
Review Process of PSA Level 2 of KBR - Concept and Experience

Martin Andernacht, Dr. Hendrik Glaser**, Dr. Martin Sonnenkalb****

* TÜV NORD SysTec GmbH & Co. KG / Große Bahnstraße 31, D-22525 Hamburg

** Ministerium für Soziales, Gesundheit, Familie, Jugend und Senioren des Landes Schleswig-Holstein - Department of Reactor Safety and Radiation Protection / Adolf-Westphal-Straße 4, D-24143 Kiel

*** Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH, Department of Barrier Effectiveness / Schwertnergasse 1, D-50667 Köln

Abstract

In Germany, a periodic safety review (PSR) has to be performed every ten years by the utility. In the past, a PSR only included a plant-specific probabilistic safety analysis (PSA) Level 1 study. Since a revised version of the German PSA guideline has been released in 2005, these plant-specific PSAs have to include a PSA Level 2, too. For the NPP Brokdorf (KBR) PSA Level 2 project, an agreement was reached between all parties involved that the study will be performed not as a part of the PSR process, but supplementary to it.

This paper will focus on conclusions and findings from a ongoing parallel review process of the first full scope PSA Level 2 performed by the utility for KBR, a typical German PWR-1300. The responsible authority "Ministerium für Soziales, Gesundheit, Familie, Jugend und Senioren des Landes Schleswig-Holstein (MSGF)" (Ministry of Social Affairs, Health, Family, Youth and Senior Citizens of Schleswig-Holstein) initiated this parallel review process in agreement with the utility KBR and the E.ON Kernkraft in 2006. The project will be completed soon. Such a review process allows that essential steps of the PSA will be reviewed and commented before the PSA Level 2 will be finished. So the benefit from this parallel review process is a significant enhancement of the quality and completeness of the PSA Level 2 study as the majority of the recommendations given by the review team has been taken over by the utility and the developer of the PSA, the AREVA NP company. Further, a common understanding and agreement will be reached at the end between all parties involved on the major topics of the PSA Level 2 study.

1 INTRODUCTION

In 2005, a revised version of the German PSA guideline /1/ - /3/ was released by the Federal Ministry for the Environment, Nature Conservation and Reactor Safety (BMU). The PSA guideline forms the basis for the PSAs performed within the PSRs of German NPPs. The German PSA guideline consists of three documents. Besides the guideline itself /1/, it comprises of a document describing the methodology of PSA Level 1 and 2 studies /2/ and a document providing data /3/ to be used mainly in the fault and event tree analysis in both PSA. According to this guideline, a plant-specific PSR for a German NPP has to include a PSA Level 2 now. However, according to an agreement between all parties involved in the NPP Brokdorf (KBR) PSA Level 2 project, the study is not part of the PSR, but supplementary to it. In 2006, the work on the first full scope PSA Level 2 study performed by the utility for the KBR, a typical German PWR-1300, was started. This Level 2 PSA covers full power plant states only. The PSA Level 2 is based on the results of the Level 1 PSA, i.e. the defined core damage states and their frequencies. The project will be completed soon.

The supervisory authority responsible for the KBR – MSGF – initiated a review process for the KBR PSA Level 2 parallel to the development of the analysis. The review is being conducted by a review team of national and international PSA and NPP experts. Since the TÜV NORD SysTec is the leading technical support organisation to the MSGF, two staff members of TÜV NORD SysTec, who are also member of the review team, are organising the review team work and meetings in close collaboration with the MSGF. The project management of the review is being led by the MSGF.

The intention of this parallel review process was to review, comment, and discuss essential steps of the PSA development immediately after they have been drafted by the developer before completion of the whole PSA Level 2. As the majority of the recommendations given by the review team has been taken over by the utility and the developer of the PSA, the major benefit from this parallel review process is a significant enhancement of the quality and completeness of the PSA Level 2 study and a common understanding and agreement on the content of the PSA Level 2 study at the end between all parties involved.

This paper gives an overview on how this review process was performed and details the first experience.

