IRSN

RAPPORT

TOWARDS A PSA HARMONIZATION FRENCH-BELGIAN COMPARISON OF THE LEVEL 1 PSA FOR TWO SIMILAR PWR TYPES

Patricia DUPUY, François CORENWINDER,
Jeanne-Marie LANORE,
D. GRIFFROY, P. De GELDER, M. HULSMANS

Rapport IRSN/Département d'évaluation de sûreté N° 518

Juin 2002

INSTITUT DE RADIOPROTECTION ET DE SÛRETÉ NUCLÉAIRE
DÉPARTEMENT D'ÉVALUATION DE SÛRETÉ

RAPPORT DES/518

TOWARDS A PSA HARMONIZATION
FRENCH-BELGIAN COMPARISON OF THE LEVEL 1 PSA
FOR TWO SIMILAR PWR TYPES

Patricia DUPUY, François CORENWINDER, Jeanne-Marie LANORE, *
D. GRYFFROY, P. De GELDER, M. HULSMANS **

PSAM 6 Conference

Puerto Rico, June 23-28, 2002

* IRSN/DES/SERS
** AVN Brussels

Juin 2002

TOWARDS A PSA HARMONIZATION : FRENCH-BELGIAN COMPARISON OF THE LEVEL 1 PSA FOR TWO SIMILAR PWR TYPES

P. Dupuy[1], F. Corenwinder[1], J.M. Lanore[1], D. Gryffroy[2], P. De Gelder[2] and M. Hulsmans[2]

[1]Institute for Nuclear Protection and Safety (IRSN), BP 17, 92262 Fontenay-aux-Roses Cedex, France
[2]Association Vinçotte Nuclear (AVN), Rue Walcourt 148, B-1070 Brussels, Belgium

ABSTRACT

In the framework of the cooperation between French and Belgian regulatory authorities, a PSA comparison exercise has been carried out for several years. This comparison deals with two PSA level 1 studies for internal events, performed for both power and shutdown states : the French PSA of the 900 MWe-series PWR, and the Belgian PSA of the Tihange 1 PWR, which both concern PWRs with a similar Framatome design.

The purpose of this paper is to describe the PSA comparison methodology and to present, in a qualitative way, an overview of the insights obtained up to now. It also shows that such an "a posteriori" benchmark exercise turns out to be a step towards PSA harmonization, and gives more confidence in the results of plant specific PSA when used for applications like precursor analysis or evaluations of importance to safety.

KEYWORDS

Probabilistic Safety Assessment, PSA Comparison, PSA Harmonization, PWR, Nuclear Safety.

1. INTRODUCTION

At the end of 1998, the French and Belgian regulatory authorities launched a comparison of two level 1 PSAs for similar PWR types : the French PSA of the 900 MWe-series PWR and the Belgian PSA of the Tihange 1 PWR. These PWRs are both of Framatome design and of the same generation. The PSA comparison was carried out by IRSN (Institute for Nuclear Protection and Safety), which also developed the French PSA of the 900 MWe plant series, and by AVN (Association Vinçotte Nuclear), which performed the review of the Tihange 1 PSA.

The mutual interest in such a PSA comparison exercise was primarily motivated by the need to carefully review the PSA models, and to improve or adjust its underlying hypotheses during ongoing or future updates. To achieve these general objectives, the PSA comparison consisted of identifying and explaining the main differences between the PSA results.

Starting with a description of the comparison methodology, the authors intend to present in this paper a qualitative overview of all useful insights of the PSA comparison, rather than to give detailed quantitative results. These lessons learned might be of interest to both PSA developers and PSA reviewers.

2. GENERAL APPROACH

The general approach that has been adopted for the PSA comparison, consists of a direct comparison of the PSA results, with the primary objective to identify the main or striking differences, and to explain them by digging into systems design, operating practices, assumptions, models and data.

This approach turns out to be efficient and satisfactory since it leads to a straightforward identification of the differences between both PSA studies that have a rather significant impact on the results. For this reason, this approach was preferred to a detailed and systematic analysis of the typical elements of a PSA (analysis of initiating events, accident sequences, systems, data, operating practices, human reliability), where the interpretation of the PSA results is put off till the end of the comparison exercise.

3. METHODOLOGY

The first stage of the PSA comparison exercise consisted of a global comparison of the results for initiating event families at full power. At this stage, the exercise was limited to the comparison of the initiating event definitions and frequencies, and the corresponding core damage frequencies (CDF).

This global comparison allowed a preliminary identification and explanation of some striking differences, mostly regarding specificities in plant design and operating practices. Nevertheless, to provide useful insights, this global comparison turned out to be not enough, showing the need for a more detailed comparison.

