Status and Perspectives of PSA activities in Belgium

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Abstract: For more than two decades, the Belgian Technical Support Organization, Bel V[1], has been stimulating the development and use of PSA as a complementary approach to deterministic safety analysis. This paper summarizes (1) the current status of PSA for the Belgian nuclear power plants (NPP), (2) the current use of these PSAs, and (3) some perspectives for future development and use of PSA.

After the completion of a first full cycle of establishment, review, insights and some applications of a plant-specific PSA for each NPP in Belgium, an update of all PSA models has now been performed within the framework of the recent Periodic Safety Reviews (PSR). Worthwhile mentioning is, among many other things, the scope extension of the Level 2 PSA. For the power reactors, a fire and flooding PSA has also been started.
Early 2012, the update of the Level 1 PSA of each NPP and the Level 2 PSA of some NPP is completed for internal events, whereas the development of fire and flooding PSA is ongoing.

The first use of PSA, performed so-far by the licensee Electrabel and his architect-engineer Tractebel Engineering[2], consisted and still consists of the systematic design re-evaluation of the nuclear power plants within the framework of PSRs. This has led to some specific insights and to several plant modifications. In addition, in a PSA policy issued by the end of 2006, the licensee has announced to take up more active ownership of PSA models and applications, which is now gradually being implemented through a process of “continuous PSA”. The overall objective of this process is not only to establish up-to-date, more detailed and regularly improved PSA models, but also, and most importantly, to use these models more intensively for various PSA applications.

The paper gives an overview of the status of the current PSA models and applications for the Belgian NPPs. Some future challenges on development and use of PSA are also described.

Keywords: PSA Update, PSA Application, Risk-Informed Decision Making.

1. INTRODUCTION

After the completion of a first full cycle of establishment, review and interpretation of results of a plant-specific PSA for each NPP in Belgium, a comprehensive update of all PSA models has been planned within the framework of the next Periodic Safety Reviews (PSR).

Almost simultaneously, and partially to comply with the WENRA Reference Levels for PSA, a full-scope PSA Level 2 as well as fire and flooding PSA have been launched for all Belgian NPP units, while the licensee has also announced to improve the use of the Belgian PSAs by means of several applications.

This paper deals with the progress made since the start of the PSA updates and scope extensions, and since the announcement of the licensee’s policy for PSA-related activities. In particular, the role of the licensee and his architect engineer on the one hand, and the Belgian TSO, Bel V, on the other hand, is emphasized.

It is also shown how the WENRA Reference Levels for PSA have been instrumental in obtaining the licensee’s commitment to a broader and better use of the Belgian PSAs.

Finally, some perspectives and future challenges are described.

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[1] Bel V is the Technical Support Organisation (TSO) of the Belgian regulator, the Federal Agency for Nuclear Control (FANC). Bel V was called AVN formerly (i.e., before April 2008).
[2] Electrabel and Tractebel Engineering are part of the GDF Suez Group.

2. STATUS OF PSA IN BELGIUM

2.1. Original PSA for Belgian NPP

In the framework of the previous PSR of the Belgian NPPs[3], a first full cycle of analysis, modelling and review of PSA has been completed [1]. The Level 1 PSA models of all seven PWR units covered internal events (without internal fire or flooding) in power and shutdown states. Limited-scope Level 2 PSA models were also developed (to identify containment failure modes, but without source term evaluation) and probabilistically quantified for three units only (Tihange 1 and twin-unit Doel 1-2).

The PSA has been developed by the architect-engineer Tractebel Engineering on behalf of the utility Electrabel. An on-line regulatory review of each PSA has been performed by Bel V[1], and has been concluded by a PSA Evaluation Report including recommendations for improvements of PSA models and related issues (such as methodological issues, data and model accuracy, precision, completeness), for a more detailed exploration of PSA results, for PSA documentation issues, and for PSA scope extension. These recommendations were to be considered during the next PSA updates.

2.2. PSA Updates in the recent PSR

Within the context of the recently terminated PSR[4], a comprehensive update of all existing PSA models has been performed.

For Bel V, the main objective of these PSA updates was to verify the robustness of each plant in its current state[5], by

- taking into account all changes to systems, operational practices and procedures, and considering an extended operating experience;
- taking into account more refined models and best-estimate hypotheses where needed (including error corrections, missing elements, well-balanced modelling);
- reconsidering some PSA methodologies to be applied in view of the current state-of-the-art;
- extending the scope of the PSA with additional internal events and plant operating states;
- applying a full-scope PSA Level 2 approach to all plant designs.

