Reviewing the Application Methods of New Requirements Related to DSA for Continued Operation of PHWRs

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1. Introduction

In the nuclear industry, deterministic safety analysis (DSA) is used to confirm that plant safety functions can be satisfactorily achieved and that the required structures and systems, in combination with operator actions, will keep the releases of radioactive material from a nuclear facility below acceptable limits. Deterministic safety analysis provides the licensing basis for new and existing nuclear facilities. REGDOC-2.4.1 was published by CNSC (Canadian Nuclear Safety Commission) in 2014. This document supersedes the following regulatory documents: RD-310[2]; GD-310[3]; and RD-308[4]. REGDOC-2.4.1 includes amendments to reflect lessons learned from the Fukushima nuclear event and to address findings from the CNSC's Fukushima Task Force Report, as applicable to RD-310 and RD-308. This regulatory document sets out the requirements of the CNSC for deterministic safety analysis for NPPs and SMR.

The 30-year design fatigue life of Wolsong Units 2, 3, and 4, which are pressurized heavy water reactors, will be terminated in 2026, 2027, and 2029, respectively. Therefore, if safety analyses are conducted to continue operations, the newly issued REGDOC 2.4.1 requirements may be applied. This paper reviews considerations for applying the REGDOC-2.4.1 requirements to domestic pressurized heavy water reactors.

2. Requirements for DSA

In this chapter, the requirements outlined in REGDOC-2.4.1 and the key findings described in this are reviewed. The guidance included in this document provides information to the applicant or further elaborates on requirements. This is intended to offer guidance for licensees and applicants on how to comply with the requirements. The licensee is required to review and consider the guidance, and if not followed, they must explain how the chosen alternative approach meets regulatory requirements.

2.1. Events to be analysis

This section focuses on identifying events that could potentially challenge the safety or control functions of the power plant. It provides guidance for determining the scope and classification methods of identified events. Specifically, for event classification, it categorizes them into normal operation, anticipated operational occurrences (AOO), design basis accidents (DBA), and beyond design basis accidents (BDBA) based on probabilistic studies and engineering judgments.

2.2. Acceptance criteria

It provides guidance for acceptance criteria for normal operation, AOO, DBA, and BDBA. For normal operation, it states that the settings of safety systems should be effective. For AOO and DBA, it indicates that radiation exposure to the general public should not exceed prescribed limits. The acceptance criteria are as follows:

- AOO : 0.5 mSv
- DBA : 20 mSv

To demonstrate compliance with qualitative acceptance criteria for AOO and DBA, it is necessary to verify derived acceptance criteria. For BDBA, it is essential to verify whether the designed nuclear power plant meets the established release limit requirements for safety objectives and whether the procedures and equipment for accident management requirements are effective.

2.3. Methods and Assumptions

The analysis shall provide the appropriate level of confidence in demonstrating conformity with the acceptance criteria. To achieve the appropriate level of confidence, the safety analysis shall:

1. Be performed by qualified analysts
2. Use a systematic analysis method and verified data
3. Use justified assumptions, verified and validated models and computer codes
4. Incorporation of conservatism and conducting appropriate reviews

Guidance is provided for assumptions made to simplify the analysis, as well as assumptions related to the operational modes of the nuclear power plant, availability and performance of systems, and actions of operators. These assumptions may intentionally be set in a realistic or conservative direction.

2.4. Documentation

Deterministic safety analysis reports should be comprehensive and sufficiently detailed to allow for deterministic review. To achieve this, they should include the following:

1. Technical justification for analyzed accidents, key phenomena, and processes
2. Description of the facility under analysis
3. Analysis methods and assumptions
4. Codes and uncertainties related to the analyzed events
5. Conclusions regarding compliance with acceptance criteria

2.5. Review and update of DSA

The analysis results should be evaluated based on relevant requirements, applicable experimental data, expert judgment, and comparison with similar calculations and sensitivity analyses. Depending on the purpose of the analysis, one or more of the following techniques should be used to review the analysis results:

1. Supervisory review
2. Peer review
3. Independent review by qualified individuals
4. Independent calculations using alternate tools and methods to the extent practicable

Deterministic safety analyses should be periodically reviewed and updated to reflect changes related to enhancements in knowledge and understanding of nuclear power plant components, conditions (including aging effects), operational parameters and procedures, research findings, and physical phenomena.

