Overview of Fire PSA and supporting software

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ABSTRACT

Continually increasing requirements on nowadays full scope Probabilistic Safety Assessment (PSA) Level 1 (L1) and Level 2 (L2) as whole, which is multiplied by importance of specific data for all modes of operation of nuclear power plant, highlight role of input data used in PSA quantification process. This fact also emphasizes the role of capability to process all necessary information to analyze all nuclear plant modes by appropriate way.

Even if above-mentioned aspects are relevant for all parts of nowadays PSAs, their importance is critical for internal hazards including specific fire analysis (internal fire analysis constitutes one of the most challenging PSA tasks).

Application of tailored information system forms one of the ways to speed up analyzing process, enhances manageability and maintainability of particular PSA projects and provides effective reporting mean to document process of work as well as traceable and human readable documentation for customers.

This paper provides brief overview of VUJE approach and experience in this area. The paper introduces general purpose of database developed for fire PSA. Paper explains as this basic data source is enhanced by adding several relatively independent tiers to employ all common data for fire PSA purpose. Paper also briefly introduces capability of such system to generate integrated documentation covering all stages of fire analyses, covering all screening stages of fire analysis as well as future plans to enhance this part of work in such a way to be capable to build automatic interface between PSA model and fire database to enable PSA model parameters automatic updating and expansion of fires in combinations of initiating events (for example fire and seismic event).

The final section brings a brief overview of the results of the fire PSA completion of nuclear power plant Mochovce 3 and 4 units, focused on the most significant contributors to the Core Damage Frequency (CDF).

1 INTRODUCTION

One of the most complex events of internal hazards originating from the sources located on the site of nuclear power plant from PSA point of view is fire.

General guideline for PSA level 1 is formed by specific safety guide [1] that also covers topic of internal fire analysis. However; regarding internal fires [1] the guide offers only high
level requirement for probabilistic analysis of fire events occurring on the site of a nuclear power plant and evaluation of their potential impact on safety and performance of particular analytical tasks requires additional guidelines including appropriate data source. One of the most comprehensive documents in this area is [2]. Consequently more precise requirements introduced by [2] lead to the expansion of work. This expansion is further multiplied by close relationships between PSA level 1 and fire PSA as well as by general requirements of [1], etc. regarding traceable documentation of work. Finally, all mentioned factors imply necessity to use a tailored information system as a way to speed up analyzing process, enhance manageability and maintainability of particular PSA projects and provide effective reporting mean to document process of work and provide traceable human readable documentation for customers.

The aim of this paper is to introduce fire PSA database system used by VUJE and its capability to generate integrated documentation covering all stages of fire analysis including interface with used PSA software, comparison between VUJE fire data processing system and database system suggested by NRC NUREG/CR-6850 as well as future plans to enhance this part of work towards building an automatic interface between PSA model and fire database to enable automatic update of PSA model parameters. The big challenge for the future is a combination of internal and external hazards, such as internal fire and seismic event, which is currently in the development phase. The scope of this paper is divided into following basic sections:

2 GENERIC CRITERIA AND FUNCTIONAL ELEMENTS FOR AN EFFECTIVE FIRE PSA DATABASE

The objective of such work is to develop a database that can quickly and accurately assess all relevant information related to the potential equipment failures for fire scenarios of interest, e.g. total failure of all circuits in a compartment, failure of cables within a specific raceway, impact of failures based on specific equipment failure modes etc.

Database building process must specify the criteria for creating an analytical tool that will enable analysts to conduct the necessary analyses efficiently and accurately. It is obvious that manual compilation of all fire PSA aspects is hardly possible due to the low efficiency and human errors that can be introduced while repetitively manipulating large volumes of data. As follows from [1] and [2] the fire PSA database should support the following analytical tasks:

- Plant boundary definition and partitioning,
- Components Selection,
- Cable Selection,
In satisfying the above mentioned basic criteria, the database can serve as the primary location for information regarding equipment, cables, etc., and it can be also used as fire PSA report generator.

3 IMPLEMENTATION OF SPECIFIC FIRE PSA DATABASE

Development and implementation of fire PSA database was inspired by recommendations given in Appendix W of [2]. Development process comprised the following main stages:

- Review and enhancement of current PSA database
- Analysis of fire PSA requirements and functionalities
- Implementation of fire PSA database.