Moreover, significant improvements in maintainable up-to-date PSA documentation and ready-to-use computer models were expected.

As a first step of the PSA update, a preparatory study has been conducted to establish the detailed scope of the Level 1 and Level 2 PSA updates. This preparatory study involved Electrabel, Tractebel Engineering and Bel V. Bel V has substantially contributed to this preparatory study with a structured approach, set out in a roadmap, and with a significant amount of relevant information and expertise that was compiled, assessed and transformed into proposals to be discussed. This input was mainly derived from Bel V's recommendations published in its previous PSA Evaluation Reports, from a detailed comparison between Level 1 PSAs of Tihange 1, the French 900 MWe-series PWRs and the South-African Koeberg PWR [2], from insights gained through the PSA-based Event Analysis program of Bel V and through Bel V's participation in the SARNET research program (PSA Level 2), from the WENRA[6] reference levels for PSA (see below), from positions of other nuclear regulators and international organisations, as well as from conference proceedings and papers in literature.

At the end of this preparatory study, the agreed scope of the PSA update for the Belgian NPPs included inter alia the following elements:

- PSA Level 1 (internal events):

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[3] Second PSR of the older units Doel 1-2 and Tihange 1. First PSR of the units Doel 3 & 4 and Tihange 2 & 3.
[4] Third PSR of the older units Doel 1-2 and Tihange 1. Second PSR of the units Doel 3 & 4 and Tihange 2 & 3.
[5] Reference Date : 1st January 2005.
[6] WENRA is the association of the Nuclear Regulatory Authorities from European countries with nuclear power plants (http://www.wenra.org).

- For all plants, a long list of generic or plant-specific technical improvements had to be implemented, such as updates of plant operating states including short-duration transition states and more detailed modelling of shutdown states, an extended list of initiating events, revised thermal-hydraulic studies (supporting the definition of accident sequences and success criteria), consideration of potential impact of secondary line breaks (SLB, FWLB) on safety equipment (area dependency in some older plants), updates of the primary pump seal LOCA model, modelling of several recovery times for loss of off-site power (introducing time dependencies and additional system recoveries), identification and modelling of all relevant plant modifications and procedural changes, improved modelling of compressed air and ventilation systems, better coherence in the modelling of some plant systems (e.g. I&C), coherent approach for taking into account plant-specific data or operational experience (Bayesian approach), update of initiating event frequencies, update of failure probabilities and failure rates (new data base), update of CCF quantification methodology and data, re-evaluation of sump clogging probabilities, modelling of potential human errors committed during plant operating state transitions, updated quantification methodology, systematic and more detailed analysis and interpretation of results, analysis of importance measures, updated and/or new sensitivity analyses, uncertainty analysis, etc.
- Regarding HRA[7] methods, the choice was made to improve or update the previous, first generation HRA approach for a few aspects, rather than to switch to a completely different second generation methodology. In addition to the diagnostic errors and the errors of omission (already covered in this HRA approach), the CESA[8] approach had to be used to identify and model also the most important errors of commission.
- Issues related to improvements of PSA documentation (modelling, hypotheses, etc.) were also discussed, and keeping track of plant modifications and procedural changes resulting from PSA had to be improved.

- PSA Level 2: a full-scope Level 2 PSA had to be developed for every plant (by means of an analysis of four representative units), including power and shutdown states, analysis of containment isolation failure, update of PDS[9] attributes and PDS frequencies, construction of a generic APET[10] to cover all phenomenological issues applicable to any of the Belgian plants, use of plant-specific MELCOR models, improved methodology for expert judgement, human reliability model for SAM[11] actions, APET and source term quantification for the representative units, more detailed analysis of results and sensitivity analyses, etc.

As a second step, the implementation of the update of the Level 1 internal events PSA has been done by Tractebel Engineering, commencing with the qualified transfer of all existing PSA models to a more recent version of the PSA Level 1 code RiskSpectrum and the establishment or update of technical PSA documents and databases that are common for all NPP units, followed by the detailed update and documentation of each plant-specific PSA. A similar approach was followed for the Level 2 PSA, in which a so-called “generic APET” common to all Belgian PWR units was first constructed, and then further elaborated and quantified for the Doel 3 unit. As in the previous PSR, Bel V has performed an on-line review, to the extent possible.

