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Lessons Learnt from Review of PSA Studies for VVER-type Reactors

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Abstract

The last decade many Level 1 PSA studies were performed in Russia, Ukraine, and Armenia for VVER-type reactors. As a rule, theses studies were carried out within multinational bilingual projects. The authors were involved in some of them from either PSA team or review team side. The paper presents main findings of the review which could be useful for PSA practitioners and reviewers of other multi-faceted projects. The paper analyses importance of the key issues in terms of quality and consistency of PSA. The experience gained from the reviews was used for developing PSA norm documents issued by the Russian Regulatory Body.

Introduction

The last decade many Level 1 PSA studies either supported by US DOE [1-3] and the Swiss governmental organizations [4] or within TACIS projects [5] were performed in Russia, Ukraine and Armenia for VVER-type reactors. As a rule, these studies were carried out within multinational bilingual projects. Some PSAs being carried out for NPP in design [6-8] were financed by utility. The PSA studies performed were extensively reviewed. The review process is becoming increasingly important in ensuring adequacy of the PSA [9-11]. As it is indicated in Table 1, review of some PSAs was conducted several times by different teams.

1 Review experience

Review is usually requested by one of the following institutions:

- Regulatory Body,
- Organization invested money in the PSA project or
- Utility/NPP that is going to use the PSA for applications.

Regulatory review is intended to perform validation of the PSA if the PSA is the part of the licensing process. The conclusion of the review can be taken into account for decision making whether license for plant construction/operation should be issued or modifications proposed for plant design/operation can be approved.

The regulatory review is often limited by time and budget. Another issue of the regulatory review may be associated with the lack of PSA practitioners in the Regulatory authority system. In addition, it can be a problem to find experienced experts from the nuclear industry of the same country who are really independent. The institution of independent consultants is not widely practiced in Eastern Europe. Some regulatory authorities resolve this issue by inviting independent peer review missions (IPSART) from the IAEA. However, as it is stated in [12] IPSART does not replace internal, independent reviews and it does not perform a validation of the PSA nor it replaces quality assurance. Possibly, extension of the CENS activity (Centre for Nuclear Safety, located in Bratislava, Slovakia) could be beneficial for these countries.

PSA reviews performed during last four years

Table 1

VVER Plant, Country, Main developer of the PSA	Year of the review	Type of the review
Armenia Unit 2, Armenia, SOGIN, Italy	2003	US DOE sponsored independent review
Temelin Unit 1, Czech Republic, Scientech, USA	2003	IAEA IPSART
Tianwan, China, Atomenergoproekt, St.Petersburg	2000, 2002	IAEA IPSART
Bushehr, Iran, Atomenergoproekt, Moscow	2002	IAEA IPSART
Kola Units 1,2,3, Russia, Kola NPP	2000-2002	Regulatory review
Rostov, Russia, Atomenergoproekt, Nizhny Novgorod	2000	Regulatory review
Balakovo Unit 1, Russia, Atomenergoproekt, Moscow	2002	Regulatory review
Kalinin NPP Unit 3, Russia, Atomenergoproekt, Nizhny Novgorod	2002	Regulatory review
Novovoronezh Unit 3, Russia, Atomenergoproekt, Moscow	2001	Regulatory review
	2001-2002	US DOE sponsored independent review
Novovoronezh Unit 4, Russia, Atomenergoproekt, Moscow	2002	Regulatory review
Novovoronezh Unit 5, Russia, SEC NRS, Russia	2001	IAEA IPSART
Mochovce NPP, Slovakia, VUJE	2001	IAEA IPSART
Bohunice V1, Slovakia, Relko	2002	IAEA IPSART
South Ukraine Unit 1, Ukraine, Energorisk	2000	IAEA IPSART
	2001-2002	Regulatory review
	2002	ET&D and GRS
Zaporozie Unit 5, Ukraine, EIS and Energorisk	2001	IAEA IPSART
	2001-2002	Regulatory review
	2001-2002	US DOE & GRS sponsored independent review