2 OBJECTIVE OF THE REVIEW

The objective of the KBR Level 2 PSA is:

- to gain insights into the progression of severe accidents and on the basic physical phenomena and the plant-specific response to it,
- to provide a basis for the evaluation and, if necessary, the development of plant-specific preventive or mitigative accident management measures.

Additionally, the MSGF has the objective:

- to use the results to enhance the KBR specific basis for the evaluation of off-site emergency planning strategies.

There is no guidance or any other requirements existing in Germany so far on how the review process of a PSA Level 2 study has to be performed and what detail of results is to be expected. MSGF specified the overall boundary conditions for the parallel review as follows:

- Check if the developed PSA Level 2 study models the progression of severe accidents, the relevant plant-specific processes and boundary conditions of KBR and, as well, the relevant physical phenomena in a appropriate way.
- Confirm that the methodology used for the PSA Level 2 analysis is in accordance with the German PSA guideline.
- Develop relevant review criteria for the review process.
- Discuss the results of the PSA Level 2 and provide feedback, questions and recommendations for improvement to the utility and the developer of the PSA, respectively.
- No check of models in applied computer codes as long as the codes are appropriate for the topic in question.

This approach for the review process is based on the German PSA guideline /1/ - /3/ and considers the national and international standards and relevant literature on Level 2 PSA development and review /4/ to /6/.

The detailed requirements and review topics for the individual review groups as well as individual review criteria had to be specified in the context of the forthcoming work with the KBR Level 2 PSA. More details are provided in the following chapter.

3 THE REVIEW TEAM

MSGF and TÜV NORD SysTec created a catalogue of requirements on the experts to be nominated for the review team. The objective of this catalogue was to cover all fields of knowledge correlating with the PSA Level 2, for instance:

- system analysis and system operating experience for the PSA Level 1/2 interface,
- competence in PSA methods,
- modelling and nodalisation of core, reactor system and containment in integral severe accident codes,
- accident progression and severe accident phenomena,
- structural and containment analysis,
- source term evaluation and release category definition,
- event tree development and probabilistic quantification.

The review team comprised, on the one hand, representatives of the German expert organisations - two of TÜV NORD SysTec, one of the Gesellschaft für Anlagen- und Reaktorsicherheit (GRS) mbH and one of EnergieSystemeNord (ESN). On the other hand, after a worldwide scoping process to cover the PSA experts, the team was completed by two German speaking experts, one from Risk Management Associates (RMA, USA) and one from RELCON Scandpower (Sweden). Thus, it was possible to obtain the international experience in this field without translation problems. A further member of the team is an expert in risk research and risk communication from the University of Kiel.

Most of the review team meetings have been led by MSGF and were held on the KBR site. During the review team meetings, the PSA Level 2 results have mainly been presented by a plant expert of the KBR supported from time to time by the developer Areva. In addition, two to three representatives of the utility (E.ON Kernkraft) participated in the review team meetings. All these experts from the developer and the utility have not been a part of the review teams. The review team members only will also write the final review report.

4 THE REVIEW PROCESS

4.1 Conduction of Review Team Meetings

The review is conducted primarily within the scope of prepared review team meetings. The entire review team met in several review meetings and discussed different topics according to the progress of the PSA Level 2 as shown in Table 1.

To make the review process more efficient, the review team established several working groups to deal with questions relevant to the knowhow and special experience of the review team members and with main topics of PSA Level 2. The topics of these working groups are similar to the topics of the meetings listed in Table 1. Each of this working group consists of two to three experts. Since these usually are members of more than one group, there are intersections between these working groups.

Table 1: Review Meetings and Discussed Topics

Meeting	Emphasis / Topics
Kick-Off Meeting	<ul style="list-style-type: none"> • Familiarisation with the Plant • Arranging the Review Procedure
1 st Review Meeting	<ul style="list-style-type: none"> • Plant Description / Design • Methodology Used for Level 2 PSA • Interface with Level 1 PSA
2 nd Review Meeting	<ul style="list-style-type: none"> • Event Tree and Release Categories • Containment Structural Analyses • MELCOR Application / Plant Nodalisation, Deterministic Accident Analyses
3 rd Review Meeting	<ul style="list-style-type: none"> • Source Term Analyses • Topics from Meeting 1 and 2 with Updated Documents
4 th Review Meeting (Forthcoming)	<ul style="list-style-type: none"> • Release Category Definition • Probabilistic Quantification • Final Meeting

4.2 Main Emphasis of the Review Process

At the first meeting, the review team made a plant survey to get familiar with the plant, its safety systems and the containment structures. After that, the team planned the review process, established working groups, and scheduled the subsequent tasks.