3.1 Analysis of fire PSA requirements and functionalities and implementation of fire PSA database

Basic requirements on the scope of fire PSA database follows from the current experience as well as from standards as [1] and [2]. However basic analysis of desired functionalities reveals deep complexity of database topic. Thus, the final decision was to establish two separate fire databases. The first of them is used as basic fire PSA database supporting following part of standard fire analysis:

- Plant boundary definition and partitioning (scope and boundary of fire compartments),
- Components Selection and querying including capability to provide cross information (mainly power and location dependency),
- Qualitative Screening based on relevance of compartment occupying equipment and fire impact including possible spreading path as well as reporting support for this activity,
- Quantitative Screening including central maintenance of input data like fire frequencies, unique list of considered initiating events from PSA level 1 and presentation of results.

This part was implemented as the extension of current PSA database by adding appropriate information tables.

Above introduced architecture, i.e. extension of current PSA database bears potential problem with data integrity. Therefore, crucial data are stored in one place in order to avoid data inconsistency problem. However, specifics of fire PSA process demands accurate tools, so special fire back-end application was developed. This software application, which is called fire PSA database, links basic PSA database common data. Fire PSA database implements several help tables and strong data querying support as well as handling all data operations including reporting in accordance with desired functionalities defined at the beginning of this section.
3.2 Description of fire PSA analysis

Real fire PSA analysis which always follows PSA level 1 consist of the following six stages:

A. Preparation of common inputs
B. Preparation of cable data
C. Qualitative analysis combined with assigning of appropriate initiating events
D. Quantitative analysis
E. Detailed analysis (which is not supported by database tools)
F. Reporting (which is supported by database tools via preparing fire report appendixes).

A. Preparation of common inputs

All fixed information that is stored in relevant tables of PSA database is gathered within the data preparation stage, namely:

(A-1) Assignment of “fire flags” for all potential fire sources of analyzed plants

(A-2) Preparation of fire frequencies for particular bins and list of plant operational states (POS), including POS duration. Fire frequencies include also appropriate frequencies for hot work that contains weight factors to consider frequent maintenance activity during shutdown.

(A-3) Assignment of rooms to the particular fire compartment.

B. Preparation of cable data

This stage uses technical data background from particular plant, i.e. electronic and paper documentation. Plant data are transferred into cable database, i.e. list of cables, list of trays with location etc. Each cable is assigned by an appropriate consequence that can be induced by fire. Information prepared in such a way enables easy incorporation of prepared data into fire PSA analysis.

C. Qualitative analysis combined with assigning appropriate initiating events

This stage uses all available information from current PSA database and performance is supported by a special form. Work as such consists from the following steps:

(C-1) Determination of potential fire spreading paths

(C-2) If the analyzed compartment is cable or channel compartment then results from stage B must be incorporated into available compartment information.

(C-3) Usage of uniform approach to perform qualitative screening of questioned compartment or to assign appropriate initiating event (IE).
Figure 1: Flowchart for step (C-3)

Activity within step (C-3) is supported by special form that substantially facilitates the work.

Figure 2: Form used to perform Qualitative analysis combined with assigning of appropriate initiating events (C-3).

Form introduced in Figure 2 is used to assign potential fire spreading paths, provides basic information as compartment identification, description, location etc. as well as enables
access to the much common and helpful information as list of ignition sources, list of PSA components, power supply dependencies, list of compartments room etc. Except of this information, feature form facilitates preparation of documentation by storing comments and by automatic insertion of rationales, e.g. “Fire load of compartment, Fire resistance etc.” Finally, if questioned compartment survives qualitative screening, the form is used to assign appropriate initiating events for particular plant operates states, i.e. analysis is always done as full scope.

D. Quantitative analysis

The aim of quantitative analysis is to prepare background for quantitative screening based on fire to the core damage frequency (CDF) contribution. This process only requires adding conditional core damage probabilities (CCDP) for assigned events and the rest of process runs fully automatic. Used software takes into account only non-screened compartments. Software calculates overall fire frequency for all relevant compartments, summing contribution of particular ignition sources as well as hot work frequency relying on data prepared in Stage A. Preparation of common inputs that are combined with assignment initiating events. Output of this stage is a list of compartments sorted in descendent order according to compartments CDF contribution, together with cumulative CDF. So this final list is directly used as input for detailed analysis task.

