Mapping the Risks of Swedish NPPs to Facilitate a Risk-Informed Regulation

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Abstract: The Swedish Radiation Safety Authority (SSM) has initiated a work to map the risks of the Swedish NPPs based on PSA results. The risk map will characterize and describe the most dominating risks of each plant. The main objective of this work is to utilize the risk map as a base for a risk-informed regulation approach. To be risk-informed means that a graded approach can be applied where issues related with higher risks can be prioritized over issues with lower risk. This graded approach will be applied at for example incoming applications for plant changes and reported incidents to decide what issues that should be prioritized for further evaluation and/or reviews.
The work with the risk map started late in 2013 and the first revision will be finalized during summer 2014. The risk map will be a living document in order to serve as a tool for integrated risk-informed decision making at SSM.
The work with the risk map has provided challenges along the way. Many of the challenges are related to differences in performing and presenting the results of the PSAs for different NPPs. A research need to develop guidance for harmonized PSA result presentation to resolve some of the identified issues has been identified.

Keywords: PSA, Risk-Informed, Risk Insights, Integrated Decision Making

1. INTRODUCTION

The Swedish Radiation Safety Authority (SSM) initiated late in 2013 a work with the purpose to map the risks of the Swedish NPPs based on existing PSA results.

The risk map will provide information about the most dominating risks for each plant. This includes for example the most risk contributing sequences, initiating events, systems, components, manual operations etc. The main purpose is to utilize the study as a base for risk-informing regulatory activities. The risk map can support the decision making when prioritizing what areas and issues to focus on in order to assure that the focus is on those matters that have the highest safety significance.

1.1. Acronyms and abbreviations

The following acronyms and abbreviations are used in the paper:

BWR	Boiling Water Reactor
CDF	Core Damage Frequency
NPP	Nuclear Power Plant
MCS	Minimal Cut Set
NPSAG	Nordic PSA Group
PSA	Probabilistic Safety Assessment
PWR	Pressurized Water Reactor
RDF	Risk Decrease Factor
RIF	Risk Increase Factor

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SAR	Safety Analysis Report
SSM	Swedish Radiation Safety Authority (Strålsäkerhetsmyndigheten)

2. BACKGROUND

Sweden has ten NPPs in operation at three different sites with three different licensees. In total there are nine PSA models that represent the NPPs (Forsmark units 1 and 2 are represented by one common PSA model).

The licensees develop their own PSAs. The PSAs are provided to SSM, mainly as part of safety documentation deliveries. As a result of a recent SSM initiative, PSAs will now be delivered every year, every second year as a full delivery and in between as intermediate updates. Depending on delivery, reviews with different scopes are performed. The PSAs are then available for supporting different regulatory uses (PSA applications).

SSM strives for a more integrated approach in decision making processes concerning safety related issues. SSM accedes to IAEA´s view that an integrated decision making process imply that all insights and requirements relating to a safety or regulatory issue should be considered in reaching a decision [1]. This includes insights and requirements from

- Mandatory requirements (law, regulations and other applicable rules)
- Requirements and insights from deterministic analysis
- Requirements and insights from probabilistic analysis
- Other considerations (cost-benefit, doses to workers etc.)

As a step towards a more risk-informed regulator, SSM did strengthen its PSA competence and resources significantly in 2013. This has made it possible to become more active in using PSA for various applications and to incorporate a more integrated perspective in safety related issues within the department of nuclear power safety at SSM. Various new PSA activities have been initiated and developing a risk map is one of them.

3. OBJECTIVES

The risk map is a tool to incorporate the vision of a risk-informed regulation. To be risk-informed means that a graded approach can be applied where issues related with higher risks can be prioritized over issues related with lower risk. This graded approach will be applied at for example incoming applications of plant changes and reported events to decide the level of attention for each case.

