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NPSAG/NKS: Interpretation and Evaluation of the Technical Specification Criteria

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Abstract

The use of risk-informed methods has been discussed since the late 1980s in the Nordic countries. However, at that time the industry and authorities were not ready for the use of these methods and the use of them have been limited. The common understanding right now is that the industry and authorities are ready for adoption of risk-informed strategies, and the use of risk informed methods in daily operation at the nuclear power plants (NPPs) as well as for long term evaluation and definition of rules and regulations is increasing.
The authorities are strengthening the rules and regulations with regard to redundancy and diversification in the safety systems. There are several ongoing projects at the NPPs, such as modernization, power upgrade etc. These projects will require modification of the Technical Specifications (TS). The requirements on a risk analysis to verify exceptions will be a natural part of the TS update. To summarize; there are both activities and trends at the plants that will result in TS changes (modernizations, increase of electrical power, risk informed strategies). At the same time, authorities are increasing the requirements on risk informed evaluation of the TS.
TS evaluation from a risk point of view raises several questions:
- How shall the TS conditions be evaluated?
- What aspects shall be taken into consideration?
- Can a prolonged/shortened surveillance test interval (STI) or allowed outage time (AOT) affect the experienced importance of the equipment?
-What do the conditions in the TS with regard to AOT really represent? Are they conditions that shall be used when spare part storage and/or maintenance strategies are developed or do they represent how a real situation (unavailable component) shall be managed?
To form an idea of the opinion on these questions phase 1 of the project is based on a literature study and interviews with persons at the Swedish and Finnish utilities and authorities. A short background to the current TS is also given and the role of PSA in the TS evaluation process is briefly discussed. Methods, discussions and comments with regard to STI and AOT analyses respectively are presented. Together this serves as a background for the recommendations for phase 2 of the project.

Key words

Risk-Informed Decision Making, Technical Specifications, TS Evaluation

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Acronyms and abbreviations

AOT	Allowed Outage Time
FKA	Formarks Kraftgrupp AB
FNS	Fortum Nuclear Service
FSG	Fristående säkerhetsgranskning (Independent Safety Review)
LCO	Limiting Conditions for Operation
MERITS	Methodically Engineered Restructured and Improved Technical Specifications
NRC	Nuclear Regulatory Commission (US)
OKG	Oskarshamns Kraftgrupp
PSG	Preliminär Säkerhetsgranskning (Preliminary Safety Review)
RAB	Ringhals AB
RAW	Risk Achievement Worth
RG	Regulatory Guide (from NRC)
RIF	Risk Increase Factor
SKI	Statens Kärnkraft Inspektion (Swedish Nuclear Power Inspectorate)
STI	Surveillance Test Interval
STUK	Säteilyturvakeskus (Radiation and Nuclear Safety Authority Finland)

1. Introduction

Studies on risk-informed methods have been a part of NKS activities since late 1980´s, but at that time the industry was not ready for the use of these methods. The common understanding right now is that the industry and authorities are ready for adoption of risk-informed strategies. It shall be noted that Finland has developed the use of risk-informed analyses, whereas this area has been less focused in Sweden.

The use of risk informed methods in daily operation at the Nuclear Power Plants as well as for long term evaluation and definition of rules and regulations is increasing. Risk informed methods have been applied on a case by case basis during the past few years, but it is expected that these methods will be applied in a quite different manner in the coming years.

One important example is the Swedish Regulators statute SKIFS 2004:2 [1]. SKIFS 2004:2 defines that exemptions from the deterministic requirements are only acceptable if a risk analyses is performed (SKIFS 2004:2 §16). It can be noticed that the exceptions from the Technical Specifications in most cases are exceptions from the deterministic requirements. The new requirements in SKIFS 2004:2 indicate an increased number of TS excemptions based on risk informed analysis.

The authorities are strengthening the rules and regulations with regard to redundancy and diversification in the safety systems. In parallel, there is an increased understanding that in most cases it is not optimal to have a too short test interval and that it is not optimal from a safety stand point to require shut down of the plant as a universal method when a component is unavailable.

There are several ongoing projects at the NPPs, such as modernization, increase of electrical output etc and these projects will require modification of the TS. The requirements on a risk analysis to verify excemptions will be a natural part of the TS update.

To summarize; there are both activities and trends on the plants that will result in TS changes (modernizations, increase of electrical power, risk informed strategies). The authorities are increasing the requirements on risk informed evaluation of the TS.

Evaluation of TS from a risk point of view raises several questions:

- How shall the TS conditions be evaluated?
- What aspects shall be taken into consideration?
- Can a prolonged/shortened test interval or AOT (allowed outage time) affect the experienced importance of the equipment?
- The conditions in the TS with regard to AOT, what do they really represent? Are they conditions that shall be used when spare part storage and/or maintenance strategies are developed or are they representing how a real situation (unavailable component) shall be managed?

This report presents the results of the first step in the process, which has been to:

- Information gathering, review of performed projects (especially in US and Finland since the risk informed process has been used most extensively there)
- Definition of aspects to be considered in a TS evaluation. Both positive and negative aspects shall be included.

- Description of the background of the TS today. What was the intention when the TS were written. What would the NPP like the TS to define? What would the authority like the TS to define?

Step 2 of the project is planned to comprise the following:

- Development of guidelines for evaluation of TS changes (with regard to the aspects defined in step 1).
- Propose an alternative design of the TS (or similar), where different aspects on AOT criterion can be satisfied.

Step 1 of the project has been based on a literature study and interviews with persons at following nuclear facilities and authorities:

Sweden

- FKA
- OKG
- RAB
- SKI

Finland

- FNS
- STUK
- TVO

Section 2 of this report presents the background to the current TS. The purpose is to provide some knowledge on the background, before methods for evaluating changes are discussed (know where you are from or you won't know where you are going).

Section 3 discusses briefly the role of PSA in the TS evaluation process, to put this report and its contents in perspective. Section 4 presents the literature study that has been performed as part of this project.

Sections 5 and 6 present methods, discussions and comments with regard to STI and AOT analyses respectively.

Section 7 presents some short comments on quality requirements on the PSA model.

Finally, section 8 presents discussion, conclusions and recommendations for the next phase of the project.

2. Background to Current TS

Since the PSA methods have evolved and gained acceptance the possibility to use a risk-informed approach for optimizing and evaluating STIs and AOTs has been introduced. The original TSs though were based on deterministic analyses and assumptions.

The information in this section is mainly based on interviews with Ralph Nyman, SKI, and Kalle Jänkälä, FNS.

2.1. BWR TS

The first Swedish BWR TS were created in the early 1970-ies, at the time when the Ågesta plant was in operation and Oskarshamn Unit 1 had just been started up. Key persons working with the development of the first harmonized Swedish TS at that time observed that the very first operational rules för Ågesta and O1 were not good enough. The development of the TSs for Barsbebäck, Forsmark and Oskarshamn became hence based on lessons learnt from a US BWR TS.

The very first demands on STIs and AOTs were based on deterministic calculations. A 30 day STI became an established practice and it was applied to safety relevant components at the plant e.g., diesel generators and ECC pumps. Regarding the AOT a 48 hour criterion became an established praxis. The criterion was based on a failure in a 2*100% safety system train – if train A failed the plant had to investigate if it could be repaired within 48 hours and before starting the eventual repair of train A, train B had to be verified operational by a test. Otherwise a plant shutdown was required. Current AOTs are based on the harmonized structure developed during late 1970´s till mid 80´s.

A Swedish licensee can today add new demands/LCOs of safety and risk importance to the TSs. The opposite, to remove demands/LCOs from the TSs, based on PSA evalution, is not allowed with the present regulation in Sweden.

In *Figure 1* the method applied by OKG to determine if a component should be part of the TS (STF) or not is presented.