If a review is organized by the organization that has sponsored the PSA project, it is aimed at assessing effectiveness of investments and looks like a posterior cost-benefit analysis. The most effective way is to perform on-line review, i.e. while completing each particular task. In this case the review can assist the PSA team to identify possible drawbacks in the analyses and timely eliminate them, thus promoting to provide for the PSA quality. It should be understood that any review is the conflict of interests. If the PSA to be reviewed is carried out within a commercial project, the PSA team does not strive for perfection in producing an ideal PSA, rather the PSA as good as possible within limited budget and time. Therefore, the PSA team looks forward to receiving a positive appreciation of the PSA and is not happy to get a great number of comments. The review experience has shown that the most important and difficult point is to create the cooperative spirit between the review and PSA teams. The key to success in motivation of the PSA team to improve the PSA seems to be allocation of some part of the PSA budget (about 20%) to incorporating review comments into the PSA documentation and model.

Utilities usually originate a request for a review, when an external contractor conducts the PSA. In this case responsibility of the plant staff is usually restricted to providing plant documentation, e.g. system descriptions, and consultations. The capacity and experience of the plant PSA team is hence limited, and the review is needed to assess the validity of the results and conclusions obtained in the PSA and their applicability to plant needs.

The experience shows that most reviews start when the PSA team has finished the final report and are usually performed within quite a limited budget and time period. Therefore, it is difficult to perform a review in depth. It was found that about 80% of comments provided by the reviewers are usually related to the following areas:

- Scope of the analysis
- Assumptions and limitations of the study
- Omissions in the probabilistic model compared with experience of a reviewer
- Output of data analysis task, i.e. values used for quantification

On the other hand, in some reviews there is a tendency to globalize the requirements when a reviewer does not try to answer the question whether significant contributors to core damage frequency could have been omitted or not. It is usually characteristic of the reviewer who has a limited practical experience in the PSA development and insures himself against potential errors in the review by requiring everything in a general manner. However, it is impossible to perform an ideal PSA because it will take years and it will cost a fortune. Therefore, such comments are useless because the Regulatory authority cannot support impracticable requirements. This point is in line with the IAEA-TECDOC-1135 [13] recommendation that it is not necessary to independently verify every detail even in the case of an extensive review.

Experience gained from the reviews and problems found have stimulated to develop Russian national regulatory documents in this area.

2 Technical issues identified in the reviews

Experience has shown that some issues are frequently recurring in review comments. It appears that there are some root causes, which are the basic reasons why the same discrepancies recur. The authors tried to identify the root causes, which are listed below.

- Limitations in the scope of the study

Typical situation is the PSA under review did not address an adequate range of internal initiating events, component groups susceptible to common cause failures, pre-accident human errors, etc.

- Lack of design information

Plants with VVER-type reactors are under design in Russia, Ukraine, Iran, India, and China. The PSA is developed at the PSAR stage first, e.g. to get a license for starting plant construction. The PSA at the PSAR stage has special features because of limited information, e.g. lack of emergency operating procedures. On the other hand, PSA results may affect the design basis when the PSA has already been performed. This raises an issue related to iterative PSA updating.

- PSA is not living in some aspects

Changes to the design or operation of the plant, including safety-upgrading measures recommended by the PSA, are frequently implemented to increase the level of safety. It is not easy to evaluate all the effects of the plant changes on the PSA. For instance, minor contributors might be initially screened out by frequency; however, for the increased level of safety they may become significant. This fact has to challenge re-development of the initiating event list, followed by considerable efforts at modeling.

- Problematic input data

The attitude to the Bayesian approach sometimes makes a religion of the method. In this case the PSA team believes that all the problems with lack of data can be always solved by using the Bayesian updating method. As a result, no attention is paid to applicability of the generic data/Bayesian priors to the plant to be analyzed. Priors used in the updating process are often inconsistent with the plant specific data in terms of both component/initiating event definitions and numerical values. Experience shows that differences in defining initiating events are a major cause of variation in initiating event frequencies from one source to another.

- Poor coordination between PSA tasks

Typical example is the inconsistency between definitions of the boundaries and failure modes used in system and data analyses, in particular for new components if manufacturer data is applied. The PSA component boundaries in the system analysis typically extend beyond the equipment, failure modes, and failure causes specifically defined by manufacturer. For instance, the PSA boundary for a «pump» typically includes the pump mechanical components, motor, circuit breaker, and local control circuits. The manufacturer's data for "pump" failures may include only the mechanical parts of the pump because other vendors are responsible for the other subcomponents.

