PSA Guidance for the Comprehensive Review of Nuclear Power Plants

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Were I come from: BfS

- BfS - Federal Office for Radiation Protection, founded November 1989,
- BfS support the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety,
- Main areas of BfS:
  - radiation protection,
  - waste management,
  - nuclear safety.
Examples for current activities at BfS (1)

- Licensing of intermediate storage facilities for spent fuel at all sites of the NPPs (project group)
- Radiation hygiene, medical and biological effects of ionising radiation
- Radiation hygiene of non-ionising radiation: ultraviolet radiation by the sun, micro-wave, mobile telephone, etc.
- Medical X-Ray applications
- Protective means for electromagnetic fields

Examples for current activities at BfS (2)

- Central Register of professional radiation exposure
- Independent emission control measurements of NPPs
- Environmental surveys, IMIS-System
- Government custody of nuclear fuel currently not in use
- Waste repository Projects (Konrad, Gorleben, Morsleben)
- Support of BMU in all technical questions on nuclear safety
What are tasks of BfS in nuclear safety?

- initiating, co-ordination and supervision of research-activities
- support on further development of the regulatory system and guidelines
- support of BMU for its tasks of Federal Supervision (documentation, reports, reviews, technical expertise)
- registration office for reportable events in nuclear facilities
- international Co-operation
- own scientific research (only very limited due to personal capacity)

Range of instruments for the purpose of supervision by the authority

- basic supervision (random inspection on site)
- induced supervision (“reacting” supervisory activities due to special events, modification or backfitting measures, and annual outage),
- special supervisory issues (“acting” supervision of focal issues regarding current and safety-relevant topics as e.g. fire protection, ageing),
- periodic safety review.
Aim and procedural aspects of periodic safety review (PSR)

The periodic safety review
• complements continuous plant supervision by Federal States Authority,
• aims at an overall plant safety evaluation according to state of science and technology,
• is performed every ten years,
• has been conducted by the licensee for the first PSRs on a voluntary basis.

Current regulations on Safety Review in Germany

• Performing Safety Review at ten years intervals including a plant-specific PSA is mandatory required by the recent amendment of the Atomic Energy Act (2002),

• the conduction of Safety Review (formerly PSR) of the NPP and specified dates on which the results thereof shall be submitted to the supervisory authority are determined by the relevant new article.
Scope of PSR

• a deterministic review of safety features according to protection goal oriented requirements of nuclear regulations and the accident spectrum to be considered,
• description of the equipment and measures for special, very rare events as well as of the severe accident management concept,
• description of operational management and evaluation of operating experience,
• a probabilistic safety analysis,
• a review of the plant’s physical protection concept.

PSA determines:

• what is possible?
• how likely is it?
• how bad is it?
There exist three levels of PSA

level 1: estimation of the frequency with which accidents occur,
level 2: determination of the effluents which can leave the plant,
level 3: estimation of the radiological consequences of the accident in the environment

Objectives of the probabilistic safety analysis

• to determine and quantify event sequences which can lead to a hazard for fuel element cooling. The active functions of the containment envelope have to be considered in the probabilistic safety analysis,
• to determine quantitative values of frequencies of occurrence of these events,
• to evaluate the balance of the safety concept and to determine vulnerabilities.
Flow chart of the Probabilistic Safety Analysis (PSA) within the framework of the Periodic Safety Review

- Plant information, plant walk downs, operating experience
  - Initiating events
  - Event sequence analyses
  - Fault tree analyses
    - Modeling of dependent failures
    - Quantification of dependent failures
    - Reliability parameters
  - Plant dynamic analyses, Conditions of effectiveness
  - Modeling of human actions
  - Quantification of human actions
  - Evaluation of results, documentation

Quality Assurance

Task Force of regulatory body:
- restricted to Level 1+ PSA
- LPSA optional
- external events not required

Group of PSA experts:
- technical details regarding methods and data

Regulatory requirements on PSA as part of first series of PSR

- Probabilistic Safety Analysis
  - German PSA Guide (Status 1996)
    - PSA Methods
    - PSA Data

- Deterministic Safety Status Analysis

Periodic Safety Reviews
Hierarchy of Atomic Regulatory Prescriptions

Atomic Energy Act

Legally binding

Ordinances

Administrative provisions

General Administrative Provisions
Regulatory Guidelines
RSK-Guidelines
Recommendations of the RSK and the SSK