- The first and very important task for the working groups was to fix the review criteria and requirements on a PSA Level 2 in each working field. These requirements are based on the German PSA guideline and the international practice /1/ to /6/. The resulting catalogue of requirements is an independent paper and will be issued as an appendix to the review report. It should be used as a recommendation for the next revision of the German guideline. It consists of the following main topics:
 - method of analysis,
 - PSA Level 1/2 interface,
 - release categories and event tree,
 - deterministic analyses used for event tree quantification,
 - structural analysis of containment,
 - determination of branching probabilities,
 - determination of source term,
 - quantification of event tree, and
 - presentation of main results.

On the basis of the review criteria and requirements, the working groups created question catalogues for the several PSA Level 2 development steps.

For the first review meeting, besides a plant description, draft versions of the chapters "Methodology" and "PSA Level 1/2 Interface" were provided by the PSA developer AREVA, who developed the PSA Level 2 on behalf of KBR. The first chapter gives an overview of the basics of the PSA Level 2. For the deterministic severe accident and source term analysis,

the MELCOR 1.8.5 code /8/ should be used. It was mentioned that the plant-specific MELCOR input deck is the first one made for a German PWR-1300 by AREVA. Further, it was pointed out that the PSA Level 2 should be made as an integrated project together with the PSA Level 1 completed earlier using the RiscSpectrum code /7/. This caused a longer discussion on the PSA Level 1/Level 2 interface. The interface is accomplished through the definition of “Core Damage States (CDSs)”, which also define the initial and boundary conditions necessary for conducting severe accident analyses. The objective of the CDSs is to combine event sequences from the PSA Level 1 accident analysis that result in similar severe accident progression, containment response, and fission product release to the environment.

Today, as state of the art, PSA programs can calculate a PSA in one step from the initiating events as starting point of the PSA Level 1 up to the definition of the release categories and the source terms as a result of the PSA Level 2. Nevertheless, a large number of PSA Level 2 worldwide uses a so-called two-step approach if PSA Level 2 is calculated with another computer code than that applied for PSA Level 1. So, in the methodology part of the German PSA guideline /2/, both procedures, referred to as two-step and as integrative approach, are described. Depending on the chosen approach, the PSA guideline requirements on the definition of the interface and the CDSs are very different. For the two-step approach, typically a larger number of criteria used to define the CDSs is specified while most of these criteria are described as not necessary for the integrated approach. The reason for this is the expectation that in the integrated approach all information needed to characterise the sequences are directly taken from the PSA Level 1 part of the project.

AREVA used the integrated approach for the PSA Level 2 of KBR. This caused a longer and in-depth discussion on the required detail of the CDS definition, starting at the second review team meeting. The experience from the KBR PSA Level 2 review shows that even if an integrated approach is chosen, the requirements on the CDS definition are higher than currently defined in the German guideline for this approach. Since various event probabilities in the event tree for the severe accident progression are filled into the event tree as individual values, calculated by several computer codes, a binning process to combine event sequences from the Level 1 accident analysis, that result in similar severe accident progression, is necessary. So, an appropriate definition of the CDSs is essential.

At the end of the first meeting, the review team came, based on the presented documents, to the conclusion that the presented chapters describe a practicable framework to conduct a PSA Level 2 which should fulfil the German requirements /1/ to /3/.