- Poor coordination between PSA team and plant

If the PSA team does not include active representatives from the plant operating staff, it is impossible to assure that the models and data used are good representations of the actual plant design and operational practices and give an overall adequate picture of plant behavior. The involvement of plant personnel should be obligatory at least in the special investigation of the failure events, while allocating to PSA failure modes, and the detailed assessment of human interactions, especially for operator actions for which no written procedures are available.

- Deterministic mentality of PSA team members

PSA is usually used as a complement to the deterministic approaches to address plant safety concerns. It is very useful if some members of a PSA team have deterministic background. However, sometimes deterministic experience has a negative impact on the PSA development. It was found in some reviews that application of deterministic principles (e.g. single failure criterion) to PSA tasks resulted in screening out either beyond design basis accidents or multiple failures because they seemed to be "impossible".

- Model simplification

Model simplification is usually caused by budget and schedule limitation. Typically this leads to loosing important dependencies. Simplification of the model without loosing any dependencies requires very high qualification of PSA analysts. Purpose of a PSA is not only quantification of a safety level in terms of the frequency of core damage or large early release. If the PSA is used only for this purpose then the PSA degenerates in PR tools. The PSA is engineering quantitative and qualitative analysis (searching and ranking) of weak points of the NPP under consideration, which often exist due to subtle dependencies.

- Deficiency of the methodology applied to model treatment and quantification

Depending on the complexity of the overall model, the elimination of circular logic loops existing due to interdependencies between support systems may be a complex task. The complexity is considerably increased by the inclusion of I&C and its dependencies on the support systems and by fault tree options created by logic flags (house events). Lack of detailed procedures in this area resulted in incorrect breaks of the logic loops in many PSAs.

It is found in reviews that some combinations of human actions are truncated out during the preliminary quantification although typically human action dependencies have not been considered at this stage, e.g. a minimal cut set representing six different human errors was screened out in one PSA. Now it is required by Russian regulatory documents that human error probability is set to 1.0 to ensure that the related human action dependency is not eliminated in the process of the preliminary quantification

- Bilingual problems

Multi-language issues appear when there is difference in languages between PSA producers and PSA users (e.g. Russian, which is the working language in Russia, Ukraine, and Armenia, and English). Documents are either generated in Russian or English and eventually majority of documents should be translated to both languages. From the very beginning, a common glossary of terms is very important as the different translators tend to translate the same terms differently. Typical situation when a number of translators work on a number of PSA work packages resulting in inconsistency in terms and phrases. Tracking changes in both languages become an additional problem. As a rule, a limited number of the experts involved in the PSA project are fluent in both languages. Therefore, adequate changes are not always incorporated in the documents, files, and models written in opposite language.

- Rare events frequencies

It was found that large and medium LOCAs may be significant contributors to core damage frequency at VVER plants. However, frequencies of the LOCAs differ considerably. An example of IE frequencies for Medium LOCAs provided in [14] illustrates the point. In [14] it is clearly indicated that neither design differences nor leak size influences the results of initiating events frequencies estimates. Difference in values was caused by different generic exposures assigned to zero event prior data. Therefore it may be concluded that the Bayesian method is very sensitive to the prior data chosen and there is a very high uncertainty associated with frequencies of sufficiently large breaks. The international consensus would be very useful to make PSA results being comparable.

3 Russian regulatory documentation in the PSA area

To improve efficiency of regulatory reviews in Russia a detailed procedure was developed and exercised in practice. In 2002, the guidance on how to carry out the regulatory authority review of a PSA was published [15].

To improve quality of PSAs the experience gained from the reviews was used for developing PSA rules issued by the Russian Regulatory Body. Although the main Russian regulation document [16] and followed Policy statement of the Russian regulator Gosatomnadzor [17] call for performing PSA for NPPs, no specific requirements to content and quality of the PSA were published officially until very recently. In March 2003, Gosatomnadzor issued Safety Guide [18], which contains detailed requirements to each PSA task.

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