Standardized Probabilistic Safety Assessment Models: First Results and Conclusions of a Feasibility Study.

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The Spanish Nuclear regulatory body (CSN) has implemented the SISC (Sistema Integrado de Supervisión de Centrales), a regulatory system inspired by the USNRC Reactor Oversight Process (ROP). As such, the system makes use of PSA results and insights in several tasks. Inspection results are assessed by PSA quantification, determining the consequences of licensee performance deficiencies by mapping onto a PSA model any failures to comply with rules and regulations. A re-quantification of the model yields the impact of the performance deficiency in the plant risk. The outcome is used to take decisions on further regulatory actions. In addition, whenever applicable, inspection scope is driven by PSA importance, be it the baseline inspections or special inspections, reactive to events.

The PSA models obtained from the licensee during the main licensing process are the main ingredient and driving element at the basis level of this regulatory system.

The cumulated CSN experience in FT/ET quantification of Spanish plants with industry PSA models includes the use of and knowledge about, different computational platforms, and different modeling cultures at the different plants. As exemplified in the case of the precursors and significance determination of inspection findings, inter-comparison between results in these different contexts is essential, but sometimes doubts appear about whether or not the same problem would give similar results in different environments. In view of this, CSN has initiated an important harmonization activity, aimed at obtaining a standardized modeling. Furthermore, because as regulators, CSN staff needs independent views on licensee models, this effort will be directed towards obtaining PSA models independent from licensees.

SPAR (Standardized Plants Analysis Risk) concept, taken from the approach followed by USNRC in its regulatory system, is being studied and analyzed by CSN in collaboration with UPM, with the aim to overcome problems and drawbacks appeared by application of the SISC during these last years. The strategy followed is based in the comparison of current and actual PSA of Spanish NPP, in order to collect, identify and agree which the characteristics, hypotheses and modeling approaches (both at ET and FT level) are most adequate and convenient for SISC purposes.

This contribution reviews CSN-UPM activities in the development and application of a feasibility study for the development of suitable Standardized Probabilistic Safety Assessment (PSA) models for Spanish NPP. Main activities and results, as well as some preliminary conclusions of this feasibility study are covered.

I. INTRODUCTION

The Spanish Nuclear regulatory body (CSN) performs its functions using PSA models which are developed by the operators of Spanish NPPs. These PSA models have been assessed and are periodically inspected by CSN, which is one reason why its use has been considered acceptable.

On the other side, USNRC performs their functions using their own SPAR models (Standardized Plant Analysis Risk), which confers their regulatory assessment a higher independence.

SPAR (Standardized Plant Analysis Risk) models, promoted by the USNRC Office of Research, have been developed specifically to individual US NPPs, but following standard criteria regarding their methodology and level of detail in order to assess the various nuclear power stations on an equal basis. They are kept updated by Idaho National Laboratory (INL).

The USNRC has on several occasions pondered the possibility of using PSA models from the industry and has consistently favored the use of SPAR models.

For the sake of an adequate comparison among the SISC (Sistema Integrado de Supervisión de Centrales) for Spanish NPPs, and the Reactor Oversight Process (ROP) for US NPPs, the PSA models used in both systems should be comparable. With this aim, CSN is promoting the development of suitable Standardized Probabilistic Safety Assessment (PSA) models for Spanish NPP (SPAR-CSN), that will make closer the modeling strategies of both types of approaches.

II. OBJETIVES

The current purpose of the project considers the elaboration of a standardized PSA model independent from the industry, providing a high-level view of risk in the evaluation of findings in Spanish NPPs, comparable in scope to SPAR models for their risk assessments. To this end, the conclusions drawn from the comparison of the existing industry models are used to establish a common set of assumptions and standard modeling techniques to be used in CSN models. The SPAR-CSN models aim to:

a) Better understanding of the main contributors to risk in NPPs.
b) Prioritizations in inspection and surveillance tasks of Spanish NPPs through the analysis of systems and components importance.
c) Precursor analysis of operating incidents occurred in Spanish NPPs in order to determine closeness to a core damage scenario.
d) Assessment of inspection findings of the SISC.