At the second meeting some months later, the draft of detailed chapters on the general event tree design and the release category definition, the MELCOR plant model development and the severe accident analyses used for the quantification of the event tree and finally the containment structural analyses (see Table 1 above) were presented and discussed. One main point discussed, which is also an essential one in the German PSA guideline /2/, was the determination of the plant-specific radionuclide release pathways and its appropriate modelling in the deterministic analyses. The review team accepted that MELCOR 1.8.5 /8/ was used for the severe accident analysis instead of the latest MELCOR 1.8.6 /9/ version (for stability reasons at that time) and accepted that first analyses are only performed for the quantification of the event tree followed by additional analyses used for the source term quantification. The latter ones should, according to the PSA developer, use the completed input deck including the modelling of all relevant radionuclide pathways while the first ones should concentrate on aspects focused on the core melt phenomena inside the containment with a reduced input deck. Although this approach is in accordance with the PSA guideline it is not the preferred way in the opinion of the review team since a completed input deck should typically be used for both kind of analyses. This means there should, in general, be no differentiation between the purposes of these analyses. This would allow having a larger

number of analyses for all topics of the PSA Level 2. The required detail of the documentation of the MELCOR analyses results is currently being discussed. Unfortunately, the PSA guideline does not clearly specify the detail of results to be presented for severe accident and, in particular, source term analyses.

In addition, a longer discussion on the required detail of the MELCOR plant nodalisation was started during the second and the following review team meeting. Many recommendations from the reviewer, based on their extensive knowledge on MELCOR applications for different NPPs, have finally been taken over by the developer of the PSA. Nevertheless, one handicap in the review process was that the MELCOR input deck itself was not made available for a review. This caused extra attention of the reviewer to assess the results of the analyses presented later.

A last point which should be mentioned with regard to the second meeting was a deeper discussion on the way containment structural analyses are to be performed. The PSA guideline /2/ specifies the main boundary conditions for such a kind of analysis, but it does not specify if it should be a self-contained analysis or a comparative one to an existing study of a similar but not identical containment. In an intensive discussion process a common understanding of the requirements on the analysis could be developed. This led to the common conclusion that a self-contained study should be performed.

The PSA guidelines require further that the uncertainties in the analysis, and specifically in the physical phenomena of a PSA Level 2, are to be considered. These uncertainties were addressed by the developer and the review discussions are still ongoing. The preliminary review findings are that the guideline requirements can be met with the chosen approach.

Like many other PSA Level 2, the KBR study was started after the PSA Level 1 had been finished. In accordance with the German guideline, the objective of the PSA Level 1 is to quantify frequencies of CDSs. In the guideline, these CDSs should also be described as the basis for the PSA Level 1/2 interface. However, the experience gained in the review showed that the requirements for CDSs as the end states of PSA Level 1 and the plant damage states (PDSs) as the PSA Level 1/2 interface differ. As described by A. Torri (member of the review team) in /10/, it should be considered to place the interface regarding the plant damage states such that they distinguish the reliability of systems and accident management measures (analysed in PSA Level 1) from the probability of physical phenomena (analysed in PSA Level 2). In the event trees the PDSs then become the interface between all of the active system and human action top events (including those now addressed as part of the PSA Level 2) and the top events addressing the uncertain physical phenomena analysed in PSA Level 2. With this PDS interface the probabilities of the physical phenomena events are only dependent on the PDSs. In the German guideline model, the probabilities of the physical process events are dependent on the CDS and on the outcome of all of the system and human action events in the expanded PSA Level 1+ model.

Not all of the details can be presented in this paper. The further review process showed that corrections were necessary in several methodological details. This could not be recognised at the first review meeting referring to the PSA chapter "Methodology", because it needed deeper insights into the PSA Level 2 of KBR than possible at this early stage. Nevertheless, the first step in the review was very important to evaluate the basic method that was chosen for the KBR PSA Level 2, and to give a signal to the PSA developer that the concept would generally be accepted by the review team. So, it seems appropriate to call this step "review of the concept".

5 SUMMARY AND CONCLUSIONS

The PSA Level 2 study performed by the utility for KBR, a typical German PWR-1300, is the first study of this NPP type. This PSA Level 2 covers full power plant states only and will be completed very soon. Thus, also the parallel review is first-of-a-kind in Germany, and many findings of this process can be used for other similar projects.

