Fukushima Accident Implications on PSA and on the Regulatory Framework in Canada

Y. Akl, S. Yalaoui
Canadian Nuclear Safety Commission, Ottawa, Canada

Abstract:

Fukushima Daiichi accident has led the Canadian Nuclear Safety Commission (CNSC) to take three major undertakings regarding the conduct of the Probabilistic Safety Assessment (PSA). First, is the amendment of the Regulatory Document S-294 "Probabilistic Safety Assessments for Nuclear Power Plants" to require the extension of Level 1 and Level 2 PSA to cover irradiated fuel bay events; the inclusion of external events and their potential combinations; and the multi-unit considerations. The second undertaking is the re-evaluation, by the licensees, of the site-specific external hazards to evaluate if the current design protection is sufficient. The third undertaking is about the new requirement directing a utility to provide a whole site PSA, or a methodology for a whole site PSA, as well as an update of the baseline PSA to take into account Fukushima–driven enhancements.

This paper will provide a brief description of the CNSC undertakings with the focus on the technical challenges regarding the development of the whole site PSA.

Keywords: Fukushima, PSA, Multi-unit PSA.

1. INTRODUCTION

Following the Fukushima Daiichi accident, the Canadian Nuclear Safety Commission (CNSC) took the following three major undertakings with regard to the conduct of the Probabilistic Safety Assessment (PSA) for Canadian Nuclear Power Plants (NPPs):

- Amendment of the Regulatory Document S-294 "Probabilistic Safety Assessments for Nuclear Power Plants" to address Fukushima lessons learned
- Re-evaluation, using modern calculations and state of the art methods, of the site-specific hazards to evaluate if the current site-specific design protection for each external event assessed is sufficient (a corrective plan should be proposed whenever gaps are identified);
- Request to develop a whole site PSA, or a methodology for a whole site PSA, as well as an updated PSA which takes into account requisite Fukushima–driven enhancements.

CNSC staff actions will be discussed with a focus on the technical challenges and implications regarding the development of the whole site PSA. The challenges include: the issue of safety goals applicability on per unit-year or per site-year basis; PSA results aggregation for the whole range of initiating events (internal and external initiating events) and operational modes.

Finally, a perspective on CNSC actions for the development of whole site safety goals as well as a multiunit PSA methodology will be discussed.

2. FUKUSHIMA AMENDMENTS TO S-294 REGULATORY DOCUMENT

The regulatory standard S-294 “Probabilistic Safety assessment (PSA) for Nuclear Power Pants” [1] was first issued by the Canadian Nuclear Safety Commission (CNSC) in April 2005. The standard sets high level requirements for the development of Level 1 and Level 2 PSA with a formal quality assurance process, and requires the licensees to seek CNSC acceptance of the methodology and computer codes to be used for the PSA. The standard, also, requires the inclusion of both internal and external events, consideration of both at power and shutdown operational states, as well as the inclusion of sensitivity analysis, uncertainty analysis, and importance measures.

Following to the CNSC Fukushima Task force (FTF) recommendation, the regulatory standard S-294 is amended and re-issued as REGDOC 2.4.2 [2], in April 2014, after two rounds of public consultations. Amended REGDOC 2.4.2 includes some completely new requirements as well as the previous requirements some of which were made more explicit. The amendments are:

a. **Objectives of the PSA:** These were newly added following to the CNSC FTF recommendation which noticed that the previous S-294 [1] does not spell out the purpose and the objectives for the conduct of the PSA. The added objectives are in accordance with those listed in the IAEA SSG-3 [3].
b. **Consideration of other radioactive sources:** This was added as an amendment to the existing requirement directing the Licensees to perform a Level 1 and Level 2 PSA for each NPP by explicitly stating that other radioactive sources other than the reactor core, such as the irradiated fuel bay, shall be considered. The licensees may, with the agreement of persons authorized by the Commission, choose an alternate analysis method to conduct the assessment.
c. **Multi-unit considerations**: This was added as an amendment to the existing requirement which directed the Licensees to perform a Level 1 and Level 2 PSA by specifically stating that the multi-unit impact shall be considered in the PSA.
d. **Inclusion of external events and their potential combinations:** This was added as an amendment to the existing requirement to make it more explicit for the Licensees to include site specific initiating events (internal events, internal hazards, and the external hazards) as well as the potential combinations of external hazards. The licensees may, with the agreement of “persons authorized” by the Commission, choose an alternate analysis method to conduct the assessment of internal hazards and external hazards.
e. **PSA update:** The PSA periodic update was changed from 3 to 5 years to align with the deterministic safety analysis update. PSA models shall be updated sooner if the facility undergoes major changes.
f. **Public disclosure:** This requirement is newly added following to the public request for an increased disclosure of the PSA results and in accordance with licensees' public information programs established under RD/GD-99.3 [4], *Public Information and Disclosure*. The amendment requires that a summary of the

3. RE-EVALUATION OF SITE-SPECIFIC EXTERNAL EVENTS

The CNSC Fukushima Task force urged the licensees, through implementation of the S-294 (in force at that time), to re-evaluate, using modern calculations and state-of-the-art methods, the site-specific magnitudes of each external event and to evaluate if the current site-specific design protection is sufficient. If gaps are identified a corrective plan should be proposed.

Licensees have completed a state of the art Probabilistic Seismic Hazard Assessment (PSHA) and completed the PSA analyses of the seismic events either through a PSA-Based Seismic Margin Assessment (SMA) or a Seismic PSA.

Wind hazard assessment is also performed and a Wind PSA is completed at Ontario Power Generation (for Pickering A and Pickering B Nuclear Generating Stations), while work is underway at Bruce Power for both Bruce A and Bruce B.