Therefore, in a second stage, some initiating event families and accident sequences at full power have been selected for such a more detailed comparison. This selection was mostly done on the basis of the following criteria :

- a high contribution to the CDF in one or both studies;
- safety issues and concerns raised during current safety analyses;
- significant differences between PSA results, either in terms of CDF or in terms of contributions to the global risk (TCDF).

The first selection criterion led to retaining the LOCA and LOOP families for a more detailed comparison. In view of the second criterion, it was decided to analyse high-pressure core damage sequences such as LOFW induced sequences, as well as containment bypass sequences with the potential of large early releases, such as SGTR core melt sequences. As for the third criterion, homogeneous boron dilution was selected. Three other initiating event families that satisfied the last criterion (loss of heat sink, loss of electrical buses, and ATWS), have not been examined in detail because it was found that some obvious plant design differences had a very significant impact on the PSA results.

The detailed comparison has been performed down to the level of dominant core damage sequences or minimal cut sets, meanwhile trying to explain the observed differences by looking at data, system design characteristics, functional and thermal hydraulic assumptions in accident sequence analysis, event tree construction, and human factor modelisation.

Results and findings of the detailed comparison of some particular initiating event families in full power states (large LOCA, steam generator tube rupture, and loss of offsite power) have been presented at the PSAM 5 Conference [1].

Since then, other initiating event families have been selected for a detailed comparison. Moreover, the comparison of initiating events and accident sequences for shutdown states has been launched.

4. INSIGHTS

In addition to the examination of differences observed for the selected initiating event families and the further extension of the comparison to other families, an effort has been made to categorize and summarize all the valuable insights of the PSA comparison exercise, and to draw lessons in view of future or ongoing PSA updates. An overview of these insights is given in this section.

a. The PSA comparison exercise has been useful to mutually corroborate the results and the underlying hypotheses for a majority of dominant accident sequences and to verify that the dominant accident sequences are based on functionally similar assumptions.

   Indeed, the comparison has revealed many similarities between the two studies, in terms of results and risk contributions, as well as in terms of PSA methodology and assumptions. As a matter of fact, even though this PSA comparison exercise has focused on the identification and analysis of discrepancies, which was its principal technical objective, the comparison has shown that there are many more similarities than discrepancies between both PSA.

   More precisely, the detailed comparison of large LOCA, SGTR and LOOP has shown that the dominant core damage sequences of both studies are related to the same critical safety functions with similar functional hypotheses for the systems involved, whereas the different CDF can often be explained by plant specificities (either design differences or data).

   Also, the initiating events considered in both studies are mostly the same, even if they are sometimes grouped into different families. The very few exceptions are some initiating events which do not lead to reactor trip or automatic ECCS actuation and which have not been considered in the Belgian PSA, as well as some initiating events characterizing the loss of support systems with a different design (loss of heat sink, loss of electrical buses).

   The observation of all those similarities eventually leads to more confidence in the PSA models and results.

b. Even though the plants are globally similar, the PSA comparison exercise has revealed some unexpected dissimilarities in system design. This can be illustrated by the following examples :

   - the LPSI system injection lines to the RCS, at Tihange 1, have a common part with a MOV which doesn't receive any automatic actuation signal : a closed position of this valve, due to a human error during test and maintenance, has a significant impact on the LOCA results in the Belgian PSA ;

- the containment spray system (CSS) design differences, being essentially a higher redundancy in Tihange 1 and a different recirculation mode initiation (automatic in French plants but manual in Tihange 1), clearly show up in the LOCA results of both PSA ;

- the different AFW tank capacity and operator actions required for AFW tank refilling explain some important differences between the results for LOOP and LOFW ;

- the different design of both CCWS and ESWS do justify a different definition and modelling of the "loss of heat sink" initiating events.

In this respect, the PSA comparison exercise offers a good opportunity to compare different design options and assess their impact on PSA results. It also demonstrates the need for plant specific, sufficiently detailed PSA models.

c. For nearly all initiating event families that have been scrutinized, the PSA comparison exercise allowed to detect important differences in operating experience and reliability data. Typical examples are the following ones :

   - with respect to operating experience feedback, it is worthwhile to mention a plant specific event that leads to consider, in the French PSA, a common cause failure-to-open of all pressurizer safety valves due to a maintenance error ;

   - the different origin of data leads to differences in reliability data for several important system components, and to a different value for the offsite-power recovery time in case of LOOP, which all have a considerable impact on the PSA results;

   - a different expert judgement leads to a different large LOCA frequency (by one order of magnitude), and to different CCF groups for AFW pumps (either being grouped according to the pump type or according to the failure causes).

   The impact on the PSA results of the first and the second example shows the importance of plant-specific data. The third example points out some assumptions or data for which harmonization may be desirable.

d. The PSA comparison exercise has revealed some differences in functional or thermal-hydraulic hypotheses, which are reflected in the success criteria.

