Preliminary Human Reliability Issues in Reviewing SMART® PSA

Chang-Ju Lee*, Cheol Sheen
Korea Institute of Nuclear Safety, 19 Kusong-dong, Yuseong, Daejeon 305-338, Republic of Korea
**Corresponding author: cjlee@kins.re.kr*

1. Introduction

Human reliability analysis (HRA) identifies the human failure events (HFEs) that can negatively impact normal or emergency plant operations, and systematically estimates probabilities of HFEs using data (when available), models, or expert judgment.

In case of newly-conceptualized reactors like SMART (System-integrated Modular Advanced Reactor), HRA results must be provided by first evaluating the applicability of a set of human errors that has been typically applied in PSAs for existing PWRs. Additional human errors should also be identified reflecting its unique design and operational features.

The objective of this paper is double-folded: 1) to discuss a direction of HRA used in confirming risk level of SAMRT-type reactors; and 2) to extract preliminarily considerable points or issues for regulatory verification, referred to available safety guides.

2. Status of pre-SMART HRA

A similar methodology was used for the incipient design of SMART [1]. However, due to lack of details of the design, most of HFEs were evaluated using expert judgment, and pre-initiator HFEs were not appropriately identified. Approximately 14 numbers of HFEs were presented with a range of probabilities between 5.0E-4 and 5.0E-2, as shown in Table I. It is noted that six major minimal cutsets out of eight causing core damage were dependent on HFEs.

Table I: HFEs used in pre-SMART HRA [1]

HFEs	Description of HFEs	HEP
CCOPH-CWSG	Fails to Initiate SG Cooling using CCW (Execution)	1.00e-2
EGOPHGT01E	Fail to Start AAC & Connect at 1E 4.16KV Bus	1.00e-3
FBOPH-EBD	Fails to Initiate Emergency Boration (Diagnosis)	5.00e-4
FBOPH-EBE	Fails to Initiate Emergency Boration (Execution)	1.00e-2
FBOPH-FBD	Fails to Initiate F&B (Diagnosis)	5.00e-2
FBOPH-FBE	Fails to Initiate F&B (Execution)	1.00e-2
FBOPH-MK	Fails to Initiate Makeup Pumps	5.00e-3
FBOPH-REC	Fails to Initiate Recirculation Cooling	1.00e-2
FSOPH-RHRSE	Fails to Actuate PRHRS Open Signal (Execution)	1.00e-3
FSOPH-SG-COOL	Fails to Actuate PRHRS Open Signal (Diagnosis)	1.00e-3
FWOPH-FWE	Fails to Initiate FW Cooling (Execution)	5.00e-3
MSOPH-SG-ISO	Fails to Isolate Steam & Feed Line	5.00e-2
MSOPH-SG-SGTR	Fails to Isolate Steam & Feed Line	5.00e-3
RT-MANUAL	Fails to Initiate the Reactor Trip	5.00e-4

3. Applicable Safety Guides for Screening Issues

In order to assure technical adequacy of SMART HRA, when submitted, we are willing to apply available requirements, suggested in draft IAEA safety guide [2].

In section 5.96 of the safety guide, it is required that the human errors that can contribute to safety system failure be identified and included in the fault tree model, adopted a structured and systematic approach. Also the guide requires HRA be consistent with the analysis carried out in other parts of level 1 PSA. In addition, the HRA should be carried out in close cooperation with plant operation and maintenance staffs to ensure that the analysis reflects details of plant's design and operation under normal and accident conditions. In this way, the analysis may provide confidence that comprehensive analysis has been carried out to determine the contributions to the core damage frequency from all types of human errors.

Therefore, a systematic review should be carried out of plant procedures to identify pre-initiator tasks such as repair, maintenance, test or calibration. And post-initiator actions should be carried out by plant operators for the systems modeled in level 1 PSA, which are so-called Type A and Type C human interactions, respectively.

In section 5.107 of the guide, it is required that human error probabilities (HEPs) used reflect the factors that can influence performance of operators, including level of stress, time available to carry out a task, availability of operation procedures, level of training provided, environmental conditions, etc. They can be identified by the task analysis carried out as part of design evaluation.

In other guidelines for performing HRA of future reactors, followings are generally required to take functional attributes in the analysis [3]:

- Use a systematic process to review normal and emergency procedures and work practices to identify and define HFEs that would result in initiating events or pre- and post-accident HFEs that would contribute to or negatively impact the mitigation of initiating events,
- Account for dependencies between human actions when evaluating HFEs,
- Place HFEs in PSA logic models such that the impact of the HFEs on components, trains, and systems are properly accounted for,
- Develop the probabilities of the identified HFEs taking into account scenario and plant-specific factors (e.g., procedures, simulator training, plant operating state-specific performance shaping factors, man-machine interface, and equipment

accessibility) and incorporating dependencies between different HFEs,
- Use plant-specific engineering evaluations to determine cues and the available time window for required operator actions and the environments present at the sites for performing required actions,
- Model recovery actions only when it had been demonstrated that the action is plausible and feasible.

4. Identified Preliminary HRA Issues

After considering the requirements in the guidelines as mentioned in the previous section, we can identify some preliminary considerable points or questions for the purpose of regulatory verification in the area of SMART HRA, as summarized;

1) Consistency of level of details with a design: Can it give insights on important measures of human actions and design-specific and scenario-specific factors?
2) V&V methods for expert judgment: Are they used adequately against data availability from similar plants? Are derived data of upper and lower bounds confirmed?
3) Best-estimate HEP reflecting plant-specific design: Is it based on the plant-specific design and system interactions? Is the up-to-date methodology used for focusing on facilitated evaluation of dependency between multiple HFEs?
4) Consideration of pre-initiator errors: Can it give proper insights on pre-initiator errors, including recovery actions?
5) Rationale for applicable experiences: Can it give a clear rationale, if other experiences or data are applied?
6) Use of scenario-specific performance shaping factors (PSFs): Is it based on plant-specific and sequence-specific affecting factors? Is the up-to-date methodology used for focusing on key PSFs, evaluation of the influence of each PSF on human actions with discrete scales, etc.?
7) Rationale for human action times: Can it give adequate outputs of plant-specific engineering evaluation for determining operator's action times?
8) Rationale for recovery actions: Can it give a clear rationale or calculation sheets for adopted recovery actions in HRA? Are there specific rules used for excluding and including the recovery actions?
9) Adoption of errors of commission: Can it give a clear rationale and insights on the likelihood of errors of commission, if adopted? And does it include POS cases for shutdown and refueling modes?
10) Uncertainty characterization: Can it give proper insights on the characteristics of specific uncertainty in the quantification results?

5. Conclusions

With referring the recent safety guides for assuring new design reactors, we can identity some considerable issues in the area of HRA for SMART. For the purpose of regulatory verification to the SMART PSA, this study has extracted applicable results.

There is also another concern for providing steps of the integrated review approach, which is:

- Identification of specific methodology or data which cannot be applicable to the HRA of SMART,
- Determination of level of depths for the sensitivity study to compromise design uncertainty in a newly-conceptualized reactor.

It is noted that, in the design certification by the nuclear regulatory organization, special treatment or documentation may be needed in order to assure the technical adequacy of human factors assumed in the accident sequences of SMART.

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REFERENCES

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