06.19	WU2	WU2	SULOOP	Human Error
12	2006.11.29	HB5	HB5	SULOOP	Electrical
13	2008.08.08	KR1	KR1	SULOOP	External
14	2009.06.24	HB2	HB 1&2	MULOOP	Human Error
15	2009.09.03	WU2	WU2	SULOOP	Electrical
16	2010.07.06	SKR1	SKR1	SULOOP	Electrical
17	2011.04.19	KR3	KR 3&4	PMULOOP	Human Error
18	2012.02.09	KR	KR 1	SULOOP	Human Error
19	2014.05.18	HU 5	HU 5	PMULOOP	Instrumentation
20	2014.10.01	HB 2	HB 2	PMULOOP	Human

The result of this analysis shows that five of twenty LOOP incidents were due to human errors. Human errors also have the potential of causing multi-unit LOOPs. This analysis also reveals that most of the human errors are related to poor or inappropriate work management. It is also of note that these human errors occurred during both low power shutdown modes and full power operation modes. There were 11 SULOOPs, 6 MULOOPs and 3 PMULOOPs. Another insight gained from the Korean operation experience is that most of the LOOP incidents are plant or switchyard centered. However, some plants do share the same switchyard. Thus the switchyard is identified as the most important location of MULOOP.

3. A Process for Analyzing Category-B Actions for MULOOP

The process being proposed for identification and quantification includes five major steps. They are developing a fault tree for the switchyard; cataloging all potential human actions for the systems identified; selecting those human actions that can be initiators; identifying the error of commission (EOC) paths for those human actions; and quantifying the human error probabilities (HEPs). This process is depicted in Fig.1 and described further in the following subsections;

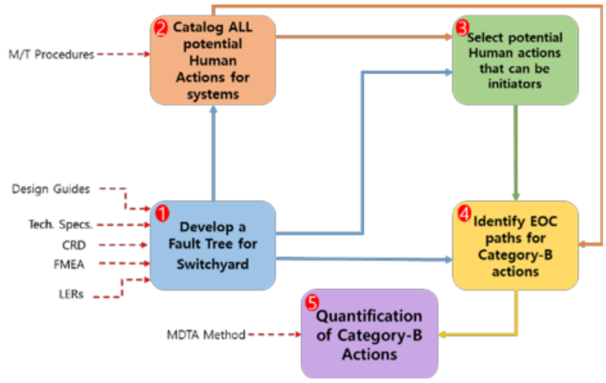

Fig. 1. A process for category-B actions analysis for MULOOP

3.1. Step 1: Develop a Fault Tree for the Switchyard

The first step of the process is to develop a fault tree (FT) for the switchyard. The FT cutsets will help to identify the important systems in the switchyard, which are to be further investigated. As the switchyard is sometimes shared by two units, this is a good basis to evaluate all systems that could contribute to the failure of the switchyard. As shown on fig.1, there are several inputs to facilitate the execution of this step.

The plant specific design guides or general design criteria (GDC) should be evaluated with specific reference to electrical systems. For example, GDC 17 “Electrical Power systems” and GDC 18 “Inspection and testing of electrical power systems” may specify important insights for relevant systems. Important system functions may be identified.

Technical Specifications includes detailed requirements for system functions including limiting conditions of operation (LCOs), safety limits, design feature, surveillance, and etcetera. Conditions, where human actions (and types) are needed, can also be identified.

Failure modes and effect analysis (FMEA) are the failure modes of each component and their effect on the switchyard systems should be analyzed.

The component reliability data (CRD) contain the failure rates of each component and may be provided by the manufacturer of each component of the switchyard. The failure rate of the component may determine if they are included in the FMEA.

Licensee Event Reports (LERs) are event reports provided by the licensee to the regulators. In the case of

Korea, the Korea Institute of nuclear safety (KINS) reviews and provides these in the OPIS database. They can help to identify some SSCs and even scenarios for human action on those SSCs.

It should be noted that while the main idea of developing the switchyard FT in step 1 is to identify systems (which is the input for step 2), other insights may be gotten from the inputs to step 1. These insights can serve as inputs to other stages of the process (steps 3 and 4).

3.2. Step 2: Catalog all potential actions for systems

The identified switchyard systems, structures, and components (SSCs) in step 1 should inform the type of the maintenance and testing (M/T) procedures to be used at this stage. The M/T procedures can show most of the procedural stages when human action is needed. All these human actions need to be identified and cataloged in a logical order at this stage.

3.3. Step 3: Select potential human actions that can be initiators.

Selection of potential category-B actions can be achieved at this stage by utilizing the results and insights from both step 1 and 2. Those human actions that are potential EOCs are selected and cataloged. The catalog should include procedure step number, step title, action type, component, and system.

3.4. Step 4: Identify EOC paths for the category-B Actions

This step involves the identification of the error of commission (EOC) paths for the potential human actions derived from the previous step. Inputs from steps 1, 2 and 3 need to be harmonized at this stage in order to show an acceptable EOC path. The EOC paths for the identified category-B actions need to be clearly specified as this would aid the next step of quantification.

3.5. Step 5: Quantification of the Category-B Actions

The quantification of category-B actions is essential in that it gives a valuable input to estimate the initiating event frequency. The cause based decision tree method (CBDTM) is recommended in this procedure. The CBDTM was developed by the electric power research institute (EPRI) to quantify EOCs albeit post-initiators. The CBDTM is recommended for several reasons among them are; (1) CBDTM does not do human error identification and was developed specifically for quantification of human errors; (2) CBDTM is simple and traceable such that an independent reviewer could easily trace back the resultant HEPs; (3) It has a comprehensive technical basis and explicitly considers organizational process factors; (4) the PSFs used are very sensitive, indicating the importance of the PSFs used in this method. One of the disadvantages of CBDTM is that it does not consider time factor. However, time is not normally a priority in quantifying human-induced initiating events while utilizing the M/T procedures.

4. Conclusions

In summary, this procedure identifies systems via FT, utilizes procedures to identify human actions, determines the errors, and quantifies those errors for potential human-induced initiating events.

The suggested methodology for identification follows a search scheme like some other methods including CESA and ATHEANA. However, this proposed method is different for several reasons

- It is proposed for category-B actions which are human-induced initiators
- It follows a Scenario-system-action search scheme
- It suggests the use of maintenance procedures
- It recommends the use of the CBDT method for quantification.

The authors believe that the MULOOP may be a worthwhile scenario for verifying the viability of this process to analyze category-B actions in nuclear power plants. Further work shall be undertaken in the near future to verify this method.

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REFERENCES

[1] D.I. Gertman, et al., Review of findings for human error contribution to risk in operating events, U.S. Nuclear Regulatory Commission, Washington, D.C., 2001.

[2] CSNI, Human Reliability Analysis in Probabilistic Safety Assessment for Nuclear Power Plants, OECD/NEA, 2004.

[3] U.S. NRC, Reevaluation of Station Blackout Risk at Nuclear Power Plants, Analysis of Loss of Offsite Power Events: 1986-2004, NUREG/CR-6890, U.S. Nuclear Regulatory Commission, 2005.

[4] Y. Kim and J. Kim, Identification of human-induced initiating events in the low power and shutdown operation

using the Commission Error Search and Assessment method, Nuclear Engineering and Technology, 47(2): p. 187-195, 2015.

[5] Volkanovski, A., et al., Analysis of loss of offsite power events reported in nuclear power plants. Nuclear Engineering and Design, Vol.307: p. 234-248, 2016.