More in particular, the review of Bel V focused on the following themes:

- Implementation of additional plant operating states and associated assumptions (initial conditions, system availabilities, etc.);
- Integration of new initiating events into the PSA models (e.g., very small LOCA, additional ISLOCA initiators, loss of compressed air, loss of offsite power with several recovery times, etc.) or justifications to neglect some initiating events (e.g., loss of a single train of the component cooling system);
- Additional system models (e.g., compressed air systems and some ventilation systems);
- Plant system modifications not yet modelled in the PSAs;

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[7] HRA: Human Reliability Analysis

[8] CESA: Commission Errors Search and Assessment (PSI, Switzerland).

[9] PDS: Plant Damage State.

[10] APET: Accident Progression Event Tree.

[11] SAM: Severe Accident Management.

- Update of initiating events frequencies[12] and use of new database for equipment failure rates[13];
- Implementation of the new HRA methodology and use of plant-specific procedures;
- Modelling choices made during the quantification using the RiskSpectrum PSA software;
- Coherency of the PSA results with the expected impact of plants-specific characteristics.

Early 2012, Bel V started writing a new Evaluation Report, intended to make a global regulatory assessment of the PSA update, to collect issues left opened at the end of the update, and to make recommendations for the next PSA updates.

2.3. Development of Fire and Flooding PSA

In early 2009 (i.e. beyond the starting dates for the PSR), and in order to comply with the WENRA Reference Level O1.1[14], Tractebel Engineering began to establish fire and flooding PSA models.
Early 2012, the methodologies have been selected or developed for fire PSA and their implementation has been started. For flooding PSA, appropriate methodologies still have to be chosen or developed.

The Fire PSA methodology is based on the NUREG/CR-6850 [6], developed jointly by US-NRC and EPRI. This NUREG is closely followed except for three points:

- Fire frequencies: generic data (from US-NRC) have been adapted to take into account the Belgian Operational Experience Feedback;
- Human Reliability Analysis methodology: to keep the studies consistent with the existing models for internal initiators, it has been decided to adapt the existing human error probabilities (HEP) to take into account post-fire conditions, rather than changing them strongly by applying a totally new methodology. The chosen methodology is based on the NUREG-1921 [7];
- Shutdown States: only power operation was taken into account in the NUREG/CR-6850, however, in Belgium it has been decided to develop fire PSA models in every Plant Operating State[15].

3. CURRENT USE OF PSA FOR BELGIAN NPP

3.1. Systematic Design Re-evaluation in the PSR

The first use of PSA consists of the systematic design re-evaluation of the nuclear installations. Indeed, the main objective of the PSA study, within the framework of the PSRs, was to confirm the robustness of the deterministic design, to identify design or operational weaknesses (if any), and to address these weaknesses (if necessary), e.g. by evaluating the importance of possible improvements to systems and procedures.

Based on the global results and sensitivity studies of the original PSAs, some general insights were already obtained in the previous PSRs, including:

- High importance of shutdown states, producing a core damage frequency per hour that is much greater than in power states.
- High importance of the second-level protection systems (the so-called “bunkerized systems”), that were designed for most Belgian NPPs in order to bring and keep them in safe shutdown conditions after external man-made hazards, and that constitute also a backup for first-level protection systems in mitigating the consequences of several internal events.
- High sensitivity of the PSA results to the sump clogging probabilities.

The development of PSA has also led to specific insights and to several plant modifications. In some cases, the results and insights obtained – in an early, intermediate or final stage of the PSA projects – have directly

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[12] As much as possible based on the Belgian Operational Experience Feedback, otherwise NUREG-5750 [3], NUREG-1829 [4], French studies, plant-specific system fault trees, or expert judgement were used.
[13] As no Belgian plant-specific data were available, the Nordic T-Book [5] was used.
[14] WENRA RL O1.1 requires PSA scope extension to Fire and Flooding PSA. See section 3.3 of this paper for more information about implementation of WENRA Reference Levels for Belgian NPP.
[15] The recently released NUREG/CR-7114 [8] gives guidance to conduct a low power/shutdown fire PSA. It has not yet been decided to which extent this methodology would be followed.

led to a number of safety improvements of equipment and operating practices. In other cases, PSA findings have given a decisive push to safety arguments that were not necessarily new, but that did so far not prevail in re-evaluations of design or operational practices. In many cases, however, the individual modifications were obvious safety improvements and have not explicitly been motivated with probabilistic arguments in the general process of management of plant changes. This explains that, for most Belgian plants, there is no readily available and complete list of modifications that can – partly or entirely – be attributed to specific PSA results or PSA insights. It was one of Bel V's recommendations towards the utility to keep a better track of such changes.