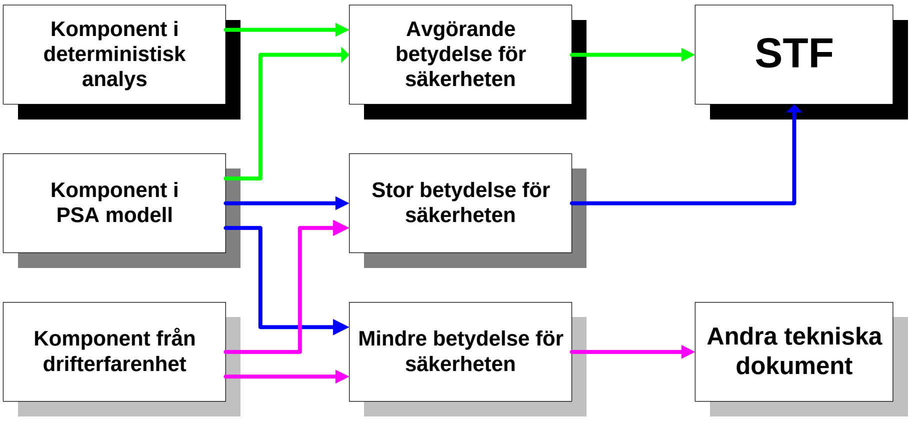

Figure 1 *General survey of the method to create a Technical Specification [2].*

2.2. PWR TS

The Swedish PWR plants have followed the Westinghouse (W) standard TS since the start of operation. At that time the W standard was based on NUREG-0542. NRC did not add any specific demands on AOT for individual LCOs in the TS. These times were instead specified for the licensing of the US plants. The history of AOTs in US TSs is found in the NRC report *Recommended interim values of LCOs for ECCS components* [3]. These results were compared with the allowed AOT in the TSs. The new calculations on average unavailability of ECCS components were estimated for the large LOCA situation as a function of outage time per month.

Today Ringhals Unit 2, 3 and 4 PWR have TSs based on W standard ITS, documented in the NUREG-1431 rev 2. The conversion to the new standard has been performed according to the MERITS.

2.3. VVER TS

For the Finnish Loviisa plants the TS was developed during the construction. Since the Russian VVERs did not have any TS it was developed based on some principles from US plants. The main principles have remained unchanged over the years, but some adjustments have been done. For example, the shutdown states are now included and the number of tests has increased, from around 100 in the early 1980´s to more than 500 today.

2.4. Comments on TS and its Development

SKI:

- The Swedish BWR TS strategy is improperly documented, since there is no documented “official domestic BWR standard” to follow and update. However, there is of course a “harmonized domestic structure” that all BWR plants have followed and adopted during a long time. The question if the methods used by the licensees today are sufficient for TS updates and changes are a matter of how deeply the instructions are reviewed and with which purpose this is done. If risk-informed TS optimizations are utilized, these procedures have to be trimmed and tailored for this technique.

3. The Role of PSA in the TS Evaluation Process

In the evaluation process of TS changes there are many aspects that must taken into account. It is obvious that the PSA cannot represent all relevant aspects that should be considered – and that should never be the intention. If PSA cannot represent all relevant aspects, does it add any information to use the PSA?

There are very few ways of analyzing the impact of plant changes to the overall risk. Therefore, the PSA add valuable information.

It can be noticed that both STUK and SKI require changes in the TS to be verified with PSA (SKI does not formally require this but the practice has been this). Also, the US NRC has fully adopted a risk informed decision process, in which PSA (PRA) plays an important role.

The aim of phase 1 of this project has not been to study the role of PSA in the decision process and to define all other aspects. The intention of Phase 2 of the project is to develop a guideline for evaluating TS changes with PSA, and in such a guideline it must of course be clear what the role of PSA is.

It is vital to understand that PSA is only a tool in the process. In Regulatory Guide 1.174 [4] following is stated about the requirements of changes in the TS:

- The proposed change meets the current regulations unless it is explicitly related to a requested exemption or rule change.
- The proposed change is consistent with the defense-in-depth philosophy
- The proposed change maintains sufficient safety margins
- When the proposed change result in an increase in core damage frequency or risk, the increase should be small and consistent with the Commission´s Safety Goal Policy Statement

- The impact of the proposed change should be monitored using performance measurement strategies

To meet the requirements of the list above the process (in RG1.174) is presented as four elements:

- Element 1: Define the proposed change. All aspects of the proposed change shall be identified. All structures, systems and components (SSCs), procedures and activities that are covered by the proposed change shall be evaluated. Specifically the original reasons for the program shall be understood.
- Element 2: Perform engineering analysis. The analyses can include traditional engineering analyses and PRA. The licensee shall verify that the fundamental safety principles of the plant are not compromised. Safety margins and defense-in-depth may be affected by the proposed change and the licensee should therefore re-evaluate these to support the LB change. The PRA changes shall meet defined acceptance criteria and uncertainties shall be evaluated.
- Element 3: Define implementation and monitoring program. The purpose is to avoid an unexpected increase in number of failures due to unanticipated degradation. An implementation and monitoring plan should be developed to ensure that the engineering evaluations conducted remain valid.
- Element 4: Submit propose change.

Also, the RG1.174 provides requirements about quality assurance and documentation of TS changes.

The intention of this project and report, at least in current phase, has been to describe the PSA evaluation of element 2 above. In RG1.174 there are acceptance criteria stated but it is not considered certain that these can be considered acceptable in the Nordic countries and hence this project has focused on methods and practice that can lead to some common understanding. Before understanding what, and if, acceptance criteria can be defined the method has to be understood.

- In phase 2 of the project more focus should be on the role of the PSA in the evaluation process.

4. Information Gathering

In this section some relevant reports and projects are summarized. The reports are organized by organization.

4.1. ABB Atom

In 1985 ASEA-ATOM did a survey to map the Swedish NPPs and authorities view on the development of the TS. The results were summarized in the report "*Utveckling och optimering av säkerhetstekniska föreskrifter med hjälp av PRA-metodik – En sammanfattning av synpunkter inhämtade från skandinaviska kraftbolag och myndigheter*" [5].

This report has no significance today, but it shows that this discussion was on-going already 1985.

4.2. IAEA 1991 – 2007

IAEA has for a long period of time studied the risk based/informed analysis of the TS. Following reports has been identified as interesting:

- *Use of Probabilistic Safety Assessment to Evaluate Nuclear Power Plant. Technical Specifications* [7]
- *Case Study on* the *Use of PSA Methods: Assessment of Technical Specifications for the Reactor Protection System Instrumentation* [8]
- *Risk Based Optimization of Technical Specifications for Operation of Nuclear Power Plants* [9]
- *Risk Based Test Interval and Maintenance Optimisation* [10] (part of an IAEA project)
- *Advances in safety related maintenance* [11]
- *Maintenance, Surveillance and In-service Inspection in Nuclear Power Plants* [12]
- *Development and Application of Level 1 Probabilistic Safety Assessment for Nuclear Power Plants* [13]

In *Risk Based Optimization of Technical Specifications for Operation of Nuclear Power Plants* [9] some important aspects that should be taken into consideration are presented. The recommendations are on a generic level, but it is considered very good for orientation.

In safety series NS-G-2.6 guidance is given with regard to development of TS. In this respect also PSA (or reliability analyses) are mentioned. In draft DS34, in a similar way as in Regulatory Guide 1.175 [6], changes of STIs are discussed. This is very brief though and not useful in this project.

4.3. NKS

Within the NKS framework a number of studies have been performed regarding risk informed decision making based on PSA. SUPER-ASAR, comparison between different PSAs, has been a driver – but the studies of most relevance are the NKS-SIK-1 project and study on decision criteria. These are presented below.

4.3.1. NKS/SIK-1: Safety Evaluation by Use of Living PSA and Safety Indicators, 1990-93

The start point for Living PSA in Sweden could be said to be the NKS-SIK-1 report. The report *Safety Evaluation by Living Probabilistic Safety Assessment Procedures and Applications of Operational Activities and Analysis of Operating Experience* [14] also describes different types of application for PSA.

As a part of the main study a pilot study of test interval optimization is performed: *Pilot Study: Analysis of Prescribed Testintervals, Oskarshamn 2* [15].

Both reports can serve as a basis, but they do not discuss in detail how evaluation shall be done of changes in the TS. The effect of uncertainties is discussed only in a limited manner. It can be noticed that the report *Risk Based Test Interval and Maintenance Optimisation* [16] is a continuation of the pilot study with the aim of studying uncertainties.

4.3.2. Decision Criteria

In the report *Decision criteria in PSA applications* NKS-44 [17] there is an extensive survey of the decision process and decision criteria in risk informed decision making within the nuclear industry. The basis is PSA and the circumstances that is present within the nuclear industry (authority and a part holding the license).

4.3.3. NKS/RAS 450

The NKS/RAS programme (1985-89) comprised a project called RAS-450 *Optimization of Technical Specifications by use of probabilistic methods* [18]. The report describes the status and the different problems that could be valid in analysis of test interval and allowed outage times.