E. Detailed analysis

As it was already mentioned this stage is not supported by database tools and particular analysis uses hand calculations or specific fire codes, if any.

G. Reporting

This stage covers issuing of final fire PSA report. This part of work is perfectly supported by developed fire database system. Information stored during analytical process enables detailed documentation of process as whole by generating specialized reports for particular steps required by methodology in [2], see example for in appendix A.

4 OVERVIEW OF FIRE PSA

![Figure 3 : Fractional contribution of initiating events to the total CDF (INTFIRE – 6%)](image-url)
Analyses of internal fires show that significant contribution of fires to the CDF that should be reflected in overall plant results are fires of turbine hall. Dominant scenario is a fire of compartment of turbines and main feedwater pumps in full power. This scenario has more than 54% of the total contribution of internal fires to the CDF (Figure 3).

5 CONCLUSIONS

If specific fire database development of which was inspired by NUREG/CR-6850 is compared with NUREG/CR-6850 paradigm it is obvious that developed product is leaner. In spite of usage of simpler concept than this suggested by NUREG/CR-6850 and considerable amount of time devoted to development of fire database, its usage provides valuable services that substantially facilitate work process as a whole. Used database system stores only permanent information like plant partitioning data, bins fire frequencies, data of used initiating events etc. The rest of information that can be affected by changes like quantification of results is stored only like help information in supporting tables and queries that can be easy automatically updated. Any change is also automatically reflected by related reports what provides quite comfortable working environment.

We would like to extend scope of work performed by software as well as to introduce some new features. Possible areas for further improvement are as follows: Automatic data exchange between PSA and fire software, i.e. actualization of CCDP for used initiating events and introducing of uncertainty analysis into quantification process, i.e. combination of uncertainty boundaries of available fire frequencies and CCDP by using of an approximated analytical methods.

Further extension of the database is intended to be focused on assessment tools developed to evaluation of the combination of hazards. Advanced database should include:

• Boundaries of seismic resistant building structures
• List of equipment with increased seismic resistance
• Ability of the seismic qualified structures to prevent fire propagation
• Detailed description of the fire compartments at the building structures boundaries with increased seismic resistance.

The developed database system can be extended by additional functionalities that can be used in order to provide an extra documentation concerning internal quality audits performed by independent fire specialist.

Finally, creation of described database tool provided an excellent opportunity for deeper understanding of the fire PSA topic, as well as a good starting background for young PSA team members who were involved in this activity.

REFERENCES


**APPENDIX A**

*VUJE, a. s.*

**Fire Compartment:** UNA-30.07.02  
**Internal ID:** 162

**Description:** Alternating busbar 0.4 kV

**Details:** Valves control in train from and to PWT 2, 4 and 6. On LOCA isolation an administrative reactor shutdown is assumed in POS_14 and POS_PWR. Malfunction of KLC71 venting system check valves can prolong maintenance time during shutdown. MOVs between accumulator tanks and reactor are opened and interlocked in POS_14 and POS_PWR. During the unit shutdown are closed however, under certain concurrent circumstances could the capacity of both tanks spill into reactor in POS_1.

Fire that can spread through the ventilation system KLC75 may damage the safety important fire compartment UNA-30.03.00X, damage has no impact on the final IU.

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**Building / Rooms:** 800/1-02

**List of Ignition sources:**
- 3BJA42
- 3BJA43
- 3BNK50
- 3BNK51
- 3BNK52
- 3BNK53
- 3BNK54

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**Fire propagation**

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**PSA components:**
- 3BNK50
- 3BNK51
- 3BNK52
- 3BNK53
- 3BNK54

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**POS: P14 IE IRT_P14_1**

| Total Fr.: 7.760E-06 | Component 6.75E-06 | Hot Work 1.01E-06 | Cable 0.00E+00 |

**POS: PWR IE IRT_PWR_1**

| Total Fr.: 8.983E-04 | Component 7.82E-04 | Hot Work 1.16E-04 | Cable 0.00E+00 |