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A Study on the Domestic Application of Canadian Regulatory Document REGDOC-2.4.1(Deterministic Safety Analysis) for CANDU

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1. Introduction

Following the 2011 disaster in Fukushima, Japan, there has been a world-wide trend to strengthen preparedness against accidents that might be less possible than DBA, but more severe than it. CNSC has issued REGDOC-2.4.1, *Deterministic Safety Analysis*, which supersedes RD-310, GD-301 after Fukushima disaster. This document is one of the CNSC's regulatory documents and sets out requirements and guidance for the preparation and presentation of a safety analysis that demonstrates the safety of a nuclear facility. REGDOC-2.4.1 provides information on preparing and presenting deterministic safety analysis reports, including the selection of events to be analyzed, acceptance criteria, safety analysis methods, safety analysis documentation, and the review and update of safety analysis. It also includes amendments to reflect lessons learned from the Fukushima nuclear event, and will be used to assess new license application for reactor facilities. In this paper, REGDOC-2.4.1 will be introduced and findings from it will be offered to the existing domestic CANDU plant for reference

2. Methods and Results

The identified events in REGDOC-2.4.1 is classified, based on the probabilistic analyses and engineering judgments, into three classes of events as follows [1, 2] :

2.1 Classification of events in REGDOC-2.4.1

- Anticipated Operational Occurrences(AOO) : these include all events with frequencies of occurrence equal to or greater than 10^{-2}/reactor year
- Design-Basis Accidents(DBA) : these include events with frequencies of occurrence equal to or greater than 10^{-5}/reactor year, but less than 10^{-2}/reactor year
- Beyond-Design-Basis Accidents(BDBA) : these include events with frequencies of occurrence less than 10^{-5}/reactor year.

Classifying events are needed because each plant state has different safety analysis requirements and acceptance criteria. Safety analysis requirements reflect the level of protection, based on the principle of defense in depth. The normal plant states and accident conditions are considered in the safety analysis.

Plant states fall into two states, operational states (normal operation and AOOs) and accident conditions (DBAs and BDBAs). The design authority, however, establishes the plant design envelope, which is the subset of all plant states considered in the design(normal operation, AOOs, DBAs and Design Extension Conditions(DECs)) as established in REGDOC-2.5.2, *Design of Reactor Facilities: Nuclear Power Plants*, [3](see figure 1).

		Plant Design Envelope			
	Operational states		Accident conditions		
Plant states	Normal operation	Anticipated operational occurrence	Design-basis accident	Beyond-design-basis accidents	
				Design-extension conditions	Practically eliminated conditions
				No severe fuel degradation	Severe accidents
Design rules	Design basis			Design extension	Not considered as design extension
Classification frequency, 1/y	~ 1	> 10^{-2}	10^{-2} ~ 10^{-5}	> 10^{-5}	
Radiological acceptance criteria	ALARA	0.5 mSv	20 mSv	No criteria	
Deterministic acceptance criteria	Normal conditions of operation	Fitness for service	Integrity of physical barriers	Containment performance limits	No criteria

Fig. 1 Plant states

2.2 Considerations of classifying events in REGDOC-2.4.1

Figure 1 shows plant states. AOOs are events that are more complex than the normal operation manoeuvres, with the potential to challenge the safety of the reactor, and which might be reasonably expected to happen during the lifetime of a plant.

DBAs are events not expected to occur during the lifetime of a plant. But, based on the principle of defense in depth, they are considered in the design of a plant. BDBAs are events with low probabilities of expected occurrence. They may be more severe than DBAs, leading to significant core damage, challenges to the integrity of the containment barrier, and, eventually, to the release of radioactive material from the plant.

DECs is defined as a subset of BDBAs considered in the design of new NPPs in REGDOC-2.5.2[3]. In RD-337 version 1[4], DECs are referred to as "credible BDBAs", meaning that conditions and/or events which are "practically eliminated" due to their extremely low probability of occurrence are not included into DECs.

DECs may take into account accidents from the reactor core, spent fuel pools and multiple units at a site, etc. Such accidents could be triggered by operator errors, multiple failures of equipment, internal or external events and, most probably, by a combination of events and failures.

DECs do not replace BDBAs in most occurrences in REGDOC-2.4.1 because analysis will consider events of lower frequency than DECs in searching for cliff-edge effects, or in analyzing bounding events. In view of REGDOC-2.4.1, Severe Accidents are defined as accidents which are excluded from the design of new NPPs, but some accident with higher probabilities can be included into DECs.

The assessed frequency of occurrence is the basis to classify events, but such assessments may have significant uncertainties. Therefore, an event that its predicted frequency falls on the threshold between two classes of events, or that has substantial uncertainty in the predicted event frequency is classified into the higher frequency class.

Other factors, such as relevant regulatory requirements or historical practices, may affect the selection of certain events for inclusion. The design authority may request that certain events be analyzed as DBAs, or as representative severe accidents to establish an understanding of safety margins or the robustness of the design. Certain scenarios are more critical and should be analyzed as DBAs with past practices and experience.

Some plant operating modes may be used only for short periods of time. Normally, events are classified without regard to the frequency of these operating modes. However, in classifying events, frequency of operating modes may be considered on a case-by-case basis.

2.3 Study on domestic application

REGDOC-2.4.1 is a regulatory document that supersedes RD-310, GD-310, and RD-308 after Fukushima, specifying requirements for deterministic safety analysis for AOOs, DBAs and BDBAs. Although the document refers to BDBAs, it does not specify requirements for DECs. This is because the analysis discussed in REGDOC-2.4.1 considers events of lower frequency than DECs, unlike the design process. Deterministic BDBA analysis supports the evaluation of safety goals along with PSAs. It also demonstrates the adequacy of the design provisions and accident management programs. Therefore, deterministic safety analysis should be performed to demonstrate that the complementary design features will function as designed in DECs. It also should be performed for the highest challenge to maintaining the containment function.

Moreover, content of the document is connected closely to other regulatory documents, such as REGDOC-2.5.2, and so on. Thus, it is desired that a document which provides pragmatic and clear direction for safety analysis on application of these documents to domestic CANDU plants is developed.

3. Conclusions

Currently, studies to establish the event classification framework and acceptance criteria for BDBAs in order to enhance the safety operation of domestic nuclear power plants have been doing briskly in the country. In this perspective, a study of DECs for domestic PWRs has already begun, and accordingly, it is expected that safety analysis studies of BDBAs including DECs for domestic CANDU plants also are required. Therefore, the Canadian regulatory perspective and requirements as the designer of CANDU would be substantial guidance to the domestic CANDU plants. Consequentially, it is expected to develop a practical document that enables domestic CANDU plants to adapt quickly and easily to the Canadian regulatory documents.

REFERENCES

[1] CNSC, RD-310, "Safety Analysis for Nuclear Power Plants", 2012.
[2] CNSC, REGDOC-2.4.1, "Deterministic Safety Analysis", 2014
[3] CNSC, REGDOC-2.5.2, Design of Reactor Facilities: Nuclear Power Plants, 2014
[4] CNSC, RD-337, Design of New Nuclear Power Plants, 2008.