To carry out this aims, several steps and recommendations will be developed to:

- Obtain standardized models, minimizing differences of methodology and modeling.
- Model the same phenomena and events following a common set of criteria, retaining the unique features of each facility (design, procedures or own data).

III. SPAR-CSN METHODOLOGY PROPOSAL

As a first step, a feasibility study has been proposed, that prompts the following methodology, see Figure 1, to obtain the SPAR-CSN models:

Step 1a: ET analysis.
The tasks to be undertaken throughout this analysis are:

- Gather the NPPs information and study each sequence in their respective ET.
- Detailed review of information from each header.
- Once all headers have been identified, development of a standard ET with a common nomenclature.

Step 1b: FT and safety systems analysis.
The selection of the systems to be analyzed is based on the ETs headers from the previous step. Alongside with the step 1a, FTs are analyzed with criteria similar to those used for ETs.

Step 1c: Analysis of type 3/5 human actions pertaining to each ET.

Step 1d: Data base analysis.
In this step the following tasks are performed:

- Review of the generic and specific database building methodology and data sources used in each PSA to be compared.

- Comparison of the methodology and data sources used for the initiating events selection, frequency based classification and frequency value obtaining in each NPP analyzed.

Step 2a1: Comparison of the ETs, success and failure sequences and success criteria of each header from Spanish PSA models.
A comparison of the success sequences of the PSA models will be performed. In the comparison of the headers the following aspects will be emphasized:

- Success criteria of each system.
- Available times from specific or generic calculations.

Step 2a2: Comparison of the ETs, success sequences and success criteria of each header from SPAR-NRC models ETs.
In the comparison the following aspects will be emphasized:

- Gathering of SPAR-NRC models hypotheses.
- SPAR-NRC models ETs.
- SPAR-NRC headers description and their success criteria.

Step 2a3: Comparison of the ETs, success sequences and success criteria of each header from level 1 PSA models ETs from other NPPs.
In the comparison the following aspects will be emphasized:

- ETs and success sequences.
- Success criteria.

With the results from the steps 1a, 2a1, 2a2 and 2a3 the step 3a, the proposal for standardized ETs and success criteria can be developed.

Step 2b1: Analysis of FTs corresponding to each ET header from the analyzed NPPs.
In this step the following tasks will be undertaken:

- Comparison of the description and functional analysis of each system in the analyzed NPPs.
- Comparison of the modeling hypotheses from each PSA. Classification and discrimination of differences.

Step 2b2: Comparison between FTs models from the selected systems in the step 1b, paying special attention to:

- Implementation of the modeling hypotheses listed and explained in the PSAs.
- Location of the implicit modeling hypotheses, particularly those which mean additional differences in the models.
- Comparison of common cause and system single failures, special events and type 1/3 human actions modeled in the FTs.
- Analysis and comparison of the modeling techniques for common events in the PSAs.

Step 2c1: Human actions from each header included in each ET of the analyzed NPPs are compared.

Step 2c2: Type 3/5 human actions from the SPAR-NRC models related with each ET studied are selected and compared with the human actions of the analyzed NPPs.

Step 2c3: The EOPs related with the sequences included in each ET are analyzed.

Step 2d1: Comparison of the data base from the analyzed NPPs.

Step 2d2: Comparison of the data base from other NPPs.

Step 3a: Proposal of headers, ETs and success criteria for the SPAR-CSN model.
In this step the following tasks will be undertaken:

- An analysis to determine which headers and transfer sequences are common between the analyzed NPPs is performed.
- The goal is to select a unique set of headers representative for all the analyzed NPPs.
- The selected set of headers is compared with the SPAR-NRC models and with other PSAs to verify its adequacy and completeness.
- Proposal of the ET for each initiating event in the SPAR-CSN model.
- The success criterion for each header in each ET is compared in all the analyzed NPPs.
- The success criteria proposal is verified and compared with the hypotheses and the success criteria of the SPAR-NRC models.

