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User-friendliness and transparency in PSA modelling

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Abstract: Most of the probabilistic safety assessments (PSA) for Nuclear Power Plants were originally created to make conservative estimates of the core damage frequencies for internal events, which might occur during power operation. The PSA models have then been expanded to replace conservative estimates with more realistic assumptions and to include other types of initiating events, modes of operation and end states. The development has resulted in very large and detailed models, which are hard to understand completely, even for an experienced PSA engineer. Today, the trend to increase the level of detail and the scope of the PSA models continues as a consequence of regulatory requirements. Hence the Nordic PSA Group (NPSAG) has initiated a project with the aim of identifying methods to reduce the complexity of the PSA models. This paper presents and discusses the results of the first part of the project in which areas of importance for the user-friendliness and transparency of a PSA are identified.

Keywords: PSA, PRA, transparency, quality of risk analysis, risk-informed applications

1. INTRODUCTION

Most of the probabilistic safety assessments (PSA) for Nuclear Power Plants were originally created to make conservative estimates of the core damage frequencies for internal initiating events, which might occur during power operation. The PSA models have then been expanded to replace conservative estimates with more realistic assumptions and to include other types of initiating events, modes of operation and end states.

The development has resulted in very large and detailed models, which are hard to understand completely, even for an experienced PSA analyst. Further complexity can also be added by an inhomogeneous modelling caused by the involvement of different contractors in different phases of the development of the PSA. The consequence is that it is difficult to review the PSA properly and to perform a proper quality assurance, something that is very important when using the models to perform risk-informed applications. Further, the complexity of the PSA models makes it hard to keep them updated and increases the risk that analysts that do not fully understand the old modelling introduce errors.

Today, the trend to increase the level of detail and the scope of the PSA models continues as a consequence of regulatory requirements. Hence the Nordic PSA Group (NPSAG, http://www.npsag.org/home/) has initiated a project with the aim of identifying methods to manage the complexity of the PSA models.

This report presents and discusses the results of the first part of the project in which areas of importance with respect to the user-friendliness and transparency of a PSA are identified. Interviews were performed with PSA analysts from the Nordic countries and a structured review of their PSA studies has been conducted.

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2. OVERALL PROJECT PLAN

In the project the different types of PSA models and documentation of the NPSAG members will be studied. This includes PSA models for both pressurized water reactors (PWR) and boiling water reactors (BWR) created with two different softwares (RiskSpectrum [1] and FinPSA [2]).

The work will be performed in the following three phases:

1. Pre-study. Identification, evaluation and prioritisation of the problem areas.
2. Method development. Detailed analysis of the main problem areas. Identification of methods to solve the problems.
3. Pilot study. Demonstration of the method development with a selected PSA-study.

To include experiences, views and ideas from as many PSA engineers as possible in the evaluation an expert group, consisting of PSA engineers from different organizations, will be formed with which the project group an discuss findings and conclusions between each phase of the project.

This report presents and discusses the results of the first part of the project in which areas of importance with respect to the user-friendliness and transparency of a PSA are identified.

3. IDENTIFICATION OF AREAS OF IMPORTANCE FOR THE USER-FRIENDLINESS AND TRANSPERICY OF A PSA

In the first part of the project, PSA engineers at the Swedish and Finnish facilities were interviewed, and typical Nordic PSA models (Forsmark 3, Ringhals 1 & 3, Olkiluoto 1/2) were studied.

3.1. Interview of end users

The aim of the interviews has been to find what problems, connected to the user-friendliness and transparency of the PSA, which the users have based on the way they use PSA today. Further, they were asked to rate potential future applications to make it possible to assess which future development of the PSA that will be desirable. Below the discussions about some of the main problem areas that were identified are summarized.

3.1.1 Documentation / Tractability of Assumptions

All users agreed that it is a hard and time-consuming task to keep the PSA documentation up to date. Often large parts of the PSA have little influence of the results but still substantial resources are needed to keep the model and documentation up to date. In some cases detailed descriptions about systems and modelling make the documentation more user-friendly but at the same time the effort to keep descriptions and references up to date increases. It is often difficult to understand the PSA model based on the documentation, and also to find explanations of limitations and simplifications that are made. However, the overall opinion was that increasing the amount of documentation was no solution to the problem. Rather efforts should be made to improve the quality of the existing documentation and keeping the PSA model well-structured, logical and uniform.