Proposals for modifications have emerged in two different ways:

- On initiative of the licensee or his architect/engineer.
  According to the licensee, quite some opportunities for improvement have been identified, decided and already implemented in an early stage of PSA development ("early feedback"). These proactive modifications to the plant and to operating procedures were then directly taken into account in the PSA model.
  However, this practice also constitutes a challenge for the quality assurance of the PSA models and PSA documentation, since it may occur that some modifications in design or procedures are finally not implemented as initially proposed, so that differences between "as build" and "as modelled" may exist that need to be resolved a-posteriori.
- On initiative of Bel V (formerly AVN) based on its regulatory review.
  The established PSA results were explicitly used to address an unresolved issue regarding operating practices during cold shutdown for intervention. The issue was whether or not it should be instructed to open the pressuriser manhole before installing steam generator nozzle dams during mid-loop operation without full unloading of the reactor core. Initial discussions based on deterministic arguments had remained inconclusive. However, the PSA results finally demonstrated that not opening the pressuriser manhole would lead to unacceptable CDF figures. As a consequence, the licensee decided, in 2002, to modify operating practices accordingly.

Some examples of hardware and procedural modifications to one or several plants, decided on initiative of the licensee on the basis of *the original PSAs (previous PSRs)*, are:

- Interconnections between the safety injection system and the containment spray system, allowing for additional backup of low-pressure safety injection and recirculation, or feeding of high pressure safety injection, by means of some spray pumps.
- Audible alarm and flashing light for low primary coolant level (during mid-loop operation in cold shutdown).
- Improvement of a considerable number of accident procedures for power states.
- Establishment of accident procedures for shutdown states.
- Improvement of the actuation logic of cooling tower fans (being the ultimate heat sink of the component cooling system).
- Improvement of the actuation logic of the second-level protection system ("bunker") in shutdown states.
- Configuration of an additional backup pump in the chemical and volumetric control system, to improve protection against loss of primary pump seal injection.
- Installation of passive autocatalytic hydrogen recombiners (PARs), beneficial for the PSA Level 2 results.

More recent examples of hardware and procedural modifications to one or several plants, proposed by the licensee on the basis of the *updated PSAs (recently terminated PSR)*, but still to be elaborated and implemented, are:

- Additional improvements of accident procedures for power states and shutdown states, based on PSA Level 1.
- Additional recoveries to be added in function restoration guidelines (FRG) or severe accident management guidelines (SAMG), based on Level 1 and Level 2 PSA.
- Automatic opening of interconnections between redundant trains of the component cooling system.
- Additional measures to avoid inadvertent drop of primary coolant level during mid-loop operation (in cold shutdown).

- Specific system modifications as a result of modelling compressed air systems in the PSA.
- Enlarged system availabilities (steam generators, number of LPSI trains) in specific plant operating states (intermediate and cold shutdown).
- Potential installation of filtered containment venting system, based inter alia on the extended PSA Level 2 results.

Nevertheless, one of the main findings formulated by Bel V (AVN) in its Evaluation Reports is that – after the establishment of the initial PSA models – there has not been a sufficiently systematic and profound analysis and use of PSA results in order to fully meet the objectives and to maximise the benefits of such a large effort. Time and human resources constraints at the very end of a fairly long development project have certainly been contributing factors.

Therefore, it was requested by Bel V to investigate PSA results again and more thoroughly in a dedicated PSA evaluation phase after the completion of the PSA update in the most recent PSR. This additional effort should have the potential to gain new risk insights, to pinpoint additional particular weaknesses in design or operational practices, and hence to find still further opportunities for safety improvements. However, besides some new insights and additional safety improvements identified after a “first evaluation” of the new PSA results, only few additional safety improvements (related to plant design or operational procedures) have been reported by the licensee or his architect-engineer. Hence, the use of PSA insights in order to identify such potential safety improvements still remains to be intensified in the framework of new (ongoing or future) projects (PSR, plant life extensions, etc.).