The issues to risk-inform could be decisions regarding proposed changes to

- The design or operation of a NPP
- The plant technical specifications
- Instructions regarding inspection, testing, quality assurance, maintenance and outages
- Emergency operating procedures and accident management measures

The risk insights can also be used as a tool to plan and prioritize activities in the regulatory body operation, such as

- Safety related research
- Changes to regulations
- Response to incidents
- Enforcement actions
- Inspections

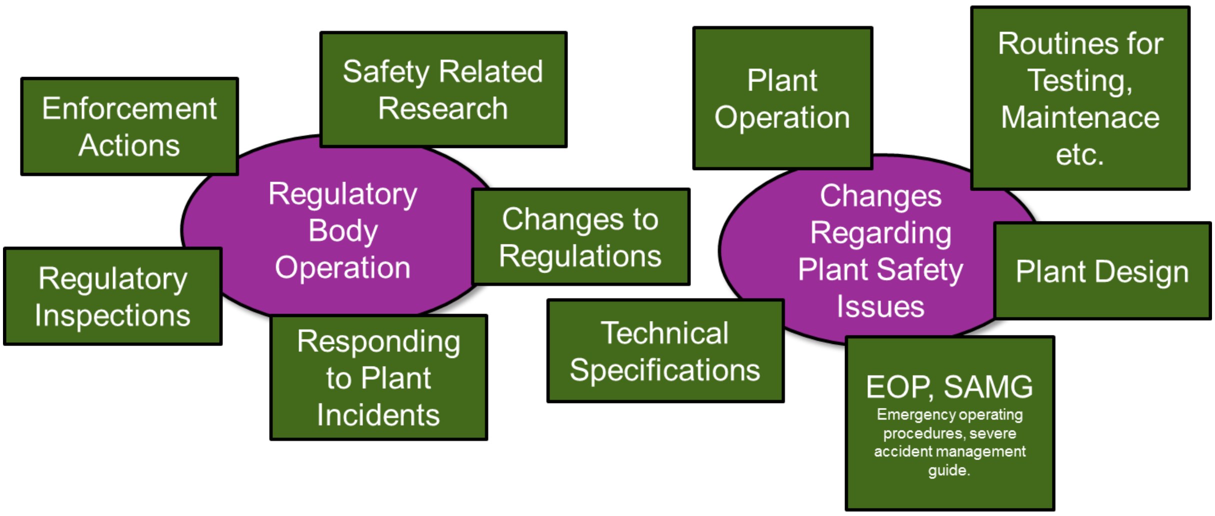
Sweden has a broad variety of reactor designs. There are three PWRs and seven BWRs that were connected to the commercial grid between the years 1972 to 1985. Due to the uniqueness to each reactor it is not trivial to know where each reactor has its weakest points and what the most contributing risks are for each individual reactor. A system that might be the most dominant in the contributing MCS list for one reactor might be of less significance to another reactor, for example due to an existing complete diverse system at the second reactor. The risk map will serve as a tool to understand what is important for each reactor from a risk point of view.

As a second benefit the differences of the results obtained in the risk map can be evaluated. The differences might originate from different use of methods, conservatisms etc. in the analyses. The different results could also be due to actual differences in design or operator instructions of the reactors. Knowledge about differences and their reasons can be important both for further refining analysis approaches and for prioritization of safety enhancing measures.

Another objective with developing the risk map is to increase the knowledge among the analysts and inspectors at SSM about the dominating risks.

Hence, the risk map will reflect the current risk profiles for all NPPs in Sweden. For specific cases also additional analyses with specific modifications in the PSA model will be performed.

The figure below summarizes different areas in the regulatory processes where an integrated decision making can be implemented.



4. SCOPE

The first version of the risk map will cover full power level 1 PSA. In the future the aim is to continue the development to also cover low power and shutdown states as well as level 2 PSA results and insights. In parallel to the development of the risk map structure, the risk map will continuously be updated with references to SAR, PSA models and PSA documentation of the current PSA studies. The risk map will always reflect current PSA studies and results and, in this way, it will be a living risk map.

The first version of the risk map will be finished in the summer of 2014 and will contain the following information:

- References to the current PSA models that represent the as-built and as-operated reactors
- References to the current SAR
- Important quantitative and qualitative results of each plant, such as
  - dominating CDF sequences
  - important system/components
  - dominating initiating events
  - important simplifications and conservatisms
  - dominating compartments/boundaries identified in the area event analysis
  - results and insights from uncertainty- and sensitivity analyses
- Risk parameters and metrics used for different types of applications in the risk-informed approach.

The above information will be documented in two reports. Because of the nature of the information, one of the reports containing sensitive information will have a higher level of confidentiality. The documentation structure of the first version of the risk map is outlined below.