So, the primary question is whether this review is seen as a benefit. The authors of this paper clearly answer this question “yes”. The review experience and insights gained by the reviewers could be fed into the process very early, which led – in our opinion – to a benefit for the PSA. This has been finally made possible by the readiness of the utility to discuss the recommendations of the review team and to use the majority of it for improving the PSA Level 2. Thus the benefit from this parallel review process will be a significant enhancement of the quality and completeness of the PSA Level 2 study in general. A final statement cannot be made yet as the study still has not been fully completed.

Further, due to the larger number of comments and recommendations for further improvement of the study, the initial intention of the review team meetings underwent some modifications. Besides the review of new chapters, a repeated review of revised chapters was performed which caused some extra work. There exists some potential to make this process more efficient in future projects.

In this context, the inclusion of national and international experts in the review team was very useful because of their practical experience with PSA Level 2 which could be integrated in this project. Moreover, the following aspects are regarded as beneficial by the authors:

- We have also made good experience with the working groups. So, every working group is able to discuss detailed questions, and not every person of the review team has to be involved in every discussion in detail. These groups should work independently, but they should have intersections to guarantee the flow of information between the working groups.
- It is an advantage to include persons of the KBR plant staff in the review team meeting process. So, the review team has a direct access to the knowledge about plant safety systems and operation modes. Especially for the international experts, the familiarisation with the plant was much easier by asking the staff directly.
- We have made good experience with the first step in the review process, in which we developed the review criteria for a PSA Level 2. This is a good framework for the whole process.
- We believe, the composition of the review team was well made. The team includes the necessary number of experts at the same time being as small as reasonable.
- With regard to the experience of the utility, in our opinion it should be considered if there is a need for the inclusion of the headquarters staff in addition to the plant staff.

Another benefit results in suggestions for the German guideline, in some details described above, for instance the PSA Level 1/2 interface and the detail of documentation required for analysis results for some topics.

Finally, we believe a common understanding and agreement will be reached between all parties involved on the major topics of the PSA Level 2 study at the end.

6 REFERENCES

- /1/ Leitfaden Probabilistische Sicherheitsanalyse (Entwurf), Sicherheitsüberprüfung für Kernkraftwerke gemäß § 19a AtG, 31. Januar 2005
- /2/ Methoden zur probabilistischen Sicherheitsanalyse für Kernkraftwerke
Stand: August 2005
Facharbeitskreis Probabilistische Sicherheitsanalyse für Kernkraftwerke
BfS-SCHR-37/05, Salzgitter, Oktober 2005
- /3/ Daten zur probabilistischen Sicherheitsanalyse für Kernkraftwerke
Stand: August 2005
Facharbeitskreis Probabilistische Sicherheitsanalyse für Kernkraftwerke,
BfS-SCHR-38/05, Salzgitter, Oktober 2005
- /4/ International Atomic Energy Agency
Implementation of Accident Management Programs in Nuclear Power Plants
Safety Report Series No. 32, IAEA, Vienna, March 2004
- /5/ International Atomic Energy Agency
Safety Assessments and Verification for Nuclear Power Plants
Safety Guide No. NS-G-1.2, Vienna, 2001
- /6/ International Atomic Energy Agency
Review of Probabilistic Safety Assessments by Regulatory Bodies
Safety Reports Series No. 25, jointly sponsored by IAEA, OECD/NEA, IAEA, Vienna,
2002, ISBN 92-0-117502-7
- /7/ Relcon Scandpower AB
RiskSpectrum Analysis Tool, Theory Manual
Version 3.0.0, 2008
- /8/ R. O. Gauntt et al.
MELCOR Computer Code Manual, Version 1.8.5
SNL, Albuquerque, SAND2000-2417, May 2000
- /9/ R. O. Gauntt et al.
MELCOR Computer Code Manuals Vol. 1: Primer and Users' Guide Version 1.8.6
September 2005
SNL, Albuquerque, SAND2005-5713, September 2005
- /10/ A. Torri (Risk Management Associates)
Level 2 PSA – Eine optimierte und zielgerichtete Methode
TÜV Symposium Probabilistische Sicherheitsanalysen in der Kerntechnik
Mannheim, 17. und 18. April 2008