3.2. PSA Policy and Applications by the Licensee

While PSA has now become a consolidated element of periodic safety review, a tangible use of PSA in safety management by the utility has – since a few years – also emerged. Clearly, the level of ownership over the PSA at the utility has evolved significantly over the last years.

Whereas the Belgian utility, Electrabel, is the real owner and end user of the PSA, it is in practice the architect-engineer, Tractebel Engineering, who performs the bulk of the supporting analysis and modelling work. Nevertheless, with its PSA policy issued in December 2006, Electrabel has taken up more active ownership over the PSA models and its applications. The objective is to obtain not just more extensive or improved and up-to-date PSA models, but – most importantly – also more PSA applications, within a process of “continuous PSA”. The PSA policy adopts a risk-informed approach and holds out the prospect of several applications.

Bel V has welcomed Electrabel’s PSA policy and its process of “continuous PSA”, as these initiatives attempt to meet several regulatory recommendations (regarding ownership, involvement, resources, regular updates, PSA applications, and ultimate goals of PSA) that were put forward in the PSA Evaluation Reports of Bel V (AVN) and discussed during project follow-up meetings.

During the first year after the publication of the PSA policy, a “PSA standing committee” was created that actively involves PSA team members from the architect-engineer as well as dedicated staff from the licensee (at headquarters and both NPP sites). This group has gradually attempted to concretize the PSA policy, first by identifying all potential PSA applications, next by performing a prioritization exercise, and now by gradually implementing the selected applications while maintaining models up-to-date in a process of “continuous PSA”.

Currently, the selected PSA applications are included in a PSA management system of the utility. Within this context, the utility has written, besides its overall PSA policy, a more strategic document, entitled “Strategy for PSA-based applications”, in order to justify the selection and prioritization of its PSA applications (other strategic documents, on PSA model updates and upgrades, and on PSA competence management, are also expected). In addition, a more detailed set of procedures has been or is being developed (at the time of writing this paper), and should evolve in the future as applications are gradually being implemented at several levels of the utility’s organization (corporate level, site level).

3.3. Compliance with WENRA Reference Levels for PSA

In January 2006, the WENRA RHWG (Reactor Harmonisation Working Group) concluded an exercise consisting in defining so-called Reference Levels (RLs) for different issues in nuclear safety of nuclear power plants and in benchmarking national regulations and the implementation of the RLs in the nuclear power plants. The final report of this exercise can be found on the WENRA website (www.wenra.org). Some RLs were later on revised resulting in a revised document with the complete set of RLs, published in January 2008, and also available on the WENRA website.

In response to this exercise, all participating countries set up an action plan to integrate the missing RLs into their legally binding and publicly available regulations and to implement the RLs that were considered not or not fully implemented in the nuclear power plants. As can be seen from the 2006 RHWG report, Issue O (Probabilistic Safety Analysis) was amongst the issues with the highest fraction of RLs that were not incorporated in the national regulations and not or not fully implemented in practice. This was also the case for Belgium, resulting in the following actions.

In Belgium, issuing regulations belongs to the competency of the FANC (Federal Agency for Nuclear Control). Therefore, to incorporate the WENRA RHWG RLs into legally binding regulations, FANC started an important effort, not only in view of incorporating the RLs related to PSA, but to incorporate the WENRA RHWG RLs in a global effort into legally binding regulations. Bel V participated in the review of the regulations as proposed by FANC. The whole exercise was concluded, at the end of 2011, with the publication of a Royal Decree integrating all WENRA RHWG RLs into a legally binding and publicly available Belgian regulation.

Concerning the implementation of the RLs for the Belgian nuclear power plants, discussions were started with the licensee, Electrabel, to set up an action plan aiming to implement all RLs. For 9 RLs of Issue O (PSA), specific actions have been defined. Some of them are related to PSA scope extensions, other are related to PSA applications. For three RLs, these actions have meanwhile been concluded. Some actions, e.g. those concerning the development of representative full-scope Level 2 PSAs and internal fire and flooding PSAs for all units will last until 2015.

In conclusion, from a regulatory point of view, the WENRA Reference Levels for PSA have been instrumental in obtaining the licensee's commitment to a broader and better use of the Belgian PSAs. Indeed, the Belgian action plan for implementation of the WENRA reference levels contains the commitment to establish a general PSA policy that outlines the role of PSA in the decision making process to support safety management. It also defines the PSA scope and the kind of PSA applications that would be needed to meet all Reference Levels regarding PSA.