- **Main report.** This report will be public and includes only non-confidential information. It describes the purpose and scope of the risk map. It also describes risk measures that are used in the result presentations and examples of some regulation processes in SSM where insights from PSA can be utilized.
- **Appendices.** The appendices will be treated as confidential information and are divided in three parts.
  - **Appendix 1.** In this report the PSA results and insights are presented qualitatively and quantitatively. The first version include the following chapters for each specific plant:
    - **Introduction.** Includes a synoptic presentation of the results that are extracted from the PSA chapter in the SAR.
    - **Initiating events.** Presents the fractional contribution from different individual and groups of initiating events.
    - **Sequences.** Presents and describes qualitatively which sequences (MCS) that have the highest contribution to the total CDF.
    - **Sensitive Areas.** Comprises a list of the most contributing compartments identified in the area event analyses. The dominating sequences and important components in the compartments are described qualitatively.
    - **Events.** The basic events (excluding the initiating events) with the highest RDF and RIF respectively are presented. A basic event represents a failure mode, for example a component failure or an unsuccessful manual action. For a description of RDF and RID, see section 4.1.

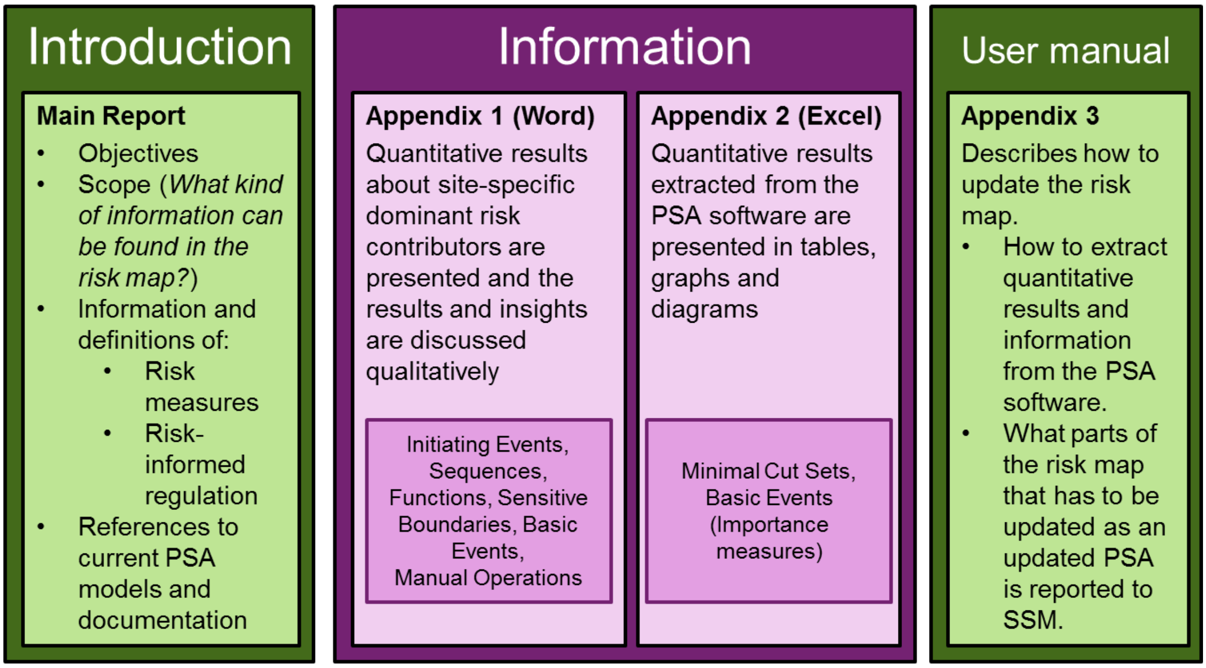
- **Event- and system groups.** Presents which systems and groups of events that dominate the contribution to the total risk. A system group includes all initiating events and failure modes related to that system. An event group can be for example "manual actions" or "relay failures".
- **Operator actions.** Presents the manual actions with the highest RDF and RIF respectively.

The following sections will not be included in the first version but are suggestions for further development.

- **Functions.** This section will present the reliability of the credited safety functions in the analysis and their relative contribution to the total risk.
- **Sensitivity analysis.** This section will describe results and insights from various sensitivity analyses.
- **Uncertainty analysis.** This section will describe results and insights from various uncertainty analyses.