Step 3b: Proposal for the standardization of FT models for each system.
This step is performed consistently with the standardization proposal of headers and human actions in the steps 3a and 3c.
In this step the following tasks are undertaken:

- A standardized block diagram is built for each system, based on the NPPs diagrams.
- A common nomenclature of system equipment and logic elements of the FTs is proposed.
- The information from steps 2b1 and 2b2 is drawn and a first evaluation and proposal of hypotheses and modeling techniques is performed.
- The information from steps 3a and 3c is drawn to evaluate the human actions and the operation conditions applicable in the standardized FT modeling of the safety systems.
- The information from steps 2d1 and 2d2 is drawn to determine the data sources to use in the SPAR-CSN FTs. A graphic model is built, with the help of software, which gathers, displays and clarifies the performed proposals.

See Figure 2 for a detailed diagram of the methodology followed regarding FT analysis.

Step 3c: Proposal of human action in the SPAR-CSN ET model.
In this step the following tasks will be undertaken:

- Initially all common human actions in the NPPs are selected.
- A new ET is modeled including EOPs, using the ET developed in step 3a and the EOPs analyzed in step 2c3.
- Additional human actions from headers not common to all the NPPs but present in the SPAR-CSN ET are added.
- The need for more human actions is analyzed using the SPAR-NRC models and the SPAR-CSN ET with EOPs.

Step 3d: Proposal of data base which will be taken into account in the SPAR-CSN ETs and FTs.

Step 4: Modeling of the SPAR-CSN model using SAPHIRE or Risk Spectrum. The initiating event frequencies and their contribution to the core damage frequency are compared.

Step 5: Verification of the SPAR-CSN model.
A high level comparison of the risk profile of the plant will be performed.

