

# **Call for Research Proposals for participation in the New Coordinated Research Project (CRP) sponsored by the International Atomic Energy Agency (IAEA)**

## **<< Probabilistic Safety Assessment (PSA) Benchmark for Multi-Unit/Multi-Reactor Sites >>**

**<< I31031 >>**

### **Summary of the CRP**

This CRP was recently approved and will be implemented by the Division of Nuclear Power, Nuclear Power Technology Development Section (NPTDS).

Many nuclear power plants (NPPs) may include units/reactors of the same or different types, designs or age, which are all located at one single site. Past probabilistic safety assessments (PSA) of NPPs have estimated the risk arising from damage to a single unit at a time. The risk for a site with multiple units/reactors has been determined by simply summing up or combining the risks of individual units. This simplified approach has several limitations as it ignores potentially complex interactions during a severe event at a multi-unit site, in particular from external hazards. In addition, assessing the impact of shared equipment requires a holistic view of the entire site.

This CRP will bring together experts from the Member States with water cooled reactor technologies to utilize, test and further develop their current or planned PSA methods and assumptions by conducting and comparing results of a meaningful benchmark exercise.

### **Duration**

4 years

Expected starting date: 01-2018

### **Background Situation Analysis**

Safety assessments of NPPs in the past and present were predominantly based on deterministic and probabilistic approaches applied to a single unit. The risk at a site with multiple reactors was often represented by summing up, or combining in a simplistic fashion, the risks of individual units, sometimes restricted only to internal initiating events. This simplified approach has several limitations as it ignores potentially complex interactions during a severe event impacting a multi-unit site, in particular from external hazards. The proper assessment of the impact of shared equipment also requires looking at the entire site in a holistic way.

The need for consideration of multi-units effects while performing a Level-1 PSA (Level 1 refers to the calculation of Core Damage Frequency - CDF) was already indicated in the IAEA safety guide SSG-3 (2010, i.e. pre-Fukushima) and further elaborated in TECDOC-1804 (2016). However, these publications provide very limited guidance on how such analyses can be performed or evaluated in the case of sites with more than one reactor unit and/or type, or how they should be used in Level-2 PSA (Level-2 refers to the calculation of the frequency, magnitude and other relevant characteristics of the release of radioactive material to the environment, e.g. calculation of Large Release Frequency - LRF). In addition, there is a lack of information from ongoing national developments in the area of Multi-Units PSA that are publically available.

Shortly after the Fukushima Daiichi accident, International Workshop on the Safety of Multi-Unit Nuclear Power Plant Sites against External Natural Hazard was organized by IAEA/NSNI & India Atomic Energy Regulatory Board and the Bhabha Atomic Research Centre (BARC) in Mumbai, India,

17-19 October 2012. The importance of multi-unit considerations was strongly emphasized and the need for further research and development identified.

One main conclusion from a 2014 CANSAS Pressurized Heavy Water Reactor (PHWR) Safety Workshop, which focused on post-Fukushima R&D status and needs, was the need for improving PSA methodologies applied to multi-unit, multi-reactor-type sites in an integrated way. A subsequent international workshop was held in Ottawa in November 2014 with large number of participants and very similar outcome.

Currently, there are a few practical studies being performed in different countries (who have all expressed interest in contributing to this CRP) on Multi-Unit PSA (MUPSA), for instance:

Chinese professionals at SNERDI have done a pilot study on the risk metrics with mathematical inference, and special considerations on MUPSA after the Fukushima accident. They applied their findings to the practical PSA model of a benchmark two-unit NPP and obtained useful conclusions and insights, some of which have been published.

CANDU Owners Group (COG) Joint Project 4499 Whole Site PSA was initiated in 2014 with the following stages:

- Phase A: Review of the Safety Goals Framework - public communication tool;
- Phase B: Perform risk aggregation studies - quantify whole-site risk;
- Phase C: Perform pilot application (2017) for Pickering NPP whole-site PSA.

A Level-1 and Level-2 MUPSA study is initiated for Bilibino NPP in Russia. A methodology is being developed and the modeling work has started in mid-2017.

An integrated Level-1 and Level-2 full scope twin-unit PSA model (cross-connected PSA models of two units in one project) has been developed by UJV Rez for Dukovany NPP in the Czech Republic.

MUPSA activities are being conducted in Korea. Several research papers have been published.

A few papers have also recently been published by PSA practitioners providing a methodology or methods to address MUPSA considerations. For instance, several papers from US, Korea, China, and France were published at PSAM12, PSAM13 and PSA-2015 international conferences.

The first practical MUPSA study can be referred as Seabrook PSA (mid-1980's, considering two units), which presented the integrated site risk in the form of the famous Farmer Curve. Several methods have since been proposed and are being developed around the world to cover multi-unit PSA considerations including risk-related safety goals and Level-1/Level-2 MUPSA risk metrics and risk aggregation issues. These methods are not harmonized, but have the same objectives. Therefore, a benchmark is a useful means of fostering detailed technical discussions and facilitating mutual learning and improvements in the various methods. The results from this CRP will also be useful to other advanced reactor types including Small Modular Reactors (SMRs).

### **Scope of the CRP**

The scope of the new CRP is to share expertise and participate in common benchmark calculations. These calculations will involve the development of Multi-Unit/Multi-Reactor-Type PSA (MUPSA), based on single-unit PSAs available in Member States. Qualitative insights for safety – the goal of any PSA – in the context of MUPSA can be something not obvious from single unit PSAs and they can be different for different NPP sites. Evaluating these in the context of specific site/layout features is the main novel research aspect in this CRP. The insights gained from the exercise may further identify technology solutions to reduce those risks that are specific to multi-unit sites. The CRP will also encourage cooperation and foster exchange of information among the participants.