4.4. Reports from NRC

In the US the use of risk informed decision making has increased steadily and to a large extent US NRC has encouraged this. Since 1998 NRC has a risk informed decision making programme.

There are a number of regulatory guides about this. NRC has also issued a large number of "NUREGs" with methodology and applications. Some of these, considered very important, are listed below:

- *Handbook of Methods for Risk-Based Analyses of Technical Specifications* [19]
- *RG1.174, An Approach for Using Probabilistic Risk Assessment in Risk-Informed Decisions on Plant-Specific Changes to the Licensing Basis* [4]
- *RG 1.177, An Approach for Plant-Specific, Risk Informed Decisionmaking: Technical Specifications* [20]
- *An Approach for Plant-Specific, Risk-Informed Decisionmaking: Inservice Testing, Regulatory Guide 1.175* [6]
- *SRP. 16.1 Risk-informed decisionmaking: Technical Specifications* [21]

The report *Handbook of Methods for Risk-Based Analyses of Technical Specifications* was released in 1994. In the report methods for reliability- and risk based methods are described thoroughly. Many different aspects, positive and negative, that shall be considered are presented.

RG1.174 forms the basis for risk informed decision making in the reports 1.17x. The basis for how changes in TS shall be evaluated is presented, e.g. that both CDF and LERF shall be used. In specific, the accepted changes in risk shall be small and that cumulative effects of several changes shall be considered. The methods used must be well documented and it shall be possible to do a normal review of the method. The whole process for user initiated plant changes is presented.

In RG1.175 the aspects relevant for STI changes are presented. Also, evaluation of changes with PSA is discussed. The discussion is not detailed but different aspects that may be relevant are presented, e.g. failure data and changes on CCF. The document is very relevant.

4.5. SKI rapporter

In 1999 Torbjörn Andersson performed a study commissioned by SKI on AOTs and how they affected the reactor safety. The study was presented in a SKI report; *Förslag till reparationskriterier för de svenska kokvattenreaktorerna. Säkerhetstekniska driftförutsättningar (STF)* [22].

Another of the reports previously mentioned, *Risk Based Test Interval and Maintenance Optimisation* [10] was also carried out within the limits for the SKI research program.

The Swedish Nuclear Power Inspectorate Regulatory Code 2004:1, *Statens kärnkraftinspektions föreskrifter om säkerhet i kärntekniska anläggningar* [23], requires a safety analysis of the plant and of the TS. It can be noted that a requirement is that the TS shall be up to date. This has been interpreted by the authority and the utilities as a requirement that TS changes should be evaluated using PSA.

The Swedish Nuclear Power Inspectorate Regulatory Code 2004:2, *Statens kärnkraftinspektions föreskrifter om konstruktion och utförande av kärnkraftsreaktorer* [1], makes new demands on safety in Swedish nuclear power plants. Article 16 is of extra interest since it renders maintenance during operation possible.

The Finnish regulatory guides, YVL-guides present requirements on Technical Specifications and PSA. The relevant regulatory guides from this project's perspective are:

- *YVL-1.8, Repairs, modifications and preventive maintenance at nuclear facilities* [24]
- *YVL 2.8, Probabilistic safety analysis in safety management of nuclear power plants* [25]

The YVL-1.8 Guide presents how STUK regulates repairs, modifications and preventive maintenance of systems, components and structures at nuclear facilities during operation. The guide further describes the obligations related to this work imposed on power companies.

YVL-2.8 sets requirements for the use of PSA in the safety managements. The Guide states that *"The technical specifications shall be reviewed by PSA in such a way that the coverage and balance of technical specifications are ensured. The review must cover all operating states of the plant. Especially such failure states, in which the change of operating state of the plant may result in a greater risk than the repair of the plant during operation, shall be reviewed with PSA. The results of the review shall be submitted to STUK in conjunction with the application for an acceptance of technical specifications."*

4.6. Experiences

4.6.1. Finnish experiences

In Finland, both Fortum and TVO have conducted risk-informed applications of TS changes.

Fortum has applied a risk-informed evaluation of STI on emergency diesel generators [26]. The analysis resulted in a proposal to extend the test interval from two to four weeks, and this has been approved by STUK.

Method development on the optimization of AOTs has been carried out in two Masters' Theses at Fortum [27-28] and also presented at the PSAM8 conference in New Orleans 2006 [29]. The method has been applied to emergency cooling pumps of Loviisa NPP. As a result of the analysis the AOT for a single pump failure should be kept at three weeks, but the AOTs for multiple pump failures should be increased from immediate shutdown up to three days.

TVO has adopted an approach based on Burden-Importance Ratio (BIR) to evaluate the STIs [30]. BIR measures the proportional burden (estimate of costs including work hours and production losses) in relation to the proportional importance of the component (Fussel-Vesely importance measure). The approach has originally been introduced by Vesely [31], and VTT has been testing and developing its use for application in Finland. The analyses have resulted to suggestions of changes in test intervals, e.g. extension of TI for MFW, AFW and Boron System isolation valves, AFW pumps and check valves. For high risk batteries the TI could be shortened, and for low risk batteries extended.

TVO has applied two methods to evaluate the AOTs. First, an evaluation how long power operation can be continued so that shutdown risk corresponds to the risk of continued operation was conducted. The second approach was developed by STUK, and it is based on the minimization of risk during failure state assuming that the repair takes always the whole AOT and with a certain probability the plant shutdown is needed when AOT exceeded.

So far the Finnish applications have been separate studies on a group of components/equipment or a set of systems. At both utilities there is ongoing development work to adopt a risk-informed approach for TS at plant level.

4.6.2. Swedish Experiences

In Sweden, all utilities have had some sort of activity regarding risk-informed applications of TS changes. The evaluation of STIs have mainly been based on a complete test schema and evaluated on plant level. None of the utilities have actually made any changes to their STIs based a risk-informed method though.

The status of AOT evaluation differs more between the utilities. While FKA have not performed any analysis, OKG has made some Ringhals, on the other hand, has performed an analysis where the results have been implemented in the TS. The analysis is based on repair time distribution and probability to exceed the AOT. Calculations have been made both before and after the new TS and the results have been compared.

4.6.3. US Experiences

Current experiences from the US indicate that the process applied is based on RG1.174 [4], which implies an evaluation against a number of ratios. The example below is based on changes in AOTs:

- CDF increase with component unavailable
- LERF increase with component unavailable

- CDF increase with component available
- LERF increase with component unavailable
- RIF/RAW

The method used for AOT evaluation is based on the same principles as the Swedish TSs today, i.e. risk for continued operation is compared to a predefined risk measure and not to the risk of a plant shutdown. RG1.174 states clear limits for the accepted CDF and change in related to TS changes, see *Figure 2* and *Figure 3* below.

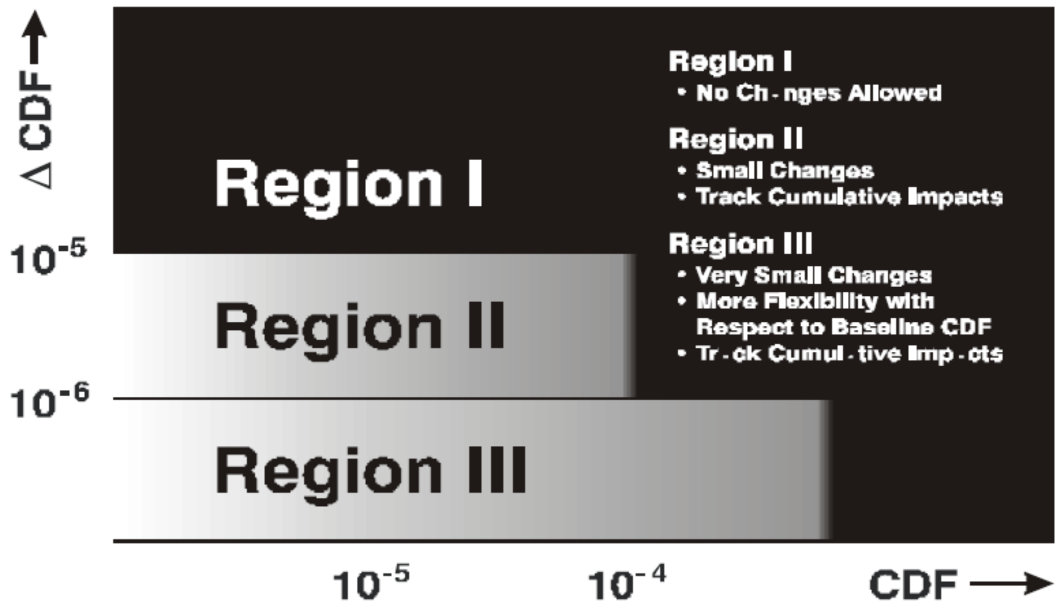

Figure 2 *Acceptance guidelines for Core Damage Frequency (CDF) according to RG1.174 [4]*