- **Appendix 2.** This appendix is in excel-format where quantitative results extracted from the PSA models are presented in tables and graphs. Examples of data included are the most contributing MCS and the results from the sensitivity analysis of the basic events.
- **Appendix 3.** The purpose of this appendix is to be a user manual on how to extract the results from the PSA models when updating the risk map.

The figure below shows an overview of the risk map documentation structure.



4.1 Risk Measures

Evaluating the impact on the risk from suggested changes in the plant or reported incidents can be done using different types of importance measures. The risk map will include some important risk parameters that can be applied in different kinds of analyses.

All the Swedish PSA studies are implemented in the software RiskSpectrum. From the software some risk measures can be extracted directly from the result files [2]. The two importance measures used primarily in the risk map are the *Risk Decrease Factor* and the *Risk Increase Factor*, and are briefly described below.

Risk Increase Factor (RIF)
The RIF is a measure of the impact on the total risk level if for example a component would be completely unreliable, i.e. always fail. It is also known as the risk achievement worth.

Risk Decrease Factor (RDF)
The RDF is a measure of the impact on the total risk level if for example a component would be completely reliable, i.e. never fail. It is also known as the risk reduction worth.

The RIF and RDF can be calculated for basic events, groups of basic events, parameters and CCF-groups.

4.2 Use of PSA as an integrated tool

Incorporation of a risk-informed approach at the regulator makes it important that also non-PSA analysts and inspectors have basic knowledge of what kind of information that is possible to extract from a PSA. The work with the risk map will therefore be communicated within the whole department of nuclear power safety at SSM. The PSA analysts should be able to provide risk insights to various issues where decisions regarding safety have to be made.

5. CHALLENGES

During the work with developing the risk map various challenges have been obtained along the way. Some of the challenges were expected and also some challenges that were not foreseen came across during the work. Some of the challenges are

- Compare and interpret results. This is a complex task due to many factors, for example;
    - different methodologies and assumptions are used in different studies
    - different groupings of initiating events and consequences in result presentations
- Different structure and level of detail in result presentations lead to difficulties to find the desired information.

The identified differences in result presentations structure emphasized a need for guidance on how to present results from PSA. A project proposal to develop guidance for result presentation was worked out and presented to the NPSAG.

Other issues to take into consideration when using and comparing the results from PSA studies are the quality assurance, level of details and methods used. These might be different for different plants. These issues are however outside the scope of this paper.

Utilizing PSA as a part in risk-informed decision making requires the user to have a certain level of knowledge about the specific PSAs. It is important to know what important assumptions, simplifications, conservatisms and non-conservatisms etc. that are included in each PSA. As often emphasized within the field of risk analysis, it is not enough to be able to extract the numbers from the PSA - the results should also be explained in a qualitative way. The analyst must understand where the dominating sequences originate from and also the uncertainty and sensitivity in high level results due to uncertainties in event parameters, assumptions and limitations.

6. RESULTS

The development of the risk map is a recently initiated activity at SSM. The first version is scheduled for summer 2014.

The first stages of the work have identified challenges for the oncoming work. Many of these challenges are due to site differences in PSA approaches, in particular related to PSA model structure and quantification, presentation and interpretation of results. This has resulted in a project proposal within the NPSAG with the title ”Development of a harmonized method for PSA result presentation”. A harmonized result presentation will make it easier and faster for a reviewer to compare and understand results from different studies. It is also important that the result presentations are comprehensive and cover all important aspects from a risk point of view.

7. CONCLUSION

The work with the risk map started late in 2013 and is part of SSMs ambition to become a risk-informed regulator to a greater extent than today. It is expected that the further development and use of the risk map at SSM will be beneficial for increased risk insights, in particular for the PSA group, but also for SSM in general. The application of the risk map information in various tasks will support prioritization of work. Further, spread of PSA knowledge outside the PSA group is also expected to be a benefit of this work.

SSM wish to get in contact to other authorities and organizations around the world to exchange experience regarding similar activities.

References

[1] IAEA-TECDOC-1436. “*Risk informed regulation of nuclear facilities: Overview of the current status*”, February 2005
[2] RiskSpectrum Analysis Tools – Theory Manual, version 3.2.1, Scandpower AB