KTA Safety Standards

Nuclear technology

DIN Standards, international technical Standards

Detailed requirements laid down in the atomic license notifications

Participants of the Atomic Licensing Procedure

Advisory bodies
RSK
SSK

Experts and expert organisations (for example, GRS)

General public

Authorised experts and expert organisations (for example, TÜV)

Federal Ministry for the Environment Nature Conservation and Nuclear Safety (BMU)

Licensing and supervisory authority
Ministry of the Land (federal state)

License applicant operating organisation

Federal Office for Radiation Protection (BfS)

other federal authorities

other Land and subordinate authorities

Experts for non-nuclear topics

other federal authorities

Verantwortung für Mensch und Umwelt
Current status and results of PSA (1)

- PSA’s for all 19 German NPP’s mostly within the framework of the PSR and all PSR’s were finished,
- most PSA were performed by the vendor in co-operation with the plant utilities,
- PSA were mainly reviewed by expert organisations (TÜV, GRS),
- technical modifications and backfitting measures, increasing experiences on modern PSA-methods, staff-know-how transfer derived from PSR,

Current status and results of PSA (2)

- risk analyses for two reactor types (PWR, BWR) and an additional Level 2 PSA (PWR) study were performed in the frame of nuclear regulatory investigation programme and has been led to important insights on:
  - low power and shut down PSA,
  - BDBA-analysis including preventive accident management and core damage state evaluation,
  - Level 2-analyses by using large event tree methodology and several simple computer models take into account core melt phenomena.
PSA results for German NPP

Extension and update of the regulatory PSA requirements

| Verantwortung für Mensch und Umwelt |  |

- **Periodic Safety Reviews**
- **Probabilistic Safety Analysis**
- **German PSA Guide (Draft 2002)**
- **PSA Methods**
- **PSA Data**
- **Deterministic Safety Status Analysis**

**Atomic Energy Act last amendment**
- internal and external initiating events,
- determination of core damage states including AM and their frequencies,
- involvement of LPSA,
- quantification of uncertainties,
- Level 2 PSA for full-power states
Extension of event analysis

General approach and methods for event analysis shall be maintained:

- deduce a total spectrum of plant-specific internal initiating events by a systematic procedure,
- quantitative criteria are also given in order to exclude initiators if
  - total frequency of plant hazard states below $10^{-7}$ per year
  - entirety of contribution of all these events is below $10^{-6}$ per year.

Intended extensions of the spectrum of initiating events are directed on:

- involving further internal events (e.g. missile effects),
- especially site-specific, external events
  (earthquake, flooding, various weather conditions, explosion pressure wave and unintentionally aircrash impact).

External hazards

- Explicitly described methods comprise the following external IE:
  - Aircraft crash impact (unintentional),
  - explosion,
  - site flooding,
  - earthquake.
Approach in principle for external IE

- At first a screening (“graded process of evidence”) is foreseen in order to determine the extent of analyses,
- the steps of the graded process of evidence for the various external IE are explicitly described,
- generic data to be used are also recommended,
- uncertainties of probabilistic results have to be ascertained in case of detailed analyses.

Example (aircraft crash hazard)

- the graded process of evidence regarding aircraft crash impact:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Extent of analysis</th>
</tr>
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<tbody>
<tr>
<td>- structures designed according to the state of the art (RSK-Guideline) and not located in military training zones</td>
<td>- analysis is not necessary</td>
</tr>
<tr>
<td>- contribution is negligible compared to the other contributions in the PSA</td>
<td>- a simplified conservative analysis regarding the consequences of impact on important areas, A: e.g. primary circuit B: e.g. turbine building C: separated emergency building</td>
</tr>
<tr>
<td>- not negligible</td>
<td>- detailed probabilistic analysis on plant areas (A, B, C), e.g. by Monte-Carlo-methods</td>
</tr>
</tbody>
</table>
Number of military aircraft crashes in Germany

- Number of military aircraft crashes (> 7,5 t) in Germany

Number of military aircraft crashes (> 7,5 t) in Germany

PSA FOR LOW-POWER AND SHUTDOWN (LPSA) (1)

Objectives:
- to determine and evaluate the contributions of low-power and shutdown states to plant hazard states
- optimizations of technical measures and emergency procedures
PSA FOR LOW-POWER AND SHUTDOWN (LPSA) (2)

The following points will be addressed:

• Required information on outage planning and organisation, maintenance measures and shift prescriptions,
• Plant dynamic analyses for low power and shutdown states, success criteria,
• Identification of different operational phases with by and large constant boundary conditions for the event analysis,
• Identification of initiating events for each phase,
• Estimation of initiating event frequencies,
• Reliability data for systems and components,
• Human factor analysis.

