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Performance Shaping Factors Assessments And Application to PHWR Outages

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1. Introduction

According to NRC's 'Office of Analysis and Evaluation of Operational Data', 82% of reactor trips and accidents during an outage is caused by events related to human errors.

Since enhancing the quality of a PSA is a current issue, analysis for a human error is required to improve the quality of the PSA and to minimize uncertainties in the HRA method.

For a PHWR in Korea, the HRA method developed by AECL is being used. However this method has an excessive conservatism on human actions related to the maintenance and the test and also on the dependency evaluation between human actions which causes high core damage frequency .

Moreover as PSFs(Performance Shaping Factors) are not properly considered in the HRA method, a re-evaluation of the HRA is currently required.

In this study, a new HRA method based on ASEP and THERP is introduced and compared to the existing HRA method. Henceforth 10 chosen human actions during PHWR outages are then calculated using this HRA method. Finally the PSFs in the new HRA method are re-evaluated to minimize any uncertainties.

2. Methods

2.1 Features of new HRA method

New HRA method is primarily based on the THERP and ASEP HRA methods. SRO(Stimulus, Organism, Response) model which provides a technical basis for a human error evaluation is simplified by assuming that the human information procedure and task performance can be classified into execution and diagnosis steps.

And the decision trees for HEP and the detailed rules reflect the current state of the art HRA used in the PSA of Korean NPPs.

3. HRA for Post-Initiating HFEs

3.1 Identifying human actions related to a CDF

During a PHWR outage, 4 possible initiating events are identified which are a Loss of service water, HTS leaks, total loss of class 4 Power and loss of shutdown cooling event. Human actions are included in these 4 events. For these initiating events, accident scenarios are developed for an adequate use of the HRA. Based on these scenarios, human actions that could possibly affect a CDF are evaluated.

Table 1. Identified human actions related to a CDF

	Human actions	*Description*
1	*OPHTS*	*Operator bottle-up and fill-up the HTS & stop SDC pump to induce thermosiphoning*
2	*OPAFW*	*Operator starts AFW/CND systems to supply makeup to SG following loss of SDC. Previous operator action was required to star the systems*
3	*OPMFW*	*Operator starts MFW system to supply makeup to SG. Previous operator action was required to start AFW/CND systems*
4	*OPEWS1*	*Operator initiates makeup to SG via EWS system following loss of SDC. Previous operator action was required to start AFW/CND systems*
5	*OPEWS2*	*Operator initiates makeup to SG via EWS system following loss of SDC. Previous operator action was required to start AFW/CND systems*
6	*OPECC1*	*Operator initiates MPECC following loss of SDC. Previous Operator action was required to start AFW/CND systems and EWS system*
7	*OPECC2*	*Operator initiates MPECC after failure of thermosiphoning operation*
8	*OPECC3*	*Operator initiates MPECC after MKUP*
9	*OMRS*	*Operator isolates bleed line & start D2O recovery system following HTS leak*
10	*OPSDC*	*Operator starts SDC*

3.2 Calculation results

3.2.1 Diagnosis Error

Available time for a diagnosis is given to calculate the basic HEP. Allocated available time to diagnosis the corresponding task is then used as input data. Since the calculated result is shown in median value, it is converted to a mean value by using Eqs (1). Also the error factors used in this calculation are assumed lognormal and thus the THERP suggest value is being used. After calculating the mean value, weighting factor for the diagnosis error is calculated from detailed rules.

Each attribute of the detailed rules are divided by its severity.

$$Mean = Median * EXP\{(\frac{\ln EF}{1.645})^2 / 2\} \quad (1)$$

3.2.2 Execution Error

First of all, the task type and stress level should be defined before evaluating an execution error. Using a previously defined task type and stress level as an input parameter, the basic HEP is calculated using the data from THERP. Then the recovery factor for an execution error can be calculated by using the decision rules. Then the two values calculated are added to obtain execution error.

3.2.3 Human Error Probability

Human error probability is evaluated by summing the execution and diagnosis errors. Thus CDF for 4 initiating events are calculated by using the human error probability and compared to the results AECL achieved. The results using ASEP which is widely used for a HRA is also considered in this study.

HRA using this method resulted in a conservative mitigation when compared to ASEP, but an increased conservatism when compared to the results of AECL.

Table 2. Human Error Probability

Human actions	*Diagnosis Error*	*Execution Error*
OPHTS	0.2×10^{-2}	1.6×10^{-2}
OPAFW	0.9×10^{-3}	0.1×10^{-2}
OPMFW	5.1×10^{-4}	2.5×10^{-4}
OPEWS1	5.1×10^{-4}	2.5×10^{-4}
OPEWS2	1.0×10^{-4}	0.5×10^{-3}
OPECC1	1.0×10^{-4}	0.5×10^{-2}
OPECC2	1.0×10^{-2}	1.0×10^{-4}
OPECC3	1.4×10^{-2}	0.1×10^{-1}
OMRS	1.4×10^{-3}	0.1×10^{-2}
OPSDC	2.5×10^{-4}	2.5×10^{-4}

Table 3. CDF according to 4 Initiating Events

	CDF(New method)	*CDF(AECL method)*
ILOSW	3.93×10^{-4}	5.75×10^{-4}
HTS Leak	4.18×10^{-7}	1.36×10^{-8}
ILOCL4	1.95×10^{-10}	7.70×10^{-10}
ILOSC	7.41×10^{-8}	2.17×10^{-8}
Total	3.93×10^{-4}	5.76×10^{-5}

3.2.4 Quantification of Performance Shaping Factors

Performance shaping factors are one of the important factors related to decision rules and a quantification of these performance shaping factors are expected to minimize any uncertainties. By changing the performance shaping factors, human error probability is re-calculated. Thus CDF is re-calculated for 4 initiating events to confirm which attributes are the most influential factors. CDF calculated according to the change of performance shaping factors for each decision rule is compared to CDF calculated by new HRA method. As a result, most factors were changed within a small range but for the MMI level and the verification by a supervisor mostly affected to the CDF.

Table 4. CDF according to quantification of PSFs

PSFs	*CDF*
Task	3.93×10^{-4}
Stress	3.93×10^{-4}
MMI	4.00×10^{-4}
Supervisor	4.01×10^{-4}
Procedure	3.95×10^{-4}
Education	3.94×10^{-4}

4. Conclusions

Human error probability during a PHWR outage is calculated using a new HRA method and the CDF calculated for 4 initiating events are compared in this study. Also quantification of performance shaping factors is performed to minimize the uncertainties of decision rules in HRA. Human error probability and sensitivity analysis results are expected to supplement the current state of art HRA method and to minimize any uncertainties. Thus improvements in quality of PSA are expected.

REFERENCES

[1] Kirwan B, "A guide to practical Human Reliability Assessment", Taylor & Francis, 1994
[2] P.Santamura, A.Nainer, S.Aprodu and R.E.B.Henderson, "Analysis Report: Generic CANDU Probabilistic Safety Assessment-Methodology", 91-03660-AR-002,AECL, Jul.2002