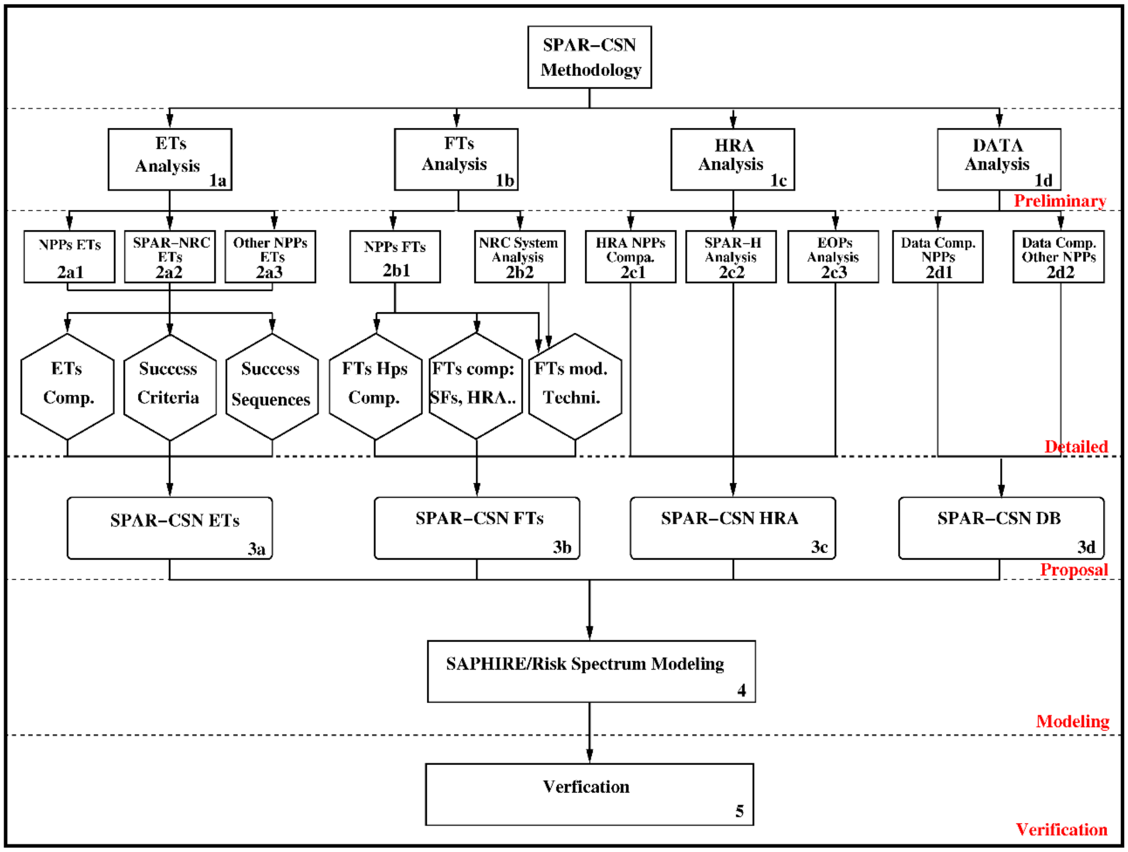

Fig. 1. SPAR-CSN Methodology

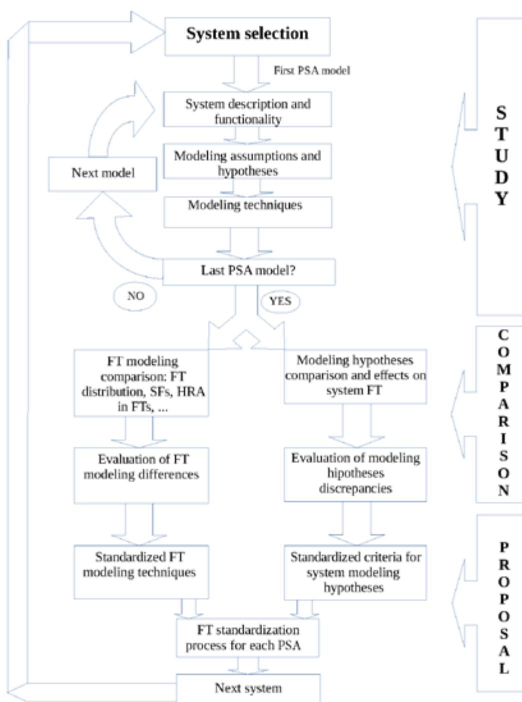

Fig. 2. FT SPAR-CSN Methodology

IV. EXPECTED RESULTS

As result of this project the following results are expected:

1. High level comparison between the PSAs from the analyzed NPPs and the equivalent SPAR-CSN models in terms of:
   - Modeling of ETs.
   - Scope of the FT modeling.
   - Scope of the human reliability for the human actions modeled in the corresponding ETs.
   - Use of generic data bases and of specific data.

2. Analysis of the differences between the PSAs of the analyzed NPPs (PWR-W). This requires an independent re-evaluation of the PSAs. Furthermore, this process allows identifying questions and aspects which might be useful in the inspections and evaluations.

3. A generic, representative, standardized model of the PSAs for the analyzed NPPs (PWR-W) with a similar scope to the SPAR-NRC models, which can be used as platform for the models of more NPPs. This will include, at least:
   - ET modeling. An example of Generic Transient (GT) standardized ET which also includes the related EOPs to each step is shown in the Figure 3.
   - Success criteria and available time of the human actions.
   - FT modeling. An example of HPSI top FT and HPSI block diagram are shown in Figures 4 and 5, respectively.
   - Specific data.

