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Risk Spectrum HRA And Conditional Quantification Tools: Practical Plant Specific Implementation

Dusko Kancev[a], Gerben Dirksen[b], Rainer Hausherr[a]

[a]*Nuclear Safety, NPP Goesgen-Daeniken AG, Switzerland*
[b]*Process and Safety Engineering, Framatome GmbH, Germany*

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This paper addresses the performance of human reliability analysis (HRA) as part of the development of a new plant-specific, full-scope industrial-scale L1/L2 PSA-model at the NPP Goesgen-Däniken (KKG), Switzerland. The main focus of the paper is aimed at the development of the new, plant-specific HRA using the ***RiskSpectrum***® HRA Tool as well as the relatively new ***RiskSpectrum***® feature – the Conditional Quantification tool. KKG, together with their supplier Framatome GmbH, embarked on the substantially thorough project – *PSASPECTRUM* – of migrating the KKG`s existing PSA model from ***Riskman***® (ABS Consulting, 2016.) to ***RiskSpectrum***® (RiskSpectrum AB, 2022) environment.

The HRA, as one of the main work packages in a project of this type, is also being performed and enhanced in accordance with the state-of the art guidelines. The plant-level PSA modelling is performed in a systematic way, based on specifically tailored, PSA-related event sequence diagrams (ESDs). These ESD accommodate the various, PSA-relevant operator actions (OAs). The OAs are being modelled and linked to their corresponding ESDs in a way that assures a direct linked to the plant`s operating manual (OM) or the emergency operating procedures (EOP). The ***RiskSpectrum***® HRA Tool (RiskSpectrum AB, 2022) is applied for the actual qualitative modelling of the various OAs as well as the quantitative modelling, i.e. the derivation of their corresponding human error probabilities (HEP). After modelling the PSA-relevant OAs with the ***RiskSpectrum***® HRA Tool (RiskSpectrum AB, 2022), the ***RiskSpectrum***® Conditional Quantification tool (see Figure 1) is then being applied to consider and model the HRA-dependencies between/among OAs appearing within a same minimal cut set. Since there are more than 50 OAs within the *PSASPECTRUM* project designated as PSA-relevant, the number of potential combinations is quite large.

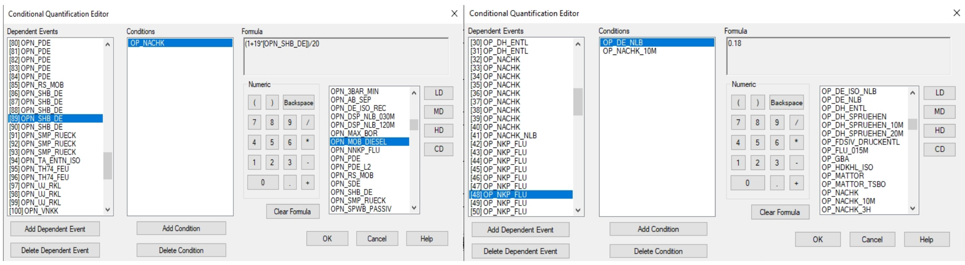

Fig. 1. Applying equations for the conditional quantification; (b) Applying user-defined rounding figures to meet the ENSI 1E-5 condition.

The HRA-dependencies are estimated according to the THERP-methodology (Swain, Guttmann, 1983):

$$P(CHEP \mid LD) = (1 + 19 \cdot P(NHEP))/20 \quad (1)$$
$$P(CHEP \mid MD) = (1 + 6 \cdot P(NHEP))/7 \quad (2)$$
$$P(CHEP \mid HD) = (1 + P(NHEP))/2 \quad (3)$$

Moreover, there is one additional constraint that needs to be adhered to. Namely, according to the guidelines of the Swiss federal regulator ENSI, no combination of OAs may be better than 1E-5 (or 1E-6 in case of consideration of the emergency response team). Hence, the process of performing the plant-specific HRA on such an industrial-scale PSA model development with simultaneous adhering to the various guideline constraints is quite a complex task. In this regard, the KKG and Framatome teams, with the help of both the *RiskSpectrum*® HRA and Conditional Quantification tools, have developed a new methodology, that accommodates for an efficient way of performing the HRA by simultaneous consideration of the ENSI requirements.

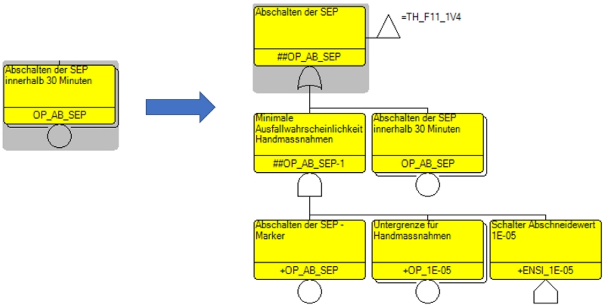

Fig. 2. Applying equations for the conditional quantification.

According to this new methodology (Figure 2), firstly all the OAs are being replaced by small fault trees (FTs) using a new, quite comfortable tool – the *RiskSpectrum*® PSA Macro (RiskSpectrum AB, 2022). This can be also supported by ModelBuilder by replacing each OA basic event with a transfer gate, then it will link automatically to the FT as shown in Figure 2. After the implementation of the OA dependencies using the *RiskSpectrum*® Conditional Quantification tool, each of the initiating event (IE) groups are inspected in terms of their contributions to CDF and LERF. The main risk-relevant combinations with combined HEP < 1E-5 are then identified and the dependency is set to a user-defined value (see Figure 1, (b)). A parallel new, "clone" model is then quantified by setting the house event "+ENSI_1E-05" to TRUE. This generates a cut set list with additional MCS, which have replaced each combination with a value 1E-5 (or 1E-6 if so defined). Due to additional cut sets, the result in the variation, clone model will be slightly larger than in the nominal model. Hence, some of the cut sets with combined HEPs > 1E-5 will be removed using post-processing. Iteratively, when the final result of the cloned model becomes less than 1% higher than the one in the nominal model, one can argue that any other remaining combined HEP < 1E-5 are insignificant for the result.

The conclusion of the paper summarizes the advantages of using *RiskSpectrum*® HRA tool and the Conditional Quantification tool, both due to the guaranteed systematization of HRA-PSA modelling and the simplification of quality assurance and model maintenance in future as well as in the light of implementing and adhering to the guidelines of the Swiss federal regulator ENSI.

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Disclaimer

The views, assumptions, opinions and analysis expressed in this article are those of the authors and do not necessarily reflect the official policy or position of their employer (NPP Goesgen-Däniken AG, Framatome GmbH).

References

ABS Consulting, 2016. RISKMAN.
ENSI. 2018. Probabilistic Safety Analysis (PSA): Quality and Scope. ENSI-A05/e.
RiskSpectrum AB. 2022a. RiskSpectrum® HRA Tool
RiskSpectrum AB. 2022b. RiskSpectrum® Model Builder.
RiskSpectrum AB. 2022c. RiskSpectrum® PSA
RiskSpectrum AB. 2022d. RiskSpectrum® PSA Macro
Swain, A. D., Guttmann, H. E. 1983. Handbook of Human Reliability Analysis with Emphasis on Nuclear Power Plant Applications. NUREG/CR-1278.