Participants in the CRP are expected to have an active program on PSA development, ideally having performed single-unit PSA studies in the recent past. As part of the proposal, the attached questionnaire must be completed and attached to the proposal.

### **Specific Research Objectives**

- (1) Successfully complete the benchmark exercises and document lessons learned.
- (2) Develop best practice guidance for conducting Level-1 & Level-2 multi-unit PSAs.
- (3) Identify and discuss main risk contributors and specific safety-related insights dealing with multi-unit risk.

### **Activities** (to be undertaken by the participants)

- Submission and Evaluation of Proposals – 2017 December
- Participation in 1<sup>st</sup> Research Coordination Meeting (RCM) – 2018/1Q (tentative March 20-22)
- Documentation of in-house expertise and experience – 2018 May
  - Status and Scope of existing Single-Unit PSA Models (hazards, IEs, POSs, Level(s), etc.) and MUPSA, if available
  - Description of PSA model(s) and code(s)/tools used
  - Methodology, Process, Calculations for Risk Aggregation (if available)
  - Risk Metrics for Site (existing/proposed)
  - Etc.
- Description of National Benchmark (MUPSA Level-1) to be contributed to CRP – 2018 June
  - Site location and layout, # units, type, age and relative orientation, etc.
  - Relevant hazards and initiating events
  - Discussion on common systems
  - Discussion on site management structure and human reliability
  - Discussion on severe accident mitigation strategies (SAMG, FLEX, etc.)
- Submission of National Benchmark (MUPSA Level-1) Results – 2018 December
- Written submissions on MUPSA Level-1 to Final Report (TECDOC) – 2019 March
- Participation in 2<sup>nd</sup> RCM – 2019/2Q
- Description of National Benchmark (MUPSA Level-2) to be contributed to CRP – 2019 June
- Submission of National Benchmark (MUPSA Level-2) Results – 2020 June
- Written submissions on MUPSA Level-2 to Final Report (TECDOC) – 2020 September
- Participation in 3<sup>rd</sup> RCM – 2020/4Q
- Technical review of Final Report (TECDOC) – 2021 March

### **Outputs**

- Final benchmark synthesis report (TECDOC)
- Joint conference and journal publications

### **Outcomes**

- Improved capabilities and expertise in Member States operating multiunit NPP sites to conduct meaningful PSA studies for multiunit NPP sites
- Input to revising the "Framework and Process for Multi-unit Site PSA" (parallel Nuclear Safety Department activity)

### **Funding**

The IAEA will contribute €1500 per year towards each contract and support financially the attendance of CRP participants that have made substantial contributions (through contract or agreement) in the three research coordination meetings (RCM) planned to be held during the CRP.

### **Application Procedures**

Interested scientists should submit their research contract or agreement proposal that cover part(s) or all of the scope of the CRP, along with the completed questionnaire attached (*the scope of the coverage of a proposal is to be determined by the Project Officer after evaluating the proposal and the capacity of the scientist(s) involved and the capability of the institute*). The standard research contract/agreement proposal form is available at <http://cra.iaea.org/cra/forms.html>.

Research proposals should be submitted by email to [Official.Mail@iaea.org](mailto:Official.Mail@iaea.org) by 2017 December 15.

Any administrative question should be addressed to the Research Contracts Administration Section (NACA) via [research.contracts@iaea.org](mailto:research.contracts@iaea.org).

Technical enquiries should be addressed to the project officer for this CRP, Mr Matthias Krause ([M.Krause@iaea.org](mailto:M.Krause@iaea.org)).

Further general information relating to the participation in CRPs and the Coordinated Research Activities in general is available on <http://cra.iaea.org>.

### Questionnaire on the Status and Prerequisites related to a Multi-Unit PSA\* (MUPSA)

*\* The term "Multi-Unit PSA" is used here in the context of either several NPP units (multi-unit), or several facilities (multi-facility) with potential for radioactive releases, located on the same site.*

No.	Question	Your Answer	Comments
1	<b>Country:</b>		
2	Name of applicant(s) and organization wishing to participate in the CRP:		One person must be designated as "Chief Scientific Investigator (CSI)", plus one (optional) Alternate.
3	Organization, which develops the PSA models:		
4	Other organizations involved in performance of the PSA studies:		
5	<b>Site Name (existing or planned):</b>		
6	Number of NPP units at the site:		
7	Number of other facilities (e.g. Spent Fuel pools) at the site:		
8	Type and Size (MWth) of NPP units (design):		If units of several types are located at the site, please list all of them.
9	If the plant has shared building/structures, please list them:		If buildings/structures are shared between particular NPP units, please specify between which ones.
10	Scope of completed PSA studies for single units (analysis levels/plant operational states/initiating events and hazards):		Please specify PSA levels, operational states, and scope of initiating events/hazards covered in your PSA for single units. If the scope is different for different units, please provide this information for each unit.
11	Software used for PSA model development:		Please specify software name and Version.
12	The year of completion of your single unit PSAs:		Please specify the year of completion of your PSA (separately for each unit).

No.	Question	Your Answer	Comments
13	If your PSAs received an independent peer review, please specify the name of reviewer/organization and the year of review:		Please provide this information separately for each unit.
14	Is a MUPSA included in your current PSA-related activities/project (yes/no)?		
15	If you answered 'yes' for the previous question, please provide a brief description of objectives/scope/schedule of your MUPSA project:		
16	If you published papers on MUPSA, please provide full references:		
17	Please provide any additional information, which you consider helpful or important in the context of your MUPSA-related activities:		