PSA LEVEL 2 FOR POWER OPERATION STATES (1)

Objectives:

• determination of a plant-specific possible spectrum of relevant severe accident scenarios and impacts from accident phenomena,
• estimation of radioactive materials released inside and outside the containment and their frequency, quantity and quality,
• investigation of sensitivities and uncertainties,
• evaluation of mitigative AM-measures and efficiency of the AM concept.
PSA LEVEL 2 FOR POWER OPERATION STATES (2)

The following points will be addressed:

• necessary prerequisites and assumptions derived from Level 1 analyses,
• determination of representative core damage states,
• deterministic analyses of accident progression (e.g. physical and chemical phenomena, containment behaviour ...),
• probabilistic event tree analyses,
• uncertainty-, sensitivity- and importance-computations and
• description and evaluation of results, quality assurance and documentation.

TREATMENT OF UNCERTAINTIES

• chapter on treatment of uncertainties in PSA will be provided,

Questions:
• how to make explicit the different causes of uncertainties,
• how to perform such type of analysis and
• especially how to deal with non-quantifiable uncertainties.
Structure of PSA report to be elaborated the license

• Introduction
• Scope and extent of PSA
• PSA performance
  - plant-specific input data
  - initiating events (list)
  - event sequence analyses
  - fault tree analyses
  - reliability data
  - human reliability
  - common cause failures
  - computer codes
  - evaluation of results
  - quality assurance
• Assessment of PSA results

Review of PSA

• general application of the PSA models, assumptions, analytical methods, data and numerical results,
• understanding the range of uncertainties in core damage frequencies, containment performance, and releases of radioactive effluents.
Elements of a PSA check list (1)

• assessment of the used computer code with regard to weak points and application limits,
• check of the treatment of NON-operators on fault-tree level (negated gates) or on the level of the event sequence diagram (intact system function),
• review of the boundary conditions postulated in the individual calculations ("logic switches") for the activation/deactivation of fault-tree interconnections and basis events,
• review of the cut-off criteria in the individual calculations with regard to the result,
• check of randomly selected minimal cutsets with regard to plausibility at different levels,

Elements of a PSA check list (2)

• uncertainty analyses with coupling of the uncertain parameters within defined groups of failures of functional elements,
• determination of the influence of the variation of the reliability parameters on the results.
Global assessment in the frame of PSR

Criteria for the assessment

- does the evaluation of operating experience confirm sufficient reliability of the respective system?
- are the accidents to be considered which cover all plant conditions controlled by the existing engineered safety features according to the protection goal oriented requirements with the required efficiency and reliability?
- are there technical equipment and measures for beyond-design-basis plant conditions?
- were vulnerabilities and/or imbalances within the safety concept identified?
Conclusions (1)

- In the frame of Periodic Safety Reviews plant specific Level 1+ PSA for all German NPP have been carried out throughout the 1990ies,
- Approach and methods were based on German PSA guide and associated technical documents on PSA methods and data,
- Important results of PSA have demonstrated that PSA is a valuable tool for evaluation and enhancement of safety of NPPs and supplements the regulatory decision making based primarily on deterministic approach,
- This role of PSA will be further strengthened by the recent amendment of the Atomic Energy Act which makes Safety Review mandatory,
- However, findings and experiences resulted from comprehensive PSA studies and plant-specific PSA as well as from the regulatory investigation programme on probabilistic methods reflect the need to extent and update the German PSA guide and technical documents.

Conclusions (2)

- These activities are focused on the areas: extension of internal and external event spectrum, determination of core damage frequencies, concideration of AM including repair, implementation low power and shutdown PSA and PSA Level 2 at power operation,
- Drafts were elaborated and are now in discussion and are expected to be published at the end of 2004.