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Evaluation of Safety Margin for OPR1000 LBLOCA according to the Guidance of SMAP of NEA/CSNI

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1. Introduction

At the beginning of commercial nuclear power plant in seventies rules and criteria were defined with the objective that the plant could be considered as safe if they were satisfied. During this period, the design basis accidents (DBAs) were defined and Appendix K was assembled. Due to several weaknesses in the knowledge base, conservatisms were introduced at almost all levels of the approach. DBA was considered as the major safety case. The safety margin concept was then strongly linked to the DBA and to related conservative approaches, which were defined to get, on one hand, an envelope accident and, on a second hand, to increase knowledge about plant physical behavior.

The occurrence of the TMI-2 accident showed quite soon that more complicated scenarios, resulting from out-of-design sequences of events needed to be addressed. This gave rise to the incorporation of system reliability engineering techniques and to the development of the probabilistic approach to safety analysis. Nowadays plant changes that can cause exacting operating modes including power uprates, life extension, or increased fuel burnup always challenge the concept of safety margin, and OECD (Organization for Economic Co-operation and Development) NEA/CSNI started international project of SMAP (Safety Margins Action Plan)[1].

This paper introduces the concept of safety margin based on the SMAP project, and exemplary safety margin calculation according to the guidance of SMAP project with slight improvement is discussed.

2. Integrated Risk and Safety Margin (IRSM)

OECD/NEA SMAP developed advanced regulatory method in the view point of IRSM (Integrated Risk and Safety Margin) for the plant. This new regulation aims to resolve the multiple safety objectives, and quantitatively evaluate the generalized safety margin by consolidating the deterministic approach and stochastic approach at the same time. Set of triplets in decision making process for the safety issue is composed of;

- Scenarios
- Frequency
- Consequence

SMAP has been developed based on above triplets.

2.1 Risk Space

The assessment of generalized safety margins requires consideration of all possible scenarios having non-negligible likelihood; this almost complete set of scenarios was named the risk space and is described through a set of PSA-like event trees which provides capability to analyze multiple safety objectives. The development of a base case risk space is in some aspects similar to the event tree delineation in classical PSA, but the capability to address different safety objectives and to evaluate generalized safety margins introduce additional requirements that result in important methodological differences.

The risk space has following features;

- Initial event is selected depending on the safety objectives.
- Event tree and fault tree is determined depending on the safety objectives, sequences, and end states.
- Sequence in event tree of IRSM addresses all the scenarios that affect the risk profile.
- Sequences are grouped considering safety functions, related components, and consequences.
- Risk space should be composed to quantitatively consider change of plant operation amendment.

2.2Deterministic Calculation

The deterministic methods used to estimate the dynamic behavior of the plant under accident conditions can be summarized as follows:

- Very conservative (Appendix K approach for LOCA)
- Best estimate bounding,
- Realistic conservative
- Best estimate plus uncertainties (BEPU).

BEPU is preferred due to the rapid improvement of computer code and knowledge on the transient and phenomena.

2.3 Uncertainty Treatment

Uncertainty can be classified into the aleatory and the epistemic uncertainty. Aleatory uncertainty results from the effect of “inherent randomness” or “stochastic variability”. It represents the nondeterministic and unpredictable random nature of the performance of the system and its components. Epistemic uncertainty results from the "imperfect knowledge" regarding values of parameters of the underlying computational model. The parameters as such are deterministic in nature, i.e. they have fixed and invariable values which are not precisely known.

General considerations that apply to the quantification of uncertainties and to the determination of the approach that is best suited to the application. Fig. 1 is a schematic that attempts to summarize the process of determining uncertainties. This process involves minimization of uncertainties, identification of significant contributors, and accuracy requirements.

