WGRISK Site-Level Project: Status update and Preliminary insights for the "Risk Aggregation" focus area

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Outline

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I. Introduction

Current PSA practice:

- Probabilistic safety goals established or adopted by most OECD NEA member countries are expressed on a per reactor unit basis (**per reactor year**).
- PSAs are being developed for individual reactor units.
- Safety Goals are established on a reactor unit basis

I. Introduction

Although current PSA practice has provided valuable insights about the risk for the individual unit being considered, there is increasing interest in assessing and understanding the "**total risk**" from accidents involving:

- all major radiological sources at a nuclear installation:
  - reactor units
  - spent fuel pools (SFPs)
  - dry cask storage (DCS) facilities
  - radioactive waste management facilities)
- encompassing impacts of both internal and external hazards during all operating modes

II. WGRISK Site-Level PSA Project

June 2015: Committee on the Safety of Nuclear Installations (CSNI) approved WGRISK activity on Site-Level PSA

Objective of the task is the collection of information on:

- how member countries address multi-unit and/or multi-source issues in PSA of NPP sites that contain multiple radioactive sources
- challenges and developments of Site-Level PSA
- actual and intended uses and applications of Site-Level PSA

II. WGRISK Site-Level PSA Project

Task to be performed in two phases:

- **Phase 1 (Lead Country: Canada)** – Survey and Questionnaire on Site Level PSA Developments
- **Phase 2 (Lead Country: Germany)** – CSNI/WGRISK International workshop on Site-Level PSA (spring 2018) followed by a Summary Report to be issued in June 2018)

Core group:
Canada, Czech Republic, France, Germany, Japan, Korea, USA

II. WGRISK Site-Level PSA Project

Phase 1:

- **Initial survey completed** (December 2015)
- **Core group agreed on 3 focus areas:**
  1. Risk aggregation
  2. Multi-source interactions or dependencies
  3. Risk metrics and safety goals

- **Canada is leading activities under focus areas**

III. Risk Aggregation focus area

Assessing the "**total risk**" introduces additional issues that need to be addressed, including:

1. Selection and definition of risk metrics used to characterize risk at the site level
2. Aggregation of risks across the spectrum of hazard groups with different degrees of uncertainty and PSA maturity (**unit-level aggregation**)
3. Aggregation of risks across all major radiological sources and operating modes (**site-level aggregation**)
4. Presentation and communication of site level PSA results to decision makers and to the general public

III. Risk Aggregation focus area

Preliminary results and insights from the “risk aggregation” focus area include:

1. Challenges related to defining PSA risk metrics
2. Results from an international survey regarding risk aggregation for comparison with national safety goals
3. Challenges related to risk aggregation, and
4. Risk aggregation methods, considering the different degrees of uncertainty and PSA maturity for different hazards

IV. Risk aggregation survey

comparison against safety goals

Country	Risk Aggregation?	Remarks
Belgium	No	PSA not used to demonstrate safety goals
Canada	Yes	Safety goals are expressed as the sum of all accident sequences
France	No	PSA results are used only as orientation values
Germany	No	PSA results used mainly within PSR . A specific guidance document on the use of PSA in regulatory decision making apart from PSR is under preparation. The existing PSA Guidance documents do not cover risk aggregation; however R&D activities are ongoing in Germany on risk aggregation for multi-unit multi-source sites in order to support the regulatory body on this topic.
India	Yes	PSA used for RIDM. Intent is to aggregate risk of all nuclear facilities at a site.
Japan	Yes	
Korea	Yes	Safety Goal for single unit in terms of CDF and LRF may be used in Korea. Rule-making process is in progress. For Safety Goal for a site with multi-unit, need more study to establish criteria
Romania	Yes	
Switzerland	Yes	
UK	No (for existing)	Expected to be applicable to new builds. BSLs and BSOs provided for the overall summed risk impact from all the facilities on a site, and for a full-scope PSA
United States	Yes	The existing USNRC safety goals, QHOs, and subsidiary numerical objectives based on CDF and LERF are applied on a per-reactor basis with consideration of the risks from all initiators except deliberate malevolent acts (e.g., sabotage, terrorist attacks) to the extent supported by the state-of-the-art in evaluation techniques.