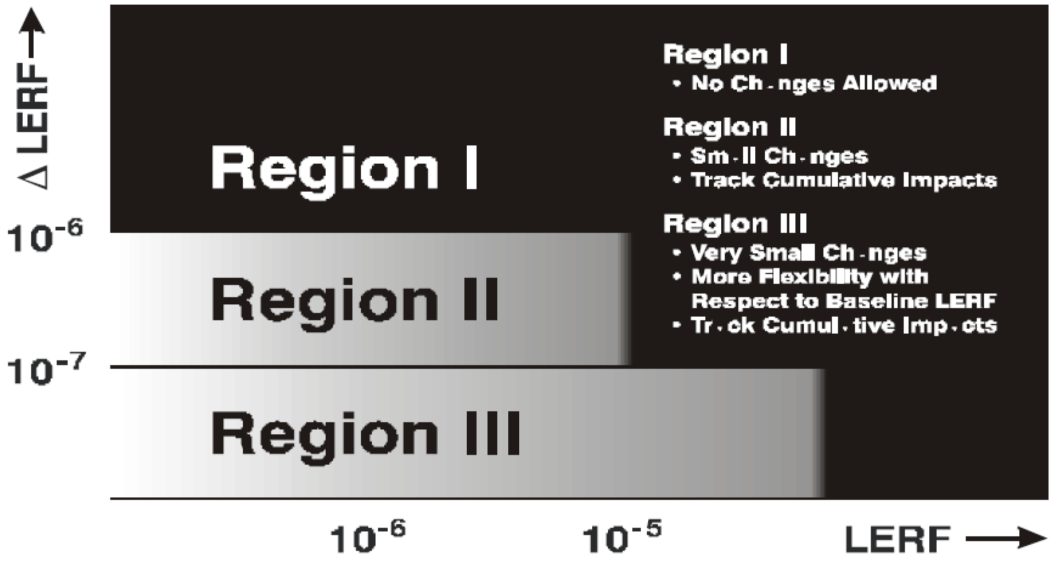

Figure 3 *Acceptance guidelines for Large Early Release Frequency (LERF) according to RG1.174 [4]*

In the US some TS-related work is and has also been done within the BWR Owners Group. The routine is that the industry as a whole (led by Nuclear Energy Insitute) decides on a group of desirable risk-informed TS changes, or initiatives, that provide cost savings and are justifiable based on risk. To provide a basis for specific changes this committee typically funds the development of Licensing Topical Reports. Usually a plant volunteers to be a test case for the Topical Report so that both the utilities and the NRC can work out any problems with the methods in the Topical Report before they are finalized. The NRC reviews these Topical Reports, and once they are approved the plants can implement plant-specific TS changes based on the approved topical reports.

Over the past 5 years a number of initiatives have had Topical Reports written and approved, and a number of utilities are now implementing them. Other initiatives are still having Topical Reports written. Generally these are applicable to both BWRs and PWRs. In general, the believe is that risk-informed TS changes have an excellent cost-benefit, but there is some lead time involved in developing Topical Reports for NRC approval before the utilities can implement them. The US industry also believes that most of the cost-beneficial risk-informed TS changes have been identified already, and there are few if any new ones being identified.

Some of the completed and implemented initiatives include:

- Missed surveillances (this is felt to be highly cost-effective)
- Increased flexibility in mode restraints
- Impact of non-technical specification design feature on operability requirements (barriers)

Some initiatives in progress include:

- Relocate surveillance intervals to licensee control (this is also felt to be highly cost-effective)
- Risk-informed completion times with configuration risk management or maintenance rule backstop

- TS required actions preferred end states (hot standby, cold shutdown)

5. Evaluation of STIs

5.1. Methods

There are different methods that may be used for evaluation of STIs. The methods may be based on component specific changes or they may be based on an overall evaluation on plant level.

According to *Handbook of Methods for Risk-Based Analyses of Technical Specifications* [19] the total risk impact from a test can be expressed:

$$R_T = R_D + R_C$$

Where:

$R_T =$ Total risk for the test

$R_D =$ Risk contribution detected by the test (test-limited risk)

$R_C =$ Risk contribution caused by the test (test-caused risk)

The risk contribution caused by the test can be divided in several parts according to:

$$R_C = R_{Trip} + R_{Wear} + R_{Config} + R_{Down}$$

Where:

$R_{Trip} =$ Risk that the test causes an initiating event

$R_{Wear} =$ Risk of wear out of the equipment

$R_{Config} =$ Risk that the plant configuration is incorrect when the test has been performed (causing an increased risk)

$R_{Down} =$ Risk due to component unavailability during the test

By comparing the risk contribution detected by the test with the risk contribution caused by the test the effectiveness of a single test can be evaluated, i.e. if

$R_D > R_C$ the test is risk-effective

Based on this an optimal test interval

$$\text{MIN } R_T = R_D + R_C$$

In *Figure 4* a plot of the risk contribution detected by the test, caused by the test, and their corresponding total risk is depicted.

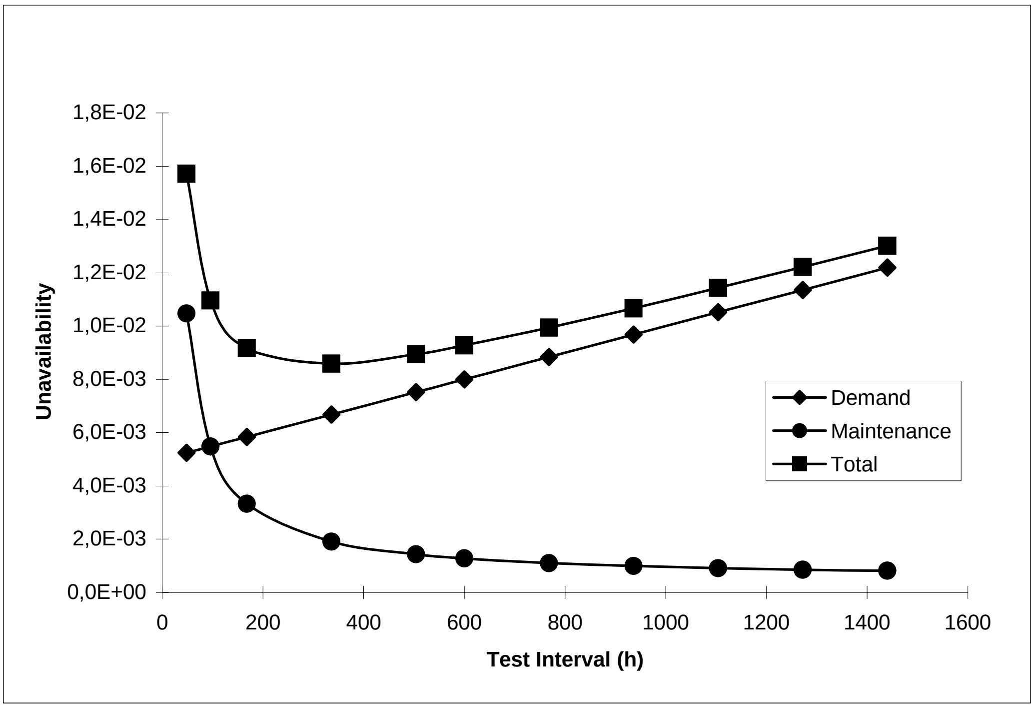

Figure 4 *Risk contribution of surveillance testing versus test interval. R_D is denoted Demand, R_C Maintenance and R_T Total [19]*

The other perspective is to view all changes in a test program in one analysis on plant level. The methods for this are normally based on the formula for R_T above. In most cases R_C is neglected, i.e. the risk for shutdown, wear out etc. is considered not to be affected by the test frequency. Prolonging of one component/system STI may for example be acceptable if another component/system has a reduced STI. This idea is based on:

$$R_{Tot} = \sum_{j=1}^{n} R_{Dj}$$

Where:

R_{Tot} =	Total change in risk of a complete test program
R_{Dj} =	Change in risk due to change in one test interval

It can be noted that the above formula is simplified, since relations between different tests are not taken into account. The idea that is shown by the formula is that trade offs can be made between different tests. If R_{Tot} is zero, then the new test program neither increases nor decreases the overall risk.

