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Risk Informed Decision Making
A Pre-Study

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Abstract

Examples of risk-informed decisions are establishing maintenance programmes, optimising inspection policies and justifying plant modifications, and revising technical specifications. Applications in daily situations can be such as accepting or rejecting exemptions from technical specifications.

The aim of this pre-study was to identify the status of risk-informed decision making at Swedish and Finnish nuclear power plants and nuclear safety authorities. Responses to a questionnaire were obtained either by interviews or by e-mail from two Swedish and two Finnish NPPs, SKI and STUK.

The development of a risk-informed decision procedure based on decision analytic ideas is worth recommending. A clear documentation format is a part of such procedure. In order to serve as a basis for final decision, the documentation should include clearly defined decision criteria, qualification of PSA model for the issue under analysis, description of most important uncertainties and assumptions.

Key words

Risk-informed decision making, RIDM, nuclear power plants, safety authorities, Finland, Sweden, questionnaire

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Foreword

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Espoo, December 2003

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Appendix

1 Introduction

A seminar on the status and plans of applications of risk informed principles both by nuclear authorities and industry in Finland and Sweden was organised within the NKS/SOS-2 project during the NKS programme period 1998-2001 (Pulkkinen & Simola 1999). Examples of risk-informed decisions are establishing maintenance programmes, optimising inspection policies and justifying plant modifications, and revising technical specifications. Applications in daily situations can be such as accepting or rejecting exemptions from technical specifications. Since the seminar in 1999, the application of probabilistic safety assessments (PSA) in safety related decision making has been continuously increasing.

The environment of decision making concerning nuclear power plant safety is complex. There are several parties involved, like the power company with its different departments of the utility, and the safety authority. Even the public want their opinions and objectives to be taken into account. In addition to this, the complexity of the plant makes the decisions difficult. The complexity of the decision making environment and applicable decision making procedures are discussed in an illustrative way by Vaurio (1998).

The aim of this pre-study was to identify the status of risk-informed decision making at Swedish and Finnish nuclear power plants and nuclear safety authorities. We obtained responses to our questionnaire either by interviews or by e-mail from two Swedish and two Finnish NPPs, SKI and STUK. We summarise the answers completed with information from available documents in chapter 2. In chapter 3 we discuss the elements of a good decision making process. Conclusions and recommendations from this pre-study are given in chapter 4.

2 Status of risk-informed decision making (RIDM) in Sweden and Finland

In this chapter, we summarise the results obtained in interviews, responses obtained to questionnaires, and information obtained from other documents. First we briefly describe the regulatory policies in Finland and Sweden, and after that, the practical work at utilities. The questionnaire is in Appendix 1.

2.1 Regulatory requirements and RIDM

In Finland, STUK has very recently issued the updated regulatory guide YVL 2.8 “Probabilistic safety analyses (PSA) in the licensing and regulation of nuclear power plants” (STUK 2003). According to this new guide, the licensee has to use the PSA in support of licensing of new NPPs and of resolving for safety issues at operating NPPs. Use of PSA in the safety management of plant operation and maintenance covers the following long term issues:

- main risk contributors
- personnel training
- plant changes and backfitting
- Disturbance and &emergency operating procedure improvements
- analysis of technical specifications
- in-service inspection and testing
- maintenance planning
- graded quality assurance
- cost benefit analysis

Short term issues are exemptions of technical specifications and analysis of safety margins during incidents. STUK has performed pilot studies to develop methodology for solving the above mentioned issues. The latest pilot studies have concentrated on in-service inspection and testing and graded quality assurance.

In Sweden, the use of PSA in various decision making situation at first sight seems less mandatory than in Finland in the sense that there are not as explicit requirements in the regulatory guides. In the Swedish regulatory guide SKIFS 1998:1 (SKI 1998) it is stated that utilities should use PSA, and guides are very general. The application of PSA e.g. in testing and maintenance activities are voluntary, but in principle SKI is promoting the use of PSA. SKI has an internal “handbook for PSA review” which supports SKI reviews and inspections of PSA activities at licensees. This means that in practice SKI takes part in detail in the PSA processes, including the development of models and documentation.

In Finland, STUK has the PSA models for its own use. In Sweden SKI does not use the models as frequently as STUK. STUK uses the model to review the PSA analyses made by the licensees as a part of risk-informed applications or safety related decisions. The main tools for reviewing the analyses are sensitivity studies with respect to data and model assumptions. SKI also reviews the PSA in respect to all aspects. This complete review is made in connection to the updating of the entire PSA. In the time between, the use of PSA models by the regulator is more sporadic.