The connection between the PSA model, the documentation and databases like the failure mode and effects analysis (FMEA), cable data bases for the modelling of room dependencies and other data sources could be improved in order to increase the user-friendliness.

Suggestions to simplify the documentation included different types of screening. For instance a classification of systems could be made based on their risk importance. Systems of high importance could be described in more detail than systems of less importance. Special attention should be paid to the description of important dependencies between components, both within one system and between different systems.

3.1.2 Living PSA / The update process for the PSA model

To minimize the work with updating the PSA model and documentation most users try to accumulate smaller updates to be able to include them in the PSA at the same time later. Still the update process is often very time-consuming. A problem is that the PSA tend to be a patchwork of different modelling techniques and documentation structures since new parts often are added without a revision of the older parts.

3.1.3 Review of changes in the PSA and quality assurance

Tools for automatic data generation and comparisons between databases should be used as often as possible to minimize the risk of including manual errors. The main problem is difficulties to find reviewers that are qualified to examine and question the details of the most complex and specific parts of a PSA, e.g. I&C modelling. In some cases a peer-review process can solve the problem but for plant specific parts it can still be difficult.

3.1.4 Realism contra complexity

A realistic modelling is necessary for the usefulness of some applications, and hence a certain complexity cannot be avoided. However, all users agreed that an adjustment must be made between realism and complexity. For parts of the models, that do not influence the results, simplified modelling based on conservative assumptions should be possible to use in most cases. Further realistic background analysis and screening analysis should be performed in an increased amount to decide which events and components that it is necessary to include in the PSA models. Dependencies are very important but sometimes there are simpler ways to include the important failure combinations than to model each small component and auto-generate CCF-groups. Another suggestion that was given at the interviews was to create, either manually or by extended software tools, simpler “light-PSA” for repeated applications where the need of realism is smaller and form modules of more complex parts that can be included in the PSA model when they are needed.

3.1.5 Handling of uncertainties

Due to a lack of time and recourses all users was of the opinion that too few uncertainty and sensitivity analysis are made today. When the PSA model is updated frequently, it is hard to keep uncertainty and sensitivity study chapters up-to-date. Some of the interviewees also referred to that long calculation times made it impossible to perform the necessary or wanted amount of sensitivity analyses. This implies that important contributions to the uncertainty can be overlooked, partly due to the models complexity.

3.1.6 Quantification

To be able to use the PSA for decision making it is important that the calculation times are reasonable. During the interviews the users that use the software RiskSpectrum said that long calculation times were a problem while the users of FinPSA did not find this to be a concern. The different experiences can partly be explained by use of different tools, but also partly by different modelling approaches. The importance of the software suppliers being pro-active in development of the tools and also regarding modelling techniques was pointed out.

3.1.7 Result presentation and communication

It is difficult to summarize the results of the complete PSA model in a clear and compressed way. Often the most important results are not numbers, like the values of the core damage frequency, but the explanation behind the final numeric results. Risk importance measures are useful means in the interpretation of results. The target group must be considered and different result presentations must be developed for different audiences. The large, complex PSA models make it difficult to communicate assumptions and results with the regulatory authority and people in other parts of the plant, e.g. the maintenance staff.

3.1.8 Modelling of plant changes, modernisation projects and power up-rates

At the moment many of the Nordic nuclear power plants are performing or planning to perform substantial plant changes, modernisation projects and power up-rates. Unlike smaller plant changes larger changes are difficult to include in the current PSA model since this should reflect the plant that is in operation at the time. Hence a second PSA study must be developed to evaluate the safety of the plant after the plant changes. It is often required to have the new PSA available before the modified plant is taken into operation, which can cause problems since the final, detailed specifications of the plant changes are finished late. Hence ideal solutions can be introduced to be able to complete the PSA without access to the final plant documentation. To model modernisation project is also challenging since clear instructions about how to model the new technology that is introduced can be missing.