5.1.1. Methods Used

Following methods have been used:

FKA:

- Small analyses for some specific STIs have been performed, where the effect on the core damage frequency has been studied. The results have not been used for implementation, only for R&D purposes.

FNS:

- Testing program for emergency diesel generators has been evaluated based on a component specific method where an in-depth check of failure modes has been performed. The basic idea behind the evaluation was to show that the test interval could be prolonged without causing more than a minor change in the overall core damage frequency. This was based on the maintenance personnel's' judgement that the frequent tests of the diesels actually caused more failures than they revealed. The evaluation resulted in a proposal to prolong the test interval from two to four weeks. The application for a TS change was approved by STUK.
- A model that will cover all test intervals in TS is under development. It will be tested on a single system and based on this experience the method will be evaluated.

OKG:

- Optimization of a test program on plant level has been performed. The method is based on the idea that a prolonged STI in one system will result in a shortened interval in another to keep the core damage frequency at constant level. The results have not been used for implementation though, only for R&D purposes.

RAB:

- An evaluation based on a complete test interval schema for the plant was performed within the project MERITS for Ringhals unit 2-4. The W standard STIs were used, but the evaluation resulted in no changes.

TVO:

- An optimization has been performed based on the component burden-to-importance ratio (Fussel Vesely). The method aims at comparing the resources used for the test with the test´s importance:

  BIR = relative burden / relative importance

  If the BIR value is equal to 1 the allocation of resources is optimal. If the value is >> 1 too many resources are used for the test and if it is << 1 too little resources are used.

  For test cases with a large derivation of BIR = 1 new test intervals have been introduced and ΔCDF has been calculated. Analyses have resulted in suggestions of changes in STIs, e.g. an extension for AFW pumps and check and isolation valves.

5.2. Areas to Specifically Consider in the Evaluation

When evaluating changes in STIs there are a number of parameters that may influence the result:

- Does the PSA model represent the evaluated changes in a satisfactory way?
- A test can result in adverse effects such as a test-caused trips, maintenance etc. How should this be taken into account?
- How should different plant configurations be considered? Different configurations may result in different risks.
- Which risk measures should be studied; core damage, large early release frequency, large release frequency?

- Which operating modes should be considered?
- Which initiating events should be considered? Area events, LOCA, etc?
- Is it acceptable to decrease the barrier against LOCA for example and instead increase the barrier against transients, i.e. can trade offs in the defense-in-depth functions be accepted?
- Not only uncertainties in component data will affect the result, but also the distribution of time-dependent/time-independent data within the component model. Objects where the time-dependent data are dominant will receive a shorter STI than an object where the time-independent data are.
- Can the changed STI affect the failure data?
- Staggered alternatively sequential testing must be considered. Normally in the PSA model the tests are supposed to be randomly distributed within the test intervals.
- The effect on the CCF events by changed STIs should be considered.
- There are several different tests that affect the same component. How should this be considered?
- If an error is found in the PSA model – how should this be handled?

Table 1 *Comments on specific areas given in the answers regarding STIs*

Area	**Specific comments**
Adverse effects	• No specific comments.
Configurations	• It may be a tedious task to analyze all configurations. Hence some different configurations ought to be analyzed to verify that the effects are non significant.
Risk measures	• CDF is the main measure. Other measures only used for orientation. • Both CDF and LERF shall be used *The reason given for only analyzing CD is that it is considered stable, e.g. level 2 results are much more uncertain.* *What is LERF?*
Plant operation modes	• Power operation
Initiating events	• All initiators shall be included. To be able to use a PSA model for this purpose requires all initiators to be included. • Only the internal events are of interest *The reason given for only including internal events is that those results are considered most stable, e.g. fire and flooding are considered conservative.*
Effect on function barriers	• It is vital that functions in the TS are not affected significantly.

Area	Specific comments
Failure data	• This must be considered in evaluation of prolonged STIs regarding stand-by failure modes.
Time dependent and -independent data	• No specific comments
Testing schema	• The analysis should presuppose that tests are staggered, if the licensee wants to use some other strategy (e.g. sequential) – this should be verified specifically.
CCF	• This must be considered in evaluation of prolonged STIs regarding stand-by failure modes.
Several tests affecting same components	• If relation is persistent this should not be a problem.
Updates of / errors in the PSA model	• Will be dealt with in accordance to the normal treatment of changes in the PSA model. • Case dependent.

5.3. Comments on STI evaluation

FKA:

- How to address objects that are not part of the TS, should that be part of the evaluation?
- How to include new objects – that are not part of SAR?
- Can non-safety relevant equipment be part of the evaluation?
- It must be considered that different tests may test different failure modes.
- Is it really necessary to perform these types of analyses? Why should we accept this burden?

FNS:

- No specific comment.

OKG:

- OKG has a method for reactor safety evaluation. The method used must comply with this method. Hence this may mean that the availability for system functions may not be degraded significantly.

RAB:

- No specific comment.

SKI:

- Should not cause large changes in availability for functions. How to make this comply with the safety functions of the SAR?

STUK:

- Should not focus on specific test intervals but on grouped tests (into entities). It is not enough to optimize individual test intervals but rather the whole maintenance system.
- The simple expressions used in PRA are insufficient for the optimization of test intervals. Test intervals shall be justified also based on physical processes taking place.
- Bounding analyses are often made to check how large changes would affect the analysis results. The importance of PSA in decision-making is decreased if the decisions are sensitive.

TVO:

- An evaluation of risks connected to the tests, e.g. transient risks, should be performed.
- Besides a quantitative analysis, a comprehensive qualitative analysis should be performed with result interpretation and evaluation within a larger group having different expertise (expert panel).

5.4. Conclusions on STI Analysis

STI analyses are performed in different ways among the utilities in the Nordic countries. While some have chosen to optimize a test based on its importance others have been looking at a complete test schema with the aim to keep the CDF constant. One important thing to stress here is that depending on which method is chosen different issues will be of importance when it comes to uncertainties. If trade offs are made within a system for example the sensitivity to changes in failure data is greater than if trade offs are made between systems.

There seems however to be a common opinion that the STI changes in the end, independent of method used for calculating the intervals, should be evaluated by calculating the impact on the CDF. In Finland, both the utilities and the authority stress that also the impact on LERF should be evaluated and taken into consideration. The opinion on which initiating events that should be the base for the evaluation differs though. While the opinion in Sweden more or less seems to be that only the internal events analysis is realistic enough to use, the standpoint in Finland is that the full scope PSA should be used.

Even though some work has been done on STI evaluation it, the evaluation has resulted in a TS change only for the Loviisa plants.

The question on how non-safety systems or systems not modeled in the PSA should be treated is of great importance here. One idea would be to require a certain level of detail for the model to be approved for STI analyses. Another interesting area where no consensus seems to be reached is how an impact of the STI changes on the safety functions should be handled.

A question that has not yet been addressed is whether it would be acceptable to introduce even a minor increase in the CDF due to changed STIs regardless of the original CDF.

6. Evaluation of AOTs

6.1. Methods

6.1.1. Methods for Evaluating Single AOTs

There are several methods that may be used for evaluation of the specific AOTs. Three main methods are:

1. Risk of continued operation with objects unavailable compared with an accepted frequency
2. Risk of continued operation with objects unavailable compared with an accepted probability (risk budget)
3. Risk of continued operation compared to plant shutdown (with objects unavailable)

These are the three main alternatives, but there are several variants based on these two methods.

The methods are described briefly by following chapters.

6.1.1.1. Frequency that May not be Exceeded

The methods that use this approach indicate which AOTs that may be relevant to be considered in further studies. The measures used can e.g. be the risk increase factor or an absolute risk increase frequency, compared to the nominal risk.

The method does not give any guidance to the length of the AOT, but it can be an indication where it might be acceptable to perform maintenance at power operation (preventive or corrective). The method can hence be considered a way to avoid risk peaks at power operation, due to maintenance activities.

The guidance on AOT length is simple: if the risk frequency is close to the nominal risk frequency, the AOT can be long, and if the risk is increased significantly the AOT must be short.