Regulators want to make sure that PSA is not used selectively. For instance, when defining a risk-informed inspection programme, the whole programme should be considered instead of only some selected systems.

2.2 PSA application areas

The plants have applied PSA in many areas. In the following, we have divided the application areas to plant modifications, optimisation of test and maintenance, risk-informed in-service inspections, and exemptions of technical specifications. Further, risk-informed operator training and risk follow-up activities could be mentioned as PSA applications.

Plant modifications

One of the most common uses of PSA is safety improvement based on PSA results, and there are plenty of applications both at Finnish and Swedish utilities in this area. For instance, in relation to the modernisation program of Olkiluoto units 1993-1999, the utility and contractors were supported with PSA based examinations in 17 safety related projects. In Barsebäck PSA Level 1 has been used as a tool for plant upgrading and modification since the beginning of 1998. Ideas and proposals regarding modification of both hardware and software that has some impact on safety are tried out with the PSA-model. Loviisa has used the PSA to identify dominating accident sequences and plant modifications to reduce the core damage frequency (CDF) since 1989. (Pulkkinen & Simola 1999)

One example from FKA is the use of an investment analysis method based on net present value to analyse the safety-economic aspects of plant modifications. In these analyses also risk and availability impact of modifications is analysed (Slottsmöte 2003). The main objective of the development of the method is to enable the evaluation of various investments with regard to safety "regardless its aim, e.g. power upgrade, availability increase, risk reduction or a combination of these". The analysis shows the profitability of the investment, so that the investments can be ranked either regardless of purpose or e.g. according to risks.

Optimisation of testing, maintenance and in-service inspections

Our examples of test interval optimisation come from Loviisa. There extensions of test intervals of containment isolation valves and diesel generators have been justified using PSA results.

In Olkiluoto, PSA is also used in connection of defining maintenance classes for components. The PSA and availability analyses are used to steer the selection of the maintenance strategy classes carried out by the maintenance supervisors.

Risk-informed in-service inspections (RI-ISI) represent a large application area requiring expertise from many disciplines. RI-ISI methodologies have been developed, tested and/or adopted to various extent at many Nordic NPPs. In Finland, STUK has conducted a pilot study to test the applicability of a rather qualitative approach, close to the EPRI methodology (EPRI). TVO has made its own pilot study, also based on the EPRI approach. In Sweden, there has been a pilot study for Oskarshamn 1, where a quantitative approach based on the use of a code developed by DNV has been applied. The most extensive RI-ISI application has been performed at Ringhals, where the project RIVAL has been conducted following the WOG RI-ISI methodology. The project was completed in 2002 for the unit R2 and the results have been submitted to SKI for review. Project is still going on for R3 and R4 units.

Exemptions form Technical Specifications

There are several examples of deviations from allowed outage times (AOTs) or postponement of repairs to next outage that have been justified by PSA and accepted by the regulatory body both at Swedish and at Finnish plants. These PSA applications are of different nature compared to the above-discussed ones in the sense that both the analyses and their approval typically have a tight time schedule. In Finland, STUK requires the safety assessment of a temporary exemption of Technical Specifications to be done with PSA, and it is provided that the extension of AOT contributes very little to the core damage frequency compared with normal operation. In Sweden SKI gets an "announcement of temporary deviation from TechSpec." from the Swedish utilities. SKI can then call for more detailed information on analyses.

Besides the temporary exemptions, there are also cases where permanent changes to Technical Specifications are proposed based on PSA analysis, because an inconsistency between deterministic AOTs and actual risk impact has been identified.

2.3 PSA qualification for RIDM

There are very different application areas for PSA and a basic PSA model is not sufficient for many applications. Depending on the decision case, only a part of the PSA model is used in the analysis. PSA model includes hidden assumptions and properties that require thorough knowledge on the background and limitations of the model.

According to the interviews, there are usually no generic guidelines for qualifying PSA applications, since the analysed cases are different. Analysis results are checked e.g. using the minimal cut set lists, importance measures for basic events and accident sequences.

A Finnish study related to the qualification of PSA for applications was performed in 2001 within the national reactor safety research programme (Holmberg et al. 2001). The study introduced templates to document relevant items that should be taken into account when qualifying PSA for any application. The main analysis steps are shortly summarised below:

- General information about the case, validation of proper definition of the scope for the PSA application
- Modifications made in the PSA model
- Validation of the sufficiency of analyses and result presentation
- Validation of the result interpretation
- Validation of the sufficiency and quality of documentation

RI-ISI is a good example of PSA application where several problems with the PSA qualification for the purpose may be encountered. Piping "components" are not modelled in the same detail as active components, and thus the evaluation of both piping failure probabilities and their consequences usually requires lot of additional work.