4. Quantification and validation of the results against available models.

5. Analysis of the needs of expanding the standardized PSA modeling to other Spanish NPPs.

6. CSN staff training.

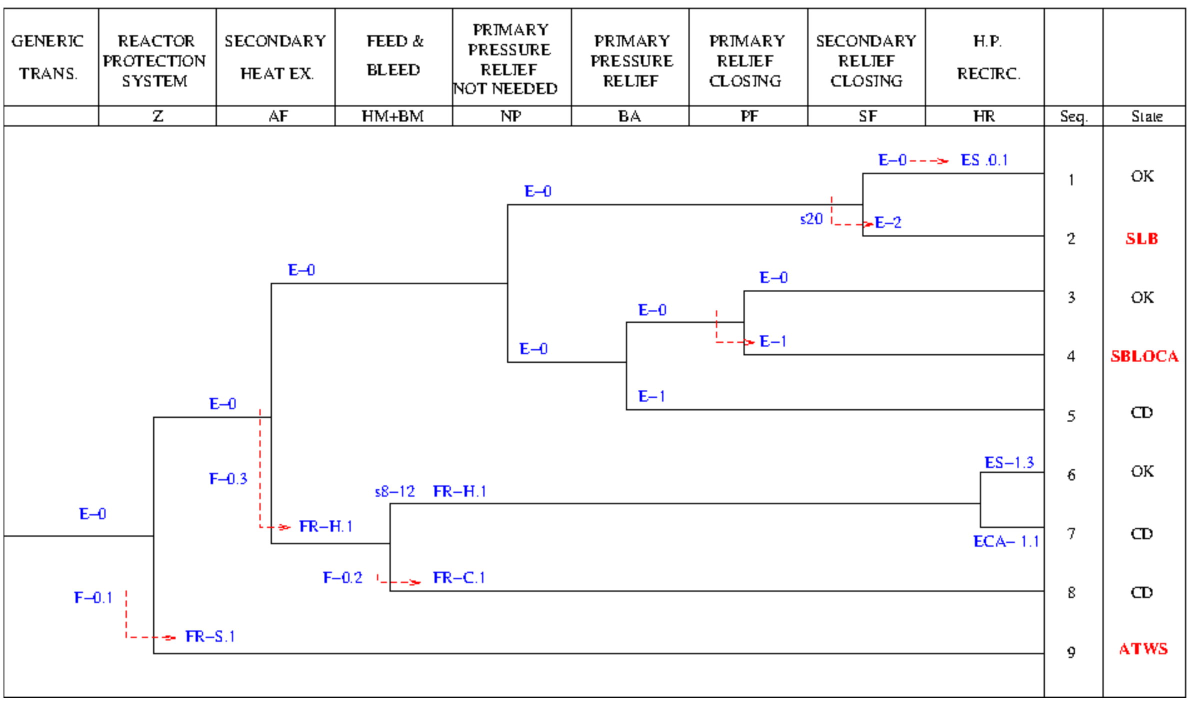

Fig. 3. ET for GT with EOPs

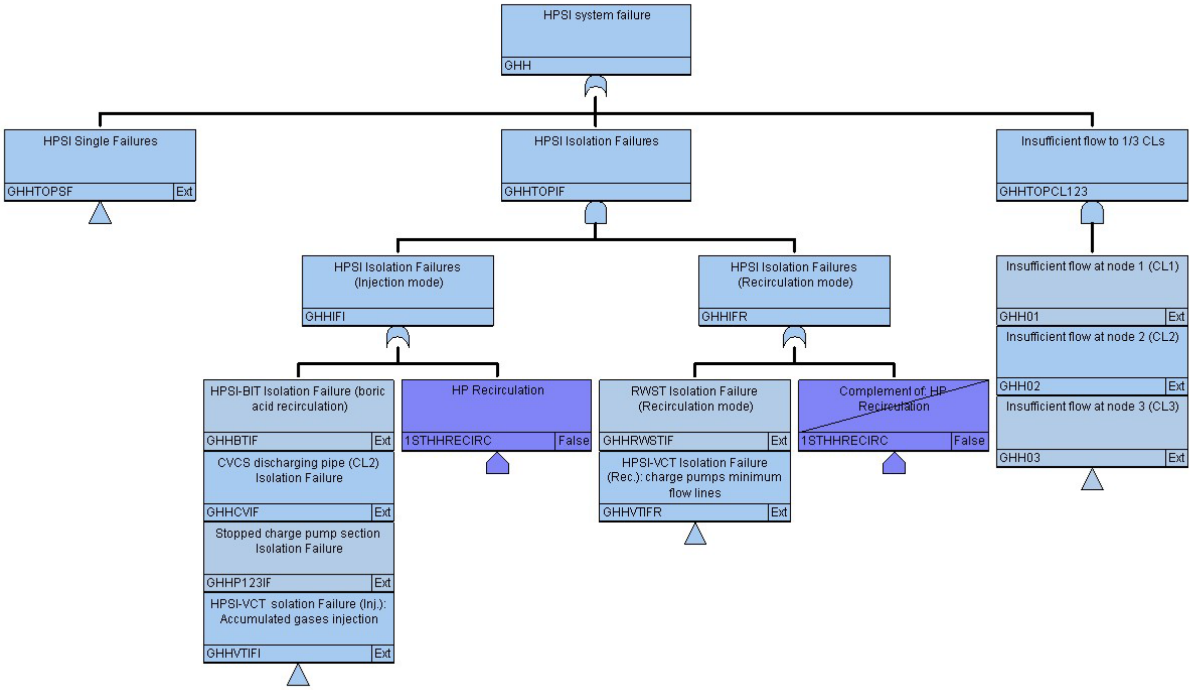

Fig. 4. HPSI FT top

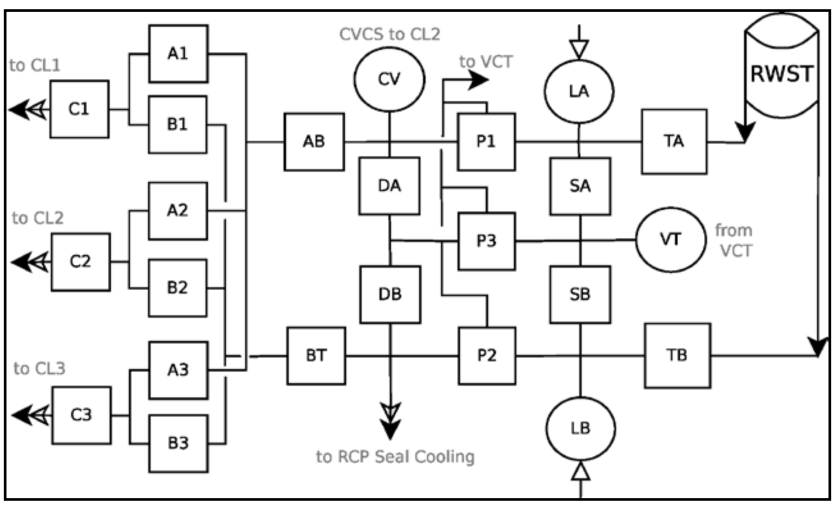

Fig. 5. HPSI block diagram

V. CONCLUSIONS

The main conclusions drawn from this preliminary study are summarized within the following points:

- A methodology for the development of SPAR-CSN models has been successfully elaborated.
- The development of SPAR-CSN models is viable, with a similar scope to the SPAR-NRC models.
- It is feasible to standardize ETs, success criteria, FTs and human actions between the analyzed Spanish NPPs, though they have design differences that must be taken into account.
- ETs differences:

1. Each analyzed NPP has its own modeling regarding transfers between ETs, though it is possible to standardize it into a new proposed ET.

2. There are several differences in the requirements for the containment safety systems between the analyzed NPPs in level 1 PSA due to design differences.
3. There are differences in the classifications of LOCA break size categories made for the analyzed NPPs.

- FTs differences:
  1. Modeling Techniques: although the main branches of each SI system FT follow similar modeling rules, several differences have been found between the different PSA FT models: system operating modes and main failures distribution in the FT, transfer gates use, impossible failure combinations removal techniques, etc. These differences are easily solvable in a standardizing process.
  2. Modeling Hypotheses: comparing PSA FT models and documentation for every SI system, a wide set of discrepancies in assumptions and hypotheses have been found. Some of these are based on real design differences, so they will have to persist even after the standardization process, but this is not the case for few others. Hence, the latter will require a more detailed evaluation based on the CSN experience.
- Human reliability: A similar approach to the SPAR-H method will be employed, but taking into account additional human actions which are common and relevant in the analyzed NPPs.
- Data sources:
  1. There is a generic data base that was already agreed by the Spanish NPPs and CSN, which could serve as a starting point for the standardized data base.
  2. A reasonably complete list of data sources has been gathered from the Spanish NPP APS documentation, which could be used to build a generic data base for the future SPAR-CSN models. These include both Spanish NPPs and international experience sources.

ACKNOWLEDGMENTS
The UPM group acknowledges the technical and financial support granted by the CSN.

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