4. PERSPECTIVES

In Belgium, PSA has now become a consolidated evaluation tool of periodic safety reviews, on the one hand, and is also gradually used more intensively by the licensee within the context of a global PSA policy and an associated strategy for PSA-based applications.

Moreover, the licensee has recently announced a strategy for future PSA maintenance (for the already established Level 1 and Level 2 PSA models), as part of his process of "continuous PSA" that has been set up during the last PSR and has become fully active since the closure of that PSR.

In response to this proposal by the licensee, Bel V reflected on how to integrate its regulatory review in the maintenance schedule as proposed by the licensee. In this reflection, Bel V took into account its experience feedback of the reviews performed in the past. These were almost exclusively done "on-line" (i.e. in a very interactive way with the licensee and the architect-engineer). For the future, Bel V feels that an "on-line" review remains most appropriate when discussing issues of scope and methodology. However, for the review of the implementation of an agreed and well-defined "roadmap" an "off-line" review seems now more appropriate. This issue will be further discussed with the licensee and architect-engineer, since it might have an impact on planning issues.

Finally, the new prospects regarding PSA applications that are announced, currently developed and soon implemented by the licensee, as well as the increasingly interest to use PSA insights in the framework of new (ongoing or future) projects (PSRs, plant life extensions, etc.), are creating promising perspectives for an intensified use of PSA in plant safety management.

5. CONCLUSION

PSA Level 1 models for all Belgian NPPs have been established and updated, for internal events and all plant operating states, in the framework of the successive Periodic Safety Reviews. PSA Level 2 models are also gradually established or updated, with a considerable scope extension during the most recent PSR. Early 2012, the update of the Level 1 PSA of each NPP and the Level 2 PSA of some plants is completed for internal events, whereas the development of fire and flooding PSA as well as the Level 2 PSA of the other plants is ongoing.

Among the achievements of the design re-evaluation and the re-assessment of operational practices, which were performed during the successive PSRs by means of PSA, one can mention several important risk insights and an increasing number of resulting plant modifications. Nevertheless, the use of PSA insights to identify potential safety improvements still remains to be intensified in the framework of new (ongoing or future) projects (PSR, plant life extensions, etc.).

With a PSA policy issued by the end of 2006, the licensee Electrabel has also started to take up more active ownership over the PSA and its applications, which are now being gradually implemented and maintained in a process of "continuous PSA". Moreover, a strategy for regular "PSA updates" and "PSA upgrades", in order to keep the PSA models up-to-date, has also been announced.

From a regulatory point of view, the WENRA RHWG Reference Levels for PSA have been instrumental in Belgium for decisions on PSA scope extensions and on development of several PSA applications.

References

[1] M. Hulsmans, P. De Gelder, D. Gryffroy et al. (AVN), "Regulatory Use of PSA in Belgium – Status, Lessons Learned and Perspectives", PSAM 7 - ESREL'04 Conference, volume 1, pp. 701-706, Springer, Berlin (D), 13-18 June 2004.

[2] F. Corenwinder, P. Dupuy, J.M. Lanore (IRSN); D. Gryffroy, P. De Gelder (AVN); H. M. Kussman, S. Rokita (NNR), "Improving Quality of NPP PSA by International Comparisons", PSAM 8 Conference, New Orleans (USA), ASME Press, 15-19 May 2006.

[3] NUREG-5750, "Rates of Initiating Events at U.S. Nuclear Power Plants: 1987-1995", February 1999.

[4] NUREG-1829, "Estimating Loss-of-Coolant Accident (LOCA) Frequencies through the Elicitation Process", April 2008.

[5] T-book, "Reliability Data of Components in Nordic Nuclear Power Plants", 6th edition, 2005.

[6] NUREG/CR-6850 "EPRI/NRC-RES Fire PRA Methodology for Nuclear Power Facilities. Final Report", September 2005.

[7] NUREG-1921 "EPRI/NRC-RES Fire Human Reliability Analysis Guidelines", Draft Report for Comment, November 2009.

[8] NUREG/CR-7114 "Methodology for Low Power/Shutdown Fire PRA", Draft Report for Comment, December 2011.