2.4 Decision criteria

In RIDM, there are usually some deterministic criteria that have to be fulfilled or weighted together with PSA results. The fulfilment of some safety related deterministic criteria, e.g. defence in depth, is generally a requirement. Other criteria related to RIDM can be e.g. radiation protection, availability aspects or investment costs.

Decision criteria in PSA applications were discussed in an NKS-report (Pulkkinen et al. 2001) in the NKS/SOS-2 project. The report discussed principles that can be used for evaluating the mixture of criteria that decision-maker may consider to use in the decision analysis process. The report provides a general list of principles and compares PSA-criteria with these principles.

2.4.1 PSA criteria

The basic PSA based decision criteria are core damage frequency (CDF), large early release frequency (LERF) and various importance measures. A qualitative criterion that has to be fulfilled is that there are no single or few dominant risk factors. For the CDF and LERF there are target values set by safety authorities, but utilities may also have their own target values.

The US Regulatory Guide 1.174 (NRC 1998) describes an approach for using PSA in risk-informed decisions, and discusses also some applicable decision criteria. These criteria, complemented and justified with the requirements of STUK's regulatory guide YVL 2.8 are used as a basis of decision criteria at TVO.

Importance measures are typically used to support the decision making. According to TVO, the situation often requires new search of minimal cut sets. The coarse analysis is always made on the basis of existing generic up to date minimal cut sets rather quickly. The detailed analysis requires more work.

From the PSA analysis, it is possible to choose different criteria, e.g. different importance measures, which do not necessarily lead to same results. In the NKS/SOS-2 project, a pilot study on risk-informed safety classification was conducted for Loviisa plant (Jänkälä 2000). This study discussed the use of different importance measures, not only from the classification point of view, but also in general. The study concludes that it is often useful to consider two importance measures simultaneously. Risk Increase Factor (RIF) is a good importance measure for setting reliability targets and possibly useful in initially classifying new systems or groups of redundant identical components. Conditional Core Damage Probability (CCDP) is useful for in-service-inspection purposes and for setting frequency targets for initiating events and comparing the safety significances of initiating events. Fussell-Vesely (FV) importance can give reasoning for component requalification, and is well suited for consideration of modifications.

2.4.2 Deterministic criteria

Generally some deterministic safety criteria have to be fulfilled. There may also be other kind of criteria, e.g. in investment analyses some cost-related criteria are used.

Usually, the decision criteria are used on case by case basis. Certain deterministic criteria have to be met always. The design and operation rules can be interpreted as deterministic decision criteria. These rules must be fulfilled, and they cannot be compensated by any other characteristics of the system. A good example of such design rule is the single failure criterion. PSA-based decision criteria can be used to complement the deterministic rules with certain limitations. For example, SKI does not accept PSA arguments violating the defence in depth principle, and trade off between deterministic rules and PSA arguments is not allowed. Generally, it is agreed that PSA should not be used against defence in depth barriers. This does not mean that the defence cannot be optimised.

2.5 Procedures for RIDM

According to the interviews, there are usually not very formal procedures established for risk-informed applications. Anyhow, there are often some instructions for the use of PSA in applications.

TVO has an internal procedure on the use of PSA that is included in the operation handbook. This procedure contains e.g. decision making criteria concerning PSA. There is no specific documentation for RIDM, the main documentation can be found in Minutes of the Internal Safety Committee meeting.

In Loviisa, in complex modifications a special committee has been named to screen options and to develop new concepts. The committee consists of members from different departments depending on the subject. PSA results are calculated for few/best options. Plant leadership or QA & Safety meeting decides and selects the path and responsible "host" for each modification. Sometimes the need for risk evaluation is identified e.g. by Operations or Maintenance. Idea meetings are not necessarily documented, but main decisions at official meetings are. Examples of such meetings are QA & Safety meeting, Modification work meetings and plant management meetings. All bases for decision making are not necessarily in the minutes. A good description of safety-related decision making at Loviisa plant can be found in (Vaurio 1998).

FKA has an instruction for living PSA (Instruktion för LPSA-verksamhetet). The instruction gives brief list of requirements for PSA: resources, PSA culture & PSA model.
FKA’s primary areas of PSA applications are:
- analyse and evaluate need of plant modifications
- optimise safety improvements
- risk follow-up / PSA indicators
- optimisation of tech specs
- optimisation of operation and maintenance
- analysis of disturbances
- fill up SKIFS 1998:1

For complex modifications, FKA has a separate instruction on the use of integrated safety analysis (ISA). In the case of integrates safety analysis, four analysis methods used together:
- deterministic analysis,
- PSA,
- MTO (human-technology-organisation) &
- analysis of operating experience

The project leader of an ISA project group assures that the necessary information is exchanged between different analysis parts. Project leader also sees that the analyses are integrated to a homogeneous final report. In ISA instructions it is written that PSA results should be presented so that non-PSA people can understand them. The ISA analysis is reviewed independently.