   It must be noticed that such differences mostly impact minor accident sequences, the main assumptions being quite similar for both PSA. Nevertheless, an effort was made to clearly identify the basic assumptions that are different, and to investigate the interest of a better validation or additional calculations supporting these assumptions. This could be most useful to improve the quality of PSA models in view of PSA applications (e.g., precursor analysis).

   Typical examples are the secondary side safety valve actuation in case of LOOP, a few success criteria in SGTR sequences (e.g., HPSI and RHRS), and the importance of support systems such as dedicated ventilation systems.

e. The PSA comparison exercise led to the identification of some dissimilarities in modelling choices, even if, on the whole, the models were mostly similar.

The detailed analysis was a good opportunity to assess the impact of each modelling assumption that apparently differed between both PSA. This allowed identifying :

- models or assumptions that could be improved in one study, taking account of those applied in the other study (e.g., the improvement of the modelisation of recovery actions by the emergency response team in the French PSA, the consideration in the Belgian study of some initiating events or reactor states that were neglected, etc.) ;

- models for which a better harmonization is desirable (e.g., the type of LOOP initiators and their frequencies, the probabilistic leak rate profile in case of induced RCP seal LOCA, etc.) ;

- particular assumptions in one study with significant impact on the results, which could also be applicable to the other study (e.g., an accident sequence duration that may be taken larger than 24 hours, and different scenarios of AC recovery prior to core damage in case of station blackout, which are both considered in the French PSA).

f. The PSA comparison exercise was an opportunity to compare the structure and complexity of the PSA models.

The comparison enabled the PSA groups of both IRSN and AVN to explore other ways to define or group the initiating events, or to construct the event trees. In particular, some more complicated accidents, such as station blackout and simultaneous loss of main feedwater and auxiliary feedwater, are modelled as separate initiators with their own frequencies and event trees in the French PSA, whereas in the Tihange 1 PSA these scenarios are embedded in the accident sequences of the original initiating events (LOOP or loss of main feedwater).

Another example, which was clearly observed in the SGTR event trees, is the choice to construct event headers either as single system missions, or as safety functions involving several options with different system missions.

In general, it was concluded that the structure of the PSA model should be understandable for other PSA practitioners (e.g., in view of PSA applications), but avoiding oversimplification of the accident sequences.

g. The PSA comparison exercise was an opportunity to peer review the PSA models, and to identify some minor deficiencies in the models. Typical examples are :

- an inappropriate event tree coupling for induced LOCA sequences after LOOP ;

- a human factor modelisation, in case of total loss of feedwater, which takes no account of accident specific procedures ;

- some accident sequences that have been overlooked, or neglected without appropriate justification.

5. CONCLUSIONS

The PSA comparison exercise has revealed many similarities between the French PSA of the 900 MWe-series PWR and the Belgian PSA of the Tihange 1 PWR, not only in terms of dominant accident sequences, but also in terms of underlying assumptions, modelling and data. It has also been found that the differences in the accident sequences and their minimal cut sets are often justified by

plant specificities related to system design, operating procedures, operating experience, etc. Therefore, this comparison is very useful to mutually corroborate the results of both PSA.

Such an "a posteriori" benchmark exercise also turns out to be a step towards PSA harmonization, apart from the writing of "a priori" PSA standards. Indeed, although many differences in the PSA results are justified as they are related to differences in design and operating practices, the PSA comparison also revealed several elements in methods, models and data that have a significant impact on the PSA results. Typical examples have been found among the initiating events and their frequencies, the reliability data of safeguard system components, some modelling choices, and some functional or thermal-hydraulic hypotheses related to success criteria. These are elements for which PSA model improvements are desirable.

In practice, IRSN, who performs its own PSA, is going to incorporate the main insights, as far as possible, during the future updating of the 900 MWe-series PWR PSA.

From AVN's point of view, the PSA comparison exercise provides technical elements and arguments for discussion with the Belgian architect-engineering company and utility, in the framework of the PSA review by AVN.

More generally, from both French and Belgian side, it is found that the fruitful exchange of ideas between PSA specialists of different organisations, either developers or reviewers, can lead to a cross-fertilization of the PSA models, and should finally lead to a higher regulatory confidence in the quality of the PSA models, in particular when these models are used for PSA applications (e.g., precursor analysis) and in risk-informed decision-making.

The PSA comparison exercise is currently continued for both full power and shutdown states. In addition, the PSA comparison has also been extended to other PWRs of a similar Framatome design, in particular the Koeberg PWR, with the participation of the South-African regulatory body NNR.

6. REFERENCES

[1] Dupuy P., Corenwinder F., Lanore J.M., Gryffroy D., De Gelder P. and Hulsmans M. (2000). Comparison of the level 1 PSA for two similar PWR types : the French 900 MWe-series PWR and the Belgian Tihange 1 PWR. *Proceedings of the PSAM 5 Conference, Osaka (Japan)* **1**, 559-564.