IV. Risk aggregation survey

- **Is-there a need for developing new risk metrics for the site level or is-it sufficient to extend the existing unit-level risk metrics?**
  - Are the current unit-level metrics readily extendable to the site level?
  - Is there a need to develop site-level risk metrics for all 3 PSA levels?
  - Is it necessary and feasible to develop an integrated multi-unit PSA model to directly calculate site-level risk metrics (e.g., using Boolean logic)?
- **Is-there a need to consider risk aggregation from the purely quantitative aspect or should we broaden the understanding of aggregation to include the qualitative insights gained from the PSA?**
  - What are acceptable approaches to quantitative aggregation: simple summation, other methods, bounding approaches?
- **What site level results should be produced from risk aggregation and how can these results be effectively communicated to end users?**

V. Draft Working Document

Preliminary insights

1. Challenges of risk aggregation at the unit level

The concern with simple summation of the risks from different hazards arises largely because of the following:

- Differing levels of maturity of the analyses used in the construction of the PSAs for the various hazard groups;
- Approximations made to facilitate the construction of the PSA models; and
- Nature and magnitude of the uncertainties associated with the analyses.

V. Draft Working Document

Preliminary insights

2. Challenges of risk aggregation at the site level

- **Level 1 PSA risk metric aggregation**
  - Risk aggregation needs to respect Boolean logic to prevent double-counting of the simultaneous occurrence of the consequence at more than one source. Since some of the unit core damage scenarios involve core damage on multiple units, one cannot simply add up the individual unit CDF/FDF values to obtain a meaningful result for a site CDF/FDF.

V. Draft Working Document

Preliminary insights

- **Level 1 PSA risk metric aggregation**
  - For a site with *n* units, there will be *2n–1* possible combinations of core damage states.
  - This is an incentive for using bounding approaches instead of a rigorous investigation of all potential interdependencies.
  - Using Boolean algebra, the following equation provides a bounding estimate for the site-level CDF (*CDF(site)*):

$$CDF\,(site) \leq \sum_{i=1}^{n} CDF_{unit\_i}$$

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Preliminary insights

- **Level 2 PSA risk metric aggregation**
  - L(E)RF is a measure defined over a continuous variable (e.g., the amount of radioactivity released for a specified radionuclide).
  - Aggregating the unit level L(E)RF to obtain a site level L(E)RF requires some care as there could be simultaneous occurrence of sequences in which the aggregated (total) release meets the L(E)RF criteria, even if the individual unit releases do not meet these criteria.
  - To estimate S-LRF, it is not sufficient to consider only scenarios for which the release from individual units reaches the large release threshold. Potential scenarios affecting multiple units, for which only the aggregate (total) release reaches the large release threshold, must also be considered.

V. Draft Working Document

Preliminary insights

Level 2 PSA risk metric aggregation

CANDU Owners' Group (COG) report proposes a simplified methodology to convert the unit level LRF results to a site level LRF that represents whole-site risk. For instance, the S-LRF for a four-unit site would be equal to:

- 4 **x** the LRF contributions from single or multi-unit sequences arising from initiating events affecting only one unit initially (including those that can subsequently propagate to multiple units, such as a secondary steam line break), ***plus***
- 2 **x** the LRF contributions from sequences arising from initiating events potentially affecting two adjacent units simultaneously, ***plus***
- 1 **x** the LRF contributions from sequences arising from initiating events affecting four units simultaneously, (such as loss of offsite power, seismic events, etc).

Conclusions

- During Phase 1 of the WGRISK Site-Level PSA Project, an international survey regarding risk aggregation practices has been conducted
- The survey indicates that, even though there are different practices in different countries, there is increasing interest in assessing and understanding the total aggregated risk from accidents involving all major radiological sources at a nuclear installation
- More work is needed on risk aggregation to support regulatory decisions
- Technical challenges related to risk aggregation have been identified and discussed among member countries
- This will serve as a technical basis for Phase 2 of the WGRISK Site-Level PSA Project in which an international workshop on site-level PSA will be conducted in Germany

Questions?

Thank You!