6.1.1.2. Risk Budget

There are some alternative ways to use a risk budget method, but the basic idea is to compare the conditional risk probability with an accepted risk probability. There are two main principles:

- AOT based on a single event in a system
- AOT based on accumulated risk contribution from a system

In the first case a single repair is studied (assumed to occur) and compared with the accepted risk probability:

$$AOT_x = \frac{P_{Acceptedriskprobability}}{f_{power,x}}$$

In this case the $P_{acceptedriskprobability}$ means the accepted probability per occurrence. If the expected number of occurrences are taken into account the formula would be:

$$AOT_x = \frac{F_{Acceptedriskprobability}}{f_{power,x} \cdot \lambda_x}$$

In this case $F_{acceptedriskprobability}$ means the yearly accepted risk probability and the λ_x means the failure rate of the equipment.

The acceptable, e.g., conditional core damage probability can be determined by different methods. For example, the acceptable conditional core damage probability due to maintenance can be distributed among all possible maintenance activities.

It can be noticed that the method described in RG1.174 [4] constitute a combination of a frequency that must not be exceeded and a conditional core damage probability.

6.1.1.3. CONTINUED OPERATION VS SHUT DOWN

The previously described methods presuppose continued operation of the plant. These methods do not take into account that shut down may be a risk itself. Shut down from power operation with unavailable components is normally though not to be insignificant from a risk perspective.

A method taking this into account is the comparison of the risk for continued operation with unavailable equipment versus the risk of shutting the plant down (degraded).

Figure 5 below describes a risk curve for staying in power operation conditions with unavailable equipment and a risk curve presenting the shut down risk with unavailable equipment.

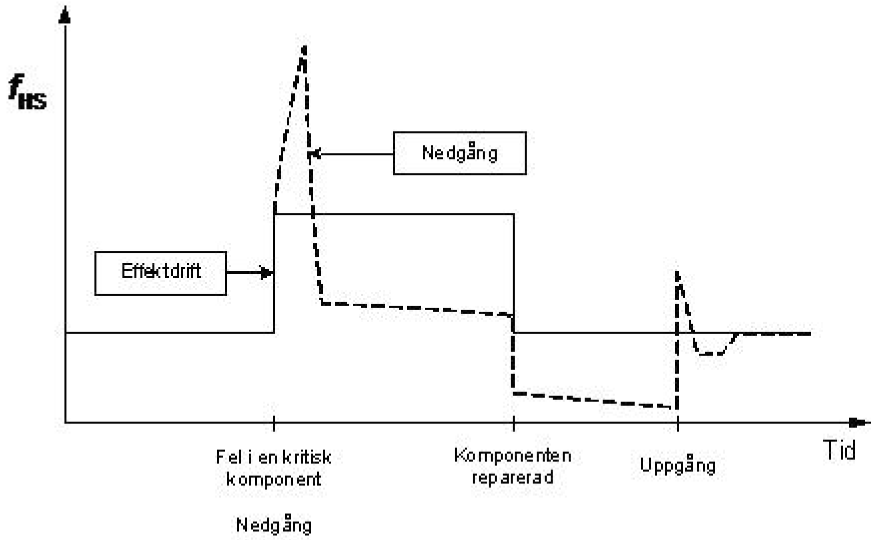

Figure 5 *Example of two risk curves: One representing continued power operation with unavailable equipment and one representing shut down with unavailable equipment.*

In its simplest form, the AOT could be computed according to:

$$AOT \cdot f_{power,x} = P_{SD,x} + P_{forcedoutage} + P_{startup}$$

Where $f_{power,\,x}$ represents increase in risk at power operation with unavailable equipment x, $P_{SD,x}$ represents the shut down risk with equipment x unavailable,

$P_{forcedoutage}$ and $P_{startup}$ represents the frequency at cold/hot standby and start up risk respectively.

A development of this method that has been used by both TVO and Ringhals (not exactly in the same way, but similarly) is to include the probability of repair into the equation. The equation could then be written as:

$$\Delta CD_{AOT} = P_{>aot,x} \cdot \left(P_{SD,x} + P_{forcedoutage} + P_{startup}\right) + f_{power,x} \cdot AOT$$

Where ΔCDF_{AOT} means the total increase in core damage probability, $P_{SD,x}$, $P_{forcedoutage}$ and $P_{startup}$ as in previous formula. $P_{>aot,x}$ represents the probability that AOT cannot be met and the plant needs to shut down.

In this case the $P_{>aot,x}$ needs to be determined. One proposed way of doing this is do analyze the existing statistics for repairs, and to develop a repair time distribution. The length of the AOT and the probability of shut down will hence be dependent. The formula will hence have a minimum. This can be exemplified with *Figure 6*, which shows the minimum for two and three diesels unavailable.

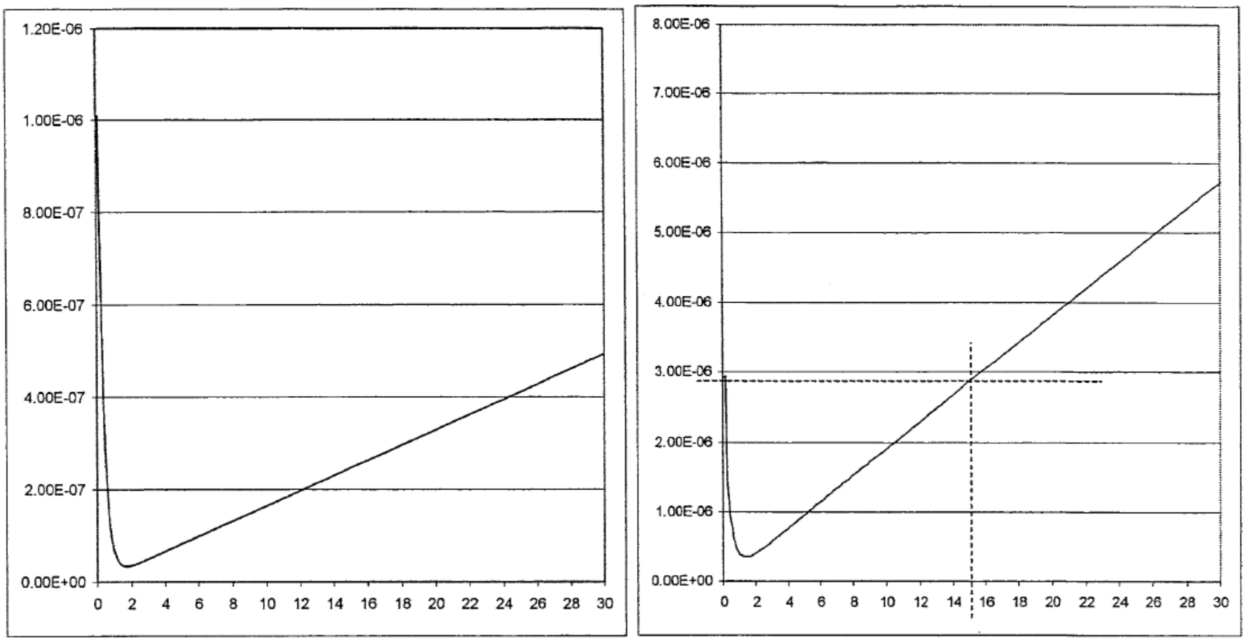

Figure 6 *Risk curve for two and three diesels unavailable [32]*

6.1.1.4. Comment to Methods

It can be realized that the formula

$$\Delta CD_{AOT} = P_{>aot,x} \cdot \left(P_{SD,x} + P_{forcedoutage} + P_{startup}\right) + f_{power,x} \cdot AOT$$

is a generic formula that represents the various methods from above. The difference lies in the treatment of $P_{>aot,x}$.

The problem should hence be to determine $P_{>aot,x}$ in an acceptable way. It is not obvious how this probability distribution should be calculated. There are many different aspects to this, e.g.:

- Is it only the repair time of the component that will form the basis for the usage of the AOT?
- How is the repair time affected by changes in AOT?

6.1.2. Method for Evaluating the Normal PSA Changes

Given that there is an AOT requirement on equipment, how will this affect the PSA? The previous section described the evaluation of a specific (single) AOT, i.e. if the equipment really is unavailable – what is the risk and what risk is acceptable. This does not give a measure about the overall risk, but only the risk if the event occurs.

It is reasonable that changes in AOTs will also be reflected in a change of the overall core damage frequency. Thereby there should be a relation from the AOTs to the PSA model, e.g. via the maintenance probabilities for the equipment.