2.6. Quality of DSA

Safety analyses should be subject to a comprehensive Quality Assurance (QA) program covering all activities that affect the quality of the results. All data sources must be referenced and documented, and each step of the process should be recorded and archived to allow for independent review.

3. Application methods

In this chapter, the review of application methods for the deterministic safety analysis technical standards outlined in REGDOC-2.4.1 for domestic pressurized heavy water reactors, as presented in Chapter 2, is provided.

3.1. Events to be analysis

Currently, event classification in safety analysis follows the Canadian Requirements C-6[5], classifying events from class 1 to class 5. However, it should be reclassified into three event categories (AOO, DBA, BDBA) using probabilistic frequency in PSA. Normal operation should also be considered if a new operating mode has been introduced or significant design changes have been implemented.

3.2. Acceptance criteria

According to REGDOC-2.4.1, while there are radiation exposure limits for the general public, these criteria are only applicable to new nuclear power plants, so they may not need to be applied. However, before performing the analysis to demonstrate whether qualitative acceptance criteria for each event category is met, it is necessary to establish Derived Acceptance Criteria (DAC) quantitatively. The DAC should include:

1. Applicability to specific NPP systems and accident scenarios
2. Clear boundaries between safe and unsafe conditions
3. Based on experimental data
4. Incorporation of margins or safety factors considering uncertainty

3.3. Methods and Assumptions

The main analysis methods presented in relation to Defense-in-Depth (DID) are as follows:

- Conservative analysis method : DID 3
- BE (Best Estimate) method including uncertainty evaluation : DID 3
- BE analysis method : DID 2 & DID 4

The event classes and corresponding analysis methodologies outlined in REGDOC-2.4.1 are presented in Table I below. The appropriate analysis method should be selected for the reclassified accidents and performed accordingly

Table I: The methodology for defense in-depth analysis according to event

class	*frequency*	*DID class*
AOO	≥ 10^{-2}	DID 2
		DID 3
DBA	10^{-2}>~ ≥10^{-4} (single-failure)	DID 3
	10^{-4}>~ ≥10^{-5} (multiple failures)	DID 3
BDBA	10^{-5}>~ ≥10^{-7} (multiple failures)	DID 4

3.4. Documentation

The documentation guidance outlined in REGDOC-2.4.1 has been found to have minimal differences from the methods currently being applied domestically.

3.5. Review and update of DSA

The guidance for review and updates outlined in REG DOC-2.4.1 has been found to have minimal differences from the methods currently being applied domestically. However, when updating safety analyses, it is essential to maintain validity while considering the following:

- The actual status of the NPP
- Permitted plant configuration and allowable operating conditions
- Predicted plant end-of-life state
- Changes to analytical methods, safety standards and knowledge that invalidate existing safety analysis

3.6. Quality of DSA

The guidance for quality assurance outlined in REGDOC-2.4.1 has been found to have minimal differences from the methods currently being applied domestically.

4. Conclusions

In this paper, considerations were reviewed for the application of the requirements outlined in REGDOC-2.4.1 to domestic PHWRs. Significant differences were noted in event classification, acceptance criteria, and analysis methodologies compared to existing practices. Firstly, event classification necessitates the reclassification of events from the existing 5 classes to 3 classes (AOO, DBA, BDBA). Secondly, quantitative acceptance criteria, referred to as Derived Acceptance Criteria (DAC), need to be established for each class to supplement the qualitative acceptance criteria provided for each event class. Finally, appropriate analysis methodologies must be selected and applied for each event class (AOO, DBA, BDBA). Particularly, for the newly introduced AOO, thorough review is required as it necessitates the use of the BE analysis methodology, which was not previously utilized.

REFERENCES

[1] CNSC, REGDOC-2.4.1, “Deterministic Safety Analysis”, 2014
[2] CNSC, RD-310, “Safety Analysis for Nuclear Power Plants”, 2012.
[3] CNSC, GD-310, “Guidance on Safety Analysis for Nuclear Power Plants”, 2012.
[4] CNSC, RD-308, “Deterministic Safety Analysis for Small Reactor Facilities", 2011
[5] CNSC, C-6 Rev.0, “Requirements for the safety analysis of CANDU nuclear power plants”, 1980.