3.1.9 Supply of qualified staff

It is difficult to build up a group of qualified staff at the plants. One problem is that there are few senior experts, and it takes time to educate new experts. Still it is not believed that the necessary qualifications can be achieved at Universities but experiences must be gained by working in the industry. However, it is good if new engineers get a general knowledge of plant operation before starting with PSA.

3.1.9 Applications

The opinions about which current and potential future applications that are of the most importance differed significantly between the users. Everybody agreed that some of the current applications, like assessment of the overall plant safety, are important but for future applications the rating was more different. An explanation for this is probably that current plant modifications and modernisation projects influence which issues the utilities find most relevant.

3.2. Evaluation of PSA models and documentation

A structured review has been made of the elements of four Nordic PSA models, chosen to include different reactor types (BWR and PWR) and different software tools (RiskSpectrum and FinPSA), and the belonging documentation to find characteristic parts that can affect the complexity. The review was focused on the following elements:

1. Analyzed plant operating modes
2. Analyzed end states
3. Main elements of the PSA, e.g.
    - Initiating Events
    - Sequence analysis/ Event Tree structures
    - System analysis / Fault Tree structures
    - Modelling of dependencies
4. Use of Boundary Conditions
5. Use and structure of analysis cases
6. Characteristics based on the PSA software (RiskSpectrum / FinPSA)
7. Handling of results
8. Applications

The overall structure of the model for internal initiating events is similar. The balance between event trees and fault trees is similar and the sequence analyses, system analyses, common cause failures data analyses are alike. However, there are substantial differences, e.g. in the modelling of area events, common cause initiators, the amount of analysed sequences and level 2 PSA. The features of the PSA tools explain some of the differences, e.g.

- Use of house events, boundary conditions and attributes is different
- RiskSpectrum users have used a lot of linked event trees, which is not possible in FinPSA
- For level 2 PSA, FinPSA users use the older DOS version tool SPSA, which supports a completely different approach for modelling of accident progression in level 2.

On the other hand, some of the modelling differences are caused by different approaches for the merging of initiating events with similar or nearly similar consequences together. The Swedish approach is to model events like a fire in room X or a LOCA in pipe segment Y, as separate cases. The Olkiluoto 1/2 PSA approach is to merge cases with similar consequences together, and to model only the compound cases.

The Swedish models tends to have a larger number of event trees, which on one hand is explained by more complex sequences, but also by an intentional approach to increase the transparency of the event trees by the use of linked event trees describing functional blocks. However, an increased number of linked event trees tends to increase the calculation times.

The level of details of the PSA documentation is similar. Olkiluoto 1/2 PSA has fewer chapters but they are larger in volume compared to Swedish documentation practice, where the content is divided into a large number of "smaller" reports. All PSA:s contain a designation system for the building blocks in the models, although they are applied to a varying extent, and some sort of simplified users guide for the PSA model. Some plants also have guidelines for modelling techniques, i.e. a guide in order to create standardized and uniform fault tree and event tree structures. Prerequisites, assumptions and limitations are generally documented separately for specific topics, and hence spread through out the PSA documentation.

4. CONCLUSION

The current PSA models and documentation are extensive and time consuming to keep up-to-date. This is a challenge from the quality point and from the user-friendliness point of view. A problem is that the PSA tend to be a patchwork of different modelling techniques and documentation structures since new parts often are added without a revision of the older parts. It can also be difficult to find experienced people to review the analyses.

One of the key questions is to find an appropriate balance between realistic modelling and complexity. Even if today's computers make it possible to create large and complex models with reasonable quantification time, it seems that attention should be paid to see possibilities to simplify the models, as well.

The general opinion is that an increased documentation will not improve the transparency and user-friendliness of the PSA:s. This is more likely to be achieved by an improved documentation quality, and by development and appliance of guidelines for modelling techniques, designations and a comprehensive users guide.

PSA tools also have a strong effect on the modelling approach. In this study, experiences from the RiskSpectrum and FinPSA tool have been compared and some preliminary insights have been gained. Both are powerful tools and capable of handling complex models. However, the differences in the features e.g. related to the manipulation of fault tree and event tree logic, database interface, the quantification principle and post processing facilities guide the users to different modelling solutions.
Some of the current problems could most likely be solved by PSA software development, and in general it is important that the software suppliers prioritize issues regarding transparency and user-friendliness in their software development.

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