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Risk-informed Analysis of Training Effectiveness for Mitigating Accidents of Nuclear Power Plants

Chang-Ju Lee*
Korea Institute of Nuclear Safety, 34 Gwahak-ro, Yuseong, Daejeon, Korea, 305-338
**Corresponding author: cjlee@kins.re.kr*

1. Introduction

A critical area for deriving expected benefits from training and exercise is the measurement of "training effectiveness" - how well the training inputs are serving the intended purpose. This aspect is often neglected by nuclear organizations, saying that measurement is difficult. However, I believe that a technique in nuclear society has developed sufficiently to measure most important aspects of training by way of human reliability analysis (HRA) used in probabilistic safety assessment (PSA) of nuclear power plants (NPPs). The consequences of errors caused by lack of training can be evaluated in terms of the overall vulnerability to human error of the facility under consideration.

This study presents current situation and considerations for measures of robustness on nuclear accidents and HRA technique on the training effectiveness. In view of risk-informed approach with this consideration and an example case, I'd like to identify appropriate relationship between risk measures of robustness and training effectiveness.

2. Measures of Robustness on Accidents including Training Effectiveness

Following the severe accident of the Fukushima Dai-ichi NPP on 11 March 2011, the European Council requested that a comprehensive safety and risk assessment, including "stress tests" performed at national level complemented by a peer review. As a result of the stress tests, significant measures to increase robustness of plants have already been decided or are considered. Such measures include provisions of additional mobile equipment to prevent or mitigate severe accidents, installation of hardened fixed equipment, and the improvement of severe accident management (SAM), together with appropriate staff training measures [1].

It is noted that the main measures required by the stress tests specifications are cliff-edge effects and their coping time determination. In most cases, a conservative approach may be applied to calculating the coping times associated with identified cliff-edge effects. In all cases, EU national reports extensively assessed the plant responses to specific events, also indicating the margins, as a time, available until specific remedial measures need to be undertaken.

The important factor to be considered is whether effective countermeasures can be implemented within the coping time to prevent core damage. For some cases a cliff-edge effect is apparent in that it appears that there may be insufficient coping time to implement countermeasures taking into account the stress tests conditions. The peer review team on the EU national reports, in terms of added value and the overall safety benefits, recommended that national regulators should consider the following findings [1]:

1) Availability of a variety of mobile devices, with prepared quick connections, procedures on how to connect and use and <u>staff training</u> for deployment of such equipment. Engineered and prepared connections as well as <u>drills</u> on the use of this equipment significantly add to the robustness for beyond design basis events.
2) Using alternative means of cooling including alternate heat sinks. Steam generator gravity feeding supply from stored condenser cooling water, alternate tanks or wells on the site, or water sources in the vicinity (reservoir, lakes, etc.) is an additional way of enabling core cooling and prevention of fuel degradation. Some plants identified possible <u>actions</u>, including additional analysis that might be needed.
3) The methods and tools for accident management <u>training and exercises</u> are to be further enhanced, utilizing lessons learned from the use of all available means (such as desk-top training, use of multi-function or full-scope simulators).

Regular and realistic SAM training exercises, including the use of the necessary equipment, with consideration of multi-unit accidents, long-duration events, etc. are part of the measures expected in almost all countries to improve SAM preparedness. The use of the existing NPP simulators is considered as being a useful tool but needs to be enhanced to cover all possible accident scenarios.

Also, the U. S. NRC is planning to engage stake-holders, after Fukushima Dai-ichi accident, to (1) inform the development of acceptance criteria for reasonable protection of equipment needed to respond to beyond-design-basis external hazards and multi-unit events, (2) assess the need to supplement equipment to support beyond-design-basis and multi-unit event mitigation, and (3) discuss the need to develop and provide training on supporting strategies [2].