This means that the evaluation should, to be able to reflect this, not only be based on historical repair times but also have a connection to the AOT.

It is reasonable that a bounding analysis should be performed assuming that the whole AOT is used, if a failure occurs.

6.1.3. Methods Used

Following methods have been used:

FKA:

- Have not been used.

FNS:

- Method development has been carried out in two Master's Theses [27-28], and also presented in PSAM conference [29]. Currently not used, but is planned to be used. The optimization of AOTs takes into account shutdown risks and realistic repair times. Conditional probabilities (the repair is / is not managed to be completed within the AOT) are included in the calculation. The optimal AOT is sensitive in the direction of short AOTs, but not so sensitive towards longer AOTs, providing flexibility in the choice.

OKG:

- Have not been used. Only some research and demonstration projects.

RAB:

- Evaluation based on repair time distribution and probability to exceed the AOT. If the AOT is exceeded (with a probability) the conditional core damage probability for shut down is used. The repair time is used for quantifying core damage probability when in power operation (with unavailable eq.). The method is then used both before and after the new TS and the results can be compared.

TVO:

- Two methods have been applied to evaluate the AOTs: 1) Evaluation how long power operation can be continued so that shutdown risk corresponds to the risk of continued operation, 2) Minimization of risk during failure state assuming that the repair takes always the whole AOT and with a certain probability the plant shutdown is needed when AOT exceeded (approach developed by STUK).
- Quantitative analyses supplemented with qualitative assessment with plant experts prior to final proposal for changes in TS.

6.2. Areas to Specifically Consider in the Evaluation

Some relevant questions are:

- What types of initiating events should be studied?
- What is the measure (CDF, LERF)?
- What method should be used for evaluating singular AOTs?
  - Is it necessary to evaluate the single AOTs?
  - How should CCFs be treated (potential simultaneous failures)?
  - How should mitigating/preventive actions be considered?
  - How should different configurations be considered?
  - How should several simultaneous maintenances be analyzed?
- How should the average PSA be adapted?
  - Is it necessary to evaluate the complete PSA?
  - How should several simultaneous maintenances be analyzed?

The table below summarizes some specific remarks with regard to AOT analyses given by the different organizations.

Table 2 *Comments on specific areas given in the answers regarding AOTs*

Area	**Specific comments**
Initiating events	• Kaikki, allt, alles, full scope!! • The analysis shall focus on internal events
Risk measure	• Both level 1 and 2 • Only core damage • Focus on core damage and also consider other aspects, e.g.
Mitigating actions	• Should be considered (some gave this comment)
Configurations	• It may be a tedious task to analyze all configurations. Hence some different configurations ought to be analyzed to verify that the effects are non significant.
Plant operation modes	• Power operation
Effect on function barriers	• It is vital that functions in the TS are not affected significantly (some gave this comment)
CCF	• Completeness of the PSA-model, e.g., CCF-modeling
Several simultaneous AOT	• No specific comment on this.

Area	Specific comments
Repair time distribution	• Necessary to consider uncertainties in repair time distribution (when using probability to exceed AOT)
Planned shutdown model	• Important to consider uncertainties in the shutdown model

6.3. Comments on AOT Analyses

FKA:

- How non-safety related equipment shall be treated? Is it OK to include equipment that has no TS requirements in the evaluation of the TS criteria for some equipment?
    - Shall the TS represent all objects having some safety relevance? What does this, in that case, mean? Is it not reasonable the TS only shall represent the equipment in the SAR?
- How shall new equipment be treated (equipment that is not originally in the TS or SAR)? E.g. Diversified 314, diversified 322, automatic boron system…
- How shall equipment that is not addressed by the PSA be treated – like indications (not needed to automatically start or regulate the system, but needed for operator information).
- The requirement in TS today, with regard to AOT, is that the plant is required to go to cold shutdown if the requirements cannot be met. Is this really the optimal situation? At FKA some situations have been identified where this is probably not the correct procedure.
- It is very important that the methodology will consider "odd" situations.
- The method should also look at the SAFIR program, if something has been developed as part of this.
- Is it really necessary to perform these types of analyses? Why should we accept this burden?

FNS:

- The TS should represent both "quality requirement" and requirement on stock-keeping (i.e. a requirement that this object shall be operational) and risk-optimal guidance in a real situation.
- In Loviisa there is already in use a maintenance program that uses risk-importance measures and TS as decision criteria for defining the maintenance class. So this is a risk-informed approach. E.g. the spare part stock is defined according to the maintenance class of the equipment.

OKG:

- It can be hard to "sell" the evaluation of continued operation with unavailable equipment versus plant shutdown.
- It is hard to determine a realistic shutdown risk at a real shutdown with unavailable equipment (several ways of performing the shutdown).

- The current low power model is used mainly to find “weak passages” and not to make a realistic numerical evaluation.
- The method should be based on increased risk at continued operation – not compared to shut down.

RAB:

- There are different arguments for different methods. Ringhals has just performed an evaluation of the new TS for the PWRs and that method is based on a repair time distribution and the probability that the AOT is exceeded. This is though only representing the PSA evaluation, though, since the new TS is based on Westinghouse standard (MERITS).

SKI:

- No, there are no specific method developed at SKI for evaluation of AOT:s. A general approach is however, if the licensee present relaxations for a demand or a LCO in the TS, the riskimpact of the relaxation or prolonged repair times have to be performed and part of the application to SKI
- To large content the AOT demands express safety margins on system reliability consequently also the time for unavailability, level of redundancy left at a failure and how to deal with that situation, repair during operation and/or shutdown mode, etc
- Clear description of the safety case and the acceptance criteria in any application, in obvious as well as in very complex applications, and how the particular issue e.g., TS issue impacts on those.
- SKI has seen that there have been situations and mismatches between what a TS application apply for (e.g., a relaxation of demands) and how components referred to in the application are treated in the fault tree analysis. Examples of observation is e.g.; - the application apply for a change affecting all components in all redundancies in a system, but the FT:s pays attention only to some of those components

STUK:

- PRA is just one input to the decision-making process. Often the results are so clear that uncertainty analysis is not necessary. If there are uncertainties, other viewpoints become more important. In most cases, PRA is used in qualitative way. Our method is relative, and is based on minimizing the total risk, including shutdown and continued operation. Absolute values are not needed, and as can be seen from our pilot examples, absolute risk goals can not be defined in reasonable ways. For example, in case of 4xCCF of Olkiluoto diesels, the minimum risk that can be obtained, is equal to 20 years of operation, corresponding to AOT of 4 days. No other AOT rule can lower this risk. Immediate shutdown would cause risk comparable to 80 years of operation.
- According to our understanding, it is not necessary to compute the time-dependent behaviour of shutdown risk. Event tree for planned shutdown will do, and the same for start-up. What matters, is the probability of repairing the failed component in the allowed outage time. If any other AOT than zero is defined, it should also be reasonable: there should be a good probability that the component can be repaired during the AOT. In this respect, also the analysis of the repair statistics is a part of AOT development.

- In general, we do not accept proposals based on risk numbers only. Each case must contain physical analyses, and the solutions must be argued on physical bases or needs. Risk analysis can provide useful insights, but we do not consider PRA as a design tool.
- Since PRA is based on renewal theory, its results are “valid” only when there are significant numbers of renewal cycles, i.e. in the long run. Peeking inside one renewal cycle is not meaningful due to simplistic failure models used in PRAs. Therefore our applications are based mostly on mean values, or expected values.

TVO:

- Important areas: model requirements and limitations: quantitative methodology taking into account different aspects, so that no single methodology is used; inclusion of comprehensive qualitative analysis with result interpretation and evaluation in larger group having different expertise (expert panel).
- TS represent requirements that safety significant/related systems are kept operable. From the risk point or view this is also applicable: ensuring that risk significant systems is kept operable as well as possible, but also the risk minimization is considered if a failure state exists. Principally the evaluation of AOT/LCO requires a multi criteria optimization including evaluation both from the economical and nuclear safety point of view.

6.4. Conclusions on AOT Analysis

There is a general point of view that the basis for AOTs is a thorough systems analysis, in which PSA is one input.

There are different methods, and the methods may give very different results.

It does not seem like there is a general agreement on what method to be used, which initiators to be considered, or what type of result that should be studied.

