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Preliminary Evaluation Methodology of ECCS Performance for Design Basis LOCA Redefinition

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1. Introduction

To improve their existing regulations, the USNRC has made efforts to develop the risk-informed and performance-based regulation (RIPBR) approaches. As a part of these efforts, the rule revision of 10CFR50.46 (ECCS Acceptance Criteria) is underway, considering some options for 4 categories of spectrum of break sizes, ECCS functional reliability, ECCS evaluation model, and ECCS acceptance criteria. Since the potential for safety benefits and unnecessary burden reduction from design basis LOCA redefinition is high relative to other options, the USNRC is proceeding with the rulemaking for design basis LOCA redefinition.

An instantaneous break with a flow rate equivalent to a double ended guillotine break (DEGB) of the largest primary piping system in the plant is widely recognized as an extremely unlikely event, while redefinition of design basis LOCA can affect the existing regulatory practices and approaches.

In this study, the status of the design basis LOCA redefinition and OECD/NEA SMAP (Safety Margin Action Plan) methodology are introduced. Preliminary evaluation methodology of ECCS performance for LOCA is developed and discussed for design basis LOCA redefinition.

2. Redefinition of Design Basis LOCA

The recently proposed rule published by USNRC would divide the current spectrum of LOCA break sizes into two regions by determining a “transition break size (TBS)”. The first region includes small size breaks up to and including TBS. The second region includes breaks larger than TBS up to and including the DEGB of the largest RCS pipe.

LOCAs in the smaller break size region will continue to be “design basis accidents (DBA)” and will continue to be analyzed by current methods, assumptions and criteria. LOCAs due to pipe breaks larger than the TBS can be analyzed by the more realistic and less stringent analysis methods, since it will become “beyond design basis accidents (BDBA).” However, licensees should maintain the ability to mitigate all LOCAs. A number of possible changes to licensed power reactors are considered as a result of redefining the design basis LBLOCA. These include the extension of diesel generator start times, optimization of containment spray system setpoints and improvement of fuel management, etc. However, there are some technical issues to be resolved, and out of them, the ECCS evaluation methods for analyzing LOCAs for break sizes larger than the TBS should be developed.

3. SMAP Safety Margin Quantification Method

OECD/NEA SMAP methodology is an advanced safety margin quantification method, based on IRSM (Integrated Risk and Safety Margin) by consolidating the deterministic and stochastic approach. At first, all possible scenarios having non-negligible likelihood are considered. Then, for selected scenarios, the transient behaviors of NPP are analyzed using best-estimate thermal-hydraulic (BE-TH) codes including various uncertainties or conservative evaluation model. The probability of exceedance in a given event scenario, conditional exceedance probability of the safety limit is obtained by the analysis mentioned above, and it gives an indication of the existing margin to damage in a particular transient path. Figure 1 shows the concept of conditional exceedance probability.

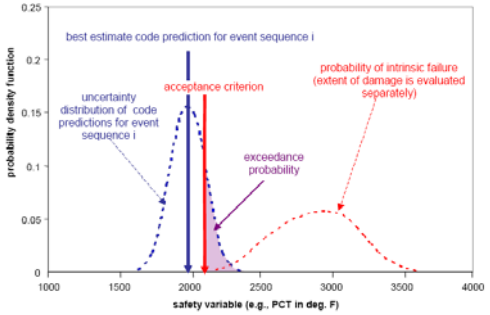

Fig. 1. The probability of exceedance in a given event scenario

4. Preliminary Evaluation Methodology of ECCS Performance for BDBA LOCA

If the acceptance criteria shown in Fig. 1 are set as safety limit of 1204°C PCT and 17% total clad oxidation, we can assure the safety margin by calculating distance between calculated values and the safety limits. Therefore we set acceptance criteria as current ones.

In SMAP methodology, when a plant is modified, how much the modification erodes the safety margin before modification is focused on. The core damage (CD) paths for event scenario of relatively low probability are not considered assuming they are minor contributors to the margin change.

Meanwhile, we need to decide how distant from the acceptance limit is acceptable. The exceedance probability for safety limit only is not meaningful since the frequency that the event sequence occurs should be considered. Then, conditional exceedance probability concept is employed, and it can be used for regulatory purpose.

In case of LOCA, we can identify the initiating events frequency above TBS from the previous studies [2] as shown in Fig 2. From Fig. 2, let us set TBS as break with occurrence frequency of 1E-5/RY; then, if we want to get the CDF above TBS,

$$CDF_{>TBS} = \int_{TBS}^{DEGB} I(z) P_{exc|I}(z) dz \qquad (1)$$

where $I(z)$ is initiating event frequency and $P_{exc|I}(z)$ is conditional exceedance probability according to break size.

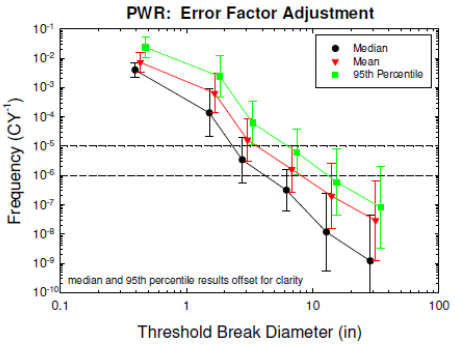

Fig. 2. PWR error-factor adjusted LOCA frequency estimates

If we assume the conditional exceedance probability for all the initiating break sizes is constant,

$$CDF_{>TBS} = P_{cond.exc} \int_{TBS}^{DEGB} I(z) dz \qquad (2)$$

where $P_{cond.exc}$ can be obtained by considering only DEGB LOCA conservatively. For example, if we want to set $CDF_{>TBS}$ as 1E-7 for the occurrence frequency of breaks above TBS of 1E-4/RY, $P_{cond.exc}$ should be below 1E-3, by analyzing the all possible scenarios of DEGB LOCA by using BE-TH code. For DEGB LOCA scenario, so far as the failure probability of ECCS (e.g. SIT, HPSI, etc) is relatively low and a modification increase or does not significantly decrease ECCS availability, $P_{cond.exc}$ is expected to be very smaller than 1E-3 for each CD path. Therefore, in most cases, only OK path of LBLOCA is considered to calculate $P_{cond.exc}$.

When analyzing the transient behaviors of NPP, epistemic and aleatory uncertainties affecting TH behavior should be considered. In addition, single failure and loss of offsite power assumption can be deleted during TH analysis, since LBLOCA is treated as beyond design basis accident.

For various plant modification, $P_{cond.exc}$ can be obtained through the procedure mentioned above, $P_{cond.exc}$ should be less than determined value for regulatory purpose.

For future work, this methodology should be more systematized and feasibility study for the real NPPs should be performed. Extensive discussions between regulatory body and licensees should be also accomplished.

5. Application for EDG Start Time Extension of APR1400

Detailed results will be presented in the presentations.

6. Conclusion

The USNRC is proceeding with the rulemaking for design basis LOCA redefinition. In consequence of that, a number of possible changes to licensed power reactors are considered. However, there are some technical issues to be resolved, and out of them, the ECCS evaluation methods for analyzing LOCAs for break sizes larger than the TBS should be developed.

In this study, using OECD/NEA SMAP methodology to quantify the safety margin of NPPs, preliminary evaluation methodology of ECCS performance for BDBA LOCA is developed. For future work, this methodology should be more systematized and feasibility study for the real NPPs should be performed. Extensive discussions between regulatory body and licensees should be also accomplished.

REFERENCES

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