3. Current HRAs in consideration of Training

Performance shaping factors (PSFs) used in HRA are the factors that combine with basic human error tendencies to create error-likely situations. In general terms PSFs can be described as those factors which determine the likelihood of error or effective human performance. It should be noted that PSFs are not automatically associated with human error. PSFs such as quality of procedures, level of time stress, and effectiveness of training, will vary on a continuum from the best practicable (e.g., an ideally designed training program based on a proper training needs analysis) to worst possible (corresponding to no training program at all) [3].

A literature search was undertaken to identify published sources of information regarding the factor on training and exercise effectiveness in various HRA methods [4]. At first, the potential beneficial influence of the factor is included in the SPAR-H (Simplified Plant Analysis Risk Human Reliability Assessment) method. PIFs of SPAR-H method are:

- Available time
- Stress and stressors
- Experience and training
- Complexity
- Ergonomics (& Human Machine Interface)
- Procedures
- Fitness for duty
- Work processes

Next, ATHEANA (A Technique for Human Error Analysis) can be used to develop detailed qualitative insights into conditions that may cause problems. It may generate a solid basis for redesign of working procedures, training, and interface, and it may be used as a tool for scenario generation.

For the purpose of CREAM (Cognitive Reliability and Error Analysis Method) HRA, the first step is a task analysis. Based on this a list of operator activities is produced, from which a Common Performance Conditions (CPCs) analysis is carried out. We can find a factor on training in nine CPCs:

① Adequacy of organization.
② Working conditions.
③ Adequacy of the man-machine interface and operational support.
④ Availability of procedures/plans.
⑤ Number of simultaneous goals.
⑥ Available time.
⑦ Time of day.
⑧ Adequacy of training and experience.
⑨ Quality of crew collaboration.

For each activity a CPC level is determined, for example adequacy of training and experience is described as high experience, low experience or inadequate. The expected effect of these levels of experience on performance is respectively - improved, not significant and reduced. The method goes on to describe a way of quantifying these descriptors.

Table I shows the matrix comparing diagnosis PSF multipliers for training and exercise (experience) in some HRA methods.

Table I: Diagnosis PSF Comparison Matrix (at power condition)

	PSF Levels	SPAR-H Multipliers	ASEP Multipliers	K-HRA Multipliers
Training/ Exercise	Low	10	10	5
	Nominal	1	1	1
	High	0.5	0.1	1/3

4. An Example Case

Follow-up Korean regulatory actions of Fukushima Dai-ichi accident are diverse, where a category on "severe accident mitigation" requires strengthening operators' training and exercises against severe accidents. Utility operators are required to get enhanced training program utilizing various accident scenarios, and extend training times from nominal 8 hours per 2 years to 10 hours per 1 year.

KHNP assessed the effect of this action in terms of the sensitivity study of level 1 PSA for Wolsung NPP and Ulchin 5&6 NPPs, respectively. An assumption was made that diagnostic human errors, focusing on events above 30 minutes' coping time, can be reduced up to 1/3 value of current human error level. Even though this assumption on the human error reduction rate may have an argue point between experts, he shows that core damage frequency (CDF) of Wolsung NPP is reduced to about 90% level [5]. About 28 items of basic event for calculating CDF affect to the evaluation. Also it seems that selection of specific method, as denoted in Table I, is more or less affecting to the evaluation result.

5. Conclusions

This study focuses on the effectiveness of training, therefore, shows diverse consideration of quantitative factors in current HRA methods. Considering recent safety enhancing effect analysis for follow-up actions of the Fukushima Dai-ichi accident, we can point out great importance about associated training for doing effective accident mitigation will be more emphasized.

REFERENCES

[1] Peer review report – Stress tests performed on European nuclear power plants, ENSREG, 2012.

[2] NUREG-1650, R4, The United States of America National Report for the 2012 Convention on Nuclear Safety Extraordinary Meeting, 2012.

[3] D. Embrey, Performance Influencing Factors (PIFs), Human Reliability Associates Ltd., 2000.

[4] RR 679, Review of human reliability assessment methods, Health and Safety Executive, 2009.

[5] Safety Enhancing Effect Analysis after following Improvement Plan of Safety Examination of Domestic NPPs, KHNP, 2012.