2.6 Main problems identified in relation to RIDM

The problems related to risk informed decision making can be divided in following main categories: quality of PSA, communication between parties involved, and acceptance of risk informed decision making.

PSA quality is identified to cause some problems. This is naturally dependent both on the quality and degree of detail of the PSA model, and the application in question. There are uncertainties both in data and models, and these uncertainties should be taken into account when evaluating the weight of PSA-based arguments in the decision making.

The use of importance measures is not always straightforward. The subject, e.g. pipe or system, can be divided into many parts in different ways, and criteria for individual parts or for the whole can give different answers. Sensitivity analyses and the simultaneous use of two importance measures can give additional insight to the risk evaluations.

Understanding between parties involved has been recognised as a problem in some answers. PSA is not easy to understand by people who are not very familiar with the methodology. Interpretation of the results of probabilistic analyses seems to be more difficult than of deterministic ones. This can be one reason why the risk information does not seem to be appreciated as much as PSA analysts would expect. PSA analysts feel that decisions are often made based on intuition or unreasonable deterministic rules. On the other hand, decisions are usually made with several aspects in mind, some of them being less explicit than probabilistic and deterministic safety analyses. Inputs from different disciplines and aspects are important for the decision making by the manager.

3 Good decision making

In this chapter we discuss the principles of good decision making. These principles can be seen as the ideal situation, which is usually not met in practice. However, the decision theoretical framework could be used as a checklist to verify case by case that the most important principles have been followed to a reasonable extent taking into account the importance of the decision and available resources for the analysis process.

Risk-informed decision making aims at taking PSA results, together with other analyses, into account in decision making. The interdisciplinary nature of the safety related work, complex decision making situation involving several parties (e.g. utility, safety authority) and several decision objectives create the following needs:

- need to combine expertise from several disciplines
- need to satisfy several decision making criteria
- need to take uncertainty into account
- need to make decisions in a transparent way
- need to structure decisions

Often, the decisions are made at ad hoc manner, due to time or other constraints, without considering all important aspects of the decision problem under consideration. Decision analysis provides a structured approach for transparent treatment of above needs. It aims at helping the decision maker to choose between several, complex and often contradicting alternatives. However, in practical risk-informed decision making, it is not always possible to follow the principles of decision analysis in their whole extend. Thus, decision analytic principles must be seen as a reference for good decision making process, not a strict guideline. The characteristics of good decisions can bee seen such a reference:

- takes into account the goals, opinions, and feedback from the management
- takes into account the opinions and feedback from experts and colleagues
- shares the responsibility of the decision in a proper way
- reached quickly and effectively a consensus
- achieves the best solution in ideal circumstances
- is based on the deep understanding of the decision situation and the factors having impact over it
- is coherent and consistent

In addition to above characteristic of a good decision, the decision theory gives an ideal framework for a good decision making process, which should have the following phases:

1. Identification of the decision making problem

- what must be decided
- why it must be decided
- what are the goals of decision making

2. Structuring of the decision problem

- identification of decision making criteria
- identification of decision options or alternatives
- identification of factors effecting the decisio0ns
- identification of the consequences of decision options

3. Identification of uncertainties

- what are the uncertain variables related to the decision problem

4. Quantification of decision criteria

- definition of the variables corresponding the decision criteria
- definition of the method to measure the decision criteria
- definition of the weighting of decision criteria (= definition of multi-criteria value value function)
- quantification of risk attitude

5. Modelling of the decision situation

- modelling the consequences of each decision option, taking into account the uncertainties and values
- quantification of the value/utility function or decision table
- quantification of the value/utility of each decision option
- identification of best decision

6. Sensitivity analyses

- analysis of the sensitivity of decisions on changes in assumptions
- analysis of change point: how the factors related to the decision should change in order to change the order of the decision options
- analysis of value of additional information

7. Making the decision

- the decision maker is responsible for the decision, not the model
- one must not escape the responsibility behind the models

The above list of phases corresponds, actually, to the phases of decision analysis. Many of the phases are not possible in practice. However, when a decision making process starts, it is advantageous to check the above list and identify the relevant phases to the decision at hand. In principle, the above list could be formulated as a flowchart for risk-informed decision making.