However, in general, it seems that the practically used methods are more similar, than what the comments received from other participants show. In specific, it can be noticed that persons at STUK and at SKI seem to have different points of view.

Since the methods may result in quite drastically different results, it is probably reasonable that several methods are used and the results compared.

It seems that the amount of sensitivity studies is fairly small. The results in the methods are stated to be fairly stable and the necessity of sensitivity analyses is therefore reasonably low. This can however be very case and method dependent.

7. Quality Requirements on PSA Model

To establish which quality requirements that should be put on the PSA model has not been the main objective for this project. However, it can be understood that it is of vital importance that the PSA model meets certain criteria, both from a completeness and quality perspective.

Unlike the US, neither Sweden nor Finland follow any specific standard when it comes to PSA model quality. In the US the ASME standard *Standard for Probabilistic Risk Assessment for Nuclear Power Plant Applications* [33] is applied to Level 1 and 2 PSAs for internal events during full power operation. Draft guides for external events and low power and shutdown conditions are under development by the ANS. Among the Swedish utilities the general opinion is that the status of the living PSA is granted by the internal review and the PSG/FSG. TVO has developed an own PSA instruction, which refers RG 1.174 [4].

In order to perform an evaluation of TS changes some basic requirements should be fulfilled:

- Evaluation should be transparent and easy to communicate Evaluation should be based on known principles It should be possible to transform the evaluated TS criteria to the model (i.e. the model must reflect the different aspects for the studied criteria)It should be possible to perform analyses for structures, systems and/or components

When it comes to the authorities, SKI of course follows the SKIFS 2004:1 [23] and STUK YVL 2.8 [25]. SKI has also published the collective knowledge and experience from earlier reviewing activities in *Tillsynshandbok PSA* [34]. International guidance documents are also looked at, such as the ones published by IAEA. Guidance and legislation developed by other authorities as well as at standardization organizations as SIS, ASME, ANS, and IC are also followed.

In RG1.174 [4] an over-riding requirement is that the PSA should realistically reflect the actual design, construction, operational practices, and operational experience. This may sound obvious but it requires, among others, a structured way of updating the model after outage periods. RG1.174 [4] also states that the methods used should be based on known principles. A method that is not very well documented and generally accepted is not approved for use.

While STUK emphasizes that a full scope PSA model including internal initiating events, internal hazards (fire, flooding), and external hazards is of high importance RG1.174 [4] suggests that missing initiating events, and even operating modes, can be treated qualitatively in many cases.

A suggestion is that some kind of checklist should be developed in order to facilitate the approval of the use of the PSA model for risk-informed TS changes.

8. Discussion and conclusions

8.1. Some general items for discussion

- The role of PSA in the decision making process? How extensive shall this project be?
- Should there be a Swedish BWR standard?
- Should there be a check list for STI and AOT analyses?
- How extensive sensitivity studies shall be required?
- Which initiators shall be included?
- What risk measures shall be studied (CDF/LERF)?
- How to consider non-safety equipment? Shall post accident mitigation systems be taken into account?
- How to consider new equipment, not part of the TS or SAR previously?

- The project does not today consider TS exemptions

8.2. Conclusions

On a general level, it seems that there is a reasonable agreement on what type of methods that exist and what they represent. The application of STI analyses are also fairly converging. However, the convergence is not that clear for AOT analyses.

There is not a common agreement on the basis for the analyses (e.g. types of initiating events and risk measures to be studied). In Finland the general agreement is to include all initiators and to study both PSA level 1 and 2.

There seems to be a general acceptance for STI evaluation on plant level, i.e. making trade offs between different systems. The process for performing STI evaluation is fairly straightforward, but the result may be sensitive to e.g. parameter data and will likely require a set of sensitivity analyses.

With regard to AOT, there seems to be a common understanding in Finland about the method to be applied. The same is not valid for Sweden. STUK has actively participated in the development of the method in Finland, which may be a reason for its adoption.

Due to the difference in results for various methods for AOT analyses, it is reasonable that different results are provided as justification for the chosen alternative. Example, results for both optimal risk solution and risk for continued operation could be presented.

Moreover, the PSA model should in some way reflect the changes in the AOT changes. This is probably best achieved by a dependency of the maintenance probability and the AOT. It may also be reasonable to show a bounding analysis where the full AOT is used.

To facilitate the TS change process, an idea could be to have a check list. This check list should present different areas that, in some way, should be considered during the analysis. The analyst can then use this check list to “prove” that important areas have been considered (should be discussed but may necessarily not mean that sensitivity analyses shall be performed). Example on items in the check list could be:

- Parameter data (stability, relation time dependent/independent)
- CCF issues: are they considered sufficiently?
- System configuration: may different configuration affect the results?
- Mitigating actions: have mitigating actions been considered, e.g. test of other diesel etc., effect on results?
- Effect on safety functions: may some be degraded significantly?

It is though important to recognize that different organizations may have different views on how the analysis should be performed on a detailed level. This must be considered in the continued work. But, there is a need to agree on the general guidelines for performing TS evaluation.

8.3. Continued Work, Phase 2

The general purpose of this project is to develop a guideline that can facilitate the use of PSA in interpretation and evaluation of TS criteria.

However, there are several ways and levels of detail on which a guideline can be written. Also the scope of the guideline has to be defined.

Scope

The scope of the guideline could be:

- To describe how to use PSA in the evaluation process
- To describe the whole process of making changes in the TS (like RG 1.174)

These are two different levels of scope. The initial goal of the project was to develop a guideline on how to use PSA in the development process.

The guideline should also facilitate the review process at the authority.

Methods

It is considered reasonable that the guideline provide examples of methods that may be applied. These should though not be on a too detailed level though, causing that the development of methods will be stopped. However, it would most probably facilitate the process if some general areas could be agreed upon, like:

- How different types of initiators should be treated in the analysis
- What type of measure (CD, LERF) etc. that should be used

Also, recommendations in which situations different types of methods may be applied should be part of the guideline (like plant level STI analysis or analysis on component level).

The guideline should also comprise recommendations for:

- Treatment when components are not part of the PSA
- If consequence mitigation systems should be included in the PSA during the evaluation (based on the input from the seminar the answer is yes)?
- Shall systems not included in the SAR be included in the PSA during the evaluation (based on the input from the seminar the answer is yes)?

It is believed to be beneficial if a check list could be provided, where the most important areas with regard to the evaluation are covered. This check list shall provide guidance, but not on a too detailed level. The analyst can then use this check list to “prove” that important areas have been considered.

Quality requirements on the PSA

This is not believed to be the main objective of this guideline, but some general requirements could be established.

The first step of phase 2 is, together with interested parties, to agree in detail upon the contents of the guideline. The information above should be used as input to that discussion.

9. References

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Abstract

The use of risk-informed methods has been discussed since the late 1980s in the Nordic countries. However, at that time the industry and authorities were not ready for the use of these methods and the use of them have been limited. The common understanding right now is that the industry and authorities are ready for adoption of risk-informed strategies, and the use of risk informed methods in daily operation at the nuclear power plants (NPPs) as well as for long term evaluation and definition of rules and regulations is increasing.

The authorities are strengthening the rules and regulations with regard to redundancy and diversification in the safety systems. There are several ongoing projects at the NPPs, such as modernization, power upgrade etc. These projects will require modification of the Technical Specifications (TS). The requirements on a risk analysis to verify exceptions will be a natural part of the TS update. To summarize; there are both activities and trends at the plants that will result in TS changes (modernizations, increase of electrical power, risk informed strategies). At the same time, authorities are increasing the requirements on risk informed evaluation of the TS.

TS evaluation from a risk point of view raises several questions:

- How shall the TS conditions be evaluated?
- What aspects shall be taken into consideration?
- Can a prolonged/shortened surveillance test interval (STI) or allowed outage time (AOT) affect the experienced importance of the equipment?
- What do the conditions in the TS with regard to AOT really represent? Are they conditions that shall be used when spare part storage and/or maintenance strategies are developed or do they represent how a real situation (unavailable component) shall be managed?

To form an idea of the opinion on these questions phase 1 of the project is based on a literature study and interviews with persons at the Swedish and Finnish utilities and authorities. A short background to the current TS is also given and the role of PSA in the TS evaluation process is briefly discussed. Methods, discussions and comments with regard to STI and AOT analyses respectively are presented. Together this serves as a background for the recommendations for phase 2 of the project.

Key words: Risk-Informed Decision Making, Technical Specifications, TS Evaluation

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