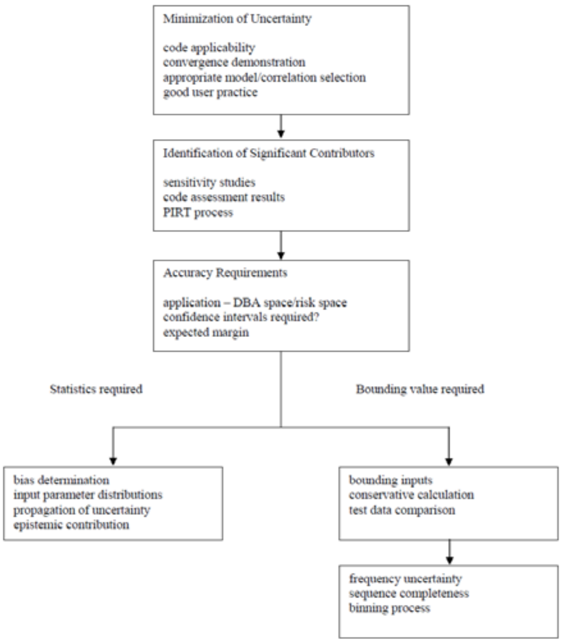

Fig. 1. Schematic of Uncertainty Quantification Process

3. Sample Calculation

3.1Selection of Sample Calculation

OPR1000 plant was selected for the example calculation according to the above procedures. And LBLOCA (large break loss of coolant accident) was target transient. The MARS code (MARS-KS version 2.0) was used for the LBLOCA analysis. The MARS code is a realistic multi-dimensional thermal-hydraulic system analysis of light water reactor transients. MARS can also be connected, by means of dynamic linkage using DLLs, to other codes such as 3D kinetics code MASTER and containment analysis codes, CONTAIN and CONTEMPT.

3.2 Uncertainty Analysis

MOSAIQUE code was used to support the uncertainty analysis for the thermal hydraulic calculation developed by KAERI. The key features of MOSAIQUE are as follows [2];

- Handles various distributions: MOSAIQUE can handle Normal, Lognormal, Beta, Gamma, Uniform, Discrete, Empirical, Functions of other variables.
- Create samples for variables: Latin Hypercube Sampling (LHS) or traditional random sampling can be applied.
- Run computer codes using the created input files on multiple PCs: MOSAIQUE run computer codes on multiple PCs/multiple CPUs across the intranet. Currently, MOSAQUE can handle several codes such as MARS, RELAP5, MAAP, GAMMA, FDS, FLACS and TRACE

3.3 PSA Tool

The CONPAS code was used to modify the original event tree of UCN3&4 plant. The quantification of each accident scenario frequency in the event tree was performed using MS Excel program.

3.4 Base Case Calculation

The MARS nodalization model for UCN3/4 is shown in Fig.2. Steady was calculated prior to calculate the transient. The target values for steady calculation are those for general safety analysis.

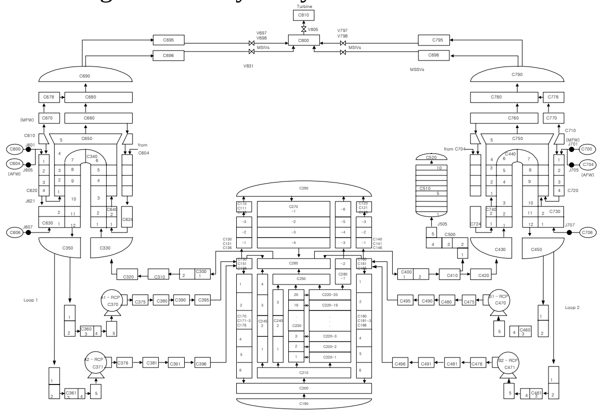

Fig. 2. Nodalization for MARS Analysis of OPR1000 LBLOCA

3.5 Results

Detailed results will be presented in the presentations.

5. Conclusions

This paper presents the first attempt of domestic plant for the calculation of safety margin according to the guidance of SMAP.

REFERENCES

[1] NEA/CSNI/R(2007), Task Group on Safety Margins Action Plan (SMAP) Safety Margins Action Plan - Final Report, 2007

[2] KINS/KAERI, NEA/CSNI/ SM2A Appendix, Contribution To Appendix Of Sm2a Final Report, 2009