4 Conclusion and recommendation for further work

The extensive use of risk-informed principles in decision making requires certain prerequisites. An organisation applying RIDM should clearly define the responsibilities for making the needed PSA calculations and define a way to review their applicability in the decision case under consideration. In other words, the RIDM activities should be realised in an organised way. This requires wide understanding and good documentation of the PSA model. The assumptions and modelling principles of the issues under analysis should be communicated to each party of the decision making process in an understandable and revisable way.

In Finland, the plant personnel have participated in the PSA projects, and the PSA model is rather familiar to the personnel. In Sweden, the role of outside consultants has been more important in PSA projects, and the model may in some cases be non-familiar to the personnel. However, it is important that the modelling principles and assumptions are known by the parties of RIDM process, and more education may be needed to implement the RIDM principles in everyday decision making.

According to the answers to the questionnaire of this study, there are generally no formal procedures for RIDM. FKA's Integrated Safety Analysis instructions could be considered as a RIDM procedure, but it does not set very explicit requirements for the use of PSA results.

Although the decision cases are different, there is much common in them, and many issues of RIDM process could be described in guidelines or procedures. Furthermore, a good or an ideal RIDM process should have certain phases (see section 3). Thus, the development of a RIDM procedure based on decision analytic ideas is worth recommending. A clear documentation format is a part of such procedure. In order to serve as a basis for final decision, the documentation should include clearly defined decision criteria, qualification of PSA model for the issue under analysis, description of most important uncertainties and assumptions.

Since risk-informed in-service inspection (RI-ISI) represents a rather large PSA application area, and there are lots of RI-ISI activities going on both in Finland and Sweden, case studies could be related to this topic. There are open questions related to the problem areas mentioned in section 2.6: PSA quality for the purpose, communication between disciplines, and acceptance criteria. We are currently proposing for NKS a study mainly related to PSA quality issues. Another interesting topic could be to compare approaches used to integrate multidisciplinary knowledge e.g. in expert panels, in order to define a common Nordic view or best practices for this purpose.

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Attachment

Within the NKS/SOS-2.1 project we highlighted the need of transparency and comprehensive communication between various parties representing several disciplines in the decision making situation. The studying of risk-informed decision making (RIDM) in practice, with an aim to develop good practices for a RIDM process, was identified by the project group as one interesting subject for future NKS-activities.

Within the NKS-R framework, we are now running a small pre-project on risk-informed decision making. We aim at identifying and defining the steps of risk-informed decision making process. These include e.g.

- the identification of decision issues requiring risk-informed approach,
- defining the way of using PSA results in the issue,
- defining the way of communication between experts representing various disciplines,
- the selection and justification of decision criteria,
- justification of the final decision.
- In addition, the principles for documenting the decision cases will be considered, giving emphasis on transparency and traceability.

Within the pre-project, we intend to interview Swedish and Finnish utilities and nuclear safety authorities to identify in what kind of decision making situation PSA has been used, or is intended to be used. We have prepared the following questionnaire to help this task. We hope that you have time to consider these questions (even write down answers, if possible) before the interview, during which we try to fill up the questionnaire as well as possible.

We are also exploring the interest for case studies to test the framework. The case studies are proposed to be carried out in a separate NKS-project during 2003.

Questionnaire on risk informed decision making in practice

In what kind of decisions you have used PSA results as decision criteria? What are the main reasons for applying/not applying PSA in decisions?

Has the PSA been the only decision criterion, or has the decision making process included other, deterministic criteria?

Do you apply a formal procedure in risk-informed decision making?

Is the PSA model qualified for the decision situation? If so, how?

What PSA related decision criteria (e.g. importance measures) you use? How has their use been justified? What other (e.g. deterministic) criteria are used? Name some examples.

How these decisions have been made? What parties (what kind of experts, what departments of your organisation, etc.) are involved in the decision process? Why? How the consensus between participants in the decision process has been reached? Can you give examples?

Has the decision making process been documented? How? Do you have any publicly available documentation on the decision cases?

What problems, pitfalls have you identified in RIDM?

Can you identify any advantages or problems in using PSA/RIDM as an argument in proposing decision options to be accepted by safety authority (i.e. in discussions with safety authority)?

Can You identify any advantages or problems in using PSA/RIDM as an argument in proposing decision options to be accepted in your own organisation?

In what kind of safety related decision situations PSA/RIDM fits/doesn't fit?

Do you have interest to participate in 2003 in an NKS-project, where some case studies would be analysed to test the framework for RIDM?

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Key words: Risk-informed decision making, RIDM, nuclear power plants, safety authorities, Finland, Sweden, questionnaire

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