In addition, the licensees have performed a hazard screening analysis of internal and external hazards. The screening methodology takes into account the frequency as well as the consequences of the associated hazards. A given hazard is screened out if it is already considered in the existing PSA; the source of hazard is outside the screening distance; the event is below the screening frequency level; or if the impact of the hazard is too low.
For natural external hazards such as: external flooding, tornadoes, snow pack, and extreme weather conditions, the concept of a Review Level Condition (RLC), originally used for the purpose of the seismic margin assessment, and is adopted based on current Canadian and International regulations and standards.
External hazards combinations were classified in the following categories:

- *Coincidental hazards* which occur simultaneously without a common mechanism.
- *Consequential hazards* with a causal relationship, such as a train derailment following to an earthquake, or a flooding following an earthquake.
- *Correlated hazards* originating from the same parent event, such as the lightening following an extreme meteorological event.

Seismically induced fires and floods are typically considered by Canadian Licensees. OPG and Bruce Power developed a common methodology for a qualitative assessment of the seismic consequential floods and fires for their respective NPPs.

4. TECHNICAL CHALLENGES FOR THE WHOLE-SITE PSA

After the Fukushima Daiichi accident there is an increasing interest from all Canadian stakeholders regarding the risk posed by Multi-unit sites. In December 2012, at the Darlington Nuclear Generating Station Hearing, Commission Members inquired about the unit of the numerical safety goal and asked if the total CDF and LRF for Darlington site would be four times the calculated unit CDF and LRF. Similar question was raised

during the Pickering Hearing, in May 2013, where an intervener from the public questioned that the risk posed by the six units at the Pickering station is arguably six times more than Quebec's single unit Gentilly-2 Nuclear Generating Station or the Point Lepreau Nuclear Generating Station in New Brunswick. The site integrated risk raises three fundamental questions as stated below:

4.1. Risk aggregation over the whole range of initiating events and operational modes at the unit level

There is no international consensus for comparing the safety goals with the aggregated PSA results (both internal and external events for full power and shutdown operating modes). IAEA SSG-3 [3] stated that even if this was not explicitly specified in INSAG-12 [5] for which scope of PSA the numerical values are applicable; it is yet assumed that a full scope PSA is meant. Also, the survey conducted by OECD/NEA [6] showed that, in general, all countries aim at using full scope (internal and external events, full power and shutdown operating modes) PSA to assess CDF and LRF. However, it is well established that the simple summation of internal events CDF/LRF and external events CDF/LRF will provide a biased result that can lead to misinterpretations [7]. The bias is primarily due to the large uncertainties as well as the conservative assumptions associated with the external events PSA. Typical PSA results for the seismic events show a big gap in the mean and the median CDF value and this gap increases with increasing uncertainties.

4.2. Integrated Site Risk

Given the current CANDU PSA practice, the CDF and LRF at the site level can not be derived through a simple multiplication by the number of units in the station. Current CANDU PSAs are conducted on an individual representative unit where the multi-unit effects are duly considered. These include the common mode initiating events that can affect all the units (e.g., Loss of offsite power impact on the reliability of common mitigating systems), as well as the events in the adjacent units leading to harsh environment (e.g., Secondary Side Steam Line Breaks and Feedwater Line Breaks in the adjacent unit). Therefore, simply multiplying the unit CDF/LRF by the number of units, would give a result that is overestimated where some of the accident sequences are double counted.

4.3. Comparison with Safety Goals

Current CDF and LRF safety goals are established on a reactor-year basis. Therefore, there is a need to define site safety goals that is in line with Nuclear Safety Control Act (NSCA) [8] and with the fundamental safety objective [9].

4.4. Technical PSA Challenges

For Level 1 PSA, the challenges are:

- Re-defining the initiating events per site per year,

- Common Cause Failures to be redefined as “single unit common cause failures” and “multiunit common cause failures”,
- Revisiting credited Human actions in Level 1 PSA to account for MU effect.
- Considering the interactions among units, and,
- Level 1 end states to include sequences that will lead to core damage in a single or multi units.

For the Level 2 PSA, the technical challenge consist of extending the Level 2 PSA to include Plant Damage Sates and Release Categories for accident sequences involving one or more units, as well as the consideration of accident progression for the different core damage scenarios.

CNSC staff is following-up on the international developments in the Level 3 PSA to consider if there may be a need to extend the PSA scope to include a Level 3 PSA to calculate the site integrated risk and the health effects.

5. CNSC Initiatives

CNSC staff is following up with the Canadian industry, through the CANDU Owners Group (COG) Risk & Reliability Group, on the development of a methodology for whole site PSA as well on other topics of interest in the PSA area.

In parallel, CNSC has established a Working Group on Safety Goals to propose site safety goals.

CNSC is also working with the international community and will host the international workshop on Multi-Unit PSA November 17-20, 2014. The workshop is co-organised with IAEA, USNRC, and OECD and will address the following topics:

- Experience with Multiunit PSA
- Technical challenges in Multi-unit PSA
- Selection of Risk metrics for the multiunit sites
- Role of site safety goals in the licensing process
- Radiological Consequences Analysis in multi-facility sites

6. CONCLUSION

Since the Fukushima accident, CNSC staff amended the regulatory document S-294 which is now published as REGDOC 2.4.2 which specifically include the requirements on Multi-unit impacts as well as the consideration of radioactive sources other than the reactor core, such as the irradiated fuel bay. Re-evaluation of external events and the hazards screening analyses, through the implementation of S-294, is completed by the Licensees as part of the CNSC Fukushima Task Force recommendations.

CNSC staff is also engaged with industry and international community for the development of a whole-site PSA methodology, and a CNSC working group for the development of site safety goals has been established.

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